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Filtration Ingestion and Assimilation Rates of the Mysid Shrimp Neomysis Americana Smith, Fed Three Food Sources

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ABSTRACT

FILTRATION, INGESTION, AND ASSIMILATION RATES
OF THE MYSID SHRIMP NEOMYSIS AMERICANA SMITH,
FED THREE FOOD SOURCES

Robert W. Grabb
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Laboratory grazing and assimilation experiments were conducted on the mysid shrimp Neomysis americana in an attempt to assess the suitability of three potential food sources. It was hypothesized that the smaller size classes were primarily herbivores, not becoming omnivorous until attaining lengths of approximately 5-6 mm. Four size classes of mysids from the summer generation, juveniles, immature, adult males, and adult ovigerous females were each fed three concentrations of Artemia salina nauplii, the rotifer Brachionus plicatilis, and the diatom Coscinodiscus lineatus. The mean lengths of the size classes utilized, plus or minus one standard deviation, were 2.5 ± 0.4 mm, 4.5 ± 0.5 mm, 8.0 ± 0.5 mm and 8.5 ± 0.6 mm respectively. Grazing experiments were conducted for 24 hours under 12 hour light:12 hour dark photoperiods at 15 °C. On a dry weight basis, ingestion was found to increase with decreasing prey and predator size. Percent assimilations on the various food sources were determined according to Conover's (1966) ratio method. Results indicate that while the smaller shrimp are omnivores, they are unable or unwilling to ingest Artemia nauplii. Assimilation rates are highest for all sizes when fed on the rotifer Brachionus plicatilis. Rotifers were the food source highest in organics (88.5 ± 3.4%) and are judged to be the most suitable food of the three offered for future culture attempts.

DEDICATION

This thesis is dedicated to my three children, Robby, Dawn, and Kristen. They have made it all worthwhile.

ACKNOWLEDGEMENTS

The completion of this thesis culminates a period in my life which has been both frustrating and encouraging. It has, however, proven to be an invaluable and rewarding experience which I will remember for years to come.

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I am especially grateful to my in-laws, Mr. and Mrs. John Gordon, who have been extremely helpful and supportive during this period. I wish to acknowledge my parents, Mr. and Mrs. Robert Grabb, as their faith and love have been an encouragement throughout my education.

To my wife, Camille, I offer my sincerest and heart-felt thanks and appreciation. She has been a tremendous inspiration, and has provided unending moral support. Without her continuous love and assistance,

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INTRODUCTION

The oppossum shrimp Neomysis americana Smith is by far the most common mysid in shallow coastal waters of eastern North America (Williams, et al., 1972) and undoubtedly the most abundant in the Western North Atlantic Ocean (Wigley and Burns, 1971).

In recent years, mysid shrimps have been recommended by the Environmental Protection Agency as organisms suitable for bioassays in determining the effects of various pollutants. Primarily this is because of their extreme sensitivity and short life cycle. The most commonly used mysid to date is Mysidopsis bahia (Nimmo et al., 1977) which is an estuarine species found from Galveston Bay, Texas, to Miami, Florida (Molenock, 1969; Odum and Heald, 1972). M. bahia is particularly useful because of the ease with which it can be cultured and maintained. This mysid has been used in both acute static and chronic toxicity tests to determine the effects of cadmium (Nimmo et al., 1978) and Kepone (Hansen et al., 1976). They are cultured at the Environmental Research Laboratory, Gulf Breeze, Florida, and transported by air to mobile bioassay units conducting field surveys of industrial waste.

Though seemingly well suited, there are drawbacks to the use of Mysidopsis bahia. While a number of private and government labs have begun their own cultures of M. bahia from stocks obtained from the Environmental Research Laboratory, Gulf Breeze, Florida, Dr. DelWayne Nimmo (personal communication) has stated that they can not get enough of them to supply everyone who requests mysids for research and testing. Addition-

ally, the E.P.A. recommends that bioassay procedures be done on indigenous organisms whenever possible.

The widespread abundance of Neomysis americana would therefore seem to make it ideally suited for bioassay procedures. Only two studies are known of in which N. americana was, or is being, used as a test organism. Jacobs and Grant (1974) used it to test Kraft Mill effluent and Dr. William Lang is currently using it in bioassay tests at ERL, Narragansett (personal communication).

The reason for this underutilization seems to be a direct result of the inability to culture N. americana in the laboratory for extended periods of time over a number of generations. Mass mortalities after the first couple of days are common, but not as prevalent as gradual declines, or 'die-offs', in the population. This observed occurrence can most probably be attributed to one of two things: either there is a build-up of toxic metabolites, or an insufficient or nutritionally inadequate diet is provided. Literature review and personal communications indicate that this gradual 'die-off' of the population tends to occur regardless of whether flow-through systems or periodic water changes in static systems are utilized. Both of these procedures will aid in preventing a buildup of toxic metabolites by diluting them. This tends to indicate that a buildup of toxic metabolites is not in this case the prime factor which could adequately explain the population declines.

Two methods of feeding seem to be characteristic of mysids. Mysids are capable of picking up with the thoracic endopods large food masses which are then consumed while swimming, as well as filtering detritus and microplankers from the water with their mouth parts. Accord-

ing to Tattersall and Tattersall (1951), the latter method seems to predominate, with mysids appearing to filter feed almost continuously.

In order to satisfy this primary mode of feeding, it would seem desirable to provide the mysids with an inexhaustable supply of filterable food. The very problem of maintaining delicate organisms such as N. americana in closed systems may be directly related to the capacity of such systems to tolerate these high inputs of organic materials. For this reason, providing nutrition for the mysids has to involve carefully controlled portions of food stuffs so as not to overload or degrade the water quality.

There is indirect evidence that the diet of mysids may vary according to their size (Blegvad, 1922; Kost and Knight, 1975; Allen, 1975). Whether this is due to some active selection process, or merely a reflection on the individuals' ability to cope with, handle, or to assimilate a certain range of food sizes is unknown. This study was undertaken to try to determine whether N. americana is truly omnivorous throughout its life cycle. The hypothesis is that newly hatched juveniles are primarily filter feeding herbivores, only becoming omnivores after attaining a size of 5-6 mm. In addition, determinations of the optimal prey concentrations permit a more controlled approach to feeding, alleviating the chances of over-loading the culturing systems utilized.

The three food sources chosen are successfully or routinely used at present in attempts at culturing mysids, have been shown to be present in the guts of field collected Neomysis spp., or are of a size range considered to be within the manipulative range of even the smallest shrimps.

Among the most widely used foods for invertebrate culture is the brine shrimp Artemia salina. Commercially available cysts can be hatched

within 48 hours, and provide active, nutritious nauplii at low cost. Most attempts at maintaining mysids in the laboratory have relied heavily on Artemia salina as the primary food provided (Nimmo et al., 1978). Newly hatched nauplii are approximately 250 μm and mysid shrimp larger than about 5 mm are known to ingest them and grow (Allen, 1975).

The diatom Coscinodiscus sp. was chosen as the second food source largely on the basis of work done by Kost and Knight (1975) on Neomysis awatschensis collected from the Sacramento-San Joaquin Delta area. Examinations of the gut contents of approximately 1500 mysids showed high percentages of detritus and diatoms. Of the forty different genera identified in the shrimp guts, Coscinodiscus spp. and Melosira spp. predominated. Coscinodiscus spp. were more prevalent in regions of higher salinity. Coscinodiscus lineatus averages approximately 100 μm in diameter, and was chosen additionally because of its widespread occurrence in the lower Chesapeake Bay region.

The rotifer Brachionus plicatilis was chosen as the third food source primarily because it's size range (approximately 150-250 μm) was within the manipulative range of even the juvenile shrimps. In addition, this rotifer has been reported to be a nutritious food source for larval yellowtail, Seriola dorsalis (Harada, 1970) and larval anchovies Engraulis mordax (Theilacker and McMaster, 1971).

Three concentrations of the three chosen food sources were supplied to four size classes of the mysid shrimp Neomysis americana in 24 hour grazing experiments. The ingestion rates and percentage assimilation on each were calculated, and graphed as a function of the average prey concentrations occurring during the grazing period.

LITERATURE REVIEW

The mysid shrimps (Crustacea: Mysidacea) seem to be universally regarded as being omnivores, capable of ingesting organic detritus, smaller crustaceans, diatoms, and in general whatever is available at the time in the estuary. They have been appropriately termed "Scavengers of the Sea", filter feeding on microscopic plants, animals, and detritus (Tattersall and Tattersall, 1951). As briefly mentioned in the Introduction, there appear to be two distinct means of feeding which are characteristic of all mysids. In one method large food masses are picked up by the thoracic endopods. Once the food is suitably oriented below the mouthparts it is brought close to the mandibular palps, and the first and second endopods press the food over the mandibles, and the distal endites of the maxillules bite into the mass breaking off small fragments. Since the mandibles are asymetrically arranged, the food bitten off by the incisors automatically passes on to the lacinae mobiles and then to the molar processes where it is ground to a fine pulp before being shunted to the mouth (Tattersall and Tattersall, 1951).

That mysids are both scavengers, and capable of this mode of feeding, is born out by the following observations. Tattersall and Tattersall (1951) witnessed Neomysis integer carrying dead mysids and amphipods while consuming them. Green (1970) found that Acanthomysis sculpta would readily eat injured or freshly killed members of its own species, and anything else it could capture. Simmons and Knight (1974) in their work on Neomysis intermedia found cannibalism to be common, as did DeGraeve and Reynolds (1975) with Mysis relicta. Allen (1975) found

however that Neomysis americana would eat only dead animals of its own species, regardless of their relative size or time of death, as long as they showed no signs of life.

Filter feeding by mysids is the other method by which food is obtained. The thoracic exopodites which provide locomotion for the animal are also responsible for producing the feeding currents. The thoracic exopodites are rapidly whirled so that their tips describe a series of ellipses (Cannon and Manton, 1927). The resultant incoming currents which are created bring minute organisms or suspended particles of detritus towards the animal. The main food groove is a ventral tube formed by the ventral wall of the body, bases of the thoracic limbs, and the overlapping setae of the basal joints of the endopods. Within the groove, food passes forward into an expansion near the mouth as a result of an anteriorly directed current caused by the suction creating movements of the maxillae and the exhalant respiratory currents which are produced by the exopods of the first thoracic appendages. The comb of setae on the proximal endite of the maxilla acts as a filterer, the food collected being pushed onto the mouth by the long maxillar setae and the comb of setae on the proximal endites of the first thoracics. The food is then transferred to the interlocking ventral incisor processes of the mandibles, then to the dorsal molars where it is ground, then sucked into the esophagus by peristaltic action (Tattersall and Tattersall, 1951).

In addition to continuous filter feeding, Cannon and Manton (1927) observed Hemimysis lamornae to feed directly off the bottom. In the laboratory when these particular mysids were kept in still sea water which contained little live plankton, the suspended matter soon settled to the bottom. The food then became insufficient for feeding by filtering during horizontal swimming. Under these circumstances the mysid was

observed to swim down to the bottom and assume a vertical position, resting on the antennal scales and inner flagella of the antennules. They then gathered fine particles which were stirred up by the movements of the thoracic exopods.

Inorganic particles invariably must be consumed during this last mode of feeding. In fact, some investigators have suggested that aquatic invertebrates pass fine inorganic particles through the gut removing adsorbed colloidal materials and microbiota (Fox, 1950; Hargrave, 1970).

Usually, the method by which an animal's primary diet is determined is through the analyses of the gut contents of field collected animals. A number of these analyses have been conducted on various mysid shrimps from different habitats. In general, they merely serve to reinforce the opinion that these shrimps are capable of consuming a wide variety of both plant and animal material.

Blegvad (1922) analysed the gut contents of the mysid shrimps Mysis flexuosa, M. neglecta, and M. inermis, and found them to contain quantities of fine detritus, fresh plant remains, copepoda, ostracoda, and similar small crustaceans. Vorstman (1951), and Kinne (1955), found that the guts of Neomysis vulgaris contained animal remains (Rotatoria, Copepoda, Amphipoda), several species of diatoms and other plant planktonic organisms, as well as abundant detritus and sand grains. Murano (1966) in his work on the mysids Neomysis intermedia and N. japonica, deduced that they consume detritus as well as other substances which fall to the bottom. Gut analyses of Schistomysis spiritus (Mauchline, 1967) revealed particulate matter mixed with sand grains, various diatoms, dinoflagellates, filamentous algae and leaf fragments, as well as spores and seeds of a terrestrial origin which were presumably carried into the estuary by the rivers. Mauchline (1971a, 1971b) also looked at the gut

contents of Paramysis arenosa and Neomysis integer. She found P. arenosa to contain large quantities of an unidentifiable fine particulate matter, sand grains, naviculoid diatoms, and microcrustacean remains. Likewise, N. integer contained remains of harpacticoid copepods, sand particles, unidentifiable fine particulate organic matter, fragments of leaves, macroalgae and other terrigenous material. Naviculoid diatoms were only occasionally present. Lasenby and Langford (1973) in their analyses of the gut contents of Mysis relicta collected from two freshwater lakes, also found them to consume detritus, algae, and zooplankton. An interesting conclusion which they drew by comparing the gut contents with time and depth of sampling, was that by day this mysid appeared to be a detritivore along the bottom, while at night when it migrated upward it became a voracious carnivore preying on Daphnia spp.

More recently Kost and Knight (1975) examined the gut contents of approximately 1500 Neomysis awatschensis collected from the Sacramento-San Joaquin Delta area over a 13 month period. The most abundant identifiable items in the gut contents were detritus and diatoms. There also appeared to be seasonal changes in the relative occurrence of detritus and diatoms in the gut, presumably a reflection of their availability. The percentage of detritus relative to diatoms was greater during the winter months as opposed to the summer months. Conversely, the percentage of diatoms increased during the summer. Of the forty different genera of diatoms identified in the shrimp guts, Coscinodiscus spp. and Melosira spp. were by far the most prevalent, with the remaining 38 genera occurring sporadically during certain months and at particular locations in the study area. Animals and other recognizable items in the guts were less abundant than the detritus and diatoms, but included two genera of green algae, one dinoflagellate, rotifer loricas, crustacean

fragments, sponge spicules, pollen grains, and apparently fragments of higher plants. Phytoplankton samples were taken at the same time as the mysid collections and examined. Many of the diatoms found in the shrimp guts were similar to those in the phytoplankton samples. However, a number of Chlorophyta, Cyanophyta, and Chrysophyta which were present in the phytoplankton samples, were not in the shrimp guts. They were unable to determine from the analyses whether the shrimps ingested these green algae and other forms and digested them beyond recognition or whether they somehow selected against them.

Allen (1975) has analysed the gut contents of a number of Neomysis americana, the mysid studied in these experiments. He found them to contain diatoms, dinoflagellates, fragments of macrophytic plants, and crustacean appendages. Though he was unable to identify the majority of the organic gut contents as plant or animal material, he did identify the phytoplankters Navicula, Nitzschia, Fragellaria, and Ceratium at various times. Thoracic appendages and chitinous fragments, most of which appeared to be derived from copepods, also commonly occurred in the guts.

The literature indicates that although mysids are omnivores, capable of both filter feeding and manipulating large particles, there is either a change in preference, or ability to handle different diets depending on the size of the shrimp. Blegvad (1922) in his work on Mysis flexuosa, Mysis neglecta, and Mysis inermis, found that mysids less than 6-7 mm in length would not eat the pieces of mussel flesh that the larger mysids were fed. Lasenby and Langford (1973) report that while Mysis relicta tends to be a voracious carnivore preying on Daphnia spp. at night, the gut contents of mysids smaller than 4-5 mm did not contain cladoceran remains. Kost and Knight (1975) in their work on Neomysis mercedis found that the importance of detritus in the gut contents increased with

the increasing size of the shrimp, diatoms being more and more abundant in the progressively smaller shrimp. Allen (1975) also noted that the Artemia salina nauplii used as a food item in his study proved to be too large for Neomysis americana which were less than about 5 mm in length. This reported change in food preference, as a function of size, may not be due so much to an inability to handle adequately or ingest animal and detrital material, as it is a selection against them. Pechén-Finenko and Pavlovskaya (1976), in their work on Neomysis mirabilis used the radiocarbon method to compare the efficiencies when fed on Peridinean algae (Gymnodium kowalevskii), plant and animal detritus, and melanin. The plant detritus was obtained from a mixture of labelled unicellular Platymonas sp. algae and ground Cladophora thallomes that had undergone decomposition for four months at 10-20° C. The animal detritus was dried pulverized labelled gammarid bodies. Melanin was obtained by acid hydrolysis of algae (Cystoseira and Ceramium) in the laboratory and used as an analog of natural humus to feed the animals. They found that the algae was consumed most efficiently, and based on the size of the rations, was most significant in nutrition. More recently Foulds and Mann (1978) fed Mysis stenolepis on suspensions of ^{14}C-labelled raw cellulose and ^{14}C-labelled barley hay. They found that Mysis stenolepis digested sterile cellulose with efficiencies of at least 30% and sterile hay slightly less.

Raymont and Conover (1961), however, found in their work on Neomysis americana that there was no effect on the carbohydrate level when mysids were fed on phytoplankton (Skeletonema costatum at 4° C) for 20 hours, or starved for the same period of time. They concluded therefore that mysids do not contain sufficient carbohydrate reserves to meet their

energy requirements, particularly during periods of food scarcity, and therefore other metabolic substrates must be utilized as well. They felt it unlikely that this species could survive solely on phytoplankton, if carbohydrate was its only source of carbon.

Since mysids have been shown to be omnivorous, and possess the ability to utilize a wide range of food items, it would therefore seem logical that laboratory maintenance would be a relatively easy task. On the contrary, the literature reveals that this has yet to be the case. Few researchers have concerned themselves with the long term culture of mysids through a number of generations. Rather, most researchers collect mysids in the field and bring them back to the lab to conduct their tests. In a number of instances, the testing dictates that the mysids be starved, so again no feeding regime is necessary or undertaken. For longer experimental tests, some attempts at feeding have necessarily been undertaken in an attempt to try and maintain healthy test organisms. A starving or weakened animal existing on its reserves will obviously compound or exaggerate any stresses to which it is subjected during testing situations.

A number of people have attempted to offer various species of mysids a wide array of diets with varying amounts of success. As previously stated, Artemia salina is one of the most widely used food items for those attempting invertebrate culture. Hauenschild (1972), however, cautions against extensive use of the Artemia nauplii because the high fat content in the fresh hatch may be poorly tolerated in the long run. As an alternative he proposes that finely chopped bivalve flesh may be an effective food for mysids. In fact, Blegvad (1922) did use mussel flesh as the primary diet offered to Mysis flexuosa, M. neglecta, and

M. inermis. Because of the ease with which Artemia can be hatched, it continues to be the primary choice, though sometimes with additional items as supplements. The largest difficulty seems to be the fact that the ingestion rates of mysids on Artemia have not been researched, or at least documented. Most researchers simply add the Artemia ad libitum, or in sufficient quantities to keep the mysids feeding for a certain period of time.

Murano (1966) used Artemia and daphnids as the food offered to Neomysis intermedia and N. japonica. Clutter and Theilacker (1971) also relied on Artemia as a food source, as did Simmons and Knight (1975). Both fed unspecified amounts, however. Nimmo et al. (EPA-600/9-78-010) in their culture work with the mysid Mysidopsis bahia, fed them 48 hour old Artemia salina nauplii daily "ad libitum". This has proven to be successful for Mysidopsis bahia which they have been able to maintain for up to thirteen months without even changing water in a static system. They have had no such success using Neomysis americana under similar conditions. Mr. Alston Badger of the U.S.E.P.A. Field Station at Bears Bluff, S.C. (personal communication) has had some success with Neomysis americana fed heavy ad libitum concentrations of Artemia salina nauplii. He also indicated that his flow through system did experience periodic mass mortalities, however. Dr. E.T. LaRoe of the Florida Department of Environmental Regulation (personal communication) tried a few years ago to culture the mysid shrimp Mysidium columbiae to be used as the food source for the squid Sepioteuthis sepiodea. Brine shrimp were also his choice as the food for the mysids, although at times he mixed in diatoms and miscellaneous plankton samples (of which several species of copepods tended to dominate). According to his recollections, he was able to

rear the mysids through a couple of generations, although for some reason the population slowly declined.

The literature also reveals a variety of other foods which have been attempted. Hair (1971) fed dried Daphnia spp. to Neomysis awatschensis. Mauchline (1971b) fed live barnacle nauplii and harpacticoid copepods to the mysid Neomysis integer. Lasenby and Langford (1973) fed Mysis relicta adult Daphnia pulex, fourth instar Orthocladius and Trissocladius chironomid larvae, and moss washings consisting of epiphytes, epifauna, and inorganic particles. DeGraeve and Reynolds (1975) in their work on M. relicta offered a diet of pulverized trout starter mash with occassional Artemia supplements. Allen (1975) in his work on the maintenance of N. americana used primarily a brine shrimp and zooplankton diet. He also added mixed diatom cultures several times a week as a supplement, and on occassions, tried a number of dried tropical fish foods, fresh water Daphnia spp., and oligochaete Tubifex. Pechén-Finenko and Pavlovskaya (1976) used the algae Gymnodium kowalevskii as a food source for Neomysis mirabilis. Burton et al. (1976) in work on N. americana held in flow through systems, utilized detritus and finely chopped shrimp daily as their food source. Foulds and Mann (1978) fed Mysis stenolepis partially decomposed Zostera leaves and Artemia. Bowers and Grossnickle (1978) used lab cultured Ceriodaphnia reticulata and finely ground tetramin fish food to feed Mysis relicta.

While a wide variety of food sources have been tried for various mysids, the amounts utilized and a measure of their success have been unreported. Few attempts have been made to ascertain the ingestion rates of mysids on potential food sources. Calculations of assimilation rates and efficiencies are little more common.

Lucas (1936) used the diatom Nitzschia closterium in an attempt to ascertain ingestion rates for the mysid Neomysis vulgaris. Though he readily admits that his results were inconclusive, he found that the mysids tended to "live longest" at cell densities of between 25-100 cells mm^{-3}. The survival decreased at concentrations above and below these. The ingestion rate, however, was highest at concentrations around 1000 cells mm^{-3} where he obtained values of the order of $6x10^{6}$ cells $animal^{-1}$ $hour^{-1}$.

Raymont and Conover (1961) used the diatom Skeletonema costatum at 4^{o} C as the food offered to N. americana during their studies on its carbohydrate content. They obtained an ingestion rate of between 28-120 x 10^{4} cells day^{-1}.

In the last few years, some assimilation rates and/or efficiencies for various mysids on different food sources have been reported by Lasenby and Langford (1973), Pechen-Finenko and Pavlovskaya (1976), Bowers and Grossnickle (1978), and Foulds and Mann (1978).

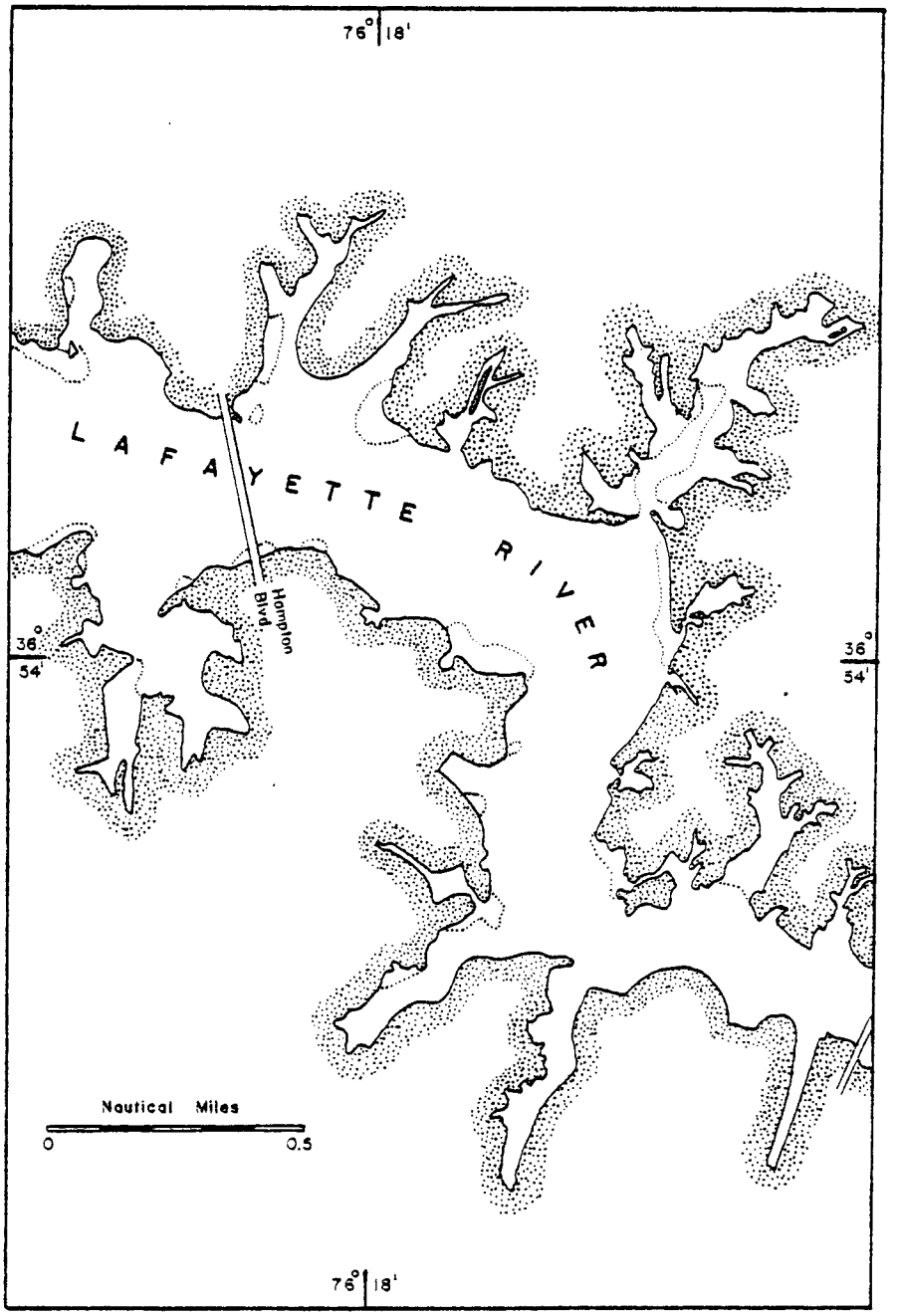
That mysids tend to be omnivorous seems beyond doubt. This thesis is designed to evaluate the suitability of three potential food sources for various size classes, as well as to determine the optimal concentrations and percentage assimilation of each.

METHODS

Collection and Maintenance of Specimens

The opossum shrimp Neomysis americana is regarded as being a relatively euryhaline, eurythermal estuarine inhabitant. Its normal habitat tends to be along the bottom, though it is reported to make excursions into the near surface waters at night (Whitely, 1948; Hulbert, 1957; Bainbridge, 1961; Herman, 1963). There seems to be some disagreement as to whether this species displays a typical diurnal vertical migration, or merely a more random type of dispersion or wandering. Decreasing light intensity with sunset and depth is felt to be a major factor responsible for these observed behaviors. Because of this, the source of the mysids utilized in these experiments was from night tows at ebb tide in the Lafayette River Estuary, a tributary of the lower Chesapeake Bay, Virginia (Figure 1). The Lafayette River was chosen as the most desirable collection site for two reasons: close proximity to the Department of Oceanography allowed for rapid transportation and accessibility; and the fact that mysids were reportedly available on a year-round basis (Mr. D. Campbell, personal communication). Collections were made with a 0.5 m #10 mesh (aperture size 153 μm) plankton net. The net was either towed at slow speeds from a small boat, or suspended from the platform which extends below the west side of the Hampton Boulevard Bridge. In the latter case, the maximum ebb current at the time of collection provided the towing velocity. Sampling depth in both cases was approximately 1-2 m off the bottom.

Figure 1. Map of Lafayette River Estuary where mysids were collected to stock the maintenance aquarium in the laboratory.


76° 18'
LAFAYETTE RIVER
Hampton Blvd
36° 54'
36° 54'
Nautical Miles
0
0.5
76° 18'

Mysids are known to be delicate organisms, often sustaining high initial mortalities if handled roughly during the collection process. All possible care was taken during the collection process so as to minimize shock and/or physical damage. The initial sampling tow was for a period of five minutes and was used to gauge the expected sampling densities. The following towing times were then lengthened or shortened, depending on the mysid densities encountered, and no attempt was made to quantify the number of mysids captured. The mysids were dip rinsed into the cod end of the plankton net, which was then emptied into a five-gallon polyethylene bucket containing water from the collection site for transfer back to the laboratory. Aeration was provided with a portable, battery operated air pump. Temperature and salinity measurements were taken upon return to the laboratory.

Upon arrival at the laboratory, the mysids were siphoned from the bucket into 203 mm(193.7 mm x 66.7 mm) culture dishes (Carolina Biological Supply). Excess debris, dead or obviously stressed individuals, and other unwanted specimens were removed with a large bore 25 ml pipette, the end of which had been enlarged and fire-polished. Circular plexiglas covers were made for each culture dish. Through the center of each a hole had been drilled allowing for the insertion of an air stone. This resulted in the creation of a doughnut type of circulation which, in addition to aeration, provided the mysids with a direction of orientation. The dishes were then placed in a Percival Model I-35 Biological Incubator for acclimation to the 15-17^{o} C temperature of the maintenance aquarium.

The following day any additional debris or dead mysids which had accumulated were removed. Salinity adjustments, if necessary, were made by adding high salinity 0.3 μm filtered seawater at 15^{o} C. Incremental

changes were approximately 2 °/oo every 20 minutes. The mysids were removed from the culture dishes with the large bore 25 ml pipette and added directly to the maintenance aquarium.

The maintenance aquarium (design described in Appendix I) in which the specimens were kept was located in a wooden box in Room 113 at the Department of Oceanography. This box is serviced by an independent air conditioning unit which resulted in a maximum temperature fluctuation of 1.5-2.0° C over a 24-hour period, with 15° C minimum. Eight foot fluorescent lighting fixtures situated above the aquarium provided light and the photoperiod utilized was 12:12. Salinity was kept between 20-22 °/oo with appropriate additions of de-ionized water at the same temperature as the aquarium.

The aquarium was initially set up in September 1978 and the mysids were added as the conditioning agents. Periodically mysids were added throughout the year and utilized for preliminary experimentation and to perfect various techniques and procedures. Mysids were last collected from the Lafayette River on June 20, 1979, and added to the maintenance aquarium on June 21, 1979. The primary diet fed to the mysids in the aquarium were Artemia salina nauplii hatched on a daily basis. Half of the hatch was added in the morning and the remainder in the afternoon. The daily harvest of the cultured rotifer Brachionus plicatilis, when not needed for experimental purposes, was also added to the tank. Periodically some of the diatom culture of Coscinodiscus lineatus was added, but not on a regular basis.

In a conditioned system the measurable ammonia (as total NH_4^+) should be less than 0.1 ppm. Only the unionized ammonia appears to be toxic to marine animals, however, sublethal levels are known to impair

or decrease growth, fecundity, physical stamina, and the organisms disease resistance (Spotte, 1970; Atz, 1964).

Jawed (1969) in his work with Neomysis rayii found that ammonia-N, as opposed to amino-N and urea, was the dominant form excreted. It accounted for 76% of the total nitrogen excreted at his test temperature of 10° C. He also found that nitrogen excretion decreased with decreasing temperature.

Further evidence as to the seasonality of the amounts of nitrogen excreted by mysid shrimps was put forth in the work by Chin (1974) on Neomysis awatschensis. He found that the nitrogen excretion declined sharply to low levels in January and February, but then increased in April. They decreased again in early summer to autumn, and then maintained a relatively constant level until December.

It is known that dissolved oxygen and pH levels are the two most important factors affecting ammonia toxicity. The design of the maintenance aquarium provided more than adequate aeration and the buffering ability of the oyster shells helped to maintain the pH within acceptable limits.

After mysids had been in the tank for approximately five weeks, water samples were removed and analyzed for nitrate, nitrite, and unionized ammonia. This was done to insure that the biological filter was performing properly under load. Analyses were performed utilizing a Hach Water Analysis kit with a DR/2 Field Spectrophotmeter. The results of the analyses indicated concentrations of 0.0132 mg/liter Nitrite (NO_2^-), 8.25 mg/liter Nitrate (NO_3^-), and 0.00310 ppm unionized Ammonia. All readings fell within the acceptable limits, according to Spotte (1970). These limits for closed recirculating systems are

0.1 ppm, 20.0 ppm, and 0.01 ppm, respectively.

Mysids were removed for experimental purposes only after they had been in the aquarium a minimum of four days. While adults, both male and female, as well as immatures, could be readily observed and removed for experimentation, the juveniles presented another problem. The number of juveniles needed for an experimental run, the volume of water in the tank, and the lack of high density algal concentrations for food combined to make the maintenance aquarium impractical as a ready source. Because of this, ovigerous females in late stages of development were removed from the aquarium and placed in the culture dishes of 20 °/oo, 0.3 μm filtered seawater. The water was changed daily by siphoning through a 110 μm mesh filter. Fresh 0.3 μm filtered seawater at 20 °/oo and 15° C was added. Two hundred ml of Coscinodiscus lineatus culture were added daily as food.

Aeration was provided through the use of the plexiglas covers, and the dishes were kept in the Percival Incubator at 15° C under a 12 hour light:12 hour dark photoperiod. As a female released her brood, she was removed and replaced in the aquarium. When enough juveniles were available, they were removed to their own 203 mm culture dish and treated the same as the adults. Specimens utilized, therefore, were from a number of broods, which tended to minimize any inter-brood variation that might otherwise have affected the experimental results.

For a variety of technical reasons, the actual thesis experiments for data collection purposes did not begin until June 25, 1979. Experiments were run on mysids which belong to the so-called summer generation. This generation matures more rapidly and attains a slightly smaller adult size than the larger, overwintering generation (Wigley and Burns, 1971).

Experimentation

Experiments were conducted on four size classes of the mysid shrimp Neomysis americana Smith. These size classes were designated Juveniles (newly released individuals), Immature (sexual characteristics not yet readily discernible), Adult Males, and Adult Females (ovigerous). Each size class was offered three different food sources, at three different concentrations. The food sources utilized were newly hatched nauplii of the brine shrimp Artemia salina, the rotifer Brachionus plicatilis, and diatom Coscinodiscus lineatus. The initial prey concentrations desired were 15, 30, and 60 brine shrimp/ml; 15, 30, and 60 rotifers/ml; and 500, 1500, and 3000 diatoms/ml. Experiments were run for 24 hours and were conducted on only one size class and prey species at a time. Three pairs of culture dishes, each containing ten mysids, received one of the three prey concentrations, while an additional two dishes contained prey alone and served as controls for growth and mortality.

The volume of each grazing container was 1000 ml. At the end of the 24 hour grazing period the mysids were removed and the prey concentrations per ml determined to allow calculation of the Ingestion rates of prey per mysid per hour.

An additional part of the experimental design was an estimation of the percentage assimilation by the mysids at each prey concentration offered. Conover's ratio method (1966) of calculating assimilation was utilized. This method assumes that no inorganics are assimilated, and requires a determination of the percentage of organics in both the prey species and fecal material of the predator. Because of this, the actual ingestion experiments were preceeded by a period of starvation in an attempt to purge the gut of any material previously ingested in the

aquarium or culture dishes. It is believed that mysids have a high metabolic rate requiring almost continuous feeding. The possibility of weakening, or adversely stressing the mysids during the period of starvation, had to be considered and taken into account. In order to accomplish this, an initial starvation experiment was conducted to determine how long the mysids could survive in 20 °/oo, 0.3 μm filtered seawater. Ten individuals in each of the four size classes to be utilized in the ingestion experiments were placed in the large circular 203 mm glass culture dishes. Each dish contained 1000 ml of 20 °/oo, 0.3 μm filtered seawater at 15° C. The dishes were covered with the plexiglas covers, placed in the Percival incubator at 15° C, and aerated. Upon death, the mysids were removed to prevent cannibalism by the remaining individuals. The time it took for 50 and 100 percent of the mysids to die was recorded. This information is presented in Table 1. While the somewhat standard starvation period of 24 hours seemed satisfactory for the three largest size classes, it was felt that this time might put an undue amount of stress on the juveniles. In order to be consistent throughout the experimentation, a shorter period of time, 12 hours, was decided upon and subsequently used throughout.

Initially, pre- and post-grazing prey concentrations were to be determined by making visual counts on three 1-ml aliquots. Receipt of a Model ZB Coulter Particle Counter in January, 1979, allowed for its integration into the experimental design in lieu of the visual counts. Equipment problems, however, were largely responsible for delaying the start of experimentation until summer 1979.

Length measurements of the mysids used in each experiment were also made. This provided a more concise way of classifying the size classes utilized as opposed to that of development. Lengths were measured to

Table 1. Approximate time required for starvation of mysids in the four size classes utilized in the experiments. Ten individuals were utilized per size class.

Size Class	Approximate time required for 50% (5 of 10) of the mysids to die	Approximate time required for 100% mortality
Juveniles	1.5 days	3.0 days
Immature	4.5 days	7.5 days
Males, Adult	4.5 days	9.5 days
Females, Adult/Ovigerous	6 days	13 days

the nearest 0.5 mm. Measurements were taken from the anterior portion of the carapace between eyestalks, to the tip of the telson. Length measurements were made after the initial 12 hour starvation period, and prior to commencing the grazing period. Overall, the approximate lengths of the size classes utilized were: juveniles - 2.5 mm; immature - 4.5mm; adult males - 8.0 mm; and adult ovigerous females - 8.5 mm. These data, broken down further into mean lengths per experiment, are presented in Table 2.

Each ingestion experiment was begun by first removing 90 mysids of a particular size class from the maintenance aquarium, or culture dishes in the case of the juveniles. Fifteen mysids were placed in each of six large culture dishes containing 1000 ml of 20 °/oo, 0.3 μm filtered seawater at 15° C. The photoperiod of the incubator was 12 hour light: 12 hour dark on the same schedule as that of the maintenance aquarium. The only difference was that illumination in the incubator was provided by fluorescent lights both above and below the culture dishes in order to provide an indirect light source.

The grazing experiments were designed to be run on groups of ten mysids each. Fifteen animals were starved per bowl initially to insure that the grazing containers would each begin with ten healthy individuals. This 33% safety margin during the initial starvation period was designed to safeguard against any mysids which were stressed, damaged during handling, or in a previously weakened state. In all cases, the ten most active individuals per bowl, as determined by swimming speed and overall movement, were selected for the grazing experiments. An a priori requirement stated that if greater than 30% mortality occurred in the mysids in any one dish during the grazing experiment, then the experiment should

Table 2. Lengths of mysids utilized in the experiments.

Size class: Juveniles

Experiment #	Food Source	Mean length per experiment (mm)	Overall mean per size class (mm)
J-7	A. salina	2.4 ± 0.3	
J-8	B. plicatilis	2.5 ± 0.3	2.5 ± 0.4
J-9	C. lineatus	2.5 ± 0.4	

Size class: Immature

Experiment #	Food Source	Mean length per experiment (mm)	Overall mean per size class (mm)
I-12	C. lineatus	4.7 ± 0.5	
I-13	B. plicatilis	4.6 ± 0.4	4.5 ± 0.5
I-14	A. salina	4.3 ± 0.4	

Size class: Adult/ovigerous females

Experiment #	Food Source	Mean length per experiment (mm)	Overall mean per size class (mm)
F-15	C. lineatus	8.6 ± 0.7	
F-16	B. plicatilis	8.5 ± 0.6	8.5 ± 0.6
F-23	A. salina	8.4 ± 0.5	

Size class: Adult males

Experiment #	Food Source	Mean length per experiment (mm)	Overall mean per size class (mm)
M-18	A. salina	8.1 ± 0.6	
M-20	B. plicatilis	8.1 ± 0.5	8.0 ± 0.5
M-21	C. lineatus	8.2 ± 0.5	

be rerun.

Mysids were removed individually from the starvation culture dishes with the large bore 25 ml pipette and transferred to a 102 mm concave beaker cover. Excess water was removed with a disposable Pasteur pipette, leaving the mysid extended in a shallow pool of water. Length measurements were taken through a dissecting scope as previously described and recorded. The mysid was then rinsed with 20 °/oo, 0.3 μm filtered seawater into a small 100 ml beaker. Once the beaker contained ten mysids it was filled to 40 ml with additional 20 °/oo, 0.3 μm filtered seawater. This procedure was followed for each group of ten mysids regardless of size class or prey species being utilized.

The prey harvest or stock solution to be utilized in a particular experiment was made to 500 ml. Aliquots were counted on the Model ZB Coulter Counter and the mean concentration plus or minus one standard deviation determined (for culturing methods and procedures for determining desired prey concentration see Appendices II-IV). The volume of the 500 ml stock solution needed to yield the desired concentration per ml in one liter was calculated. This volume was placed in a 500 ml beaker and 20 °/oo, 0.3 μm filtered sea water added to bring the total volume to 500 ml. Each culture dish then received 460 ml of 20 °/oo, 0.3 μm filtered seawater at 15° C. The 500 ml prey solution was then added to bring the container volume to 960 ml. Finally, the beaker containing the ten mysids in 40 ml of 20 °/oo, 0.3 μm filtered seawater was added. The total volume of the grazing container was now 1000 ml or 100 ml per mysid. The time of addition of the mysids was recorded, and denoted as t=0. Two additional culture dishes each received a 500 ml aliquot of known prey concentration and 500 ml of 20 °/oo, 0.3 μm filtered seawater. These

served as controls for growth and/or mortality in the prey during the grazing period.

In each experiment, the start of the six grazing containers was staggered by 15 minutes. As each container received its ten mysids it was covered with the plexiglas cover, placed in the Percival Incubator, and aerated. The two control dishes received the same treatment. The temperature of the incubator was set at 15° C and the photoperiod was 12 hour light:12 hour dark synchronized with the maintenance aquarium. The aeration and indirect lighting prevented the prey species from either settling to the bottom of the dishes, or actively migrating to a point light source. Although experiments were not begun at precisely the same time, all experiments were exposed to a total of 12 hours light and 12 hours dark. It was deemed better to continue the photoperiod to which the mysids were accustomed, than to start all animals at the beginning of a dark or light period.

The mysids were allowed to graze undisturbed for 24 hours. At the end of this 24 hour period the grazing containers were individually removed. The number of mysids still alive was determined visually. For subsequent grazing and ingestion calculations this value was denoted as N. Mysids which were dead at the end of the grazing period were, for statistical purposes, assumed to be dead at the start. The rationale behind this was that if a mysid died during the experiment, then most likely it was already in a weakened or stressed condition at the start, and as such contributed little to the overall number of prey ingested.

The mysids were then removed from the grazing containers utilizing the large bore 25 ml pipette and a 355 μm mesh cylindrical sieve. The end of the sieve was submerged in the grazing containers, and the mysids

were individually removed from the grazing containers with the pipette and re-deposited inside the sieve. When all ten mysids had been deposited in the sieve enclosure, it was removed from the grazing container. The mesh size allowed the prey to pass through and remain in the grazing container while it retained the mysids. The mysids were rinsed from the mesh sieve into a 51 mm glass culture dish.

As mentioned previously, determining the percentage of assimilation of the mysids at the specific prey species and concentrations,required the removal of samples of fecal material from each of the grazing containers. After removing the mysids, the grazing medium was swirled with the pipette in a clockwise or counter-clockwise manner around the perimeter of the grazing container. This resulted in the concentration and deposition of the fecal material and other debris in the center of the grazing container. Unlike copepods, mysids do not egest fecal pellets which are encased in a strong peritrophic membrane. Mysids egest long fecal strands, and the membrane which encases the fecal material tends to be very delicate and is easily ripped or destroyed if attempts are made to pick it up with microprobes. The fecal strands were therefore removed utilizing capillary tubes (0.8-1.1 x 100 mm). By placing a finger over the end of the capillary tube and inserting it into the grazing container, then slowly releasing it, fecal samples were drawn up. Extractions in this manner were done while viewing the fecal material and capillary tube tip under a dissecting scope. The sample of fecal material was then blown out into a small 51 mm culture dish. Almost all that was visible in each of the grazing containers was removed. The reasoning behind this was twofold : first, the maximum amount of egested fecal material obtainable from each dish was necessary in order to provide

large enough dry and ash weight measurements; and second, large amounts of fecal material remaining in the grazing containers confounded post-grazing prey concentration determinations with the Coulter Counter.

With the fecal material removed, the entire contents of the grazing containers were re-sieved, in the case of B. plicatilis or A. salina, or an aliquot removed in the case of C. lineatus, and post-grazing prey concentrations per ml determined with the Coulter Counter.

The fecal material in the 51 mm culture dishes was again set in motion, this time by squirting in 20 °/oo, 013 μm filtered seawater from a polyethylene squirt bottle. The fecal material again became concentrated in the center of the dish. It was removed with another capillary tube and transferred to pre-ashed, pre-weighed 25 mm glass fiber filters. Five drops of a 0.5 Molar Ammonium formate (NH_4CHO_2) solution were added dropwise in an attempt to remove any adventitious salts. Each drop was absorbed by the filter paper prior to adding the next (Conover, 1966).

The filters containing the fecal material were placed in 70 mm aluminum pans and dried for 12 hours at 75° C in a Precision Mechanical Convection Oven. At the end of the drying period, the samples were removed from the oven and placed in a dessicator for approximately 30 minutes and allowed to cool to room temperature. Dry weight measurements were taken using a Model CL41 Unimatic Balance. The samples were then placed in a Model 184 Fisher Isotemp Furnace and ashed at 500° C for 12 hours.

Following the ashing period, the furnace was turned off and allowed to cool to 200° C. The samples were then removed and placed in a dessicator for 45 minutes to one hour and allowed to cool to room temperature. Ash weight measurements of the samples were again taken using the

Unimatic Balance. The dry weights and ash weights of the fecal material removed from each grazing container allowed the calculation of the Ash Free Dry Weight:Dry Weight Ratio of each.

Subsequent calculations of the percent assimilation also required a knowledge of the Ash Free Dry Weight:Dry Weight Ratio of each food source. Stock solutions of each of the three prey species were prepared and aliquots removed. These were counted on the Coulter Counter and the stock prey concentration per ml determined. Aliquots of each prey solution were then slowly filtered with a Millipore Apparatus onto pre-ashed, pre-weighed, 0.3 μm glass fiber filters. The filtrate was then refiltered onto an additional pre-ashed, pre-weighed glass fiber filter. Each filter received five drops of the 0.5 Molar Ammonium Formate solution and was then placed in a 70 mm aluminum pan for drying. The purpose of the filter with filtrate only was to serve as a check for any sea salts which might still be retained in the pores of the paper in spite of the Ammonium Formate. Any dry weight or ash weight gain observed on the paper containing filtrate only was subsequently subtracted from the dry and ash weights of the prey samples. Replicates of each prey solution and filtrate were simultaneously run. The pans containing the filter papers and samples were dried, weighed, ashed, and re-weighed according to the procedure already outlined for the fecal samples. The Ash Free Dry Weight:Dry Weight Ratio of each food source was then calculated for use in the determinations of Percent Assimilation for each grazing container. These data are summarized for each food source in Table 3.

A knowledge of the wet weight and dry weight of the mysids utilized in the experiments was also necessary for subsequent analysis of the

Table 3. Data utilized in determining percent organic content per food source offered.

	B. plicatilis		C. lineatus		A. salina	
	A (gms)	B (gms)	A (gms)	B (gms)	A (gms)	B (gms)
Dry weight of sample	0.0092	0.0073	0.0220	0.0220	0.0410	0.0350
Sea salt dry weight correction	0.0020	0.0018	0.0031	0.0030	0.0033	0.0028
Adjusted dry weight	0.0072	0.0055	0.0189	0.0190	0.0377	0.0322
Ash weight of sample	0.0017	0.0012	0.0096	0.0092	0.0071	0.0070
Sea salt ash weight correction	0.0007	0.0005	0.0019	0.0021	0.0015	0.0013
Adjusted ash weight	0.0010	0.0007	0.0077	0.0071	0.0056	0.0057
Ash Free Dry Weight	0.0062	0.0050	0.0112	0.0119	0.0321	0.0265
Ash Free Dry Weight: Dry Weight	0.8611	0.9091	0.5926	0.6263	0.8515	0.8230
Mean percentage organics	88.51	3.39%	60.95	2.39%	83.73	2.02%

data. To accomplish this, ten mysids in each of the larger size classes (13 in the case of the juveniles) were segregated in 102 mm culture dishes of 20 °/oo, 0.3 μm filtered seawater. The mysids in a particular size class were then removed with the 25 ml large bore pipette, and transferred to a concave 102 mm beaker cover. Excess water was removed with a disposable Pasteur pipette, leaving them stranded in a thin layer of water. The mysids were individually picked up with a microprobe and momentarily placed on a piece of absorbent towel to remove excess water clinging to the appendages and body. They were then transferred to a pre-ashed, pre-weighed 25 mm glass fiber filter paper. This paper plus sample was then weighed on the Unimatic CL 41 Model Balance and an average wet weight per individual in a particular size class calculated. Replicates were conducted. The filter papers containing the mysids were placed in 70 mm aluminum pans and dried for 12 hours at 75° C in a Precision Mechanical Convection Oven. At the end of the drying period the filter papers and samples were removed from the oven and placed in a dessicator for approximately 30 minutes to cool to room temperature. Dry weights of the samples were determined with the Unimatic Balance and an average dry weight per individual in a particular size class calculated. The average dry weights of the two replicates were combined and the mean dry weight per individual in a size class, plus or minus one standard deviation, calculated. These data are summarized in Table 4.

Statistical Methods

Calculation of Ingestion Rates

Initial and final calculations of the prey stock concentrations were determined by counting ten, two-ml aliquots on the Coulter Counter. This resulted in a mean concentration plus or minus one standard deviation.

Table 4. Wet/Dry Weights of mysid size classes utilized in experimentation.

	A (gms)	B (gms)
Juveniles		
Wet weight of 13 mysids	0.0008	0.0008
Dry Weight of 13 mysids	0.0005	0.0003
Mean dry weight (gms)	0.0004	
Dry weight/individual (gms)	6.20×10^{-5}	
Immature		
Wet weight of ten mysids	0.0103	0.0112
Dry weight of ten mysids	0.0017	0.0023
Mean dry weight (gms)	0.0020	
Dry weight/individual (gms)	2.00×10^{-4}	
Males (Adult)		
Wet weight of ten mysids	0.0537	0.0515
Dry weight of ten mysids	0.0108	0.0096
Mean dry weight (gms)	0.0102	
Dry weight/individual (gms)	1.02×10^{-3}	
Females (Adult/Ovigerous)		
Wet weight of ten mysids	0.0522	0.0522
Dry weight of ten mysids	0.0114	0.0113
Mean dry weight (gms)	0.0114	
Dry weight/individual (gms)	1.14×10^{-3}	

The necessary volumes of the prey stock required to yield approximately the desired prey concentration per ml in each grazing container (CO±SO) were calculated and subsequently added. Two additional dishes containing a known concentration of prey per ml (CO*±SO*) were also prepared and served as controls for growth and mortality in the prey during the experiment. At the end of the 24 hour grazing period, prey concentrations per ml in the controls (CT*±ST*) and each of the six grazing containers (CT*±ST*) were determined.

A t-test was performed to determine if there was a significant difference (α=0.05) in the initial and final prey concentrations per ml in the controls. No significant difference indicated no growth or mortality, while a significant difference indicated growth. The experiments utilizing C. lineatus as prey consistently showed growth, while those utilizing A. salina or B. plicatilis did not.

The next step in those experiments utilizing A. salina or B. plicatilis was conducting a t-test on each of the individual grazing containers. A significant difference (α=0.05) in the pre- and post-grazing prey concentrations indicated grazing had occurred, whereas no significant difference indicated otherwise. In cases where there was no significant difference, no further calculations were performed as the results obtained would have been inconclusive.

As previously mentioned, the C. lineatus controls always exhibited growth. This fact confused the interpretations when using the t-test on the pre- and post- grazing prey concentrations. No significant difference (α=0.05) indicated that while the cell concentrations were increasing due to growth, the mysids were likely grazing back the population. A significant difference, on the other hand, merely indicated a lower or

higher grazing rate in the individual bowls. Because of this, subsequent calculations were performed regardless of the pre- and post- grazing prey concentrations in each bowl.

For experiments in which A. salina and B. plicatilis were the prey, no significant difference in pre- and post- control concentrations meant that the growth coefficient (K) was assigned the value zero. Experiments utilizing C. lineatus, which did show growth in the controls, required that the growth coefficient (K) be calculated.

The formula for calculating the growth coefficient (Conover, 1966) is:

$$k = \frac{\ln CT^* - \ln CO^*}{t} \qquad (1)$$

where,

CT* = Concentration of Prey in control flask at time t (t = 24 hrs)

CO* = Concentration of Prey in control flask at time 0

This formula assumes no error in any of the terms. While t is assumed to be error free, both CT* and CO* were not. These values were determined with the Coulter Counter and possessed error terms designated ST* and SO* which represent plus or minus one standard deviation about their respective means. Because of this, the error term (SK) associated with the growth coefficient (K) was calculated according to the equation

$$SK = \frac{\ln \left(1 \pm \frac{ST^*}{CT^*}\right) - \ln \left(1 \pm \frac{SO^*}{CO^*}\right)}{t} \qquad (2)$$

While each control dish was assumed to begin with identical CO* values, the final concentrations in each, CT*, as determined by counting

were not. This resulted in slightly different growth coefficients (K) being obtained for each. They were denoted K1 and K2 for control dishes 1 and 2 respectively. Likewise, depending on how the positive and negative signs were arranged in the formula for SK, four possible error terms were calculated for each dish. These were denoted $SK1_{1-4}$ and $SK2_{1-4}$ for each dish. The growth coefficients as well as all possible error terms were hand calculated. The maximum possible positive and negative error terms for each growth coefficient were chosen and denoted SK1 Max, SK1 Min, SK2 Max, and SK2 Min. The control dishes were designed to be replicates as much as possible. Therefore, any differences in the growth coefficients were due to unknown factors which could not be controlled. As such, the most accurate growth coefficient was taken to be their mean ($\bar{K}$) and was calculated according to the formula

$$\bar{K} = \frac{K1 + K2}{2} \tag{3}$$

The standard error of this mean was then calculated by using the maximum positive error (SK1 Max or SK2 Max) and the maximum negative error (SK1 Min or SK2 Min) of the two values (K1 and K2) according to the formulas:

$$S\bar{K}\ \text{Max} = \frac{SK\ \text{Max (1 or 2)}}{2} \tag{4}$$

$$S\bar{K}\ \text{Min} = \frac{SK\ \text{Min (1 or 2)}}{2} \tag{5}$$

This yielded error bounds which were applied to the mean growth coefficient. The $S\bar{K}$ values calculated, both maximum and minimum, tended to be symmetrical about $\bar{K}$ to three places. The growth coefficient and

error term subsequently utilized in succeeding calculations on the individual dishes was therefore taken to be $\bar{K} \pm \overline{SK}$.

The grazing coefficient (G), with units hour^{-1}, is calculated (according to Conover, 1966) with the formula:

$$G = \frac{\ln CO - \ln CT + kt}{t} \qquad (6)$$

where,

CO = Concentration of Prey at time 0 in grazing container

CT = Concentration of Prey at time t in grazing container

K = Growth coefficient

t = 24 hours

As before, this formula assumes no error in any of the individual terms. Assuming t to be error free and inserting the error terms the formula becomes:

$$G = \frac{\ln(CO \pm SO) - \ln(CT \pm ST) + (\bar{K} \pm \overline{SK})t}{t} \qquad (7)$$

which then can be broken down into the grazing coefficient (G) and its associated error term (SG)

$$G = \frac{\ln CO - \ln CT + \bar{K}t}{t} \qquad (8)$$

$$SG = \frac{\ln\left(1 \pm \frac{SO}{CO}\right) - \ln\left(1 \pm \frac{ST}{CT}\right) \pm \overline{SK}t}{t} \qquad (9)$$

There are then eight possible error terms, SG(1-8), depending on how the signs are arranged in the calculations. These values were calculated, sorted, and the maximum positive and maximum negative errors

picked. They were denoted SG Max and SG Min and were thereafter applied as the error bounds on G in subsequent calculations.

The next step for each grazing container was the calculation of the Filtration Rate (F) in units of ml swept clean per mysid per hour. Conover (1966) gives the formula for F as:

$$F = \frac{(G)(V)}{N} \tag{10}$$

where,

G = grazing coefficient (hr^{-1})

V = volume of the grazing container (ml)

N = number of mysids grazing

The volume utilized in each grazing container and control was 1000 ml and assumed to be error free. N, the number of mysids grazing, was taken to be the number of mysids alive at the end of the 24 hour grazing period, for reasons previously stated. The grazing coefficient, along with its error component, had already been calculated.

The error bounds on F, as determined above, were calculated according to the following equations:

$$SF1 = \frac{(SG\ Max)\ V}{N} \tag{11}$$

$$SF2 = \frac{(SG\ Min)\ V}{N} \tag{12}$$

where SF1 is now the maximum positive error on F, and SF2 is the maximum negative error.

Ingestion rates are known to be a function of the prey concentration. Although initial and final concentrations had already been cal-

culated, the average prey concentration over the 24 hour period had to be determined. According to Conover (1966), the average prey concentration, denoted c, is calculated according to the formula:

$$c = \frac{CO(e^{(K-G)t} - 1)}{(K-G)t} \quad \text{units} = \# \text{ Prey/ml} \tag{13}$$

where CO, K, G, and t have been previously defined.

This equation again calculates the average prey concentration assuming no error in any of the component terms. If the errors are included, the formula for average prey concentration, hereafter denoted C, becomes:

$$C = \frac{(CO \pm SO)\ (e^{[(K \pm SK) - (G \pm SG)]t} - 1)}{[(K \pm SK) - (G \pm SG)]t} \tag{14}$$

which can be broken down into the base value C, and its error term SC.

$$C = \frac{CO\ (e^{(K - G)t} - 1)}{(K - G)t} \tag{15}$$

$$SC = \frac{(\pm SO)(e^{(\pm SK - (\pm SG))t} - 1)}{(\pm SK - (\pm SG))t} \tag{16}$$

There are 32 possible combinations, or values, for SC. These values were calculated, sorted, and the maximum positive error (SC Max) and maximum negative error (SC Min) determined.

The actual ingestion rate (I), with units of # prey per mysid hour,

can now be calculated according to the formula (Conover, 1966):

$$I = F(C) \tag{17}$$

Taking into account the errors on F (SF1 and SF2) and C (SC Max and SC Min), the four possible errors on I (denoted SI) can be calculated according to the formulas:

$$SI(1) = SF1\ (SC\ Max) \tag{18}$$

$$SI(2) = SF1\ (SC\ Min) \tag{19}$$

$$SI(3) = SF2\ (SC\ Max) \tag{20}$$

$$SI(4) = SF2\ (SC\ Min) \tag{21}$$

As before, the maximum positive error and maximum negative error were chosen, denoted SI Max and SI Min respectively, and applied as the error bounds on the base value I.

With the exception of the growth coefficient ($\bar{K}$) and its error term ($S\bar{K}$), subsequent calculations on the individual grazing containers were performed by computer. The program used is found in Appendix V.

The ingestion rates per grazing container were also calculated after normalizing for the dry weights of the mysids. The dry weight (in gms) of individual mysids in a particular size class was determined by drying replicate samples. The mean dry weight per individual, plus or minus one standard deviation, was calculated utilizing the replicates and multiplied by N to give the dry weight (in gms) of N mysids in a given grazing container. This value of N (now called DW) was substituted into the program and used to calculate a new ingestion rate (I') and its associated error (SI'). The units of I' are now prey/gm dry weight mysid/hour. These results are tabulated per grazing container

and are located in Appendix VII.

A further normalization of the data was also performed, this time to adjust I' for the gm dry weight of the prey ingested in lieu of the prey number. This was done by first determining the mean dry weight (in gms) of an individual prey plus or minus one standard deviation (Table 5). The average prey concentration per ml (C) was then converted to average gm dry weight prey per ml plus or minus one standard deviation ($C' \pm SC'$). The mean ingestion value (I') and prey concentration (C'), and the maximum and minimum errors associated with each, were multiplied to obtain the ingestion rate, I", and its error bounds ($\pm SI"$). The units of I" are now gm dry weight prey/gm dry weight mysid/hour.

A further transformation of the data was required before the ingestion rate vs. prey concentration graphs of the various size classes on the different preys could be superimposed. To accomplish this, the log C and log ($I" \pm SI"$) values were calculated.

An a priori assumption at the start of experimentation stated that the ingestion rates observed would be a function of the prey concentration. The prey concentration, therefore, became the independent variable, and the ingestion rate observed the dependent variable. The experiment was designed such that two replicate grazing containers were run simultaneously at as close to identical prey concentrations as possible. In all cases, they were treated identically. Any variability which occurred in the replicates was assumed to be a result of the inherent variability in the individual test organisms. The best estimate, therefore, of the ingestion rates at the average prey concentration in the two containers was taken to be the mean of the replicates and the error associated with this mean was the standard error of the mean.

Table 5. Food Source Dry Weight Data

	A (gms)	B (gms)
Coscinodiscus lineatus		
Dry weight of 240 ml sample (@ 6677.5 ± 566.6/ml)	0.0220	0.0220
Sea salt dry weight correction	0.0031	0.0030
Adjusted dry weight of sample	0.0189	0.0190
Mean dry weight of sample (gms)	0.0190	
Mean dry weight of prey (gms/prey	1.2×10^{-8}	
(+ 1 standard deviation)	$+ 1.1 \times 10^{-9}$	
(- 1 standard deviation)	$- 9.5 \times 10^{-10}$	
Brachionus plicatilis		
Dry weight of 240 ml sample	0.0068	0.0054
Sea salt dry weight correction	0.0048	0.0037
Adjusted dry weight of sample	0.0020	0.0017
Mean dry weight of sample (gms)	0.0019	
Mean dry weight of prey (gms/prey)	1.32×10^{-7}	
(+ 1 standard deviation)	$+1.62 \times 10^{-7}$	
(- 1 standard deviation)	-4.69×10^{-8}	
Artemia salina		
Dry weight of 50 ml sample	0.0205	0.0201
Sea salt dry weight correction	0.0034	0.0033
Adjusted dry weight of sample	0.0171	0.0168
Mean dry weight of sample	0.0170	
Mean dry weight of prey (gms/prey)	7.64×10^{-7}	
(+ 1 standard deviation)	$+2.46 \times 10^{-7}$	
(- 1 standard deviation)	-1.52×10^{-7}	

These mean values per replicates are distinguished from the actual values per grazing container by the addition of the bar superscript over the symbol. The units, however, remain unchanged.

The following graphs were constructed from the data generated:

--Ingestion ($\bar{I}$) vs. prey concentration ($\bar{C}$) for each size class on a particular prey species

--Ingestion ($\bar{I}'$) vs. prey concentration ($\bar{C}$) for each size class on a particular prey species

--Ingestion ($\bar{I}'$) vs. prey concentration ($\bar{C}$) for all size classes on a particular prey species

--Ingestion ($\bar{I}'$) vs. log prey concentration (log $\bar{C}'$) for each size class on all three food sources

--Log of ingestion (log $\bar{I}''$) vs. log prey concentration (log $\bar{C}'$) for each size class on all three food sources

Calculation of Assimilation Rates

The percentage of organics contained in each food source was determined by drying, weighing, ashing, and re-weighing replicate samples. This allowed a determination of the Ash Free Dry Weight:Dry Weight Ratio of each food source. The fecal samples which were removed from each grazing container at the end of the grazing periods were also dried, weighed, ashed, and re-weighed. There was no way to conduct replicates on a single grazing container as almost all of the fecal material removed was necessary for a single measurement.

Conovers Ratio Method (Conover, 1966) was utilized to determine the percentage assimilation. The formula he gives is:

$$U = \frac{F - E}{(1-E)F} \cdot 100 \qquad (22)$$

where

U = Percent assimilation

F = Ash Free Dry Weight:Dry Weight Ratio of food source

E = Ash Free Dry Weight:Dry Weight Ratio of fecal material

As previously stated, F values were determined by drying and ashing replicates and as such, possessed an error term (±FS) which represented one standard deviation on F. Since there was no way to conduct replicates on individual grazing containers, the value E was assumed to have a negligible error. Any error associated with it should have been due to errors in experimental procedure and common to all samples.

If the errors are included in the formula, the percentage assimilation per grazing container (US) then becomes

$$US = \frac{(F \pm FS) - (E)}{(1 - E)(F \pm FS)} \cdot 100 \qquad (23)$$

There are four possible values for US depending on sign arrangement. The maximum and minimum values were chosen, and denoted US Max and US Min respectively. These are the maximum and minimum possible assimilations and the errors they represent were determined by their differences from U.

The program utilized in calculating percent assimilation and its error is contained in appendix VI.

The mean percent assimilation and its standard error for each pair of replicates was determined. The rationale for this is the same as that previously stated for the ingestion calculations. The average prey concentration present in the two replicates was also utilized in graphing the Percent assimilation ($\bar{U}$) vs. Prey concentration ($\bar{C}$) for each size class on each of the three food sources.

RESULTS

Ingestion Rates

The four size classes of mysids utilized in the experiments were each fed three concentrations of three different food sources. A single size class was fed all three prey concentrations simultaneously. Replicates were performed on each concentration. A total of twelve, 24-hour grazing experiments were conducted, each consisting of six grazing containers and two controls. The results per grazing container for each experiment are found in Appendix VII.

An asterisk (*) indicates that there was no significant difference ($\alpha = 0.05$) in the calculated pre- and post- grazing prey concentrations in the grazing container. In only two experiments did this occur, those in which the juvenile and immature mysids were fed A. salina. There was no significant difference in any of the juvenile grazing containers, whereas only the highest concentrations failed to show a significant difference for the immature. In those cases where there was no significant difference, no further calculations were performed as the results would have been inconclusive.

The number of mysids alive at the end of each grazing experiment is termed N. In no instance was the maximum permissible mortality of 30% exceeded; however, it was equalled in a few cases. Mortality during the grazing periods tended to be greatest in the smaller size classes, and decreased with increasing age or size of the test organism.

The growth coefficient ($\bar{K}$) and its associated error term ($\pm S\bar{K}$) were calculated by hand where applicable. No significant difference in the control prey concentration per ml over the 24 hour period was taken as an indication of zero growth or mortality. The growth coefficient is a dimensionless number and is utilized in subsequent computer calculations.

The grazing coefficient (G), filtration rate (F), average prey concentration (C), and ingestion rate (I), along with their maximum possible positive and negative errors were calculated by computer for each grazing container. The grazing coefficient has units of $hour^{-1}$, filtration rate of ml $mysid^{-1}$ $hour^{-1}$, average prey concentration of number of prey ml^{-1}, and ingestion rate (I) of number of prey ingested $mysid^{-1}$ $hour^{-1}$.

The mean ingestion rate ($\bar{I}$) for the two replicate containers at a particular prey concentration was calculated and plotted versus their average prey concentration. These data per experiment are summarized in Tables 6-17. The error bars applied to each point represent the maximum possible standard errors of these means and are not necessarily symmetrical about them. Figure 2 depicts the mean ingestion rates ($\bar{I}$) observed when A. salina was the prey species offered. Since there was no significant difference for any of the juvenile grazing containers, no graph was prepared. The absence of a significant difference at the highest prey concentration in the immature experiments resulted in a missing data point. Interpretations of trends, or drawing conclusions from two point graphs will be avoided. Suffice to say, the results of the ingestion experiments for the immature size class fed A. salina were inconclusive. Figure 3 shows the results obtained with B. plicatilis as the prey spe-

Table 6. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Juveniles
Food source: Artemia salina

	J-7-1 & J-7-2	J-7-3 & J-7-4	J-7-5 & J-7-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	*	*	*
Average Prey Concentration, $\bar{C}'$ (gm d.w. prey / ml)			
($\bar{C}'$)			
(log $\bar{C}'$)			
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)			
($\bar{I}$ Max)			
($\bar{I}$ Min)			
Ingestion Rate, $\bar{I}'$ (# prey / gm d.w. mysid hour)			
($\bar{I}'$)			
($\bar{I}'$ Max)			
($\bar{I}'$ Min)			
Ingestion Rate, $\bar{I}''$ (gm d.w. prey / gm d.w. mysid hr.)			
($\bar{I}''$)			
(log $\bar{I}''$)			
($\bar{I}''$ Max)			
(log $\bar{I}''$ Max)			
($\bar{I}''$ Min)			
(log $\bar{I}''$ Min)			

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 7. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Juveniles
Food source: Brachionus plicatilis

	J-8-1 & J-8-2	J-8-3 & J-8-4	J-8-5 & J-8-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	11.5	24.5	48.1
Average Prey Concentration, $\bar{C}'$ (gm d.w. prey / ml)			
($\bar{C}'$)	1.5×10^{-6}	3.2×10^{-6}	6.4×10^{-6}
(log $\bar{C}'$)	-5.82	-5.49	-5.20
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)	26.6	37.4	79.5
($\bar{I}$ Max)	32.7	48.6	101.0
($\bar{I}$ Min)	20.4	25.8	57.1
Ingestion Rate, $\bar{I}'$ (# prey / gm d.w. mysid hour)			
($\bar{I}'$)	$4.3 \times 10^{5}_{5}$	6.1×10^{5}	1.3×10^{6}
($\bar{I}'$ Max)	5.3×10^{5}	7.9×10^{5}	1.7×10^{6}
($\bar{I}'$ Min)	3.3×10^{5}	4.2×10^{5}	9.4×10^{5}
Ingestion Rate, $\bar{I}''$ (gm d.w. prey / gm d.w. mysid hr.)			
($\bar{I}''$)	5.7×10^{-2}	8.1×10^{-2}	1.7×10^{-1}
(log $\bar{I}''$)	-1.24	-1.09	-0.770_{-1}
($\bar{I}''$ Max)	1.5×10^{-1}	2.3×10^{-1}	4.6×10
(log $\bar{I}''$ Max)	-0.824	-0.638	-0.337_{-2}
($\bar{I}''$ Min)	2.8×10^{-2}	3.6×10^{-2}	7.9×10
(log $\bar{I}''$ Min)	-1.55	-1.44	-1.10

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 8. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Juveniles
Food Source: Coscinodiscus lineatus

	J-9-1 & J-9-2	J-9-3 & J-9-4	J-9-5 & J-9-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	570.8	1805.2	3562.9
Average Prey Concentration, $\bar{C}'$ (gm d.w. prey / ml)			
($\bar{C}'$)	6.74×10^{-6}	2.13×10^{-5}	4.20×10^{-5}
(log $\bar{C}'$)	-5.17	-4.67	-4.38
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)	323.6	356.8	668.3
($\bar{I}$ Max)	356.4	444.8	793.1
($\bar{I}$ Min)	289.9	268.1	541.1
Ingestion Rate, $\bar{I}'$ (# prey / gm d.w. mysid hour)			
($\bar{I}'$)	5.26×10^{6}	5.80×10^{6}	1.09×10^{7}
($\bar{I}'$ Max)	5.80×10^{6}	7.23×10^{6}	1.29×10^{7}
($\bar{I}'$ Min)	4.71×10^{6}	4.36×10^{6}	8.79×10^{6}
Ingestion Rate, $\bar{I}''$ (gm d.w. prey / gm d.w. mysid hr.)			
($\bar{I}''$)	6.2×10^{-2}	6.8×10^{-2}	1.3×10^{-1}
(log $\bar{I}''$)	-1.21	-1.17	-0.886
($\bar{I}''$ Max)	7.5×10^{-2}	9.4×10^{-2}	1.7×10^{-1}
(log $\bar{I}''$ Max)	-1.12	-1.03	-0.770
($\bar{I}''$ Min)	5.2×10^{-2}	4.8×10^{-2}	9.7×10^{-2}
(log $\bar{I}''$ Min)	-1.28	-1.32	-1.01

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 9. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Immature
Food source: *Coscinodiscus lineatus*

	I-12-1 & I-12-2	I-12-3 & I-12-4	I-12-5 & I-12-6
Average Prey Concentration, $\bar{C}$			
(# prey / ml)			
($\bar{C}$)	479.6	1428.5	2891.2
Average Prey Concentration, $\bar{C}'$			
(gm d.w. prey/ml)			
($\bar{C}'$)	5.66×10^{-6}	1.69×10^{-5}	3.41×10^{-5}
(log $\bar{C}'$)	-5.25	-4.77	-4.47
Ingestion Rate, $\bar{I}$			
(# prey / mysid hour)			
($\bar{I}$)	408.5	1293.5	2581.2
($\bar{I}$ Max)	450.6	1391.6	2714.3
($\bar{I}$ Min)	365.3	1194.5	2447.7
Ingestion Rate, $\bar{I}'$			
(# prey / gm d.w. mysid hour)			
($\bar{I}'$)	2.0×10^{6}	6.5×10^{6}	1.3×10^{7}
($\bar{I}'$ Max)	2.2×10^{6}	7.0×10^{6}	1.4×10^{7}
($\bar{I}'$ Min)	1.8×10^{6}	6.0×10^{6}	1.2×10^{7}
Ingestion Rate, $\bar{I}''$			
(gm d.w. prey / gm d.w. mysid hour)			
($\bar{I}''$)	2.4×10^{-2}	7.7×10^{-2}	1.5×10^{-1}
(log $\bar{I}''$)	-1.62	-1.11	-0.824
($\bar{I}''$ Max)	2.9×10^{-2}	9.1×10^{-2}	1.8×10^{-1}
(log $\bar{I}''$ Max)	-1.54	-1.04	-0.745
($\bar{I}''$ Min)	2.0×10^{-2}	6.6×10^{-2}	1.3×10^{-1}
(log $\bar{I}''$ Min)	-1.70	-1.18	-0.886

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 10. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Immature
Food source: *Brachionus plicatilis*

	I-13-1 & I-13-2	I-13-3 & I-13-4	I-13-5 & I-13-6
Average Prey Concentration, $\bar{C}$			
(# prey / ml)			
($\bar{C}$)	12.2	26.4	52.1
Average Prey Concentration, $\bar{C}'$			
(gm d.w. prey / ml)			
($\bar{C}'$)	1.61×10^{-6}	3.48×10^{-6}	6.88×10^{-6}
(log $\bar{C}'$)	-5.79	-5.46	-5.16
Ingestion Rate, $\bar{I}$			
(# prey / mysid hour)			
($\bar{I}$)	21.0	28.6	63.5
($\bar{I}$ Max)	26.6	38.4	90.1
($\bar{I}$ Min)	15.3	17.6	36.5
Ingestion Rate, $\bar{I}'$			
(# prey / gm d.w. mysid hour)			
($\bar{I}'$)	1.1×10^{5}	1.4×10^{5}	3.2×10^{5}
($\bar{I}'$ Max)	1.4×10^{5}	1.9×10^{5}	4.5×10^{5}
($\bar{I}'$ Min)	8.1×10^{4}	8.5×10^{4}	1.9×10^{5}
Ingestion Rate, $\bar{I}''$			
(gm d.w. prey / gm d.w. mysid hour)			
($\bar{I}''$)	1.3×10^{-3}	1.7×10^{-3}	3.8×10^{-3}
(log $\bar{I}''$)	-2.89	-2.77	-2.42
($\bar{I}''$ Max)	1.8×10^{-3}	2.5×10^{-3}	5.9×10^{-3}
(log $\bar{I}''$ Max)	-2.74	-2.60	-2.23
($\bar{I}''$ Min)	8.9×10^{-4}	9.4×10^{-4}	2.1×10^{-3}
(log $\bar{I}''$ Min)	-3.05	-3.03	-2.68

*- Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 11. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Immature
Food Source: *Artemia salina*

	I-14-1 & I-14-2	I-14-3 & I-14-4	I-14-5 & I-14-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	8.9	25.4	*
Average Prey Concentration, $\bar{C}'$ (gm d.w. prey / ml)			
($\bar{C}'$)	6.80×10^{-6}	1.94×10^{-5}	
(log $\bar{C}'$)	-5.17	-4.71	
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)	9.4	38.4	
($\bar{I}$ Max)	12.6	49.3	
($\bar{I}$ Min)	6.2	27.4	
Ingestion Rate, $\bar{I}'$ (# prey / gm d.w. mysid hour)			
($\bar{I}'$)	4.7×10^{4}	1.9×10^{5}	
($\bar{I}'$ Max)	6.3×10^{4}	2.4×10^{5}	
($\bar{I}'$ Min)	3.1×10^{4}	1.4×10^{5}	
Ingestion Rate, $\bar{I}''$ (gm d.w. prey / gm d.w. mysid hour)			
($\bar{I}''$)	3.6×10^{-2}	1.5×10^{-1}	
(log $\bar{I}''$)	-1.44	-0.824	
($\bar{I}''$ Max)	6.3×10^{-2}	2.4×10^{-1}	
(log $\bar{I}''$ Max)	-1.20	-0.620	
($\bar{I}''$ Min)	1.9×10^{-2}	8.5×10^{-2}	
(log $\bar{I}''$ Min)	-1.72	-1.07	

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 12. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Females (Adult/ovigerous)
Food source: Coscinodiscus lineatus

	F-15-1 & F-15-2	F-15-3 & F-15-4	F-15-5 & F-15-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	410.0	1433.3	3020.1
Average Prey Concentration, $\bar{C}'$ (gm d.w. prey / ml)			
($\bar{C}'$)	4.84×10^{-6}	1.69×10^{-5}	3.56×10^{-5}
(log $\bar{C}'$)	-5.32	-4.77	-4.45
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)	1360.8	1808.2	2721.0
($\bar{I}$ Max)	1377.4	1840.5	2846.1
($\bar{I}$ Min)	1343.1	1775.1	2593.7
Ingestion Rate, $\bar{I}'$ (# prey / gm d.w. mysid hour)			
($\bar{I}'$)	1.20×10^{6}	1.59×10^{6}	2.40×10^{6}
($\bar{I}'$ Max)	1.21×10^{6}	1.62×10^{6}	2.51×10^{6}
($\bar{I}'$ Min)	1.18×10^{6}	1.56×10^{6}	2.29×10^{6}
Ingestion Rate, $\bar{I}''$ (gm d.w. prey / gm d.w. mysid hour)			
($\bar{I}''$)	1.4×10^{-2}	1.9×10^{-2}	2.8×10^{-2}
(log $\bar{I}''$)	-1.85	-1.72	-1.55
($\bar{I}''$ Max)	1.6×10^{-2}	2.1×10^{-2}	3.3×10^{-2}
(log $\bar{I}''$ Max)	-1.80	-1.68	-1.48
($\bar{I}''$ Min)	1.3×10^{-2}	1.7×10	2.5×10^{-2}
(log $\bar{I}''$ Min)	-1.89	-1.77	-1.60

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 13. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Females (Adult/ovigerous)
Food source: *Brachionus plicatilis*

	F-16-1 & F-16-2	F-16-3 & F-16-4	F-16-5 & F-16-6
Average Prey Concentration, $\bar{C}$			
(# prey / ml)			
($\bar{C}$)	8.9	21.7	48.0
Average Prey Concentration, $\bar{C}'$			
(gm d.w. prey / ml)			
($\bar{C}'$)	1.17×10^{-6}	2.86×10^{-6}	6.34×10^{-6}
(log $\bar{C}'$)	-5.93	-5.54	-5.20
Ingestion Rate, $\bar{I}$			
(# prey / mysid hour)			
($\bar{I}$)	49.3	74.1	100.6
($\bar{I}$ Max)	53.3	79.9	113.9
($\bar{I}$ Min)	45.1	67.8	86.7
Ingestion Rate, $\bar{I}'$			
(# prey / gm d.w. mysid hour)			
($\bar{I}'$)	4.3×10^{4}	6.5×10^{4}	8.9×10^{4}
($\bar{I}'$ Max)	4.7×10^{4}	7.0×10^{4}	1.0×10^{5}
($\bar{I}'$ Min)	3.9×10^{4}	5.9×10^{4}	7.7×10^{4}
Ingestion Rate, $\bar{I}''$			
(gm d.w. prey / gm d.w. mysid hour)			
($\bar{I}''$)	5.7×10^{-3}	8.6×10^{-3}	1.2×10^{-2}
(log $\bar{I}''$)	-2.24	-2.07	-1.92
($\bar{I}''$ Max)	1.4×10^{-2}	2.0×10^{-2}	2.9×10^{-2}
(log $\bar{I}''$ Max)	-1.85	-1.70	-1.54
($\bar{I}''$ Min)	3.3×10^{-3}	5.0×10^{-3}	6.5×10^{-3}
(log $\bar{I}''$ Min)	-2.48	-2.30	-2.19

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 14. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Females (Adult/oviqerous)
Food source: *Artemia salina*

	F-23-1 & F-23-2	F-23-3 & F-23-4	F-23-5 & F-23-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	9.6	28.3	56.3
Average Prey Concentration, $\bar{C}'$ (qm d.w. prey/ml)			
($\bar{C}'$)	7.33×10^{-6}	2.16×10^{-5}	4.30×10^{-5}
(log $\bar{C}'$)	-5.13	-4.67	-4.37
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)	6.7	21.6	36.9
($\bar{I}$ Max)	9.0	28.6	49.1
($\bar{I}$ Min)	4.3	14.3	24.2
Ingestion Rate, $\bar{I}'$ (# prey / qm d.w. mysid hour)			
($\bar{I}'$)	5.9×10^{3}	1.9×10^{4}	3.2×10^{4}
($\bar{I}'$ Max)	7.9×10^{3}	2.5×10^{4}	4.3×10^{4}
($\bar{I}'$ Min)	3.9×10^{3}	1.3×10^{4}	2.1×10^{4}
Ingestion Rate, $\bar{I}''$ (qm d.w. prey / qm d.w. mysid hour)			
($\bar{I}''$)	4.5×10^{-3}	1.5×10^{-2}	2.4×10^{-2}
(log $\bar{I}''$)	-2.35	-1.82	-1.62
($\bar{I}''$ Max)	7.9×10^{-3}	2.5×10^{-2}	4.3×10^{-2}
(log $\bar{I}''$ Max)	-2.10	-1.60	-1.37
($\bar{I}''$ Min)	2.4×10^{-3}	7.9×10^{-3}	1.3×10^{-2}
(log $\bar{I}''$ Min)	-2.62	-2.10	-1.89

*- Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 15. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Males (Adult)
Food source: Artemia salina

	M-18-1 & M-18-2	M-18-3 & M-18-4	M-18-5 & M-18-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	8.5	26.2	56.5
Average Prey Concentration, $\bar{C}'$ (gm d.w. prey / ml)			
($\bar{C}'$)	6.49×10^{-6}	2.00×10^{-5}	4.32×10^{-5}
(log $\bar{C}'$)	-5.19	-4.70	-4.36
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)	16.0	35.8	39.2
($\bar{I}$ Max)	19.1	44.1	52.6
($\bar{I}$ Min)	12.9	27.5	24.7
Ingestion Rate, $\bar{I}'$ (# prey / gm d.w. mysid hour)			
($\bar{I}'$)	1.6×10^{4}	3.5×10^{4}	3.8×10^{4}
($\bar{I}'$ Max)	1.9×10^{4}	4.3×10^{4}	5.1×10^{4}
($\bar{I}'$ Min)	1.3×10^{4}	2.7×10^{4}	2.4×10^{4}
Ingestion Rate, $\bar{I}''$ (gm d.w. prey / gm d.w. mysid hour)			
($\bar{I}''$)	1.2×10^{-2}	2.7×10^{-2}	2.9×10^{-2}
(log $\bar{I}''$)	-1.92	-1.57	-1.54
($\bar{I}''$ Max)	1.9×10^{-2}	4.3×10^{-2}	5.1×10^{-2}
(log $\bar{I}''$ Max)	-1.72	-1.37	-1.29
($\bar{I}''$ Min)	7.9×10^{-3}	1.6×10^{-2}	1.5×10^{-2}
(log $\bar{I}''$ Min)	-2.10	-1.80	-1.82

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 16. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Males (Adult)
Food source: Brachionus plicatilis

	M-20-1 & M-20-2	M-20-3 & M-20-4	M-20-5 & M-20-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	8.5	19.3	49.0
Average Prey Concentration, $\bar{C}'$ (gm d.w. prey / ml)			
($\bar{C}'$)	1.12×10^{-6}	2.55×10^{-6}	6.47×10^{-6}
(log $\bar{C}'$)	-5.95	-5.59	-5.19
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)	50.7	89.1	90.9
($\bar{I}$ Max)	56.3	99.3	105.9
($\bar{I}$ Min)	44.6	78.0	75.4
Ingestion Rate, $\bar{I}'$ (# prey / gm d.w. mysid hour)			
($\bar{I}'$)	5.0×10^{4}	8.7×10^{4}	8.9×10^{4}
($\bar{I}'$ Max)	5.6×10^{4}	9.7×10^{4}	1.0×10^{5}
($\bar{I}'$ Min)	4.4×10^{4}	7.6×10^{4}	7.4×10^{4}
Ingestion Rate, $\bar{I}''$ (gm d.w. prey/ gm d.w. mysid hour)			
($\bar{I}''$)	6.6×10^{-3}	1.1×10^{-2}	1.2×10^{-2}
(log $\bar{I}''$)	-2.18	-1.96	-1.92
($\bar{I}''$ Max)	1.6×10^{-2}	2.8×10^{-2}	2.9×10^{-2}
(log $\bar{I}''$ Max)	-1.80	-1.55	-1.54
($\bar{I}''$ Min)	3.7×10^{-3}	6.5×10^{-3}	6.3×10^{-3}
(log $\bar{I}''$ Min)	-2.43	-2.19	-2.20

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Table 17. Average prey concentrations and mean ingestion rates calculated for the two replicates at a particular prey concentration per experiment.

Size class: Males (Adult)
Food source: *Coscinodiscus lineatus*

	M-21-1 & M-21-2	M-21-3 & M-21-4	M-21-5 & M-21-6
Average Prey Concentration, $\bar{C}$ (# prey / ml)			
($\bar{C}$)	494.5	1606.8	3293.7
Average Prey Concentration, $\bar{C}'$ (gm d.w. prey / ml)			
($\bar{C}'$)	5.84×10^{-6}	1.90×10^{-5}	3.89×10^{-5}
(log $\bar{C}'$)	-5.23	-4.72	-4.41
Ingestion Rate, $\bar{I}$ (# prey / mysid hour)			
($\bar{I}$)	1034.8	2539.5	4566.5
($\bar{I}$ Max)	1081.4	2637.5	4762.7
($\bar{I}$ Min)	985.3	2440.6	4362.8
Ingestion Rate, $\bar{I}'$ (# prey / gm d.w. mysid hour)			
($\bar{I}'$)	1.0×10^{6}	2.5×10^{6}	4.5×10^{6}
($\bar{I}'$ Max)	1.05×10^{6}	2.6×10^{6}	4.7×10^{6}
($\bar{I}'$ Min)	9.5×10^{5}	2.4×10^{6}	4.3×10^{6}
Ingestion Rate, $\bar{I}''$ (gm d.w. prey / gm d.w. mysid hour)			
($\bar{I}''$)	1.2×10^{-2}	3.0×10^{-2}	5.3×10^{-2}
(log $\bar{I}''$)	-1.92	-1.52	-1.28
($\bar{I}''$ Max)	1.4×10^{-2}	3.4×10^{-2}	6.1×10^{-2}
(log $\bar{I}''$ Max)	-1.85	-1.47	-1.21
($\bar{I}''$ Min)	1.0×10^{-2}	2.6×10^{-2}	4.7×10^{-2}
(log $\bar{I}''$ Min)	-2.00	-1.59	-1.33

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Figure 2. Graph of ingestion rates (number of prey/mysid/hour) versus average prey concentration (number of prey/ml) for the two adult size classes of mysids when fed Artemia salina. Error bars represent the maximum positive and negative standard errors about the mean.

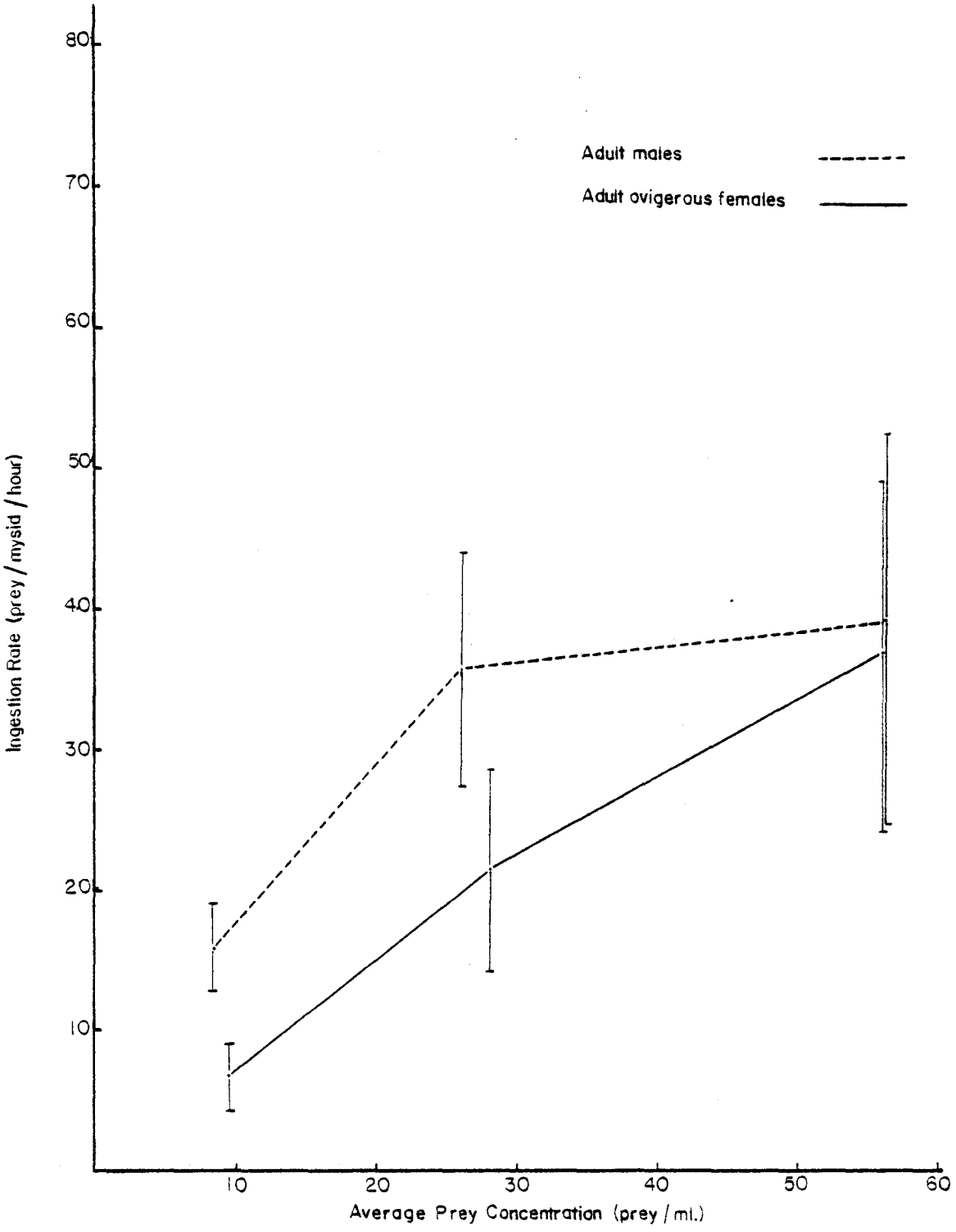
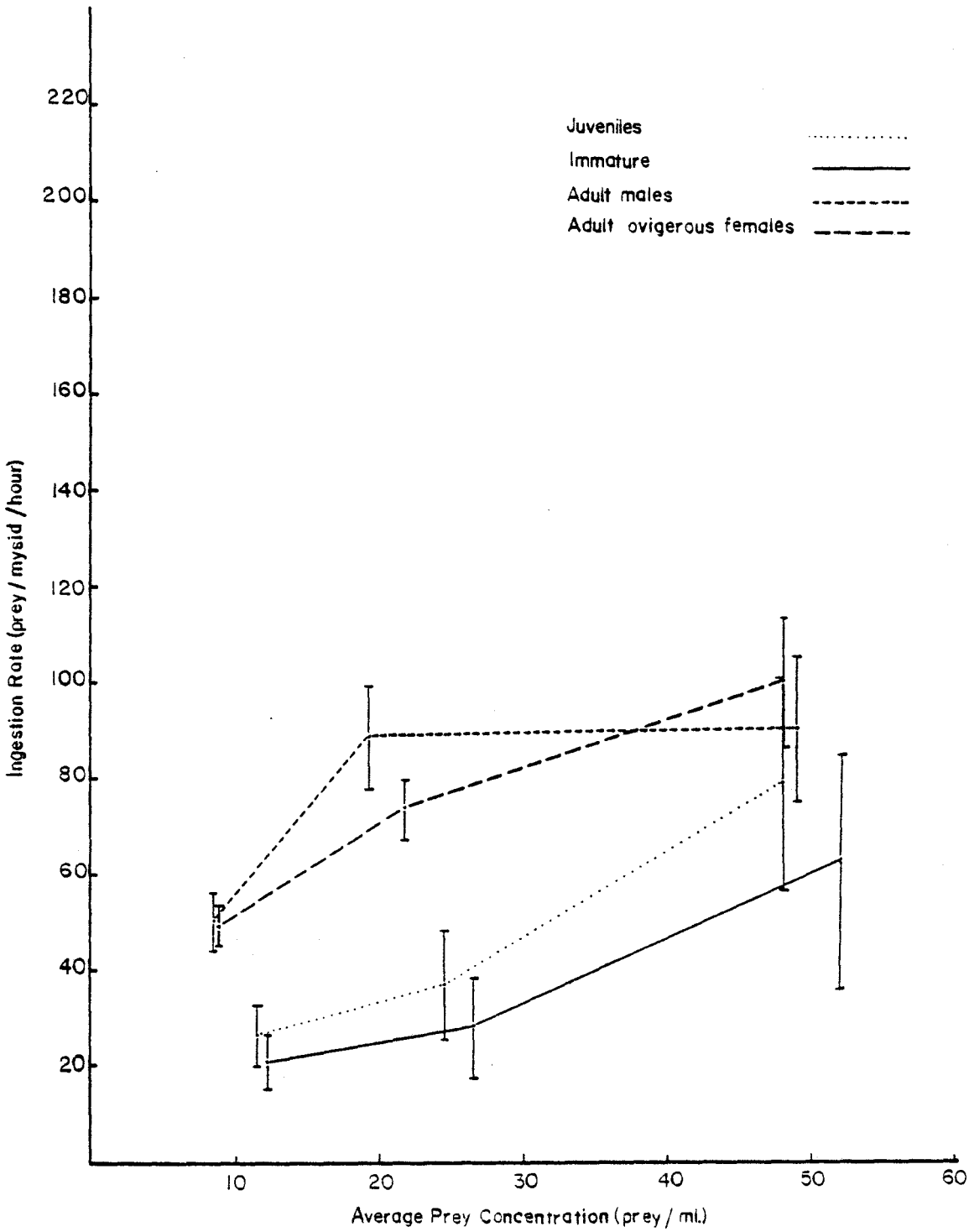

Adult males
Adult ovigerous females
Ingestion Rate (prey / mysid / hour)
80
70
60
50
40
30
20
10
10
20
30
40
50
60
Average Prey Concentration (prey / ml.)

Figure 3. Graph of ingestion rates (number of prey/mysid/hour) versus average prey concentration (number of prey/ml) for the four size classes of mysids when fed the rotifer Brachionus plicatilis. Error bars represent the maximum positive and negative standard errors about the mean.


Juveniles
Immature
Adult males
Adult ovigerous females
Ingestion Rate (prey / mysid / hour)
220
200
180
160
140
120
100
80
60
40
20
10
20
30
40
50
60
Average Prey Concentration (prey / ml.)

cies for all four size classes. Figure 4 presents the ingestion rates observed for various concentrations of C. lineatus.

The ingestion rates were then recalculated by normalizing for the body weight (dry weight in gms) of the number of mysids alive at the end of each experiment. This value, DW, was substituted for N in the computer program (Appendix V). The ingestion rates (I') were recomputed utilizing the same values for initial and final prey concentrations, and the growth coefficients already determined for each grazing container. The units of I' became the number of prey ingested per gm dry weight mysid per hour. These data per experiment are presented in Appendix VII, along with their maximum possible positive and negative errors.

The mean ingestion rates ($\bar{I}'$) for the replicate containers in each experiment (Tables 6-17) were again plotted versus their average prey concentration ($\bar{C}$). The error bars applied to each point represent the maximum and minimum possible standard errors associated with each. The graphs generated for each size class on a given food source were combined and are presented in Figure 5 for A. salina, Figure 6 for B. plicatilis, and Figure 7 for C. lineatus.

At this point, comparisons of the ingestion rates between size classes are possible, but only for a particular food source. No such comparisons can be made between the various food sources due to dissimilar scales on the axes. In order to facilitate comparisons of all three food sources simultaneously, the average prey concentrations per ml ($\bar{C}$) were converted to gm dry weight of prey per ml ($\bar{C}'$). The logarithm was taken ($\log \bar{C}'$) to permit graphing of the entire range of prey concentrations utilized. These data are presented in Tables 6-17 for the replicates in each experiment.

Figure 4. Graph of ingestion rates (number of prey/mysid/hour) versus average prey concentration (number of prey/ml) for the four size classes of mysids when fed the diatom Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.

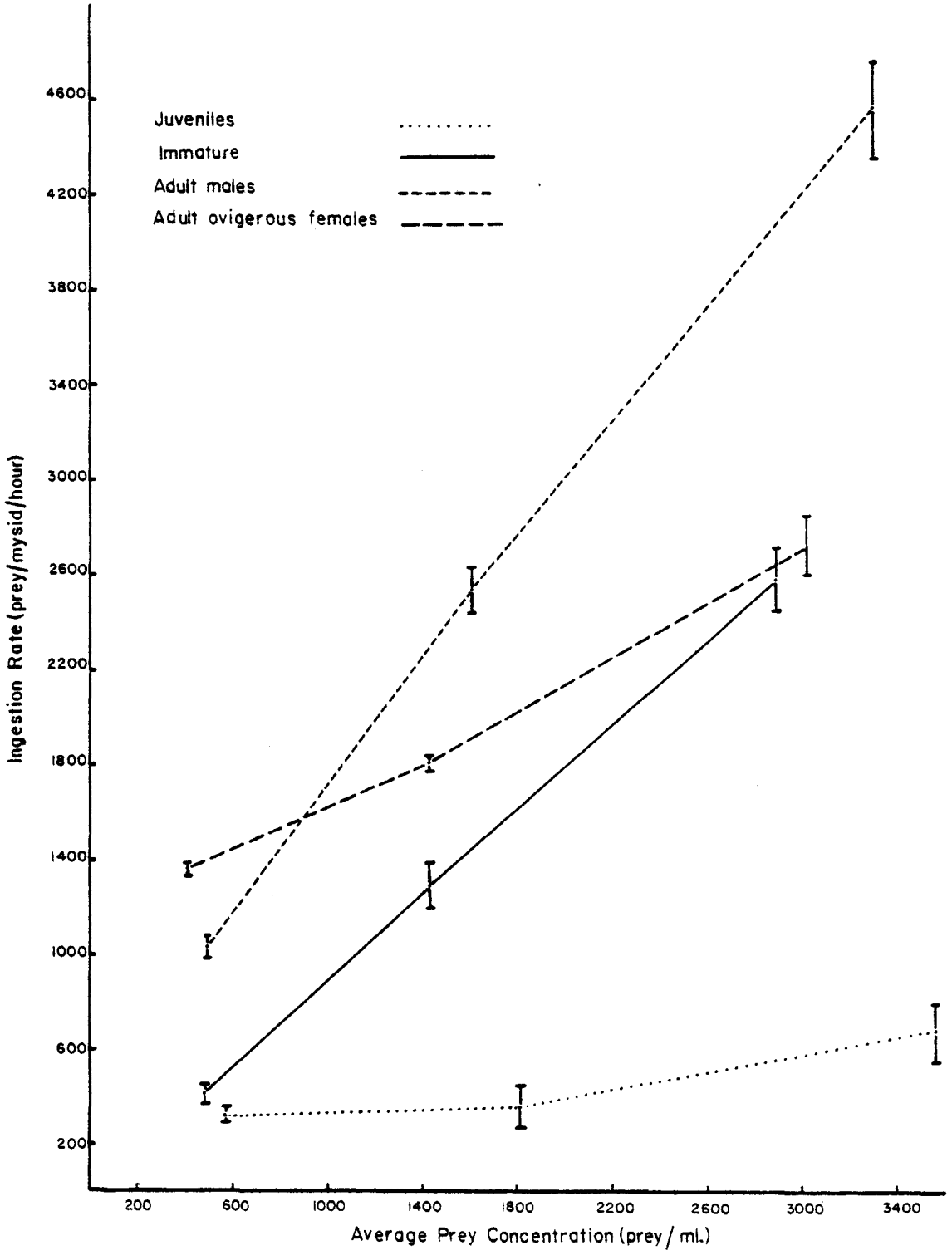

Juveniles
Immature
Adult males
Adult ovigerous females
Ingestion Rate (prey/mysid/hour)
4600
4200
3800
3400
3000
2600
2200
1800
1400
1000
600
200
200
600
1000
1400
1800
2200
2600
3000
3400
Average Prey Concentration (prey / ml.)

Figure 5. Graph of ingestion rates (number of prey/gm dry weight mysid/hour) versus average prey concentration (number of prey/ml) for the two adult size classes of mysids when fed Artemia salina. Error bars represent the maximum positive and negative standard errors about the mean.

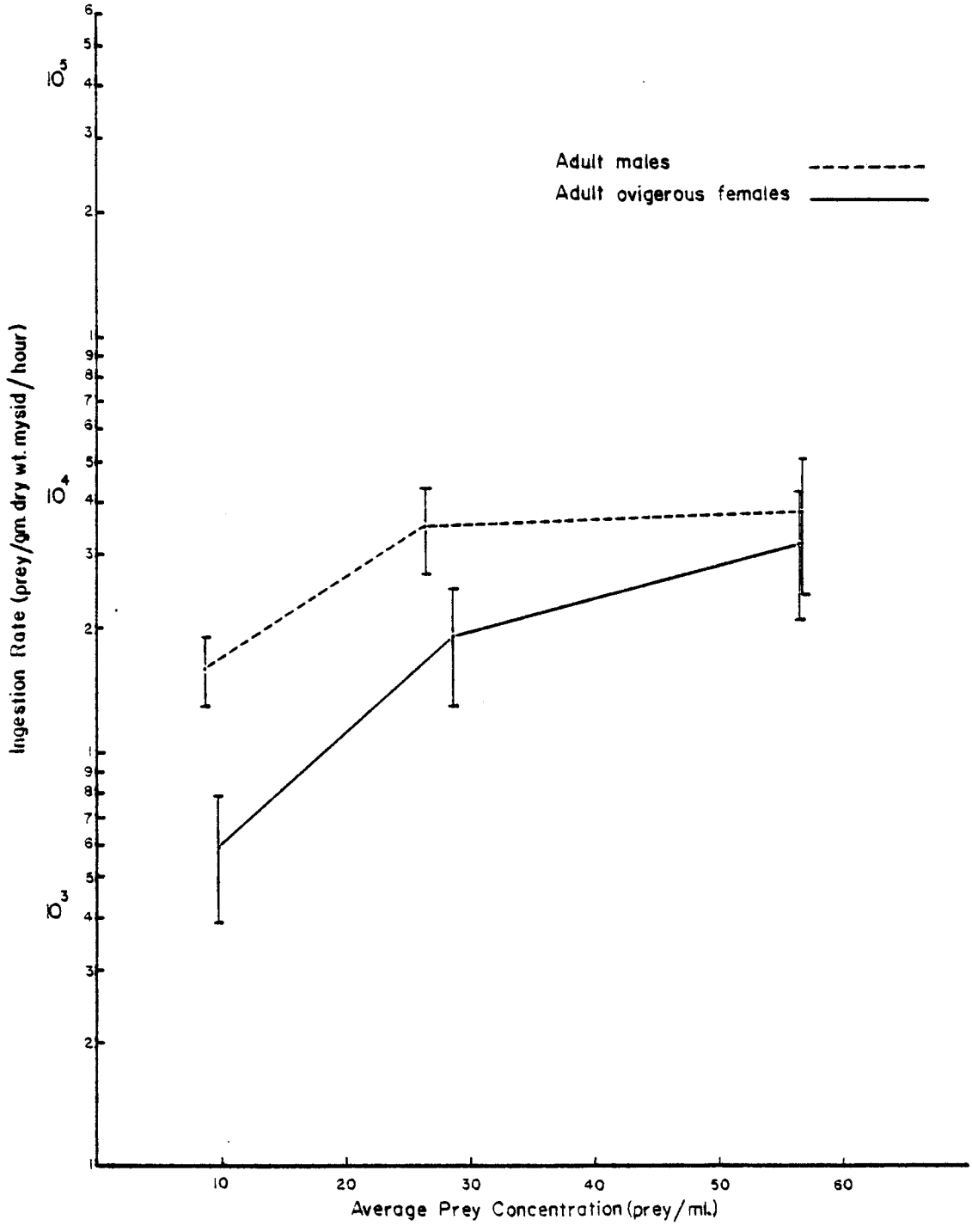

Adult males
Adult ovigerous females
Ingestion Rate (prey/gm. dry wt. mysid / hour)
10³
10⁴
10⁵
10
20
30
40
50
60
Average Prey Concentration (prey/ml.)

Figure 6. Graph of ingestion rates (number of prey/gm dry weight mysid/hour) versus average prey concentration (number of prey/ml) for the four size classes of mysids when fed the rotifer Brachionus plicatilis. Error bars represent the maximum positive and negative standard errors about the mean.

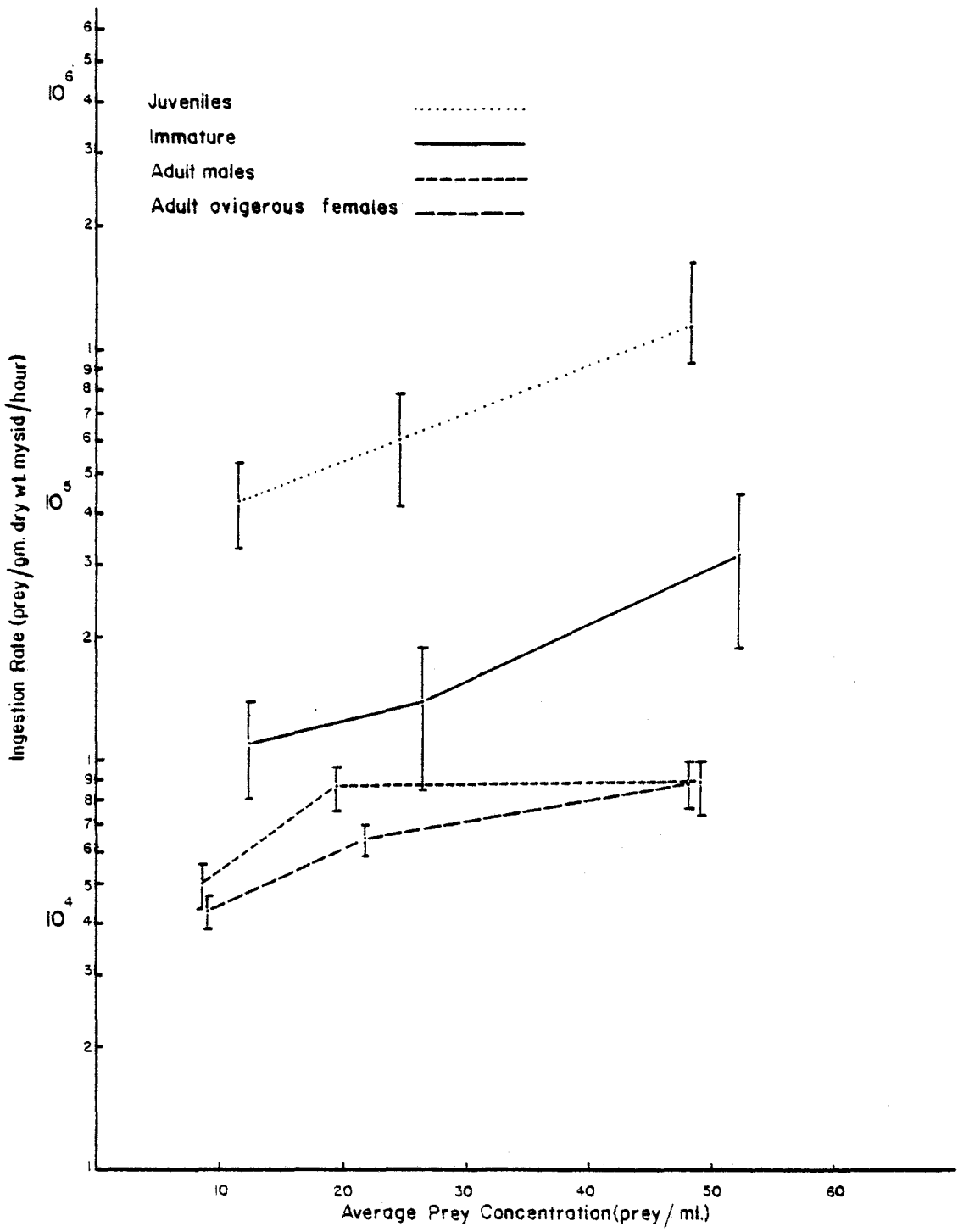
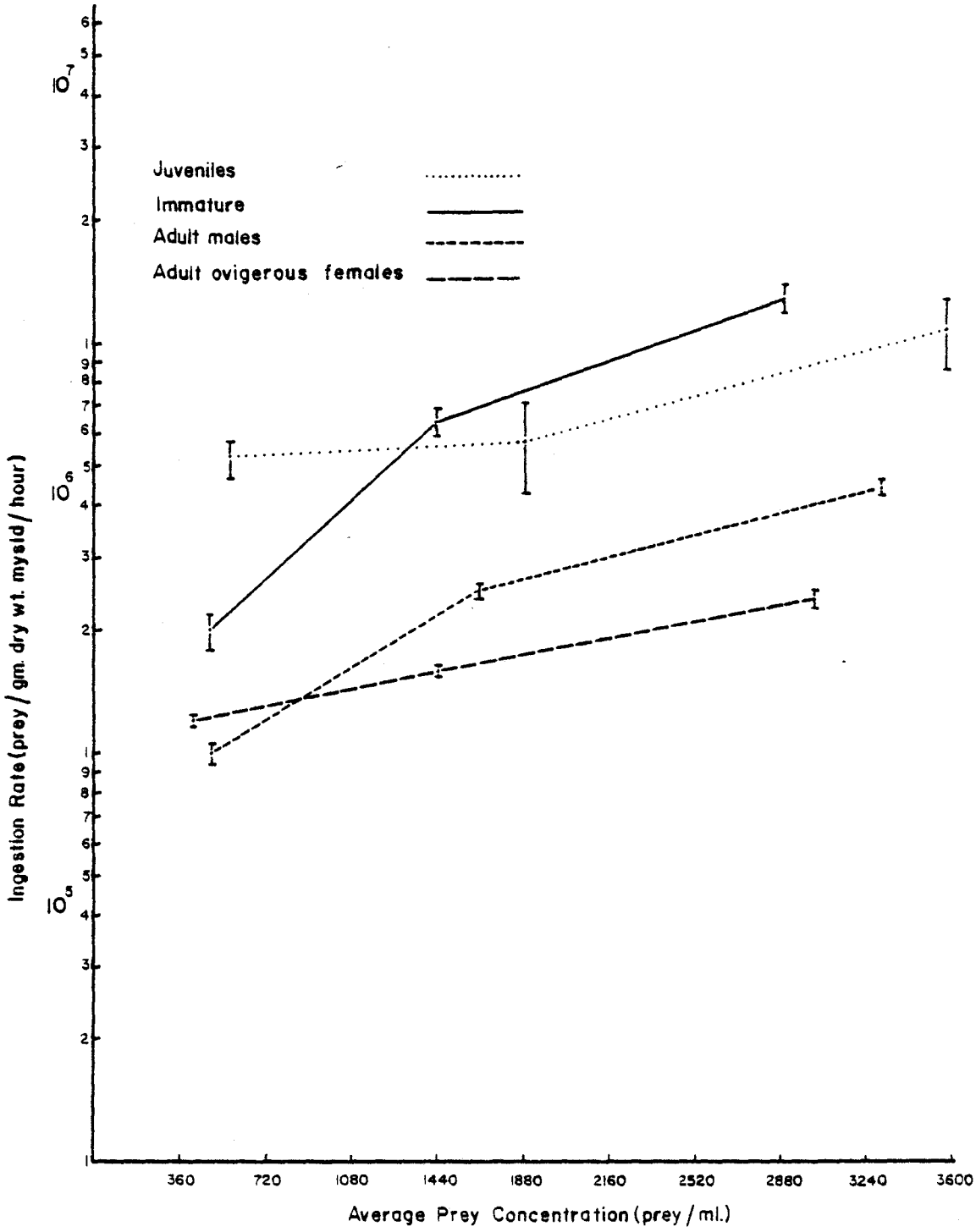

Juveniles
Immature
Adult males
Adult ovigerous females
Ingestion Rate (prey/gm. dry wt. mysid/hour)
Average Prey Concentration (prey/ml.)
10
20
30
40
50
60

Figure 7. Graph of ingestion rates (number of prey/gm dry weight mysid/hour) versus average prey concentration (number of prey/ml) for the four size classes of mysids when fed the diatom Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.


Juveniles
Immature
Adult males
Adult ovigerous females
Ingestion Rate (prey / gm. dry wt. mysid / hour)
10^7
10^6
10^5
360
720
1080
1440
1880
2160
2520
2880
3240
3600
Average Prey Concentration (prey / ml.)

Figures 8-11 contain graphs of the mean ingestion rate ($\bar{I}'$) versus the average prey concentration (log $\bar{C}'$) per ml for each size class on all food sources. While this depicts ingestion versus the dry weight concentration of prey, the ingestion rate itself is still in terms of prey number. Therefore, the number of prey ingested per gm dry weight mysid per hour (I') was converted to gm dry weight of prey ingested per gm dry weight mysid hour (I"). These values are also presented in Tables 6-17 along with their respective maximum and minimum errors. The logarithm of I" was taken, again to permit graphing of the entire range of observed ingestion rates.

The final results are shown in Figures 12-15. These are graphs of the ingestion rates (I") for each size class of mysid utilized, versus increasing prey concentration. All three food sources, though different in size and makeup, can now be compared on a dry weight basis. Likewise, ingestion rates are now on a dry weight basis facilitating direct comparisons between food species.

Percent Assimilation

The formulas utilized in calculating the percentage assimilation on each grazing container were presented in the Methods-Statistical Analysis section. The computer program utilized is contained in Appendix VI. Tables 18-29 summarize the data used in calculating the percent assimilation (U) as well as the results of those calculations. It will be noticed that there is no data for experiments conducted on the juvenile and immature size classes when Artemia salina was the prey species. As stated in the Methods section, the fecal strands per grazing container were removed prior to determining the post-grazing prey concentrations. In

Figure 8. Graph of ingestion rates (number of prey/gm dry weight mysid/hour) versus average prey concentration (log gm dry weight of prey/ml) for the juvenile mysids when fed Brachionus plicatilis and Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard error about the mean.

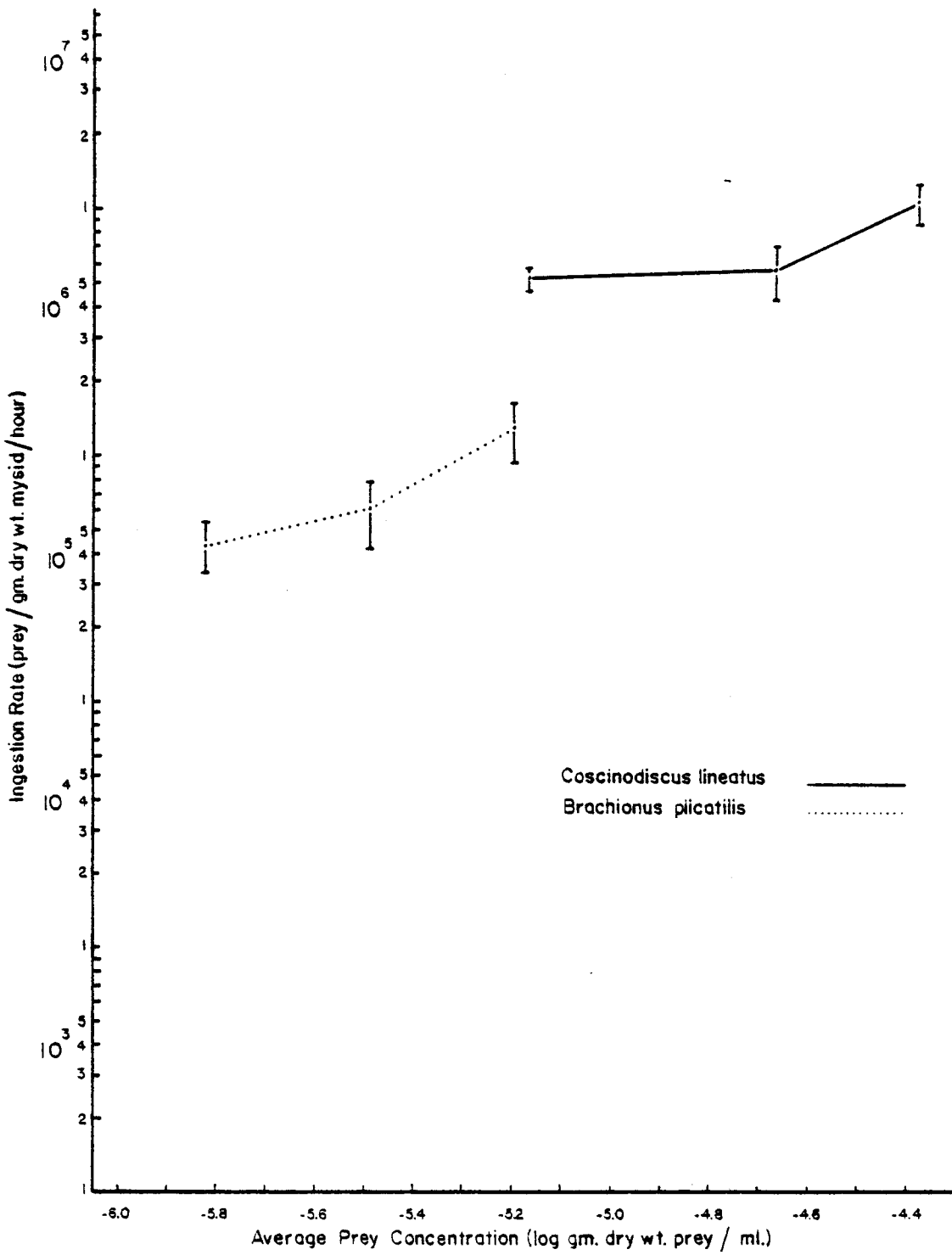

Ingestion Rate (prey / gm. dry wt. mysid / hour)
Average Prey Concentration (log gm. dry wt. prey / ml.)
Coscinodiscus lineatus
Brachionus plicatilis
-6.0
-5.8
-5.6
-5.4
-5.2
-5.0
-4.8
-4.6
-4.4

Figure 9. Graph of ingestion rates (number of prey/gm dry weight mysid/hour) versus average prey concentration (log gm dry weight of prey/ml) for immature mysids when fed Brachionus plicatilis and Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard error about the mean.

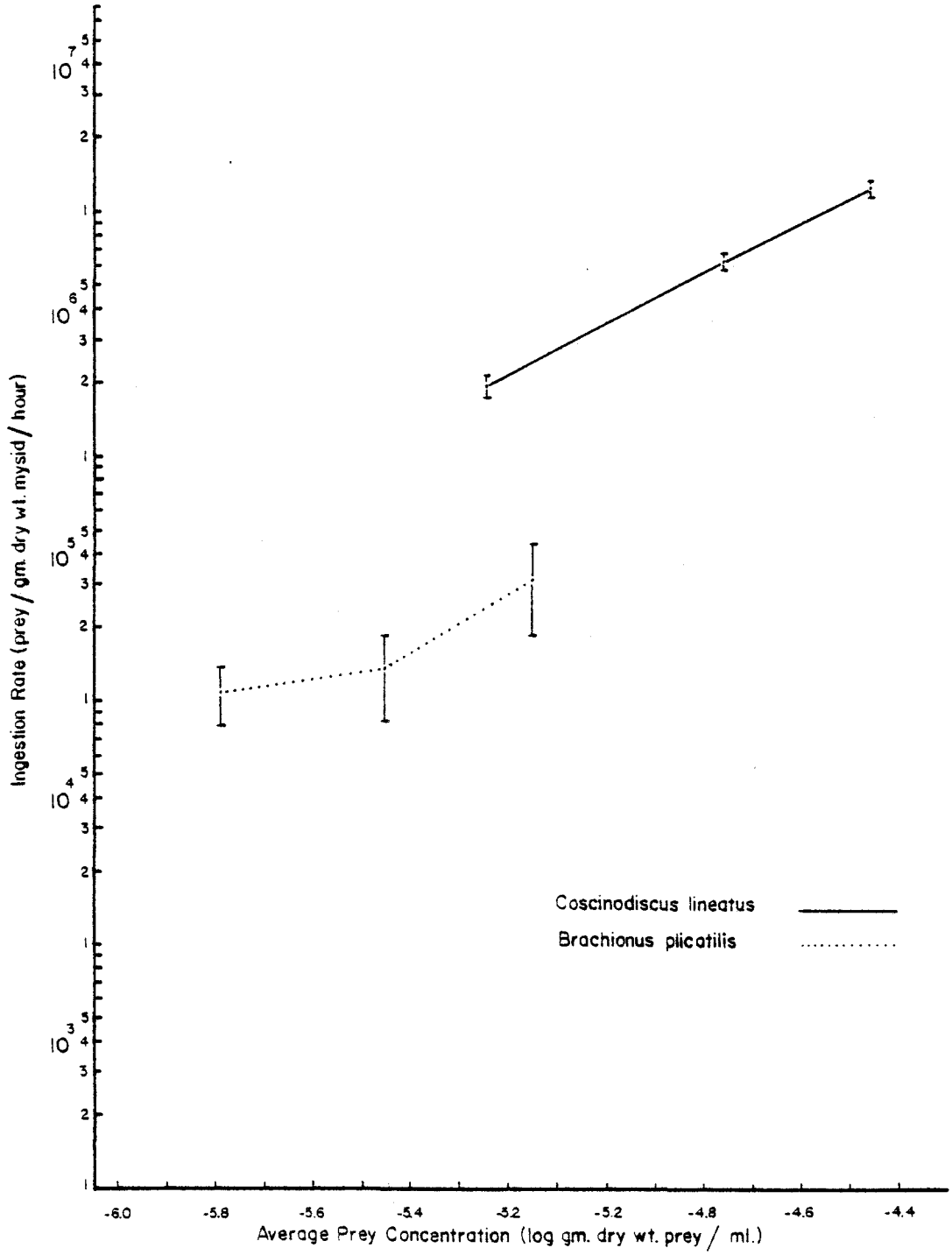

Ingestion Rate (prey / gm. dry wt. mysid / hour)
10^7
10^6
10^5
10^4
10^3
-6.0
-5.8
-5.6
-5.4
-5.2
-5.2
-4.8
-4.6
-4.4
Average Prey Concentration (log gm. dry wt. prey / ml.)
Coscinodiscus lineatus
Brachionus plicatilis

Figure 10. Graph of ingestion rates (number of prey/gm dry weight mysid/hour) versus average prey concentration (log gm dry weight of prey/ml) for adult male mysids when fed Artemia salina, Brachionus plicatilis, and Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.

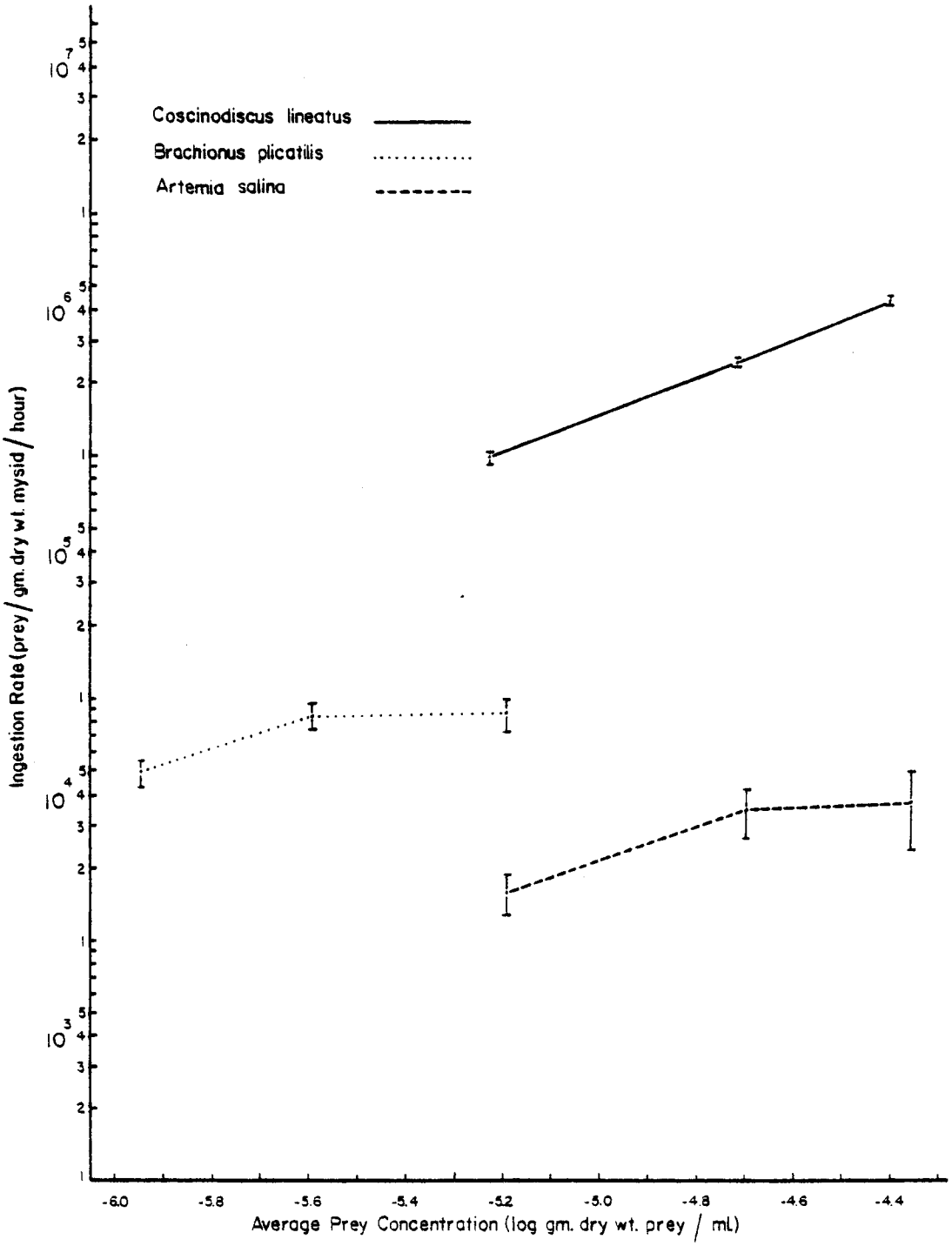

Coscinodiscus lineatus
Brachionus plicatilis
Artemia salina
Ingestion Rate (prey / gm. dry wt. mysid / hour)
Average Prey Concentration (log gm. dry wt. prey / mL)
-6.0
-5.8
-5.6
-5.4
-5.2
-5.0
-4.8
-4.6
-4.4

Figure 11. Graph of ingestion rates (number of prey/gm dry weight mysid/hour) versus average prey concentration (log gm dry weight of prey/ml) for adult/ovigerous female mysids when fed Artemia salina, Brachionus plicatilis, and Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.

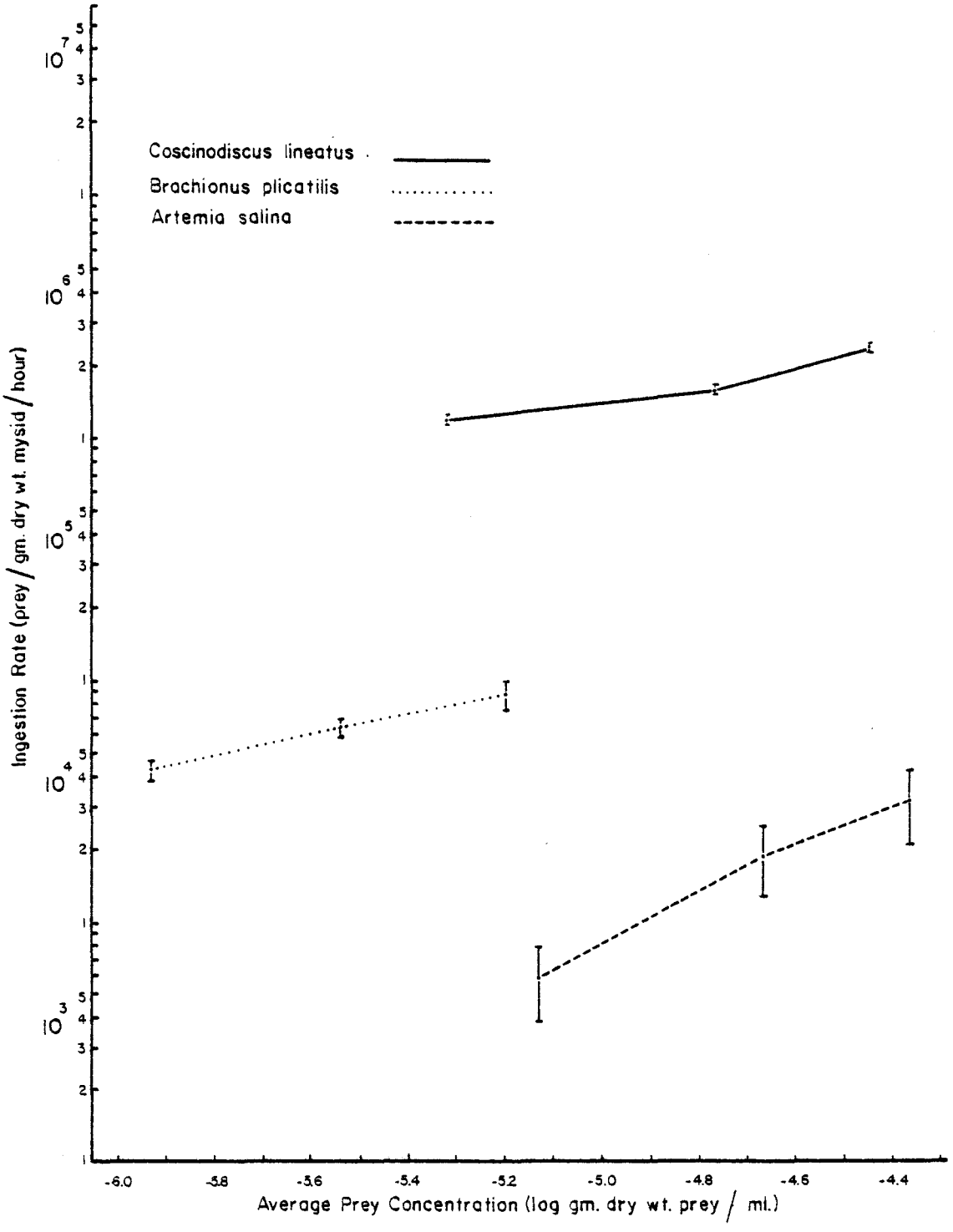

Coscinodiscus lineatus
Brachionus plicatilis
Artemia salina
Ingestion Rate (prey / gm. dry wt. mysid / hour)
Average Prey Concentration (log gm. dry wt. prey / ml.)
-6.0
-5.8
-5.6
-5.4
-5.2
-5.0
-4.8
-4.6
-4.4

Figure 12. Graph of ingestion rates (log gm dry weight of prey/gm dry weight mysid/hour) versus average prey concentration (log gm dry weight of prey/ml) for juvenile mysids when fed Brachionus plicatilis and Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.

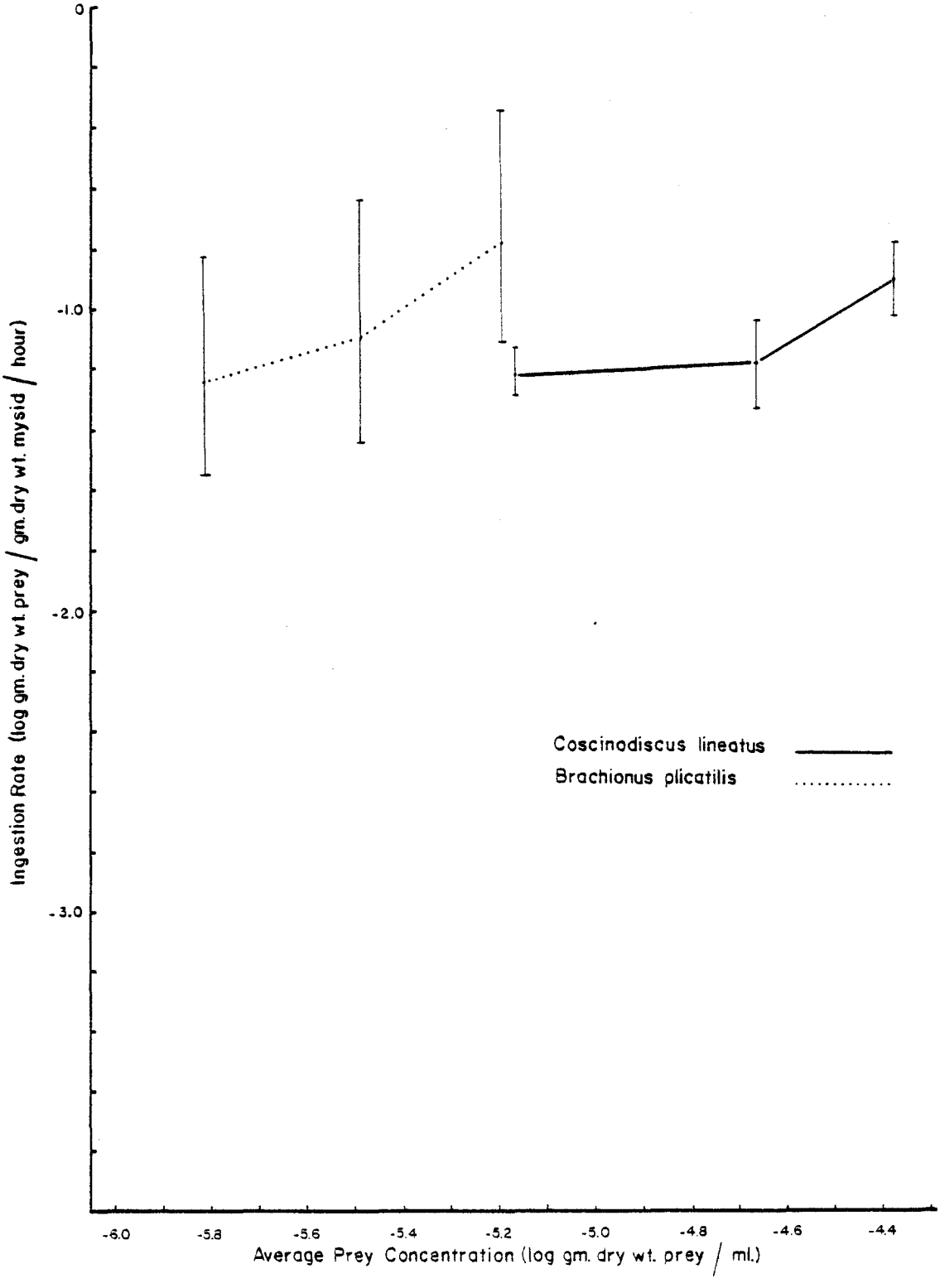

0
-1.0
-2.0
-3.0
Ingestion Rate (log gm. dry wt. prey / gm. dry wt. mysid / hour)
Coscinodiscus lineatus
Brachionus plicatilis
-6.0
-5.8
-5.6
-5.4
-5.2
-5.0
-4.8
-4.6
-4.4
Average Prey Concentration (log gm. dry wt. prey / ml.)

Figure 13. Graph of ingestion rates (log gm dry weight of prey/gm dry weight mysid/hour) versus average prey concentration (log gm dry weight of prey/ml) for immature mysids when fed Brachionus plicatilis and Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.

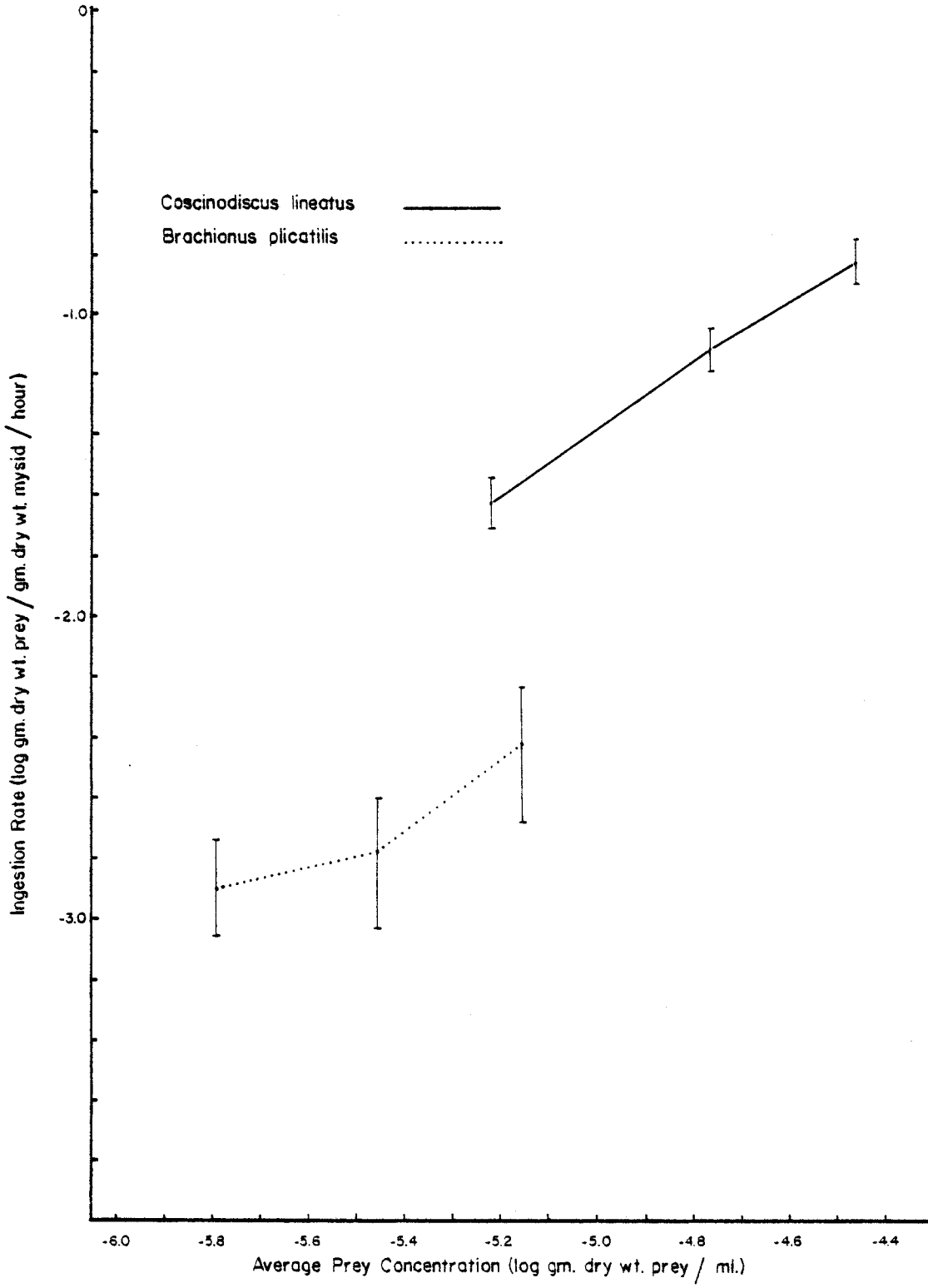

Coscinodiscus lineatus
Brachionus plicatilis
0
-1.0
-2.0
-3.0
Ingestion Rate (log gm. dry wt. prey / gm. dry wt. mysid / hour)
-6.0
-5.8
-5.6
-5.4
-5.2
-5.0
-4.8
-4.6
-4.4
Average Prey Concentration (log gm. dry wt. prey / ml.)

Figure 14. Graph of ingestion rates (log gm dry weight of prey/gm dry weight mysid/hour) versus average prey concentration (log gm dry weight of prey/ml) for adult male mysids when fed Artemia salina, Brachionus plicatilis, and Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.

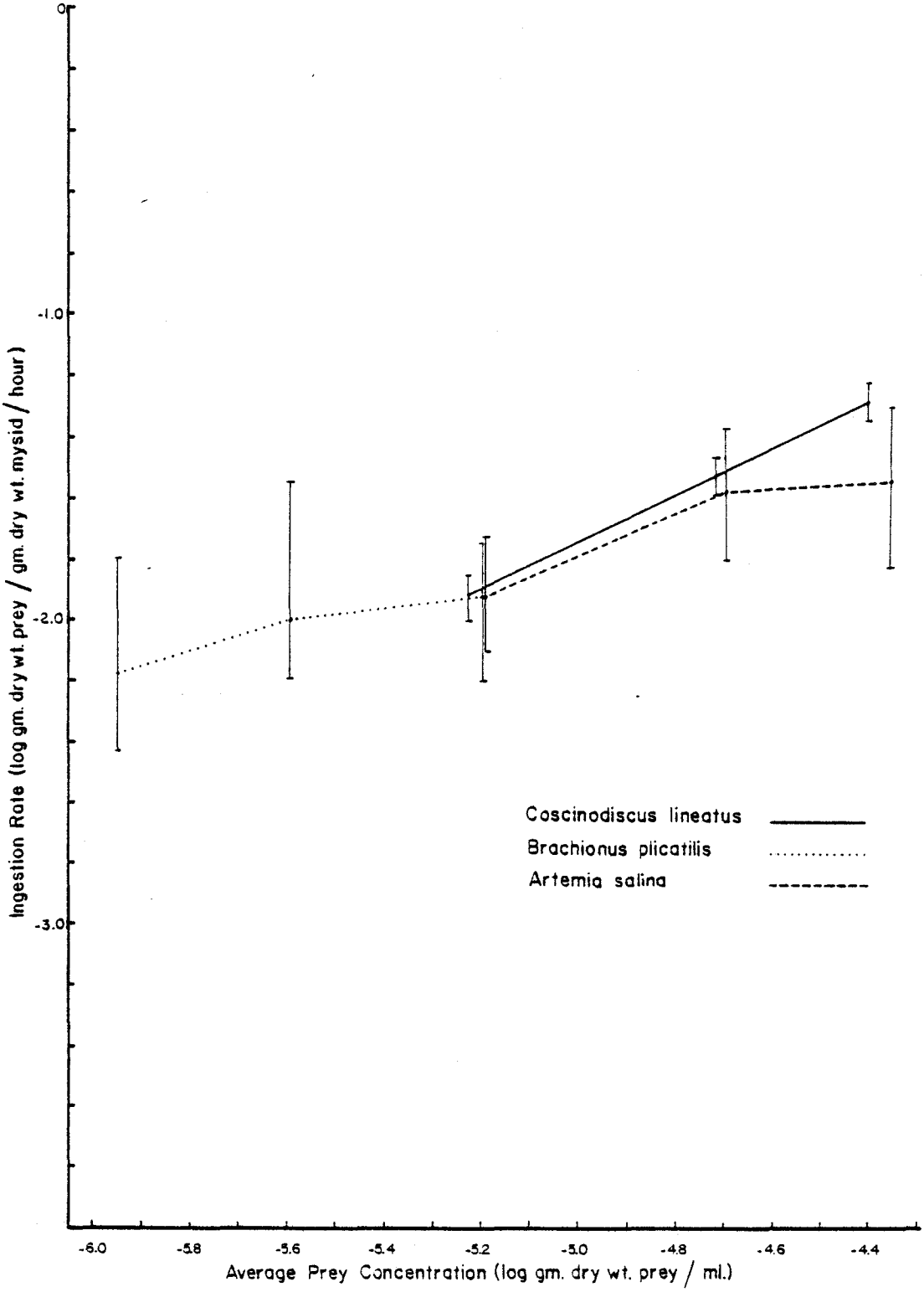

0
-1.0
-2.0
-3.0
Ingestion Rate (log gm. dry wt. prey / gm. dry wt. mysid / hour)
-6.0
-5.8
-5.6
-5.4
-5.2
-5.0
-4.8
-4.6
-4.4
Average Prey Concentration (log gm. dry wt. prey / ml.)
Coscinodiscus lineatus
Brachionus plicatilis
Artemia salina

Figure 15. Graph of ingestion rates (log gm dry weight of prey/gm dry weight mysid/hour) versus average prey concentration (log gm dry weight of prey/ml) for adult/ovigerous female mysids when fed Artemia salina, Brachionus plicatilis, and Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.

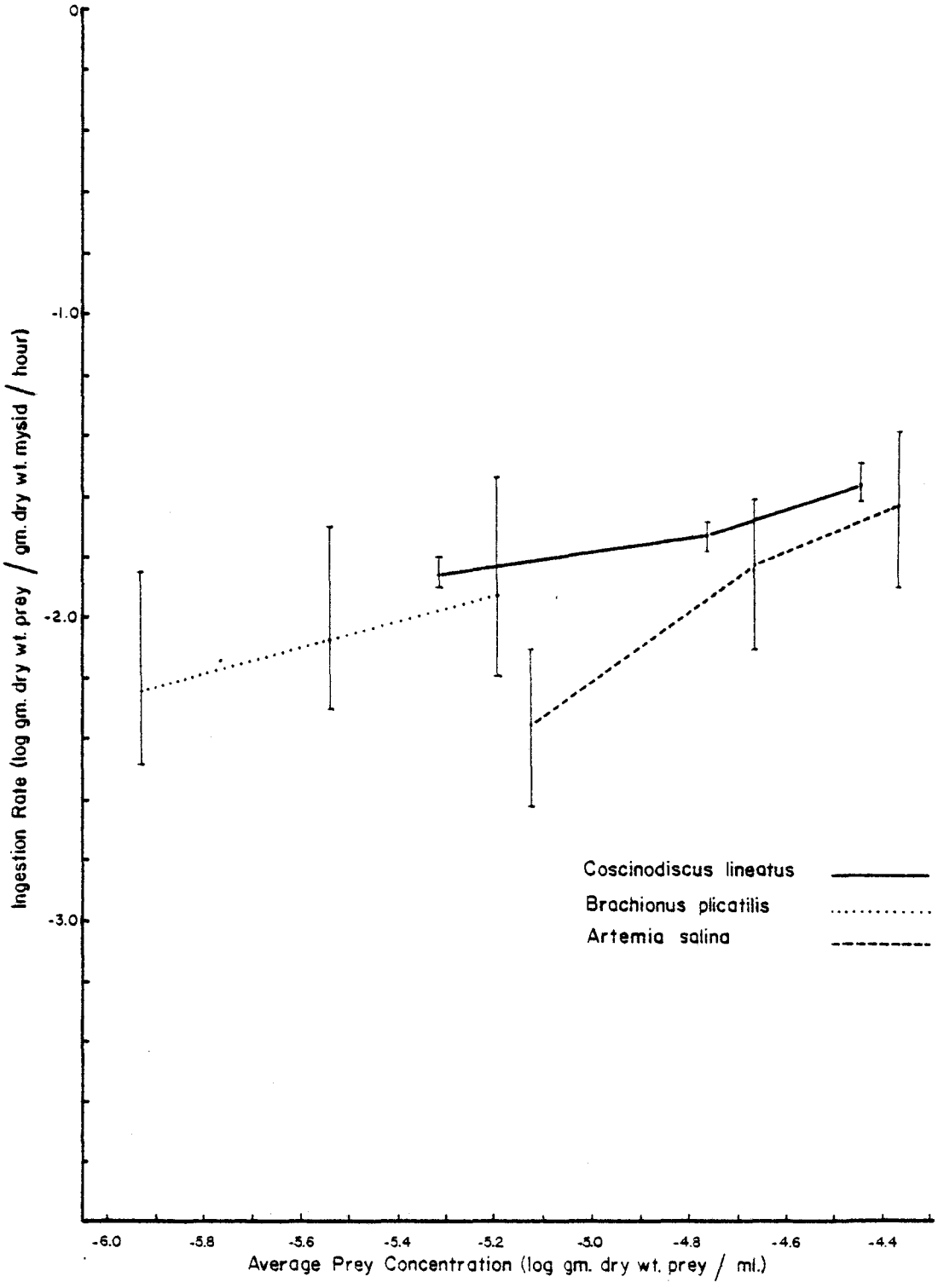

0
-1.0
-2.0
-3.0
Ingestion Rate (log gm. dry wt. prey / gm. dry wt. mysid / hour)
-6.0
-5.8
-5.6
-5.4
-5.2
-5.0
-4.8
-4.6
-4.4
Average Prey Concentration (log gm. dry wt. prey / ml.)
Coscinodiscus lineatus
Brachionus plicatilis
Artemia salina

Table 18. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Juveniles
Food source: Artemia salina

	J-7-1	J-7-2	J-7-3	J-7-4	J-7-5	J-7-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.8373	0.8373	0.8373	0.8373	0.8373	0.8373
(±FS)	0.0202	0.0202	0.0202	0.0202	0.0202	0.0202
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	Unable to recover sufficient amount of fecal material from grazing containers to perform calculations.					
(±ES)						
Average Prey Concentration, C						
(# Prey / ml)						
(C)						
(SC Max)						
(SC Min)						
Percent Assimilation, U						
(U)						
(SU Max)						
(SU Min)						
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)						
(S$\bar{U}$ Max)						
(S$\bar{U}$ Min)						

Table 19. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Juveniles
Food source: Brachionus plicatilis

	J-8-1	J-8-2	J-8-3	J-8-4	J-8-5	J-8-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.8851	0.8851	0.8851	0.8851	0.8851	0.8851
(±FS)	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339
Fecal Material						
Ash Free Dry Wt.: Dry Wt. Ratio						
(E)	0.2342	0.2500	0.2183	0.2183	0.2824	0.2588
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)	11.5		24.5		48.1	
(SC Max)	2.5		5.1		10.1	
(SC Min)	2.5		5.0		9.7	
Percent Assimilation, U						
(U)	96.0	95.7	96.4	96.4	94.9	95.5
(SU Max)	9.0	9.1	8.9	8.9	9.3	9.2
(SU Min)	8.4	8.4	8.3	8.3	8.6	8.5
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)	95.9		96.4		95.2	
($S\bar{U}$ Max)	6.4		6.3		6.6	
($S\bar{U}$ Min)	6.0		5.9		6.1	

Table 20. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Juveniles
Food source: Coscinodiscus lineatus

	J-9-1	J-9-2	J-9-3	J-9-4	J-9-5	J-9-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.6095	0.6095	0.6095	0.6095	0.6095	0.6095
(±FS)	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	0.3506	0.3313	0.3265	0.3169	0.3214	0.3230
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)	570.8		1805.2		3562.9	
(SC Max)	23.0		78.5		144.5	
(SC Min)	24.2		76.5		85.0	
Percent Assimilation, U						
(U)	65.4	68.3	68.9	70.3	69.7	69.4
(SU Max)	8.9	8.9	8.8	8.8	8.8	8.8
(SU Min)	8.2	8.2	8.2	8.1	8.2	8.2
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)	66.8		69.6		69.5	
($S\bar{U}$ Max)	6.3		6.2		6.2	
($S\bar{U}$ Min)	5.8		5.8		5.8	

Table 21. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Immature
Food source: Coscinodiscus lineatus

	I-12-1	I-12-2	I-12-3	I-12-4	I-12-5	I-12-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.6095	0.6095	0.6095	0.6095	0.6095	0.6095
(±FS)	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	0.5455	0.4583	0.5200	0.3170	0.2727	0.2727
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)	479.6		1428.5		2891.2	
(SC Max)	28.9		92.3		135.8	
(SC Min)	29.3		89.1		135.2	
Percent Assimilation, U						
(U)	23.1	45.8	30.6	70.3	76.0	76.0
(SU Max)	9.9	9.4	9.7	8.8	8.7	8.7
(SU Min)	9.1	8.7	9.0	8.1	8.0	8.0
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)	34.4		50.4		76.0	
($S\bar{U}$ Max)	7.0		6.9		6.1	
($S\bar{U}$ Min)	6.5		6.3		5.7	

Table 22. Summary of experimental data used in the calculation of percentage assimilation (U) for the spedific size class at the average prey concentration offered.

Size class: Immature
Food source: Brachionus plicatilis

	I-13-1	I-13-2	I-13-3	I-13-4	I-13-5	I-13-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.8851	0.8851	0.8851	0.8851	0.8851	0.8851
(±FS)	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339
Fecal Material						
Ash Free Dty Wt. : Dry Wt. Ratio						
(E)	0.5417	0.5862	0.5217	0.5000	0.4194	0.5313
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)	12.2		26.4		52.1	
(SC Max)	3.1		6.6		12.6	
(SC Min)	3.0		5.8		12.2	
Percent Assimilation, U						
(U)	84.7	81.6	85.8	87.0	90.6	85.3
(SU Max)	12.1	12.9	11.7	11.4	10.5	11.9
(SU Min)	11.2	11.9	10.9	10.6	9.7	11.0
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)	83.1		86.4		88.0	
($S\bar{U}$ Max)	9.1		8.3		8.4	
($S\bar{U}$ Min)	8.4		7.7		7.8	

Table 23. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Immature
Food source: Artemia salina

	I-14-1	I-14-2	I-14-3	I-14-4	I-14-5	I-14-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.8373	0.8373	0.8373	0.8373	0.8373	0.8373
(±FS)	0.0202	0.0202	0.0202	0.0202	0.0202	0.0202
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	Unable to recover sufficient amount of fecal material from grazing containers to perform calculations.					
(±ES)						
Average Prey Concentration, C						
(# prey / ml)						
(C)						
(SC Max)						
(SC Min)						
Percent Assimilation, U						
(U)						
(SU Max)						
(SU Min)						
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)						
($S\bar{U}$ Max)						
($S\bar{U}$ Min)						

Table 24. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Females (Adult/ovigerous)
Food source: Coscinodiscus lineatus

	F-15-1	F-15-2	F-15-3	F-15-4	F-15-5	F-15-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.6095	0.6095	0.6095	0.6095	0.6095	0.6095
(±FS)	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	0.5000	0.4773	0.4565	0.4898	0.4800	0.4848
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)		410.0		1433.3		3020.1
(SC Max)		12.7		37.4		142.4
(SC Min)		14.2		38.4		137.8
Percent Assimilation, U						
(U)	35.9	41.5	46.2	38.5	40.9	39.7
(SU Max)	9.6	9.5	9.4	9.5	9.5	9.5
(SU Min)	8.9	8.7	8.7	8.8	8.8	8.8
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)		38.7		42.3		40.3
($S\bar{U}$ Max)		6.8		6.7		6.7
($S\bar{U}$ Min)		6.3		6.2		6.2

Table 25. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Females (Adult/ovigerous)
Food source: Brachionus plicatilis

	F-16-1	F-16-2	F-16-3	F-16-4	F-16-5	F-16-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.8851	0.8851	0.8851	0.8851	0.8851	0.8851
(±FS)	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	0.5294	0.5000	0.5625	0.6500	0.6087	0.6500
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)		8.9		21.7		48.0
(SC Max)		2.1		4.5		8.6
(SC Min)		2.2		4.3		8.6
Percent Assimilation, U						
(U)	85.4	87.0	83.3	75.9	79.8	75.9
(SU Max)	11.9	11.4	12.4	14.4	13.4	14.4
(SU Min)	11.0	10.6	11.5	13.3	12.4	13.3
Mean Percent Assimilation, $\overline{U}$						
($\overline{U}$)		86.2		79.6		77.8
($S\overline{U}$ Max)		8.4		10.2		10.2
($S\overline{U}$ Min)		7.8		9.4		9.4

Table 26. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Females (Adult/ovigerous)
Food source: Artemia salina

	F-23-1	F-23-2	F-23-3	F-23-4	F-23-5	F-23-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.8373	0.8373	0.8373	0.8373	0.8373	0.8373
(±FS)	0.0202	0.0202	0.0202	0.0202	0.0202	0.0202
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	0.4828	0.5556	0.5000	0.5882	0.6154	0.6429
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)	9.6		28.3		56.3	
(SC Max)	1.7		4.9		9.7	
(SC Min)	1.6		4.6		9.0	
Percent Assimilation, U						
(U)	81.9	75.7	80.6	72.2	68.9	65.0
(SU Max)	6.8	7.4	6.9	7.8	8.1	8.5
(SU Min)	6.5	7.1	6.6	7.4	7.7	8.1
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)	78.8		76.4		67.0	
($S\bar{U}$ Max)	5.3		5.5		6.0	
($S\bar{U}$ Min)	5.0		5.2		5.7	

Table 27. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Males (Adult)
Food source: Artemia salina

	M-18-1	M-18-2	M-18-3	M-18-4	M-18-5	M-18-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.8373	0.8373	0.8373	0.8373	0.8373	0.8373
(±FS)	0.0202	0.0202	0.0202	0.0202	0.0202	0.0202
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	0.6471	0.7000	0.5217	0.5500	0.4667	0.5000
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)	8.5		26.2		56.5	
(SC Max)	1.8		5.1		10.8	
(SC Min)	1.8		5.1		9.9	
Percent Assimilation, U						
(U)	64.4	54.7	78.8	76.3	83.0	80.6
(SU Max)	8.6	9.6	7.1	7.4	6.7	6.9
(SU Min)	8.2	9.1	6.8	7.0	6.4	6.6
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)	59.5		77.5		81.8	
($S\bar{U}$ Max)	6.8		5.2		4.9	
($S\bar{U}$ Min)	6.5		5.0		4.7	

Table 28. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Males (Adult)
Food source: Brachionus plicatilis

	M-20-1	M-20-2	M-20-3	M-20-4	M-20-5	M-20-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.8851	0.8851	0.8851	0.8851	0.8851	0.8851
(±FS)	0.0339	0.0339	0.0339	0.0339	0.0339	0.0339
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	0.4500	0.5555	0.5555	0.4615	0.5652	0.6316
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)	8.5		19.3		49.0	
(SC Max)	2.3		4.9		9.8	
(SC Min)	2.5		5.0		9.4	
Percent Assimilation, U						
(U)	89.4	83.8	83.8	88.9	83.1	77.7
(SU Max)	10.8	12.3	12.3	10.9	12.5	13.9
(SU Min)	10.0	11.4	11.4	10.1	11.6	12.9
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)	86.6		86.3		80.4	
($S\bar{U}$ Max)	8.7		8.7		9.8	
($S\bar{U}$ Min)	8.1		8.1		9.1	

Table 29. Summary of experimental data used in the calculation of percentage assimilation (U) for the specific size class at the average prey concentration offered.

Size class: Males (Adult)
Food source: Coscinodiscus lineatus

	M-21-1	M-21-2	M-21-3	M-21-4	M-21-5	M-21-6
Food Source						
Ash Free Dry Wt. : Dry Wt. Ratio						
(F)	0.6095	0.6095	0.6095	0.6095	0.6095	0.6095
(±FS)	0.0239	0.0239	0.0239	0.0239	0.0239	0.0239
Fecal Material						
Ash Free Dry Wt. : Dry Wt. Ratio						
(E)	0.4701	0.4412	0.4103	0.5313	0.4091	0.5641
(±ES)	0	0	0	0	0	0
Average Prey Concentration, C						
(# prey / ml)						
(C)	494.5		1606.8		3293.7	
(SC Max)	29.6		91.5		227.0	
(SC Min)	30.8		89.3		212.0	
Percent Assimilation, U						
(U)	43.2	49.4	55.4	27.4	55.6	17.1
(SU Max)	9.4	9.3	9.1	9.8	9.1	10.0
(SU Min)	8.7	8.6	8.5	9.0	8.5	9.3
Mean Percent Assimilation, $\bar{U}$						
($\bar{U}$)	46.3		41.4		36.4	
($S\bar{U}$ Max)	6.7		6.9		7.1	
($S\bar{U}$ Min)	6.2		6.4		6.6	

these two sets of experiments, the fecal strands were either missing entirely, or pale and translucent containing little (if any) material. This resulted in insufficient material to make any determinations regarding assimilation. The fact that no significant difference in pre- and post-grazing prey concentrations was found supports this occurrence.

Each table indicates the particular size class and food source upon which the data was based. The Ash Free Dry Weight:Dry Weight Ratios of both the food source utilized, and the fecal material removed from each grazing container, are presented. For the food sources, the data are in the form of the mean plus or minus one standard deviation of the replicates. As stated in the Methods section, replicates were unobtainable when determining the Ash Free Dry Weight:Dry Weight Ratio of the fecal material. Therefore, the error associated with these measurements was assumed to be constant and assigned the numerical value of zero. Given these values, the computer program was able to calculate the percentage assimilation (U) and the maximum and minimum possible errors.

Figures 16-18 are graphs of the mean percentage assimilation ($\bar{U}$) for the two replicate containers versus the average prey concentration ($\bar{C}$). Figure 16 is for the two adult size classes when fed Artemia salina. Data was unavailable for the juveniles and immature size classes. Figure 17 depicts the percentage assimilation for each of the four size classes when fed Brachionus plicatilis, and Figure 18 presents graphs of assimilation for the four size classes when fed Coscinodiscus lineatus.

Figure 16. Graph of percent assimilation versus average prey concentration (number of prey/ml) for the two adult size classes of mysids when fed Artemia salina. Error bars represent the maximum positive and negative standard errors about the mean.

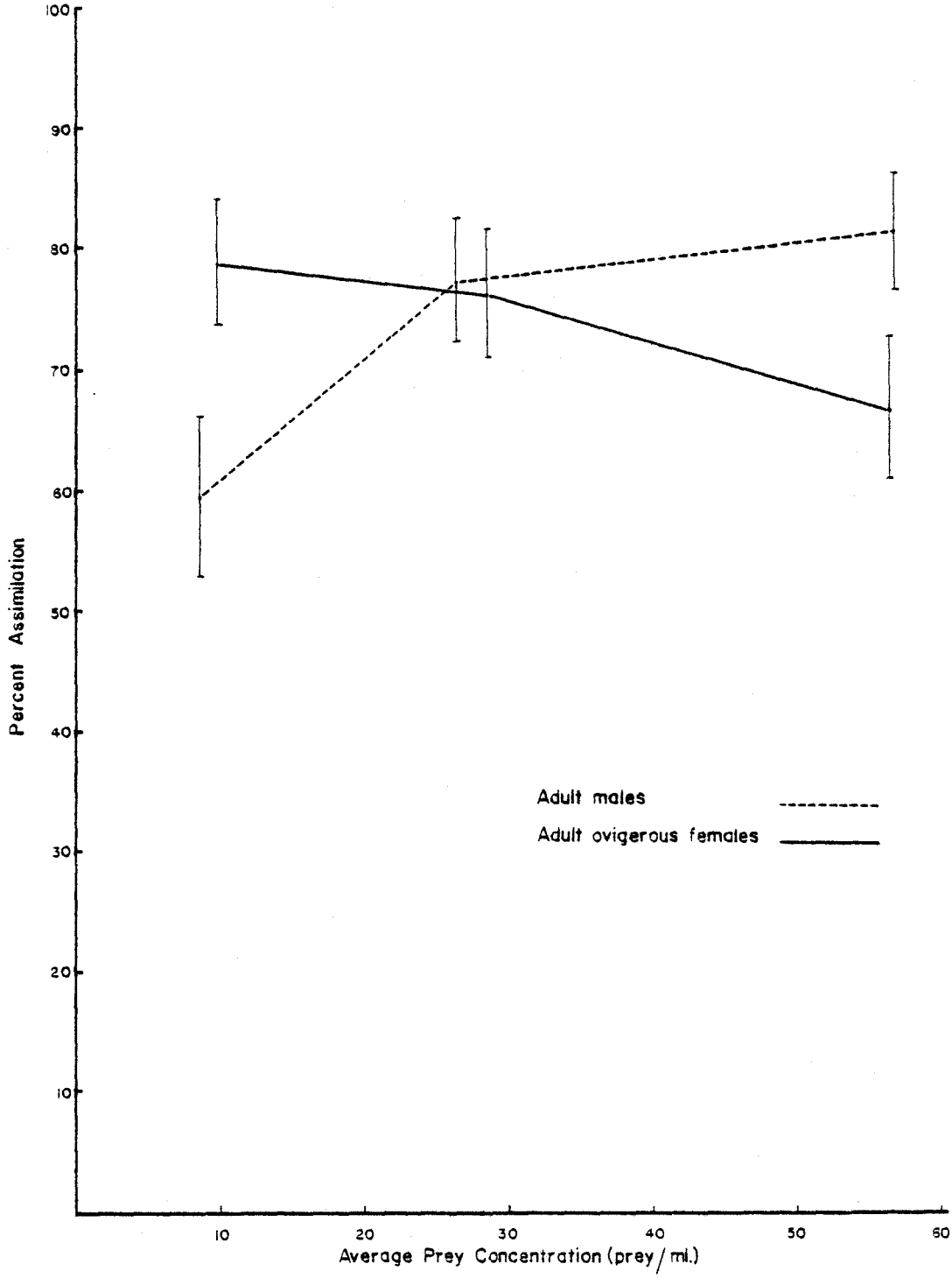

100
90
80
70
60
50
40
30
20
10
Percent Assimilation
Adult males
Adult ovigerous females
10
20
30
40
50
60
Average Prey Concentration (prey / ml.)

Figure 17. Graph of percent assimilation versus average prey concentration (number of prey/ml) for the four size classes of mysids when fed the rotifer Brachionus plicatilis. Error bars represent the maximum positive and negative standard errors about the mean.

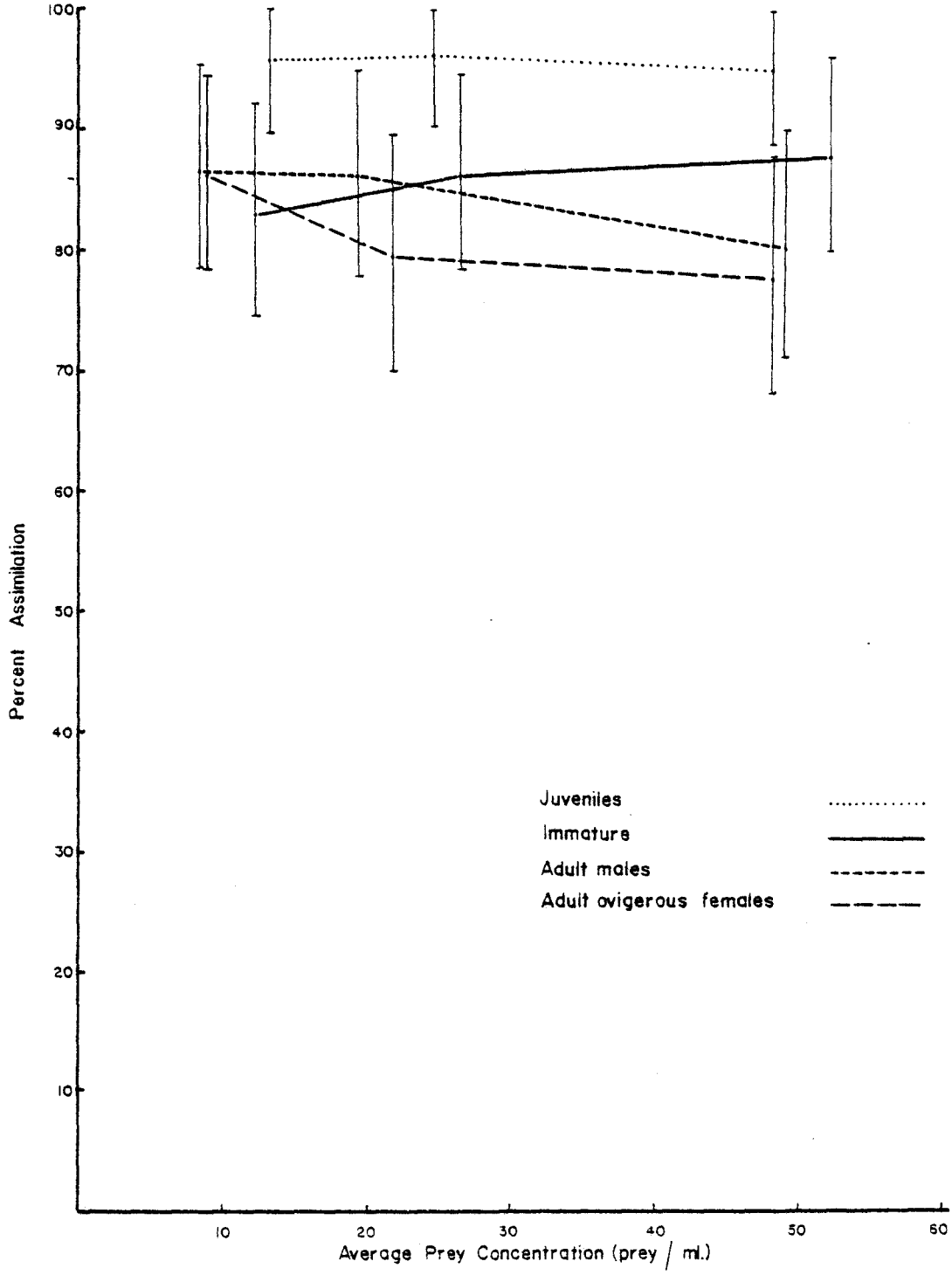
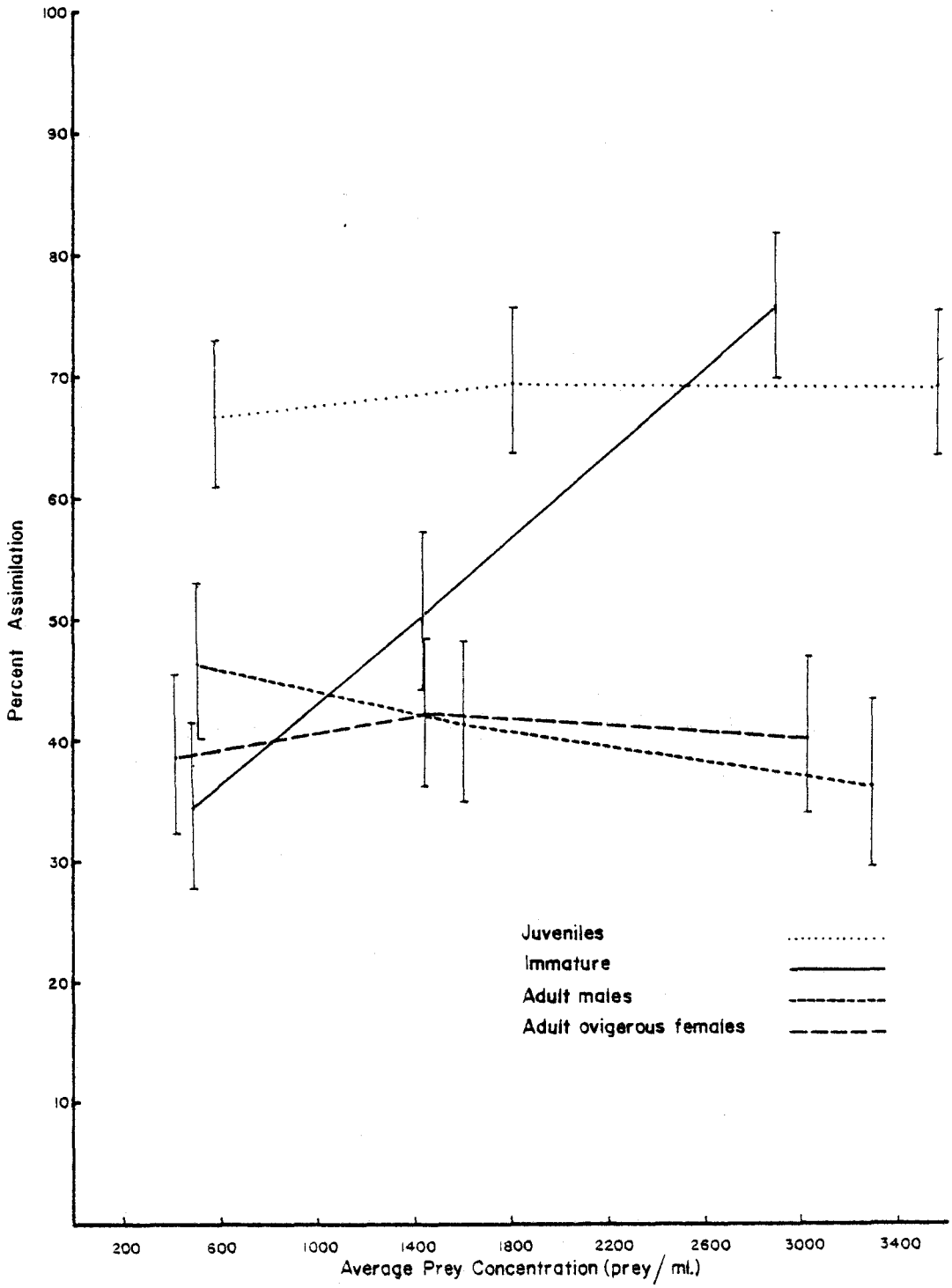

100
90
80
70
60
50
40
30
20
10
Percent Assimilation
10
20
30
40
50
60
Average Prey Concentration (prey / ml.)
Juveniles
Immature
Adult males
Adult ovigerous females

Figure 18. Graph of percent assimilation versus average prey concentration (number of prey/ml) for the four size classes of mysids when fed the diatom Coscinodiscus lineatus. Error bars represent the maximum positive and negative standard errors about the mean.


Percent Assimilation
100
90
80
70
60
50
40
30
20
10
200
600
1000
1400
1800
2200
2600
3000
3400
Average Prey Concentration (prey / ml.)
Juveniles
Immature
Adult males
Adult ovigerous females

DISCUSSION

It has only been in the last two decades that extensive investigations of feeding, growth, and food conversion in filter feeding zooplankton have been undertaken. Most of the progress has been made in studies dealing with the species of Calanus and related genera. This tends to be the result of an overall feeling that the calanoid copepods are the most abundant and ecologically significant marine herbivores. While mysids are by no means restricted to filter feeding, this method is probably their primary means of obtaining nourishment (Tattersall and Tattersall, 1951). In addition, a widespread lack of comparable data pertaining specifically to the mysid shrimps necessitates the use of that which is available. The literature which is available on the subject shows considerable variation, both in the individual methods used to attack a problem, and the results and interpretations of the various researchers.

The rationale for picking the three food sources provided as prey in these experiments has already been discussed. The three concentrations of each were decided on prior to the commencement of the actual thesis experiments. Since this thesis was designed with the underlying hope of determining those prey concentrations which might facilitate the successful laboratory culture of Neomysis americana, no attempt was made to approximate those found in nature.

Artemia salina was offered at initial concentrations of 15, 30 and 60/ml. Most of the studies in which mysids have been fed Artemia relied on ad libitum additions of 24-48 hour old nauplii a couple of times a

day. Robertson and Frost (1977) found that the copepod Aetideus divergens reached maximum ingestion at concentrations of 200-300 nauplii/liter. Floyd (1977) found concentrations of 30/ml satisfactory for development of Palaemonetes pugio larvae. Since the desire was to find the minimum prey concentrations necessary to elicit maximum ingestion rates, the above concentrations were chosen as a base upon which to start. In reality, the average prey concentrations encountered during the 24 hour grazing periods were less than these values due to grazing by the mysids.

Brachionus plicatilis was also offered at initial concentrations of 15, 30 and 60 rotifers/ml. Theilacker and McMaster (1971) found that best growth of the larval anchovy, Engraulis mordax, occurred when fed rotifers at densities of 10-20/ml. The anchovy larval size of 5-10 mm is comparable to that of the adult mysids. Rotifer densities actually encountered by the mysids in nature are likely to be far below these levels.

Two recently published studies have addressed the microzooplankton populations found in two estuaries of the Chesapeake Bay. Grant and Berkowitz (1979) analyzed the plankton populations of the Gunpowder River, Maryland, in the vicinity of the C. P. Crane power generating station during March-June, 1979. Keratella cochlearis, Brachionus calyciflorus and B. plicatilis, and Notholca marina were the dominant rotifers depending on sampling month, and appeared in densities up to about 4000 per 0.1 m^3 ($\sim$0.4/ml). Ecological Analysts Inc. (1979) studied the microzooplankton present in the Southern Branch of the Elizabeth River, Virginia, in the vicinity of Portsmouth Power Station, during November 1977-October 1978. They found that the Phylum Rotifera was

represented primarily by Brachionidae in the form of Brachionus plicatilis, and occasionally other unidentified species of the same genus. Densities encountered, however, were only about four per m^3. While these values are far below those offered in the laboratory, it is not my contention that N. americana survives in nature solely by preying on rotifers.

Coscinodiscus lineatus was offered at densities of approximately 500, 1500, and 3000 cells/ml. Frost (1972) found Calanus pacificus obtained maximum ingestion on 87 μm Centric sp. at concentrations around 50 cells/ml. Robertson and Frost (1977) found maximum ingestion rates for Aetideus divergens, feeding on the 103 μm diatom Coscinodiscus angstii, occured at about 50-75/ml. In the same study, however, concentrations of the 13 μm diatom Thalassiosira fluviatilis approaching 6000/ml failed to produce maximum ingestion. The size of both the prey and predator seem to have an effect on the concentration required to produce this maximum ingestion rate. Adult mysids are much larger than the copepods mentioned above, and as identical concentrations were to be used on all size classes, the above densities were chosen. As with the rotifers, these densities are unlikely to ever be encountered in nature. Dr. Harold Marshall (1979) has recently completed an assessment of the phytoplankton composition in the lower Chesapeake Bay off the city of Cape Charles, Virginia. Over a year period, samples taken approximately monthly were examined, and indicated occurrences of one or more of the following: Coscinodiscus asteromphalus, C. execentricus, C. granii, C. marginatus, C. nitidus, and C. radiatus.

Coscinodiscus marginatus was the seasonally dominant species in the Chesapeake Bay waters off Cape Charles and Old Plantation Creek. Maxi-

mum densities of Coscinodiscus spp. encountered were only as high as 6-7/ml. Again, these concentrations are far below those utilized in the present laboratory experiments but it is highly unlikely that mysids show a generic preference in nature.

As indicated in the methods section, Conover's ash-ratio method (1966) of determining assimilation was utilized. Sample dry weights during the experiments were obtained after drying for 12 hours at 75° C in a mechanical convection oven. The standard drying time is 24 hours, with temperatures of 50-105° C being recommended. Winberg (1971) found that samples of 100-300 mg wet weight reached a constant weight in 2-3 hours. The largest samples dried during my experimentation were intact adult male and female mysids, possessing wet weights of approximately 50 mg. Although wet weights of the fecal samples could not be determined, they probably did not exceed 20-30 mg. In retrospect, a considerably shorter period of time than 12 hours probably would have been adequate. The literature also indicates that once constant weight has been reached, prolonged drying at temperatures not exceeding 105° C does not affect the results (Lappalainen and Kangas, 1975). Therefore, though longer than necessary, the 12 hour drying period utilized throughout the experimentation seems justifiable and defensible.

Sample ash weights were obtained by ashing at 500° C for 12 hours. Temperatures which exceed 550° C result in significant losses in sodium and potassium which in turn result in a reduction in weight of the mineral fraction after incineration. Even prolonged incineration between 400-450° C does not produce noticeable losses of these elements (Winberg, 1971). Winberg (1971) also found 20-24 hours sufficient for the complete combustion of organic matter in a sample weighing 100 mg. Lappalainen

and Kangas (1975), on the other hand, used considerably shorter periods of time, two to four hours at 550 °C. They ashed three species at 550 °C for three hours, then continued ashing and weighing repeatedly until a total of 27 hours ashing time had elapsed. They found only a 0.2% decrease in ash weight from that reached in three hours. In the present study a compromise of 12 hours ashing time was utilized again because of the small initial sample dry weights.

Factors which might affect the observed filtration and ingestion rates during experimentation

In general, a variety of factors are thought possibly to have some effect on an organisms filtration and ingestion rates. These are container volume, duration of experiment, temperature, prior starvation, food size, food concentration, food age, predator size, and predator sex. The experimental design addresses some of these, and attempts are made to hold them constant where possible and/or to minimize their effects throughout.

Low container volumes tend to depress the filtration (or grazing) rates of filter feeders. As the volume of the grazing container increases, so does the volume filtered. Marshall and Orr (1955) found that the volume filtered by Calanus depended on container volume only up to about 70-100 ml. Thereafter there was no further increase at least up to a size of one liter. Anraku (1964) found a similar volume effect, but the optimum value was slightly greater. The volume of the grazing containers in all of my experiments was one liter. Each container contained ten mysids at the start for an average initial volume of 100 ml per mysid. While mysids are not comparable in size to Calanus, the lack of specific data for mysid shrimps, the size of the proposed grazing con-

tainers, and the desire to use at least ten mysids required the adoption of these volumes.

Animals tend to feed more at the beginning of an experiment than later on (Mullin, 1963). The reasons for this are not clear, but are likely the result of handling during transfer or prior starvation. Experimental durations have been anywhere from minutes (Peters, 1975; Foulds and Mann, 1978) to hours (Lasenby and Langford, 1973; Bowers and Grossnickle, 1978) to days (Frost, 1972). Grazing experiments conducted using radioisotope labelled food are necessarily shortened to prevent excretion of the label. Conventional experiments tend to be run for periods of 12-24 hours. Experiments which are run too long run the risk of bacterial builduns and accumulations of feces which in turn may be reingested. All experiments were run for 24 hours.

Grazing rates are felt to be generally highest at the temperatures to which the animals are acclimated (Anraku, 1964). Conover (1966), however, found that increases of 3-5° C in a range of 2-11° C failed to produce any effect on Calanus hyperboreus feeding on diatoms. The maintenance aquarium was kept at a temperature of 15-17° C and all experiments were run at 15° C.

It has already been indicated that prior starvation may be a factor in the initial elevation of grazing rates. Frost (1972) found starved Calanus ingested at higher rates than unstarved at high concentrations of the diatom Thalassiosira fluviatilis (>4000 cells/ml). At densities below what he termed the critical concentration, starved fed like unstarved. In these experiments the possible effect of prior starvation was outweighed by the desire to assure a purging of the mysid gut contents prior to grazing. The starvation period was reduced, however,

from the more standard 24 hours to 12 hours on the basis of the results obtained in the preliminary starvation experiments (Table 1).

The effects of food size, concentration, and age on grazing and ingestion rates are well documented. In general, filter feeding zooplankters will graze the larger sizes over the smaller when fed simultaneously, provided the foods are within the physical limitations set by the feeding apparatus. The mechanism for this particle size selection in passive and possibly active filteres is still unclear. The three completely different food sources presented to the four size classes of mysids in these experiments embrace a range of sizes but were always offered individually. Because of this, no direct attempt at ascertaining preferences between the three food sources was made. Comparisons of ingestion on a dry weight basis are attempted and will be discussed.

Mullin (1963) found decreasing filtration rates for C. hyperboreus with increasing age of T. fluviatilis. Conover (1966) found that the age of the food culture utilized had an effect on filtration rates in some cases and none in others. The Artemia used in the experiments were always 48 hour old nauplii (Appendix II). The rotifers were harvested in the same manner for each experiment and there is no reason to suspect any pronounced differences in their makeup (Appendix III). The Coscinodiscus were always from 7-10 day old cultures (Appendix IV). Variations due to food age were therefore consistent between experiments if not minimal throughout.

Perhaps the most widely investigated factor is the effect that food concentration has on filtration and ingestion rates. Both field and laboratory studies support the observation that filtration rates decline above some critical food density in response to further increases in

prey concentrations. Some authors believe that there is a limiting (or threshold) concentration below which animals do not filter. Once this limit is reached, filtration proceeds at an elevated rate. This threshold will vary according to predator and species of prey. The possible ecological value derived from this type of behavior is two-fold. One, the predator saves the energy which would be expended in fruitless searches for insufficient foods, and secondly, it provides a haven or refuge for rare phytoplankton, facilitating their repopulation. Other researchers, however, discount this theory and instead believe that filtration continues at even low concentrations though at reduced rates (Frost, 1975; Lam and Frost, 1976). As the food supply increases, the animal increases its clearance rate until some maximum is reached. The subsequent decreases in filtration observed is variously attributed to saturation or clogging of the filtration apparatus, tie-ups in the mastication process, or to an active decrease in the filtration by the animal itself.

Ingestion rates on the other hand tend to increase with increasing prey concentrations until a maximum is reached dependent on the size of the organism. Whether or not the ingestion rate remains at this maximum (Frost, 1972) or decreases (Anraku, 1964) at still higher prey concentrations depends on the study one reads. Despite the general agreement that filtration rates decline while ingestion rates increase to some maximum, no such consensus exists as to the behavior or shape of the ingestion curves at low and intermediate concentrations.

Several types of graphs, or presentations, of ingestion rates have been devised. The data are usually fit in one of two ways, either rectilinearly by employing two straight lines, or curvilinearly by a quasi-

hyperbolic function. Whether or not one method is preferable to the other again depends primarily on which article one happens to be reading. There are also those who indicate that it makes no difference which one is used. Mullin et al. (1975) used statistical analyses on Frost's data (1972) in an attempt to distinguish between the two models. They could find no statistical difference between them. With the rectilinear model, one assumes that there is no interference between the particles in the capture-ingestion mechanism until some critical concentration is reached, and that the rate at which water is swept clear of food is a constant within this range of concentrations. With the curvilinear model, the degree of interference tends to increase continuously with the food or particle concentration so that the rate of ingestion decreases (Mullin et al., 1975).

Since the experimental results were based on only three concentrations of prey per experiment, elaborate graphical methods were precluded. Because of this, the graphs were prepared by merely connecting the mean ingestion values observed for the average prey concentrations of the particular food source being used.

Predator size also has an obvious effect on filtration and ingestion, with rates increasing with increasing size of the organism (Harris and Paffenhoffer, 1976; Paffenhoffer and Harris, 1976). Ingestion per weight of the organism, however, has been shown to either decrease (Ryther, 1954) or remain constant (Harris and Paffenhoffer, 1976) with increasing concentrations. In these experiments, the ingestion rates were additionally normalized by correcting for the gm dry weight of the individual mysids per size class in order to examine this possible effect.

Predator sex also appears to have some effect on the filtration and

ingestion rates but again the mechanism and/or advantages are unclear. Raymont and Gross (1941) found filtration rates of male Calanus finmarchicus to be 0.07-0.03 of those of the females in the population. Mullin (1963) found filtration rates of male C. helgolandicus fed Ditylum brightwelli to be 0.3-0.1 of those of the females. For C. finmarchicus, he found the females filtered at a rate of 80 ml/day/copepod while the males did not filter at all. While copepod males are slightly smaller than females, this is not entirely a size-related effect. Both Conover (1956) and Harris and Paffenhoffer (1976) normalized their data for the weight of the copepods, confirming the existence of the reduced male filtration rates. Two of the four size classes in these experiments were adult mysids. They were broken down into adult males and adult/ovigerous females. In Neomysis americana, as is the case for copepods, female mysids tend to be larger than their male counterparts. Once the data had been normalized for mysid dry weight, ingestion rates of the two adult size classes were compared and contrasted with an eye towards the possibility of a sexual effect.

The observed ingestion rates for the various size classes of mysids fed a particular prey species

Artemia salina

Newly hatched Artemia nauplii were provided as the sole available food source to four size classes of mysid shrimps. Figure 2 depicts the resulting ingestion rates obtained, with ingestion (number of prey/mysid/hour) plotted versus the average prey concentration (number of prey/ml). There are only two graphs presented, those for the adult males and the adult/ovigerous females. It will be recalled that no significant difference ($\alpha = 0.05$) in the pre- and post-grazing concentra-

tions for any of the juvenile grazing containers was detected. As such, no subsequent calculations could be carried out, and no graph plotted. There was also no significant difference ($\alpha = 0.05$) in the pre- and post-grazing prey concentrations for the immature mysids at the highest concentration of Artemia offered (approximately 60 Artemia / ml). While it was felt that the Artemia were most likely outside the "filtering" range of both the juvenile and immature mysids, their ability to grasp large particles with the mandibles did not automatically preclude them as a possible food source. The lack of detectable grazing in the smaller size classes is not unexpected, however. Lasenby and Langford (1973) reported that while adult Mysis relicta appeared to be carnivorous at night preying on Daphnia spp., the gut contents of shrimps smaller than 4-5 mm did not contain cladoceran remains. Allen (1975) indicates that Artemia nauplii appeared to be too large for N. americana less than about 5 mm in length. The mean length of the immature mysids used in these experiments was 4.5 ± 0.5 mm (Table 2). They therefore fall in the approximate size range where a change in feeding preference or ability may occur. While I have no firm basis for excluding the lower two ingestion values which were obtained for the immature mysids, their validity is questionable. It seems unlikely that the mysids would ingest Artemia at concentrations of 10 and 30 per ml and not at 60 per ml. Aliquots of a stock solution of Artemia of supposedly known concentration were added to each grazing container. No attempt was made to remove aliquots, count and determine the actual pre-grazing Artemia concentration in individual grazing containers. It is possible that either an over or underestimation of the stock concentration occurred, or, due to a non-random dispersal in the stock container itself, aliquots of unequal Artemia densities were

added to the grazing containers. In addition, there was very little if any fecal material present in any of the juvenile or immature grazing containers at the end of the 24 hour grazing period. The material which was evident was semi-transparent or pale orange in color and insufficient in quantity for analysis. This was the case even in the immature bowls in which a significant decrease in Artemia was indicated. If the mysids were consuming the Artemia one would expect to find fecal material. It is also possible that fecal material was being excreted, but was subsequently being filtered and reingested. This might explain the physical appearance of those fecal strands observed as each reingestion should serve to further decrease the percentage of unassimilated organics in the feces. This does not, however, adequately explain the lack in quantity detected. It is also logical that the lack of a substantial amount of fecal material indicates a corresponding lack of ingestion at all concentrations. Because of these questions and because it is extremely difficult to draw conclusions from two point curves under any circumstances, I feel it prudent to say that the results of the experiments in which immature mysids were fed Artemia were inconclusive.

If we consider just the results of the adult mysids, male and female, we notice first what appears to be a predator sex effect on ingestion. The mean length of the adult males used in the experiments was 8.0 ± 0.5 mm (Table 2) while that of the adult females was 8.5 ± 0.6 mm (Table 2). Assuming normality and utilizing a z-test we find a significant difference ($\alpha = 0.05$) in the size ranges. Though smaller, the adult males ingest more than the adult females. Even after the ingestion rates have been normalized for the dry weights of the mysids (Figure 5), the disparity remains. Though sex effects on ingestion rates have been previously

reported, this is directly opposite that found in copepods (Raymont and Gross, 1941; Conover, 1956; Mullin, 1963; Harris and Paffenhoffer, 1976). A possible explanation for this discrepancy lies in the reproductive state of the females used in these experiments. The preliminary starvation experiments conducted in conjunction with this thesis, and observations of mysids held in standard saltwater aquaria indicate that the adult/ovigerous females are the last to die. It is possible that when ovigerous, females exhibit reduced filtration and ingestion rates. A substantiation of this assumption will require simultaneous experimentation on both ovigerous and nonovigerous females with comparisons to the rates obtained for adult males.

The adult males seem to show maximum ingestion at concentrations of about 20-25 Artemia per ml. With only three data points, it is difficult to say exactly where the ingestion rate begins to level off with further increases in the prey concentration. The adult females do not show any such pronounced maximum. Instead, their ingestion rate continues to gradually increase even up to the maximum prey concentrations offered, approximately 55 Artemia per ml. At this concentration, however, they are only approaching the level of ingestion of the males. It is possible that further increases in the prey concentration would have resulted in just such a maximum.

Brachionus plicatilis

The cultured rotifer Brachionus plicatilis was provided as the sole available food source to four size classes of the mysid shrimp Neomysis americana. Figure 3 depicts the resulting ingestion rates obtained, with ingestion (number of prey / mysid / hour) plotted versus the average

prey concentration (number of prey / ml). In general we see that ingestion rates increase with the size of the organism. This is not unsuspected and agrees with results published in the literature (Harris and Paffenhoffer, 1976; Paffenhoffer and Harris, 1976). As was the case when fed Artemia, the adult males again show higher initial ingestion rates than the adult/ovigerous females. Possible explanations for this behavior have already been discussed. The juvenile mysids, however, also show consistently higher rates than those of the larger immature mysids. This was not expected. The hypothesis was that the juveniles were primarily herbivores, only becoming omnivores after attaining a size of about 5 mm. That they apparently can and do ingest rotifers tends to indicate that they are not strict herbivores, but indeed omnivores capable of filtering or capturing small zooplankters. Food size is therefore probably more important than food type. Preferences, on a dry weight basis, and percentage assimilation, will be discussed shortly.

Only the adult males seem to have reached a maximum ingestion rate, occurring somewhere around 15-20 rotifers / ml. The two smallest size classes show continued increases even up to the maximum concentrations offered. The female ingestion rates surpass those of the males at the highest concentrations though the slope of the increase seems to be decreasing. Figure 6 presents the same data now normalized for mysid dry weight (ingestion = number of prey / gm dry weight mysid / hour). Again, even after normalization, the adult males exhibit a higher initial ingestion rate than the females indicating the possible predator sex effect on ingestion. We also see from this figure that the smaller size classes ingest more on a per weight basis than the larger size classes (Ryther, 1954).

Coscinodiscus lineatus

Figure 4 shows the results of the grazing experiments when the four size classes of mysids were fed three concentrations of the diatom Coscinodiscus lineatus. Ingestion (number of prey / mysid / hour) is plotted versus average prey concentration (number of prey / ml). While the three largest size classes show increasing rates with increasing concentrations, the juvenile ingestion rate appears to be fairly constant in the range of 300-600 cells / mysid / hour. In this instance it is possible that a decrease in the prey concentration might have resulted in a decreased ingestion rate. The adult males again ingest at the highest rates, and are higher than the adult females except at the lowest prey concentrations. The ingestion rate is almost twice that of the females at the highest prey concentration. As previously mentioned, no explanation other than the possible effect due to predator sex is apparent and can be invoked as the cause of this disparity. Both the immature and adult male size classes show almost linear increases in ingestion with increasing prey concentration, the females slightly less.

Figure 7 depicts the same data after normalizing ingestion rates for the dry weight of the mysids. In general, the same trend as that observed for Brachionus is evident, namely that ingestion per weight of the mysids decreases with increasing size. The exception to this are the immature, which ingest more per weight than the juveniles at higher concentrations. Reasons which might adequately explain this are unavailable at the present time.

Factors which might affect the observed assimilation rates during experimentation

There are only a few factors considered to possibly have some effect on the assimilation of organic matter by zooplankton. In general they are temperature, predator size, age of food culture, length of exposure or acclimation to food source, food species offered, and food concentration. Previous studies which have attempted to address or estimate the effects of these factors are often contradictory.

Since the temperatures throughout experimentation, as well as in the maintenance aquarium, were held as constant as possible, any possible temperature effect on assimilation was discounted. For predator size effects, the usual trend is for decreasing efficiency with increasing size, though there seem to be some studies to counter this. The use of four size classes of mysids for a particular food source, however, permits an examination of this possible effect as it pertains to mysids. While it has been shown that the age of the food culture does have an effect on filtration and ingestion rates, its effect on assimilation is somewhat less clear cut. The general feeling is that food age does, or at least should have an effect on assimilation. Conover (1966) was unable to find a significant difference in percentage of assimilation when Calanus hyperboreus was fed old and log phase cultures of the diatom Thalassiosira fluviatilis. He also found no significant effect in regards to the length of exposure of C. hyperboreus to the food source.

The effect that diet or food species has on the percentage of assimilation is not unlike what one might suspect. The degree of assimilation is felt to be largely determined by the chemical composition and caloric value of the food source offered. Conover (1966) grazed Calanus

hyperboreus on a number of different species of diatom concluding that organisms with a lower ash content were assimilated more completely than were those with larger amounts of ash.

Perhaps the most widely disputed factor, however, is the possible effect that food concentration has on the percentage of assimilation. There appear to be two schools of thought surrounding the effects of food concentration; one assumes that the assimilation efficiency decreases at high food concentrations while the second believes that it remains fairly constant at a high level in spite of increasing prey concentrations. The decreasing assimilation efficiency of zooplankters at constant ingestion rates has been explained by the term "superfluous feeding". This concept was first proposed by Beklemishev (1954) and he states later on (Beklemishev, 1962 p.108) that "There is superfluous feeding when actively feeding animals stop responding to an increase in standing crop of their food by an increase in assimilation". This concept of superfluous feeding does have some support in the literature. Richman (1958) found decreasing assimilation efficiency with increasing food abundance in Daphnia pulex, and Schindler (1971) found the same trend when he fed a number of food species to Diaptomus gracilis.

The second school of thought which maintains that assimilation efficiencies stay relatively constant seems to have more support, however. Marshall and Orr (1955) observed more or less constant high assimilation efficiencies for Calanus finmarchicus regardless of the quantity of available food. Conover (1966) found the same to be true for Calanus hyperboreous fed Thalassiosira fluviatilis. Pechen-Finenko and Pavlovskaya (1976) in their work on Neomysis mirabilis also found that assimilability of the algae Gymnodium kowalevskii was virtually constant over a range

of concentrations.

The three food sources used in the experiments, Artemia salina, Brachionus plicatilis, and Coscinodiscus lineatus, were found to be approximately 84, 89, and 61 percent organic respectively (Table 3). Direct comparisons of these values to those in the literature are difficult due to the variety of methods used (i.e., dry weight, ash weight, caloric content, Carbon, etc.) in determining assimilation by the various authors. The values do, however, appear to be close to those one might expect. Theilacker and McMaster (1971) found Brachionus plicatilis in their cultures to be 92.2 ± 2.0 percent organic while Conover (1966) lists Coscinodiscus sp. as having a mean organic content of 43.8 percent over a range of 30.0-62.7 percent. The value of 83.7 ± 2.0 percent obtained for Artemia salina nauplii in these experiments is also reasonable since newly hatched nauplii are known to be rich in organics.

The observed assimilation rates for the various size classes of mysids fed a particular prey species

Artemia salina

The results of the assimilation determinations were graphed by food source offered. Figure 16 depicts the percent assimilation versus average prey concentration (number of prey/ml) for adult males and adult ovigerous females when fed Artemia nauplii. It will be recalled that insufficient fecal material in the juvenile and immature grazing containers at the end of the 24 hour grazing period precluded determinations of assimilation. This was attributed primarily to a lack of ingestion but also may have been the result of reingestion of the fecal material by the mysids.

For the adult males we see an assimilation curve which closely parallels that of ingestion. Assimilation increases with increasing prey concentration to a maximum at a concentration around 25 Artemia per ml. Thereafter it appears to maintain a fairly constant 75-80 percent. This is similar to the type of response found by Marshall and Orr (1955) and Conover (1966).

The assimilation curve generated for the adult females is somewhat more difficult to interpret. The rate appears to be fairly constant at first, decreasing at the higher prey concentrations. This can not really be interpreted as an indication of superfluous feeding (Beklemishev, 1962) since decreasing assimilation efficiency does not appear to coincide with a constant maximum ingestion rate. Both male and female experiments were run under identical conditions, though not simultaneously. The observed decrease is therefore most likely attributable to the increasing prey concentration. The rationale behind this response,

or any other possible explanations as to its cause are unclear and would be conjecture at this point.

The magnitude of the values obtained compares favorably with those found in the literature. Lasker (1966) found an 88% assimilation of Artemia nauplii by Euphausia pacifica. Lasenby and Langford (1973) found that when adult Mysis relicta were fed Daphnia pulex (79% organic), assimilation values were 52% and 85% according to the ash-ratio and gravimetric methods utilized. In their case they believed that the gravimetric method provided the more accurate value.

Brachionus plicatilis

Figure 17 depicts the results obtained for the four size classes of mysids when fed on the rotifer Brachionus plicatilis. Percentage assimilation is plotted versus average prey concentration. From this figure it is evident that percentage of assimilation tends to decrease with increasing size of the organism. The juvenile size class shows the highest assimilation at a relatively constant 95% (range of 95.2-96.4) regardless of prey concentration. The immature mysids also show a relatively constant but lower assimilation efficiency of approximately 85% over the three prey concentrations in spite of increasing ingestion rates (Figure 3). The adult males show a constant assimilation with increasing ingestion and a decreasing assimilation at constant ingestion. This seems to more closely approximate those results expected by the superfluous feeding adherents. The adult/ovigerous females show decreasing assimilation efficiencies with increasing prey concentrations and ingestion. The curve is for the most part very similar in shape to, though slightly higher than, that obtained when fed Artemia nauplii. Though the males and females initially assimilate at approximately the

same efficiency (86%), the females show a much more rapid decrease with increasing prey concentration. At the highest prey concentrations offered they are again fairly close at 78-80%.

None of the size classes show what I would consider to be dramatic differences in assimilation as a result of increasing prey concentrations. The adult females show the maximum variation over the range of concentrations and it is only about 8%.

Brachionus is higher in organics than Artemia and the assimilation efficiencies of at least the males and females seem to be correspondingly higher also. This agrees with what Conover (1966) found regarding the effects of food species on assimilation. The values obtained here also tend to agree with the results reported by Lasenby and Langford (1973). In their experiments, when Mysis relicta was provided what they termed a low inorganic food source, fourth instar Orthocladius and Trissocladius chironomid larvae, the ash-ratio assimilation percentage was 82%.

Coscinodiscus lineatus

Figure 18 shows the assimilation efficiencies observed for the four size classes of mysids when fed on increasing concentrations of Coscinodiscus lineatus. Percentage assimilation is plotted versus average prey concentration per ml. As with the rotifers, the general trend of decreasing assimilation with increasing prey concentration is evident.

The juvenile size class was the only size to show a relatively constant ingestion rate (Figure 4) and it was stated that I believed them already to be at their maximum ingestion rate. Percent assimilation also appears to be relatively constant at approximately 67-69% over the range of prey concentrations offered.

The adult males show a rather steady decrease in assimilation, 46.3%

to 36.4 %, with increasing prey concentrations in spite of the rather dramatic increases in ingestion rates over the same concentrations.

The adult/ovigerous females seem to show a fairly constant assimilation of approximately 40% (range 38.7-42.3%). This is also in spite of increasing ingestion rates though far less dramatic than those of the adult males.

Assimilation efficiencies observed for the immature size class when fed Coscinodiscus lineatus are the hardest to explain. Assimilation increases dramatically and almost linearly from 34% to 76% over the range of prey concentrations. The shape of the graph is very close to that of ingestion. In theory it is possible that saturation or maximum prey concentrations have yet to be reached and a levelling out of the ingestion and assimilation rates will occur at still higher concentrations. I do not believe this to be the case. Rather, this curve seems most probably the result of experimental errors of some sort, variation in the test organisms, an uncontrolled or unknown factor, or the method by which mysids feed.

Mysid feeding methods may have a profound effect on both the ingestion and assimilation rates presented here. It is known that they are capable of both filtering, and grasping larger prey with the mandibles, masticating it prior to ingestion. This latter method may result in the loss of fragments of particulate matter into the water which are not counted, thereby resulting in inflated ingestion rates. While this is a problem to be considered with both Artemia and Brachionus, it may be worse with the diatom Coscinodiscus. It is unknown whether or not the entire test of a large Coscinodiscus is ingested by the mysids. If not, and if it is broken up by the mandibles, a much larger percentage of the

cell sap or organics contained in the diatom may be lost as soluble or particulate matter to the water. This would obviously serve to exaggerate the observed percentage assimilation. No attempt was made in these experiments to estimate this error and it cannot be invoked to explain the assimilation efficiencies of the immature mysids without also being considered for the other size classes. Suffice it to say that no apparent reason is available to adequately explain the immature assimilation efficiencies at this time.

Food preferences or suitability of the three food sources for the four sizes of mysid shrimps

The three food sources offered in these experiments, Artemia salina, Brachionus plicatilis, and Coscinodiscus lineatus, were intentionally quite different. Not only are they from three distinct phyla, they also encompass a wide range of sizes and are varied in respect to their individual makeups. Coscinodiscus is the smallest, yet highest in ash content. Artemia is the largest, but possesses an organic content slightly lower than that of Brachionus. No attempt was made to determine either the carbon content or caloric value of the individual food sources. This decision was reached after conversations with Dr. G. T. F. Wong, Department of Oceanography, Old Dominion University. Dr. Wong indicated it would require an additional year of study for a biological oceanographer to acquire sufficient expertise in this area in order to both correctly utilize the equipment and to derive meaningful data from it.

No single study known in the literature lists comparable values, in terms of carbon content or caloric value, for all three of the above food sources. In addition, the values one obtains will likely change

or vary in response to the culturing techniques, makeup of the population, growth phase of culture at time of analysis, and analytical techniques. Because of this variability, reported values, when available, should only be compared in a broad sense to those derived in a particular study.

Robertson and Frost (1977) report that a single Artemia nauplius contains more than 60 times as much carbon as a single 108 μm cell of Coscinodiscus angstii, obtaining values of 0.76 μg carbon/nauplius and 0.01168 μg carbon/diatom cell. Theilacker and McMaster (1971) analyzed their cultures of Brachionus plicatilis but reported the results in terms of calories/gm dry weight of organic substance (i.e. 5335 ± 135). Because of these difficulties, I attempted to compare the ingestion rates of the four size classes of mysids for the three food sources on a dry weight basis.

Figures 8-11 depict the resulting ingestion rates for a particular size class (number of prey/gm dry weight mysid/hour) versus the average prey concentrations offered (log gm dry weight of prey/ml). The prey concentrations are now comparable and it can be seen that on this basis alone, less Brachionus/ml was offered than Coscinodiscus and Artemia. The ingestion rates, however, remain in terms of prey number and this representation still does not yet adequately counter the effects of prey size. It can be seen from all four figures that ingestion tends to decrease with increasing prey size. This is not unexpected and most likely reflects the longer handling time required for succeedingly larger prey, or the fact that fewer large prey are required in order to achieve the same degree of "fullness".

As a result, Figures 12-15 were prepared. The axes remain unchanged,

the abscissa continuing to be in units of log gm dry weight of prey/ml. The ordinate, ingestion, is now in units of log gm dry weight of prey/ gm dry weight of mysid/hour. This now permits a direct comparison of the amount of material ingested per mysid per hour on all three food sources regardless of the actual numbers of prey each represents. When viewed in conjunction with the percentage of organics available in each food, and the percentage actually assimilated, some conclusions can be drawn regarding mysid preferences or the suitability of each.

Juveniles

Figure 12 shows the ingestion curves obtained for the juvenile size class of mysids when fed Brachionus and Coscinodiscus. No curve is available for Artemia due to the previously mentioned lack of significant grazing. The shape of the individual ingestion curves and the probable indications of each have also been discussed earlier in this section. Use of a log scale was necessary in order to permit the simultaneous representation of the various curves but does result in a certain amount of distortion.

Of primary importance is the indication that juvenile mysids appear to ingest both diatoms and rotifers about equally on a dry weight basis. This further substantiates the fact that the juvenile mysids are not strictly herbivores as originally hypothesized, but in fact omnivores capable of filtering or capturing small zooplankters. While there does not appear to be any pronounced "preference", it will be recalled that the foods were only offered individually. A more precise estimation of mysid preference can only be determined if the food sources are offered simultaneously with individual grazing rates calculated.

In regards to the "suitability" of these two foods for juvenile

mysids, we can recall that Brachionus was calculated to be approximately 89% organic as opposed to 61% for Coscinodiscus. Additionally, the juvenile mysids assimilated approximately 95% of the rotifers and only about 69% of the diatoms. Given this information, it seems logical to say that a diet of rotifers appears to be the most suitable of the two food sources for juvenile mysids.

Immature

Figure 13 depicts the ingestion rates observed for the immature mysids again for only two food sources, Brachionus and Coscinodiscus. Reasons for the lack of a curve when Artemia was provided were discussed previously. This figure indicates that the immature mysids ingested up to 40 times more Coscinodiscus than Brachionus on a dry weight basis. While the ingestion curve for Coscinodiscus closely resembles that of the juveniles, it is a drastic decrease in ingestion of rotifers that is responsible for the disparity. No explanation for the discrepancy between these results and those obtained for the juveniles is available.

Assimilation of rotifers by the immature was approximately 86% over the range of concentrations provided. Those for Coscinodiscus were more confusing going from 34% to 76%. While there appears to be a preference for the diatoms in this case, it is difficult to say which is really the more suitable. Low assimilation of the diatoms could still mean that the higher percentage of organics and assimilation of the rotifers is sufficient to offset the decreased ingestion and still provide more nutrition.

Adult males

Figure 14 presents the ingestion rates derived for adult/male mysids on all three of the food sources. On a dry weight basis, all three foods appear to be ingested at close to the same rates. The maximum ingestion rates for Artemia and Coscinodiscus are two and four times the maximum observed for Brachionus. This may not be a true representation, however, since the average prey concentration of rotifers offered was less than that of the other two prey species according to dry weight. It is possible that further increases in rotifer concentrations might have resulted in an ingestion curve closer in magnitude to those obtained on Artemia and diatoms. In fact, if a comparison of ingestion rates is made at the one prey concentration where all three are represented we notice almost identical ingestion rates.

Another interesting trend appears to be that of decreasing ingestion with increasing organic content of the food and assimilation by the mysids. This is not entirely an effect due to prey size since the Artemia, which are larger than the rotifers, appear to be ingested at a higher rate.

These results tend to indicate that the adult males are quite omnivorous over a wide range of prey sizes, and they appear to require, or ingest, more food as the percentage of organics available in the food source decreases. Given the close similarity in the curves and the much higher assimilation efficiencies obtained on the rotifers and Artemia, I am inclined to believe that these would prove more suitable than diatoms as a primary food source in culture attempts.

Adult/ovigerous females

Figure 15 depicts the ingestion curves obtained for the adult

ovigerous females again for all three prey species. When compared to those observed for the adult males we notice a slight decrease in the rates of all three. Possible explanations for these decreases in spite of a significant increase in size of the females have already been discussed.

Ingestion rates for the three food sources, on a dry weight basis, are again fairly close though they show more variation than did those of the adult males. The maximum rates were achieved with Coscinodiscus, slightly less with Artemia and Brachionus, indicating the possible correlation with organic content in the food. The approximate mid range prey concentration where all three food sources are represented resulted in a wider range of ingestion rates. At this concentration we also get the impression of increasing ingestion with decreasing prey size.

As was the case with the adult males, the adult females appear to be omnivorous, in general ingesting more material as the organic content decreases. The fact that assimilation is 30-40% higher on rotifers and Artemia than on Coscinodiscus tends to indicate that the lowered ingestion rates are more than offset by the increased assimilation efficiencies. It therefore seems preferable to supply either of these two food sources, as opposed to diatoms, in culturing attempts.

Estimations of the "suitability" of the three food sources, for each of the size classes utilized, have been proposed. True preferences, however, can only be determined if the food sources are offered simultaneously. While this study tends to indicate that rotifers are the best of the three food sources offered, the long term effects that a rotifer diet might have on growth, reproduction, fecundity, and general mysid health in culture, will require additional experimentation.

CONCLUSIONS

1. Juvenile mysids (2.5 ± 0.4 mm) do not appear to be strict herbivores as hypothesized, but omnivores capable of ingesting both rotifers and diatoms. They do not ingest 48 hour Artemia salina nauplii indicating that some type of size selection process is involved. Whether this selection is active or passive is unclear, but is most likely attributable to some maximum prey size above which the mysids find it difficult to grasp and masticate prey. Brachionus plicatilis and Coscinodiscus lineatus are ingested at approximately equal rates on a dry weight basis. With Coscinodiscus, relatively constant ingestion rates of 300-600 diatoms/mysid/hour occur over the range of prey densities offered. Densities less than the minimum 500 cells/ml offered here might be sufficient to elicit maximum ingestion.

2. Immature mysids (4.5 ± 0.5 mm) ingest approximately 40 times more Coscinodiscus than Brachionus on a dry weight basis. Results when fed Artemia nauplii were inconclusive.

3. Adult males (8.0 ± 0.5 mm) and adult/ovigerous females (8.5 ± 0.6 mm) ingest all three food sources. Though significantly smaller than the females, the males ingest more prey/mysid/hour than the females. This holds true even after ingestion rates have been normalized for mysid weight. These data can best be explained as resulting from the effects of predator sex on ingestion rates.

Effects directly attributable to the reproductive state of the females utilized here will require further experimentation. Maximum ingestion for adult males appears to occur at concentrations of 20-25 nauplii/ml and 15-20 rotifers/ml.

4. Ingestion rates increase with increasing predator size on a given food source. After normalization for mysid weight, the reverse is true, namely, decreasing ingestion per weight with increasing predator size. Comparisons of ingestion rates per size class, on a dry weight basis, tend to show decreasing ingestion with increasing prey size and organic content. This possibly reflects the longer handling times required for progressively larger prey, or, it may be an indication that fewer prey are needed to achieve the same degree of "fullness". Interpretations are confounded somewhat since the three food sources were only offered individually, and prey concentrations of each on a dry weight basis were not identical.

5. Percentage assimilation of the mysids decreases with increasing ash content of the prey species offered. Assimilation also decreases with increasing predator size for a particular prey source. In general, assimilation efficiencies overall appear to be fairly constant throughout the range of prey concentrations offered. Support for the "superfluous feeding" concept clearly occurs in only one instance. Adult males fed Brachionus plicatilis show decreasing assimilation which appears to coincide with the attainment of constant ingestion.

6. Considering the results obtained from these experiments, it is recommended that culturing attempts include foods in the size range

of approximately 150-250 μm. While adults are capable of ingesting a wide range of sizes, there is evidently an upper limit to that which the juveniles and immature can adequately handle. Artemia salina nauplii appear to be above this limit. Since assimilation efficiencies increase with increasing organic content of the food, and are highest in the smallest sizes, the diet should also be high in percent organics. The rotifer Brachionus plicatilis seems to satisfy all requirements. In addition, it is easily cultured in the laboratory. Prey densities less than about 60/ml should prove sufficient for all size classes of mysids, including ovigerous females, and likely can be further reduced on the basis of more extensive experimentation.

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Appendix I

Design of maintenance aquarium

The maintenance aquarium in which the mysids were kept was an all glass rectangular aquarium measuring 75 cm x 30 cm x 30 cm. Though capable of holding approximately 67.5 liters of water, it actually contained only about 45 liters allowing for space taken up by the biological filter and incomplete filling. As previously stated, the optimal desired temperature was 15° C. In actuality, the lighting and cooling equipment in operation around the tank caused a maximum temperature fluctuation of 1.5-2° C over a 24 hour period. The aquarium was located in a previously constructed wooden box in the Department of Oceanography. This box was serviced by an independent air conditioning unit inserted in its side and provided the necessary cooling capacity. Eight foot fluorescent lighting fixtures suspended approximately 30 cm above the tank provided illumination. The photoperiod utilized was 12 hour dark:12 hour light.

The aquarium was initially filled with natural seawater and diluted with de-ionized water to obtain a salinity of 20°/oo. Subsequent additions of 0.3 μm filtered seawater or de-ionized water were made when necessary in order to maintain a salinity range of between 20-22°/oo. All four sides, and the top of the aquarium, were covered with 1.9 cm styrofoam sheeting. This served to reduce the lateral lighting components, the intensity of the overhead illumination, and provided insulation which prohibited rapid fluctuations in water temperature.

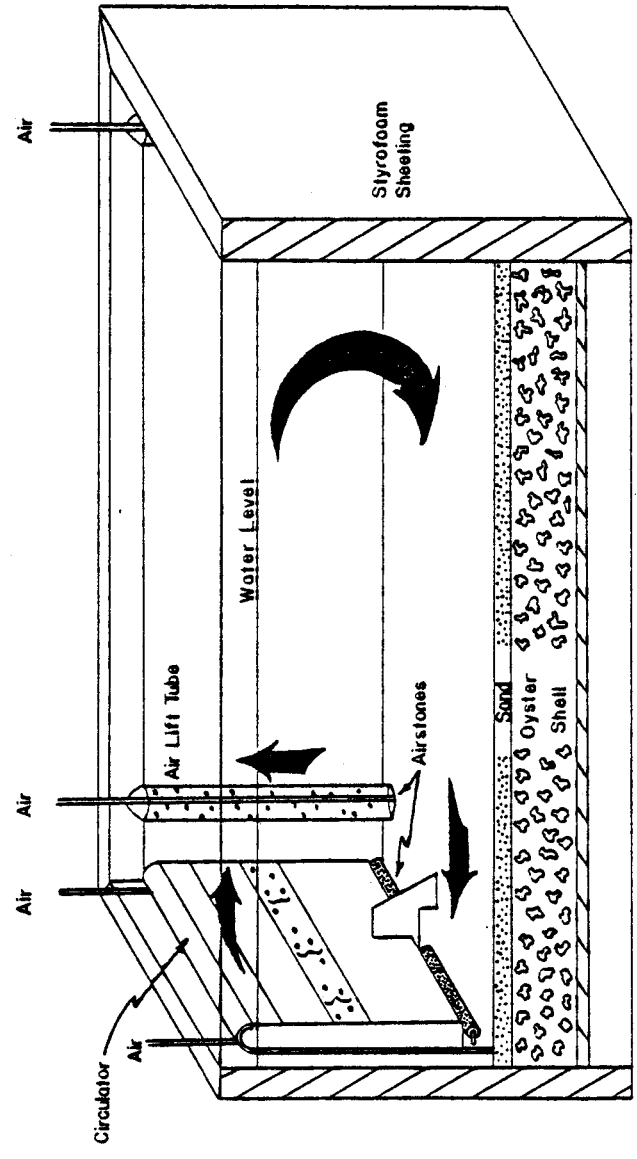
The primary biological filter consisted of a 6.4 cm layer of crushed oyster shell. This not only provided suitable surfaces for the nitrifying bacteria but also helped to effectively maintain optimal alkalinity and pH levels.

Two cylindrical air lift discharge tubes (3.8 cm x 25.4 cm) were located in the rear corners of the tank and extended below the oyster shell to the base of the filter. Air stones connected to 0.95 cm tygon tubes running down the center of the discharge tubes served as the lifting and primary aeration devices. The discharge tubes were approximately 95% submerged, and the top 2.5 cm was cut at a 45 degree angle to permit some directional discharge capabilities. A diagram of the maintenance aquarium is presented in Figure 19.

Filter feeding by mysids is probably the normal and general means of gathering food. Some mysids (Hemimysis lamornae [Cannon and Manton, 1927]) have been reported to feed off the substrate. This behavior has also been observed periodically in N. americana. To facilitate this mode of feeding a particle size smaller than the 2-5 mm oyster shell was deemed necessary. The oyster shell was therefore overlain by an additional 1.3-2.5 cm layer of coarse sand.

The exact dependency of mysids on flowing water is not really known, but most likely is a direct result of both respiratory and feeding behaviors (Allen, 1975). He also found that without exception, numbers of mysids could not be kept alive for more than a few days without air stone generated currents in spite of sufficient dissolved oxygen levels. It is also known that mysids tend to oritent themselves into or toward the prevailing horizontal currents when swimming and feeding (Clutter, 1969).

Figure 19. Design of maintenance aquarium used throughout investigation.

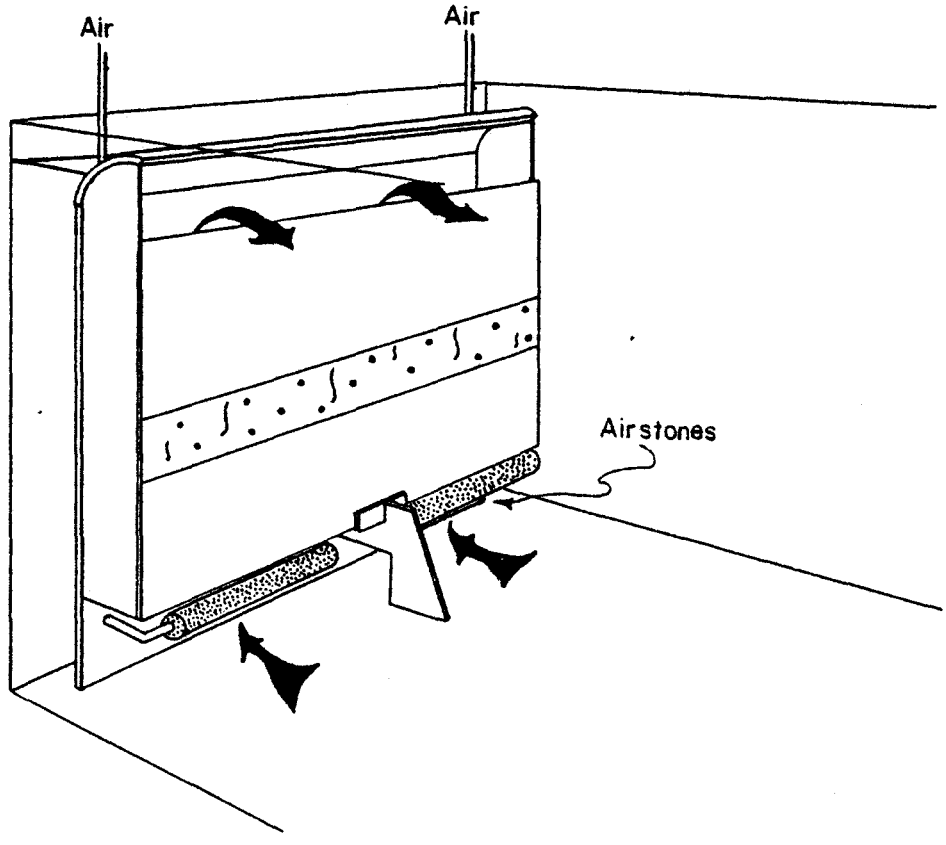

Air
Styrofoam Sheeting
Water Level
Air Lift Tube
Air
Air
Airstones
Sand
Oyster Shell
Air
Circulator

Due to the size and shape of the oyster shell particles, flow immediately adjacent to the bottom would be expected to be turbulent rather than laminar. The sand layer, in addition to enhancing the mysids along bottom feeding behavior, served to promote these more desirable laminar flow patterns.

To further improve laminar flow, as well as to insure a saturated oxygen level in the tank, I constructed and placed along one side of the tank an air lift circulator similar to that described by Salser and Mock (1973). A diagram of this circulator is presented in Figure 20. This circulator was supplied with air via two- 0.95 cm air lines and was kept in operation continuously. The preferable laminar flow patterns were therefore accentuated and it additionally helped to keep non-motile food sources in suspension longer by preventing their being drawn into the filter.

The design of the maintenance aquarium proved satisfactory for both maintenance and limited culture of N. americana. Although mysids were periodically added to the aquarium to replace those individuals removed for preliminary experimentation, survival seemed quite good. Copulation was observed on a couple of occasions, and newly released juveniles were often apparent weeks after the previous additions had occured. Personal feeling is that if Coscinodiscus, or other suitable algal cultures, were regularly added or cultured in the tank itself, continuous culture of N. americana in a closed recirculating system would be possible.

Figure 20. Design of air lift circulator used in maintenance aquarium to provide circulation (after Salser and Mock, 1973).


Air
Air
Airstones

Appendix II

Methods of culturing and obtaining the necessary concentrations of *Artemia salina* nauplii

Artemia salina nauplii were obtained by hatching commercially available eggs from San Francisco Bay. Hatching was carried out using two, one-liter glass separatory funnels equipped with stopcocks. One-half teaspoon of eggs were added to each funnel, on an alternating schedule, and the funnels were filled with 20°/oo, 0.3 μm filtered sea water. Two glass rods, one long to supply air at the bottom, and the other relatively short to vent air at the top, were inserted into the neck of the funnel through a rubber stopper. The funnels were mounted vertically in a ring stand and connected to an air supply. Aeration at room temperature provided hatches in approximately 48 hours.

After hatching was completed, the air was disconnected and time allowed for the empty egg cases and debris to float to the surface. Preliminary separation of the nauplii and the empty egg cases was accomplished by slowly draining the funnel contents into a two liter beaker. As the water level dropped, the floating egg cases adhered to the sides of the funnel. The stopcock was closed before those remaining could drain into the beaker. A further separation of the nauplii from the unhatched cysts was accomplished by utilizing the method described by Floyd (1977). A large plastic funnel, roughened on the inside, was placed inside of a large cardboard box. The bottom of the funnel contained a drain tube, inserted through a stopper, which protruded through

a hole in the base of the box. After clamping the tube, the Artemia solution in the two-liter beaker was poured into the funnel. A high intensity light source was inserted through another hole in the side of the box near the base of the funnel. The hatching water was allowed to settle and the nauplii permitted ample time to migrate towards the light at the bottom. The funnel was then slowly drained back into the two-liter beaker. This solution was filtered through a 110 μm fine mesh screen sieve to collect the nauplii. The nauplii were washed off the screen into a 250 ml graduated cylinder and made up to a volume of 200 ml with 20°/oo, 0.3 μm filtered sea water. This solution was poured into a clean 600 ml beaker and an additional 300 ml of 20°/oo, 0.3 μm filtered sea water added to bring the final volume to 500 ml.

The concentration of Artemia per ml in this stock solution was determined by counting with the Model ZB Coulter Particle Counter. A ten ml aliquot of the stock solution was removed and added to another beaker containing 490 ml of 20°/oo, 0.3 μm filtered sea water. Eight to ten, two-ml aliquots were counted using a 1000 μm aperture tube. Filtered sea water was used as a blank to correct for any possible impurities and/or electrical interferences. Each of the counts obtained was then corrected for the percentage of coincidence according to the following formula,

$$\% \text{ Coincidence} = \frac{(1.25 \times 10^{-7})(D^3)(n)}{\Upsilon} \qquad (24)$$

where:

D= aperture size in μm

n = number of counts

Υ = volume counted in μl

The corrected counts were each rounded to the nearest whole number, and the mean Artemia concentration per 2 ml plus or minus one standard deviation determined. This permitted an estimation of the approximate number of Artemia/ml present in the stock solution. The volume of stock solution required to yield grazing concentrations of approximately 15, 30, and 60 Artemia/ml in each of the grazing containers and controls was ascertained and subsequently added at the start of each experiment.

Post-grazing prey concentrations per ml in both the controls and grazing containers were determined in much the same way. At the end of the 24 hour grazing period, the entire contents of the controls and grazing containers was resieved with the 110 μm mesh sieve. The nauplii were washed off the screen and made to a volume of 500 ml according to the procedure outlined above. The 500 ml solutions derived from containers possessing initial densities of approximately 15 nauplii/ml were counted directly on the counter. Solutions from containers in which initial concentrations were approximately 30 and 60 Artemia/ml required dilutions in order to minimize coincidence. To accomplish this, 50 ml and 25 ml aliquots were removed and added to beakers containing 450 ml and 475 ml filtered sea water respectively, and counted on the counter. The counts obtained were again corrected for coincidence utilizing equation (24), and the mean concentration per ml calculated. A t-test was used to compare the pre- and post-grazing prey concentrations in both controls and individual grazing containers. The actual concentation values per ml obtained for each container per experiment are located in Appendix VII.

Appendix III

Methods of culturing and obtaining the necessary concentrations of the rotifer *Brachionus plicatilis*

Brachionus plicatilis starter cultures were originally obtained courtesy of Mr. Tom Leggett, Virginia Institute of Marine Science, in October 1978. The method of culture used here was modeled after one which he found to be simple yet effective. The rotifers were fed the green algae *Chlorella sp.* as food. This algae was obtained initially from Dr. John Dupuy, Virginia Institute of Marine Science, and was cultured independently in 20 liter glass carboys in the Department of Oceanography of Old Dominion University. Nineteen liter batch cultures of f/2 medium (based on medium "f" in Guillard and Ryther, 1962) plus soil extract were autoclaved and innoculated approximately every two weeks. Algal densities on the order of 10^7 cells/ml were achieved prior to withdrawing aliquots for rotifer feeding purposes. Sea water used throughout the culturing was 0.3 μm filtered sea water of 20°/oo salinity. The carboys were aerated continuously at room temperature. Illumination was provided by a 122 cm fluorescent lighting fixture suspended approximately 25-30 cm above the carboys on an 18 hour light:6 hour dark photoperiod.

The rotifers were cultured in two, 3.8-liter glass jars. Aeration was continuous and accomplished by inserting a long glass tube connected to an air supply to the bottom of the jars. Though continuous, aeration was not vigorous, but only sufficient to keep the contents in motion.

The seawater used throughout the rotifer culturing and counting procedures was 20°/oo, 0.3 μm filtered seawater. Cultures were maintained at room temperature and no strict lighting regime was followed. Illumination was provided by the natural overhead fluorescent laboratory lights. Water in the culture jars was changed daily and 500 ml of new Chlorella was added to each jar.

Both of the rotifer jars were handled identically, but on an alternating schedule. On any given day only one jar was harvested. After harvesting both jars were screened and fed. The following day the other jar was harvested. While harvesting occured on a daily basis, an individual jar was actually harvested only every other day.

Harvesting was accomplished by screening 750 ml of the 3000 ml rotifer/algal solution through a 53 μm fine mesh screen sieve. The sieve retained the rotifers while allowing the algal solution to pass through. The harvested rotifers were washed off the screen with filtered seawater into a 102 cm glass culture dish. If the harvest was not required for a grazing experiment, it was added to the maintenance aquarium. The remaining 2250 ml of culture was then screened with the 53 μm sieve. The culture jar was rinsed clean and 500 ml of new Chlorella culture added. The rotifers were washed from the sieve back into the jar and new filtered seawater added to bring the volume back to 3000 ml.

The second jar was handled in approximately the same manner except the entire contents were screened and fed 500 ml Chlorella. This method of culturing consistently yielded concentrations in the range of 200-250 rotifers/ml. On those occasions when rotifers were required for grazing experiments, harvest volumes were sometimes increased to insure adequate amounts. Any excess rotifers not necessary for the controls

or grazing containers were subsequently re-added to the culture jar.

When needed for experimental purposes, the rotifer harvest was rinsed from the 53 μm mesh sieve into a 250 ml graduated cylinder and made to a volume of 200 ml with filtered seawater. This solution was poured into a clean 600 ml beaker and an additional 300 ml of filtered sea water added to bring the volume to 500 ml. The concentration of Brachionus per ml in this stock beaker was determined by performing counts with a model ZB Coulter Particle Counter. A five ml aliquot of the stock solution was removed and added to a beaker containing 495 ml of filtered seawater. Eight to ten, 2-ml aliquots were counted using the 1000 μm aperture tube. Filtered seawater was used as a blank to correct for any possible impurities and/or electrical interference which might affect the counts. Each count obtained was corrected for the percent coincidence according to equation (24) presented in Appendix II. The corrected counts were rounded to the nearest whole number, and the mean rotifer concentration per 2 ml plus or minus one standard deviation determined. This permitted an estimation of the approximate number of rotifers present per ml in the stock solution. The volume of the stock solution required to yield pre-grazing prey concentrations of approximately 15, 30, and 60 rotifers/ml in each of the grazing containers and controls was ascertained and subsequently added at the start of each experiment.

Post-grazing prey concentrations per ml in both controls and grazing containers were determined in much the same way. At the end of the 24 hour grazing period the entire contents of the controls and grazing containers were reseieved with the 53 μm mesh sieve. The rotifers were washed off the screen and made to a volume of 500 ml according

to the procedure outlined above. The 500 ml solutions derived from containers possessing initial densities of 15 and 30 rotifers/ml were counted directly on the counter. Solutions from containers in which initial concentrations were approximately 60 rotifers/ml required dilutions in order to minimize coincidence. To accomplish this 100 ml aliquots were removed and added to beakers containing 400 ml of filtered seawater for counting. All counts obtained were again corrected for coincidence utilizing equation (24), and the mean concentrations per ml calculated. A t-test was used to compare the pre- and post-grazing prey concentrations in both controls and individual grazing containers. The actual values per ml obtained for each container per experiment are located in Appendix VII.

Appendix IV

Methods of culturing and obtaining the necessary concentrations of the diatom Coscinodiscus lineatus

Cultures of Coscinodiscus lineatus were maintained in the laboratory throughout experimentation. Batch cultures were grown in autoclaved 3.8 liter glass jugs of f/2 medium (based on medium "f" given in Guillard and Ryther, 1962). Illumination was supplied by a 122 cm fluorescent lighting fixture suspended 46-61 cm above the culture jugs on an 18 hour light:6 hour dark photoperiod. Cultures were continuously aerated at room temperature. Three glass tubes penetrated a rubber stopper inserted into the neck of the jugs. Two tubes were long and extended to the bottom of the container. One of these was connected to an air supply and the other one was utilized to withdraw samples. The third tube was relatively short and permitted air to vent at the top. The seawater used throughout the culturing and counting procedures was 20°/oo, 0.3 μm filtered. New batches of media were innoculated approximately every two weeks and cultures used for experimental purposes were 7-10 days old.

Coscinodiscus was originally isolated from a natural seawater sample taken approximately one-half mile west of the first island of the Chesapeake Bay Bridge Tunnel on 30 September, 1978. Single diatom cells were isolated by performing serial dilutions in filtered seawater. The cells were transferred through a series of 5 cm glass culture dishes containing filtered seawater utilizing glass capillary tubes (0.8-1.1 x 100 mm).

By placing a finger over the end of the capillary tube and inserting it into the culture dishes, then slowly releasing it, individual cells were drawn up. Extractions in this manner were performed while viewing the samples under a dissecting scope. A single diatom cell was placed in each of ten test tubes containing autoclaved f/2 medium and allowed to grow at room temperature. Cells from eight of the ten test tube cultures were transferred to 125 ml Erlenmeyer flasks containing autoclaved f/2 medium on 19 October, 1978. Aliquots of the test tubes were examined at this time under a high powered binocular microscope. All eight cultures were identified as being Coscinodiscus lineatus with the help of Ms. Karen Wark of Old Dominion University. These stock cultures were subsequently used to innoculate the 3.8 liter culture jugs and were periodically transferred to fresh f/2 media. Cultures used were unialgal but not necessarily bacteria free as no attempt was made to pre-filter the air entering the culture vessels.

Coscinodiscus was withdrawn from the jugs as needed for experimental purposes. A piece of tygon tubing, approximately 61 cm long, was connected to the long glass tube which protruded from the rubber stopper and extended to the bottom of the jug. Placing a finger over the vent tube increased the air pressure in the jug and forced samples out through the tube. Samples were dispensed into a 250 ml graduated cylinder, and a total of 500 ml was placed in a clean 600 ml beaker. Concentrations of Coscinodiscus per ml in this stock beaker were determined by performing counts on a Model ZB Coulter Particle Counter.

A ten ml aliquot of the stock solution was removed and added to a beaker containing 490 ml of filtered seawater. Eight to ten, two-ml aliquots were counted using a 400 μm aperture tube. Filtered seawater

was used as a blank to correct for any possible impurities and/or electrical interference which might affect the counts. The mean of five runs was subtracted from that obtained for each count. Each count was further corrected for the percent coincidence according to equation (24) presented in Appendix II. The corrected counts were rounded to the nearest whole number, and the mean diatom concentration plus or minus one standard deviation determined. This permitted an estimation of the approximate concentration of diatoms present per ml in the stock solution. The volume of stock solution required to yield pre-grazing concentrations of 500, 1500, and 3000 cells/ml in each of the grazing containers was ascertained and subsequently added at the start of each experiment.

Determinations of the post-grazing prey concentrations per ml in both controls and grazing containers differed somewhat. It was felt that sieving of the contents, as was done in experiments with Artemia and Brachionus, might lyse, damage, or otherwise destroy the integrity of the diatoms. To prevent this, the grazing containers were aspirated with the large bore 25 ml pipette to distribute the diatoms throughout the container. A ten ml aliquot was removed and added to a 100 ml beaker containing 90 ml of filtered seawater.

The diatom concentration per ml in these beakers was then determined by counting on the Coulter Counter according to the procedure previously mentioned. All counts obtained were again corrected for coincidence utilizing equation (24), and the mean concentrations per ml calculated. A t-test could not be used to compare the pre- and post-grazing prey concentrations in both controls and individual grazing containers due to the confounding factors of growth and grazing which occured during the period. The actual values per ml obtained for each container per experiment are located in Appendix VII.

Appendix V

Computer program utilized in the calculation of ingestion rates per experiment

```
C       CO=CELL CONCENTRATION AT T=0
C       SO=STANDARD DEVIATION ON CO
C       CT=CELL CONCENTRATION AT T=24
C       ST=STANDARD DEVIATION ON CT
C       K =GROWTH COEFFICIENT FOR DIATOM FOOD SOURCE
C       SK=STANDARD DEVIATION ON K
C       N =NUMBER OF MYSIDS ALIVE AT T=24
C       DW=DRY WEIGHT OF N MYSIDS
        DIMENSION SG(8),SC(32),SI(4)
        REAL I,K,N
10      TYPE 210
210     FORMAT(1X,///,'0INPUT CO,SO,CT,ST,K,SK,AND N OR DW')
        READ(5,*)CO,SO,CT,ST,K,SK,N
        T=24.0
        J=1
        G=((ALOG(CO)-ALOG(CT))+K*T)/T
        DO 100 I1=1,2
        ER1=SO/CO
        IF((I1/2)*2.EQ.I1)ER1=ER1*(-1)
        DO 100 I2=1,2
        ER2=ST/CT
        IF((I2/2)*2.EQ.I2)ER2=ER2*(-1)
        DO 100 I3=1,2
        ER3=SK*T
        IF((I3/2)*2.EQ.I3)ER3=ER3*(-1)
        SG(J)=(ALOG(1+ER1)-ALOG(1+ER2)+ER3)/T
        J=J+1
100     CONTINUE
        CALL SORT(SG,8,SGMAX,SGMIN)
        TYPE 220
220     FORMAT(1X,///,'0G,SGMAX,SGMIN')
        WRITE(5,*)G,SGMAX,SGMIN
        V=1000.0
        F=(G*V)/N
        SF1=(SGMAX*V)/N
        SF2=(SGMIN*V)/N
        TYPE 240
240     FORMAT(1X,///,'0F,SF1,SF2')
        WRITE(5,*)F,SF1,SF2
        C=(CO*(EXP(T*(K-G))-1))/(T*(K-G))
        J=1
        DO 300 I1=1,2
        ER1=SO
        IF((I1/2)*2.EQ.I1)ER1=ER1*(-1)
        DO 300 I2=1,2
        ER2=SK
        IF((I1/2)*2.EQ.I1)ER2=ER2*(-1)
```

Appendix V
continued

```
      DO 300 I3=1,2
      ER3=SGMAX
      IF((I1/2)*2.EQ.I1)ER3=SGMIN
      DO 300 I4=1,2
      ER4=SK
      IF((I4/2)*2.EQ.I4)ER4=ER4*(-1)
      DO 300 I5=1,2
      ER5=SGMAX
      IF((I5/2)*2.EQ.I5)ER5=SGMIN
      SC(J)=ER1*(EXP((ER2-ER3)*T)-1)/((ER4-ER5)*T)
      J=J+1
300   CONTINUE
      CALL SORT(SC,32,SCMAX,SCMIN)
      TYPE 250
250   FORMAT(1X,///,'0C,SCMAX,SCMIN')
      WRITE(5,*)C,SCMAX,SCMIN
      I=F*C
      SI(1)=SF1*SCMAX
      SI(2)=SF1*SCMIN
      SI(3)=SF2*SCMAX
      SI(4)=SF2*SCMIN
      CALL SORT(SI,4,SIMAX,SIMIN)
      TYPE 270
270   FORMAT(1X,///,'0I,SIMAX,SIMIN')
      WRITE(5,*)I,SIMAX,SIMIN
      GO TO 10
      STOP
      END
      SUBROUTINE SORT(S,N1,SMAX,SMIN)
      DIMENSION S(N1)
      SMAX=S(1)
      SMIN=S(1)
      DO 100 I=2,N1
      B=S(I)
      SMAX=AMAX1(SMAX,B)
      SMIN=AMIN1(SMIN,B)
100   CONTINUE
      RETURN
      END
```

Appendix VI

Computer program utilized in the calculation of assimilation rates per experiment

```
C       U =PERCENT ASSIMILATION
C       US=STANDARD DEVIATION ON U
C       F =ASH FREE DRY WEIGHT:DRY WEIGHT RATIO OF FOOD SOURCE
C       FS=STANDARD DEVIATION ON F
C       E =ASH FREE DRY WEIGHT:DRY WEIGHT RATIO OF FECAL MATERIAL
C       ES=STANDARD DEVIATION ON E
        DIMENSION US(16)
10      TYPE 200
200     FORMAT(1X,///,1X,'INPUT F,FS,E,ES')
        READ(5,*) F,FS,E,ES
        U=((F-E)/((1-E)*F))*100
        J=1
        DO 100 I=1,2
        FS1=FS
        IF((I/2)*2.EQ.I) FS1=FS*(-1)
        DO 100 I2=1,2
        ES1=ES
        IF((I2/2)*2.EQ.I2)  ES1=ES*(-1)
        DO 100 I3=1,2
        ES2=ES
        IF((I3/2)*2.EQ.I3)  ES2=ES*(-1)
        DO 100 I4=1,2
        FS2=FS
        IF((I4/2)*2.EQ.I4) FS2=FS*(-1)
        US(J)=(((F+FS1)-(E+ES1))/((1.-(E+ES2))*(F+FS2)))*100
        J=J+1
100     CONTINUE
        WRITE(5,*)US
        CALL SORT (US,J,USMAX,USMIN)
        TYPE 210
210     FORMAT(1X,///,1X,'U,USMAX,USMIN')
        WRITE(5,*)U,USMAX,USMIN
        GO TO 10
        STOP
        END
        SUBROUTINE SORT (US,N,USMAX,USMIN)
        DIMENSION US(16)
        USMAX=US(1)
        USMIN=US(1)
        DO 100 I=2,N
        B=US(I)
        USMAX=AMAX1(USMAX,B)
        USMIN=AMIN1(USMIN,B)
100     CONTINUE
        RETURN
        END
```

Appendix VII. Experimental data for juvenile size class fed three concentrations of Artemia salina.

	C- 7-7	C- 7-8	J- 7-1	J- 7-2	J- 7-3	J- 7-4	J- 7-5	J- 7-6
Initial Food Conc.								
(CO)	22.3*	22.3*	15.1*	15.1*	30.1*	30.1*	60.2*	60.2*
(±SO)	8.2	8.2	4.4	4.4	8.8	8.8	17.5	17.5
Final Food Conc.								
(CT)	19.3*	21.0*	12.0*	12.8*	24.0*	22.8*	47.5*	47.3*
(±ST)	5.0	3.8	5.6	6.8	9.3	8.6	9.8	9.2
Mysids alive at t=24								
(N)	-	-	9	7	7	9	10	10
(DW)	-	-	0.00055	0.00043	0.00043	0.00055	0.00062	0.00062
Growth Coefficient, K								
(K)	0	0						
(±SK)								
$(\bar{K})$								
$(\pm S\bar{K})$								
Grazing Coefficient, G								
(G)								
(SG Max)								
(SG Min)								
Filtration Rate, F								
(F)								
(SF Max)								
(SF Min)								
Average Prey Conc., C								
(C)								
(SC Max)								
(SC Min)								
Ingestion Rate, I								
(I)								
(SI Max)								
(SI Min)								
Ingestion Rate, I'								
(I')								
(SI' Max)								
(SI' Min)								

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for juvenile size class fed three concentrations of *Brachionus plicatilis*.

	C- 8-7	C- 8-8	J- 8-1	J- 8-2	J- 8-3	J- 8-4	J- 8-5	J- 8-6
Initial Food Conc.								
(CO)	28.0*	28.0*	14.0	14.0	28.0	28.0	56.0	56.0
(±SO)	5.6	5.6	2.8	2.8	5.6	5.6	11.3	11.3
Final Food Conc.								
(CT)	29.0*	27.0*	8.3	10.3	22.2	20.5	41.7	40.4
(±ST)	4.4	5.2	1.8	1.3	5.2	2.2	6.9	6.4
Mysids alive t=24								
(N)	-	-	7	8	8	7	9	7
(DW)	-	-	0.00043	0.00049	0.00049	0.00043	0.00055	0.00043
Growth Coefficient, K								
(K)	0	0						
(±SK)								
($\bar{K}$)			0	0	0	0	0	0
(±S$\bar{K}$)								
Grazing Coefficient, G								
(G)			0.022	0.013	0.010	0.013	0.012	0.014
(SG Max)			0.018	0.013	0.019	0.012	0.015	0.015
(SG Min)			0.017	0.014	0.018	0.014	0.016	0.016
Filtration Rate, F								
(F)			3.1	1.6	1.2	1.9	1.4	1.9
(SF Max)			2.5	1.7	2.3	1.8	1.7	2.1
(SF Min)			2.5	1.8	2.3	1.9	1.8	2.2
Average Prey Conc., C								
(C)			10.9	12.1	25.0	24.1	48.5	47.8
(SC Max)			3.4	3.6	6.8	7.3	14.3	14.3
(SC Min)			3.5	3.3	7.0	6.6	13.7	13.7
Ingestion Rate, I								
(I)			33.9	19.3	30.2	44.6	66.2	92.9
(SI Max)			8.7	5.9	15.8	12.8	24.1	30.4
(SI Min)			8.8	6.4	16.4	14.1	25.0	31.7
Ingestion Rate, I'								
(I')			5.5×10^{5}	3.1×10^{5}	4.9×10^{5}	7.3×10^{5}	1.1×10^{6}	1.5×10^{6}
(SI' Max)			1.4×10^{5}	9.7×10^{4}	2.6×10^{5}	2.1×10^{5}	3.9×10^{5}	4.9×10^{5}
(SI' Min)			1.4×10^{5}	1.0×10^{5}	2.7×10^{5}	2.3×10^{5}	4.1×10^{5}	5.2×10^{5}

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for juvenile size class fed three concentrations of Coscinodiscus lineatus.

	C- 9-7	C- 9-8	J- 9-1	J- 9-2	J- 9-3	J- 9-4	J- 9-5	J- 9-6
Initial Food Conc.								
(CO)	494.6	494.6	494.6	494.6	1494.5	1494.5	2905.7	2993.9
(±SO)	31.2	31.2	31.2	31.2	101.7	101.7	187.8	115.4
Final Food Conc.								
(CT)	707.5	769.0	614.0	695.5	2171.0	2141.5	4084.0	4420.2
(±ST)	45.4	39.1	74.3	74.1	71.1	116.6	112.5	193.0
Mysids alive t=24								
(N)	-	-	10	8	10	8	9	10
(DW)	-	-	0.00062	0.00049	0.00062	0.00049	0.00055	0.00062
Growth Coefficient, K								
(K)	0.015	0.018						
(±SK)	0.005	0.005						
$(\bar{K})$			0.017	0.017	0.017	0.017	0.017	0.017
$(\pm S\bar{K})$			0.004	0.004	0.004	0.004	0.004	0.004
Grazing Coefficient, G								
(G)			0.008	0.003	0.001	0.002	0.003	0.001
(SG Max)			0.012	0.011	0.008	0.009	0.008	0.007
(SG Min)			0.011	0.011	0.008	0.009	0.008	0.007
Filtration Rate, F								
(F)			0.8	0.3	0.1	0.3	0.3	0.1
(SF Max)			1.2	1.4	0.8	1.1	0.9	0.7
(SF Min)			1.1	1.4	0.8	1.1	0.9	0.7
Average Prey Conc., C								
(C)			552.1	589.4	1811.7	1798.6	3461.5	3664.4
(SC Max)			32.2	32.5	111.0	109.7	204.4	119.7
(SC Min)			34.2	33.9	107.1	108.2	196.9	120.3
Ingestion Rate, I								
(I)			441.2	206.0	261.2	452.3	1083.3	253.2
(SI Max)			39.2	46.4	90.2	124.5	176.5	89.2
(SI Min)			40.7	47.7	91.9	125.4	179.8	89.4
Ingestion Rate, I'								
(I')			7.2×10^6	3.3×10^6_5	4.2×10^6	7.4×10^6	1.8×10^7_6	4.1×10^6
(SI' Max)			6.4×10^5	7.5×10^5	1.5×10^6	2.0×10^6	2.9×10^6	1.5×10^6
(SI' Min)			6.6×10^5	7.8×10^5	1.5×10^6	2.0×10^6	2.9×10^6	1.5×10^6

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for immature size class fed three concentrations of Coscinodiscus lineatus.

	C-12-7	C-12-8	I-12-1	I-12-2	I-12-3	I-12-4	I-12-5	I-12-6
Initial Food Conc.								
(CO)	491.6	491.6	491.6	491.6	1481.5	1481.5	2980.3	3010.5
(±SO)	37.6	37.6	37.6	37.6	117.2	117.2	112.6	180.3
Final Food Conc.								
(CT)	578.1	568.0	467.0	468.5	1386.0	1367.5	2994.0	2590.5
(±ST)	54.8	41.8	30.8	55.1	35.4	84.3	146.3	144.2
Mysids alive t=24								
(N)	-	-	10	10	9	10	10	10
(DW)	-	-	0.0020	0.0020	0.0018	0.0020	0.0020	0.0020
Growth Coefficient, K								
(K)	0.007	0.006						
(±SK)	0.007	0.006						
($\bar{K}$)			0.006	0.006	0.006	0.006	0.006	0.006
(±$S\bar{K}$)			0.005	0.005	0.005	0.005	0.005	0.005
Grazing Coefficient, G								
(G)			0.008	0.008	0.009	0.009	0.006	0.012
(SG Max)			0.011	0.013	0.009	0.011	0.009	0.010
(SG Min)			0.011	0.013	0.009	0.011	0.009	0.010
Filtration Rate, F								
(F)			0.8	0.9	0.9	0.9	0.6	1.2
(SF Max)			1.1	1.5	0.9	1.1	0.9	1.0
(SF Min)			1.1	1.4	0.9	1.1	0.9	1.0
Average Prey Conc., C								
(C)			479.2	480.0	1433.2	1423.7	2987.1	2795.2
(SC Max)			40.4	39.9	130.6	128.2	116.3	192.0
(SC Min)			40.4	41.4	123.7	125.9	117.6	191.2
Ingestion Rate, I								
(I)			390.0	426.9	1257.8	1329.2	1735.2	3427.1
(SI Max)			44.6	59.6	120.8	138.7	101.1	188.3
(SI Min)			44.9	61.1	123.8	140.0	101.5	188.7
Ingestion Rate, I'								
(I')			$2.0 \times 10^{6}_{5}$	$2.1 \times 10^{6}_{5}$	$6.3 \times 10^{6}_{5}$	$6.6 \times 10^{6}_{5}$	$8.7 \times 10^{6}_{5}$	$1.7 \times 10^{7}_{5}$
(SI' Max)			2.3×10^{5}	3.0×10^{5}	6.0×10^{5}	6.9×10^{5}	5.1×10^{5}	9.4×10^{5}
(SI' Min)			2.2×10	3.1×10	6.2×10	7.0×10	5.1×10	9.4×10

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for immature size class fed three concentrations of Brachionus plicatilis.

	C-13-7	C-13-8	I-13-1	I-13-2	I-13-3	I-13-4	I-13-5	I-13-6
Initial Food Conc.								
(CO)	14.9*	14.9*	14.9	14.9	29.8	29.8	59.7	59.7
(±SO)	3.4	3.4	3.4	3.4	6.8	6.8	13.5	13.5
Final Food Conc.								
(CT)	13.6*	12.7*	10.8	8.9	23.4	23.2	45.0	45.5
(±ST)	1.7	1.9	2.2	1.6	2.6	2.0	7.4	10.9
Mysids alive t=24								
(N)	-	-	10	10	9	10	10	9
(DW)	-	-	0.0020	0.0020	0.0018	0.0020	0.0020	0.0018
Growth Coefficient, K								
(K)	0	0						
(±SK)								
($\bar{K}$)			0	0	0	0	0	0
(±S$\bar{K}$)								
Grazing Coefficient, G								
(G)			0.013	0.021	0.010	0.010	0.012	0.011
(SG Max)			0.018	0.017	0.013	0.012	0.016	0.020
(SG Min)			0.019	0.018	0.015	0.014	0.017	0.020
Filtration Rate, F								
(F)			1.4	2.1	1.1	1.0	1.2	1.3
(SF Max)			1.8	1.7	1.5	1.2	1.6	2.2
(SF Min)			1.9	1.8	1.7	1.4	1.7	2.2
Average Prey Conc., C								
(C)			12.7	11.6	26.5	26.4	52.0	52.3
(SC Max)			4.4	4.5	9.2	9.4	17.8	17.0
(SC Min)			4.3	4.2	8.2	8.1	16.7	17.2
Ingestion Rate, I								
(I)			17.1	25.0	29.6	27.5	61.3	65.7
(SI Max)			7.9	7.5	13.8	11.5	28.4	37.6
(SI Min)			8.1	7.9	15.6	13.3	30.2	38.1
Ingestion Rate, I'								
(I')			8.5×10^{4}	1.3×10^{5}	1.5×10^{5}	1.4×10^{5}	3.1×10^{5}	3.3×10^{5}
(SI' Max)			4.0×10^{4}	3.7×10^{4}	6.9×10^{4}	5.8×10^{4}	1.4×10^{5}	1.9×10^{5}
(SI' Min)			4.1×10^{4}	3.9×10^{4}	7.8×10^{4}	6.7×10^{4}	1.5×10^{5}	1.9×10^{5}

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for immature size class fed three concentrations of *Artemia salina*

	C-14-7	C-14-8	I-14-1	I-14-2	I-14-3	I-14-4	I-14-5	I-14-6
Initial Food Conc.								
(CO)	10.1*	10.1*	10.1	10.1	29.8	29.8	59.6*	59.6*
(±SO)	2.1	2.1	2.1	2.1	6.3	6.3	12.6	12.6
Final Food Conc.								
(CT)	9.3*	9.5*	7.5	8.2	20.5	22.5	50.0*	55.6*
(±ST)	2.9	1.1	1.5	1.5	3.9	4.6	15.6	16.1
Mysida alive t=24								
(N)	-	-	10	10	9	9	7	10
(DW)	-	-	0.0020	0.0020	0.0018	0.0018	0.0014	0.0020
Growth Coefficient, K								
(K)	0	0						
(±SK)								
($\bar{K}$)			0	0	0	0	0	0
(±S$\bar{K}$)								
Grazing Coefficient, G								
(G)			0.012	0.019	0.016	0.012	-	-
(SG Max)			0.017	0.016	0.017	0.018		
(SG Min)			0.017	0.017	0.017	0.018		
Filtration Rate, F								
(F)			1.2	0.9	1.7	1.3	-	-
(SF Max)			1.7	1.6	1.9	1.9		
(SF Min)			1.7	1.7	1.9	2.0		
Average Prey Conc., C								
(C)			8.7	9.1	24.9	26.0	-	-
(SC Max)			2.6	2.7	8.0	7.9		
(SC Min)			2.6	2.6	7.8	7.8		
Ingestion Rate, I								
(I)			10.8	7.9	43.1	33.8	-	-
(SI Max)			4.5	4.3	14.9	15.4		
(SI Min)			4.5	4.3	15.2	15.5		
Ingestion Rate, I'								
(I')			5.4×10^4	4.0×10^4	2.2×10^5	1.7×10^5	-	-
(SI' Max)			2.3×10^4	2.2×10^4	7.4×10^4	7.7×10^4		
(SI' Min)			2.3×10	2.2×10	7.6×10^4	7.7×10^4		

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for adult/ovigerous females fed three concentrations of Coscinodiscus lineatus.

	C-15-7	C-15-8	F-15-1	F-15-2	F-15-3	F-15-4	F-15-5	F-15-6
Initial Food Conc.								
(CO)	1002.3	1002.3	531.0	531.0	1496.5	1496.5	2906.5	3111.1
(±SO)	64.0	64.0	18.3	18.3	51.5	51.5	185.6	147.3
Final Food Conc.								
(CT)	1241.3	1270.0	285.6	332.5	1409.3	1335.0	3105.0	2961.3
(±ST)	73.7	72.3	44.2	44.0	71.3	98.1	97.7	146.7
Mysids alive t=24								
(N)	-	-	10	9	10	10	9	10
(DW)	-	-	0.0114	0.0102	0.0114	0.0114	0.0102	0.0114
Growth Coefficient, K								
(K)	0.009	0.010						
(±SK)	0.005	0.005						
($\bar{K}$)			0.009	0.009	0.009	0.009	0.009	0.009
(±S$\bar{K}$)			0.004	0.004	0.004	0.004	0.004	0.004
Grazing Coefficient, G								
(G)			0.035	0.029	0.012	0.014	0.006	0.011
(SG Max)			0.012	0.011	0.008	0.009	0.008	0.008
(SG Min)			0.011	0.011	0.008	0.008	0.008	0.008
Filtration Rate, F								
(F)			3.5	3.2	1.2	1.4	0.7	1.1
(SF Max)			1.2	1.3	0.8	0.9	0.9	0.8
(SF Min)			1.1	1.2	0.8	0.8	0.9	0.8
Average Prey Conc., C								
(C)			395.7	424.0	1452.5	1414.2	3004.7	3035.6
(SC Max)			17.8	18.0	52.9	52.2	201.3	154.3
(SC Min)			20.0	19.8	53.7	54.3	194.9	154.7
Ingestion Rate, I								
(I)			1378.6	1343.0	1670.6	1945.7	2085.7	3356.2
(SI Max)			23.0	23.5	40.4	45.7	177.0	124.3
(SI Min)			24.9	25.0	40.7	46.7	179.9	124.4
Ingestion Rate, I'								
(I')			1.2×10^{6}	1.2×10^{6}	1.5×10^{6}	1.7×10^{6}	1.8×10^{6}	3.0×10^{6}
(SI' Max)			2.0×10^{4}	2.1×10^{4}	3.6×10^{4}	4.0×10^{4}	1.6×10^{5}	1.1×10^{5}
(SI' Min)			2.2×10^{4}	2.2×10^{4}	3.6×10	4.1×10	1.6×10^{5}	1.1×10^{5}

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for adult/ovigerous females fed three concentrations of *Brachionus plicatilis*.

	C-16-7	C-16-8	F-16-1	F-16-2	F-16-3	F-16-4	F-16-5	F-16-6
Initial Food Conc.								
(CO)	30.6*	30.6*	15.3	15.3	30.6	30.6	61.1	61.1
(±SO)	5.1	5.1	2.6	2.6	5.1	5.1	10.1	10.1
Final Food Conc.								
(CT)	31.7*	31.4*	5.6	3.7	15.1	14.4	35.6	38.3
(±ST)	3.3	2.4	1.2	0.8	1.4	2.2	7.4	5.7
Mysids alive t=24								
(N)	-	-	9	9	8	10	10	10
(DW)	-	-	0.0102	0.0102	0.0091	0.0014	0.0014	0.0014
Growth Coefficient, K								
(K)	0	0						
(±SK)								
($\bar{K}$)			0	0	0	0	0	0
(±S$\bar{K}$)								
Grazing Coefficient, G								
(G)			0.042	0.059	0.029	0.031	0.023	0.019
(SG Max)			0.017	0.017	0.010	0.013	0.016	0.013
(SG Min)			0.016	0.016	0.011	0.014	0.015	0.013
Filtration Rate, F								
(F)			4.7	6.6	3.7	3.1	2.3	1.9
(SF Max)			1.8	1.9	1.3	1.3	1.6	1.3
(SF Min)			1.8	1.8	1.4	1.4	1.5	1.3
Average Prey Conc,, C								
(C)			9.7	8.2	21.9	21.5	47.2	48.8
(SC Max)			3.0	3.0	6.3	6.1	11.7	12.1
(SC Min)			3.2	3.2	5.9	6.0	12.2	11.9
Ingestion Rate, I								
(I)			44.9	53.7	80.7	67.5	106.3	95.0
(SI Max)			5.6	5.6	8.3	8.1	18.8	15.8
(SI Min)			5.8	5.9	8.9	8.3	19.7	16.1
Ingestion Rate, I'								
(I')			$4.0 \times 10^{4}_{3}$	$4.7 \times 10^{4}_{3}$	$7.1 \times 10^{4}_{3}$	$5.9 \times 10^{4}_{3}$	9.4×10^{4}	8.4×10^{4}
(SI' Max)			$4.9 \times 10_{3}$	4.9×10^{3}	7.3×10^{3}	7.2×10^{3}	1.7×10^{4}	1.4×10^{4}
(SI' Min)			5.1×10^{3}	5.2×10^{3}	7.9×10^{3}	7.3×10^{3}	1.7×10^{4}	1.4×10^{4}

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for adult males fed three concentrations of Artemia salina.

	C-18-7	C-18-8	M-18-1	M-18-2	M-18-3	M-18-4	M-18-5	M-18-6
Initial Food Conc.								
(CO)	30.7*	30.7*	10.6	10.6	30.7	30.7	61.3	61.3
(±SO)	5.9	5.9	2.1	2.1	5.9	5.9	11.9	11.9
Final Food Conc.								
(CT)	29.2*	30.8*	6.1	7.4	22.8	21.4	52.0	51.8
(±ST)	6.6	5.5	1.1	1.5	4.1	4.1	5.9	5.9
Mysids alive at t=24								
(N)	-	-	10	10	10	10	10	10
(DW)	-	-	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102
Growth Coefficient, K								
(K)	0	0						
(±SK)								
$(\bar{K})$			0	0	0	0	0	0
$(\pm S\bar{K})$								
Grazing Coefficient, G								
(G)			0.023	0.015	0.012	0.015	0.007	0.007
(SG Max)			0.016	0.017	0.016	0.016	0.012	0.012
(SG Min)			0.016	0.017	0.016	0.016	0.013	0.013
Filtration Rate, F								
(F)			2.3	1.5	1.2	1.5	0.7	0.7
(SF Max)			1.6	1.7	1.6	1.6	1.2	1.2
(SF Min)			1.6	1.7	1.6	1.6	1.3	1.3
Average Prey Conc., C								
(C)			8.1	8.9	26.6	25.8	56.5	56.4
(SC Max)			2.6	2.6	7.3	7.2	15.2	15.2
(SC Min)			2.6	2.6	7.2	7.2	14.0	14.1
Ingestion Rate, I								
(I)			18.8	13.3	32.9	38.8	38.8	39.6
(SI Max)			4.1	4.4	11.3	11.7	18.9	19.0
(SI Min)			4.2	4.4	11.5	11.7	20.5	20.6
Ingestion Rate, I'								
(I')			1.8×10^{4}	1.3×10^{4}	3.2×10^{4}	3.8×10^{4}	3.8×10^{4}	3.9×10^{4}
(SI' Max)			4.0×10^{3}	4.3×10^{3}	1.1×10^{4}	1.1×10^{4}	1.9×10^{4}	1.9×10^{4}
(SI' Min)			4.1×10^{3}	4.3×10^{3}	1.1×10^{4}	1.1×10^{4}	2.0×10^{4}	2.0×10^{4}

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for adult males fed three concentrations of Brachionus plicatilis.

	C-20-7	C-20-8	M-20-1	M-20-2	M-20-3	M-20-4	M-20-5	M-20-6
Initial Food Conc.								
(CO)	30.5*	30.5*	15.2	15.2	30.5	30.5	60.2	60.2
(±SO)	5.6	5.6	2.8	2.8	5.6	5.6	11.1	11.1
Final Food Conc.								
(CT)	28.1*	27.8*	5.4	3.1	11.5	11.0	36.7	42.1
(±ST)	5.2	3.8	1.4	0.8	3.1	1.7	4.7	6.4
Mysids alive at t=24								
(N)	-	-	8	10	9	9	10	9
(DW)	-	-	0.0082	0.0102	0.0092	0.0092	0.0102	0.0092
Growth Coefficient, K								
(K)	0	0						
(±SK)								
($\bar{K}$)			0	0	0	0	0	0
(±S$\bar{K}$)								
Grazing Coefficient, G								
(G)			0.043	0.066	0.041	0.042	0.021	0.015
(SG Max)			0.020	0.019	0.020	0.014	0.013	0.014
(SG Min)			0.018	0.018	0.018	0.014	0.014	0.014
Filtration Rate, F								
(F)			5.4	6.6	4.5	4.7	2.1	1.7
(SF Max)			2.4	1.9	2.2	1.6	1.3	1.5
(SF Min)			2.3	1.8	2.0	1.6	1.4	1.6
Average Prey Conc., C								
(C)			9.5	7.6	19.5	19.1	47.5	50.6
(SC Max)			3.2	3.2	6.4	6.9	13.9	13.7
(SC Min)			3.5	3.5	7.0	6.7	13.1	13.3
Ingestion Rate, I								
(I)			51.0	50.4	88.0	90.3	97.9	83.8
(SI Max)			7.9	6.3	14.4	10.7	17.7	21.2
(SI Min)			8.6	6.8	15.7	11.1	18.8	21.9
Ingestion Rate, I'								
(I')			$5.0 \times 10^{4}_{3}$	$4.9 \times 10^{4}_{3}$	$8.6 \times 10^{4}_{4}$	$8.9 \times 10^{4}_{4}$	$9.6 \times 10^{4}_{4}$	$8.2 \times 10^{4}_{4}$
(SI' Max)			7.8×10^{3}	6.2×10^{3}	1.4×10^{4}	1.1×10^{4}	1.7×10^{4}	2.1×10^{4}
(SI' Min)			8.4×10^{3}	6.7×10^{3}	1.5×10^{4}	1.1×10	1.8×10^{4}	2.1×10^{4}

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for adult males fed three concentrations of Coscinodiscus lineatus.

	C-21-7	C-21-8	M-21-1	M-21-2	M-21-3	M-21-4	M-21-5	M-21-6
Initial Food Conc.								
(CO)	1470.0	1470.0	505.7	505.7	1535.1	1535.1	3132.0	3076.9
(±SO)	104.9	104.9	38.8	38.8	117.7	117.7	243.9	282.2
Final Food Conc.								
(CT)	2344.3	2218.5	495.7	471.4	1687.1	1674.3	3499.3	3481.4
(±ST)	107.5	98.3	80.4	36.4	76.0	103.2	97.2	81.7
Mysids alive at t=24								
(N)	-	-	9	10	9	9	9	10
(DW)	-	-	0.0092	0.0102	0.0092	0.0092	0.0092	0.0102
Growth Coefficient, K								
(K)	0.019	0.017						
(±SK)	0.005	0.005						
($\bar{K}$)			0.018	0.018	0.018	0.018	0.018	0.018
(±$\bar{SK}$)			0.004	0.004	0.004	0.004	0.004	0.004
Grazing Coefficient, G								
(G)			0.019	0.021	0.014	0.014	0.013	0.013
(SG Max)			0.014	0.010	0.009	0.010	0.008	0.009
(SG Min)			0.014	0.010	0.009	0.010	0.009	0.009
Filtration Rate, F								
(F)			2.1	2.1	1.6	1.6	1.5	1.3
(SF Max)			1.6	1.0	1.0	1.1	0.9	0.9
(SF Min)			1.5	1.0	1.0	1.1	0.9	0.9
Average Prey Conc., C								
(C)			500.7	488.3	1603.7	1603.7	3312.3	3275.0
(SC Max)			40.0	41.9	129.3	128.2	270.9	321.0
(SC Min)			43.6	42.0	125.3	126.3	257.6	299.8
Ingestion Rate, I								
(I)			1047.7	1021.9	2516.1	2562.9	4924.0	4209.6
(SI Max)			65.9	43.9	129.3	138.6	249.8	277.5
(SI Min)			70.1	43.9	131.6	139.9	256.4	288.1
Ingestion Rate, I'								
(I')			$1.0x10^6$	$1.0x10^6$	$2.5x10^6$	$2.5x10^6$	$4.8x10^6$	$4.1x10^6$
(SI' Max)			$6.5x10^4$	$4.3x10^4$	$1.3x10^5$	$1.4x10^5$	$2.4x10^5$	$2.7x10^5$
(SI' Min)			$6.9x10^4$	$4.3x10^4$	$1.3x10^5$	$1.4x10^5$	$2.5x10^5$	$2.8x10^5$

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)

Appendix VII. Experimental data for adult/ovigerous females fed three concentrations of Artemia salina.

	C-23-7	C-23-8	F-23-1	F-23-2	F-23-3	F-23-4	F-23-5	F-23-6
Initial Food Conc.								
(CO)	29.8*	29.8*	10.4	10.4	30.8	30.8	60.8	60.8
(±SO)	7.8	7.8	1.9	1.9	5.5	5.5	10.8	10.8
Final Food Conc.								
(CT)	29.9*	31.1*	8.9	8.7	25.6	26.2	51.8	52.1
(±ST)	2.7	4.4	1.2	1.3	3.6	3.0	7.1	3.9
Mysids alive t=24								
(N)	-	-	10	10	9	10	10	10
(DW)	-	-	0.0114	0.0114	0.0102	0.0114	0.0114	0.0114
Growth Coefficient, K								
(K)	0	0						
(±SK)								
$(\bar{K})$			0	0	0	0	0	0
$(\pm S\bar{K})$								
Grazing Coefficient, G								
(G)			0.006	0.007	0.008	0.007	0.007	0.006
(SG Max)			0.013	0.014	0.013	0.012	0.013	0.010
(SG Min)			0.014	0.014	0.014	0.013	0.014	0.011
Filtration Rate, F								
(F)			0.6	0.7	0.9	0.7	0.7	0.6
(SF Max)			1.3	1.4	1.5	1.2	1.3	1.0
(SF Min)			1.4	1.4	1.5	1.3	1.4	1.1
Average Prey Conc., C								
(C)			9.6	9.5	28.1	28.4	56.2	56.3
(SC Max)			2.4	2.3	6.8	6.9	13.3	13.7
(SC Min)			2.2	2.3	6.5	6.4	12.8	12.4
Ingestion Rate, I								
(I)			6.2	7.1	24.1	19.2	37.5	36.3
(SI Max)			3.1	3.2	9.9	8.2	17.2	13.8
(SI Min)			3.2	3.3	10.3	8.7	17.9	15.3
Ingestion Rate, I'								
(I')			5.5×10^{3}	6.2×10^{3}	2.1×10^{4}	1.7×10^{4}	3.3×10^{4}	3.2×10^{4}
(SI' Max)			2.7×10^{3}	2.8×10^{3}	8.7×10^{3}	7.2×10^{3}	1.5×10^{4}	1.2×10^{4}
(SI' Min)			2.8×10^{3}	2.9×10^{3}	9.1×10^{3}	7.7×10^{3}	1.6×10^{4}	1.4×10^{4}

* - Indicates no significant difference in the pre- and post-grazing prey concentrations ($\alpha = 0.05$)