Phytoplankton Primary Production and Fish Community Structure in New Bedford Harbor: A Comparison Study to Evaluate Human Impacts

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PHYTOPLANKTON PRIMARY PRODUCTION AND FISH COMMUNITY STRUCTURE IN NEW BEDFORD HARBOR: A COMPARISON STUDY TO EVALUATE HUMAN IMPACTS

BY

ERICA LOUISE ABSHER-MITCHELL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
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OF

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DEAN OF THE GRADUATE SCHOOL

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ABSTRACT

This study fulfilled a portion of an ongoing program at the Environmental Protection Agency (Narragansett, RI) to examine cumulative human impacts in New Bedford Harbor, Massachusetts. One of the many changes New Bedford Harbor has experienced since the 1600s has been an increasing urban population along with an increased volume of poorly treated wastewater and combined sewer overflows. In addition to the threat of increased production and anoxia of harbor waters, industrial toxic wastes deposited in the harbor over the last three to four decades have raised concern for the health of estuarine inhabitants. These toxic wastes include the industrial discharge of polychlorinated biphenyls from electrical component manufacturing plants, and the discharge of heavy metals into the Acushnet River, the primary tributary into the harbor.

The Environmental Protection Agency has approached the problem by examining anthropogenic impacts on various ecosystem components. A relatively pristine estuary, the Slocums River, Massachusetts, was selected to compare parameters which may indicate differences in the state of estuarine health between the two sites. The objects of this portion of the study was to examine differences in rates of phytoplankton primary production between the two sites to detect eutrophication in New Bedford Harbor. This was measured by performing in situ incubations for production and respiration of oxygen over the summer of 1994. The top trophic consumers, estuarine fish, were also studied at both sites to examine differences in fish biomass,
abundance and diversity. Beach seining was performed at stations in both sites bimonthly in the summer of 1994 and monthly from October 1994 to May 1995. Two indices, which reflect water quality, were applied to water column parameters measured at both sites. The Estuarine Biotic Integrity index (EBI) which evaluates the quality of habitat to support estuarine fish was employed at both sites.

Average phytoplankton primary production over the summer of 1994 was higher in New Bedford Harbor, 0.61 +/- 0.16 (standard deviation) g O$_2$ m$^{-2}$ hr$^{-1}$, when compared to the average production rate in the Slocums River, g O$_2$ (standard deviation) m$^{-2}$ hr$^{-1}$. Phytoplankton biomass, measured as chlorophyll a, was significantly higher in New Bedford Harbor. The higher phytoplankton production rates in New Bedford Harbor suggest that the harbor was eutrophied, in comparison to the Slocums River. However, production from macrophytes needs to be accounted for in future studies. The eutrophication index indicated that neither estuary was eutrophied, and that a strong difference in water quality did not exist. The second index indicated that habitat was suitable for growth of submersed aquatic vegetation (SAV) in the Slocums River, but not all New Bedford stations met criteria for growth of SAV.

Higher fish biomass and abundance was evident in New Bedford Harbor where 32,027 individuals with a dry-weight biomass of 13,863 g were collected. In the Slocums River, 20,864 individuals with a dry-weight biomass of 7,710 g were collected over the study period. However, diversity was
higher in the Slocums River where the Shannon-Wiener index was 0.541 compared to 0.329 in New Bedford Harbor during the summer months. Summertime growth rates of Menidia species and Fundulus majalis were higher in New Bedford Harbor. Higher phytoplankton production resulting from urbanization of the New Bedford area may be the cause of higher fish biomass and higher growth rates of Menidia, the dominant species. Production rates do not appear to be too high to cause fish mortality from anoxia. The higher diversity in the Slocums River is likely due to a higher distribution of Spartina marsh sites. The decreased extent of marsh areas in New Bedford Harbor may be due to human impact due to extensive filling of marsh areas since the late 1700s. The Estuarine Biotic Integrity index (EBI) was applied to the marsh and beach habitats of both systems. The index showed that all stations in both systems have poor quality of habitat when compared to the eelgrass habitats of Waquoit Bay and Buttermilk Bay, Massachusetts.
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PREFACE

This thesis has been prepared according to the manuscript format and contains two papers. The first paper discusses phytoplankton primary production and in situ nutrient concentrations in New Bedford Harbor, and is prepared for submission to *Estuaries*. The second paper examines density, biomass and community structure of estuarine fish in New Bedford Harbor, and is prepared for submission to *Estuaries*.
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ABSTRACT

New Bedford Harbor, located in Massachusetts, has been subjected to human activity, including industrial discharges, in the last century. In this study, a comparison of phytoplankton primary production in the harbor, combined with historical data, was conducted to assess the impact of industrial discharges.

Significant differences were found in phytoplankton primary production between inorganic nitrogen and phosphorus parameters. The decrease in phytoplankton primary production indicated that human activity, including industrial discharges, has impacted New Bedford Harbor. The eutrophication indices suggest a strong relationship between human activity and eutrophication, indicating the necessity of ongoing monitoring and management efforts.
ABSTRACT

New Bedford Harbor, located on the southeast coast of Massachusetts, has been subjected to human impacts since the late 1600s. Human influences in the last century have included the disposal of treated wastewater into the harbor, combined sewer overflows from the city of New Bedford, and the industrial discharges of PCBs and heavy metals into the Acushnet River. Through the use of a less disturbed comparison site, the Slocums River, MA, this study attempted to examine the effect of these impacts by measuring phytoplankton primary production rates and in situ nutrient concentrations. Significant differences between the two sites were indicated for phytoplankton primary production, chlorophyll a concentrations, dissolved inorganic nitrogen and dissolved inorganic phosphorous, where all of these parameters were increased in New Bedford Harbor. These parameters indicated that human impacts, primarily in the form of increased population and wastewater discharge, have caused eutrophication of New Bedford Harbor in relation to the Slocums River. An index for the assessment of eutrophication using water quality parameters was applied. The eutrophication index, based on criteria from Delaware coastal bays, did not indicate a strong difference in eutrophication between these two estuaries.
INTRODUCTION

Anthropogenic activities are causing eutrophication of many coastal waterways and estuaries adjacent to large urbanized areas. There is a relationship between eutrophication of these marine environments and nitrogen enrichment, and this relationship results in modifications to ecosystem structure (Boynton, 1982; Rosenberg 1985; Nixon 1992; Valiela et al. 1992; Nixon 1995). A recent definition describes eutrophication as an increase in the rate of supply of organic matter to an ecosystem (Nixon 1995). Therefore, eutrophication is a process resulting from human impacts that redefines the trophic status of an ecosystem, and is mediated by a change in metabolic activity or organic inputs. Metabolic activity by primary producers is from phytoplankton, sediment microalgae and macroalgae in coastal environments.

The relationship between eutrophication and nitrogen enrichment has been examined by cross-estuary approaches, controlled experiments, historical approaches and comparison studies. A wide variety of marine systems ranging from the open ocean to heavily nutrient-loaded estuaries showed a positive correlation of primary production with dissolved inorganic nitrogen (DIN) input (Nixon 1992). Examination of the estuaries showed that these systems have the highest production of all marine systems. Plots of primary production with DIN input show that estuaries have large variation (Nixon
and Pilson 1983; Nixon 1992). This high variation is due to variation in flushing times, nutrient regeneration by the water column and the benthos, and spatial or temporal variations of both nitrogen input, primary production and light attenuation. Experiments in marine enclosures also reflected nitrogen limitation of marine environments (Oviatt et al. 1986; Oviatt et al. 1989; Oviatt et al. 1994). Controlled experiments exhibited an increase in phytoplankton production and abundance (measured as chlorophyll a) with a gradient of nitrogen loading. Changes in phytoplankton abundance or production and average DIN concentration or nitrogen loading have been recorded in some coastal ecosystems over time (Price et al. 1985; Smith et al. 1986; Johanssen and Lewis 1992; Harding 1994; Wetsteyn and Kremkamp 1994; Wienhuis and Small 1994). Most of these systems had an elevated phytoplankton abundance or production rate which was consistent with higher nitrogen availability. However, the magnitude of the response to nitrogen was not consistent, and the rate of increase was not parallel in each system (Hinga 1995). A comparison of three subwatersheds in Waquoit Bay revealed that the watershed receiving the highest groundwater concentration of nitrogen consequently had the highest rate of phytoplankton production and macroalgal biomass (Valiela et al. 1992).

We have examined in situ nutrient concentrations and phytoplankton production in New Bedford Harbor, Massachusetts, to measure the effect of cumulative human impacts. This study was part of a larger project to analyze cumulative human impacts on New Bedford Harbor using a less disturbed
reference site, the Slocums River, MA, in a comparison study (Environmental Protection Agency, Narragansett, RI). Multiple anthropogenic influences have accumulated in New Bedford Harbor since the late 1600's when agriculture was predominant. From 1755 to 1875, New Bedford Harbor was characterized as the world's largest whaling port. During the industrial revolution, the textile industry was dominant in New Bedford, and with it came many mills and industrial plants which were built along the Acushnet River from 1846-1890 (Richard Voyer, U. S. E. P. A., personal communication). Today, the city of New Bedford continues to develop and encourage the movement of new industry to the area. Municipal wastewater from the neighboring town of Fairhaven is directed into the harbor, and combined sewer overflows from the city of New Bedford contribute high volumes of untreated wastewater in times of heavy rainfall. Industrial discharges include the discharge of PCBs into the Acushnet River by electronic capacitor manufacturers between 1950 and 1970; and runoff of heavy metals, primarily Cu, from industries located on the Acushnet River. The construction of the hurricane barrier, which separates New Bedford from Buzzard's Bay, created a sediment trap for these industrial contaminants (Summerhayes et al, 1977). The control area for the study, the Slocums River, has experienced fewer alterations due to human activities over the past three centuries. There are few homes, which contain individual septic systems, and there are no industrial activities in this rural area.
Those involved in water quality management are interested in measuring eutrophication and describing estuarine health. The most direct parameter to measure eutrophication is carbon production. Unfortunately, the methods for measuring carbon production are labor intensive and require an intensive time series of measurements. There is interest in the development of an index of water quality criteria which indicates degradation of estuarine health. In the Chesapeake Bay, researchers have established the water quality criteria necessary to support submerged aquatic vegetation, a major resource for fish habitat (Dennison et al. 1993; Batiuk et al., in press). Another index ranks the state of eutrophication using water quality parameters based on parameters measured in Delaware coastal bays (Frithsen et al. 1995). This eutrophication index was based on parameters measured in Delaware coastal bays. We have measured some of these parameters in this comparison study in addition to phytoplankton production; these indices have been applied in this study to determine the state of eutrophication in New Bedford Harbor.

STUDY LOCATIONS

New Bedford Harbor (Fig. 1), an estuary with an area of 390 ha, is located on the southeast coast of Massachusetts, the Acushnet River is the major tributary to the harbor. The harbor opens into Buzzard's Bay through a hurricane barrier located at the mouth. The maximum depth of the harbor is 10 m in the dredged shipping channel. Average depth from the Coggeshell
Street bridge to the hurricane barrier is 6 m. However, there are areas outside of the shipping channel with depths reaching to 10 m (Fig 2a). The New Bedford side of the harbor, with population 100,000 (1990), consists of many industries and fish processing plants, while the City of Fairhaven, population 16,000, on the east side of the harbor consists of residential homes, marinas and fishing ports. *Spartina* marshes border the Acushnet River on the Fairhaven side, however there are few marsh areas in the middle and lower harbor. Areas of *Ulva* growth are evident along the shoreline in association with storm drains.

The Slocums River (Fig. 1), area of 180 ha, was selected as a comparison site. The estuary is much shallower with few areas where depth is beyond 3 m, and an average depth from the Gafnee Street boat ramp to the mouth of the river of 2 m. The Slocums River is bordered by a salt marsh with extensive shoreline stretches of *Spartina*, within the embayment extensive mats of *Ulva* growth are on the bottom in shallow areas. There are few homes in the area, and some agricultural activity is present.

**MATERIALS AND METHODS**

**Phytoplankton Primary Production**

Phytoplankton primary production was measured at stations A, B, C at both sites from June 3, 1994 through September 10, 1994 (Tables 1 and 2). Phytoplankton production and respiration were measured by changes of
oxygen concentration during incubations of light and dark bottles at different depths. Three 300 mL light BOD bottles and one 300 mL dark BOD bottle were incubated at four depths, 0.2 m, 0.5 m, 1 m and 3 or 4 m in New Bedford; the same number of bottles were incubated at three depths in the Slocums River, 0.2 m, 0.5 m and 1 m. The water samples were collected by dropping a Niskin bottle at one depth, the sample was brought back up to the boat and incubation bottles for that depth were filled and overflowed to remove oxygen bubbles. Three additional light bottles were filled with water from that depth and fixed immediately with chemicals for the Winkler titration (Lambert and Oviatt 1986), to determine the initial O$_2$ concentration. The bottles were hooked onto cross-bars attached to a line, so that one line had one crossbar (accommodating four bottles) at each depth. The incubations were set afloat with a buoy and weight at each station location for four hours, approximately from 10 am to 2 pm. After the incubation, the line was pulled up and bottles removed from crossbars. The incubation bottles were fixed with the chemicals for the Winkler titration to determine production of O$_2$ from the light bottles and respiration in the dark bottles. The initial samples, light and dark bottles were transported back to the laboratory where titrations were performed on an automatic burette, a Radiometer ABU 91.

Oxygen production was converted to carbon production by use of an average photosynthetic quotient (O$_2$/CO$_2$) for natural populations of 1.2, this PQ was recommended by John H. Ryther and reflects an average of photosynthetic quotients from many studies of marine algae (Ryther, 1959).
Daily production rates were calculated by assuming that the four hour incubation period represents 55% of daytime production (Vollenweider 1965). Summer production rates were calculated by assuming that 90 days were in the summer period. Carbon production to depth was calculated by integrating the area under the curve representing production as a function of depth. The areas of different depth ranges were measured in each estuary, and total production was calculated by adding the products of area of depth x integrated production at that depth.

One transect for measuring macroalgal abundance was performed in the Slocums River on August 12, 1994 and in New Bedford Harbor on August 17, 1994 (Fig. 1). The transect in the Slocums River was across a shallow embayment which was typical of the many shallow embayments in the Slocums River. New Bedford Harbor was too deep to perform a transect across the width, and the shallow areas upstream were highly contaminated, so a transect was performed along the shoreline adjacent to two storm drains. An Ekman grab with area of 0.05 m² was employed, twelve quadrats were sampled in each transect. The macroalgae from each quadrat was transported back to the laboratory where the sample was cleaned and wet weight measured. Dry weight was measured after drying the sample in a 60° C.

During phytoplankton production incubations, profiles of light attenuation, temperature and salinity were made at stations A, B, and C. Temperature and salinity profiles were performed using a Beckman salinometer. Water column light measurements and ambient light were
measured simultaneously with a LICOR LI-1000 data logger; water column incident light at depth to ambient incident light at surface ratios were recorded. Light attenuation coefficient, \( k \), was calculated by

\[
k = -\ln \left( \frac{i(z)}{i(0)} \right)
\]

where \( k \) = light attenuation coefficient, \( i(z) \) = incident light at depth, \( i(0) \) = ambient light at surface, \( z \) = depth.

**Nutrient and chlorophyll a concentrations**

Nutrients and chlorophyll a concentrations were measured by sampling at 1 m with a Niskin bottle at stations A, B and C during phytoplankton production incubations from June 3, 1994 to September 10, 1994. Nutrient samples were also taken at stations A, B, C, 1, 2, 3 and 4 from June 8, 1994 to January 1995. Samples at stations 1, 2, 3 and 4 were surface water samples collected at shoreline locations by inverting a sample bottle. Stations A, B, C, 1, 2, 3 and 4 were sampled from September 1994 to May 1995 by collecting surface samples.

Nutrient samples were filtered with a 0.4 uM polycarbonate membrane filter and preserved with chloroform in the field. Nutrient samples were analyzed for concentrations of ammonium, nitrate + nitrite, phosphate and silicate on a Technicon Autoanalyzer II (Lambert and Oviatt 1986).

Chlorophyll samples were filtered on 0.7uM Whatman glass fiber filters in the laboratory. The filters were ground, chlorophyll was extracted with
acetone, and fluorescence was determined on a Turner Designs 10 fluorometer (Lambert and Oviatt 1986).

**Application of indices**

The criteria for the eutrophication index (Frithsen et al, 1995) involved ten parameters, however, only five parameters were measured in this study. These parameters measured were nitrate + nitrite, phosphate, chlorophyll a, percent sediment organic carbon and oxygen saturation. A mean score was developed by assigning a score from 1 (oligotrophic) to 5 (eutrophic) based on criteria for each parameter; the scores were added and divided by the number of parameters used to get an average score. A replicate for each station (yearly mean) was used to obtain an average score in the eutrophication index, so that each parameter had seven replicates representing seven stations.

Sediment organic carbon (%) data required for the eutrophication index was obtained from Skip Nelson (US EPA, Narragansett, RI). Averages of percent sediment organic carbon were obtained from many samples taken on a polygon grid south of the Coggeshell street bridge in New Bedford, and south of the Gafnee boat ramp in the Slocums River, one average percent sediment organic carbon for each site was used for all replicates. Oxygen saturation data was converted from g/m$^3$ O$_2$ measurements taken for primary production estimates in the summertime taken at stations A, B and C, the average number at stations A, B and C was used for each replicate. Parameters in the Dennison water quality index used in this study were the light attenuation
coefficient, chlorophyll a, dissolved inorganic nitrogen and dissolved inorganic phosphorus. Index criteria were given for different salinity regimes, the salinity of all stations in this study ranged from 15-32, therefore the criteria for the polyhaline range was used. An average value of all stations throughout the study period was used in the Dennison index.

STATISTICS

A non-pooled t-test for two population means (assuming unequal standard deviations) was performed for nutrients, chl a, light attenuation and phytoplankton production to determine significant differences between the test site and control site (Weiss, 1995). A hypothesis test, with the null hypothesis being

$$H_0: \mu_1 = \mu_2$$

where $H_0 = \text{null hypothesis, } \mu_1 = \text{population one, } \mu_2 = \text{population two}$, for two population means with normal distribution, but not necessarily equal standard deviations involved the calculation of a test statistic. The critical values of the t-test were decided upon by the significance level, alpha $= 0.05$, and the degrees of freedom. Rejection of the null hypothesis occurred if the test statistic, $t$, fell outside of the critical values.

RESULTS

Phytoplankton Primary Production
Phytoplankton production incubations showed higher phytoplankton production rates in New Bedford Harbor. An example of one incubation from each site was typical of the difference between net production rates measured at the two sites where respiration rates were similar (Fig. 3). Production rates integrated to 1 m were higher in New Bedford with the majority of sampling dates (Table 2). Box plots of production rates measured in stations A, B and C of both estuaries showed the average phytoplankton production to be higher in New Bedford, in addition the variability was greater at the New Bedford stations (Fig. 4). The average of all net production rates integrated to 1 m was $0.58 \pm 0.12$ (standard deviation) g O$_2$ m$^{-2}$ hr$^{-1}$ in New Bedford while the average net production to 1 m in the Slocums River was $0.11 \pm 0.03$ (standard deviation) g O$_2$ m$^{-2}$ hr$^{-1}$ (Table 3). Respiration rates to 1 m in New Bedford Harbor averaged $0.09 \pm 0.06$ (standard deviation) g O$_2$ m$^{-2}$ hr$^{-1}$, and to 1 m in the Slocums River was $0.03 \pm 0.01$ (standard deviation) g O$_2$ m$^{-2}$ hr$^{-1}$ (Table 3). Station averages of phytoplankton production and respiration rates were significantly higher in New Bedford. High variation in respiration rates and small sample size made site to site differences not significant at the 5% level of significance (Table 3).

The summation of production per areas of 1 m depth, 2 m depth, and 4 m depth (Appendix D) in New Bedford was used to calculate total production across the estuary. In New Bedford Harbor, total production was $1.13 \times 10^6 \pm 1.65 \times 10^5$ (standard deviation) g C hr$^{-1}$ (Table 4, Appendix C); and divided by the area of New Bedford Harbor gives a normalized value of $0.29 \pm 0.04$ g C
m² hr⁻¹ (Table 4). In the Slocums River, the summation of plankton production at 0.2 m, to 0.5 m and 1 m (Appendix C) gave a total of $7.05 \times 10^4 +/- 1.87 \times 10^4$ gC hr⁻¹ (Table 4, Appendix C). Unfortunately, this is an underestimate of total production in the Slocums River because there are areas of the Slocums River deeper than 1 m which light enters and where production occurs. This underestimate is not likely to be great because the phytoplankton production rate was very low at 1 m, and further depths are likely to have even less production. Normalization to area in the Slocums River gives an estimate of $0.04 +/- 0.01$ g C m⁻² hr⁻¹ (Table 4). An estimate for New Bedford production rate over the summer season (June, July and August) is $165 +/- 26$ g C m⁻² summer⁻¹, and much higher than the estimated summer rate for the Slocums River, $20 +/- 3$ g C m⁻² summer⁻¹.

Macroalgae biomass was higher in almost all quadrats in the Slocums River transect when compared to the New Bedford macroalgae transect (Fig. 5). The average distribution of macroalgae in the Slocums River transect was 159 grams dry weight m⁻². In New Bedford Harbor, the average distribution across the transect was 72 grams dry weight m⁻².

There was high variability in the light extinction coefficient, k, in both New Bedford Harbor and the Slocums River. The average k measured at stations A, B and C was 0.90 in New Bedford and 0.98 in the Slocums River. The t-test showed that there were no significant differences between light attenuation coefficients in the estuaries (Table 3). Temperature and salinity
profiles at all stations indicated that the water column was well mixed throughout the summer.

**Chlorophyll a**

The yearly cycle of chlorophyll a concentrations indicated that mean phytoplankton abundance was higher in New Bedford in July and August and in the springtime during January, February and March (Fig. 6). Mean chlorophyll a concentrations across the year was 7.64 mg/m$^3$ for New Bedford and 3.28 mg/m$^3$ for the Slocums River. The difference was significant at the 5% level of significance with the nonpooled t-test for independent population means. (Table 3).

**Nutrients**

Nutrient samples analyzed from June 8, 1994 to January 28, 1995 showed significant differences between the two sites. Mean dissolved inorganic nitrogen concentrations increased over the fall and early winter at both sites. However, New Bedford showed a pattern of higher mean dissolved inorganic nitrogen concentration over the Slocums River, especially in the fall and winter (Fig. 7). A different pattern was evident for mean phosphate concentrations, where phosphate declined over late summer, fall and winter at both sites (Fig. 8). Phosphate concentrations were higher in the New Bedford month to month plot (Fig. 8). Station to station box plots of mean ammonium concentrations for each estuary demonstrated
that the average of ammonium over the study period in New Bedford Harbor was higher than station averages in the Slocums River (Fig. 9). These differences in ammonium, dissolved inorganic nitrogen and phosphate concentrations at the two sites were significant at the 5% level of significance (Table 3). In addition, station averages of phosphate were significantly different over the study period; however, mean nitrite + nitrate and silicate were not significantly different when station to station variations were taken into account.

**Application of indices**

The application of the eutrophication index (Frithsen et al. 1995) resulted in a score of 1.09 +/− 0.37 (standard deviation) for the Slocums River and 2.25 +/− 0.3 (standard deviation) for New Bedford Harbor (Table 5, Appendix E). On a scale of 1 (Oligotrophic) to 5 (Eutrophic), the index showed that the Slocums River was oligotrophic while New Bedford Harbor was slightly above oligotrophic. The parameters in the New Bedford Harbor which contribute to the increase in score were percent sediment organic carbon which had an average of 6.04% (score = 5). Average percent sediment organic carbon was 2.01% (score=2) in the Slocums River. Phosphate concentrations in New Bedford were in the range of 1.5-2.0 μM (score=2), and only 0.5-2.0 μM (score=1) in the Slocums River. Nitrate + nitrite and oxygen saturation were not significantly different, and scored a 1 at both sites. Even
though chlorophyll a values were significantly higher in New Bedford, the station means were not high enough to score above oligotrophic conditions.

According to the Dennison Water Quality index, light attenuation coefficient and chlorophyll a scored within the recommended criteria at all stations in both estuaries, however neither dissolved inorganic nitrogen nor dissolved inorganic phosphorous met the required criteria for all stations in New Bedford (Table 6). The average light attenuation coefficient was 0.90 +/- 0.22 for New Bedford, and 0.98 +/- 0.20 for the Slocums River; while average chlorophyll between stations was 7.3 +/- 2.98 ug/l for New Bedford, and 3.37 +/- 0.99 ug/l for the Slocums River. The average dissolved inorganic nitrogen for New Bedford (between the seven stations) was 8.76 +/- 4.28 uM. Two New Bedford stations failed to pass the criterion of 10 uM dissolved inorganic nitrogen; these stations were A (average = 13.2 uM) and 2 (average = 15.34). However, all stations in the Slocums River, which averaged 3.37 +/- 0.99uM, passed the criteria for dissolved inorganic nitrogen. Another failure of criteria is evident in the phosphate concentrations for New Bedford where the average of the seven stations was 1.90 +/- 0.17 uM DIP; each station in New Bedford failed to meet the criteria of 0.67 uM DIP. Four stations failed to meet the criteria for phosphate in the Slocums River, where the station mean was 0.88 +/- 0.51 uM (Table 6); these stations were B (average = 0.71uM), C (average = 0.9uM), 3 (average = 0.75uM) and 4 (average = 2.01uM).
DISCUSSION

Higher phytoplankton primary production and abundance indicated that New Bedford Harbor was eutrophied at least in relation to the comparison site, the Slocums River. This conclusion was based on the definition of eutrophication being “an increase in the rate of supply of organic carbon” (Nixon, 1995). Integral primary production per unit area was higher in New Bedford because it is a deeper system, but also primary production per unit volume was higher in New Bedford Harbor. According to Nixon (1995), another source of eutrophication besides phytoplankton production is an increase in carbon production from macroalgae. The carbon production estimates in this study are based on phytoplankton production, and do not include production from macroalgae, seaweeds, or benthic microalgae. A transect across a shallow embayment in the Slocums river showed higher macroalgae biomass than along the shoreline in New Bedford Harbor, where shallow embayments are limited. The greater percentage of shallow embayments in the Slocums River which allow light to reach the bottom along with higher macroalgal biomass suggested that production from macroalgae may have been higher in the Slocums River than in New Bedford Harbor. A study of eutrophication in many different estuaries and lagoons has shown that the shallow salt marshes and lagoons have a higher contribution of production from macrophytes over phytoplankton (Nixon, 1982).
seasonal phytoplankton production rate. The west passage of Narragansett Bay had a summertime average daily production rate of 0.7 gC/m²/day in 1971 (Oviatt et al. 1981), while the daily production rate in this study was 2.10 ± 0.14 gC/m²/day in New Bedford and 0.29 ± 0.07 gC/m²/day in the Slocums River. Light availability was also restricted in both New Bedford and the Slocums River when compared to Narragansett Bay, where in 1971 light extinction coefficient in Narragansett Bay varied from 0.5 to 0.7. The coefficient in New Bedford Harbor was 0.90 ± 0.22 and 0.98 ± 0.20 in the Slocums River. The decreased light availability in New Bedford Harbor may be due to increased phytoplankton biomass. However, in the Slocums River, decreased light transmission may be due to sediments being disturbed in shallow water regions.

Higher phytoplankton production in New Bedford Harbor, compared to the Slocums River, is likely due to increased sewage effluent directed into the harbor, resulting from high population density. In 1775, the population of New Bedford was only 500, and by the 1920’s had increased to a maximum of 125,000 in the era of the textile mills. Since the 1920’s, the population has slowly been decreasing to a present day estimate of 98,000 (Richard Voyer, EPA, personal communication). In comparison, the town of Dartmouth at the head of the Slocums River has a present day population of less than 1,000. Ammonium and phosphate concentrations are typically increased in sewage effluent, and the in situ concentrations of ammonium and phosphate are significantly higher throughout the year in New Bedford Harbor. It is likely
effluent, and the in situ concentrations of ammonium and phosphate are significantly higher throughout the year in New Bedford Harbor. It is likely that these higher in situ concentrations in New Bedford Harbor paralleled higher nutrient loadings. Higher phytoplankton production has been positively correlated with higher nitrogen loading rates in estuarine systems (Boynton, 1982; Rosenberg 1985; Nixon 1992; Valiela et al. 1992; Nixon 1995).

The eutrophication index, based on the average of five water quality parameters measured throughout the year, showed the Slocums River as being oligotrophic, and New Bedford was only slightly above oligotrophic, but not in the mesotrophic range (Frithsen et al, 1995). This contrasts direct comparison of phytoplankton primary production and chlorophyll concentrations, which show a large difference in phytoplankton biomass and production between the two sites. However, only using five of the ten parameters in the index may impede the utility of the index in showing differences in the extent of eutrophication. The only parameter which consistently showed New Bedford as being eutrophic at every station was percent sediment organic carbon, which was probably a result of the high primary production in New Bedford. However, the nutrient concentrations, oxygen concentration and chlorophyll a were not high enough to score in the mesotrophic range (score of 3). The mean parameters measured in the Slocums River throughout the year showed that at each station, water quality parameters met criteria for growth of submerged aquatic vegetation (SAV). However, yearly mean parameters in New Bedford showed that none of the
stations meet the criteria for dissolved inorganic phosphate, and some of the stations fail to meet criteria for dissolved inorganic nitrogen. Therefore the Dennison water quality index does show a difference between the two sites, but does not attempt to rank how strong the difference is.

There are several speculations as to why the index did not recognize a strong difference in eutrophication between the two estuaries, and did not classify New Bedford Harbor as eutrophic. Only five out of ten parameters in the index were measured in this study, the metrics which were not measured were total dissolved nitrogen and phosphorus, total particulate nitrogen and phosphorus, and total particulate carbon. The parameters measured only involved inorganic nutrient concentrations. In situ, inorganic, nutrient concentrations may not always give an accurate picture of the rate of primary production for several reasons: 1) high primary production may use nutrients at a high rate, leaving a low in situ nutrient concentration, 2) differences in the source of primary production, for instance a phytoplankton dominated system and a system dominated by seagrasses and benthic macroalgae may have different rates of nutrient uptake, 3) differences in benthic remineralization of nutrients, 4) different residence times, 5) high spatial and temporal variability of nutrient concentrations. There are also problems with using chlorophyll a concentrations as an indicator of eutrophication. Carbon to chlorophyll a ratios may not be constant; and chlorophyll a is not an indication of production arising from seagrasses and benthic algae. Oxygen saturation must be measured completely throughout the estuary to find
either shallow or deep areas with anoxia. The light attenuation coefficient may not always be a good indicator because high variability may arise from stirred up sediments in shallow regions during windy weather.
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Figure 1. The study area, New Bedford Harbor, and comparison site, the Slocums River, are both located on the southeast coast of Massachusetts. Locations of deep stations, A, B, and C as well as shoreline stations 1, 2, 3 and 4 are indicated. Transects for macroalgae biomass are indicated by a line with arrowheads.
Figure 2a. Depth contour plot of New Bedford Harbor.
Figure 2b. Depth contour plot of Slocums River.
Figure 3. An example of net production and respiration rate differences between New Bedford Harbor and the Slocums River. Gross production rates are represented by closed circles for New Bedford Harbor and closed squares for the Slocums River. Respiration rates are represented by open circles for New Bedford Harbor and open squares for the Slocums River. Measurements were taken in New Bedford at Station A on July 20, 1994, while the Slocums River measurements were taken at Station D, August 6, 1994.
Figure 4. Distribution of gross primary production rates integrated to 1m depth in both estuaries. Production rates were measured in New Bedford Harbor and the Slocums River from June 3, 1994 to September 10, 1994. New Bedford station A (n=3), station B (n=4), station C (n=4); Slocums River station A (n=2), station B (n=4), station C (n=4).
Figure 5. Benthic macroalgae biomass, in grams dry weight, for one transect performed in New Bedford Harbor (open bars) and the Slocums River (closed bars). Twelve quadrats in each transect were sampled for macroalgae biomass with an Ekman grab. See Figure 1 for locations of transects.
Figure 6. Mean monthly chlorophyll a concentrations throughout the year of study. Closed circles are New Bedford Harbor concentrations and open circles are Slocums River concentrations. The value for each month is an average of all stations sampled during that month.
Figure 7. Concentrations of dissolved inorganic nitrogen (DIN) measured at New Bedford stations (squares) and Slocums River stations (circles) from June 8, 1994 to January 28, 1995. The value for each month is an average of all stations sampled during that month.
Figure 8. Concentrations of phosphate measured at New Bedford stations (closed circles) and Slocums River stations (open circles) from June 8, 1994 to January 28, 1995. The value for each month is an average of all stations sampled during that month.
Figure 9. Distribution of ammonium concentrations for all stations in New Bedford Harbor and the Slocums River from June 6, 1994 to January 28, 1995.
| Station | Latitude       | Longitude      | Depth | Salinity Range |
|---------|----------------|----------------|-------|----------------|
| A       | 41°39'23"      | 70°55'         | 4.5 m | 24-31          |
| B       | 41°38'56"      | 70°55'14"      | 6 m   | 26-32          |
| C       | 41°38'5"       | 70°54'8"       | 6 m   | 30-32          |
| 1       | 41°38'56"      | 70°54'37"      | shoreline | 27-31 |
| 2       | 41°38'36"      | 70°54'30"      | shoreline | 23-32 |
| 3       | 41°38'14"      | 70°54'35"      | shoreline | 30-32 |
| 4       | 41°37'32"      | 70°54'28"      | shoreline | 30-32 |
| A       | 41°32'38"      | 71°59'15"      | 3 m   | 18-30          |
| B       | 41°32'20"      | 71°59'         | 2 m   | 24-31          |
| C       | 41°31'52"      | 71°58'40"      | 3 m   | 27-32          |
| 1       | 41°32'51"      | 71°59'57"      | shoreline | 15-31 |
| 2       | 41°32'37"      | 71°59'30"      | shoreline | 20-31 |
| 3       | 41°32'10"      | 71°58'45"      | shoreline | 28-32 |
| 4       | 41°31'45"      | 71°58'40'      | shoreline | 28-32 |

Table 1. Station locations, depths and salinity ranges for the study site, New Bedford Harbor, and comparison site, the Slocums River. Stations A, B, C were in deeper ranges of the estuary while stations 1, 2, 3 and 4 were stations where surface water was sampled.
| Station | Date    | Production (Net) | Respiration | Production (Net) | Respiration |
|---------|---------|------------------|-------------|------------------|-------------|
|         |         | g O₂/m²/hr to 1m | g O₂/m²/hr | g O₂/m²/hr to 4m | g O₂/m²/hr |
| New Bedford A | 7/1/94  | 0.35             | 0.05        | 0.89             | 0.11        |
|         | 7/20/94 | 0.88             | 0.12        | 1.28             | 0.24        |
|         | 9/10/94 | 1.12             | 0.32        | 2.33             | 0.61        |
| B       | 7/1/94  | 0.58             | 0.17        | 1.15             | 0.42        |
|         | 7/20/94 | 0.64             | 0.05        | 1.09             | 0.14        |
|         | 8/9/94  | 0.54             | 0           | 1.25             | 0.02        |
|         | 9/10/94 | 0.13             | 0.04        | 0.59             | 0.14        |
| C       | 7/1/94  | 1.24             | 0.1         | 1.66             | 0.23        |
|         | 7/20/94 | 0.47             | 0.05        | 0.9              | 0.15        |
|         | 8/9/94  | 0.34             | 0.03        | 0.89             | 0.09        |
|         | 9/10/94 | 0.25             | 0           | 0.64             | 0.03        |

Table 2. Integrated net phytoplankton primary production and respiration values to 1m depth in New Bedford Harbor and the Slocums River, and to 4m depth in New Bedford Harbor alone. Production rates were measured by using light and dark incubation bottles at depth. See Appendix A for production and respiration values at each depth.
| Station      | Date    | Production (Net) g O₂/m²/hr | Respiration g O₂/m²/hr to 1m | Production (Net) g O₂/m²/hr to 4m | Respiration g O₂/m²/hr to 4m |
|--------------|---------|----------------------------|-------------------------------|-----------------------------------|-------------------------------|
| Slocums River | 6/8/94  | 0.12                        | 0.01                          |                                   |                               |
|              | 7/7/94  | 0.09                        | 0.08                          |                                   |                               |
|              | 8/6/94  | 0.12                        | 0.04                          |                                   |                               |
|              | 8/24/94 | 0.12                        | 0.06                          |                                   |                               |
|              | 6/8/94  | 0.12                        | 0.01                          |                                   |                               |
|              | 7/7/94  | 0.08                        | 0.02                          |                                   |                               |
|              | 8/6/94  | 0.11                        | 0                             |                                   |                               |
|              | 8/24/94 | 0.16                        | 0.04                          |                                   |                               |

Table 2 - continued
| Station | Production gO₂/m²/hr to 1m | Respiration gO₂/m²/hr to 1m | k | chlorophyll a | Dissolved Inorganic Nitrogen | NH₄ | NO₃+NO₂ | PO₄ | SiO₄ |
|---------|----------------------------|----------------------------|---|--------------|-----------------------------|-----|---------|------|------|
|         | NB | SR | NB | SR | NB | SR | NB | SR | NB | SR | NB | SR | NB | SR | NB | SR | NB | SR | NB | SR |
| A       | 0.69 | 0.14 | 0.16 | 0.03 | 1.14 | 1.12 | 3.73 | 2.7 | 13.2 | 6.73 | 5.39 | 2.11 | 7.81 | 4.61 | 1.96 | 0.59 | 20.18 | 42.08 |
| B       | 0.46 | 0.08 | 0.07 | 0.03 | 0.88 | 1.07 | 7.45 | 3.74 | 7.88 | 1.56 | 4.59 | 0.85 | 3.29 | 0.71 | 2.13 | 0.71 | 14.47 | 14.36 |
| C       | 0.59 | 0.11 | 0.05 | 0.02 | 0.69 | 0.76 | 5.9  | 3.55 | 4.86 | 1.71 | 3.1  | 1.09 | 1.76 | 0.61 | 1.81 | 0.9  | 10.5  | 9.87  |
| 1       |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 2       |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 3       |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 4       |       |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Statistics | average |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| s       | 0.12 | 0.03 | 0.06 | 0.01 | 0.22 | 0.2  | 2.98 | 0.99 | 4.28 | 2.37 | 1.38 | 0.64 | 3.02 | 1.79 | 0.17 | 0.51 | 4.11  | 14.81 |
| degrees freedom | 2.25 | 2.06 | 2.82 | 7.31 | 9.36 | 8.47 | 9.75 | 7.32 | 6.92 |
| t       | 10.05 | 1.78 | 0.71 | 3.67 | 2.62 | 5.03 | 1.45 | 5.02 | 1.38 |
| t crit (alpha=0.05) | 4.3  | 4.3  | 3.18 | 2.37 | 2.26 | 2.31 | 2.23 | 2.37 | 2.37 |
| NB=SR  | NO | YES | YES | NO | NO | NO | NO | YES | NO | YES |

Table 3.
Table 4. Production estimates for phytoplankton for entire estuary at both sites. Production estimates include areas of depth (see Appendix C for area of different depths and phytoplankton production rates integrated to depths; see Appendix D for production and respiration integrations at each depth). These production rates are based on net primary production. Summertime estimates were based on the assumption that a four hour incubation (from 10 A.M. to 2 P.M.) represents 55% of daytime production, and the summer consists of 90 days, from June to August.

| Site         | gC/hr          | area of estuary | gC/m²/hr | gC/m²/day | gC/m²/summer |
|--------------|----------------|-----------------|----------|-----------|--------------|
| New Bedford  | $1.13 \times 10^4 \pm 1.65 \times 10^4$ | 3.78 km²       | 0.29 +/- 0.04 | 2.10 +/- 0.14 | 189 +/- 13  |
| Slocums River| $7.05 \times 10^4 \pm 1.87 \times 10^4$ | 1.95 km²       | 0.04 +/- 0.01 | 0.29 +/- 0.07 | 26 +/- 6   |
### Index Criteria:

| Indicator                      | Oligotrophic | > Eutrophic |
|-------------------------------|--------------|-------------|
| uM Nitrate + Nitrite          | ≤5           | >8          |
| uM Phosphate                  | ≤1.5         | >3          |
| ug/l chlorophyll a            | 15           | >45         |
| %Sediment Organic C           | 1.5          | >3          |
| O2 saturation                 | 80-105       | >120        |

### Application of index to New Bedford stations:

| Indicator                      | A  | B  | C  | 1  | 2  | 3  | 4  |
|-------------------------------|----|----|----|----|----|----|----|
| uM Nitrate + Nitrite          | 4  | 1  | 1  | 1  | 5  | 1  | 1  |
| uM Phosphate                  | 2  | 3  | 2  | 2  | 2  | .3 | 2  |
| ug/l chlorophyll a            | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| %Sediment Organic C           | 5  | 5  | 5  | 5  | 5  | 5  | 5  |
| O2 saturation                 |    |    |    | 1  |    |    |    |

Score for station: 2.6, 2.2, 2, 2, 2.8, 2.2, 2

Mean = 2.26 ± 0.3

Table 5
Application of index to Slocums River stations:

| Indicator                  | A | B | C | 1 | 2 | 3 | 4 |
|----------------------------|---|---|---|---|---|---|---|
| uM Nitrate + Nitrite       | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| uM Phosphate               | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| ug/l chlorophyll a         | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| %Sediment Organic C        | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| O2 saturation              | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Score for station: 1.2 1.2 1.2 1.2 1.2 1.2 1.4

Mean = 1.09 +/- 0.37

Table 5 - continued
### Dennison index criteria:

| Salinity regime       | Light attenuation coefficient (Kd;m-1) | Total suspended solids (mg/l) | Chlorophyll a (ug/l) | Dissolved inorganic nitrogen (uM) | Dissolved inorganic phosphorus (uM) |
|-----------------------|----------------------------------------|-----------------------------|----------------------|-----------------------------------|------------------------------------|
| Tidal freshwater      | 2                                      | 15                          | 15                   | 0.67                              |                                    |
| Oligohaline           | 2                                      | 15                          | 15                   | 0.67                              |                                    |
| Mesohaline            | 1.5                                    | 15                          | 15                   | 10                                | 0.33                               |
| Polyhaline            | 1.5                                    | 15                          | 15                   | 10                                | 0.67                               |

### Application of index:

| Location               | Light attenuation coefficient (Kd;m-1) | Chlorophyll a (ug/l) | Dissolved inorganic Nitrogen (uM) | Dissolved Inorganic Phosphorus (uM) |
|------------------------|----------------------------------------|----------------------|-----------------------------------|------------------------------------|
| New Bedford            | 0.88 +/- 0.2                           | 7.3 +/- 2.98         | 8.76 +/- 4.28                    | 1.9 +/- .88                        |
| Slocums River          | 0.94 +/- 0.2                           | 3.37 +/- 0.99        | 3.69 +/- 2.37                    | 0.9 +/- 0.51                       |

Table 6. Dennison index criteria (Dennison et al, 1993) for growth of submerged aquatic vegetation. Light attenuation coefficient, chlorophyll a, Dissolved Inorganic Nitrogen (DIN) and Dissolved Inorganic Phosphorous (DIP) were measured in New Bedford Harbor and the Slocums River.
Fish Biomass, Abundance and Community Structure in New Bedford Harbor
ABSTRACT

The effects of cumulative human impacts on fish community structure in New Bedford Harbor was examined using a comparison study with a less disturbed site, the Slocums River, MA. Between June 1994 and May 1995, monthly seine samples were taken at marsh and beach habitats in both estuaries. Eighteen species, and 32,027 individuals with a dry-weight biomass of 13,863 g were collected from New Bedford Harbor while 22 species, 20,864 individuals with a dry-weight biomass of 7,710 g were collected from the Slocums River. Summertime growth rates of *Menidia* species and *Fundulus majalis* were higher in New Bedford Harbor. In the Slocums River, fish species diversity and richness were higher. Community structure of fish species was dissimilar between the two sites, with differences in the abundance of major species and the presence of minor species. We suggest that higher phytoplankton production resulting from urbanization of the New Bedford area was the cause of higher fish biomass and higher growth rates of *Menidia*, the dominant species. The higher diversity in the Slocums River is likely due to a higher distribution of *Spartina* marsh sites when compared to New Bedford Harbor. The filling in of marsh areas in New Bedford Harbor, which were present in the late 1700s, and construction of barriers have decreased the extent of marsh and therefore have limited diversity of habitat. The Estuarine Biotic Integrity index (EBI) was applied to the marsh and beach habitats of both systems. The EBI ranked all stations in both estuaries as poor quality habitat when compared to the eelgrass habitat of
Waquoit Bay and Buttermilk Bay, Massachusetts. The EBI is recommended for eelgrass habitats, since the best correlation between poor water quality characteristics and poor fish parameters has been in eelgrass habitats. The EBI may have not been applicable to this study, since there were no eelgrass beds in the two sites.
INTRODUCTION

The observation that five of the six most important commercial fishery species in the United States are somehow dependent on estuaries, and that 75% of the nation's commercial fishery landings of fish and shellfish (by weight, 1985) are composed of estuarine dependent species (Chambers 1991) demonstrates that estuaries play a vital role in fisheries. These numbers translate into an annual economic value to society approaching $14 billion, demonstrating that estuarine ecosystems are essential to the fishing industry. Fish and shellfish depend on estuaries for reproduction, nursery areas and food sources.

Estuaries are commonly adjacent to centers of population and therefore subjected to environmental stresses attributed to anthropogenic activities. Examples of the types of human impacts which disturb fisheries are overfishing, eutrophication, industrial waste additions, dredging, introduction of artificial reefs, the filling of wetlands, and construction of barriers. Chemical stress on aquatic ecosystems affects the occurrence of some species, and encourages colonization by others. Rapid changes in overall community composition beyond the simple appearance or disappearance of indicator species are found in association with chemical stresses. These stresses include acidification, herbicides, pesticides, heavy metals, oil, pulp mill effluents and organic enrichment. In addition, heavily stressed systems
tend to have reduced biomass, abundance, species richness and species
diversity relative to pristine ecosystems (Ford, 1989). The alteration of habitat
due to dredging and the filling of wetlands will lead to declines in fish
spawning, food sources, and hiding areas.

Eutrophication of coastal waterways has many impacts. In Swedish
waters, the Kattegat and the Belt Sea, increased inputs of nutrients in
combination with relatively low water exchange and high macro-algal
biomass have led to minimal oxygen concentrations in bottom-water
(Rosenberg 1985). These events have been responsible for mortalities of
benthic animals and decreased fish catches around Sweden. Eutrophication
may change the food web structure in an ecosystem. Decreased cod stocks in
the Baltic Sea are blamed in part on the disappearance of amphipods and
other benthic fauna from deeper Baltic bottoms when an oxygen deficiency
has developed (Elmgren 1989). Eutrophication increased the amount of a
filamentous algae in the Baltic Sea which has been responsible for mortality
of Baltic Herring eggs (Aneer 1985). One hypothesis for the decline of Striped
Bass (Morone saxatilis) in Chesapeake Bay is that nutrient enrichment and
greater planktonic production have decreased concentrations of dissolved
oxygen and thus impacted deep-water habitat for adults (Price et al, 1985).

Although many reports in the literature show degradation of fish
populations due to eutrophication; there is also evidence of increased
fisheries yield with increased primary production, or eutrophication (Aleem
1972; Bentuvia 1973; Sutcliffe 1972, 1973; Cross 1975; Stevens 1977; Hansson
The concept of the sea being a farm, where input of dissolved organic nutrients regulates the level of primary production and eventually the yield of fish from marine ecosystems, was initiated about a century ago (Nixon 1992). Predictions of fish production from primary production have shown that a significant portion of fish production occurs in coastal waters where primary production is the highest (Ryther 1969; Houde and Rutherford 1993). The relationship between fisheries yield and measured primary production in a variety of marine systems, including estuaries, shows a positive correlation (Nixon 1992; Iverson 1990). However, few studies have examined individual estuarine systems for a relationship between primary production and fish production, perhaps because there are few studies reporting both primary production and fish yield for near coastal waters. Estuarine fish yield has a large variation of response to primary production due to differences between estuaries. These are differences in residence time and circulation which influence anoxic events. Differences may also be evident in transfer efficiency between trophic levels and foodweb structure, habitat structure and fishing pressure.

An Estuarine Biotic Integrity Index (EBI) has been developed to indicate estuarine ecosystem health in New England estuaries (Deegan et al. 1993). The EBI is designed to indicate the quality of habitat by using fish biological parameters. The indicators of ecosystem health in the index are top trophic level consumers, estuarine fish. Estuarine fish are higher trophic levels assumed to be sensitive to degradation since they require a wide diversity of
ecosystem functions to be sustained. The EBI was modified from the original Index of Biotic Integrity (IBI) for evaluating water quality and ecosystem conditions in freshwater streams (Karr, 1981, 1991). The EBI consists of eight metrics which evaluate the following parameters: species composition (number of species, number of estuarine spawners, number of nursery species and number of resident species), fish abundance and health (density, dominance and abnormality), and foodweb structure (% of benthic fishes). Criteria for each parameter was determined by Deegan using habitats in Waquoit Bay. Deegan tested the EBI by evaluating fish communities in eelgrass, marsh, beach and bay mouth habitats were evaluated in Waquoit Bay and Buttermilk Bay, MA. Habitats were classified as low quality on the basis of standard chemical and physical analyses (algal blooms, macroalgae, low dissolved oxygen, high nutrients, dredged channels). The eelgrass habitats which had poor water quality parameters had modified fish communities that were reflected in low EBI scores. However, marsh and open beach habitats did not have high correlation between water quality data and EBI score.

Anthropogenic impacts in New Bedford Harbor, MA, have resulted in the eutrophication of the harbor as evident by the high carbon production by phytoplankton (Absher and Oviatt, 1995). Industrial activities have also increased sediment concentrations of PCBs to 100,000 ppm in some areas (Connolly, 1992) and have increased the concentration of toxic heavy metals to more than 1% dry weight of sediments (Summerhayes et al, 1977). We
have evaluated New Bedford Harbor fish community structure in a comparison study to determine if there are differences due to human impacts. The comparison site was a less disturbed estuary, the Slocums River, MA. The area surrounding the Slocums River is rural, with a population of less than 1,000 in Dartmouth, the town at the head of the river. There are few homes along the river, which are on individual septic systems, there is no wastewater discharge into the river from the town of Dartmouth. There are no industrial activities in the area, however agricultural activities may contribute fertilizers to the watershed. The EBI was applied to generate a number for ecosystem health in both estuaries. We have investigated whether human impacts have changed fish community parameters by comparing two differently impacted sites, and whether the EBI score reflected these differences.

STUDY LOCATION

New Bedford Harbor (Fig. 1), area of 390 ha, is an estuary on the southeast coast of Massachusetts opening into Buzzard’s Bay. Industrial sites line the New Bedford side of the harbor while the Fairhaven side is more residential with fishing ports and marinas. Upstream of the Acushnet River, the major tributary to the estuary, many sites have Spartina marsh while the lower and middle harbor do not have as many sites with Spartina. Many shallow upstream areas have mats of Ulva, and shoreline areas near storm
drains around the perimeter of the harbor contain Ulva. The average depth of New Bedford Harbor, from the Coggeshall Street bridge to the hurricane barrier, is 6 m. The maximum depth of the harbor is 10 m in the dredged shipping channel; in the lower harbor there are areas outside of the shipping channel where depths reach to 10 m (Fig. 2a). A hurricane barrier separates the outer harbor from Buzzard’s Bay.

The Slocums River, (Fig. 1), a smaller estuary than New Bedford Harbor, with an area of 180 ha, is located in a rural area of southeastern Massachusetts with few homes, and no industrial activity. The average depth of the Slocums River, from the Gaffnee Street boat ramp to the mouth is 2 m. The estuary is much shallower than New Bedford Harbor, with few areas where depth is beyond 3 m, and a maximum depth is 6 m (Fig. 2b). There are extensive areas of Spartina marsh along the river, and mats of Ulva on the bottom of shallow areas.

MATERIALS AND METHODS

Collection of samples

Four stations were selected for sampling in each estuary; two stations were in the middle harbor and two stations were in the lower harbor of New Bedford (Fig. 1). Accordingly, the stations in the Slocums River were selected in the middle and lower part of the river (Fig. 1). The station habitats were either Spartina marsh or sandy or cobbly beach; the salinity ranges were similar between the two sites (Table 1). No eelgrass (Zostera marina) was
located at either site. There was more beach habitat in New Bedford in the middle and lower harbor than saltmarsh compared to the Slocums River. Marsh stations upstream of the Acushnet River were not sampled due to the PCB toxicity of the sediments.

Estuarine fish were sampled by seining shoreline stations with a 15 m x 1 m beach seine (with a 1m x 1m bag), mesh size 4.8 mm. The seine was weighted on the bottom, and contained floats at the top so that the seine collected specimens throughout the water column. One person held an end of the seine on the shore while the other person waded out and circled around and came back to the starting point. This resulted in a half circle of seined area with a diameter of 15 m and area of 88 m². Three replicate seines were performed at each station. Each station was sampled two times in June, July and August; and once a month for selected months in the fall, winter and spring (Appendix A).

The efficiency of the seine was measured by seining a section of Marsh Meadows Wildlife Preserve in Jamestown, RI. An area of 382.5 m² was closed off by stretching a beach seine from shoreline to shoreline. An initial seine of the enclosed area was performed using the beach seine employed in the study, the fish in this seine were identified and counted. Seining was continued in the enclosed area until all fish were captured. The fish abundance in the enclosed area was compared to fish abundance counted in the first seine to determine the efficiency of the seine. This procedure was performed five times at the same location to obtain a variance.
Analysis of samples

Each seine catch was analyzed for species and numbers. Fish were identified to the genus and species level, except for *Menidia menidia* and *Menidia berrylina* which were classified to the genus. If the number of a species exceeded 100, total numbers were estimated by volume displacement. Subsamples of major species were taken back to the laboratory along with minor species to measure wet weight and dry weight. Dry weights were measured after drying in a 60°C oven for 4-7 days, depending on size. Samples were preserved in buffered formalin in the field for transport back to the laboratory. Length of all species were measured on subsamples of 100, or total numbers if less than 100, either in the field or in the laboratory. On a few subsamples, length and dry weight and wet weight were measured concurrently to perform length-weight regressions.

Length-wet weight and length-dry weight regressions were performed for each species using a sample size of at least 60 individuals for dry weight, and 200 for wet weight. Some minor species collections throughout the study were not abundant enough to perform regressions, consequently length and weight were recorded on these minor species continuously throughout the study. A log (length) versus a log (wet or dry weight) plot was used to derive an equation for a straight line. These regressions were used to estimate biomass from length measurements on the rest of the samples.

Ponderal index, or condition factor, $k$, was calculated by using the equation
\[ k = \frac{W}{L^3} \]

where \( k \) = condition factor, \( W \) = weight (g), \( L \) = length (cm), (Weatherley and Gill 1987). Condition factors were calculated for major species present at each site: *Menidia* species, *Fundulus heteroclitus* and *Fundulus majalis*. A subsample of fish from many different seines and stations in each estuary was compiled to calculate \( k \) for each species.

**Application of the EBI**

The guidelines for using the EBI that were met were: 1) sample in late July and August; 2) sample at least three replicates at each station each time; 3) sample at least twice during July and August. It was also recommended to sample eelgrass habitats exclusively, however only marsh and beach habitats were available to be sampled in this study. The EBI was applied using criteria developed for either numbers or wet weight biomass of fish (Deegan et al. 1993). The criteria for were: number of species < 6, number of estuarine spawners <3, number of nursery species <3, number of resident species <4, abundance <4 g/m\(^2\) (biomass) or 3.8 individuals/ m\(^2\) (numbers), dominance <3 comprising 90% of total (biomass or numbers), abnormality >0.01, and % benthic fishes <0.9 (based on biomass or numbers). A score was developed for each station in New Bedford and the Slocums River using the average of each parameter across July and August. If the metric did not meet minimum criteria, the parameter in that observation was given a zero, otherwise the raw value of the parameter was used as a score. The scores for each station
were added to obtain an overall score which was compared to the score considered low quality habitat, which was <30.

STATISTICAL ANALYSIS

Growth Rates

Growth rates for *Menidia* species, *Fundulus heteroclitus* and *Fundulus majalis* were based on monthly length frequency data throughout the study period. Length - frequency distributions for each species were pooled together for each month and used in a bootstrapping program. A SAS program for bootstrapping monthly instantaneous growth rates was generously provided by Carol Meice (NMFS, Narragansett, RI). This program uses the bootstrap technique developed by B. Efron in 1977 (Efron 1982). The procedure involved recombining the original data randomly, with replacement, using all measurements in a pool. The program was designed to perform bootstrap sampling 100 times. Periodic growth rates were calculated by taking the mean and standard error of the 100 bootstrap samples (Krebs 1989).

Species Diversity

Two diversity indices were used, the Shannon-Wiener index and the Simpson index. The Shannon-Wiener index is an example of a type I index, which is more sensitive to changes in the rare species in the community sample. The Simpson index is a type II index, which is more sensitive to
changes in abundant species. The diversity was estimated by using a jackknife procedure for both indices (Zahl 1977). Station samples from different dates were used as replicates; a replicate was a compilation of the three seines at one station. The diversity indices and their variances were calculated for samples taken over the summer season (June-August), the fall and winter season (Sept-March) and the spring (May I and May II). In New Bedford, there were 26 replicates in the summer, 12 in the fall and 8 in the spring. In the Slocums River, there were 26 replicates in the summer, 14 replicates in the fall, and 8 in the spring. Each replicate includes three seines.

**Species Richness**

Species richness was calculated using a jackknife procedure (Heltshe and Forrester 1983). Station samples from different dates were used as individual observations, these observations were a compilation of three replicate seines at that station. The observations were recorded as presence or absence, and given a 0 or 1 respectively, of each species identified in each replicate throughout the study. If only one occurrence of species was present throughout the study, it was classified as a unique species. The estimate of species richness was calculated for both sites in the summer season (June-August), in the fall and winter (September-March) and the spring season (May I and II).

**Community Similarity**
Similarity of fish species composition between New Bedford Harbor and the Slocums River was analyzed by Dr. James Heltshe by using a program designed to test community similarity as described by Smith et al., 1990. This procedure generates a similarity matrix between the two populations of species by using a distance metric. A permutation test is run to determine if between similarities are significantly different from within similarities.

Sixteen observations were used from July and August at each location in the analysis. The observations were the compilation of three seines at each station, each station was sampled twice during July and August.

**T-test**

A nonpooled t-test for two population means, assuming that standard deviations were not equal, was performed to detect significant differences between the two sites for condition factor $k$, biomass $m^{-2}$, numbers $m^{-2}$, diversity indices, species richness and EBI scores. Rejection of the null hypothesis occurred if the test statistic, $t$, fell outside of the critical values.

A mean $k$, condition factor, was calculated from a subsample of fish of one particular species from different stations and seines. A sample standard deviation was calculated, and the t-test was performed using the overall mean and deviation of this subset.

Averages fish biomass $m^{-2}$, based on wet weight and dry weight, and abundance (individuals $m^{-2}$) were calculated for each month in each location. The t-test was performed using the mean of these monthly values and the sample standard deviation was calculated between months.
EBI scores at each station over July and August were averaged in each site. The mean between the four stations, and the sample standard deviation were used in the t-test.

The jacknife estimates of diversity and species richness along with variances were used directly in the t-test. An individual t-test was performed for summer, fall/winter and spring to detect significant differences in separate seasons.

RESULTS

Species Assemblages

Fish species assemblages were less diverse in New Bedford Harbor compared to the Slocums River. A total of 27 species were collected between the two sites from June 1994 to May 1995 (Table 2). In New Bedford Harbor, 18 species were identified and 5 species were found only in New Bedford. In the Slocums River, 22 species were identified and 9 species were found only in the Slocums River. Station 1, in New Bedford had the highest number of species (14) in New Bedford Harbor while station 3 had the lowest number of species (6). Station 1 in the Slocums River had the highest number of species (18), while station 3 had the lowest number (12). Station 1 in both locations was the furthest station upstream, the higher range of salinity may be the reason why a greater number of species was found at these stations. Over 90% of abundance in New Bedford Harbor was comprised of Menidia species and Fundulus heteroclitus. In comparison, over 90% of abundance in the
Slocums River was comprised of *Fundulus heteroclitus*, *Menidia* species and *Fundulus Majalis*. The most abundant species in New Bedford Harbor was *Menidia* species, while *Fundulus heteroclitus* dominated in the Slocums River. There was a greater number of minor species, particularly unique species, in the Slocums River. The community similarity analysis of species composition at both locations performed by Dr. James Heltshe showed that community structure was dissimilar at the 5% level of significance (Smith et al. 1990) (Table 3).

**Seine Efficiency**

The test for seine efficiency was performed five times, with an average of 88% +/- 8% (standard deviation). Total numbers of each seine was used, seine efficiency of individual species was not calculated. The location seined was a flat sandy area without any submerged marsh area, macroalgae or rocks. The raw data for calculation of seine efficiency is in Appendix B.

**Biomass and Abundance**

Dry weight biomass throughout the study in New Bedford was 13,862 g; dry weight biomass in the Slocums River was 7,710 g (Table 2). The total number of fish collected in New Bedford Harbor throughout the entire study period was 32,027 individuals. In comparison, 20,864 individuals were collected in the Slocums River (Table 2).

Monthly average biomasses m² calculated by wet weight and dry weight, were higher in New Bedford during August, 1994, through December, 1994, than in the Slocums River (Fig. 3 and 4, Appendix C). The length -
weight regressions which were used to calculate biomass throughout the study are listed in Appendix C. The other months, December, 1994, through May, 1995, had similar biomass means in the two sites. The t-test showed that mean monthly dry weight biomass from June, 1994, to May, 1995, was significantly higher in New Bedford at the 5% level of significance, where New Bedford had a monthly average of 0.24g dry weight/m² (corrected for seine efficiency) +/- 0.2 (standard deviation); and the Slocums River average was 0.10 g dry weight/m² (corrected for seine efficiency) +/- 0.05 (standard deviation) (Table 4). New Bedford had a monthly average of 0.74g wet weight/m² (corrected for seine efficiency) +/- 0.68 (standard deviation); and the Slocums River average was 0.32 g dry weight/m² (corrected for seine efficiency) +/- 0.19 (standard deviation) (Table 4). Biomass monthly means based on wet weight were not significantly different between the two sites at the 5% level of significance (Table 4), but were at the 10% level of significance. Even though dry weight and wet weight data were roughly parallel, the wet weight data was more variable, leading to less stringent differences. New Bedford had a monthly average of 0.47 individuals/m² (corrected for seine efficiency) +/- 0.46 (standard deviation); and the Slocums River average was 0.27 individuals/m² (corrected for seine efficiency) +/- 0.22 (standard deviation) (Table 4). Test of differences in monthly means of individuals m⁻² between the two sites by a t-test showed that there were no significant differences in individuals m⁻² between June 1994 to May 1995 (Table 4).

Growth Rate
Growth rates of *Menidia* species were higher in New Bedford Harbor from June to July, July to August and August to October than in the Slocums River (Fig. 6). The differences in *Menidia* growth rates were significant at the 5% level of significance (Appendix E). *Fundulus heteroclitus* growth rates were similar between New Bedford Harbor and the Slocums River (Fig. 7). *Fundulus majalis* growth rates were higher in New Bedford Harbor at the 95% confidence limit from June to July and from July to August (Fig. 8). The growth rates generated by the bootstrapping program are in Appendix F, the length-frequency data pooled for each month used in the bootstrapping program are in Appendix G, and the bootstrapping program itself is in Appendix H.

**Diversity Indices and Species Richness**

The difference in species diversity and richness between the two sites was most evident in the summer season. In summer, significant differences at the 95% confidence limit were evident for the Shannon-Wiener index where New Bedford was $0.329 +/- 0.005$ (variance of the estimator) and the Slocums River was $0.541 +/- 0.002$ (variance of the estimator); and the Simpson index where New Bedford was $0.391 +/- 0.013$ and the Slocums River was $0.666 +/- 0.001$ (variance of the estimator). Differences were evident in species richness in the summertime also, where New Bedford had $16.01 +/- 0.92$ species, and the Slocums River had $26.85 +/- 9.02$ species (Table 5, Appendix I and J). Throughout the fall/winter and the spring, the only
significant difference at the 5% level of significance was in the Shannon-Wiener index which remained higher for the Slocums River (Table 5).

**Application of the EBI**

The resulting EBI scores for stations in both sites were below the minimum criteria for good quality eelgrass habitat. An overall score of less than 30 is considered low for the EBI; total EBI scores generated from both biomass and abundances failed to score above 30 (Tables 6, 7). The average EBI score based on wet weight biomass in New Bedford was 10.06 +/- 5.18 (standard deviation) and 11.42 +/- 3.39 in the Slocums River. Average EBI scores based on numbers were 9.23 +/- 4.02 in New Bedford Harbor and 11.38 +/- 3.13 in the Slocums River. In comparison, application of the EBI using biomass in Buttermilk Bay gave a medium-quality eelgrass station a score of 36, while three low quality stations scored 27, 29 and 30. Using numbers to estimate EBI from the same data gave an EBI score of 39 for the medium quality data and the low quality stations scored 23, 30 and 33 (Deegan et al, 1993). A t-test using the mean and sample standard deviation between stations in each estuary showed no significant differences in EBI scores between the two sites (Table 8). The two sites had low EBI scores due to the failure of meeting different criteria. New Bedford failed to meet minimum criteria in number of species per replicate, which was 6 species; whereas the Slocums River met this criteria. The Slocums River failed to meet the criteria for biomass; whereas New Bedford stations scored higher in biomass. Metrics
that both sites failed to meet were number of estuarine spawners, number of nursery species and number of resident species (Tables 6,7).

**Condition factor**

The condition factor, $k$, was not significantly different between New Bedford Harbor and the Slocums River for *Menidia* species, or for *Fundulus heteroclitus* (Table 9). However, there appeared to be a significant difference at the 5% level of significance for *Fundulus majalis*, where the condition factor was higher for this species in New Bedford, $0.0032$, compared with $k=0.0025$ in the Slocums River (Table 9).

**DISCUSSION**

A comparison of fish species assemblages in New Bedford Harbor and the Slocums River with Waquoit Bay, MA, (Ayvazian 1992) showed that marsh, beach and deeper open water habitats, with the exclusion of eelgrass sites, in Waquoit Bay had a higher diversity of fish species (Table 10). The depth ranges of Waquoit Bay were up to 4 m, with most of the area less than 2 m in depth. The bathymetry was similar to the Slocums River, which had an average depth of 2 m, and is dissimilar to New Bedford Harbor which had an average depth of 4 m. Monthly seine and trawl samples collected from nearshore, shallow water marsh, and beach and deeper open water habitats in
Waquoit Bay included 48 species compared to 18 species collected in New Bedford Harbor and 22 species collected in the Slocums River during this study. However, the increased number of species collected in Waquoit Bay may be due to larger sampling effort, where eight stations in Waquoit Bay were sampled. The abundance of fish was much higher in Waquoit Bay, when compared to New Bedford Harbor and the Slocums River. The peak of monthly abundance (July-September) in Waquoit Bay ranged from 96 - 796 per 100 m², in New Bedford Harbor the peak (July-August) ranged from 66 - 149 per 100 m², and in the Slocums River the peak (July-August) ranged from 49 - 67 per 100 m².

The diversity of New Bedford and Slocums River were more similar to the fish species assemblages in Bissel Cove, Rhode Island (Nixon and Oviatt 1973) where a variety of fishing methods were employed. The average depth of Bissel Cove at mean low tide was 0.25 m. In Bissel Cove, twenty species of fish were collected in the embayment over the entire year, five of these species were unique from species collected in New Bedford Harbor and the Slocums River. However, fish biomass was higher in Bissel Cove when compared to New Bedford and the Slocums River, where summer biomass was 30 - 800 grams dry weight per 100 m² in Bissel Cove, compared to 5 - 66 grams dry weight per 100 m² in New Bedford Harbor, and 3 - 17 grams dry weight per 100 m² in the Slocums River.

The high density of macroalgae in the Slocums River, which was often pulled up in large amounts in the seine, may have interfered with seine
efficiency. Throw trap samples are more efficient than beach seines in heavily vegetated sites, with catch efficiencies for epibenthic fishes from 70% to nearly 100% (Sogard and Able, 1991). Beach seines are likely less efficient for active water column species if the seine is filled with macroalgae. The seine efficiency measured in this study, 88% +/- 8%, was performed in a sandy area without any macroalgae present. Therefore, it is likely that the seine efficiency was much lower in the Slocums River due to high macroalgae biomass.

Fish condition, biomass and growth rates measured in this study indicated that New Bedford Harbor fish populations were not degraded in relation to a comparison site. The condition factor, k, which is an indicator of health did not differ between the two sites for Menidia species and Fundulus heteroclitus. Furthermore, the condition factor of Fundulus majalis was higher in New Bedford Harbor than the Slocums River. The growth rate of Menidia species was higher from June-October, and Fundulus majalis growth rate was higher from June-August, in New Bedford Harbor than the Slocums River. Barkman (1978) has found that counting otolith daily growth rings for growth rates is more accurate than using length frequency data. The presence of cohorts in length frequency data may underestimate the growth rate. The implications of this are that there is a real difference in growth rates of Menidia and Fundulus majalis between the two sites, but these growth rates are likely underestimated. The higher condition factor and growth rate of Fundulus majalis in New Bedford Harbor may be explained by the fact that
*Fundulus majalis* prefers deeper water. Average monthly dry-weight biomass m\(^2\) was significantly higher in New Bedford Harbor. The fact that average monthly individuals m\(^2\) between the two sites were not significantly different while monthly biomass m\(^2\) was, is an indication that fish were generally larger in New Bedford Harbor. Therefore, New Bedford fish were not only in good condition, but also seemed to have higher growth rates and size.

The increased growth rate and resulting higher biomass of *Menidia* species in New Bedford Harbor may be due to the higher phytoplankton primary production and phytoplankton biomass in New Bedford Harbor (Absher and Oviatt 1995). The increased primary production was a result of high nutrient loadings due to urbanization of the harbor area. *Menidia menidia* and *Menidia berrylina* are both plankton feeders, and feed in the pelagic zone (Bigelow and Schroeder 1953). The higher rate of phytoplankton production in New Bedford Harbor could have led to the dominance of *Menidia* species in this system. In contrast, *Fundulus heteroclitus*, a benthic omnivore, was the dominant species in the Slocums River. Although high primary production may limit fisheries yields in some cases by creating anoxic areas, the eutrophication in New Bedford Harbor does not appear to limit fish yield, at least in comparison to a less disturbed site.

More diverse community structure and higher species richness in the Slocums River suggested that the Slocums River had more ecological niches available than New Bedford Harbor. A basic tenet of ecology is that each
species belongs to a particular niche, and disturbance of habitat may narrow the number of niches available. It is difficult to surmise whether the differences in diversity and species richness were due to natural variations or disruption of habitat by human impacts. The fact that the Slocums River supported many more Spartina marsh areas than New Bedford Harbor, and that more marsh areas were sampled in the Slocums River, suggests that increased diversity was due to more habitat with vegetation which typically supports a wider diversity of species than beach habitats (Heck et al. 1989, Lubbers et al. 1990, Sogard and Able, 1991).

The decreased diversity in New Bedford Harbor, relative to the Slocums River, was possibly due to human influence. A land usage map dated back to 1780 provided by Richard Voyer (EPA, Narragansett, RI) showed a larger extent of salt marsh around the harbor area than is present today. Many of these wetlands were filled for development of wharves and industrial ports. In addition, dredging of the shipping channel, construction of the hurricane barrier and other structures in the harbor have disturbed the natural habitat. These events could have led to the decreased diversity of fish species in comparison to the Slocums River and Waquoit Bay.

The EBI score showed no differences in the quality of habitat in the two estuaries. However, examination of fish community parameters measured showed real differences in fish biomass, where the biomass $m^2$ was higher in New Bedford. By contrast, diversity and species richness were higher in the Slocums River. The assumption of the index is that human disturbances will
decrease both biomass and diversity. These inversely related parameters between the two sites balanced each other to give a similar total score. The EBI is not designed to detect habitat quality in non-eelgrass habitats; the index indicated that both the Slocums River and New Bedford Harbor have poor habitats for estuarine fish compared to eelgrass habitats. Poor habitat is indicated by low dissolved oxygen, high nutrients, high biomass of macroalgae and reduced circulation (Deegan et al, 1993). Dissolved oxygen was measured at water quality stations in the middle of each estuary, the levels of oxygen were acceptable at the two sites (Absher and Oviatt 1995). Nutrient concentrations measured at fish habitat stations were higher in New Bedford than the Slocums River, but nutrients were not extraordinarily high at either site when compared to concentrations in Delaware Bay and the Dennison Water Quality Index (Absher and Oviatt 1995). Water exchange rates were fast in both estuaries with residence times of approximately two days (Ed Dettman, EPA). Therefore, it does not appear that the habitat quality of stations at the two sites was greatly compromised.

CONCLUSIONS:

Our data showed that there were real differences in fish biomass, fish growth rates and community structure between New Bedford Harbor and the Slocums River. Higher biomass and increased growth rate of Menidia species as well as Fundulus majalis in New Bedford Harbor was evident. This difference in biomass and growth rate of Menidia species may be due to the
higher rate of phytoplankton production in New Bedford Harbor which has increased the biomass of upper trophic levels. Species richness and diversity estimates showed that diversity of fish species is higher in the Slocums River. Differences in species assemblages can be explained by the presence of more Spartina marsh sites at the Slocums River. Historical maps of land usage have shown the presence of many wetland areas around New Bedford Harbor in the late 1700s, these areas have been filled for development purposes.

The Index of Estuarine Biotic Integrity did not show significant differences in the quality of habitat between the two locations. Furthermore, the EBI ranked all stations in both estuaries as poor quality habitat. The EBI is recommended for eelgrass habitats, since the best correlation between poor water quality characteristics and poor fish parameters has been in eelgrass habitats. The EBI may not be applicable to this study, since there were no eelgrass beds in the two sites.

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Figure 1. The study area, New Bedford Harbor, and comparison site, the Slocums River, are both located on the southeast coast of Massachusetts. Locations of deep stations, A, B, and C as well as shoreline stations 1, 2, 3 and 4 are indicated. Transects for macroalgae biomass are indicated by a line with arrowheads.
Figure 2a. Depth contour plot of New Bedford Harbor.
Figure 2b. Depth contour plot of Slocums River.
Figure 3. Average monthly biomass, based on dry weight, from June 1994 to May 1995. Closed circles represent New Bedford Harbor, open circles represent the Slocums River.
Figure 4. Average monthly biomass, based on wet weight, from June 1994 to May 1995. Closed circles represent New Bedford Harbor, open circles represent the Slocums River.
Figure 5. Average monthly abundance of individuals from June 1994 to May 1995. Closed circles represent New Bedford Harbor, open circles represent the Slocums River.
Figure 6. Growth rates of Menidia species based on length frequency data for the periods of June 1994 - July 1994, July 1994 - August 1994 and August 1994 - October 1994. Closed circles represent New Bedford Harbor, open circles represent the Slocums River. The range lines represent standard deviation calculated by the bootstrapping program.
Figure 7. Growth rates of Fundulus heteroclitus based on length frequency data for the periods of June 1994 - July 1994, July 1994 - August 1994 and August 1994 - October 1994. Closed circles represent New Bedford Harbor, open circles represent the Slocums River. The range lines represent standard deviation calculated by the bootstrapping program.
Figure 8. Growth rates of Fundulus majalis based on length frequency data for the periods of June 1994 - July 1994, July 1994 - August 1994 and August 1994 - October 1994. Closed circles represent New Bedford Harbor, open circles represent the Slocums River. The range lines represent standard deviation calculated by the bootstrapping program.
| Location       | Station | Depth   | Habitat        | Substrate     | Salinity range |
|----------------|---------|---------|----------------|---------------|----------------|
| New Bedford    | 1       | Shoreline | Spartina marsh | mud           | 27-31          |
|                | 2       | Shoreline | beach          | sand/mud      | 23-32          |
|                | 3       | Shoreline | beach          | cobble/shell  | 30-32          |
|                | 4       | Shoreline | beach          | sand          | 30-32          |
| Slocums River  | 1       | Shoreline | Spartina marsh | mud           | 15-31          |
|                | 2       | Shoreline | Spartina marsh | mud           | 20-31          |
|                | 3       | Shoreline | Spartina marsh | sand/mud      | 28-32          |
|                | 4       | Shoreline | beach          | sand/mud      | 28-32          |

Table 1. Description of habitat and salinity ranges for stations 1, 2, 3 and 4 in New Bedford Harbor and the Slocums River.
| Species                     | Station 1 numbers | biomass | Station 2 numbers | biomass | Station 3 numbers | biomass | Station 4 numbers | biomass | Total numbers | biomass |
|-----------------------------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|---------|---------------|---------|
| *Gasterosteus aculeatus*    | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0             | 0       |
| *Alosa pseudoharengus*     | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0             | 0       |
| *Anguilla rostrata*        | 1                 | 0.03    | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0             | 0       |
| *Apeltes quadratus*        | 2                 | 0.1     | 2                 | 0.19    | 0                 | 0       | 0                 | 0       | 4             | 0.29    |
| *Brevoortia tyrannus*      | 1                 | 0.05    | 1                 | 0.15    | 2                 | 0.02    | 12                | 23.58   | 16            | 23.8    |
| *Caranx chrysa*            | 3                 | 4.53    | 1                 | 1.45    | 0                 | 0       | 10                | 9.7     | 14            | 15.68   |
| *Clupea harengus*          | 0                 | 0       | 0                 | 0       | 0                 | 0       | 1                 | 2.94    | 1             | 2.94    |
| *Cyprinodon variegatus*    | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0             | 0       |
| *Eucinostomus lefroyi*     | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0             | 0       |
| *Fundulus heteroclitus*    | 893               | 482.45  | 2112              | 1081.78 | 98                | 85.48   | 1710              | 1243.83 | 4813         | 2893.54 |
| *Fundulus majalis*         | 329               | 351.51  | 2901              | 1686.88 | 359               | 282.98  | 930               | 752.01  | 4579         | 3073.38 |
| *Gobiosoma robustum*       | 6                 | 0.75    | 3                 | 0.411   | 9                 | 0.65    | 4                 | 0.32    | 22           | 2.13    |
| *Lucania parva*            | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0             | 0       |
| *Lutianeus griseus*        | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0             | 0       |

Table 2a
| Species                    | Station 1  |             | Station 2  |             | Station 3  |             | Station 4  |             | Total      |             |
|----------------------------|------------|-------------|------------|-------------|------------|-------------|------------|-------------|------------|-------------|
|                            | numbers    | biomass     | numbers    | biomass     | numbers    | biomass     | numbers    | biomass     | numbers    | biomass     |
| Menidia sp.                | 2590       | 1016.4      | 2983       | 1815.2      | 8134       | 1971.7      | 8772       | 2987.58     | 22479      | 7790.88     |
| Menticirrhus saxatilis     | 0          | 0           | 0          | 0           | 0          | 0           | 0          | 0           | 0          | 0           |
| Microgadus tomcod          | 0          | 0           | 0          | 0           | 0          | 0           | 0          | 0           | 0          | 0           |
| Mugil cephalus             | 5          | 28.4        | 2          | 0.61        | 0          | 0           | 0          | 0           | 7          | 29.01       |
| Myoxocephalus octodeci     | 0          | 0           | 0          | 0           | 0          | 0           | 1          | 0.19        | 1          | 0.19        |
| Opsanus tau                | 0          | 0           | 0          | 0           | 0          | 0           | 2          | 0.26        | 2          | 0.26        |
| Pleuronectes americanus    | 5          | 1.86        | 1          | 0.55        | 0          | 0           | 5          | 4.9         | 2          | 0.26        |
| Pungitius pungitius        | 0          | 0           | 0          | 0           | 0          | 0           | 1          | 0.09        | 1          | 0.09        |
| Sygnathus fuscus           | 6          | 0.73        | 1          | 0.12        | 0          | 0           | 0          | 0.09        | 7          | 0.85        |
| Tautogolabrus adspersus    | 9          | 1.3         | 20         | 0.94        | 0          | 0           | 50         | 7.98        | 79         | 10.22       |
| Tautoga onitis             | 3          | 0.23        | 4          | 0.71        | 9          | 0.6         | 22         | 1.23        | 38         | 2.77        |
| Trinectes maculatus        | 0          | 0           | 0          | 0           | 0          | 0           | 0          | 0           | 0          | 0           |
| **TOTAL**                  | 3853       | 1888.34     | 8031       | 4588.991    | 8611       | 2341.43     | 11520      | 5034.61     | 32065      | 13846.29    |

Table 2a
| Species                  | Station 1 |        | Station 2 |        | Station 3 |        | Station 4 |        | Total   |        |
|--------------------------|-----------|--------|-----------|--------|-----------|--------|-----------|--------|---------|--------|
|                          | numbers   | biomass| numbers   | biomass| numbers   | biomass| numbers   | biomass| numbers | biomass|
| Gasterosteus aculeatus   | 0         | 0      | 0         | 0      | 1         | 0.48   | 1         | 0.11   | 2       | 0.59   |
| Alosa pseudoharengus     | 1         | 1.18   | 0         | 0      | 0         | 0      | 0         | 0      | 1       | 1.18   |
| Anguilla rostrata        | 12        | 1.68   | 20        | 3.46   | 2         | 0.21   | 13        | 1.12   | 47      | 6.47   |
| Aplats quadratus         | 63        | 5.73   | 249       | 15.64  | 31        | 2.5    | 35        | 56.22  | 378     | 80.09  |
| Brevortia tyrrannus      | 217       | 219.55 | 0         | 0      | 3         | 2.11   | 0         | 0      | 226     | 221.66 |
| Carax chrysus            | 14        | 4.56   | 0         | 0      | 0         | 0      | 0         | 0      | 14      | 4.56   |
| Clupea harengus          | 0         | 0      | 0         | 0      | 0         | 0      | 0         | 0      | 0       | 0      |
| Cyprinodon variegatus    | 709       | 85.61  | 0         | 0      | 9         | 1.63   | 16        | 2.4    | 734     | 89.64  |
| Eucinostomus lefroyi     | 76        | 13.01  | 1         | 0.25   | 0         | 0      | 0         | 0      | 77      | 13.26  |
| Fundulus heteroclitus    | 1253      | 469.84 | 225       | 62.67  | 1131      | 1818.53| 5751      | 1902.5 | 8360    | 4253.54|
| Fundulus majalis         | 423       | 108.11 | 89        | 30.19  | 109       | 9.6    | 1966      | 917.62 | 2587    | 1065.52|
| Cobirosoma robustum      | 0         | 0      | 0         | 0      | 0         | 0      | 0         | 0      | 0       | 0      |
| Lucania parva            | 1         | 0.04   | 1         | 0.08   | 2         | 0.28   | 1         | 0.04   | 5       | 0.44   |
| Lutianeus griseus        | 0         | 0      | 3         | 3.7    | 0         | 0      | 1         | 0.4    | 4       | 4.1    |

**Table 2b**
| Species                      | Station 1 numbers | Station 1 biomass | Station 2 numbers | Station 2 biomass | Station 3 numbers | Station 3 biomass | Station 4 numbers | Station 4 biomass | Total numbers | Total biomass |
|------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|---------------|---------------|
| Menidia sp.                  | 3030              | 834.59            | 1230              | 266.17            | 2941              | 601.49            | 1033              | 171.35           | 8234          | 1873.6        |
| Menticirrhhus saxatilis      | 0                 | 0                 | 1                 | 5.43              | 0                 | 0                 | 1                 | 1.25              | 2             | 6.68          |
| Microgadus tomcod            | 0                 | 0                 | 6                 | 1.31              | 5                 | 3.44              | 0                 | 0                 | 11            | 4.75          |
| Mugil cephalus               | 5.4               | 18                | 22                | 0.69              | 0                 | 0                 | 109               | 38.2              | 132           | 61.29         |
| Myoxocephalus octodec        | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0             | 0             |
| Opsanus tau                  | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0             | 0             |
| Pleuronectes americanus      | 2                 | 0.26              | 0                 | 0                 | 4                 | 7.54              | 4                 | 3.54              | 10            | 11.34         |
| Pungitius pungitius          | 2                 | 0.2               | 8                 | 0.37              | 0                 | 0                 | 1                 | 0.4               | 11            | 0.97          |
| Sygnathus fuscus             | 1                 | 0.09              | 16                | 2.45              | 1                 | 0.56              | 0                 | 0                 | 18            | 3.1           |
| Tautogolabrus adspersu       | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0             | 0             |
| Tautoga onitis               | 1                 | 0.04              | 1                 | 0.74              | 0                 | 0                 | 1                 | 0.57              | 3             | 1.35          |
| Trinectes maculatus          | 1                 | 1.81              | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 1             | 1.81          |
| **TOTAL**                    | **5811.4**         | **1764.3**        | **1872**          | **393.15**        | **4239**          | **2448.37**       | **8933**          | **3095.72**       | **20851**     | **7705.94**    |

Table 2b
**SLOCUMS RIVER**

|                | JULY I | JULY II | AUGUST I | AUGUST II |
|----------------|--------|---------|----------|-----------|
| Aloès pseudoharengus | 5      | 13      |          |           |
| Anguilla        | 42     | 52      | 9        | 3         | 32        | 26        | 6         |
| Apeltes         | 48     | 3       |          | 167       | 25        |           |
| Brevoortia      |        |         |          |           |           |           |
| Caranx chrysus  | 14     |          | 7        | 1         | 5         |           |
| Caranx hippos   |        |         | 3        | 47        | 11        | 1         |
| Clupea harengus |        |         |          | 23        |           |           |
| Cyprinodon v.   | 3      | 1       | 4        | 11        | 1         |
| Euchinostomus   |        |         |          | 23        |           |           |
| F. heteroclitus | 32     | 86      | 2343     | 202       | 28        | 3         | 883       | 2         | 8        | 2095      | 123       | 22        | 809       | 292       |
| F. majalis      | 12     | 11      | 138      | 65        | 11        | 682       | 17        | 18        | 656       | 162       | 2         | 65        | 6         |
| Gobiosoma       |        |         |          | 1         |           |           |
| Lucania parva   | 1      | 1       |          | 2         | 1         |
| Lutjanus griseus|        |         |          | 1         |           |           |
| Menidia         | 202    | 6       | 439      | 463       | 15        | 442       | 1128      | 219       | 190       | 203       | 981       | 188       | 2053      | 476       | 124       | 4         |
| Menticirrhhus   |        |         |          | 1         |           |           |
| Microgadus tomcod|       |         |          | 1         |           |           |
| Mugil cephalus  | 2      |          | 107      | 18        |
| Myoxocephalus   |        |         |          |           |           |           |
| Opsanus         |        |         |          |           |           |           |
| Pleuronectes    | 1      | 1       | 1        | 3         |
| Pungitius       |        |         |          |           |           |           |
| Sygnathus       | 1      | 2       | 5        | 8         | 1         | 1         |
| T. adspersus    |        |         |          |           |           |           |
| T. onitus       | 1      |          |          |           |           |           |
| Trinectes       | 1      |          |          |           |           |           |

Table 3b
### Table 3a and 3b

Data used in analyzing community similarity (Smith et al., 1990). Species counts at stations 1, 2, 3 and 4 during July and August in New Bedford Harbor (Table 3a) and the Slocums River (Table 3b). A total of sixteen replicates from each location were used. (J. Heltsh, pers. comm.).

| Species                  | JULY I 1 | JULY I 2 | JULY I 3 | JULY I 4 | JULY II 1 | JULY II 2 | JULY II 3 | JULY II 4 | AUGUST I 1 | AUGUST I 2 | AUGUST I 3 | AUGUST I 4 | AUGUST II 1 | AUGUST II 2 | AUGUST II 3 | AUGUST II 4 |
|--------------------------|---------|---------|---------|---------|-----------|-----------|-----------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|
| Alosa pseudoharengus     |         |         |         |         | 1         |           |           |           | 1          | 2          |            |            | 45         | 788        | 4          | 97         |
| Anguilla                 |         |         |         |         | 2         | 5         | 1         | 1         | 2          |            |            |            |            |            |            |            |
| Apeltes                  | 2       | 4       | 1       | 7       | 3         | 6         | 3         |           |            |            |            |            |            |            |            |
| Brevoortia               |         |         |         |         |           |           |           |           |            |            |            |            |            |            |            |            |
| Caranx chrysus           | 2       | 4       | 1       | 7       | 3         | 6         | 3         |           |            |            |            |            |            |            |            |            |
| Caranx hippos            | 1       |         |         |         | 1         |           |           |           |            |            |            |            |            |            |            |            |
| Clupea harengus          | 193     | 238     | 17      | 218     | 171       | 246       | 47        | 296       | 111        | 144        | 6          | 985        | 45         | 788        | 4          | 97         |
| Cyprinodon v.             | 64      | 102     | 8       | 47      | 21        | 978       | 149       | 100       | 41         | 126        | 12         | 468        | 22         | 595        | 94         | 88         |
| Euchinostomus            | 424     | 79      | 5525    | 4799    | 1593      | 108       | 712       | 99        | 73         | 580        | 1697       | 716        | 86         | 1723       | 247        | 2784       |
| F. heteroclitus           | 9       |         |         |         | 3         |           |           |           | 1          |            |            |            |            |            |            |            |
| F. majalis               | 9       |         |         |         | 3         |           |           |           | 1          |            |            |            |            |            |            |            |
| Cobiosoma                |         |         |         |         | 6         | 978       | 149       | 100       | 41         | 126        | 12         | 468        | 22         | 595        | 94         | 88         |
| Lucania parva            | 1       |         |         |         | 1         |           |           |           | 2          |            |            |            |            |            |            |            |
| Lutjanus griseus         | 1       |         |         |         | 1         |           |           |           | 2          |            |            |            |            |            |            |            |
| Menidia                  | 424     | 79      | 5525    | 4799    | 1593      | 108       | 712       | 99        | 73         | 580        | 1697       | 716        | 86         | 1723       | 247        | 2784       |
| Menticirrhus             |         |         |         |         | 6         | 978       | 149       | 100       | 41         | 126        | 12         | 468        | 22         | 595        | 94         | 88         |
| Microgadus tomcod        |         |         |         |         | 1         |           |           |           | 1          |            |            |            |            |            |            |            |
| Mugil cephalus           |         |         |         |         | 1         |           |           |           | 1          |            |            |            |            |            |            |            |
| Myoxocephalus            |         |         |         |         | 1         |           |           |           | 1          |            |            |            |            |            |            |            |
| Oplatus                   | 1       |         |         |         | 1         |           |           |           | 1          |            |            |            |            |            |            |            |
| Pleuronectes             | 1       | 4       |         |         |           |           |           |           |            |            |            |            |            |            |            |            |
| Pungitius                | 1       | 4       |         |         |           |           |           |           |            |            |            |            |            |            |            |            |
| Sygnathus                | 1       |         |         |         | 1         |           |           |           | 2          |            |            |            |            |            |            |            |
| T. adspersus             | 1       | 4       | 1       | 18      | 24        | 13        | 3         |           |            |            |            |            |            |            |            |            |
| T. onitus                | 6       | 7       |         |         | 3         |           |           |           |            |            |            |            |            |            |            |            |
| Trinectes                |         |         |         |         |           |           |           |           |            |            |            |            |            |            |            |            |            |
Table 4. Nonpooled t-test for independent samples assuming unequal variances (NB=New Bedford, SR=Slocums River) for testing significant differences at the 5% level of significance for monthly average biomass (based on wet weight and dry weight) and monthly abundance from June 1994 to May 1995.
| Statistics                        | Summer | Fall/Winter | Spring |
|----------------------------------|--------|-------------|--------|
|                                  | Shannon-Wiener index | Simpson index | Species | Shannon-Wiener index | Simpson index | Species | Shannon-Wiener index | Simpson index | Species |
|                                 | NB     | SR          | NB     | SR          | NB     | SR          | NB     | SR          | NB     | SR          |
| Jackknife estimate              | 0.329  | 0.541       | 0.391  | 0.666       | 16.01  | 26.85       | 0.38   | 0.728       | 0.5    | 0.901       |
| Jackknife variance              | 0.005  | 0.002       | 0.013  | 0.001       | 0.92   | 9.02        | 0.014  | 0.007       | 0.04   | 0.044       |
| degrees freedom                 | 38.58  | 28.43       | 30.05  | 19.74       | 23.9   | 23.25       | 23.25  | 13.91       | 10.76  | 12.39       |
| t                               | 2.5    | 2.34        | 3.43   | 2.37        | 1.41   | 1.12        | 2.54   | 1.5         | 0.21   |
| t crit (alpha=0.05)             | 1.96   | 2.05        | 1.96   | 2.09        | 2.06   | 2.07        | 2.15   | 2.2         | 2.18   |
| NB=SR                           | NO     | NO          | NO     | NO          | YES    | YES         | NO     | YES         | YES    |

Table 5. Nonpooled t-test for independent samples assuming unequal variances (NB=New Bedford, SR=Slocums River) for testing significant differences at the 5% level of significance for estimates of diversity during the summer, fall/winter and spring seasons. The indices used were the Shannon-Wiener index, the Simpson index and species richness.
| Metrics                     | EBI (biomass) | NB 1 | NB 2 | NB 3 | NB 4 | SR 1 | SR 2 | SR 3 | SR 4 |
|-----------------------------|---------------|------|------|------|------|------|------|------|------|
| Species Composition         |               |      |      |      |      |      |      |      |      |
| number of species           | <6            | 3.75 | 2    | 1.5  | 5.75 | 7.25 | 6.5  | 5    | 6.25 |
| number estuarine spawners   | <3            | 0.75 | 0    | 0.75 | 2.5  | 0.5  | 0    | 0    | 0    |
| number nursery species      | <3            | 0    | 1.5  | 1    | 3    | 0.75 | 0.75 | 0    | 0.75 |
| number resident species     | <4            | 3.5  | 1.25 | 0    | 0    | 2.5  | 2.25 | 1    | 3    |
| Fish Abundance and Health   |               |      |      |      |      |      |      |      |      |
| Abundance                   | <4 g/m^2      | 0.31 | 2.68 | 1.24 | 3.06 | 0.4  | 0    | 0.4  | 1.37 |
| Dominance                   | <3            | 1.5  | 1.5  | 0    | 1.75 | 3.25 | 2.25 | 0    | 0    |
| Abnormality                 | >0.01%        | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Foodweb                     |               |      |      |      |      |      |      |      |      |
| Benthic fishes              | <0.9%         | 0    | 0    | 0    | 0.94 | 0    | 0.32 | 0.24 | 0.96 |
| Overall Score               |               |      |      |      |      |      |      |      |      |
| Low for EBI                 | <30           | 9.81 | 8.93 | 4.49 | 17   | 14.65| 12.07| 6.64 | 12.33|

Table 6
| Metrics                      | EBI (numbers) | NB 1 | NB 2 | NB 3 | NB 4 | SR 1 | SR 2 | SR 3 | SR 4 |
|------------------------------|---------------|------|------|------|------|------|------|------|------|
| Species Composition          |               |      |      |      |      |      |      |      |      |
| number of species            | <6            | 3.75 | 2    | 1.5  | 5.75 | 7.25 | 6.5  | 5    | 6.25 |
| number estuarine spawners    | <3            | 0.75 | 0    | 0.75 | 2.5  | 0.5  | 0    | 0    | 0    |
| number nursery species       | <3            | 0    | 0.75 | 1    | 3    | 0.75 | 0.75 | 0    | 0.75 |
| number resident species      | <4            | 3.5  | 1.25 | 0    | 0    | 2.5  | 2.25 | 1.33 | 3    |
| Fish Abundance and Health    |               |      |      |      |      |      |      |      |      |
| Abundance                    | <3.8 / m²     | 0.33 | 1.21 | 1.57 | 1.58 | 0.37 | 0    | 0.42 | 1.31 |
| Dominance                    | <3            | 1.75 | 2.25 | 0    | 1.5  | 2.5  | 1.75 | 0    | 0.75 |
| Abnormality                  | >0.01%        | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Foodweb                      |               |      |      |      |      |      |      |      |      |
| Benthic fishes               | <0.7%         | 0    | 0.23 | 0    | 0    | 0.23 | 0.24 | 0.22 | 0.91 |
| Overall Score                | Low for EBI   | <30  | 10.08| 7.69 | 4.82 | 14.33| 14.1 | 11.49| 6.97 | 12.97|

Table 7
| Station | EBI based on wet weight biomass | EBI based on abundance |
|---------|--------------------------------|------------------------|
|         | NB    | SR    | NB    | SR    |
| 1       | 9.81  | 14.65 | 10.08 | 14.1  |
| 2       | 8.93  | 12.07 | 7.69  | 11.49 |
| 3       | 4.49  | 6.64  | 4.82  | 6.97  |
| 4       | 17    | 12.33 | 14.33 | 12.97 |

Statistics

|         | average | NB    | SR    |
|---------|---------|-------|-------|
|         | 10.06   | 11.42 | 9.23  |
| s       | 5.18    | 3.39  | 4.02  |
| degrees freedom | 4  | 4    |
| t       | 0.76    | 1.46  |
| t crit  | 2.77    | 2.77  |
| (alpha=0.05) | YES | YES |

Table 8.
Table 9. Nonpooled t-test for independent samples assuming unequal variances (NB=New Bedford, SR=Slocums River) for testing significant differences at the 5% level of significance for condition factor k. Differences between the two sites for condition of *Menidia* species, *Fundulus heteroclitus* and *Fundulus majalis* were tested.

|                  | *Menidia* species $k$ | *Fundulus heteroclitus* $k$ | *Fundulus majalis* $k$ |
|------------------|-----------------------|-----------------------------|------------------------|
|                  | NB  | SR  | NB  | SR  | NB  | SR  |
| Statistics       |     |     |     |     |     |     |
| average          | 0.0015 | 0.0014 | 0.0032 | 0.0035 | 0.0032 | 0.0025 |
| s                | 0.0002 | 0.0006 | 0.0006 | 0.0036 | 0.0003 | 0.0025 |
| degrees freedom  | 118  | 117  | 115  |
| $t$              | 1.22 | 0.33  | 2.15 |
| $t$ crit         | 1.96 | 1.96  | 1.96 |
| (alpha=0.05)     |     |     |     |
| NB=SR            | YES | YES | NO  |
| Family               | New Bedford Harbor | Slocums River | Waquoit |
|----------------------|--------------------|---------------|---------|
| Elopidae             |                    |               |         |
| *Elops saurus*       | ✓                  |               | ✓       |
| Anguillidae          |                    | ✓             | ✓       |
| *Anguilla rostrata* | ✓                  | ✓             | ✓       |
| Clupeidae            |                    |               |         |
| *Alosa aestivalis*   |                    |               | ✓       |
| *Alosa sapidissima*  |                    |               | ✓       |
| *Clupea harengus*    | ✓                  | ✓             | ✓       |
| *Brevoortia tyrannus*| ✓                  | ✓             | ✓       |
| *Alosa pseudoharengus*|                  |               | ✓       |
| Engraulidae          |                    |               |         |
| *Anchoa hepsetus*    |                    | ✓             | ✓       |
| *Anchoa mitchilli*   |                    | ✓             | ✓       |
| Batrachoididae       |                    |               |         |
| *Opsanus tau*        | ✓                  |               | ✓       |
| Gadidae              |                    |               |         |
| *Microgadus tomcod*  | ✓                  |               | ✓       |
| Cyprinodontidae      |                    |               |         |
| *Fundulus heteroclitus*|                  |               | ✓       |
| *Fundulus majalis*   | ✓                  |               | ✓       |

Table 10
| Family Atherinidae | **Fundulus diaphanus** | ✓ | ✓ |
| | **Cyprinodon variegatus** | ✓ | ✓ |
| | **Lucania parva** | ✓ | ✓ |
| | **Menidia menidia** | ✓ | ✓ | ✓ |
| | **Menidia beryllina** | ✓ | ✓ | ✓ |
| Family Gasterosteidae | **Pungitius pungitius** | ✓ | ✓ | ✓ |
| | **Apeltes quadracus** | ✓ | ✓ | ✓ |
| | **Gasterosteus aculeatus** | ✓ | ✓ | ✓ |
| | **Gasterosteus wheatlandi** | ✓ | ✓ | ✓ |
| Family Sygnathidae | **Sygnathus fuscus** | ✓ | ✓ | ✓ |
| Family Percichthyidae | **Morone americana** | ✓ | ✓ | ✓ |
| Family Serranidae | **Centropristis striata** | ✓ | ✓ | ✓ |
| Family Pomatomidae | **Pomatomus saltatrix** | ✓ | ✓ | ✓ |
| Family Carangidae | **Caranx chrysus** | ✓ | ✓ | ✓ |

Table 10
| Species/Family         | Present | Absent | Present | Absent |
|------------------------|---------|--------|---------|--------|
| Caranx hippos          | ✓       | ✓      |          |        |
| Family Sparidae        |         |        |          |        |
| Stenotomus chrysops    | ✓       |         |          |        |
| Family Labridae        |         |        |          |        |
| Tautoga onitis         | ✓       | ✓      | ✓       | ✓      |
| Tautogalabrus adspersus| ✓       | ✓      | ✓       | ✓      |
| Family Mugilidae       |         | ✓      | ✓       | ✓      |
| Mugil cephalus         | ✓       | ✓      | ✓       | ✓      |
| Mugil curema           |         | ✓      | ✓       | ✓      |
| Family Gobiidae        |         | ✓      | ✓       | ✓      |
| Gobiosoma bosci        |         | ✓      | ✓       | ✓      |
| Gobiosoma robustum     |         | ✓      | ✓       | ✓      |
| Family Pholidae        |         | ✓      | ✓       | ✓      |
| Pholis gunnellus       |         | ✓      | ✓       | ✓      |
| Family Ammodytidae     |         | ✓      | ✓       | ✓      |
| Ammodytes americanus   |         | ✓      | ✓       | ✓      |
| Family Triglidae       |         | ✓      | ✓       | ✓      |
| Prionotus carolinus    |         | ✓      | ✓       | ✓      |
| Prionotus evolans      |         | ✓      | ✓       | ✓      |
| Family Cottidae        |         | ✓      | ✓       | ✓      |
| Myoxocephalus aenaeus  |         | ✓      | ✓       | ✓      |
| Myoxocephalus octodecimspinosus | ✓ |        |
| Family          | Species                        |
|-----------------|--------------------------------|
| Family Bothidae | *Paralichthys dentatus*    |
|                 | *Scophthalmus aquosus*       |
| Family Pleuronectidae | *Limanda ferruginea* |
|                 | *Pseudopleuronectes americanus* |
| Family Soleidae | *Trinectes maculatus*       |
| Family Tetraodontidae | *Sphoeroides maculatus* |
| Family Cyprinidae | *Notropis bifrenatus*       |
|                 | *Notropis neterolepis*      |
| Family Exocoetidae | *Hemeramphus brasiliensis* |
| Family Lobotidae | *Eucinostomus lefroyi*      |
| Family Lutjanidae | *Lutjaneus griseus*        |
| Family Scianidae | *Menticirrhus saxatilis*    |

Table 10
Appendix A. Production and respiration rates at depth for all New Bedford Harbor and Slocums River stations
| Date    | Station | Depth | Production g O2m-2hr-1 | Respiration g O2m-2hr-1 |
|---------|---------|-------|------------------------|-------------------------|
| 7/1/94 A |         |       |                        |                         |
|         |         | surface | 0.31                   | 0.13                    |
|         |         | 1m     | 0.04                   | 0.03                    |
|         |         | 2m     | 0.14                   | 0                        |
|         |         | 4m     | -0.02                  | 0.09                    |
| B       |         | surface | 0.51                   | 0.13                    |
|         |         | 1m     | 0.5                    | -0.03                   |
|         |         | 2m     | 0.16                   | 0.05                    |
|         |         | 4m     | -0.02                  | 0.02                    |
| C       |         | surface | 1.96                   | 0.08                    |
|         |         | 1m     | 0.57                   | 0.1                      |
|         |         | 2m     | 0.13                   | 0.05                    |
|         |         | 4m     | 0.01                   | 0.03                    |
| 7/20/94 A |        | surface | 0.96                   | 0.18                    |
|         |         | 1m     | 0.65                   | 0.07                    |
|         |         | 2m     | 0.14                   | 0.06                    |
|         |         | 4m     | 0.05                   | 0.03                    |
| B       |         | surface | 0.8                    | 0.07                    |
|         |         | 1m     | 0.49                   | 0.05                    |
|         |         | 2m     | 0.16                   | 0.05                    |
|         |         | 4m     | -0.03                  | 0.01                    |
| C       |         | surface | 0.51                   | 0.05                    |
|         |         | 1m     | 0.4                    | 0.04                    |
|         |         | 2m     | 0.19                   | 0.03                    |
|         |         | 4m     | 0.07                   | 0.04                    |
| 8/9/94 B |         | surface | 0.52                   | -0.09                   |
|         |         | 1m     | 0.56                   | 0                        |
|         |         | 2m     | 0.24                   | 0                        |
|         |         | 4m     | 0.1                    | 0.05                    |
| C       |         | surface | 0.36                   | 0.03                    |
|         |         | 1m     | 0.33                   | 0.03                    |
|         |         | 2m     | 0.31                   | 0.08                    |
|         |         | 4m     | 0.11                   | -0.54                   |
| 9/10/94 A |        | surface | 1.062                  | 0.36                    |
|         |         | 1m     | 1.089                  | 0.25                    |
|         |         | 2m     | 0.57                   | 0.12                    |
|         |         | 4m     | 0.0267                 | 0.05                    |
| B       |         | surface | 0.0662                 | 0.06                    |
|         |         | 1m     | 0.1908                 | 0.01                    |
|         |         | 2m     | 0.274                  | 0.08                    |
|         |         | 4m     | 0.168                  | 0.05                    |
| C       |         | surface | 0.267                  | 0                        |
| Date       | Location | Depth | Temperature | Oxygen | Dissolved | Nitrate |
|------------|----------|-------|-------------|--------|-----------|---------|
| 6/3/94 A   | Slocums River | 1m   | 0.224       | 0      | 0.01      | 0.05    |
|            |          | 2m   | 0.243       | 0.01   |           |         |
|            |          | 4m   | 0.088       | 0.05   |           |         |
| 6/8/94 B   |          | 1m   | 0.15        | -0.01  |           |         |
|            |          | 2m   | 0.04        | -0.01  |           |         |
|            |          | 3m   | 0.05        | 0.09   |           |         |
| 6/8/94 B   |          | 1m   | 0.02        | 0.13   |           |         |
|            |          | 1.5m | 0           | 0.09   |           |         |
|            |          | 1.75m| 0.07        | -0.05  |           |         |
|            |          | 2m   | 0.06        | -0.01  |           |         |
| 7/7/94 B   |          | 1m   | 0.15        | 0      |           |         |
|            |          | 0.5m | 0.16        | -0.04  |           |         |
|            |          | 0.5m | 0.12        | -0.02  |           |         |
| 8/6/94 B   |          | 0.5m | 0.11        | 0.02   |           |         |
|            |          | 1m   | 0.02        | 0.03   |           |         |
| 8/24/94 B  |          | 0.5m | 0.16        | 0.049  |           |         |
|            |          | 1m   | 0.12        | 0.018  |           |         |
| 8/24/94 A  |          | 0.5m | 0.14        | -0.01  |           |         |
|            |          | 1m   | 0.17        | -0.01  |           |         |
| B          |          | 0.5m | 0.13        | 0      |           |         |
|            |          | 1m   | 0.11        | 0.08   |           |         |
| C          |          | 0.5m | 0.2         | 0.12   |           |         |
|            |          | 1m   | 0.02        | 0.03   |           |         |
Appendix B. Water Quality data measured in New Bedford Harbor and the Slocums River from June 1994 to May 1995
| Date   | Station | Salinity | Primary production | k | chl a ug/l | DO mg/l | O2/l at 1m | DIN uM | NO3+NO2 uM | F04 uM | Si04 uM | NH4 uM | NO2 uM |
|--------|---------|----------|-------------------|---|------------|---------|-----------|--------|------------|--------|---------|--------|--------|
| 6.3.94 | A       | 25       | 0.18              | 3.36 | 7.7       |         |           | 1      | 0.3        | 0.22   | 16.96   | 0.7    | 0.09   |
| 6.8.94 | B       | 28       | 0.01              | 3.82 | 7.99      |         |           | 0.73   | 0.21       | 0.24   | 15.02   | 0.52   | 0.07   |
| 6.16.94| C       | 27       | 0.12              | 4.04 | 8.19      |         |           | 1.51   | 0.44       | 0.34   | 14.15   | 1.07   | 0.12   |
| 6.24.94| 2       | 30       | 2.82              |     |           |         |           |        |            |        |         |        |        |
|        | 3       | 31       | 2.57              |     |           |         |           |        |            |        |         |        |        |
|        | 4       | 31       | 4.58              |     |           |         |           |        |            |        |         |        |        |
| 7.7.94 | B       | 24       | 0.08              | 1.48 | 9.09      | 5.84    |           | 1.45   | 0.31       | 0.9    | 29.01   | 1.14   | 0.07   |
|        | C       | 27       | 0.07              | 1.13 | 3.39      | 6.9     |           | 2.27   | 0.28       | 1.22   | 18.28   | 1.99   | 0.1    |
| 7.25.94| 1       | 28       | 8.13              |     |           |         |           |        |            |        |         |        |        |
|        | 4       | 31       | 5.81              |     |           |         |           |        |            |        |         |        |        |
| 7.27.94| 2       | 30       | 1.94              |     |           |         |           |        |            |        |         |        |        |
|        | 3       | 31       | 2.97              |     |           |         |           |        |            |        |         |        |        |
| 8.7.94 | B       | 30       | 0.09              | 0.691 | 4.3       | 6.97    |           | 0.77   | 0.11       | 1.24   | 3.71    | 0.66   | 0.12   |
|        | C       | 30       | 0.1               | 0.449 | 3.02      | 7.33    |           | 0.65   | 0.06       | 1.23   | 2.81    | 0.59   | 0.12   |
| 8.24.94| A       | 30       | 0.09              | 1.08 | 3.33      | 6.4     |           | 2.15   | 1.76       | 0.87   | 17.44   | 0.39   | 0.23   |
|        | B       | 29       | 0.12              | 1.04 | 4.43      | 7.5     |           | 0.36   | 0.00       | 0.68   | 9.09    | 0.36   | 0.1    |
|        | C       | 31       | 0.13              | 0.709 | 4.16     | 7.57    |           | 2.04   | 0.61       | 1.11   | 6.71    | 1.43   | 0.2    |
| 10.20.94| 1      | 31       | 2.77              |     |           |         |           | 2.59   | 0.65       | 0.52   | 9.23    | 1.94   | 0.07   |
|        | 2      | 31       | 1.92              |     |           |         |           | 3.66   | 1.71       | 0.9    | 6.97    | 1.95   | 0.06   |
|        | 3      | 32       | 1.14              |     |           |         |           | 1.25   | 0.63       | 0.97   | 5       | 0.62   | 0.03   |
|        | 4      | 32       | 1.19              |     |           |         |           | 3.57   | 0.83       | 1      | 3.74    | 2.74   | 0.04   |
| 11.26.94| A      | 24       | 1.47              |     |           |         |           | 7.12   | 4.06       | 0.5    | 56.18   | 3.06   | 0.29   |
|        | B      | 31       | 2.59              |     |           |         |           | 2.55   | 1.4        | 0.64   | 12.74   | 1.15   | 0.19   |
|        | C      | 32       | 2.28              |     |           |         |           | 2.44   | 1.3        | 0.96   | 9.61    | 1.14   | 0.27   |
|        | 1      | 22       | 2.79              |     |           |         |           | 8.49   | 5.01       | 0.46   | 77.47   | 3.48   | 0.36   |
|        | 2      | 12       | 0.69              |     |           |         |           | 13.83  | 9.97       | 0.38   | 3.86    | 3.42   | 0.42   |
|        | 3      | 30       | 1.52              |     |           |         |           | 2.99   | 1.68       | 0.71   | 14.09   | 1.31   | 0.22   |
| 1.23.95 | 4  | 28  | 9.08 | 2.46 | 7.03 | 50.42 | 0.41 |
|--------|----|-----|------|------|------|-------|------|
|        | A  | 18  | 3.01 | 10.91| 8.02 | 0.4   | 52.62| 2.89 |
|        | B  | 28  | 3.17 | 3.21 | 2.14 | 0.55  | 14.62| 1.07 |
|        | C  | 30  | 6.65 | 2.1  | 1.22 | 0.62  | 6.81 | 0.88 |
|        | 1  | 15  | 3.57 | 14.19| 10.13| 0.33  | 69.52| 4.06 |
|        | 2  | 20  | 3.86 | 9.85 | 7.11 | 0.36  | 51.16| 2.74 |
|        | 3  | 26  | 6.24 | 4.49 | 3.04 | 0.5   | 22.58| 1.45 |
|        | 4  | 25  | 16.58| 3.86 | 1.07 | 25.53 | 12.72| 0.16 |
| 3.22.95| A  |     | 0.87 |      |      |       |      |      |
|        | B  |     | 1.26 |      |      |       |      |      |
|        | C  |     | 2.2  |      |      |       |      |      |
|        | 1  |     | 1.02 |      |      |       |      |      |
|        | 2  |     | 1.77 |      |      |       |      |      |
|        | 3  |     | 1.26 |      |      |       |      |      |
|        | 4  |     | 2.33 |      |      |       |      |      |
| 5.4.95 | 1  |     | 7.27 |      |      |       |      |      |
|        | 2  |     | 2.04 |      |      |       |      |      |
|        | 3  |     | 1.14 |      |      |       |      |      |
|        | 4  |     | 1.01 |      |      |       |      |      |
| 5.23.95| A  |     | 4.16 |      |      |       |      |      |
|        | B  |     | 2.83 |      |      |       |      |      |
|        | C  |     | 2.62 |      |      |       |      |      |
| mean=  |    |     | 0.099| 0.9398571| 3.36725| 7.239 | 4.0827273| 2.0973529| 0.9085294| 20.49303| 1.9963636| 0.1564706 |
| st dev|= 0.031| 0.2773061| 0.2899 | 0.5692 | 3.1998898 | 2.0486159 | 0.4828028 | 15.154711 | 1.2112948 | 0.0878201 |
| Date   | Station | Salinity to 1m | Salinity to 6m | k   | chl a ug/l | DO mg O2/l at 1m | DIN uM | NO3+NO2 uM | PO4 uM | SiO4 uM | NH4 uM | NO2 uM |
|--------|---------|----------------|----------------|-----|------------|------------------|--------|------------|--------|---------|--------|--------|
| 7.1.94 | A       | 0.17           | 0.4            | 1.73| 4.77       | 5.78             | 20.72  | 6.69       | 2.33   | 29.79   | 14.03  | 0.51   |
|        | B       | 0.51           | 1.01           | 1.03| 17.7       | 5.02             | 6.45   | 4.81       | 1.58   | 20.3    | 1.64   | 0.47   |
|        | C       | 1.27           | 1.74           | 0.969| 16.1       | 6.03             | 0.41   | 0.21       | 1.28   | 12.35   | 0.2    | 0.03   |
| 7.6.94 | 1       | 11.7           |                |     | 5.31       | 0.52             | 1.14   | 2.5        | 4.79   | 0.04    |        |        |
|        | 2       | 9.08           |                |     | 1.04       | 0.35             | 1.66   | 2.47       | 0.69   | 0.05    |        |        |
|        | 4       | 7.51           |                |     | 2.27       | 0.28             | 1.22   | 18.28      | 1.99   | 0.1     |        |        |
| 7.19.94| 1       | 9.65           |                |     | 2.53       | 0.98             | 2.62   | 16.46      | 1.55   | 0.05    |        |        |
|        | 3       | 4.4            |                |     | 5.2        | 1.43             | 2.28   | 19.69      | 3.77   | 0.19    |        |        |
| 7.20.94| A       | 11.3           | 6.78           | 1.27| 6.31       | 0.31             | 3.03   | 7.4        | 0.96   | 0.19    |        |        |
|        | B       | 13.07          | 5.07           | 0.49| 0.19       | 2.21             | 12.22  | 0.3        | 0.04   | 0.16    |        |        |
|        | C       | 13.68          | 5.92           | 0.35| 0.12       | 1.65             | 17.01  | 0.23       | 0.02   | 0.17    |        |        |
| 7.24.94| 2       | 29.96          |                |     | 3.67       | 0.11             | 1.23   | 11.66      | 3.56   | 0.03    |        |        |
|        | 4       | 21.59          |                |     | 2.94       | 0.18             | 1.02   | 19.34      | 2.76   | 0.05    |        |        |
| 8.2.94 | 1       | 8.11           |                |     | 4.67       | 3.51             | 2.91   | 5.99       | 1.16   | 0.17    |        |        |
|        | 2       | 3.9            | 1.3            |     | 3.11       | 4.99             | 2.6    | 1.94       | 0.15   | 0.19    |        |        |
| 8.4.94 | 4       | 22.25          |                |     | 0.3        | 0.08             | 2.67   | 2.34       | 0.22   | 0.14    |        |        |
|        | 3       | 10.8           |                |     | 5.72       | 0.52             | 1.9    | 8.01       | 5.2    | 0.2     |        |        |
| 8.9.94 | B       | 0.54           | 1.27           | 0.769| 5.97       | 7.18             | 1.57   | 3.54       | 7.71   | 5.61    | 0.39   |        |
|        | C       | 0.36           | 0.67           | 0.545| 6.51       | 1.55             | 0.76   | 2.6        | 5.65   | 0.79    | 0.24   |        |
| 9.10.94| A       | 1.06           | 2.5            | 0.661| 8.73       | 0.87             | 0.08   | 2.97       | 8.11   | 0.79    | 0.11   |        |
|        | B       | 0.13           | 0.8            | 0.59 | 2.95       | 7.89             | 1.45   | 0.34       | 2.33   | 5.41    | 1.11   | 0.15   |
|        | C       | 0.25           | 0.81           | 0.457| 3.13       | 7.69             | 1.52   | 0.69       | 1.66   | 3.85    | 0.83   | 0.14   |
| 10.29.94| 1      | 5.06           |                |     | 8.16       | 3.02             | 2.36   | 8.52       | 5.14   | 0.29    |        |        |
|        | 2      | 3.5            |                |     | 9.99       | 2.59             | 2.05   | 8.12       | 7.4    | 0.28    |        |        |
|        | 3      | 2              |                |     | 9.22       | 1.91             | 2.21   | 9.17       | 7.31   | 0.27    |        |        |
|        | 4      | 1.01           |                |     | 6.29       | 1.56             | 2.22   | 5.23       | 4.73   | 0.19    |        |        |
| 11.22.94| A     | 1.22           |                |     | 14.18      | 5.26             | 1.69   | 33.79      | 8.92   | 0.47    |        |        |
|        | B     | 1.55           |                |     | 12.88      | 3.67             | 2.06   | 13.03      | 9.21   | 0.46    |        |        |
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Appendix C. Phytoplankton production calculations to depth for entire estuary, New Bedford Harbor and Slocums River
| Location | Depth  | Area (km²) | Average Net Production, Integrated to Depth (g CH₄ m⁻³ hr⁻¹) | Average Net Production, Integrated to Depth (g C m⁻³ hr⁻¹) | Total Production (g C/hr) |
|----------|--------|------------|-------------------------------------------------------------|-------------------------------------------------------------|---------------------------|
| New      | 0-1 ft (0.3 m) | 0.029 | 0.20 +/- .15 | 0.06 +/- 0.05 | 1.74 x 10³ +/- 1.45 x 10³ |
|          | 0-3 ft (1 m)   | 0.94    | 0.60 +/- 0.34 | 0.19 +/- 0.10 | 1.78 x 10³ +/- 9.37 x 10³ |
|          | 0-6 ft (2 m)   | 0.74    | 0.99 +/- 0.46 | 0.31 +/- 0.14 | 2.29 x 10³ +/- 1.03 x 10³ |
|          | >6 ft (>2 m)†  | 2.06    | 1.12 +/- 0.45 | 0.35 +/- 0.14 | 7.21 x 10³ +/- 2.88 x 10⁵ |
| TOTAL    |         | 3.78    |                  |                  | 1.13 x 10⁴ +/- 1.65 x 10⁴ |
| Slocums  | 0-1 ft (0.3 m) | 0.25   | 0.04 +/- 0.02 | 0.01 +/- 0.07 | 2.5 x 10³ +/- 1.7 x 10³ |
| River    | 0-2 ft (0.7 m) | 0.7    | 0.13 +/- 0.02 | 0.04 +/- 0.01 | 2.8 x 10³ +/- 7.0 x 10³ |
|          | >2 ft (>0.7 m)³ | 1     | 0.13 +/- 0.04 | 0.04 +/- 0.01 | 4.0 x 10³ +/- 1.0 x 10⁴ |
| TOTAL    |         | 4.05    |                  |                  | 7.05 x 10⁴ +/- 1.87 x 10⁴ |

†Primary production was measured down to 4m, where production is near zero.

³Primary production was only measured down to 1m in the Slocums River, at 1 m production was low, but not at zero. Production beyond 1 m was not measured, and therefore not accounted for here.
Appendix D. Phytoplankton production and respiration integrated to incubation depths (data used in Appendix C to calculate production to depth)
### New Bedford

|       | 0.3m Production | 0.3m Respiration | 1m Production | 1m Respiration | 2m Production | 2m Respiration | 4m Production | 4m Respiration |
|-------|-----------------|------------------|---------------|----------------|---------------|----------------|---------------|----------------|
| 7/1/94 | 0.09 g O₂ m⁻³ hr⁻¹ | 0.43 g O₂ m⁻³ hr⁻¹ | 0.35 g O₂ m⁻³ hr⁻¹ | 0.05 g O₂ m⁻³ hr⁻¹ | 0.68 g O₂ m⁻³ hr⁻¹ | 0.11 g O₂ m⁻³ hr⁻¹ | 0.89 g O₂ m⁻³ hr⁻¹ | 0.11 g O₂ m⁻³ hr⁻¹ |
| A     | 0.15 g O₂ m⁻³ hr⁻¹ | 0.4 g O₂ m⁻³ hr⁻¹ | 0.58 g O₂ m⁻³ hr⁻¹ | 0.17 g O₂ m⁻³ hr⁻¹ | 0.99 g O₂ m⁻³ hr⁻¹ | 0.32 g O₂ m⁻³ hr⁻¹ | 1.15 g O₂ m⁻³ hr⁻¹ | 0.42 g O₂ m⁻³ hr⁻¹ |
| B     | 0.59 g O₂ m⁻³ hr⁻¹ | 0.03 g O₂ m⁻³ hr⁻¹ | 1.24 g O₂ m⁻³ hr⁻¹ | 0.1 g O₂ m⁻³ hr⁻¹ | 1.59 g O₂ m⁻³ hr⁻¹ | 0.12 g O₂ m⁻³ hr⁻¹ | 1.66 g O₂ m⁻³ hr⁻¹ | 0.23 g O₂ m⁻³ hr⁻¹ |
| 7/20/94 | 0.29 g O₂ m⁻³ hr⁻¹ | 0.05 g O₂ m⁻³ hr⁻¹ | 0.88 g O₂ m⁻³ hr⁻¹ | 0.12 g O₂ m⁻³ hr⁻¹ | 1.19 g O₂ m⁻³ hr⁻¹ | 0.2 g O₂ m⁻³ hr⁻¹ | 1.28 g O₂ m⁻³ hr⁻¹ | 2.24 g O₂ m⁻³ hr⁻¹ |
| A     | 0.24 g O₂ m⁻³ hr⁻¹ | 0.02 g O₂ m⁻³ hr⁻¹ | 0.64 g O₂ m⁻³ hr⁻¹ | 0.05 g O₂ m⁻³ hr⁻¹ | 1.03 g O₂ m⁻³ hr⁻¹ | 0.11 g O₂ m⁻³ hr⁻¹ | 1.09 g O₂ m⁻³ hr⁻¹ | 0.14 g O₂ m⁻³ hr⁻¹ |
| B     | 0.15 g O₂ m⁻³ hr⁻¹ | 0.02 g O₂ m⁻³ hr⁻¹ | 0.47 g O₂ m⁻³ hr⁻¹ | 0.05 g O₂ m⁻³ hr⁻¹ | 0.77 g O₂ m⁻³ hr⁻¹ | 0.11 g O₂ m⁻³ hr⁻¹ | 0.9 g O₂ m⁻³ hr⁻¹ | 0.15 g O₂ m⁻³ hr⁻¹ |
| 8/9/94 | 0.16 g O₂ m⁻³ hr⁻¹ | 0 g O₂ m⁻³ hr⁻¹ | 0.54 g O₂ m⁻³ hr⁻¹ | 1 g O₂ m⁻³ hr⁻¹ | 1.08 g O₂ m⁻³ hr⁻¹ | 0 g O₂ m⁻³ hr⁻¹ | 1.25 g O₂ m⁻³ hr⁻¹ | 0.02 g O₂ m⁻³ hr⁻¹ |
| B     | 0.11 g O₂ m⁻³ hr⁻¹ | 0.01 g O₂ m⁻³ hr⁻¹ | 0.35 g O₂ m⁻³ hr⁻¹ | 0.03 g O₂ m⁻³ hr⁻¹ | 0.69 g O₂ m⁻³ hr⁻¹ | 0.09 g O₂ m⁻³ hr⁻¹ | 0.89 g O₂ m⁻³ hr⁻¹ | 0.09 g O₂ m⁻³ hr⁻¹ |
| 9/11/94 | 0.32 g O₂ m⁻³ hr⁻¹ | 0.11 g O₂ m⁻³ hr⁻¹ | 1.12 g O₂ m⁻³ hr⁻¹ | 0.32 g O₂ m⁻³ hr⁻¹ | 2.03 g O₂ m⁻³ hr⁻¹ | 0.53 g O₂ m⁻³ hr⁻¹ | 2.33 g O₂ m⁻³ hr⁻¹ | 0.61 g O₂ m⁻³ hr⁻¹ |
| A     | 0.02 g O₂ m⁻³ hr⁻¹ | 0.02 g O₂ m⁻³ hr⁻¹ | 0.13 g O₂ m⁻³ hr⁻¹ | 0.04 g O₂ m⁻³ hr⁻¹ | 0.37 g O₂ m⁻³ hr⁻¹ | 0.08 g O₂ m⁻³ hr⁻¹ | 0.59 g O₂ m⁻³ hr⁻¹ | 0.14 g O₂ m⁻³ hr⁻¹ |
| B     | 0.08 g O₂ m⁻³ hr⁻¹ | 0 g O₂ m⁻³ hr⁻¹ | 0.25 g O₂ m⁻³ hr⁻¹ | 0 g O₂ m⁻³ hr⁻¹ | 0.48 g O₂ m⁻³ hr⁻¹ | 0 g O₂ m⁻³ hr⁻¹ | 0.64 g O₂ m⁻³ hr⁻¹ | 0.03 g O₂ m⁻³ hr⁻¹ |

### Slocums River

|       | 0.3m Production | 0.3m Respiration | 0.5m Production | 0.5m Respiration | 1m Production | 1m Respiration |
|-------|-----------------|------------------|---------------|------------------|---------------|----------------|
| 6/3/94 | 0.07 g O₂ m⁻³ hr⁻¹ | 0 g O₂ m⁻³ hr⁻¹ | 0.18 g O₂ m⁻³ hr⁻¹ | 0 g O₂ m⁻³ hr⁻¹ |
| A     | 0.01 g O₂ m⁻³ hr⁻¹ | 0.04 g O₂ m⁻³ hr⁻¹ | 0.12 g O₂ m⁻³ hr⁻¹ | 0.01 g O₂ m⁻³ hr⁻¹ |
| 6/8/94 | 0.05 g O₂ m⁻³ hr⁻¹ | 0 g O₂ m⁻³ hr⁻¹ | 0.12 g O₂ m⁻³ hr⁻¹ | 0.01 g O₂ m⁻³ hr⁻¹ |
| Date   | Location | Integration to: 0.3m | Integration to: 0.5m | Integration to: 1m |
|--------|----------|----------------------|----------------------|-------------------|
|        | Production | Respiration | Production | Respiration | Production | Respiration |
|        | g O₂ m⁻² hr⁻¹ | g O₂ m⁻² hr⁻¹ | g O₂ m⁻² hr⁻¹ | g O₂ m⁻² hr⁻¹ | g O₂ m⁻² hr⁻¹ | g O₂ m⁻² hr⁻¹ |
| 7/7/94 | B         | 0.03               | 0.036               | 0.09           | 0.11         | 0.09         | 0.08         |
|        | C         | 0.045              | 0                   | 0.1            | 0.01         | 0.08         | 0.02         |
| 8/6/94 | B         | 0.03               | 0                   | 0.12           | 0            | 0.12         | 0.04         |
|        | C         | 0.03               | 0                   | 0.12           | 0            | 0.11         | 0            |
| 8/24/94| A         | 0.05               | 0.04                | 0.13           | 0.09         | 0.12         | 0.06         |
|        | B         | 0.05               | 0                   | 0.16           | 0            | 0.16         | 0            |
|        | C         | 0.03               | 0                   | 0.16           | 0.02         | 0.16         | 0.04         |
Appendix E. Application of VERSAR/URI eutrophication index to water quality parameters measured in New Bedford Harbor and the Slocums River.
Slocums River:
Actual concentrations:

| Indicator                  | A     | B     | C     | 1    | 2    | 3    | 4    |
|----------------------------|-------|-------|-------|------|------|------|------|
| uM Nitrate + Nitrite       | 4.61  | 0.71  | 0.61  | 3.99 | 3.89 | 0.7  | 1.49 |
| uM Phosphate               | 0.59  | 0.71  | 0.9   | 0.55 | 0.64 | 0.75 | 2.01 |
| ug/l chlorophyll a         | 2.7   | 3.74  | 3.55  | 4.27 | 2.23 | 1.98 | 4.52 |
| %Sediment Organic C        | 2.01  | 2.01  | 2.01  | 2.01 | 2.01 | 2.01 | 2.01 |
| O2 saturation              | 95.68 | 95.68 | 95.68 | 95.68| 95.68| 95.68| 95.68|

Corresponding scores:

| Indicator                  | A | B | C | 1 | 2 | 3 | 4 |
|----------------------------|---|---|---|---|---|---|---|
| uM Nitrate + Nitrite       | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| uM Phosphate               | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| ug/l chlorophyll a         | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| %Sediment Organic C        | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| O2 saturation              | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
### New Bedford Harbor:
#### Actual concentrations:

| Indicator                      | A     | B     | C     | 1     | 2     | 3     | 4     |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|
| ug/l Nitrate + Nitrite         | 7.81  | 3.29  | 1.76  | 4.21  | 8.95  | 2.09  | 1.37  |
| ug/l Phosphate                 | 1.96  | 2.13  | 1.81  | 1.98  | 1.72  | 2.04  | 1.68  |
| ug/l chlorophyll a             | 3.73  | 7.45  | 5.9   | 9.06  | 12.41 | 4.61  | 10.34 |
| %Sediment Organic C            | 6.04  | 6.04  | 6.04  | 6.04  | 6.04  | 6.04  | 6.04  |
| O2 saturation                  | 90.49 | 90.49 | 90.49 | 90.49 | 90.49 | 90.49 | 90.49 |

### Corresponding scores:

| Indicator                      | A     | B     | C     | 1     | 2     | 3     | 4     |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|
| ug/l Nitrate + Nitrite         | 4     | 1     | 1     | 1     | 5     | 1     | 1     |
| ug/l Phosphate                 | 2     | 3     | 2     | 2     | 2     | 3     | 2     |
| ug/l chlorophyll a             | 1     | 1     | 1     | 1     | 1     | 1     | 1     |
| %Sediment Organic C            | 5     | 5     | 5     | 5     | 5     | 5     | 5     |
| O2 saturation                  | 1     | 1     | 1     | 1     | 1     | 1     | 1     |
Appendix F. Summary of dates and stations sampled for fish. Dates were divided into periods (July I, July II, etc.) and seasons for analyses.
| Location     | Season   | Period   | Date       | Stations |
|--------------|----------|----------|------------|----------|
| New Bedford  | Summer   | June I   | 6/22/94    | 1,2,3,4  |
|              |          | June II  | 6/30/94    | 1,2,4    |
|              |          | June III | 7/7/94     | 1,2,4    |
|              |          | July I   | 7/18/94    | 1,3      |
|              |          |          | 7/21/94    | 2,4      |
|              |          | July II  | 8/2/94     | 1,2      |
|              |          |          | 8/4/94     | 3,4      |
|              |          | August I | 8/17/94    | 1,4      |
|              |          |          | 8/21/94    | 2,3      |
|              |          | August II| 9/7/94     | 1,2,3,4  |
|              | Fall/Winter | October | 10/29/94   | 1,2,3,4  |
|              |          | December | 12/4/94    | 1,2,3,4  |
|              |          | March    | 3/31/94    | 1,2,3,4  |
| Slocums River| Spring   | May I    | 5/15/94    | 1,2,3,4  |
|              |          | May II   | 5/24/94    | 1,2,3,4  |
|              | Summer   | June I   | 6/7/94     | 1,2,3,4  |
|              |          | June II  | 6/24/94    | 2,3,4    |
|              |          | June III | 6/29/94    | 1,3,4    |
|              |          | July I   | 7/13/94    | 1,4      |
|              |          |          | 7/17/94    | 2,3      |
|              |          | July II  | 7/25/94    | 1,4      |
|              |          |          | 7/27/94    | 2,3      |
|              |          | August I | 8/12/94    | 1,4      |
|              |          |          | 8/21/94    | 2,3      |
|              |          | August II| 8/29/94    | 1,2      |
|              | Fall/Winter | October | 10/22/94   | 1,2,3,4  |
|              |          | November | 11/26/94   | 1,2,3,4  |
|              |          | January  | 1/23/95    | 1,2,3,4  |
|              |          | March    | 3/22/95    | 1,2,3,4  |
|              | Spring   | May I    | 5/4/95     | 1,2,3,4  |
|              |          | May II   | 5/23/95    | 1,2,3,4  |
Appendix G. Raw data used in calculating beach seine efficiency
Area closed off was 15 m x 25.5 m = 383 m²
Area of seine was 88 m²

| Trial one: Seine | # fish |
|-----------------|-------|
| Seine 1         | 52    |
| Seine 2         | 35    |
| Seine 3         | 48    |
| Seine 4         | 37    |
| Seine 5         | 21    |
| Seine 6         | 15    |
| Seine 7         | 3     |
| Seine 8         | 6     |
| Seine 9         | 20    |
| Seine 10        | 14    |
| Seine 11        | 3     |
| Seine 12        | 2     |
| Seine 13        | 10    |
| Seine 14        | 4     |
| Seine 15        | 0     |
| Seine 16        | 0     |
| **TOTAL**       | **270** |

Density of fish in area: 240 fish/383m² = 0.7/m²
Density of fish in seine one: 52 fish/88m² = 0.58/m²
Seine efficiency: 84%

| Trial two: Seine | # fish |
|------------------|-------|
| Seine 1          | 64    |
| Seine 2          | 70    |
| Seine 3          | 53    |
| Seine 4          | 48    |
| Seine 5          | 15    |
| Seine 6          | 20    |
| Seine 7          | 13    |
| Seine 8          | 9     |
| Seine 9          | 8     |
| Seine 10         | 6     |
| Seine 11         | 3     |
| Seine 12         | 0     |
| Seine 13         | 2     |
| Seine 14         | 1     |
| Seine 15         | 0     |
| **TOTAL**        | **312** |

Density of fish in area: 312 fish/383m² = 0.82/m²
Density of fish in seine one: 64 fish/88m² = 0.72/m²
Seine efficiency: 88%

Example of species distribution:

Trial one, Seine 1:
- Menidia: 6
- Cyprinodon: 27
- F. heteroclitus: 14
- F. majalis: 3
- Apeltes: 2
| Trial three: | Seine | # fish |
|-------------|-------|--------|
| 1 fish      | 1     | 34     |
| 2           | 2     | 12     |
| 3           | 3     | 41     |
| 4           | 4     | 36     |
| 5           | 5     | 18     |
| 6           | 6     | 15     |
| 7           | 7     | 20     |
| 8           | 8     | 2      |
| 9           | 9     | 6      |
| 10          | 10    | 0      |
| **TOTAL**   | **11**| **184**|

**Density of fish in area:** 184 fish / 383 m$^2$ = 0.48/m$^2$

**Density of fish in seine one:** 34 fish / 88 m$^2$ = 0.38/m$^2$

**Seine efficiency:** 80%

| Trial four: | Seine | # fish |
|-------------|-------|--------|
| 1 fish      | 1     | 97     |
| 2           | 2     | 101    |
| 3           | 3     | 86     |
| 4           | 4     | 52     |
| 5           | 5     | 38     |
| 6           | 6     | 40     |
| 7           | 7     | 12     |
| 8           | 8     | 9      |
| 9           | 9     | 1      |
| 10          | 10    | 0      |
| 11          | 11    | 3      |
| 12          | 12    | 0      |
| 13          | 13    | 0      |
| **TOTAL**   | **13**| **362**|

**Density of fish in area:** 362 fish / 383 m$^2$ = 0.94/m$^2$

**Density of fish in seine one:** 77 fish / 88 m$^2$ = 0.86/m$^2$

**Seine efficiency:** 92%

| Trial five: | Seine | # fish |
|-------------|-------|--------|
| 1 fish      | 1     | 77     |
| 2           | 2     | 92     |
| 3           | 3     | 62     |
| 4           | 4     | 46     |
| 5           | 5     | 22     |
| 6           | 6     | 30     |
| 7           | 7     | 11     |
| 8           | 8     | 9      |
| 9           | 9     | 2      |
| 10          | 10    | 3      |
| 11          | 11    | 1      |
| 12          | 12    | 2      |
| 13          | 13    | 0      |
| **TOTAL**   | **13**| **439**|

**Density of fish in area:** 439 fish / 383 m$^2$ = 0.114/m$^2$

**Density of fish in seine one:** 97 fish / 88 m$^2$ = 0.10/m$^2$

**Seine efficiency:** 96%
Appendix H. Average biomass, based on wet weight and dry weight, and average abundance of fish for different periods from June 1994 to May 1995. Station averages for biomass and abundance are listed at the bottom of the table.
| Location       | Period   | Station | average biomass | average biomass | average #s/m² |
|----------------|----------|---------|----------------|----------------|---------------|
|                |          |         | g wet weight/m² | g dry weight/m² |               |
| New Bedford    | June I   | 0.17    | 0.05           | 0.21           |
|                | June II  | 0.23    | 0.07           | 0.17           |
|                | June III | 0.13    | 0.05           | 0.15           |
|                | July I   | 1       | 0.33           | 1.49           |
|                | July II  | 0.64    | 0.23           | 0.66           |
|                | August I | 1.26    | 0.38           | 0.72           |
|                | August II| 2.46    | 0.66           | 1.2            |
|                | October  | 0.62    | 0.19           | 0.2            |
|                | December | 1.21    | 0.35           | 0.4            |
|                | March    | 0.06    | 0.02           | 0.03           |
|                | May I    | 0.29    | 0.09           | 0.12           |
|                | May II   | 0.78    | 0.42           | 0.23           |
| Slocums River  | June I   | 0.09    | 0.03           | 0.07           |
|                | June II  | 0.26    | 0.08           | 0.1            |
|                | June III | 0.2     | 0.13           | 0.23           |
|                | July I   | 0.56    | 0.17           | 0.53           |
|                | July II  | 0.39    | 0.11           | 0.47           |
|                | August I | 0.57    | 0.17           | 0.67           |
|                | August II| 0.59    | 0.16           | 0.49           |
|                | October  | 0.26    | 0.06           | 0.35           |
|                | January  | 0.08    | 0.02           | 0.07           |
|                | March    | 0.15    | 0.04           | 0.04           |
|                | May I    | 0.23    | 0.06           | 0.1            |
|                | May II   | 0.5     | 0.14           | 0.14           |
|                | 1        | 0.48    | 0.09           | 0.34           |
|                | 2        | 0.1     | 0.03           | 0.09           |
|                | 3        | 0.23    | 0.07           | 0.2            |
|                | 4        | 0.49    | 0.14           | 0.35           |
Appendix I. Length-wet weight and length-dry weight regressions used for estimating biomass from June 1994 to May 1995.
New Bedford Menidia species, 6/7-8/2

\[
y = 2.91x - 2.27 \\
R^2 = 0.950 \\
n = 200
\]

SR Menidia species, 6/2 - 7/13

\[
y = 2.67x - 2.13 \\
r(2) = 0.915 \\
n = 200
\]
**New Bedford Fundulus heteroclitus 6/22 - 7/21**

\[ y = 3.25x - 2.13 \]

\[ r^2 = 0.977 \]

\[ n = 400 \]

---

**SR Fundulus heteroclitus 6/2-6/29**

\[ y = 2.84x - 1.91 \]

\[ r^2 = 0.85 \]

\[ n = 400 \]
New Bedford Fundulus majalis, 6/3-8/2

\[ y = 3.21x - 2.12 \]
\[ R(2) = 0.96 \]

SR Fundulus majalis, 6/2 - 7/25

\[ y = 3.07x - 2.08 \]
\[ R(2) = 0.98 \]
New Bedford Menidia species, 8/21 (st 2, 3)

\[ y = 3.18x - 2.97 \]
\[ r(2) = 0.985 \]
\[ n = 60 \]

Slocums River Menidia species, 8/21 (st 3)

\[ y = 3.03x - 2.90 \]
\[ r(2) = 0.984 \]
\[ n = 60 \]
New Bedford Fundulus heteroclitus, 9/7, st 4 (seines 1,2,3)

\[ y = 3.33x - 2.74 \]
\[ r^2 = 0.93 \]
\[ n = 60 \]

Slocums R. heteroclitus, 8/12 - 9/1

\[ y = 3.37x - 2.78 \]
\[ r^2 = 0.994 \]
\[ n = 60 \]
$y = 2.97x - 2.16$

$R(2) = .902$

Slocums Apeltes Quadratus, 6/7-7/27

log (g wet weight)

log (length) cm
Slocums Brevoortia tyrannus, 8/12

\[ y = 3.18x - 2.25 \]

\[ R(2) = 0.97 \]
Slocums Brevoortia tyrannus, 8/12-Station 1, Seine 1

\[ \log(\text{dry weight}) = 3.69x - 3.30 \]

\[ R(2) = 0.96 \]
Mugil cephalus, Slocums River, 7/25

log (g wet weight)

log (length)

\[ y = 3.13x - 2.06 \]

\[ R(2) = 0.985 \]
New Bedford tautog, 7/18-8/4

\[ y = 3.01x - 1.88 \]

\( R(2) = .945 \)
log(g wet weight) vs log(length) cm

\begin{align*}
  y &= 3.56x - 2.21 \\
  R(2) &= 0.978
\end{align*}

New Bedford, cunner 7/7-7/17
Appendix J. Average growth rates for *Menidia* species, *Fundulus heteroclitus*, and *Fundulus majalis* based on length frequency data. Averages represent the mean of 100 estimates generated by a bootstrapping program.
### Menidia species growth rates

|               | June-July | July-August | August-October | October-December | December-May |
|---------------|-----------|-------------|----------------|------------------|--------------|
|               | NB        | SR          | NB             | NB               | NB           |
| average       | 0.53      | 0.19        | 0.28           | 0.14             | 0.31         |
| s             | 0.05      | 0.07        | 0.03           | 0.07             | 0.03         |
| degrees of freedom | 100     | 100         | 100             | 100              | 100          |
| t             | 39.52     | 18.38       | 38.76           | 35.78            | 22.28        |
| t crit (alpha = 0.05) | 1.96 | 1.96        | 1.96             | 1.96             | 1.96         |
| NB = SR       | NO        | NO          | NO              | NO               | NO           |

### Fundulus heteroclitus species growth rates

|               | June-July | July-August | August-October | October-May |
|---------------|-----------|-------------|----------------|-------------|
|               | NB        | SR          | NB             | NB           |
| average       | -0.41     | -0.37       | 0.11           | -0.09        |
| s             | 0.06      | 0.05        | 0.06           | 0.04         |
| degrees of freedom | 100   | 100         | 100             | 100          |
| t             | 4.31      | 4.34        | 1.56            | 35.92        |
| t crit (alpha = 0.05) | 1.96 | 1.96        | 1.96             | 1.96         |
| NB = SR       | NO        | NO          | YES             | NO           |

### Fundulus m.salis species growth rates

|               | June-July | July-August | August-October | October-May |
|---------------|-----------|-------------|----------------|-------------|
|               | NB        | SR          | NB             | NB           |
| average       | 0.03      | -0.72       | 0.25           | 0.07         |
| s             | 0.09      | 0.04        | 0.04           | 0.04         |
| degrees of freedom | 100 | 100         | 100             | 100          |
| t             | 135.4     | 46.85       | 26.35           | 69.3         |
| t crit (alpha = 0.05) | 1.96 | 1.96        | 1.96             | 1.96         |
| NB = SR       | NO        | NO          | NO              | NO           |
Appendix K. Growth rate estimates for *Menidia* species, *Fundulus heteroclitus*, and *Fundulus majalis* generated by a bootstrapping program. One hundred growth rate estimates were performed for each species.
New Bedford Fundulus majalis growth rates

| G1 | G2 | G3 | G4 |
|----|----|----|----|
| 0.20 | 0.23 | 0.04 | 0.08 |
| -0.05 | 0.26 | 0.05 | 0.05 |
| 0.18 | 0.20 | 0.01 | 0.11 |
| 0.11 | 0.23 | 0.07 | 0.06 |
| 0.02 | 0.35 | 0.02 | 0.14 |
| 0.19 | 0.23 | 0.05 | 0.08 |
| 0.05 | 0.29 | 0.06 | 0.08 |
| -0.11 | 0.18 | 0.09 | 0.01 |
| 0.04 | 0.30 | 0.02 | 0.06 |
| 0.09 | 0.24 | 0.01 | 0.04 |
| 0.15 | 0.20 | 0.06 | 0.07 |
| 0.08 | 0.19 | 0.06 | 0.05 |
| -0.04 | 0.24 | 0.07 | 0.04 |
| 0.16 | 0.26 | 0.11 | 0.01 |
| -0.07 | 0.26 | -0.01 | 0.13 |
| -0.09 | 0.21 | 0.10 | 0.12 |
| 0.01 | 0.25 | 0.09 | 0.01 |
| 0.02 | 0.33 | 0.05 | 0.04 |
| 0.10 | 0.25 | 0.11 | -0.03 |
| -0.01 | 0.24 | 0.06 | 0.10 |
| 0.03 | 0.23 | 0.08 | 0.09 |
| -0.20 | 0.25 | 0.12 | -0.00 |
| 0.08 | 0.22 | 0.06 | 0.01 |
| 0.17 | 0.30 | 0.04 | 0.06 |
| 0.11 | 0.19 | 0.10 | -0.06 |
| -0.02 | 0.26 | 0.05 | 0.07 |
| -0.03 | 0.22 | 0.08 | 0.04 |
| 0.10 | 0.23 | 0.08 | -0.03 |
| 0.13 | 0.24 | 0.03 | 0.05 |
| 0.07 | 0.27 | 0.06 | 0.07 |
| -0.05 | 0.25 | 0.09 | 0.03 |
| -0.09 | 0.27 | 0.09 | 0.07 |
| 0.01 | 0.26 | -0.01 | 0.18 |
| -0.11 | 0.33 | 0.11 | 0.02 |
| 0.03 | 0.24 | 0.08 | 0.06 |
| 0.04 | 0.27 | 0.10 | 0.14 |
| 0.16 | 0.30 | 0.09 | 0.05 |
| -0.20 | 0.30 | 0.09 | 0.02 |
| 0.04 | 0.29 | 0.04 | 0.12 |
| 0.01 | 0.24 | 0.03 | 0.02 |
| 0.09 | 0.28 | 0.05 | 0.08 |
| -0.01 | 0.15 | 0.14 | 0.10 |
| 0.14 | 0.29 | -0.03 | 0.06 |
| -0.10 | 0.26 | 0.14 | 0.04 |
| 0.05 | 0.29 | 0.08 | 0.00 |
| 0.03 | 0.21 | 0.03 | 0.08 |
| -0.04 | 0.20 | 0.06 | 0.07 |
| 0.06 | 0.25 | 0.09 | -0.00 |
| -0.05 | 0.29 | 0.08 | 0.02 |
| -0.06 | 0.30 | 0.02 | 0.11 |
| 0.05 | 0.23 | 0.10 | -0.01 |
| -0.01 | 0.19 | 0.07 | 0.09 |
| 0.10 | 0.29 | 0.13 | 0.02 |
| 0.06 | 0.27 | 0.07 | -0.04 |
| -0.00 | 0.20 | 0.04 | 0.03 |
|       | G1   | G2   | G3   | G4   |
|-------|------|------|------|------|
| 0.70  | 0.10 | 0.04 | 0.49 |      |
| -0.69 | 0.03 | 0.22 | 0.36 |      |
| -0.74 | 0.04 | 0.17 | 0.38 |      |
| -0.64 | 0.02 | 0.19 | 0.41 |      |
| -0.70 | 0.04 | 0.21 | 0.43 |      |
| -0.73 | 0.04 | 0.15 | 0.49 |      |
| -0.69 | 0.01 | 0.17 | 0.40 |      |
| -0.65 | 0.05 | 0.15 | 0.43 |      |
| -0.74 | 0.16 | 0.01 | 0.46 |      |
| -0.78 | 0.03 | 0.21 | 0.35 |      |
| -0.75 | 0.11 | 0.16 | 0.26 |      |
| -0.69 | 0.04 | 0.12 | 0.40 |      |
| -0.67 | 0.05 | 0.15 | 0.51 |      |
| -0.60 | 0.05 | 0.12 | 0.45 |      |
| -0.73 | 0.01 | 0.10 | 0.44 |      |
| -0.72 | 0.03 | 0.13 | 0.43 |      |
| -0.72 | 0.06 | 0.13 | 0.40 |      |
| -0.71 | 0.06 | 0.13 | 0.37 |      |
| -0.78 | 0.16 | 0.13 | 0.39 |      |
| -0.76 | 0.05 | 0.06 | 0.46 |      |
| -0.83 | 0.06 | 0.06 | 0.56 |      |
| -0.71 | 0.12 | 0.10 | 0.39 |      |
| -0.77 | 0.19 | 0.03 | 0.44 |      |
| -0.69 | 0.05 | 0.12 | 0.48 |      |
| -0.65 | 0.01 | 0.11 | 0.44 |      |
| -0.77 | 0.01 | 0.17 | 0.47 |      |
| -0.72 | 0.07 | 0.11 | 0.44 |      |
| -0.78 | 0.03 | 0.20 | 0.40 |      |
| -0.74 | 0.05 | 0.10 | 0.48 |      |
| -0.79 | 0.08 | 0.18 | 0.42 |      |
| -0.65 | 0.03 | 0.17 | 0.43 |      |
| -0.69 | 0.03 | 0.12 | 0.40 |      |
| -0.67 | -0.07 | 0.19 | 0.39 |      |
| -0.71 | 0.04 | 0.05 | 0.51 |      |
| -0.73 | 0.01 | 0.20 | 0.45 |      |
| -0.73 | 0.04 | 0.12 | 0.42 |      |
| -0.80 | 0.05 | 0.14 | 0.42 |      |
| -0.65 | 0.01 | 0.17 | 0.41 |      |
| -0.74 | 0.12 | 0.02 | 0.52 |      |
| -0.73 | 0.11 | 0.01 | 0.48 |      |
| -0.79 | 0.00 | 0.14 | 0.48 |      |
| -0.74 | 0.01 | 0.12 | 0.52 |      |
| -0.68 | 0.02 | 0.13 | 0.48 |      |
| -0.74 | 0.11 | 0.04 | 0.49 |      |
| -0.73 | 0.12 | 0.02 | 0.51 |      |
| -0.68 | 0.06 | 0.11 | 0.44 |      |
| -0.77 | 0.11 | 0.07 | 0.41 |      |
| -0.71 | 0.02 | 0.07 | 0.51 |      |
| -0.81 | 0.16 | 0.11 | 0.46 |      |
| -0.86 | 0.10 | 0.16 | 0.37 |      |
| -0.69 | 0.00 | 0.11 | 0.43 |      |
| -0.71 | 0.02 | 0.19 | 0.41 |      |
| -0.72 | 0.03 | 0.12 | 0.44 |      |
| -0.71 | 0.01 | 0.21 | 0.37 |      |
| -0.66 | 0.03 | 0.16 | 0.43 |      |

**Slocums River Fundulus magalis growth rates**

|       |       |       |       |
|-------|-------|-------|-------|
| G1    | June 1994 - July 1994 |
| G2    | July 1994 - August 1994 |
| G3    | August 1994 - October 1994 |
| G4    | October 1994 - May 1995 |
| -0.71 | 0.09 | 0.13 | 0.39 |
|-------|------|------|------|
| -0.76 | 0.10 | 0.14 | 0.41 |
| -0.74 | 0.08 | 0.11 | 0.45 |
| -0.71 | -0.00| 0.22 | 0.40 |
| -0.68 | -0.02| 0.16 | 0.50 |
| -0.72 | -0.06| 0.09 | 0.44 |
| -0.72 |-0.03 | 0.17 | 0.49 |
| -0.68 | 0.01 | 0.18 | 0.41 |
| -0.74 | 0.07 | 0.14 | 0.41 |
| -0.75 | 0.10 | 0.12 | 0.39 |
| -0.70 | 0.02 | 0.22 | 0.38 |
| -0.74 | 0.03 | 0.14 | 0.42 |
| -0.70 | 0.05 | 0.11 | 0.48 |
| -0.75 | 0.09 | 0.07 | 0.47 |
| -0.71 | 0.12 | 0.06 | 0.41 |
| -0.75 |-0.01 | 0.20 | 0.40 |
| -0.72 | 0.05 | 0.11 | 0.45 |
| -0.77 | 0.08 | 0.13 | 0.42 |
| -0.71 |-0.02 | 0.17 | 0.42 |
| -0.69 | 0.14 | 0.02 | 0.51 |
| -0.75 | 0.05 | 0.09 | 0.48 |
| -0.78 | 0.07 | 0.15 | 0.42 |
| -0.71 | 0.14 | 0.00 | 0.48 |
| -0.76 | 0.06 | 0.20 | 0.34 |
| -0.71 |-0.00 | 0.10 | 0.54 |
| -0.63 | 0.02 | 0.08 | 0.40 |
| -0.77 |-0.02 | 0.22 | 0.44 |
| -0.76 | 0.09 | 0.19 | 0.42 |
| -0.72 | 0.04 | 0.13 | 0.42 |
| -0.69 | 0.08 | 0.12 | 0.42 |
| -0.75 | 0.03 | 0.14 | 0.43 |
| -0.67 | 0.15 |-0.02 | 0.50 |
| -0.74 | 0.11 |-0.04 | 0.48 |
| -0.66 |-0.07 | 0.20 | 0.39 |
| -0.75 | 0.12 | 0.18 | 0.34 |
| -0.69 | 0.04 | 0.09 | 0.44 |
| -0.78 | 0.14 | 0.02 | 0.46 |
| -0.69 |-0.02 | 0.19 | 0.37 |
| -0.71 | 0.00 | 0.11 | 0.55 |
| -0.67 | 0.01 | 0.05 | 0.51 |
| -0.77 | 0.03 | 0.14 | 0.50 |
| -0.70 | 0.02 | 0.13 | 0.42 |
| -0.77 | 0.05 | 0.11 | 0.42 |
| -0.70 | 0.03 | 0.12 | 0.49 |
| -0.67 | 0.03 | 0.08 | 0.51 |
|      | G1  | G2  | G3  | G4  |
|------|-----|-----|-----|-----|
| 0.29 | -0.04 | -0.06 | 0.35 |
| 0.37 | 0.08  | -0.13 | 0.39 |
| 0.30 | 0.06  | -0.15 | 0.36 |
| 0.32 | 0.14  | -0.17 | 0.29 |
| 0.38 | 0.12  | -0.13 | 0.45 |
| 0.27 | 0.00  | -0.09 | 0.30 |
| 0.35 | 0.09  | -0.11 | 0.38 |
| 0.34 | -0.02 | -0.12 | 0.37 |
| 0.41 | 0.14  | -0.14 | 0.31 |
| 0.33 | 0.14  | -0.20 | 0.37 |
| 0.28 | -0.05 | -0.10 | 0.40 |
| 0.30 | 0.04  | -0.12 | 0.32 |
| 0.41 | 0.14  | -0.15 | 0.33 |
| 0.39 | 0.04  | -0.03 | 0.29 |
| 0.32 | 0.02  | -0.08 | 0.40 |
| 0.40 | 0.06  | -0.11 | 0.33 |
| 0.42 | 0.05  | -0.02 | 0.34 |
| 0.39 | 0.12  | -0.17 | 0.42 |
| 0.35 | 0.02  | -0.07 | 0.34 |
| 0.28 | -0.00 | -0.07 | 0.31 |
| 0.42 | 0.20  | -0.23 | 0.37 |
| 0.34 | -0.03 | -0.06 | 0.42 |
| 0.36 | -0.04 | -0.01 | 0.37 |
| 0.38 | 0.12  | -0.11 | 0.36 |
| 0.35 | 0.12  | -0.11 | 0.37 |
| 0.30 | -0.07 | -0.02 | 0.31 |
| 0.40 | 0.10  | -0.13 | 0.36 |
| 0.32 | 0.03  | -0.11 | 0.38 |
| 0.31 | -0.08 | -0.01 | 0.28 |
| 0.36 | 0.15  | -0.19 | 0.40 |
| 0.35 | -0.00 | -0.13 | 0.48 |
| 0.44 | 0.11  | -0.09 | 0.36 |
| 0.47 | 0.13  | -0.11 | 0.42 |
| 0.41 | 0.16  | -0.14 | 0.39 |
| 0.29 | -0.04 | -0.06 | 0.33 |
| 0.36 | 0.05  | -0.09 | 0.42 |
| 0.48 | 0.06  | 0.03 | 0.35 |
| 0.34 | 0.07  | -0.06 | 0.35 |
| 0.29 | -0.06 | -0.09 | 0.41 |
| 0.45 | 0.11  | -0.10 | 0.39 |
| 0.34 | 0.02  | -0.10 | 0.40 |
| 0.40 | 0.08  | -0.05 | 0.36 |
| 0.33 | -0.01 | -0.03 | 0.32 |
| 0.33 | 0.13  | -0.15 | 0.43 |
| 0.43 | 0.10  | -0.07 | 0.34 |
| 0.41 | 0.06  | -0.06 | 0.39 |
| 0.32 | 0.04  | -0.08 | 0.34 |
| 0.33 | 0.08  | -0.13 | 0.38 |
| 0.36 | -0.03 | -0.01 | 0.34 |
| 0.29 | 0.03  | -0.13 | 0.34 |
| 0.41 | 0.11  | -0.18 | 0.39 |
| 0.45 | 0.19  | -0.15 | 0.39 |
| 0.29 | -0.04 | -0.07 | 0.38 |
| 0.39 | 0.06  | -0.10 | 0.42 |
| 0.43 | 0.09  | -0.07 | 0.33 |

Slocums River Fundulus heteroclitus growth rates

- **G1** = June 1994 - July 1994
- **G2** = July 1994 - August 1994
- **G3** = August 1994 - October 1994
- **G4** = October 1994 - May 1995
| 0.22 | 0.09 | 0.08 | 0.06 | 0.48 |
|------|------|------|------|------|
| 0.11 | 0.10 | 0.14 | 0.02 | 0.54 |
| 0.09 | 0.24 | 0.08  | 0.02 | 0.52 |
| 0.19 | 0.24 | 0.09  | 0.04 | 0.52 |
| 0.14 | 0.15  | 0.01  | 0.17 | 0.46 |
| 0.30 | 0.13  | 0.07  | 0.17 | 0.43 |
| 0.06 | 0.20  | 0.10  | 0.00  | 0.54 |
| 0.20 | 0.14  | 0.06  | 0.03  | 0.52 |
| 0.25 | 0.08  | 0.12  | 0.09  | 0.42 |
| 0.21 | 0.13  | 0.02  | 0.01  | 0.62 |
| 0.21 | 0.08  | 0.02  | 0.08  | 0.51 |
| 0.04 | 0.18  | 0.08  | 0.10  | 0.47 |
| 0.08 | 0.16  | 0.02  | 0.10  | 0.50 |
| 0.15 | 0.13  | 0.00  | 0.16  | 0.49 |
| 0.29 | 0.12  | 0.05  | 0.14  | 0.45 |
| 0.26 | 0.13  | 0.02  | 0.06  | 0.48 |
| 0.21 | 0.05  | 0.05  | 0.20  | 0.41 |
| 0.16 | 0.19  | 0.09  | 0.20  | 0.44 |
| 0.22 | 0.06  | 0.08  | 0.17  | 0.43 |
| 0.28 | 0.17  | 0.10  | 0.05  | 0.43 |
| 0.17 | 0.13  | 0.01  | 0.15  | 0.48 |
| 0.26 | 0.03  | 0.12  | 0.04  | 0.50 |
| 0.22 | 0.14  | 0.01  | 0.13  | 0.44 |
| 0.17 | 0.15  | 0.10  | 0.13  | 0.45 |
| 0.18 | 0.15  | 0.07  | 0.08  | 0.47 |
| 0.34 | 0.12  | 0.01  | 0.09  | 0.47 |
| 0.27 | 0.15  | 0.01  | 0.04  | 0.48 |
| 0.30 | 0.07  | 0.09  | 0.09  | 0.43 |
| 0.17 | 0.15  | 0.10  | 0.04  | 0.48 |
| 0.07 | 0.32  | 0.02  | 0.01  | 0.50 |
| 0.30 | 0.03  | 0.09  | 0.06  | 0.49 |
| 0.18 | 0.25  | 0.09  | 0.06  | 0.58 |
| 0.19 | 0.14  | 0.09  | 0.05  | 0.47 |
| 0.32 | 0.06  | 0.00  | 0.21  | 0.40 |
| 0.22 | 0.13  | 0.02  | 0.11  | 0.52 |
| 0.14 | 0.09  | 0.01  | 0.19  | 0.44 |
| 0.19 | 0.13  | 0.12  | 0.04  | 0.47 |
| 0.24 | 0.08  | 0.08  | 0.17  | 0.50 |
| 0.12 | 0.14  | 0.03  | 0.11  | 0.55 |
| 0.24 | 0.12  | 0.07  | 0.08  | 0.51 |
| 0.24 | 0.04  | 0.05  | 0.20  | 0.39 |
| 0.26 | 0.20  | 0.01  | 0.09  | 0.44 |
| 0.19 | 0.04  | 0.11  | 0.09  | 0.52 |
| 0.16 | 0.15  | 0.04  | 0.08  | 0.46 |
| 0.15 | 0.22  | 0.06  | 0.02  | 0.47 |
| GI  | G2     | G3   | G4   | G5     | G6   |
|-----|--------|------|------|--------|------|
| 0.56| 0.28   | 0.34 | 0.16 | 0.16   | 0.06 |
| 0.48| 0.30   | 0.37 | 0.13 | 0.12   |      |
| 0.59| 0.27   | 0.37 | 0.16 | 0.17   | 0.05 |
| 0.55| 0.23   | 0.36 | 0.16 | 0.13   | 0.12 |
| 0.56| 0.29   | 0.30 | 0.18 | 0.18   | 0.09 |
| 0.59| 0.25   | 0.29 | 0.11 | 0.16   | 0.09 |
| 0.49| 0.29   | 0.35 | 0.18 | 0.13   | 0.12 |
| 0.56| 0.24   | 0.31 | 0.15 | 0.15   | 0.07 |
| 0.49| 0.23   | 0.34 | 0.16 | 0.11   | 0.13 |
| 0.46| 0.31   | 0.33 | 0.14 | 0.15   | 0.09 |
| 0.41| 0.29   | 0.30 | 0.14 | 0.17   | 0.05 |
| 0.57| 0.31   | 0.31 | 0.16 | 0.16   | 0.06 |
| 0.45| 0.30   | 0.34 | 0.18 | 0.23   | 0.01 |
| 0.50| 0.27   | 0.27 | 0.11 | 0.12   | 0.14 |
| 0.51| 0.33   | 0.30 | 0.16 | 0.13   | 0.13 |
| 0.52| 0.31   | 0.23 | 0.10 | 0.16   | 0.04 |
| 0.52| 0.29   | 0.28 | 0.13 | 0.18   | 0.04 |
| 0.62| 0.23   | 0.33 | 0.13 | 0.06   | 0.20 |
| 0.33| 0.29   | 0.33 | 0.18 | 0.12   | 0.13 |
| 0.58| 0.24   | 0.29 | 0.14 | 0.24   | 0.02 |
| 0.59| 0.22   | 0.30 | 0.11 | 0.10   | 0.11 |
| 0.52| 0.29   | 0.32 | 0.15 | 0.20   | 0.12 |
| 0.56| 0.25   | 0.31 | 0.16 | 0.15   | 0.12 |
| 0.50| 0.24   | 0.35 | 0.17 | 0.16   | 0.09 |
| 0.63| 0.27   | 0.29 | 0.13 | 0.17   | 0.07 |
| 0.51| 0.31   | 0.28 | 0.14 | 0.13   | 0.11 |
| 0.50| 0.35   | 0.24 | 0.15 | 0.23   | 0.04 |
| 0.54| 0.24   | 0.34 | 0.13 | 0.14   | 0.09 |
| 0.56| 0.28   | 0.31 | 0.18 | 0.16   | 0.12 |
| 0.43| 0.34   | 0.27 | 0.13 | 0.09   | 0.17 |
| 0.48| 0.28   | 0.24 | 0.15 | 0.05   | 0.22 |
| 0.63| 0.26   | 0.28 | 0.10 | 0.17   | 0.07 |
| 0.44| 0.33   | 0.33 | 0.16 | 0.13   | 0.11 |
| 0.54| 0.30   | 0.31 | 0.12 | 0.16   | 0.07 |
| 0.55| 0.24   | 0.29 | 0.13 | 0.15   | 0.09 |
| 0.56| 0.26   | 0.29 | 0.14 | 0.07   | 0.22 |
| 0.52| 0.34   | 0.36 | 0.20 | 0.14   | 0.10 |
| 0.52| 0.27   | 0.30 | 0.16 | 0.08   | 0.14 |
| 0.54| 0.31   | 0.30 | 0.16 | 0.20   | 0.04 |
| 0.57| 0.25   | 0.33 | 0.19 | 0.20   | 0.07 |
| 0.47| 0.34   | 0.28 | 0.10 | 0.11   | 0.14 |
| 0.46| 0.35   | 0.32 | 0.17 | 0.21   | 0.04 |
| 0.56| 0.24   | 0.31 | 0.12 | 0.14   | 0.08 |
| 0.50| 0.26   | 0.24 | 0.17 | 0.03   | 0.22 |
| 0.58| 0.27   | 0.33 | 0.18 | 0.16   | 0.06 |
| 0.51| 0.30   | 0.29 | 0.15 | 0.14   | 0.12 |
| 0.57| 0.31   | 0.30 | 0.16 | 0.16   | 0.08 |
| 0.55| 0.22   | 0.35 | 0.11 | 0.13   | 0.40 |
| 0.52| 0.34   | 0.29 | 0.17 | 0.12   | 0.11 |
| 0.46| 0.27   | 0.35 | 0.14 | 0.08   | 0.15 |
| 0.49| 0.32   | 0.26 | 0.11 | 0.01   | 0.23 |
| 0.55| 0.29   | 0.29 | 0.17 | 0.18   | 0.11 |
| 0.51| 0.30   | 0.27 | 0.13 | 0.14   | 0.12 |
| 0.47| 0.27   | 0.32 | 0.13 | 0.09   | 0.13 |
| 0.56| 0.26   | 0.33 | 0.14 | 0.11   | 0.13 |

 GI = June 1994 - July 1994  
 G2 = July 1994 - August 1994  
 G3 = August 1994 - October 1994  
 G4 = October 1994 - December 1994  
 G5 = December 1994 - March 1995  
 G6 = March 1995 - May 1995
| 0.50 | 0.30 | 0.35 | -0.16 | 0.20 | 0.00 |
|------|------|------|-------|------|------|
| 0.46 | 0.34 | 0.33 | -0.17 | 0.13 | 0.11 |
| 0.48 | 0.31 | 0.31 | -0.14 | 0.07 | 0.18 |
| 0.64 | 0.25 | 0.23 | -0.11 | 0.14 | 0.12 |
| 0.53 | 0.26 | 0.31 | -0.16 | 0.20 | 0.06 |
| 0.44 | 0.29 | 0.37 | -0.19 | 0.12 | 0.15 |
| 0.60 | 0.30 | 0.28 | -0.15 | 0.08 | 0.14 |
| 0.53 | 0.25 | 0.34 | -0.16 | 0.25 | 0.01 |
| 0.67 | 0.18 | 0.30 | -0.10 | 0.18 | 0.07 |
| 0.54 | 0.27 | 0.33 | -0.16 | 0.13 | 0.11 |
| 0.40 | 0.31 | 0.29 | -0.11 | 0.11 | 0.12 |
| 0.53 | 0.26 | 0.29 | -0.13 | 0.20 | 0.06 |
| 0.55 | 0.24 | 0.27 | -0.09 | 0.13 | 0.09 |
| 0.62 | 0.26 | 0.30 | -0.14 | 0.12 | 0.07 |
| 0.61 | 0.25 | 0.28 | -0.11 | 0.18 | 0.04 |
| 0.52 | 0.26 | 0.28 | -0.09 | 0.13 | 0.06 |
| 0.58 | 0.25 | 0.30 | -0.11 | 0.16 | 0.07 |
| 0.58 | 0.29 | 0.35 | -0.22 | 0.15 | 0.10 |
| 0.58 | 0.26 | 0.29 | -0.13 | 0.15 | 0.11 |
| 0.57 | 0.26 | 0.34 | -0.16 | 0.20 | 0.03 |
| 0.53 | 0.28 | 0.28 | -0.10 | 0.13 | 0.09 |
| 0.52 | 0.28 | 0.39 | -0.19 | 0.14 | 0.10 |
| 0.51 | 0.29 | 0.34 | -0.17 | 0.11 | 0.14 |
| 0.62 | 0.23 | 0.30 | -0.17 | 0.12 | 0.12 |
| 0.56 | 0.27 | 0.31 | -0.13 | 0.07 | 0.15 |
| 0.52 | 0.26 | 0.34 | -0.17 | 0.09 | 0.17 |
| 0.49 | 0.27 | 0.33 | -0.16 | 0.09 | 0.12 |
| 0.48 | 0.33 | 0.30 | -0.17 | 0.09 | 0.16 |
| 0.56 | 0.24 | 0.35 | -0.17 | 0.15 | 0.10 |
| 0.53 | 0.31 | 0.27 | -0.15 | 0.20 | 0.04 |
| 0.52 | 0.23 | 0.36 | -0.16 | 0.19 | 0.03 |
| 0.57 | 0.25 | 0.31 | -0.12 | 0.15 | 0.07 |
| 0.58 | 0.22 | 0.31 | -0.11 | 0.10 | 0.16 |
| 0.48 | 0.27 | 0.31 | -0.16 | 0.21 | 0.04 |
| 0.50 | 0.30 | 0.27 | -0.15 | 0.07 | 0.16 |
| 0.50 | 0.31 | 0.29 | -0.15 | 0.17 | 0.11 |
| 0.56 | 0.25 | 0.32 | -0.15 | 0.18 | 0.07 |
| 0.56 | 0.24 | 0.31 | -0.08 | 0.12 | 0.10 |
| 0.58 | 0.27 | 0.31 | -0.16 | 0.14 | 0.11 |
| 0.51 | 0.28 | 0.30 | -0.11 | 0.03 | 0.17 |
| 0.58 | 0.31 | 0.32 | -0.18 | 0.20 | 0.03 |
| 0.44 | 0.30 | 0.34 | -0.18 | 0.08 | 0.15 |
| 0.56 | 0.23 | 0.35 | -0.16 | 0.11 | 0.09 |
| 0.57 | 0.25 | 0.34 | -0.18 | 0.13 | 0.10 |
| 0.55 | 0.30 | 0.31 | -0.17 | 0.20 | 0.04 |
New Bedford Fundulus heteroclitus growth rates

| G1 | G2 | G3 | G4 |
|----|----|----|----|
| -0.33 | 0.05 | -0.07 | 0.14 |
| -0.42 | 0.06 | -0.08 | 0.18 |
| -0.33 | 0.13 | -0.17 | 0.20 |
| -0.36 | 0.14 | -0.15 | 0.15 |
| -0.47 | 0.19 | -0.14 | 0.22 |
| -0.29 | 0.05 | -0.12 | 0.11 |
| -0.37 | 0.11 | -0.13 | 0.11 |
| -0.47 | 0.09 | -0.06 | 0.06 |
| -0.35 | 0.12 | -0.13 | 0.13 |
| -0.33 | 0.11 | -0.18 | 0.17 |
| -0.29 | 0.09 | -0.11 | 0.11 |
| -0.45 | 0.13 | -0.09 | 0.12 |
| -0.40 | 0.06 | -0.03 | 0.08 |
| -0.36 | 0.06 | -0.12 | 0.14 |
| -0.47 | 0.10 | -0.11 | 0.11 |
| -0.41 | 0.05 | -0.03 | 0.11 |
| -0.49 | 0.21 | -0.12 | 0.13 |
| -0.31 | -0.03 | -0.02 | 0.08 |
| -0.42 | 0.08 | -0.13 | 0.19 |
| -0.41 | 0.11 | -0.07 | 0.13 |
| -0.47 | 0.05 | -0.02 | 0.12 |
| -0.41 | 0.10 | -0.10 | 0.14 |
| -0.35 | 0.16 | -0.12 | 0.11 |
| -0.34 | 0.06 | -0.13 | 0.12 |
| -0.39 | 0.10 | -0.12 | 0.11 |
| -0.38 | 0.07 | -0.08 | 0.16 |
| -0.41 | 0.13 | -0.09 | 0.10 |
| -0.43 | 0.07 | -0.05 | 0.17 |
| -0.38 | 0.06 | -0.15 | 0.21 |
| -0.51 | 0.10 | -0.04 | 0.14 |
| -0.50 | 0.23 | -0.14 | 0.11 |
| -0.43 | 0.10 | -0.11 | 0.13 |
| -0.41 | 0.08 | -0.07 | 0.18 |
| -0.48 | 0.17 | -0.06 | 0.13 |
| -0.38 | 0.11 | -0.08 | 0.16 |
| -0.37 | 0.02 | -0.09 | 0.16 |
| -0.46 | 0.14 | -0.12 | 0.13 |
| -0.43 | 0.07 | -0.01 | 0.06 |
| -0.41 | 0.16 | -0.11 | 0.09 |
| -0.38 | 0.06 | -0.09 | 0.13 |
| -0.42 | 0.26 | -0.17 | 0.16 |
| -0.53 | 0.15 | -0.04 | 0.11 |
| -0.42 | 0.05 | -0.07 | 0.17 |
| -0.31 | 0.07 | -0.10 | 0.18 |
| -0.44 | 0.09 | -0.06 | 0.11 |
| -0.39 | 0.11 | -0.10 | 0.08 |
| -0.42 | 0.17 | -0.19 | 0.22 |
| -0.48 | 0.18 | -0.06 | 0.18 |
| -0.31 | 0.02 | -0.08 | 0.12 |
| -0.46 | 0.19 | -0.12 | 0.15 |
| -0.41 | 0.07 | -0.00 | 0.10 |
| -0.50 | 0.14 | -0.09 | 0.14 |
| -0.47 | 0.13 | -0.08 | 0.14 |
| -0.45 | 0.10 | -0.14 | 0.13 |
| -0.44 | 0.14 | -0.08 | 0.17 |

G1 = June 1994 - July 1994
G2 = July 1994 - August 1994
G3 = August 1994 - October 1994
G4 = October 1994 - May 1995
| Value 1 | Value 2 | Value 3 | Value 4 |
|--------|--------|--------|--------|
| -0.38  | 0.12   | -0.12  | 0.15   |
| -0.47  | 0.19   | -0.10  | 0.16   |
| -0.41  | 0.08   | -0.06  | 0.18   |
| -0.42  | 0.10   | -0.08  | 0.16   |
| -0.47  | 0.23   | -0.13  | 0.09   |
| -0.43  | 0.11   | -0.08  | 0.10   |
| -0.41  | 0.11   | -0.07  | 0.10   |
| -0.42  | 0.10   | -0.10  | 0.15   |
| -0.40  | 0.17   | -0.10  | 0.10   |
| -0.43  | 0.14   | -0.12  | 0.17   |
| -0.45  | 0.07   | -0.07  | 0.15   |
| -0.47  | 0.15   | -0.12  | 0.18   |
| -0.39  | 0.09   | -0.07  | 0.10   |
| -0.44  | 0.18   | -0.07  | 0.19   |
| -0.30  | 0.06   | -0.06  | 0.06   |
| -0.53  | 0.17   | -0.14  | 0.24   |
| -0.39  | 0.08   | -0.07  | 0.10   |
| -0.40  | 0.17   | -0.17  | 0.16   |
| -0.45  | 0.16   | -0.06  | 0.18   |
| -0.51  | 0.24   | -0.10  | 0.06   |
| -0.38  | 0.11   | -0.08  | 0.15   |
| -0.47  | 0.16   | -0.09  | 0.05   |
| -0.43  | 0.12   | -0.07  | 0.10   |
| -0.41  | 0.07   | -0.05  | 0.12   |
| -0.47  | 0.08   | -0.05  | 0.10   |
| -0.35  | 0.14   | -0.10  | 0.16   |
| -0.28  | 0.00   | -0.11  | 0.11   |
| -0.31  | 0.03   | -0.09  | 0.14   |
| -0.41  | 0.04   | -0.00  | 0.08   |
| -0.40  | 0.12   | -0.08  | 0.13   |
| -0.38  | 0.18   | -0.15  | 0.14   |
| -0.39  | 0.06   | -0.07  | 0.06   |
| -0.32  | 0.04   | -0.07  | 0.09   |
| -0.41  | 0.13   | -0.05  | 0.04   |
| -0.47  | 0.10   | -0.01  | 0.09   |
| -0.39  | 0.11   | -0.12  | 0.11   |
| -0.50  | 0.15   | -0.08  | 0.18   |
| -0.28  | 0.00   | -0.05  | 0.04   |
| -0.39  | 0.18   | -0.12  | 0.18   |
| -0.52  | 0.25   | -0.17  | 0.13   |
| -0.44  | 0.09   | -0.08  | 0.15   |
| -0.42  | 0.13   | -0.09  | 0.10   |
| -0.51  | 0.21   | -0.12  | 0.10   |
| -0.34  | 0.01   | -0.03  | 0.10   |
| -0.42  | 0.11   | -0.12  | 0.12   |
Appendix L. Pooled length-frequency data for each month for *Menidia* species, *Fundulus heteroclitus*, and *Fundulus majalis*, this data was used for the bootstrapping estimation of growth rate.
| M. sp. | New Bedford | JUNE | length | frequency |
|-------|-------------|------|--------|-----------|
|       |             |      | (1.2)  | 1         |
|       |             |      | (2.1)  | 1         |
|       |             |      | (3.2)  | 1         |

| M. sp. | New Bedford | JULY | length | frequency |
|-------|-------------|------|--------|-----------|
|       |             |      | (2.1)  | 1         |
|       |             |      | (3.7)  | 1         |
|       |             |      | (4.6)  | 1         |

| M. sp. | New Bedford | AUGUST | length | frequency |
|-------|-------------|--------|--------|-----------|
|       |             | (2.7)  | 1      |
|       |             | (3.8)  | 1      |
|       |             | (3.9)  | 1      |

| M. sp. | New Bedford | OCTOBER | length | frequency |
|-------|-------------|---------|--------|-----------|
|       |             | (4.5)   | 1      |
|       |             | (5.1)   | 1      |
|       |             | (5.4)   | 1      |

| M. sp. | New Bedford | DECEMBER | length | frequency |
|-------|-------------|----------|--------|-----------|
|       |             | (4.5)    | 1      |
|       |             | (5.1)    | 1      |
|       |             | (5.2)    | 2      |

| M. sp. | New Bedford | MARCH | length | frequency |
|-------|-------------|-------|--------|-----------|
|       |             | (3.3) | 1      |
|       |             | (3.9) | 1      |

| M. sp. | New Bedford | MAY | length | frequency |
|-------|-------------|-----|--------|-----------|
|       |             | (3.3) | 1      |
|       |             | (3.7) | 1      |
| Month   | Species | New Bedford | June  | July  | August | September |
|---------|---------|-------------|-------|-------|--------|-----------|
|         |         |             | 49    | 38    | 34     | 51        |
|         |         |             | (7.3) | (7.4) | (7.5)  | (7.7)     |
|         |         |             | 12    | 17    | 24     | 15        |
|         |         |             | (9.8) | (9.9) | (10.1) | (10.3)    |
| September | New Bedford | November | 30    | 34    | 39     | 1        |
|         |         |             | (7.6) | (7.8) | (7.9)  | (8.1)     |
|         |         |             | 23    | 9     | 16     | 14        |
|         |         |             | (10.2) | (10.4) | (10.5) | (10.6)    |
| December | New Bedford | December  | 6     | 34    | 29     | 1        |
|         |         |             | (10.1) | (10.3) | (10.4) | (10.6)    |
| March   | New Bedford | March      | 22    | 1     | 22     | 1        |
|         |         |             | (8.3) | (8.2) | (8.3)  | (11)      |
| May     | New Bedford | May        |       |       |        |           |
|         |         |             |       |       |        |           |
|         |         |             |       |       |        |           |
| Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| New Bedford           | New Bedford           | New Bedford           | New Bedford           | New Bedford           |
| JUNE                  | JULY                  | AUGUST                | OCTOBER               | MAY                   |
| (2.1)                 | 1                     | (2.6)                 | 2                     | (3.4)                 |
| (2.2)                 | 2                     | (2.8)                 | 1                     | (3.2)                 |
| (2.9)                 | 1                     | (2.9)                 | 2                     | (3.3)                 |
| (2.4)                 | 1                     | (3)                   | 2                     | (3.4)                 |
| (2.5)                 | 1                     | (3.1)                 | 2                     | (3.5)                 |
| (4.8)                 | 5                     | (3.2)                 | 10                    | (3.6)                 |
| (5)                   | 1                     | (3.3)                 | 8                     | (3.7)                 |
| (5.1)                 | 1                     | (3.4)                 | 7                     | (3.8)                 |
| (5.2)                 | 4                     | (3.5)                 | 11                    | (3.9)                 |
| (5.3)                 | 4                     | (3.6)                 | 16                    | (4)                   |
| (5.4)                 | 5                     | (3.7)                 | 18                    | (4.1)                 |
| (5.5)                 | 10                    | (3.8)                 | 21                    | (4.2)                 |
| (5.6)                 | 7                     | (3.9)                 | 26                    | (4.3)                 |
| (5.7)                 | 3                     | (4)                   | 31                    | (4.4)                 |
| (5.8)                 | 4                     | (4.1)                 | 25                    | (4.5)                 |
| (5.9)                 | 4                     | (4.2)                 | 42                    | (4.6)                 |
| (6)                   | 6                     | (4.3)                 | 24                    | (4.7)                 |
| (6.1)                 | 4                     | (4.4)                 | 29                    | (4.8)                 |
| (6.2)                 | 7                     | (4.5)                 | 34                    | (4.9)                 |
| (6.3)                 | 3                     | (4.6)                 | 22                    | (5)                   |
| (6.4)                 | 3                     | (4.7)                 | 31                    | (5.1)                 |
| (6.5)                 | 7                     | (4.8)                 | 22                    | (5.2)                 |
| (6.6)                 | 10                    | (4.9)                 | 28                    | (5.3)                 |
| (6.7)                 | 3                     | (5)                   | 22                    | (5.4)                 |
| (6.8)                 | 5                     | (5.1)                 | 25                    | (5.5)                 |
| (6.9)                 | 4                     | (5.2)                 | 35                    | (5.6)                 |
| (7)                   | 7                     | (5.3)                 | 19                    | (5.7)                 |
| (7.1)                 | 9                     | (5.4)                 | 19                    | (5.8)                 |
| (7.2)                 | 5                     | (5.5)                 | 16                    | (6)                   |
| (7.3)                 | 6                     | (5.6)                 | 22                    | (6.2)                 |
| (7.4)                 | 1                     | (5.7)                 | 7                     | (6.5)                 |
| (7.5)                 | 2                     | (5.8)                 | 12                    | (6.6)                 |
| (7.6)                 | 3                     | (5.9)                 | 11                    | (6.7)                 |
| (7.7)                 | 4                     | (6)                   | 11                    | (7)                   |
| (7.8)                 | 1                     | (6.1)                 | 12                    | (7.5)                 |
| (7.9)                 | 2                     | (6.2)                 | 6                     | (7.8)                 |
| (8)                   | 3                     | (6.3)                 | 5                     | (8.1)                 |
| (8.1)                 | 2                     | (6.4)                 | 10                    | (8.2)                 |
| (8.2)                 | 4                     | (6.5)                 | 4                     | (8.5)                 |
| (8.3)                 | 5                     | (6.6)                 | 4                     | (8.7)                 |
| (8.4)                 | 5                     | (6.8)                 | 1                     | (7)                   |
|       | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus |
|-------|-----------------------|-----------------------|-----------------------|-----------------------|
|       | New Bedford JUNE      | New Bedford JULY      | New Bedford AUGUST    | New Bedford OCTOBER   |
| 1     | 6.7                   | 7.5                   | 8.1                   | 7.5                   |
| 1     | 6.8                   | 7.6                   | 8.2                   | 7.6                   |
| 2     |                        |                       | 8.3                   |                       |
| 2     | 6.9                   | 7.7                   |                       |                       |
| 2     |                        |                       | 8.4                   |                       |
| 1     | 7.1                   | 7.9                   |                       |                       |
| 1     | 7.2                   | 8.0                   |                       |                       |
| 1     | 7.3                   | 8.1                   |                       |                       |
| 1     | 7.4                   |                       |                       |                       |
| 1     | 7.5                   |                       |                       |                       |
| 1     | 7.6                   |                       |                       |                       |
| 1     | 7.7                   |                       |                       |                       |
| 1     | 7.8                   |                       |                       |                       |
| 1     | 7.9                   |                       |                       |                       |
| 2     | 8.0                   |                       |                       |                       |
| 1     | 8.1                   |                       |                       |                       |
| 1     | 8.2                   |                       |                       |                       |
| 1     | 8.3                   |                       |                       |                       |
| 1     | 8.4                   |                       |                       |                       |
| 1     | 8.5                   |                       |                       |                       |
| 1     | 8.6                   |                       |                       |                       |
| 1     | 8.7                   |                       |                       |                       |
| 1     | 8.8                   |                       |                       |                       |
| 1     | 8.9                   |                       |                       |                       |
| 1     | 9.0                   |                       |                       |                       |
| 1     | 9.1                   |                       |                       |                       |
| 1     | 9.2                   |                       |                       |                       |
| 1     | 9.3                   |                       |                       |                       |
| 1     | 9.4                   |                       |                       |                       |
| 1     | 9.5                   |                       |                       |                       |
| 1     | 9.6                   |                       |                       |                       |
| 1     | 9.7                   |                       |                       |                       |
| 1     | 9.8                   |                       |                       |                       |
| 1     | 9.9                   |                       |                       |                       |
| Fundulus majalis New Bedford | Fundulus majalis New Bedford | Fundulus majalis New Bedford | Fundulus majalis New Bedford | Fundulus majalis New Bedford | Fundulus majalis New Bedford |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| JUNE                        | JULY                        | AUGUST                      | OCTOBER                     | NOVEMBER                    | DECEMBER                    |
| [1.8]                       | [2.1]                       | [3.1]                       | [2.7]                       | [3.8]                       | [4]                         |
| [1.9]                       | [2.5]                       | [3.2]                       | [3.5]                       | [4]                         | [4.3]                       |
| [2]                         | [2.6]                       | [3.3]                       | [3.8]                       | [4.1]                       | [4.6]                       |
| [2.1]                       | [2.7]                       | [3.4]                       | [3.9]                       | [4.2]                       | [4.7]                       |
| [2.2]                       | [2.8]                       | [3.5]                       | [4]                         | [4.3]                       | [4.8]                       |
| [2.3]                       | [2.9]                       | [4.1]                       | [4.4]                       | [4.5]                       | [4.9]                       |
| [2.4]                       | [3]                         | [4.2]                       | [5]                         | [5]                         | [5.1]                       |
| [2.5]                       | [3.1]                       | [4.3]                       | [5.2]                       | [5.3]                       | [5.2]                       |
| [2.6]                       | [3.2]                       | [4.4]                       | [5.4]                       | [5.5]                       | [5.3]                       |
| [3]                         | [3.3]                       | [4.5]                       | [5.6]                       | [5.7]                       | [5.4]                       |
| [3.2]                       | [3.4]                       | [4.6]                       | [5.8]                       | [5.8]                       | [5.5]                       |
| [3.3]                       | [3.5]                       | [4.7]                       | [6]                         | [5.9]                       | [5.6]                       |
| [3.5]                       | [3.6]                       | [4.8]                       | [6.1]                       | [6]                         | [5.7]                       |
| [3.6]                       | [3.7]                       | [4.9]                       | [6.2]                       | [6.1]                       | [6]                         |
| [3.7]                       | [3.8]                       | [5]                         | [6.3]                       | [6.2]                       | [6.1]                       |
| [3.9]                       | [4]                         | [5.1]                       | [6.4]                       | [6.3]                       | [6.2]                       |
| [4]                         | [4.1]                       | [5.2]                       | [6.5]                       | [6.4]                       | [6.3]                       |
| [4.1]                       | [4.2]                       | [5.3]                       | [6.6]                       | [6.5]                       | [6.4]                       |
| [4.2]                       | [4.3]                       | [5.4]                       | [6.7]                       | [6.6]                       | [6.5]                       |
| [4.3]                       | [4.4]                       | [5.5]                       | [6.8]                       | [6.7]                       | [6.6]                       |
| [4.4]                       | [4.5]                       | [5.6]                       | [6.9]                       | [6.8]                       | [6.7]                       |
| [4.5]                       | [4.6]                       | [5.7]                       | [7]                         | [6.9]                       | [6.8]                       |
| [4.6]                       | [4.7]                       | [5.8]                       | [7.1]                       | [7]                         | [6.9]                       |
| [4.7]                       | [4.8]                       | [5.9]                       | [7.2]                       | [7.1]                       | [7]                         |
| [4.8]                       | [4.9]                       | [6]                         | [7.3]                       | [7.2]                       | [7.1]                       |
| [4.9]                       | [5]                         | [6.1]                       | [7.4]                       | [7.3]                       | [7.2]                       |
| [5]                         | [5.1]                       | [6.2]                       | [7.5]                       | [7.4]                       | [7.3]                       |
| [5.1]                       | [5.2]                       | [6.3]                       | [7.6]                       | [7.5]                       | [7.4]                       |
| [5.2]                       | [5.3]                       | [6.4]                       | [7.7]                       | [7.6]                       | [7.5]                       |
| [5.3]                       | [5.4]                       | [6.5]                       | [7.8]                       | [7.7]                       | [7.6]                       |
| Fundulus majalis | New Bedford | Fundulus majalis | New Bedford | Fundulus majalis | New Bedford |
|------------------|-------------|------------------|-------------|------------------|-------------|
| **JUNE**         |             | **JULY**         |             | **AUGUST**       |             |
| [8.5] 1          | [6.4] 11    | [7] 15           | [7.7] 1     | [7.9] 6          |             |
| [8.6] 1          | [6.5] 4     | [7.1] 12         | [7.4] 5     | [8] 2            |             |
| [8.7] 2          | [6.6] 8     | [7.2] 19         | [7.9] 2     | [8.1] 2          |             |
| [9] 2            | [6.7] 5     | [7.3] 10         | [8] 5       | [8.2] 8          |             |
| [9.5] 2          | [6.8] 1     | [7.4] 12         | [8.1] 2     | [8.3] 1          |             |
| [9.7] 1          | [6.9] 3     | [7.5] 12         | [8.2] 3     | [8.4] 7          |             |
| [10] 2           | [7.1] 2     | [7.54] 1         | [8.3] 2     | [8.5] 2          |             |
| [10.3] 1         | [7.2] 1     | [7.6] 12         | [8.4] 3     | [8.9] 1          |             |
| **OCTOBER**      |             | **DECEMBER**     |             |                  |             |
|                  |             |                  | [8.5] 3     | [10.5] 1         |             |
|                  |             |                  | [8.6] 6     | [12.2] 1         |             |
|                  |             |                  | [8.7] 1     |                  |             |
|                  |             |                  | [8.8] 1     |                  |             |
|                  |             |                  | [8.9] 1     |                  |             |
|                  |             |                  | [9] 1       |                  |             |
|                  |             |                  | [9.1] 6     |                  |             |
|                  |             |                  | [9.2] 3     |                  |             |
|                  |             |                  | [9.3] 1     |                  |             |
|                  |             |                  | [9.4] 1     |                  |             |
|                  |             |                  | [9.5] 1     |                  |             |
|                  |             |                  | [9.6] 1     |                  |             |
|                  |             |                  | [9.7] 1     |                  |             |
|                  |             |                  | [9.8] 1     |                  |             |
|                  |             |                  | [9.9] 1     |                  |             |
|                  |             |                  | [10] 1      |                  |             |
|                  |             |                  | [10.1] 1    |                  |             |
|                  |             |                  | [10.2] 3    |                  |             |
|                  |             |                  | [10.3] 1    |                  |             |
|                  |             |                  | [10.4] 1    |                  |             |
|                  |             |                  | [10.5] 1    |                  |             |
|                  |             |                  | [10.6] 2    |                  |             |
|                  |             |                  | [10.7] 1    |                  |             |
|                  |             |                  | [10.8] 2    |                  |             |
|                  |             |                  | [10.9] 1    |                  |             |
|                  |             |                  | [11] 1      |                  |             |
|                  |             |                  | [11.1] 1    |                  |             |
|                  |             |                  | [11.2] 1    |                  |             |
|                  |             |                  | [11.3] 1    |                  |             |
| Menidia species Slocums River | Menidia species Slocums River | Menidia species Slocums River |
|-------------------------------|-------------------------------|-------------------------------|
| **JUNE**                     | **JULY**                      | **AUGUST**                    |
| [1] 4                         | [2] 1                          | [3] 11                        |
| [1.1] 1                      | [2.1] 1                        | [3.1] 12                      |
| [1.2] 2                      | [2.2] 1                        | [3.2] 12                      |
| [1.3] 3                      | [2.3] 1                        | [3.3] 12                      |
| [1.4] 4                      | [2.4] 1                        | [3.4] 12                      |
| [1.5] 5                      | [2.5] 1                        | [3.5] 12                      |
| [1.6] 6                      | [2.6] 1                        | [3.6] 12                      |
| [1.7] 7                      | [2.7] 1                        | [3.7] 12                      |
| [1.8] 8                      | [2.8] 1                        | [3.8] 12                      |
| [1.9] 9                      | [2.9] 1                        | [3.9] 12                      |
| [2] 10                       | [3] 1                          | [4] 12                        |
| [2.1] 1                      | [3.1] 1                        | [4.1] 12                      |
| [2.2] 2                      | [3.2] 1                        | [4.2] 12                      |
| [2.3] 3                      | [3.3] 1                        | [4.3] 12                      |
| [2.4] 4                      | [3.4] 1                        | [4.4] 12                      |
| [2.5] 5                      | [3.5] 1                        | [4.5] 12                      |
| [2.6] 6                      | [3.6] 1                        | [4.6] 12                      |
| [2.7] 7                      | [3.7] 1                        | [4.7] 12                      |
| [2.8] 8                      | [3.8] 1                        | [4.8] 12                      |
| [2.9] 9                      | [3.9] 1                        | [4.9] 12                      |
| [3] 10                       | [4] 1                          | [5] 12                        |
| [3.1] 1                      | [4.1] 1                        | [5.1] 12                      |
| [3.2] 2                      | [4.2] 1                        | [5.2] 12                      |
| [3.3] 3                      | [4.3] 1                        | [5.3] 12                      |
| [3.4] 4                      | [4.4] 1                        | [5.4] 12                      |
| [3.5] 5                      | [4.5] 1                        | [5.5] 12                      |
| [3.6] 6                      | [4.6] 1                        | [5.6] 12                      |
| [3.7] 7                      | [4.7] 1                        | [5.7] 12                      |
| [3.8] 8                      | [4.8] 1                        | [5.8] 12                      |
| [3.9] 9                      | [4.9] 1                        | [5.9] 12                      |
| [4] 10                       | [5] 1                          | [6] 12                        |
| [4.1] 1                      | [5.1] 1                        | [6.1] 12                      |
| [4.2] 2                      | [5.2] 1                        | [6.2] 12                      |
| [4.3] 3                      | [5.3] 1                        | [6.3] 12                      |
| [4.4] 4                      | [5.4] 1                        | [6.4] 12                      |
| [4.5] 5                      | [5.5] 1                        | [6.5] 12                      |
| [4.6] 6                      | [5.6] 1                        | [6.6] 12                      |
| [4.7] 7                      | [5.7] 1                        | [6.7] 12                      |
| [4.8] 8                      | [5.8] 1                        | [6.8] 12                      |
| [4.9] 9                      | [5.9] 1                        | [6.9] 12                      |
| [5] 10                       | [6] 1                          | [7] 12                        |
| [5.1] 1                      | [6.1] 1                        | [7.1] 12                      |
| [5.2] 2                      | [6.2] 1                        | [7.2] 12                      |
| [5.3] 3                      | [6.3] 1                        | [7.3] 12                      |
| [5.4] 4                      | [6.4] 1                        | [7.4] 12                      |
| [5.5] 5                      | [6.5] 1                        | [7.5] 12                      |
| [5.6] 6                      | [6.6] 1                        | [7.6] 12                      |
| [5.7] 7                      | [6.7] 1                        | [7.7] 12                      |
| [5.8] 8                      | [6.8] 1                        | [7.8] 12                      |
| [5.9] 9                      | [6.9] 1                        | [7.9] 12                      |
| [6] 10                       | [7] 1                          | [8] 12                        |
| [6.1] 1                      | [7.1] 1                        | [8.1] 12                      |
| [6.2] 2                      | [7.2] 1                        | [8.2] 12                      |
| [6.3] 3                      | [7.3] 1                        | [8.3] 12                      |
| [6.4] 4                      | [7.4] 1                        | [8.4] 12                      |
| [6.5] 5                      | [7.5] 1                        | [8.5] 12                      |
| [6.6] 6                      | [7.6] 1                        | [8.6] 12                      |
| [6.7] 7                      | [7.7] 1                        | [8.7] 12                      |
| [6.8] 8                      | [7.8] 1                        | [8.8] 12                      |
| [6.9] 9                      | [7.9] 1                        | [8.9] 12                      |
| [7] 10                       | [8] 1                          | [9] 12                        |
| [7.1] 1                      | [9.1] 1                        | [10] 12                       |
| [7.2] 2                      | [9.2] 1                        | [11] 12                       |
| [7.3] 3                      | [9.3] 1                        | [12] 12                       |
| [7.4] 4                      | [9.4] 1                        | [13] 12                       |
| [7.5] 5                      | [9.5] 1                        | [14] 12                       |
| [7.6] 6                      | [9.6] 1                        | [15] 12                       |
| [7.7] 7                      | [9.7] 1                        | [16] 12                       |
| [7.8] 8                      | [9.8] 1                        | [17] 12                       |
| [7.9] 9                      | [9.9] 1                        | [18] 12                       |
| [8] 10                       | [10] 1                         | [19] 12                       |
|       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|
| **JUNE** | **JULY** | **AUGUST** | **OCTOBER** | **NOVEMBER** | **DECEMBER** |
| **Menidia species** | **Menidia species** | **Menidia species** | **Menidia species** | **Menidia species** | **Menidia species** |
| **Slocums River** | **Slocums River** | **Slocums River** | **Slocums River** | **Slocums River** | **Slocums River** |
| [10.3] | [5.8] | [6.4] | [7.4] | [9.6] | [11.4] |
| [10.5] | [5.9] | [6.5] | [7.5] | [9.9] | [11.5] |
| [11.1] | [6.1] | [6.7] | [7.7] | [10.2] | [11.6] |
| [11.2] | [6.2] | [6.8] | [8.1] | [11.7] | [11.7] |
| [6.3] | [6.9] | [8.2] | [11.9] | [11.9] | [11.9] |
| [6.32] | [7] | [8.2] | [12.1] | [12.1] | [12.1] |
| [6.4] | [7.1] | [8.3] | [12.2] | [12.2] | [12.2] |

|       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|
| **Menidia species** | **Menidia species** | **Menidia species** | **Menidia species** | **Menidia species** | **Menidia species** |
| **Slocums River** | **Slocums River** | **Slocums River** | **Slocums River** | **Slocums River** | **Slocums River** |
| [6.5] | [7.2] | [8.4] | [10.4] | [12.4] | [14.4] |
| [6.4] | [7.3] | [8.5] | [10.5] | [12.5] | [14.5] |
| [6.7] | [7.4] | [8.6] | [10.6] | [12.6] | [14.6] |
| [6.74] | [7.5] | [8.7] | [10.7] | [12.7] | [14.7] |
| [6.8] | [7.6] | [8.8] | [10.8] | [12.8] | [14.8] |
| [6.9] | [7.7] | [8.9] | [10.9] | [12.9] | [14.9] |
| [7] | [7.8] | [8.10] | [10.10] | [12.10] | [14.10] |
| [7.1] | [7.9] | [8.11] | [10.11] | [12.11] | [14.11] |
| [7.2] | [8] | [8.12] | [10.12] | [12.12] | [14.12] |
| [7.3] | [8.1] | [8.13] | [10.13] | [12.13] | [14.13] |
| [7.4] | [8.2] | [8.14] | [10.14] | [12.14] | [14.14] |
| [7.5] | [8.3] | [8.15] | [10.15] | [12.15] | [14.15] |
| [7.6] | [8.4] | [8.16] | [10.16] | [12.16] | [14.16] |
| [7.8] | [8.5] | [8.17] | [10.17] | [12.17] | [14.17] |
| [8] | [8.6] | [8.18] | [10.18] | [12.18] | [14.18] |
| [8.1] | [8.7] | [8.19] | [10.19] | [12.19] | [14.19] |
| [8.2] | [8.8] | [8.20] | [10.20] | [12.20] | [14.20] |
| [8.4] | [8.9] | [8.21] | [10.21] | [12.21] | [14.21] |
| [8.7] | [9] | [9.2] | [10.22] | [12.22] | [14.22] |
| [9.4] | [9.1] | [9.3] | [10.23] | [12.23] | [14.23] |
| [12] | [12.1] | [12.2] | [12.24] | [14.24] | [14.25] |
|                | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus |
|----------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                | Slocums River         | Slocums River         | Slocums River         | Slocums River         | Slocums River         |
| **JUNE**       | [2.8] 1               | [1.7] 1               | [2.2] 1               | [2.1] 1               | [2.5] 2               |
|                | [3.3] 1               | [1.7] 1               | [2.2] 1               | [2.1] 4               | [2.6] 4               |
|                | [3.8] 2               | [1.8] 1               | [2.3] 4               | [2.7] 9               | [3.8] 6               |
|                | [3.8] 1               | [1.9] 1               | [2.3] 3               | [2.8] 9               | [4.1] 4               |
|                | [3.9] 1               | [2] 6                 | [2.4] 5               | [2.9] 4               | [4.6] 10              |
|                | [4] 7                 | [2.1] 6               | [2.5] 13              | [3] 13                | [4.2] 13              |
|                | [4.1] 4               | [2.2] 9               | [3.5] 1               | [3.1] 25              | [4.3] 18              |
|                | [4.2] 15              | [2.3] 9               | [2.6] 16              | [3.2] 27              | [4.4] 17              |
|                | [4.3] 8               | [2.4] 14              | [2.7] 21              | [3.3] 17              | [4.5] 4               |
|                | [4.4] 8               | [2.5] 19              | [2.8] 17              | [3.4] 4               | [4.6] 16              |
|                | [4.5] 19              | [2.6] 39              | [2.9] 41              | [3.5] 15              | [4.7] 6               |
|                | [4.6] 17              | [2.7] 51              | [3] 39                | [3.6] 18              | [4.8] 7               |
|                | [4.7] 13              | [2.8] 46              | [3.1] 46              | [3.7] 28              | [4.9] 7               |
|                | [4.8] 5               | [2.9] 47              | [3.2] 63              | [3.8] 18              | [5] 11                |
|                | [4.9] 9               | [3] 53                | [3.3] 37              | [3.9] 14              | [5.1] 8               |
|                | [5] 14                | [3.1] 58              | [3.4] 18              | [4] 17               | [5.2] 13              |
|                | [5.1] 12              | [3.2] 51              | [3.5] 1               | [4.1] 12              | [5.3] 3               |
|                | [5.2] 12              | [3.25] 1              | [3.5] 27              | [4.2] 22              | [5.4] 8               |
|                | [5.3] 14              | [3.3] 42              | [3.6] 23              | [4.3] 11              | [5.5] 5               |
|                | [5.4] 26              | [3.4] 31              | [3.7] 44              | [4.4] 7               | [5.6] 6               |
|                | [5.5] 19              | [3.5] 47              | [3.8] 28              | [4.5] 2               | [5.7] 6               |
|                | [5.6] 17              | [3.54] 1              | [3.9] 30              | [4.6] 5               | [5.8] 2               |
|                | [5.7] 18              | [3.6] 37              | [4] 21                | [4.7] 8               | [6] 2                 |
|                | [5.8] 15              | [3.7] 30              | [4.1] 25              | [4.8] 2               | [6.1] 3               |
|                | [5.9] 9               | [3.8] 33              | [4.2] 28              | [4.9] 3               | [6.2] 3               |
|                | [6] 20                | [3.9] 17              | [4.22] 1              | [5] 3                | [6.3] 3               |
|                | [6.1] 15              | [4] 19                | [4.5] 9               | [5.1] 2               | [6.4] 3               |
|                | [6.2] 11              | [4.1] 14              | [4.6] 14              | [5.2] 11              | [6.5] 2               |
|                | [6.3] 5               | [4.2] 15              | [4.6] 16              | [5.3] 2               | [6.6] 6               |
|                | [6.4] 5               | [4.3] 8               | [4.6] 10              | [5.5] 2               | [6.8] 2               |
|                | [6.5] 6               | [4.4] 10              | [4.7] 17              | [5.6] 2               | [6.9] 3               |
|                | [6.6] 12              | [4.5] 16              | [4.8] 6               | [5.7] 1               | [7] 3                 |
|                | [6.7] 3               | [4.54] 1              | [4.9] 7               | [5.8] 3               | [7.1] 1               |
|                | [6.8] 6               | [4.6] 8               | [5] 4                | [5.9] 1               | [7.3] 3               |
|                | [6.9] 6               | [4.7] 9               | [5.1] 11              | [6.2] 1               | [7.4] 2               |
|                | [7] 7                 | [4.8] 6               | [5.2] 9               | [6.5] 1               | [7.5] 2               |
|                | [7.1] 4               | [4.9] 3               | [5.3] 1               | [6.7] 1               | [7.6] 3               |
|                | [7.2] 3               | [5] 3                 | [5.4] 5               | [7.1] 1               | [7.8] 4               |
|                | [7.3] 4               | [5.1] 5               | [5.5] 5               | [8] 1                | [8.1] 4               |
| Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus | Fundulus heteroclitus |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Slocums River         | Slocums River         | Slocums River         | Slocums River         | Slocums River         |
| **JUNE**              | **JULY**              | **AUGUST**            | **OCTOBER**           | **MAY**               |
| (8.7)                 | (6.1)                 | (6.7)                 | (9.2)                 | (9.4)                 |
| (8.8)                 | (6.12)                | (6.8)                 | (9.4)                 | (2)                   |
| (8.9)                 | (6.2)                 | (6.9)                 |                       |                       |
| (9.5)                 | (6.21)                | (6.6)                 |                       |                       |
| (9.6)                 | (6.3)                 | (6.7)                 |                       |                       |
|                       | (6.4)                 | (7.2)                 |                       |                       |
|                       | (6.5)                 | (7.4)                 |                       |                       |
|                       | (6.6)                 | (7.5)                 |                       |                       |
|                       | (6.7)                 | (7.6)                 |                       |                       |
|                       | (6.8)                 | (7.7)                 |                       |                       |
|                       | (6.9)                 | (7.8)                 |                       |                       |
|                       | (7)                   | (7.9)                 |                       |                       |
|                       | (7.1)                 | (8)                   |                       |                       |
|                       | (7.2)                 | (8.1)                 |                       |                       |
|                       | (7.3)                 | (8.2)                 |                       |                       |
|                       | (7.4)                 | (8.3)                 |                       |                       |
|                       | (7.5)                 | (8.4)                 |                       |                       |
|                       | (7.6)                 | (8.5)                 |                       |                       |
|                       | (7.7)                 | (8.6)                 |                       |                       |
|                       | (7.8)                 | (8.7)                 |                       |                       |
|                       | (7.9)                 | (8.8)                 |                       |                       |
|                       | (8)                   | (8.9)                 |                       |                       |
|                       | (8.1)                 | (9)                   |                       |                       |
|                       | (8.2)                 | (9.2)                 |                       |                       |
|                       | (8.3)                 | (9.4)                 |                       |                       |
|                       | (8.4)                 |                       |                       |                       |
|                       | (8.5)                 |                       |                       |                       |
|                       | (9.4)                 |                       |                       |                       |
| Fundulus majalis | Fundulus majalis | Fundulus majalis | Fundulus majalis | Fundulus majalis |
|------------------|------------------|------------------|------------------|------------------|
| Slocomb River    | Slocomb River    | Slocomb River    | Slocomb River    | Slocomb River    |
| JUNE             | JULY             | AUGUST           | OCTOBER          | MAY              |
| (2.7)            | 1                | (2.1)            | (2.5)            | (3.2)            |
| (3.1)            | 1                | (2.2)            | (2.6)            | (4)              |
| (4.6)            | 1                | (2.3)            | (2.7)            | (4.3)            |
| (5.4)            | 1                | (2.4)            | (2.8)            | (4.6)            |
| (5.5)            | 1                | (2.5)            | (2.9)            | (4.7)            |
| (5.7)            | 1                | (2.6)            | (3)              | (4.8)            |
| (6)              | 1                | (2.7)            | (3.1)            | (4.9)            |
| (6.4)            | 1                | (2.8)            | (3.2)            | (5.1)            |
| (6.6)            | 2                | (3.1)            | (3.3)            | (5.2)            |
| (6.7)            | 4                | (3.2)            | (3.4)            | (5.3)            |
| (6.8)            | 4                | (3.3)            | (3.5)            | (5.5)            |
| (7)              | 4                | (3.4)            | (3.6)            | (5.6)            |
| (7.1)            | 1                | (3.5)            | (3.7)            | (5.7)            |
| (7.2)            | 1                | (3.6)            | (3.8)            | (5.8)            |
| (7.4)            | 2                | (3.7)            | (3.9)            | (5.9)            |
| (7.5)            | 2                | (3.8)            | (4)              | (6)              |
| (7.7)            | 2                | (3.9)            | (4.1)            | (6.1)            |
| (7.8)            | 2                | (4)              | (4.2)            | (6.2)            |
| (7.9)            | 1                | (4.1)            | (4.3)            | (6.3)            |
| (8)              | 5                | (4.2)            | (4.4)            | (6.4)            |
| (8.1)            | 3                | (4.3)            | (4.5)            | (6.5)            |
| (8.2)            | 5                | (4.4)            | (4.6)            | (6.6)            |
| (8.4)            | 3                | (4.5)            | (4.7)            | (6.7)            |
| (8.5)            | 2                | (4.6)            | (4.8)            | (6.8)            |
| (8.7)            | 2                | (4.7)            | (4.9)            | (6.9)            |
| (8.8)            | 2                | (4.8)            | (5)              | (7)              |
| (9)              | 3                | (4.9)            | (5.1)            | (7.1)            |
| (9.2)            | 2                | (5)              | (5.2)            | (7.2)            |
| (9.3)            | 2                | (5.1)            | (5.3)            | (7.3)            |
| (9.4)            | 7                | (5.4)            | (5.5)            | (7.4)            |
| (9.5)            | 2                | (5.5)            | (5.6)            | (7.5)            |
| (9.7)            | 2                | (5.6)            | (5.7)            | (7.6)            |
| (10)             | 1                | (5.7)            | (5.8)            | (7.7)            |
| (10.3)           | 1                | (5.8)            | (5.9)            | (7.8)            |
| (10.5)           | 1                | (5.9)            | (6)              | (7.9)            |
| (11.1)           | 1                | (6)              | (6.1)            | (8)              |
Appendix M. SAS program for calculating instantaneous growth rates using a bootstrapping program.
*This is a MACRO written to do Bootstrap calculations of growth;
*Variable declarations;
%global nboot;
%let nboot=200;
%global n;
*n=num of obs in dataset;
%let n=126;
*bootstrap macro;
%macro boot;

data weights;
retain seed 919194;
array w(ii) w1-w&n;
do i=1 to &nboot;
   do over w;
      w=0
   end;
do j=1 to &n;
call ranuni(seed,u);
   ii=int(&n*u)+1;
      w+1;
end;
output;
end;

keep w1-w&n;
proc transpose out=w prefix=tw;
data out; merge nhh93 w;
%do i=1 %to &nboot;
    %program;
%end;
%mend boot;

%program;
*growth estimates by month;
proc sort data=out; by m ;
proc means noprint;
var length;
weight nobs;
by m ;
freq tw&i;
output out=w2 mean=mlength;
data w3;
set w2;
l=&i;
   if m=6 then x='mn6';
   if m=7 then x='mn7';
   if m=8 then x='mn8';
   if m=9 then x='mn9';
proc transpose out=w3t prefix=t;
var mlength;
id x;
by 1;
data w4;
set w3t;
g1=(log(tmn7/tmn6));
g2=(log(tmn8/tmn7));
g3=(log(tmn9/tmn8));
cg1=(log(tmn8/tmn6));
cg2=(log(tmn9/tmn8));
proc append base=bootg;
proc print;
data w5;
set bootg;
file nhhg93;
put gl 1-5 .2 g2 7-11 .2 g3 13-17 .2 cg1 19-23 .2 cg2 25-30 .2; %mend program;
data nhh 93;
infile 'nhhlen. dat';
input m length nobs;
%boot;
Appendix N. Calculation of diversity indices, the Shannon-Wiener function and the Simpson index, for the summer, fall/winter and spring seasons. The diversity estimates were generated using the jacknife procedure.
| Species                  | JUNE I | JUNE II | JUNE III | JULY I | JULY II |
|-------------------------|--------|---------|----------|--------|---------|
| Anguilla                | 1      | 2       | 4        | 1      | 1       |
| Aplite                  |        | 1       |          |        |         |
| Brevoortia              |        |         |          | 2      | 5       |
| Caranx hippos           |        |         |          | 4      | 1       |
| Clupea harengus         |        |         |          | 1      | 1       |
| F. heteroclitus         | 44     | 5       | 11       | 23     | 18      |
| F. majalis              | 10     | 60      |          | 64     | 102     |
| Gobiosoma               |        |         |          | 8      | 47      |
| Menidia                 | 85     | 94      | 104      | 14     | 113     |
| Mugil cephalus          | 1      |         |          | 1      |         |
| Myoxocephalus           |        |         |          |        |         |
| Opasus                  |        | 2       |          | 2      | 1       |
| Pleuronectes            | 1      |         |          | 1      | 1       |
| Pungitius               |        |         |          | 4      |         |
| Sygnathus               |        | 1       |          | 1      |         |
| T. adspersus            |        | 3       | 20       | 3      | 1       |
| T. onitis               |        | 3       | 4        |        | 6       |
| TOTAL:                  | 129    | 108     | 116      | 40     | 132     |

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| AUGUST I | AUGUST II | TOTAL | Shannon-Weiner | Simpson index |
|----------|----------|-------|---------------|--------------|
| 3 4 1 2 3 4 1 2 3 4 | 2 | 0.00028479 | 2.3377E-09 |
| 1 2 | 4 | 0.00052842 | 1.4026E-08 |
| 2 | 11 | 0.00128793 | 1.2857E-07 |
| 7 3 6 3 | 26 | 0.00271214 | 7.5976E-07 |
| 47 296 111 144 6 985 45 768 4 97 | 3787 | 0.11510236 | 0.01684728 |
| 149 100 41 126 12 468 22 585 94 88 | 2985 | 0.10115135 | 0.01041133 |
| 9 3 1 6 | 22 | 0.02349454 | 5.4001E-07 |
| 712 99 73 580 1697 716 86 1723 247 2784 | 22223 | 0.09065706 | 0.57723006 |
| 3 | 5 | 0.00064396 | 2.3377E-08 |
| 1 | 7 | 0.00028479 | 2.3377E-09 |
| 11 | 0.00128793 | 1.2857E-07 |
| 0 0 | 0 | 0 |
| 1 1 2 | 7 | 0.00086657 | 4.9092E-08 |
| 24 13 23 6 | 116 | 0.00952456 | 1.5593E-05 |
| 3 | 3 | 0.00128793 | 2.3377E-09 |
| 920 541 229 874 1715 2199 172 3086 345 2972 | 29250 | 0.33043111 | 0.39549244 |
| | | | | | | | 0.60450756 |
Calculation of Jacknife Estimates:
summer months

| Shannon-Weiner | Simpson Index |
|----------------|--------------|
| y(0) = 0.330431 | y(0) = 0.395492 |

Removing observations:

- y(-1) = 0.330358, y(-1) = 0.394963
- y(-2) = 0.331166, y(-2) = 0.396289
- y(-3) = 0.330974, y(-3) = 0.396242
- y(-4) = 0.329765, y(-4) = 0.394769
- y(-5) = 0.330793, y(-5) = 0.396069
- y(-6) = 0.331153, y(-6) = 0.396509
- y(-7) = 0.329934, y(-7) = 0.394596
- y(-8) = 0.330925, y(-8) = 0.394868
- y(-9) = 0.327654, y(-9) = 0.393007
- y(-10) = 0.331228, y(-10) = 0.396874
- y(-11) = 0.327812, y(-11) = 0.39119
- y(-12) = 0.332311, y(-12) = 0.384496
- y(-13) = 0.374612, y(-13) = 0.461966
- y(-14) = 0.360861, y(-14) = 0.442732
- y(-15) = 0.338344, y(-15) = 0.406622
- y(-16) = 0.300518, y(-16) = 0.351065
- y(-17) = 0.330131, y(-17) = 0.395913
- y(-18) = 0.319216, y(-18) = 0.381161
- y(-19) = 0.327486, y(-19) = 0.391036
- y(-20) = 0.326902, y(-20) = 0.391528
- y(-21) = 0.342793, y(-21) = 0.413682
- y(-22) = 0.300136, y(-22) = 0.348423
- y(-23) = 0.328181, y(-23) = 0.39333
- y(-24) = 0.312202, y(-24) = 0.384341
- y(-25) = 0.329997, y(-25) = 0.39474
- y(-26) = 0.347742, y(-26) = 0.420792
Calculation of Jacknife Estimates:
summer months

\[ y_1 = n_yo/(n-1) \]

\[ y_2 = (y_1 - JK) \]

| Shannon-Weiner | Simpson index |
|----------------|--------------|
| \( n_yo-(n-1)y_i \) | \( n_yo-(n-1)y_i \) |
| 0.332256 | 1.0538E-05 |
| 0.312056 | 0.00028743 |
| 0.316856 | 0.00014772 |
| 0.347081 | 0.00032657 |
| 0.321631 | 5.4447E-05 |
| 0.312381 | 0.00027652 |
| 0.342856 | 0.00019172 |
| 0.355581 | 0.00070603 |
| 0.399856 | 0.00501918 |
| 0.310506 | 0.00034239 |
| 0.395906 | 0.0044751 |
| 0.508431 | 0.03219195 |
| -0.774094 | 1.2168381 |
| -0.430319 | 0.5765803 |
| 0.132606 | 0.03857447 |
| 1.078256 | 0.5613608 |
| 0.337931 | 7.9587E-05 |
| 0.610806 | 0.07940907 |
| 0.404056 | 0.00563193 |
| 0.418656 | 0.00803643 |
| 0.021381 | 0.09463551 |
| 1.087806 | 0.5757716 |
| 0.386681 | 0.00332596 |
| 0.786156 | 0.20898261 |
| 0.341281 | 0.00015056 |
| -0.102344 | 0.18605614 |

\[ JK = \text{(mean)} \]

\[ \text{VAR(JK)} = 0.32900085 \]

\[ \Sigma/(n^*(n-1)) \]

\[ \text{(mean)} \]

\[ \Sigma/(n^*(n-1)) \]

\[ 0.39119296 \]

\[ 0.012898753 \]
| Species            | OCTOBER | DECEMBER | MARCH | TOTAL | Shannon-Weiner | Simpson index |
|--------------------|---------|----------|-------|-------|----------------|---------------|
| Anguilla           | 1       | 2        | 3     | 4     | 1              | 2             |
| Apeltes            | 5       |          | 2     | 3     | 4              | 5             |
| Brevoortia         | 105     | 107      | 14    | 62    | 3              | 4             |
| Caranx hippos      | 170     | 107      | 14    | 62    | 3              | 4             |
| Clupea harangus    | 5       | 107      | 14    | 62    | 3              | 4             |
| F. heteroclitus    | 170     | 107      | 14    | 62    | 3              | 4             |
| F. majalis         | 105     | 107      | 14    | 62    | 3              | 4             |
| Gobiosoma          | 75      | 39       | 55    | 1     | 114            | 2             |
| Menidia            | 75      | 39       | 55    | 1     | 114            | 2             |
| Mugil cephalus     | 2       |          | 1     | 114   | 2              | 17            |
| Myoxocephalus      | 2       |          | 1     | 114   | 2              | 17            |
| Opsanus             | 5       |          | 1     | 114   | 2              | 17            |
| Pleuronectes       | 2       |          | 1     | 114   | 2              | 17            |
| Pungitius          | 2       |          | 1     | 114   | 2              | 17            |
| Sygnathus          | 2       |          | 1     | 114   | 2              | 17            |
| T. adspersus       | 2       |          | 1     | 114   | 2              | 17            |
| T. onitis          | 2       |          | 1     | 114   | 2              | 17            |
|                     | 352     | 209      | 71    | 234   | 172            | 943           |
|                     |         |          | 100   | 19    | 32             | 1             |
|                     | 2142    | 0.37622182| 1 - Σ | 0.512286247 | 0.467713753   |
Calculation of Jacknife Estimates:
fallwinter months

|       | Shannon-Weiner | Simpson index |
|-------|----------------|---------------|
| y(0)  | 0.37622        | 0.51228625    |
| y(-1) | 0.324147       | 0.40078603    |
| y(-2) | 0.340484       | 0.44281087    |
| y(-3) | 0.360833       | 0.46306552    |
|       | 0.380478       | 0.49098709    |
|       | 0.351341       | 0.450634      |
|       | 0.481481       | 0.655427      |
|       | 0.384008       | 0.50023       |
|       | 0.375564       | 0.48665851    |
|       | 0.372709       | 0.482117      |
|       | 0.377296       | 0.48933818    |
|       | 0.376319       | 0.48787011    |
|       | 0.376595       | 0.48961606    |

\[
\text{nyo} \cdot (n-1)y_i = (y_1 - JK)^2
\]

\[
\begin{align*}
\text{nyo} \cdot (n-1)y_i &= (y_1 - JK)^2 \\
\text{mean} &= \sum (n^2(n-1)) \\
\text{mean} &= \sum (n^2(n-1)) \\
JK &= 0.38024325 \\
\text{Var.} JK &= 0.014165569 \\
& 0.499652169 \\
& 0.036551784
\end{align*}
\]
| Species                  | MAY I 1 | MAY I 2 | MAY I 3 | MAY I 4 | MAY II 1 | MAY II 2 | MAY II 3 | MAY II 4 | TOTAL | Shannon-Weiner | Simpson index |
|-------------------------|---------|---------|---------|---------|----------|----------|----------|----------|-------|----------------|---------------|
| Anguilla                |         |         |         |         | 1        |          |          |          |       | 0.00319192     | 0             |
| Apelles                 |         |         |         |         |          |          |          |          |       | 0.00319192     | 0             |
| Brevoortia              |         |         |         |         | 3        |          |          |          |       | 0.00319192     | 0             |
| Caranx hippos           |         |         |         |         | 2        |          |          |          |       | 0.00319192     | 0             |
| Clupea harengus         |         |         |         |         | 1        | 222      | 6        | 109      | 341   | 1              | 0             |
| F. heteroclitus         | 222     | 6       | 109     | 341     | 9        | 687      | 0.09715969| 0.00356494| 0.54548422| 0.09715969     |
| F. majalis              |         |         |         |         | 34       | 56       | 0.07348012| 0.00356494| 0.54548422| 0.07348012     |
| Gobiodon sp.            |         |         |         |         | 2        | 34       | 0.00319192| 0.00319192| 0.00356494| 0               |
| Menidia                 | 22      | 39      | 2       | 23      | 2        | 88       | 8        | 8        | 1     | 0.13950815     | 0.03939952    |
| Mugil cephalus          |         |         |         |         | 1        | 1        | 0.00319192| 0.00319192| 0.00356494| 0               |
| Myoxocephalus           |         |         |         |         |          |          |          |          |       | 0.00319192     | 0             |
| Opsanus                 |         |         |         |         |          |          |          |          |       | 0.00319192     | 0             |
| Pleuronectes            |         |         |         |         |          |          |          |          |       | 0.00319192     | 0             |
| Pungilus                |         |         |         |         |          |          |          |          |       | 0.00319192     | 0             |
| Syngnathus              |         |         |         |         |          |          |          |          |       | 0.00319192     | 0             |
| T. adspersus            |         |         |         |         |          |          |          |          |       | 0.00319192     | 0             |
| T. onitis               |         |         |         |         |          |          |          |          |       | 0.00319192     | 0             |
|                        | 31      | 274     | 2       | 64      | 111      | 429      | 8        | 11       | 930   | 0.31653179     | 0.41155133    |

\[\Sigma = \sum \text{species} \quad \Sigma = \sum \text{columns} \quad 0.58844867 \quad 0.41155133\]
## Calculation of Jackknife Estimates:

### Spring

| nyo-(n-1)y1 | (y1-JK)² | nyo-(n-1)y1 | (y1-JK)² |
|-------------|----------|-------------|----------|
| 0.451212    | 0.0260632| 0.629685    | 0.13085272|
| 0.170946    | 0.01411938| 0.181599    | 0.00547853|
| 0.320592    | 0.00094903| 0.405601    | 0.02246548|
| 0.673294    | 0.14706899| 0.867783    | 0.37462586|
| 0.10208     | 0.03522791| -0.710575   | 0.93391181|
| -0.031375   | 0.10313475| -0.02562    | 0.07915002|
| 0.333185    | 0.00188478| 0.38815     | 0.01753873|
| 0.296234    | 7.1622E-05| 0.309106    | 0.00285048|
| 2.318168    | 0.32854147| 2.045728    | 1.57587362|

| mean Σ/(n*(n-1)) | mean Σ/(n*(n-1)) |
|-------------------|-------------------|

| JK = 0.289771 | VAR (JK) = 0.00586581 | 0.25571613 | 0.0281406 |
| Species                                                | JUNI | JUNII | JUNIII | JULI | JULII |
|--------------------------------------------------------|------|-------|--------|------|-------|
| Alena pseudobrachyura                                | 7    | 15    | 3      | 5    | 13    |
| Anguilla                                              | 3    | 10    | 23     | 2    | 2     |
| Aploca                                                |      |       |        | 42   | 52    |
| Cerax chrysa                                          |      |       |        | 9    | 3     |
| Brevoortia                                             |      |       |        | 14   |       |
| Cerax hippocus                                         |      | 1     |        |      |       |
| Clinual harpingans                                    |      |       |        |      | 7     |
| Cyprinemus o.                                        | 3    |       |        | 3    |       |
| Euchinoamia                                           |      |       |        |      | 47    |
| F. heterocheilus                                      | 8    | 23    | 85     | 13   | 5     |
| F. marjalis                                            | 11   | 24    | 21     | 24   | 12    |
| Gobiovarun                                            |      |       |        | 11   | 138   |
| Lucemis parvus                                        | 2    |       |        | 6    | 2     |
| Latijama grimala                                       |      | 20    | 1      | 4    | 181   |
| Mantisida                                              | 9    |       | 1      | 4    | 181   |
| Manticirrhine                                         |      |       |        | 47   | 202   |
| Mugil cephalus                                        |      |       |        | 27   | 3     |
| Microgadus tomcod                                     |      |       |        | 439  | 463   |
| Mysis cephalus                                        |      |       |        | 15   | 642   |
| Ophiolepis                                            |      |       |        | 1    | 1128  |
| Planorcestes                                          | 1    | 2     | 1      | 1    | 1     |
| Pungitius                                              | 4    | 8     | 2      |      |       |
| Syngnathus                                            |      |       |        | 1    | 2     |
| T. alpestris                                           |      |       |        | 1    |       |
| T. marinus                                            |      |       |        | 1    |       |
| Trinucleen                                            |      |       |        | 1    |       |
| TOTAL:                                                | 38   | 40    | 104    | 20   | 58    |

Note: The table contains data on the abundance of various fish species in the Slocums River during different months.
| AUGUST I | AUGUST II | 4 TOTAL | Shannon-Weiner | Simpson index |
|---------|----------|---------|---------------|---------------|
| 2       | 3        | 4       | 1 2 3 4      |               |
| 32      | 26       | 6       | 250 0.026112035 | 5.8572E-07    |               |
| 1       | 14       | 5       | 245 0.025809738 | 5.8572E-07    |               |
| 1       | 11       | 1       | 24 0.003901963 | 7.8846E-06    | 0.000200335   |
| 19      | 1        | 1       | 77 0.010367343 | 1.8833E-05    | 0.178069396   |
| 8 2095  | 123      | 22 809  | 202 7439 0.1581182 | 5.8572E-07    | 0.12043591    |
| 18 656  | 162 7 65  | 6 1935 0.1053025347 | 0.12043591    | 0.178069396   |
| 0       | 0        | 0       | 0.000106126  | 6.3646E-08    |               |
| 5       | 0        | 0       | 4 0.000826899 | 3.8619E-08    |               |
| 203 981 | 188 2053 | 476 124 | 4 7306 0.158292747 | 6.3648E-09    | 0.175540915   |
| 1       | 2        | 1       | 2 0.000467403 | 5.1688E-05    |               |
| 10      | 127      | 0.015434803 |               |               |
| 0       | 0        | 0       | 0.001999825  | 3.5400E-07    |               |
| 16      | 0.00462052 | 5.8572E-07 |
| 249 1009 | 2983 2383 | 542 999 222 | 17628 Σ= | 0.526277165 1-Σ= | 0.63387 |

Σ= 0.366129828
### Calculation of jackknife estimates:

#### Summer months

| $y(0)$ | Shannon-Weiner | Simpson |
|--------|---------------|---------|
| 0.526277 | 0.63387012 |
| $y(-1)$ | 0.527958 | 0.632815 |
| $y(-2)$ | 0.524902 | 0.633325 |
| $y(-3)$ | 0.524658 | 0.633611 |
| $y(-4)$ | 0.525442 | 0.633662 |
| $y(-5)$ | 0.52318 | 0.632682 |
| $y(-6)$ | 0.527941 | 0.634594 |
| $y(-7)$ | 0.525498 | 0.632951 |
| $y(-8)$ | 0.52695 | 0.634339 |
| $y(-9)$ | 0.526127 | 0.633799 |
| $y(-10)$ | 0.527619 | 0.634563 |
| $y(-11)$ | 0.51951 | 0.630842 |
| $y(-12)$ | 0.521276 | 0.631756 |
| $y(-13)$ | 0.529536 | 0.636109 |
| $y(-14)$ | 0.545296 | 0.641417 |
| $y(-15)$ | 0.523716 | 0.632522 |
| $y(-16)$ | 0.526566 | 0.634737 |
| $y(-17)$ | 0.534334 | 0.636162 |
| $y(-18)$ | 0.501102 | 0.611952 |
| $y(-19)$ | 0.506112 | 0.62552 |
| $y(-20)$ | 0.524693 | 0.633539 |
| $y(-21)$ | 0.530334 | 0.637726 |
| $y(-22)$ | 0.520348 | 0.617077 |
| $y(-23)$ | 0.532189 | 0.63321 |
| $y(-24)$ | 0.52736 | 0.634772 |
| $y(-25)$ | 0.532435 | 0.637179 |
| $y(-26)$ | 0.529977 | 0.634537 |
|                   | Shannon-Weiner | Simpson |
|-------------------|----------------|---------|
| \( n_{\text{y}} - (n - 1) y_{\text{i}} \) | \( y_{\text{i}} - J_{\text{h2}} \) | \( y_{\text{i}} - J_{\text{h2}} \) |
| \( 0.484252 \) | 0.0032107684 | 0.660249471 | 0.43942233 |
| \( 0.560652 \) | 0.000379163 | 0.647499471 | 0.443214254 |
| \( 0.566752 \) | 0.000653933 | 0.640349471 | 0.442848477 |
| \( 0.547152 \) | 3.56662E-05 | 0.639074471 | 0.443671734 |
| \( 0.603702 \) | 0.003909015 | 0.663574671 | 0.438526763 |
| \( 0.507177 \) | 0.001156196 | 0.615774471 | 0.441802469 |
| \( 0.568752 \) | 2.90901E-05 | 0.656849471 | 0.44691914 |
| \( 0.510827 \) | 0.000912998 | 0.622149471 | 0.44269704 |
| \( 0.530027 \) | 0.000174387 | 0.635874671 | 0.443853351 |
| \( 0.492277 \) | 0.001743875 | 0.616549471 | 0.44057073 |
| \( 0.695452 \) | 0.023948869 | 0.709524471 | 0.411298665 |
| \( 0.653102 \) | 0.01216688 | 0.666224471 | 0.427710333 |
| \( 0.444802 \) | 0.009278697 | 0.577949471 | 0.431630738 |
| \( 0.599002 \) | 0.02407047 | 0.445199471 | 0.18119692 |
| \( 0.519052 \) | 0.000406443 | 0.612199471 | 0.443067164 |
| \( 0.324852 \) | 0.00679754 | 0.526574671 | 0.390363201 |
| \( 1.135652 \) | 0.353397096 | 1.181324471 | 0.09779232 |
| \( 1.030402 \) | 0.230382728 | 0.850126471 | 0.182146913 |
| \( 0.516877 \) | 0.000689948 | 0.642149471 | 0.442907021 |
| \( 0.346702 \) | 0.036653978 | 0.587494471 | 0.39621834 |
| \( 0.674502 \) | 0.177747886 | 1.050874671 | 0.42035482 |
| \( 0.378477 \) | 0.22672229 | 0.855344471 | 0.40918233 |
| \( 0.489202 \) | 0.01762143 | 0.611324471 | 0.44134744 |
| \( 0.372377 \) | 0.028571297 | 0.551149471 | 0.406548108 |
| \( 0.438952 \) | 0.01045904 | 0.617199471 | 0.429905782 |
| \( 1.407667 \) | 1.0631355437 | 17.31918625 | |

\[ \text{JK} = \frac{\sum_{i=1}^{n} y_{i} - n y_{\text{h2}}}{n(n-1)} \]
\[ \text{VAR}(\text{JK}) = \frac{\sum_{i=1}^{n} (y_{i} - n y_{\text{h2}})^2}{n(n-1)} \]
|           | OCTOBER | NOVEMBER | JANUARY | MARCH | TOTAL | Simpson index | Shannon-Weiner |
|-----------|---------|----------|---------|-------|-------|---------------|----------------|
| Alopa pseudoharen | 1 2 3 4 | 1 2 3 4 | 1 2 4 | 1 2 4 | 1 2 4 | 1 | 0.001607995 |
| Anguilla   | 0       | 0        | 0       | 0     | 0     | 0             | 0              |
| Apeltes   | 3 13 9 2 3 1 | 2 3 1 | 37 | 0.031342757 |
| Carcha chryus | 685 9 | 13 20 4 2 | 2 | 0.159678775 |
| Erevuoria | 327 30 | 94 19 1 | 18 | 0.147958569 |
| Carcha hippo | 80 84 | 44 3 2 | 213 | 0.101869848 |
| Clupea harengus | 0 | 0 | 0 | 0 |
| Cypseloto nus v. | 0 | 0 | 0 | 0 |
| Echinostomus | 0 | 0 | 0 | 0 |
| F. heteroclitus | 0 | 0 | 0 | 0 |
| F. maja lis | 0 | 0 | 0 | 0 |
| Gobiosoma | 0 | 0 | 0 | 0 |
| Lutjanus parva | 0 | 0 | 0 | 0 |
| Lutjanus griseus | 0 | 0 | 0 | 0 |
| Menidia | 127 104 105 63 114 81 5 7 37 2 49 24 | 698 | 0.159250335 |
| Menistirrhius | 0 | 0 | 0 | 0 |
| Mugil cephalus | 0 | 0 | 0 | 0 |
| Myoxocephalus | 0 | 0 | 0 | 0 |
| Opsanus | 0 | 0 | 0 | 0 |
| Pleuroneoctes | 2 1 | 3 | 0.004129486 |
| Pungitius | 0 | 0 | 0 | 0 |
| Syngnathus | 0 | 0 | 0 | 0 |
| T. adspersus | 0 | 0 | 0 | 0 |
| T. quinnus | 0 | 0 | 0 | 0 |
| Triacantho ntes | 0 | 0 | 0 | 0 |
| TOTAL: | 1223 243 105 63 271 15 15 10 37 4 49 21 24 1 2061 | 1 - Σ= | 0.695644642 |

Σ = 0.307435358

Σ = 0.695644642
Calculation of jacknife estimates:
fall/winter months

| y(-1) | y(-2) | y(-3) | ... | y(-12) |
|-------|-------|-------|-----|--------|
| 0.517212 | 0.578547 | 0.612276 | ... | 0.605275 |
| 0.609469 | 0.595915 | 0.599443 | ... | 0.606925 |
| 0.607391 | 0.606925 | 0.609378 | ... | 0.608724 |
| 0.606876 | 0.607391 | 0.606955 | ... | 0.606876 |

Shannon-Weiner: 0.607443
Simpson: 0.69256464
Calculation of jacknife estimates: fall/winter months

\[
\begin{array}{cccc}
\text{Shannon-Weiner} & \text{Simpson} \\
\text{nyo-(n-1)y}_i = (y_1/JKQ) & \text{nyo-(n-1)y}_i = (y_1/JKQ) \\
\hline
y_1 = & 1.780447133 & 1.107305675 & 3.581953905 & 7.139221192 \\
0.983092133 & 0.364997778 & 1.025081135 & 0.013489444 & 0.056215811 \\
0.544615133 & 0.03346916 & 0.072860705 & 0.056215811 & 0.056215811 \\
0.57856133 & 0.02239644 & 0.079647425 & 0.053289073 & 0.053289073 \\
0.757380133 & 0.000049543 & 0.044616995 & 0.001204609 & 0.001204609 \\
0.706846133 & 0.000373149 & 0.0218470665 & 0.047806749 & 0.047806749 \\
0.614178133 & 0.012992161 & 0.024806975 & 0.021054749 & 0.021054749 \\
0.608120133 & 0.014004859 & 0.069233715 & 0.04740102 & 0.04740102 \\
0.582389133 & 0.021278661 & 0.060531355 & 0.052614343 & 0.052614343 \\
0.620834133 & 0.0115191 & 0.049912645 & 0.04442924 & 0.04442924 \\
0.574788133 & 0.023523299 & 0.077763645 & 0.053099731 & 0.053099731 \\
0.635628133 & 0.008562369 & 0.072102453 & 0.035477538 & 0.035477538 \\
0.590791133 & 0.018070637 & 0.068418136 & 0.0509532 & 0.0509532 \\
0.614851133 & 0.012840332 & 0.069236125 & 0.045660594 & 0.045660594 \\
10.19425406 & 1.35360725 & 12.7387329 & 8.093686369 & 8.093686369 \\
\end{array}
\]

\[
\text{mean} \quad \Sigma (n^2(n-1)) \quad \text{mean} \quad \Sigma (n^2(n-1))
\]

\[
JK = 0.728161204 \quad 0.90990952 \quad 0.007437402 \quad 0.044070104
\]

\[
\text{VAR(JK)} = 0.007437402 \quad 0.007437402 \quad 0.007437402 \quad 0.007437402
\]
|                | MAY I | MAY II | TOTAL | Shannon-Weiner | Simpson index |
|----------------|-------|--------|-------|----------------|---------------|
| Alosa pseudoharengus | 4     | 1      | 2     | 17             | 0.025540756   | 0.000177042   |
| Anguilla        | 10    | 1      | 2     | 11             | 0.000177042   | 0.000566274   |
| Apheltes        | 25    | 10     | 30    | 0.039104043    | 0.000566274   |
| Carassius chrysus| 4     | 3      | 6     | 10             | 0.000566274   | 0.000566274   |
| Brevoortia      | 10    | 8      | 18    | 0.05530735     | 0.000566274   |
| Carassius hippos| 10    | 2      | 12    | 0.05530735     | 0.000566274   |
| Clupea harengus | 6     | 6      | 12    | 0.19525726-05  | 0.000566274   |
| Cyprinodon v.   | 3     | 4      | 7     | 0.0182113483   | 0.000566274   |
| Euchinostomus   | 0     | 0      | 0     | 0              | 0             |
| F. heteroclitus | 4     | 6      | 10    | 292            | 0.1478989136  | 0.000566274   |
| F. majalis      | 26    | 1      | 27    | 0.025540756    | 0.000566274   |
| Gobiosoma       | 0     | 0      | 0     | 0              | 0             |
| Lucania parva   | 0     | 0      | 0     | 0              | 0             |
| Lutjanus griseus| 0     | 0      | 0     | 0              | 0             |
| Menidia         | 102   | 75     | 177   | 0.1546787911   | 0.0718597866  |
| Menticirrhus    | 4     | 1      | 5     | 0.018203483    | 0.0718597866  |
| Micrurus tomcod | 11    | 1      | 12    | 0.018203483    | 0.0718597866  |
| Mugil cephalus  | 0     | 0      | 0     | 0              | 0             |
| Myxocyclus      | 0     | 0      | 0     | 0              | 0             |
| Opsanus         | 0     | 0      | 0     | 0              | 0             |
| Pleuronectes    | 10    | 1      | 11    | 0.168612433    | 0.0718597866  |
| Pungitius       | 9     | 1      | 10    | 0.0168612433   | 0.0718597866  |
| Sygnathus       | 0     | 0      | 0     | 0              | 0             |
| T. adspersus    | 0     | 0      | 0     | 0              | 0             |
| T. onitis       | 0     | 0      | 0     | 0              | 0             |
| Trinectes       | 9     | 1      | 10    | 0.168612433    | 0.0718597866  |
| TOTAL:          | 257   | 103    | 360   | 1240           | 0.560480564   | 0.314542165   |
|                |       |        |       | \(\Sigma_n\)   | 0.560480564   | 0.314542165   |
|                |       |        |       | \(y(n) = 0.560480564 \times 1 - \Sigma_n\) | 0.6854657835  |
Calculation of jackknife estimates:

\[
\begin{align*}
\text{spring} & \quad \text{Shannon-Wiener} & \quad \text{Simpson} \\
\text{y(1)} & = 0.5948354 \quad \text{y(1)} & = 0.702803 \\
\text{y(2)} & = 0.5414886 \quad \text{y(2)} & = 0.663942 \\
\text{y(3)} & = 0.568175 \quad \text{y(3)} & = 0.6742 \\
& \quad 0.56946 & \quad 0.689136 \\
& \quad 0.487916 & \quad 0.585831 \\
& \quad 0.549733 & \quad 0.675789 \\
& \quad 0.562392 & \quad 0.6755388 \\
\text{y(4)} & = 0.590713 \\
\end{align*}
\]

\[
\begin{align*}
\text{y1} & = \frac{n-y(1)}{n} \quad \text{y1} & = \frac{1.497624514}{1.46849239} \\
& = 0.323366514 \quad & = 0.06479229 \\
& = 0.690642514 \quad & = 0.83608683 \\
& = 0.506619514 \quad & = 0.764262638 \\
& = 0.497624514 \quad & = 0.659710683 \\
& = 1.068432514 \quad & = 1.382845683 \\
& = 0.635713514 \quad & = 0.753138683 \\
& = 0.547100514 \quad & = 0.754891083 \\
& = 0.344853514 \quad & = 0.565721683 \\
& = 4.418353114 \quad & = 1.382845683 \\
\end{align*}
\]

\[
\begin{align*}
\text{mean} & \quad \text{mean} \quad \text{mean} \\
\text{JK} & = 0.577294139 \quad 1/n(n-1) & = 0.785085233 \quad 1/n(n-1) \\
\text{VAR(JK)} & = 0.006499924 \\
\end{align*}
\]
Appendix O. Calculation of species richness for the summer, fall/winter and spring seasons. Species richness was calculated using the jackknife procedure.
### NEW BEDFORD

|       | JUNE I | JUNE II | JUNE III | JULY I | JULY II | AUGUST I | AUGUST II | sum |
|-------|--------|---------|----------|--------|---------|----------|-----------|-----|
| Anguilla | 0 0 0 0 | 0 0 0 0 | 1 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 2   |
| Apestes | 0 0 0 0 | 0 1 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 3   |
| Brevoortia | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 5   |
| Caranx hippos | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 1 1 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 7   |
| Clupea harengus | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0   |
| F. heteroclitus | 1 1 1 | 1 1 1 1 | 0 1 1 | 1 1 1 1 | 1 1 1 1 | 1 1 1 1 | 1 1 1 1 | 25  |
| F. majalis | 0 0 0 0 | 0 0 0 0 | 1 1 0 | 1 1 1 1 | 1 1 1 1 | 1 1 1 1 | 1 1 1 1 | 18  |
| Gobiosoma | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0   |
| Menidia | 1 1 1 | 1 1 1 1 | 1 1 1 1 | 1 1 1 1 | 1 1 1 1 | 1 1 1 1 | 1 1 1 1 | 16  |
| Mugil cephalus | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0   |
| Myoxocephalus | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0   |
| Opalina | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0   |
| Pleuronectes | 0 0 0 0 | 1 0 0 0 | 1 1 1 1 | 1 0 0 0 | 1 0 0 0 | 1 0 0 0 | 1 0 0 0 | 3   |
| Pungitius | 0 0 1 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0   |
| Syngnathus | 0 0 0 0 | 1 0 0 0 | 1 0 0 0 | 1 0 0 0 | 1 0 0 0 | 1 0 0 0 | 1 0 0 0 | 1   |
| T. adspersus | 0 0 0 0 | 0 0 0 0 | 1 1 1 1 | 1 1 1 1 | 1 0 0 0 | 1 0 0 0 | 1 0 0 0 | 6   |
| T. eurinus | 0 0 0 0 | 0 0 0 0 | 1 1 1 1 | 1 1 1 1 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 7   |

**TOTAL:**

\[ b = 15 \]
\[ n = 26 \]
\[ k = 1 \]

\[ S = s + (n - 1)k = 16 \]
\[ f_p = 0 \]
\[ f_p = 1 \]
\[ f_p = 2 \]

\[ \Sigma (2j) = (0 \cdot 25) + (1 \cdot 1) = 1 \]

\[ Var(S) = (n - 1)/n (\Sigma f_p k^2/n - \bar{S})^2 = 0.92 \]
|     | OCTOBER |     | DECEMBER |     | MARCH |     | sum | MAY I |     | MAY II |     | sum |
|-----|---------|-----|----------|-----|-------|-----|-----|-------|-----|--------|-----|-----|
|     | 1 2 3 4 |     | 1 2 3 4 |     | 1 2 3 |     | 1 2 |     | 1 2 3 |     | 1 2 3 |     |     |
| Anguilla | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Apelles   | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Brevoortia| 0 1 2 0 | 0 1 2 0 | 0 1 2 0 | 0 1 2 0 | 0 1 2 0 | 0 1 2 0 | 0 1 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Caranx hippos | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Clupea harengus | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| F. heteroclitus | 0 0 0 1 | 0 0 0 1 | 0 0 0 1 | 0 0 0 1 | 0 0 0 1 | 0 0 0 1 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| F. majalis | 0 0 0 1 | 0 0 0 1 | 0 0 0 1 | 0 0 0 1 | 0 0 0 1 | 0 0 0 1 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Gobiosoma | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Menidia  | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Mugil cephalus | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Myxocephalus | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Opalina | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Pleuronectes | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Pungitius | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| Syngnathus | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| T. adspersus | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |
| T. onitis | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 | 0 0 0 0 |

\[
S = s + (n - 1/n)k = 8.92
\]

\[
\sum 2f_j = (0^2j + 1^2) = 2
\]

\[
\text{Var}(S) = (n - 1/n)(\sum 2f_j - k^2/n) = 1.85
\]
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