

BIOLOGICAL PRODUCTIVITY
ASSOCIATED WITH THE SERPULID REEFS OF
BAFFIN BAY, TEXAS

By

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ABSTRACT

The upper Laguna Madre and Baffin Bay-complex has long been noted for its abundant finfish populations despite its generally persistent hypersaline condition. The purpose of this present study was to determine the contribution of the serpulid worm reefs to the productivity of Baffin Bay. The primary focus of this thesis was to test the hypothesis that fish were larger and found in higher concentrations near the serpulid worm reefs in Baffin Bay, and to quantify the abundances of potential prey items associated with the reefs. In addition, I measured the productivity (by O₂ evolution) of the epiphytic algae growing on the reefs and compared it to published seagrass studies in the upper Laguna Madre. Lastly, I examined the dependence of consumers on carbon fixed by these primary producers using stable carbon isotope ratios as tracers.

A total of 5,396 individuals representing 35 fish species, were collected by trammel net during the study. Seven fish species (*Mugil cephalus* = 27.3 %, *Pogonias cromis* = 20.2 %, *Cynoscion nebulosus* = 15.2 %, *Leiostomus xanthurus* = 12.1 %, *Arius felis* = 10.7 %, *Lagodon rhomboides* = 2.3 %, and *Sciaenops ocellatus* = 1.1 %) comprised 89.0 % of the total catch. The overall ichthyofaunal catch rate was not significantly different between reef and non-reef sites and only a seasonal effect in the catch rate data was observed. Seasonal differences can be explained by the recruitment of fish into the bay in Spring and Summer. These seasonal peaks can be attributed to three species: *Arius felis*, *Pogonias cromis*, and *Leiostomus xanthurus*. No strong evidence was found to support the hypothesis that larger fish congregate around the serpulid worm reefs.

A total of 3,150 individuals representing 19 fish species were collected by bag seine during the study. Three fish species (*Anchoa mitchilli* = 47.6 %, *Brevoortia patronus* = 38.9 %, and *Lagodon rhomboides* = 8.8 %) comprised 95.3 % of the total catch. Overall there was no significant difference in the number of individuals of all species combined per bag seine sample between reef and non-reef areas.

A total of 29 species of invertebrates were collected from the serpulid worm reefs during the study. Of the 29 species, eight (*Corophium louisianum* 70.45 %, *Hargeria rapax* 11.66, Syllidae 3.16 %, *Naineris laevigata* 2.95 %, *Polydora ligni* 2.72 %, *Nereis riissei* 1.93 %, *Balanus eburneus* 0.93% and *Anemone* 2.4%) comprised 96.2 % of the total abundance per liter of water displacement.

Biomass and photosynthetic rates compare closely between serpulid worm reef algal epiphytes and upper Laguna Madre seagrasses. Therefore, in Baffin Bay where seagrass coverage is minimal, the turf algae associated with the serpulid worm reefs may make important contributions to the carbon pool.

Stable carbon isotopic analyses of invertebrates inhabiting the serpulid worm reefs indicate a phytoplankton-based food web. This is not surprising considering the dominance of the system by the "Brown Tide" which originated in Baffin Bay in January 1990 and persisted throughout the study.

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Introduction

The upper Laguna Madre and Baffin Bay-complex has long been noted for its abundant finfish populations despite its generally persistent hypersaline condition. Local fishing guides relate they are most successful while fishing near the serpulid worm "reefs" in Baffin Bay. This observation led to the hypothesis that the reefs may be more than just gathering or hiding places where predatory fishes can ambush their prey. The area may be, in fact, more productive because of the reefs. The epiphytic algae, growing on the hard substrate provided by the worm tubes, may provide a readily accessible carbon source to local consumers.

Higher levels of production have also been observed around oyster reefs. Mobius (1877) conducted a study of oysters in which he noted that oyster banks had higher faunal diversities than other surrounding bottom types. Bahr (1974) found exceptionally high macrofaunal biomass associated with oyster reefs. Bass and Guillory (1979) reported oyster reefs to be more productive habitats for fish than margins of dredge-spoil islands. Bradley (1965) noted similar increases in productivity associated with artificially constructed shell reefs in Corpus Christi Bay, Texas. Larsen (1974), on the other hand, found minimal faunal differences between oyster reefs and mud bottoms.

Several authors have surveyed species present in the Baffin Bay-complex. Breuer (1957) conducted an ecological survey of Baffin Bay in which he reported 15 invertebrate and 26 fish species during a two year study when salinities averaged 51 ppt. According to Breuer (1957), the most noteworthy biological characteristics of Baffin Bay were the complete absence of seagrass, the near complete lack of macroalgae and the extremely

high abundance of the copepod *Acartia tonsa*. Simmons and Huckabee (1971) conducted a trammel net survey in the Laguna Salada (the western-most arm of Baffin Bay) when salinities averaged 42 ppt and collected 34 species of fish, eight of which were found year-round. This resident population included: *Mugil cephalus*, *Lagodon rhomboides*, *Cynoscion nebulosus*, *Micropogon undulatus*, *Pogonias cromis*, *Leiostomus xanthurus*, *Dorosoma cepedianum*, and *Bairdiella chrysura*. Tinnin (1974) conducted a trammel net survey in the Laguna Salada when salinities ranged from 3.3 - 27.8 ppt and reported a 29.1 % increase in total fish abundance over that reported by Simmons and Huckabee (1971). Fuls (1974) also conducted a trammel net study of the Laguna Salada when salinities averaged 18 ppt and found *M. cephalus* to be the dominant fish species in both abundance and biomass. Krull (1976) studied the small fish (< 100 mm in standard length) assemblage of the Laguna Salada concurrently with Tinnin's (1974) trammel net survey. The most abundant species collected by Krull (1976) was the bay anchovy, *Anchoa mitchilli*. Martin (1979) studied the feeding habits of *P. cromis* in Alazan Bay and Laguna Salada. Martin (1979) found the dwarf surf clam, *Mulinia lateralis*, to be the dominate prey item for *P. cromis*. The amphipod, *Corophium ascherusicum*, and the tanaid, *Hargeria rapax*, were found to be of considerable importance as food items of *P. cromis* < 100 mm in length (Martin, 1979). Dokken *et al.* (1984) studied the distribution and composition of larval fishes in Alazan Bay and found *Gobiosoma* sp. and *A. mitchilli* to make up 91 % of the total larval and postlarval fishes collected in plankton tows. Cornelius (1984) produced a two volume study on Baffin Bay. Volume I focused on phytoplankton, zooplankton, macrobenthos and ichthyofauna, while Volume II dealt

solely with the commercial black drum fishery of Baffin Bay.

Only a few published works exist on the serpulid reefs in the Baffin Bay-complex. These studies pertain primarily to reef locations, orientations, shapes and types of reefs and some limited radiocarbon dating. There are approximately 16 km² of serpulid reefs in the Baffin Bay-complex (Brown *et al.*, 1977). According to Andrews (1964), the reefs are of two types, patch reefs and reef fields. He described patch reefs as varying in outline from circular forms as small as 8 m in diameter to ellipsoidal forms 40 m in length. These vary from 0.5 - 2 m in height above the sediment. Patch reefs are found near the mouth of Baffin Bay, while the upper reaches of the bay are characterized by reef fields. Reef fields are large expanses of reef rock protruding only slightly above the bottom sediment.

The two reef types differ in their growth patterns. These patterns were described by Andrews (1964) as "random" and "oriented" growth. The patch reefs exhibit both random and oriented growth while the reef fields consist of only random growth. During random growth worm tubes grow against the substrate in an unorganized arrangement. During oriented growth, worm tubes are tightly packed parallel to one another. Growth begins as the random form and becomes oriented as the tubes turn perpendicular to the substrate and grow out from it. Patch reefs in cross section are internally stratified revealing random and then oriented growth patterns in a "stacked" arrangement.

Behrens (1968) studied the serpulid worm tubes fouling the intake pipes of the Central Power and Light (CPL) Power Plant in Corpus Christi harbor and found the worm tubes exhibited the same type of oriented growth described by Andrews (1964) for

Baffin Bay reefs. Cole (1981) reported on the serpulid reefs of Baffin Bay and provided an associated invertebrate species list. He found that reef fields often grew on a base of caliche nodules. Radiocarbon dating suggests that reef growth began about 3,000 years B.P. (Valastra *et al.*, 1972).

Hedgpeth (1953), Breuer (1957), and Andrews (1964) reported no living worms on the reefs in Baffin Bay. Cole (1981) found that living serpulid worms were established on the reefs and believed these reefs were actively increasing in size. The species found was *Hydroides dianthus* whereas the species Behrens (1968) studied in the CPL intake pipes was *Hydroides norvegica*. Personal observations made by diving around certain reef areas revealed only small numbers of live worms; these occurred only on the patch reefs near the mouth of Baffin Bay. From these observations, I do not believe that the reefs are growing significantly as in the past when vast areas of oriented growth were produced.

Currently, University of Texas Marine Science Institute (UTMSI) scientists are studying various aspects of the upper Laguna Madre and Baffin Bay in an effort to understand why this system is so productive despite low concentrations of dissolved nutrients. The purpose of this present study was to determine the contribution of the serpulid worm reefs to the productivity of Baffin Bay. The question investigated by this study was: Do high levels of primary production by the algal epiphytes associated with the serpulid worm reefs support an increased invertebrate faunal abundance on, and increased finfish populations surrounding the reefs?

Prior to the initiation of this study a "Brown Tide" algal bloom began in January

1990 (Stockwell *et al.*, 1993). The bloom persisted throughout this study and has remained unabated to the present (July 1997).

This study provides necessary baseline information pertaining to the ecological contribution of the serpulid worm reefs for the U.S. Fish and Wildlife Service (USFWS) in the event that development and channelization is someday proposed in the Baffin Bay-complex. It also provides information for later comparisons to determine the effect of the "Brown Tide" on associated serpulid worm reef flora and fauna.

Study Area

According to Brown *et al.* (1977), the geological history of the Baffin Bay-complex began about 20,000 years B.P. during the Wisconsin glacial stage of the Pleistocene epoch. During this last great glaciation of the Pleistocene, sea level fell 90 - 135 m below its current level. The Olmos, San Fernando, and Petronila Creeks converged about 3.2 km southeast of Kleberg Point. Together, these systems cut a deep valley as they extended seaward to the edge of the continental shelf. After this glaciation period, sea level rose and the submerged river valley became filled with marine deposits. Sediments deposited near the edge of the continental shelf were reworked by storms and longshore drift, eventually forming modern-day Padre Island. The drowned river valley edges were eroded to form the current margins of Baffin Bay.

Baffin Bay is located approximately 40 km south of Corpus Christi on the south Texas gulf coast. The Baffin Bay-complex consists of four bay units: Baffin Bay, Alazan Bay, Cayo del Grullo, and Laguna Salada (Fig. 1). Baffin Bay, the largest in the

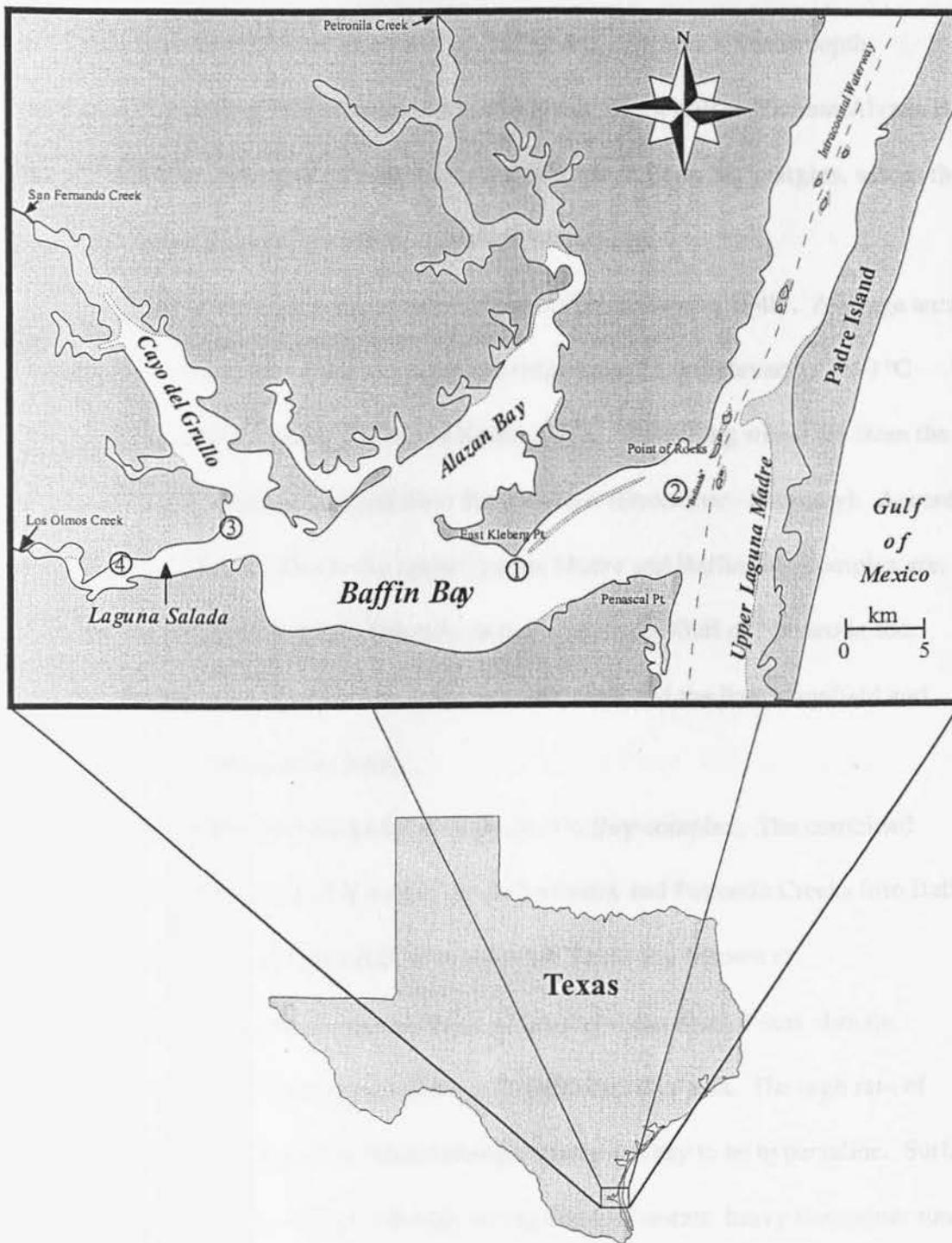


Figure 1. Location of Baffin Bay on the Texas coast along with the four study sites.

complex, is oriented east/west (28 km) and is approximately 8 km wide. At mean high tide Baffin Bay encompasses an area of 13,592 ha and averages 1.5 m in depth. According to Breuer (1957), serpulid reefs effectively block boat traffic into Alazan Bay. Cole (1981) found the serpulid reefs to be most abundant along bay margins, across the mouth of Alazan Bay, and across the mouth of Baffin Bay.

Climate in the Baffin Bay area is semiarid (Thornthwaite, 1948). Average annual precipitation is 67.4 cm. Water temperatures range from 11.0 (February) - 29.0 °C (August) (Fuls, 1974; Tinnin, 1974; and Krull, 1976). Prevailing winds are from the southeast (March - November) and from the northeast (December - February). According to Brown *et al.* (1977), tides in the upper Laguna Madre and Baffin Bay-complex are, for the most part, wind generated. The only passes open to the Gulf of Mexico in the vicinity of Baffin Bay occur at Port Aransas to the north and the Port Mansfield and Brazos Santiago Passes to the south.

There is little freshwater inflow to the Baffin Bay-complex. The combined discharge of the Olmos, San Fernando, Santa Gertrudis, and Petronila Creeks into Baffin Bay is less than the freshwater inflow to any other Texas bay (Brown *et al.*, 1977). Because of the strong southeast winds and warm south Texas climate, evaporation normally exceeds precipitation in the Baffin Bay area. The high rate of evaporation, along with limited tidal exchange, causes the bay to be hypersaline. Surface salinity ranges from 40 - 70 ppt although during times of storms, heavy freshwater runoff may drop salinities to zero (Behrens, 1966; Fuls, 1974; Jensen, 1974; Tinnin, 1974; Krull, 1976; and White *et al.*, 1989).

Methods

Two exploratory trips were taken in September 1990 to locate suitable study sites and examine reefs for living serpulids. The first excursion (by boat) concentrated on Baffin Bay from the Intracoastal Waterway (ICWW) to the west end of Alazan Bay. Six patch reefs were found in water depths (< 1.5 m) conducive to sampling by bag seine, which was the primary criterion for site selection. The second trip (by vehicle) covered the upper western reaches of Baffin Bay including Laguna Salada and Cayo del Grullo. During this second exploratory trip four suitable reef field sites were located. From the ten suitable sites (six patch reefs and four reef fields) four (two patch reefs and two reef fields) were randomly selected for study (Fig. 1). A control area was selected near each sampling site. Each control area was at least 300 m from the nearest known serpulid worm reef and at a comparable water depth.

Salinity was measured using a Goldberg refractometer. Temperature was measured using a laboratory-grade centigrade thermometer. Tide data were collected from a tide gauge maintained at Williamson's Boat Works in the Laguna Salada by the Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi. General weather conditions were noted.

Biological investigations conducted quarterly included: sampling of ichthyofauna using trammel nets and bag seines; collection of invertebrates associated with the serpulid worm reefs; and measurements of primary production and biomass of the epiphytic algae. To determine the importance of the reef epiflora to higher trophic levels, randomly

selected samples of serpulid reef associated flora and fauna were analyzed for their stable carbon isotopic ratios.

Trammel Net Collection.—Macroichthyofauna populations were assessed by diurnal use of trammel nets. Two 50 m nets were set, one close to a serpulid reef and the other in a control area. Trammel nets had an inner wall of 9 cm stretch mesh monofilament construction and outer walls of 55 cm stretch mesh nylon construction. Fish were removed from the nets every 6 h for a period of 24 h as weather conditions and boat mechanical operations would allow. All fish collected were identified, counted, and measured (standard length) to the nearest mm. Fish deemed alive and in good condition were tagged and released. Dead fish were removed from the area and preserved or destroyed to prevent baiting.

Measurements of salinity (ppt), water temperature ($^{\circ}\text{C}$), and water depth (m) were recorded to determine the environmental conditions between reef and non-reef (control) areas. Salinity was recorded after each net was initially set and just prior to net removal. Water temperature and depth were recorded at the mid point of each trammel net during each net collection period.

Macroichthyofauna populations were assessed quarterly for a period of one year (November 1990 - November 1991). Shannon diversity was calculated from equations provided by Brower *et al.* (1990). Due to uncontrollable circumstances (boat mechanical failure, and adverse weather conditions) the frequency of diurnal sampling ranged from 6 to 24 h; therefore, fish were totaled for each 24 h set prior to calculating diversity.

Diversity was compared by factorial ANOVA using experimental type (reef or control), location in bay (east and west) and season (Fall 1990, Winter 1991, Spring 1991, Summer 1991, Fall 1991) as factors. Tukey's HSD multiple range test was used to interpret significant non-interactive factors. Pearson correlation between Shannon diversity and environmental factors (salinity, water temperature, and water depth) was calculated.

Because intervals between net runs ranged from 6 to 24 h the number of fish collected at each run was divided by the number of hours between runs yielding a catch rate (fish/hour). The catch rate (fish/hour) for all species combined, and individual species, as well as the total length of individual species, were compared using a nested factorial ANOVA model. The model tested for significant differences between primary factors, location in the bay (east and west) and seasons (Fall 1990, Winter 1991, Spring 1991, Summer 1991, Fall 1991) and their interaction. The factor site (Sites 1-4) was nested within location in the bay and season while experimental type (reef/non-reef) was nested within site, location in the bay, and season. Although the sites were fixed and visited quarterly they represent a random component in the ANOVA model; therefore, both nested factors were used as random effects in the model. Tukey's HSD multiple range test was used to interpret significant non-interactive factors. When significant interaction between any two factors was indicated by factorial ANOVA, data were carefully scrutinized using independent t-test analyses. Because cell variance was found to increase with cell standard deviation, catch rate data for all species combined were square root transformed prior to statistical analyses following a Box-Cox evaluation of best transformations (Sokal and Rohlf, 1981). Individual species catch rate data were

inversely transformed following a Box-Cox evaluation of best transformations prior to statistical analyses (Sokal and Rohlf, 1981). All means (\bar{x}), standard errors (SE), and graphical representations of data are given in the untransformed format.

Bag Seine Collections.—Fish (< 100 mm total length) populations were assessed diurnally by bag seine sampling. A 9 m seine with 5 mm mesh and 1.8 x 1.8 m bag was utilized adjacent to the reefs. The seine was pulled for a distance of 7.6 m at both reef and non-reef sites. At the end of the pull the lead line of the seine was quickly brought to the water surface, trapping the catch in the bag. Samples were collected every 6 h for a period of 24 h prior to running the trammel nets. Bag seine collections were conducted quarterly for one year (November 1990 - November 1991). All fishes collected by bag seine were preserved in 10% formalin for one week and then transferred to 45% isopropyl alcohol. Fish were separated, identified, counted, and measured in standard length to the nearest mm in the laboratory. Total number of fish, total number of individual species, and standard length of individual species were compared by nested factorial ANOVA as described for the trammel net collections.

Invertebrate Collections.—Invertebrates inhabiting the serpulid reefs were sampled quarterly (February 1991- November 1991) by removing five pieces of reef substrate from each of the study reefs. Reef substrate samples were initially placed in a propylene phenoxetol solution for narcotizing prior to preservation in 10% formalin and then transported to the laboratory. In the laboratory, the number of invertebrates inhabiting

each reef sample was quantified volumetrically (number of organisms/liter of water displaced by the substrate sample), by wet weight (number of organisms/gram wet weight of substrate sample), and by exposed surface area (organisms/m²). Volume was measured via water displacement for each piece of reef substrate prior to removing the invertebrates. Exposed surface area was measured with a flexible ruler, and only surfaces originally exposed to the water column were measured. All reef samples were visually inspected and attached organisms (mussels, barnacles, and gastropods) were removed. Reef substrate samples were then dissolved using 10 % HCl similar to the method described by Gittings *et al.* (1984). Complete dissolution of the substrate was usually accomplished in 24 h. The 10 % HCl solution had little effect on the organisms present, resulting in a slurry of the organic matrix lining the interior of the worm tubes, sediment that was surrounding and filling the tubes, and the invertebrates inhabiting the reefs material. Specimens were identified and counted in the laboratory. Samples that contained organisms too abundant to easily count were first divided using a Folsom plankton splitter. Abundances of the total sample was then calculated from the subsample.

Diversity of each sample was computed using equations given by Brower *et al.* (1990). Diversity, species richness, and total number of individual species were compared between reefs using a nested factorial ANOVA model. The ANOVA model tested the significance of the factors location, and season, and the interaction between location and season. The factor, site, was nested within location and season and was designated as a random effect in the model.

Primary Production.—Areal gross primary production ($\text{g C/m}^2/\text{day}$) of algae associated with the serpulid worm reefs was estimated utilizing laboratory generated photosynthesis versus irradiance (P vs. I) parameters, seasonal quarterly biomass, and *in situ* light measurements. Primary production of the reef algae ($\mu\text{mol O}_2 \text{ g dry wt}^{-1} \text{ h}^{-1}$) was estimated using standard oxygen evolution techniques. A sample of reef containing epiphytic algal growth was removed from Site 1 (the most centrally located reef) quarterly (October 1991 - August 1992). After collection, samples were returned in ambient water to the laboratory. Photosynthesis versus irradiance (P vs. I) curves were generated, following the procedures outlined by Dunton and Tomasko (1994), by incubating small pieces of algae ($< 0.05 \text{ g dry weight}$) in a 13 ml chamber fitted with a polarographic oxygen electrode and a stirring mechanism (Rank Bros., U.K.) The polarographic electrode was calibrated using N_2 bubbled and air-saturated seawater. Two curves were produced for *Cladophora* sp. and two for *Polysiphonia* sp. each quarter. Curves were generated at temperatures of 10°C (February 1991), 20°C (October 1991 and May 1992), and 30°C (August 1991). These temperatures did not vary more than 2°C from that observed in the field at the time of collection. The algae were incubated in water collected in the field and filtered prior to incubation using a precombusted glass fiber filter ($1.2 \mu\text{m}$ nominal pore size) to remove particulates and plankton. Curves were generated within 12 h of collection of the algae. A flat cosine sensor (LI-192SA) mounted in the rear of the chamber and connected to a LI-1000 datalogger provided accurate measurements of photosynthetically active radiation (PAR). A slide projector served as a light source. Varying light levels were accomplished using 10 neutral density

slides, each progressively decreasing in opacity. The neutral density slides provided light levels that ranged from 5.5 -1000 $\mu\text{mol photon m}^{-2} \text{s}^{-1}$. Temperature in the chamber was kept constant by a water jacket connected to a refrigerated circulating bath.

Respiration rates were measured in complete darkness at O_2 concentrations near saturation and prior to collecting photosynthetic data. Data were collected for 15 min during respiration. Data for the first 5 min were discarded to eliminate system equilibration "noise." After respiration, O_2 concentration in the chamber was reduced to approximately 20 % of saturation by bubbling with N_2 . This was usually sufficient to measure production at all light levels before the chamber reached O_2 saturation. The initial light level was the lowest in intensity and was maintained in the chamber for 10 min. During the first 5 min data were not collected to allow for the transition between respiration and photosynthesis. Subsequent light levels were held constant for 6 min of which data was collected during the last 4 min. The hyperbolic tangent function was fit to the P vs. I data (Jassby and Platt, 1976) and the photosynthetic parameters were calculated simultaneously using the derivative free algorithm of Ralston and Jennrich (1978):

$$P = P_{\max} \tanh(\alpha I / P_{\max}) + R$$

where P_{\max} is light saturated photosynthesis, α is the light limited slope of the P vs. I curve, and R is respiration.

Respiration, P_{\max} , and alpha were tested for significant differences seasonally by one-way ANOVA. Tukey's HSD multiple range test was used to interpret significant

seasonal differences. Saturation irradiance (I_k) was empirically derived by P_{max}/α .

Seasonal variation in algal biomass was measured by removing six pieces of reef substrate from Site 1 quarterly (October 1991 - August 1992). The algal-covered reef substrate samples were placed in freshwater for 1 min to dislodge amphipods. Samples were then dried in a drying oven for 72 h. After drying a 5 x 5 cm square was scraped from each of the six substrate samples into preweighed crucibles and weighed to the nearest 0.01 mg. The crucibles were then combusted at 530 °C for 3.5 h to remove organics. After combustion the crucibles were allowed to cool in a desiccator prior to being weighed. The seasonal biomass was expressed as ash free dry weight. Biomass was compared seasonally by one-way ANOVA. Tukey's HSD multiple range test was used to interpret significant seasonal differences.

In situ underwater irradiance ($\mu\text{mol photons m}^{-2} \text{s}^{-1}$) was provided by Dr. Paul Montagna (UTMSI) from a site in Baffin Bay at a water depth of 2.4 m (Blanchard and Montagna, 1992). Surface irradiance was provided by Dr. Ken Dunton. The light data were collected between 20 May - 20 June 1990 during the presence of the "Brown Tide" algal bloom. Although P vs. I parameters and algal biomass were collected from November 1991 through August 1992 (also during the "Brown Tide"), the 1990 light data is a reasonable estimate of irradiance during the spring period of the current study. Algal biomass and samples for laboratory generated P vs. I parameters were collected at Site 1 from a depth of approximately 1 m. Irradiance at Site 1 was predicted using the Bouguer-Lambert Law as described by Wetzel and Likens (1991):

$$I_z = I_0 e^{-kz}$$

where I_z = irradiance at depth z , I_0 = surface irradiance, and e^{-k} is the antilog of the negative extinction coefficient (k) at depth z .

Daily gross carbon production ($\text{g C m}^{-2} \text{ day}^{-1}$) in May 1992 was calculated using the H_{sat} model (P_{max} * daily light saturation period; Dennison and Alberte, 1982, 1985) along with available biomass and photosynthetic data. Measurements of O_2 were converted to carbon assuming a photosynthetic quotient of unity:

$$\text{g C m}^{-2} \text{ day}^{-1} = \frac{P_{\text{max}} \mu\text{mol O}_2}{(\text{g dry wt.})(\text{hour})} * \frac{1 \text{ mol O}_2}{1000000 \mu\text{mol O}_2} * \frac{12 \text{ g C}}{1 \text{ mol O}_2} * \frac{\text{g dry wt.}}{\text{m}^2} * \frac{\text{hours above } I_k}{\text{day}}$$

Stable Carbon Isotopes.—To determine the importance of the reef epiflora to higher trophic levels, randomly selected floral and faunal samples were analyzed for their stable carbon isotope ratios (Fry and Parker, 1979). Samples of the epiphytic algae *Cladophora* sp. and *Polysiphonia* sp. along with invertebrate consumers living on the reefs were collected in February 1991 and May 1992, while fish samples from populations adjacent to the serpulid worm reefs were collected in May 1991. Invertebrates of like species collected at the same time were pooled into one sample to obtain sufficient material for analysis. Two individuals of each fish species selected were analyzed as replicates. Fish tissue samples were from boneless fillets. All samples were soaked in 1 N HCl for 4 - 6 hours (or until effervescence stopped) to remove carbonates, rinsed in distilled water, and then oven dried at 50 °C. Selected samples were freeze dried and then ground by mortar and pestle to a fine powder. Approximately 10 mg of animal and 30 mg of plant tissue were used for analysis. The sample to be tested was mixed with finely ground copper

wire and cupric oxide and poured into a borosilicate combustion tube (Dunton and Schell, 1987). Prepared samples were delivered to Dr. Patrick Parker's isotope lab (UTMSI) for analysis.

The dependence of local consumers on the epiphytic algae of the serpulid worm reefs was calculated using the two-carbon source mixing model of Dunton and Schell (1987):

$$\% \text{ Algal Carbon} = \frac{\delta^{13}\text{C}(\text{Animal}) - \delta^{13}\text{C}(\text{Phytoplankton}) - I}{\delta^{13}\text{C}(\text{Algae}) - \delta^{13}\text{C}(\text{Phytoplankton})} \times 100$$

where I = the trophic level of the test organism (determined from the literature) multiplied by 0.8‰ (assuming that fractionation increases the $\delta^{13}\text{C}$ value by 0.8‰ per trophic level, DeNiro and Epstein, 1978), and Phytoplankton = -22.0 (Fry and Sherr, 1984).

Identification.—Species collected were identified using Harper (1970), Bousfield (1973), Felder (1973), Fauchald (1977), Hoese and Moore (1977), McKinney (1977), Chaney (1983), and Murdy (1983).

Results and Discussion

The primary focus of this study was testing the hypothesis that fish were larger and found in higher concentrations near the serpulid worm reefs in Baffin Bay, and to quantify the abundances of potential prey items associated with the reefs (small fish surrounding the reefs and invertebrates living directly on the reefs). I also attempted to

determine the productivity (by O_2 evolution) of the epiphytic algae growing on the reefs and to compare it to published seagrass studies in the upper Laguna Madre. Lastly, I wanted to determine the potential for utilization of carbon fixed by these primary producers to local consumers, utilizing stable carbon isotope ratios as tracers. Therefore, the results will be given in the following order:

1. trammel net data (Fall 1990 - Fall 1991),
2. bag seine data (Fall 1990 - Fall 1991),
3. reef invertebrate abundance data (Winter 1991-Fall 1991),
4. O_2 production and biomass of the epiphytic algae (Fall 1991 - Summer 1992),
5. and lastly, stable carbon isotope data.

The exact dates of site specific sampling are given in Table 1. Unless otherwise indicated, all references to date will be given by season and year (Fall 1990, Winter 1991, Spring 1991, Summer 1991, and Fall 1991).

Table 1. Dates of seasonal trammel net and bag seine sampling.

	Site 1	Site 2	Site 3	Site 4
Fall 1990	19 October	20 November	15 December	16 December
Winter 1991	27 February	28 February	23 February	21 February
Spring 1991	17 May	18 May	09 May	10 May
Summer 1991	05 August	06 August	25 August	24 August
Fall 1991	22 November	23 November	17 November	15 November

Environmental Parameters

Although water temperature, depth, and salinity were measured as part of the fish fauna comparison between reef and non-reef areas of the bay, these data have merit in other parts of the study as well; therefore, it is pertinent to discuss these parameters initially and then refer back to them as necessary in other sections.

Salinity averaged 50 ppt (SE = 1.0) throughout the study. Salinity did not vary significantly between reef and non-reef areas within seasons and locations in the bay. It did however, vary significantly seasonally and between locations in the bay. Salinity steadily declined at west bay sites (Sites 3 and 4) from an average of 65 ppt (Fall 1990) to an average of 45 ppt (Fall 1991). Salinity at east bay locations (Sites 1 and 2) declined more slowly and the strong linear relationship observed at west bay sites was not as apparent throughout the same time period (Fig. 2). A sharp decline in salinity at Site 1 was observed during year two (Fall 1991 - Summer 1992)(Fig. 2). Site 1, the most centrally located reef examined, was used during the second year to measure primary productivity and biomass of the epiphytic algae. The decline in salinity in Baffin Bay from 65 ppt to < 30 ppt was due to above-normal rainfall in the area.

Water temperature did not vary significantly between reef and non-reef areas at sites within locations seasonally; however, water temperature varied significantly seasonally and between locations in the bay. During Fall 1990 water temperature at east bay sites was significantly higher than at west bay sites, while the opposite was true in Winter 1991 (Fig. 3). The passage of cool fronts during Fall, Winter and Spring can cause rapid fluctuations in water temperature along the Texas coast. Because of

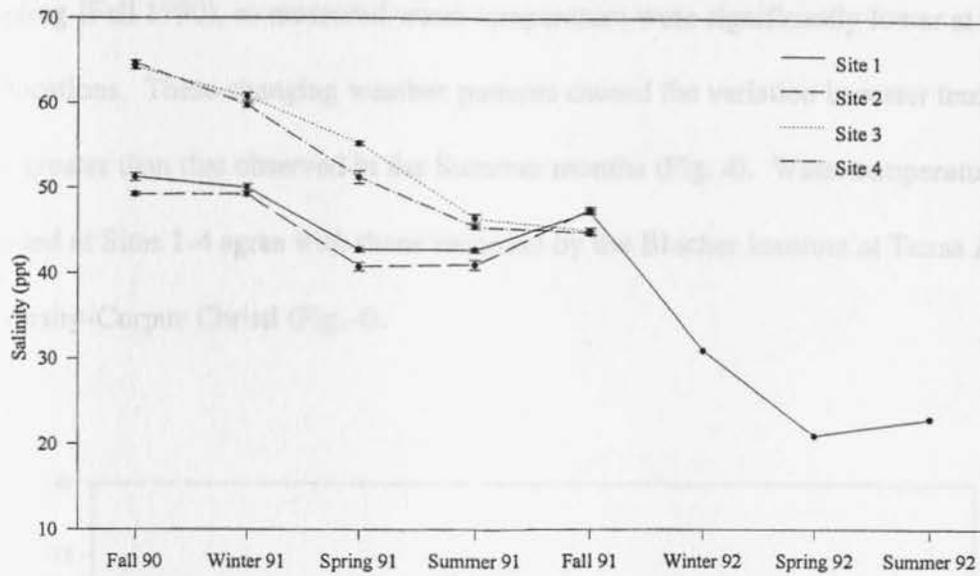


Figure 2. Average salinities measured at the study sites in Baffin Bay.

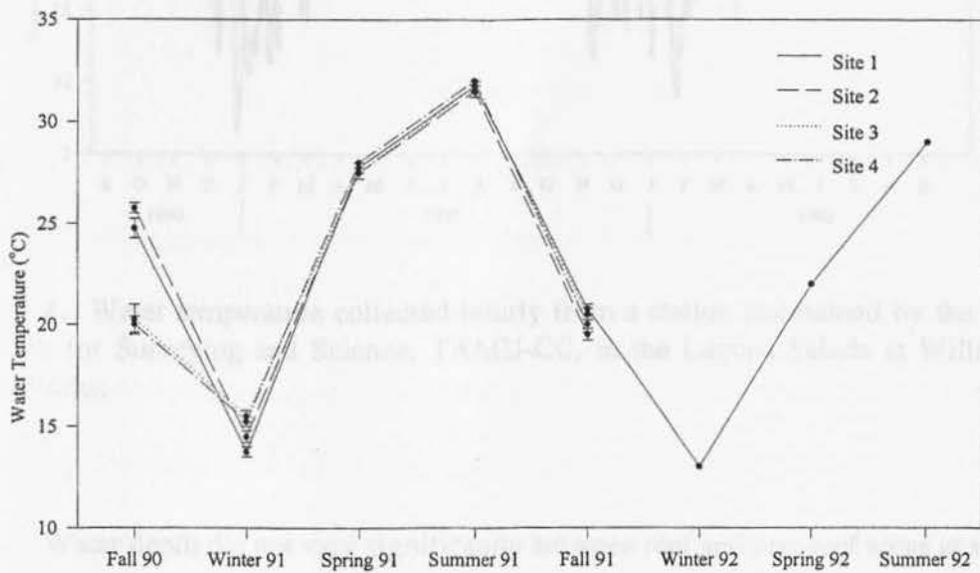


Figure 3. Seasonal water temperature measured at the study sites within Baffin Bay.

inclement weather conditions, there was almost a six week gap between east and west bay sampling (Fall 1990), so measured water temperature were significantly lower at west bay locations. These changing weather patterns caused the variation in water temperature to be greater than that observed in the Summer months (Fig. 4). Water temperatures recorded at Sites 1-4 agree with those recorded by the Blucher Institute at Texas A&M University-Corpus Christi (Fig. 4).

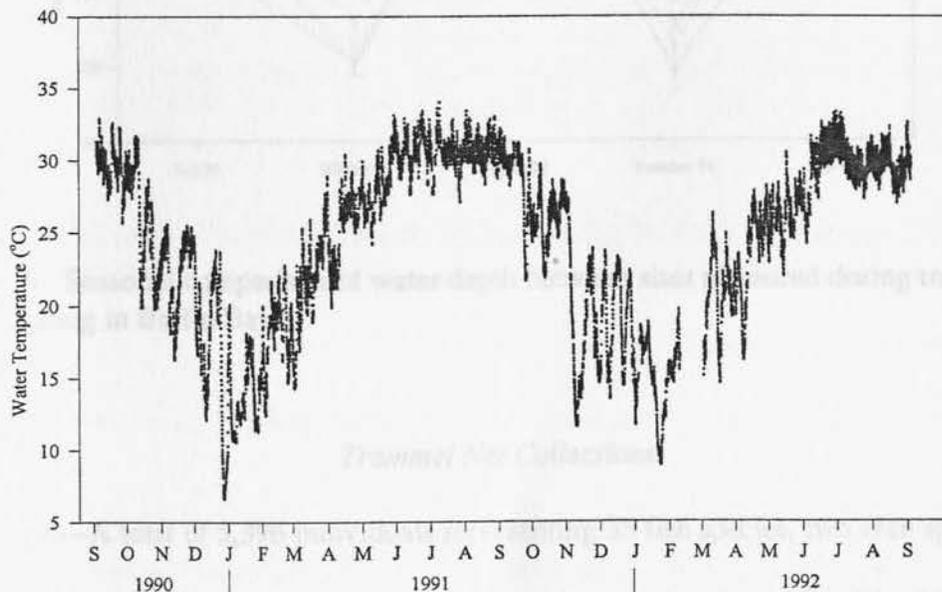


Figure 4. Water temperature collected hourly from a station maintained by the Blucher Institute for Surveying and Science, TAMU-CC, in the Laguna Salada at Williamson's Boat Works.

Water depth did not vary significantly between reef and non-reef areas at sites within seasons; however, water depth at all sites varied seasonally. Water depth was significantly higher during Spring and Fall than in Winter or Summer (Fig. 5). This

seasonal trend in water level was also observed in hourly data collected in the Laguna Salada by the Blucher Institute (Fig. 6).

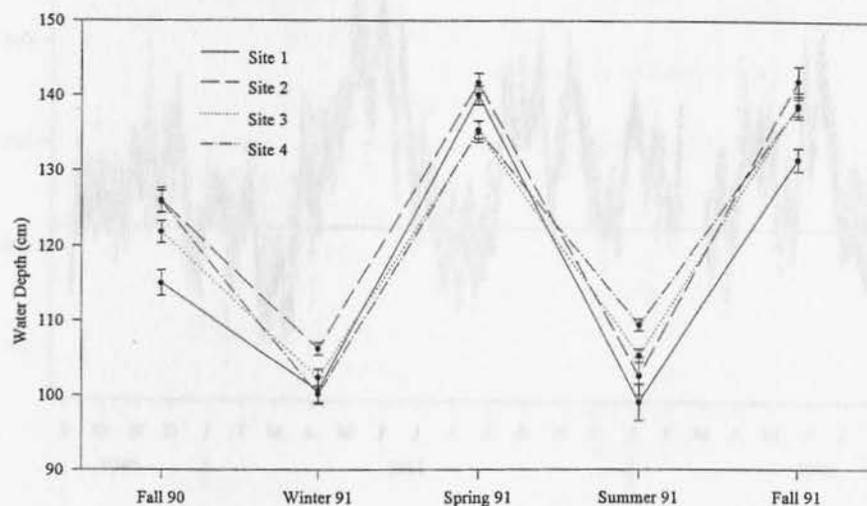


Figure 5. Seasonal comparison of water depth between sites measured during trammel net sampling in Baffin Bay.

Trammel Net Collections

Diversity.—A total of 5,396 individuals representing 35 fish species, two crab species, and one shrimp species were collected by trammel net during this study. The 35 fish species belonged to two classes, seven orders, and 20 families while the crabs and shrimp belonged to one order and three families (Table 2). See **Appendix I** for the total number of individual species collected by trammel net and their mean standard lengths. Of the 38 species collected, seven fish species (*Mugil cephalus* = 27.3 %, *Pogonias cromis* = 20.2 %, *Cynoscion nebulosus* = 15.2 %, *Leiostomus xanthurus* = 12.1 %, *Arius felis* = 10.7 %, *Trachinotus carolinus* = 7.8 %, and *Stenotomus chrysops* = 1.3 %) comprised 89.5 % of the

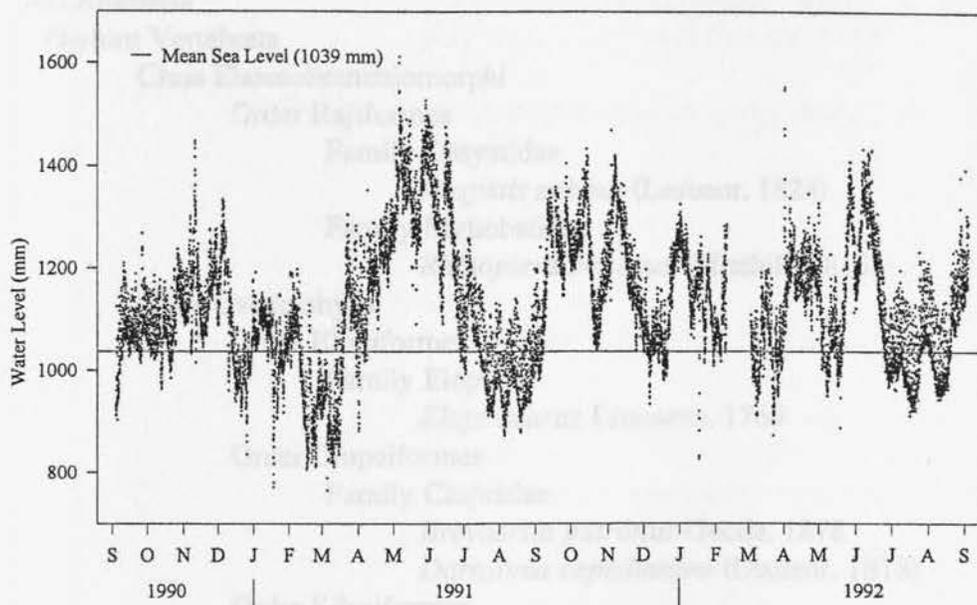


Figure 6. Water depth recorded hourly by the Blucher Institute for Surveying and Science, TAMUCC, from a tide gauge in the Laguna Salada at Williamson's Boat Works.

Lagodon rhomboides = 2.3 %, and *Sciaenops ocellatus* = 1.1 %) comprised 89.0 % of the total catch.

Shannon diversity (base e) was not significantly different between reef and non-reef collections but location in the bay and season of collection were significant in the model. The interaction between location and season was also significant. At east bay stations diversity remained stable throughout seasons, ranging from 1.71 - 1.95. At west bay sites diversity steadily increased during the study from 0.56 (Fall 1990) to 1.81 (Fall 1991) (Fig. 7). The increasing diversity at west bay sites compared to the relatively stable diversity associated with east bay sites caused the significant interaction in the

Table 2. List of species collected by trammel net in Baffin Bay.

Kingdom Animalia

Phylum Vertebrata

Class Elasmobranchiomorphi

Order Rajiformes

Family Dasyatidae

Dasyatis sabina (Lesueur, 1824)

Family Myliobatidae

Rhinoptera bonasus (Mitchill, 1815)

Class Osteichthyes

Order Elopiformes

Family Elopidae

Elops saurus Linnaeus, 1766

Order Clupeiformes

Family Clupeidae

Brevoortia patronus Goode, 1878*Dorosoma cepedianum* (Lesueur, 1818)

Order Siluriformes

Family Ariidae

Arius felis (Linnaeus, 1766)*Bagre marinus* (Mitchill, 1815)

Order Scorpaeniformes

Family Trigilidae

Prionotus tribulus Cuvier, 1829

Order Perciformes

Family Pomatomidae

Pomatomus saltatrix (Linnaeus, 1766)

Family Carangidae

Caranx hippos (Linnaeus, 1766)*Trachinotus carolinus* (Linnaeus, 1766)

Family Haemulidae

Orthopristis chrysoptera (Linnaeus, 1766)

Family Sparidae

Archosargus probatocephalus (Walbaum, 1792)*Lagodon rhomboides* (Linnaeus, 1766)

Family Sciaenidae

Bairdiella chrysura (Lacepede, 1802)*Cynoscion arenarius* (Ginsburg, 1929)*Cynoscion nebulosus* (Cuvier, 1830)*Larimus fasciatus* Holbrook, 1855*Leiostomus xanthurus* Lacepede, 1802*Menticirrhus americanus* (Linnaeus, 1758)

Table 2. continued

	<i>Micropogonias undulatus</i> (Linnaeus, 1766)
	<i>Pogonias cromis</i> (Linnaeus, 1766)
	<i>Sciaenops ocellatus</i> (Linnaeus, 1766)
Family Ehippidae	
	<i>Chaetodipterus faber</i> (Broussonet, 1782)
Family Mugilidae	
	<i>Mugil cephalus</i> Linnaeus, 1758
Family Polynemidae	
	<i>Polydactylus octonemus</i> (Girard, 1858)
Family Uranoscopidae	
	<i>Astroscopus y-graecum</i> (Cuvier, 1829)
Family Trychiuridae	
	<i>Trichiurus lepturus</i> Linnaeus, 1758
Family Scombridae	
	<i>Scomberomorus maculatus</i> (Mitchill, 1815)
Family Stromateidae	
	<i>Peprilus alepidotus</i> (Linnaeus, 1766)
	<i>Peprilus burti</i> Fowler, 1944
Order Pleuronectiformes	
Family Bothidae	
	<i>Paralichthys lethostigma</i> Jordan & Gilbert, 1844
Family Pleuronectidae	
	<i>Trinectes maculatus</i> (Bloch & Schneider, 1801)

model. This trend is nearly the inverse of that observed for salinity data (Fig. 2). Diversity at east bay sites did not significantly correlate with the measured environmental factors (salinity, water temperature, tide level). At west bay sites diversity was highly correlated with salinity (Pearson correlation = -0.81) and to a lesser degree, with water temperature (Pearson correlation = 0.51). Percent similarity between east and west bay sites loosely approximated the trend observed in Shannon diversity, becoming more similar as the study progressed (Table 3).

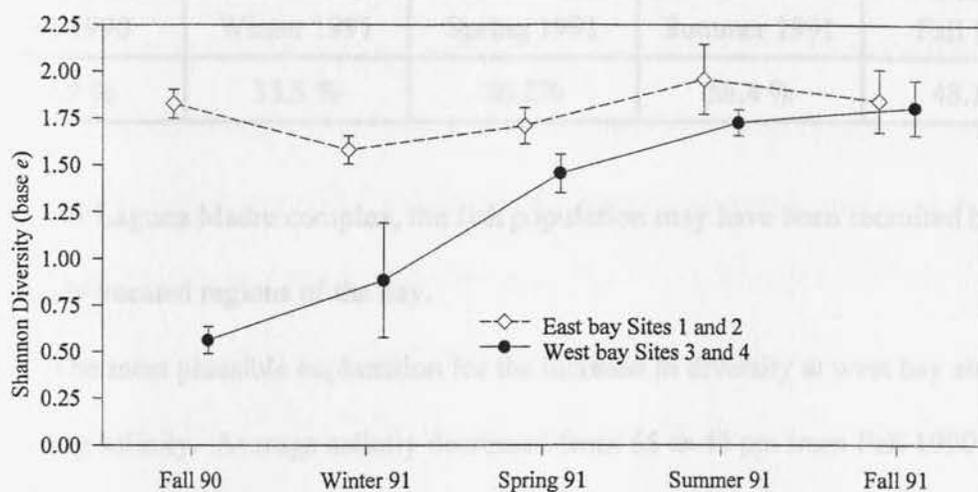


Figure 7. Seasonal comparison of Shannon diversity (base e) of trammel net collections between east and west Baffin Bay sites.

There may be several explanations for the increase in diversity at west bay sites. A severe freeze in December 1989 caused a mass mortality of fish along the entire Texas coast and especially in the upper Laguna Madre (McEachron *et al.*, 1994; Martin and McEachron, 1995). Because this study was initiated in November 1990, approximately 11 months after the freeze, fish populations may not have fully recovered in the extreme western reaches of Baffin Bay. Therefore, increasing recruitment to the upper reaches of Baffin Bay may account for the increase in diversity associated with west bay collections.

The chrysophyte bloom ("Brown Tide") is believed to have originated in the upper reaches of Baffin Bay (Stockwell *et al.*, 1993). Fish may have initially moved away from these areas, but as the "Brown Tide" ultimately affected the entire Baffin

Table 3. Seasonal comparison of percent similarity between east and west bay trammel net collections in Baffin Bay, Texas.

Fall 1990	Winter 1991	Spring 1991	Summer 1991	Fall 1991
39.9 %	33.5 %	38.2%	58.4 %	48.1 %

Bay/upper Laguna Madre complex, the fish population may have been recruited back to previously vacated regions of the bay.

The most plausible explanation for the increase in diversity at west bay sites is the decreasing salinity. Average salinity decreased from 65 to 45 ppt from Fall 1990 to Fall 1991, respectively. Correlations between diversity and salinity have been provided by many numerous authors (Breuer, 1957; Copeland and Jones, 1963; Copeland, 1967; Gunter, 1967; Hilderbrand 1969; Fuls, 1974; Tinnin, 1974; Krull, 1976; Cornelius, 1984; and others). In an ecological survey of the upper Laguna Madre, Simmons (1957) concluded that at higher salinities there were:

1. fewer species,
2. a greater number of individuals of each species,
3. larger average individual sizes of each vertebrate species, and
4. smaller average individual sizes of many invertebrate species.

Simmons (1957) reported highest diversity in the upper Laguna Madre when salinities ranged between 40-50 ppt. Cornelius (1984) found diversity was highest in Alazan Bay

when salinities ranged from 30-40 ppt. Highest diversity during the current study occurred between 41-52 ppt, substantiating Simmons' (1957) earlier findings. My study also agrees closely with a study by Simmons and Huckabee (1971) in which 3,541 individuals representing 34 species and 18 families were collected during a 13 month study while salinities averaged 42.6 ppt. Studies conducted when salinities were lower show reduced numbers of species and families. Tinnin (1974) collected 4995 individuals representing 26 species and 17 families over a 14 month period while the average salinity was 14.4 ppt. Fuls (1974) collected 7,092 individuals representing 29 species and 17 families during a 13 month study when salinities averaged 18.1 ppt. Although the previously mentioned studies used slightly different sampling equipment, compared to this study, they do demonstrate that maximum macroichthyofaunal diversity occurs in Baffin Bay when salinities are between 30-50 ppt.

Catch Rate (All Species Combined).—Overall there was no significant difference in the fish catch rate between reef sites ($\bar{x} = 6.120$, SE = 0.623 fish/h) and non-reef sites ($\bar{x} = 5.687$, SE = 0.520 fish/h), or between east ($\bar{x} = 5.911$, SE = 0.637 fish/h) and west ($\bar{x} = 5.897$, SE = 0.524 fish/h) bay locations. Seasons yielded significantly ($P < 0.05$) different catch rates. Spring showed significantly higher ($P < 0.05$) mean catch rates than other seasons. Summer showed significantly higher ($P < 0.05$) mean catch rate than Winter but was not significantly different than Fall samples (Fig. 8). The nested factor (site) was significant in the model (Table 4). Analyses of sites (within location and season) revealed that in the Spring and Fall 1991 Site 4 had significantly higher mean

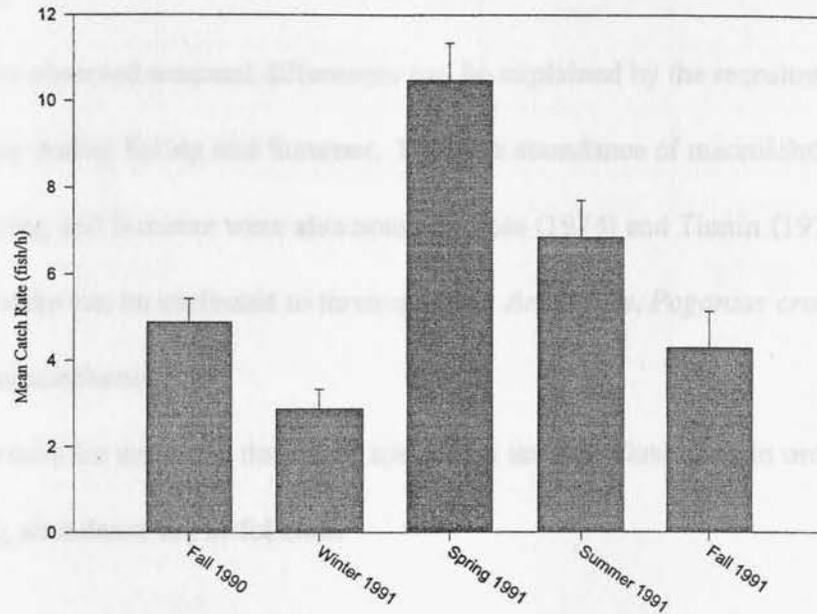


Figure 8. Comparison of the seasonal catch rate (fish/h) of all species combined collected by trammel net in Baffin Bay.

Table 4. ANOVA table for catch rate (fish/h) all species combined.

Source	DF	MS	F	P
Location (east or west)	1	0.6597	0.0291	0.8667
Season (Fall 1990 - Fall 1991)	4	217.89	10.669	0.0006
Location * Season	4	11.822	0.5075	0.7310
Site[Season,Location]	10	19.305	4.0632	0.0233
Reef/non-reef[Site,Season,Location]	20	5.9153	0.4823	0.9659

catch rates ($\bar{x} = 11.66$, SE = 1.45 and $\bar{x} = 6.66$, SE = 1.50 fish/h, respectively) than Site 3 ($\bar{x} = 7.29$, SE = 0.86 and $\bar{x} = 2.51$, SE = 0.44 fish/h, respectively). During no other seasons did mean catch rates differ significantly between sites within the two locations

(east and west bay). The interactions between factors (location, and season) were not significant.

The observed seasonal differences can be explained by the recruitment of fish into the bay during Spring and Summer. Peaks in abundance of macroichthyofauna during Spring and Summer were also noted by Fuls (1974) and Tinnin (1974). These seasonal peaks can be attributed to three species: *Arius felis*, *Pogonias cromis*, and *Leiostomus xanthurus*.

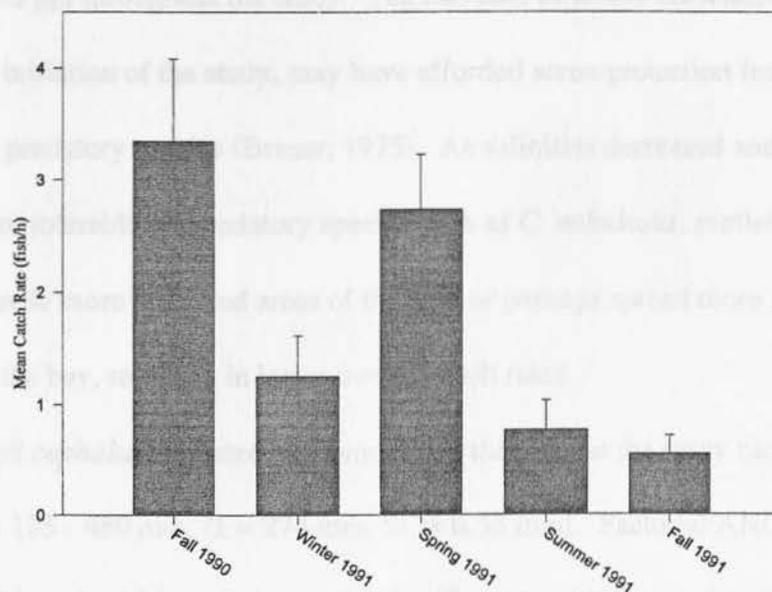
Results for the seven dominant species on an individual basis in order of decreasing abundance are as follows.

Mugil cephalus—A total of 1,483 *M. cephalus* were collected by trammel net during the study, with similar numbers collected from reef sites (47.2 %) and non-reef control sites (52.8 %). The eastern portion of the bay within the area of patch reefs, produced 19.1 % of the *M. cephalus* while 80.9 % were collected in the western portion of the bay. Mullet were collected in large numbers during all seasons (Fall 1990 = 576, Winter 1991 = 216, Spring 1991 = 498, Summer 1991 = 117) except Fall 1991 when only 76 individuals were encountered.

Mean catch rates varied significantly with location in the bay and season (Table 5). Eastern bay collections yielded a significantly lower catch rate ($\bar{x} = 0.711$, SE = 0.105) than western bay collections ($\bar{x} = 2.733$, SE = 0.379). Fall 1990 and Spring 1991 had significantly higher catch rates than other seasons (Fig. 9).

Table 5. ANOVA table for the inverse of the *Mugil cephalus* catch rate (fish/h) data.

Source	DF	MS	F	P
Location (east or west)	1	1.1051	11.8220	0.0046
Season (Fall 1990 - Fall 1991)	4	0.6446	7.1390	0.0042
Location * Season	4	0.09484	0.9890	0.4507
Site[Season,Location]	10	0.08911	2.3292	0.0799
Reef/non-reef[Site,Season,Location]	20	0.04053	0.7657	0.7445

Figure 9. Comparison of the seasonal catch rate (fish/h) of *Mugil cephalus* collected by trammel net in Baffin Bay.

Breuer (1957) found *M. cephalus* to be the most abundant fish in the Baffin Bay system and particularly in shallow water near the serpulid worm reefs. *Mugil cephalus* was also the most abundant fish collected by trammel net during the study comprising 30.65 % of the total catch. No evidence was found to suggest that *M. cephalus*

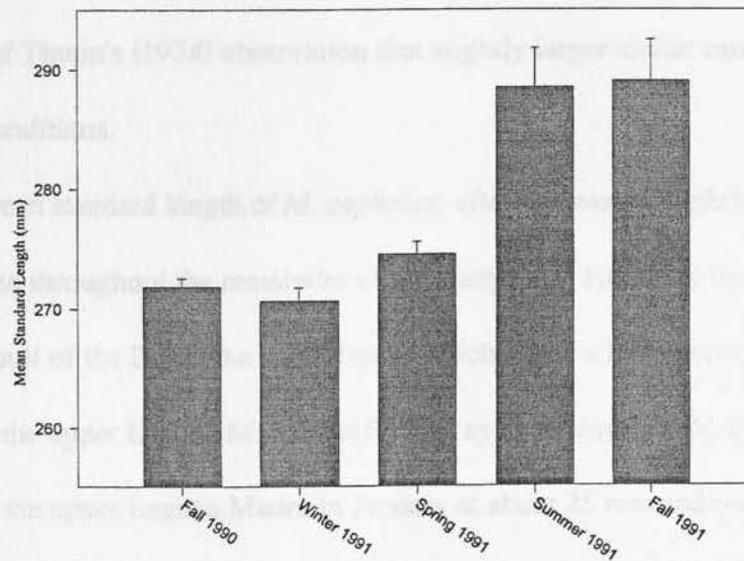
congregate in greater abundance near serpulid worm reefs. *Mugil cephalus* was found to be most abundant at west bay sites (Sites 3 and 4) and in particular in Laguna Salada.

Seasonal highs in abundance occurred in Fall 1990 and Spring 1991, but there appeared to be an overall decreasing trend throughout the study. *Mugil cephalus* has been described as a completely euryhaline species, able to tolerate extremes in temperature and salinity (Gunter, 1945; Breuer, 1957; Simmons, 1957; Springer and Woodburn, 1960; Hellier, 1962). Salinity at western bay sites (Sites 3 and 4) decreased from 65 to 45 ppt throughout the study. The elevated salinities associated with west bay sites, at the initiation of the study, may have afforded some protection from more stenohaline predatory species (Breuer, 1975). As salinities decreased and the areas became more tolerable for predatory species such as *C. nebulosus*, mullet may have moved either to more protected areas of the bay, or perhaps spread more uniformly throughout the bay, resulting in lower overall catch rates.

Mugil cephalus collected by trammel net throughout the study ranged in standard length from 175 - 480 mm, ($\bar{x} = 274$ mm, SE = 0.58 mm). Factorial ANOVA indicates the standard length of *M. cephalus* varied significantly with season, location in the bay, and the nested factor reef/non-reef. No interaction between factors was indicated (Table 6). The mean standard length of *M. cephalus* was significantly greater ($\bar{x} = 282.25$ mm, SE = 1.54 mm) at east bay locations (Sites 1 and 2), compared to west bay collections (Sites 3 and 4) ($\bar{x} = 273.05$ mm, SE = 0.60 mm). *Mugil cephalus* were significantly longer during Summer and Fall 1991 than in other seasons (Fig. 10). Although the nested factor reef/non-reef was significant in the model its level varied between sites and

Table 6. ANOVA table for the standard length of *Mugil cephalus*.

Source	DF	MS	F	P
Location (east or west)	1	11171.9	18.9783	0.0005
Season (Fall 1990 - Fall 1991)	4	6124.66	6.4658	0.0044
Location * Season	4	1087.6	1.4729	0.3067
Site[Season,Location]	10	1815.94	1.1618	0.3727
Reef/non-reef[Site,Season,Location]	20	1438.73	3.4700	0.0000

Figure 10. Seasonal comparison of standard length of *Mugil cephalus* collected by trammel net from Baffin Bay.

seasons. At Site 2 during Winter 1991 the standard length of *M. cephalus* was significantly greater at the reef ($\bar{x} = 288$ mm, SE = 1.66 mm) than at the non-reef control ($\bar{x} = 270$ mm, SE = 4.83 mm) while in Spring 1991 (Site 1) fish from the non-reef control were larger ($\bar{x} = 283$ mm, SE = 4.29 mm) compared to reef samples ($\bar{x} = 270$ mm, SE=

3.49 mm). Site 3 in Spring 1991 also produced significantly larger *M. cephalus* at the reef site (\bar{x} = 285 mm, SE = 2.49 mm) compared to the non-reef control site (\bar{x} = 277 mm, SE = 2.04 mm).

The mean size of *M. cephalus* during this study is greater than that reported by Tinnin (1974) (\bar{x} = 250 mm) when salinities averaged < 20 ppt. In contrast to Tinnin (1974), Simmons and Huckabee (1971) reported the mean length of *M. cephalus* to be 274 mm when salinities averaged 42 ppt. The average length of *M. cephalus* during this study (\bar{x} = 274.8) is in agreement with the findings of Simmons and Huckabee (1971) and is in support of Tinnin's (1974) observation that slightly larger mullet can be found during hypersaline conditions.

The mean standard length of *M. cephalus*, after decreasing slightly in Winter 1991, increased throughout the remainder of the study (Fig. 10). This increase over time may be the result of the December 1989 freeze which killed a large portion of the fish population in the upper Laguna Madre/Baffin Bay system. Juvenile *M. cephalus* are recruited into the upper Laguna Madre in January at about 25 mm and reach approximately 116 mm in their first year (Hellier, 1962). Because of reduced populations following the freeze, the new smaller recruits would have a much greater effect on the overall average size of mullet in the bay. The sporadic occurrence of significantly larger mullet collected near the serpulid worm reefs is probably a random event or an artifact of the limited sampling effort. Because east bay collections produced significantly larger *M. cephalus* than west bay collections, there is some limited evidence to suggest that reef type might influence size distribution of mullet in Baffin Bay. It is unfortunate that reef

type is confounded with position in the bay making it impossible to ascertain the precise influence on fish distribution and size. Along with the predominance of patch reefs in the eastern half of Baffin Bay, there is undoubtedly more seagrass cover in this portion of the bay. The combined effects of reef type and seagrass cover, along with the distance from the ICWW, may act together to influence population dynamics.

The influence of salinity may also explain the significant difference in average standard length for *M. cephalus* observed between east and west bay collections. The high salinities associated with west bay sites may have offered some refuge to smaller *M. cephalus*. Breuer (1957) found *C. nebulosus* conspicuously absent at salinities > 55 ppt. Large *M. cephalus* would be less influenced by predators and able to move freely throughout the bay thus resulting in significantly larger fish at east bay sites where salinities averaged < 50 ppt.

Pogonias cromis.—A total of 1,114 *P. cromis* (22.7 % of the total catch) were collected by trammel net making it the second most abundant species observed during the study. Serpulid worm reef sites produced 60.3 % of the *P. cromis* collected with the remaining 39.7 % collected at non-reef control areas. Eastern portions of the bay produced 35.6 % of the while 64.4 % were collected in the western reaches of the bay. The total number collected in Fall 1990 was 42, which increased to 107 in the Winter, reached its highest peak in the Spring and Summer (427 and 358, respectively), decreasing to 180 in Fall 1991.

Catch rates of *P. cromis* were significantly influenced by the season of collection and the nested factor reef/non-reef (Table 7). The catch rate was significantly greater at east bay sites in Fall 1990 and Winter 1991, while during Spring, Summer, and Fall 1991, significantly higher catch rates were observed at western bay locations (Fig. 11). Overall catch rates for *P. cromis* were significantly higher in Spring and Summer 1991 than in Fall 1990 or Winter 1991. Only in Fall 1991 at Site 4 was the catch rate significantly higher for the reef ($\bar{x} = 4.5$, SE = 2.12 fish/h) than the non/reef control (1.2, SE= 0.30 fish/h).

Table 7. ANOVA table for the inverse of the *Pogonias cromis* catch rate (fish/h) data.

Source	DF	MS	F	P
Location (east or west)	1	0.01823	0.2217	0.6480
Season (Fall 1990 - Fall 1991)	4	0.75472	8.7578	0.0025
Location * Season	4	0.36129	4.2535	0.0786
Site[Season,Location]	10	0.08916	2.2419	0.3925
Reef/non-reef[Site,Season,Location]	20	0.03927	1.0749	0.0315

The catch rate peaked during Spring 1991. Simmons and Huckabee (1971) reported a similar spring peak in abundance although fewer (79) *P. cromis* were collected. Tinnin (1974) concluded after collecting 271 individuals (nearly 3.5 times the number reported by Simmons and Huckabee (1971) during a "freshnet" event) that salinity plays a major role in determining the density of *P. cromis* in Texas bays. During my study four times as many *P. cromis* were collected than in Tinnin's (1974) study suggesting either

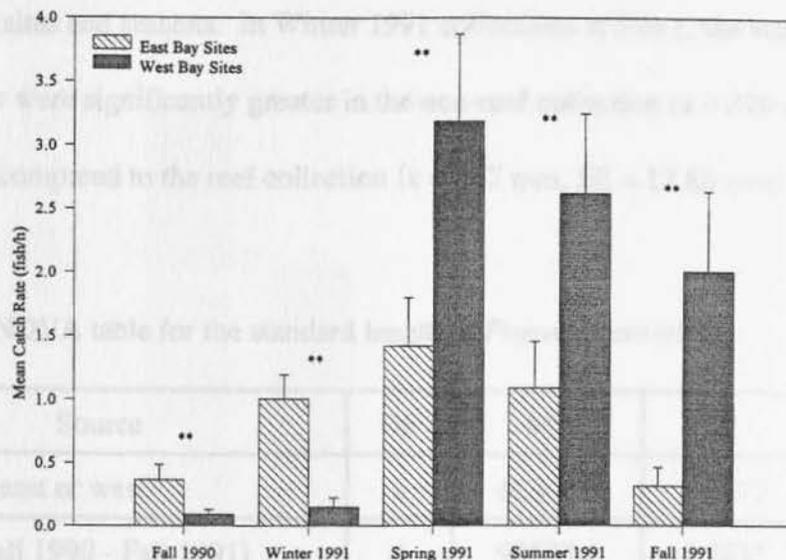


Figure 11. Seasonal comparison of mean *Pogonias cromis* catch rates (fish/h) between east and west Baffin Bay trammel net collection. (** = Significantly different $P < 0.05$)

salinity is not as important as previously believed or there had been a substantial increase in the population.

The standard length of *P. cromis* ranged in size from 105 - 870 mm ($\bar{x} = 205$ mm, $SE = 2.04$ mm) throughout the study. Results of factorial ANOVA indicates that the standard length of *P. cromis* varied significantly with location in the bay, seasonally, and the nested factor reef/non-reef (Table 8). The standard length of *P. cromis* was significantly greater ($\bar{x} = 244$ mm, $SE = 5.12$ mm) for eastern bay locations (Sites 1 and 2) compared to west bay collections (Sites 3 and 4) ($\bar{x} = 184$ mm, $SE = 1.82$). The standard length of *P. cromis* was significantly greater in Fall 1990 collections than during any other seasons. Fall 1990 and Winter 1991 also yielded significantly greater mean

standard lengths than other seasons (Fig. 16). The level of the nested factor reef/non-reef varied with sites and seasons. In Winter 1991 collections at Site 1, the standard lengths of *P. cromis* were significantly greater in the non-reef collection ($\bar{x} = 329$ mm, SE = 11.65 mm) compared to the reef collection ($\bar{x} = 237$ mm, SE = 12.88 mm).

Table 8. ANOVA table for the standard length of *Pogonias cromis*.

Source	DF	MS	F	P
Location (east or west)	1	61363.6	8.9377	0.0169
Season (Fall 1990 - Fall 1991)	4	90533.6	5.2831	0.0194
Location * Season	4	1397.54	0.1205	0.9669
Site[Season,Location]	10	31328.4	1.1355	0.3860
Reef/non-reef[Site,Season,Location]	20	26647.6	6.8891	0.0000

Large numbers of small *P. cromis* were collected in the Spring resulting in a significant decrease in standard length. Similar recruitment patterns were observed by Tinnin (1974). The significantly larger fish collected at east bay sites may be a result of a combination of salinity, seagrass cover, proximity to ICWW, or "Brown Tide." *Pogonias cromis* rely heavily on *Mulinia lateralis* populations in Baffin Bay for food (Martin 1979). *Mulinia lateralis* populations were greatly reduced in Baffin Bay during 1990 - 1992, a possible consequence of the "Brown Tide" (Montagna et al., 1993). The reduction of *M. lateralis* in Baffin Bay may have caused *P. cromis* to abandon the upper

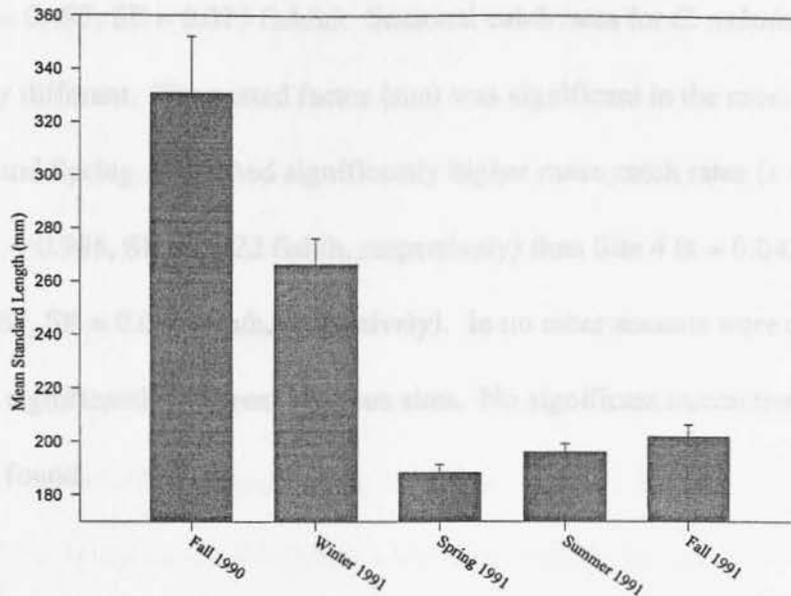


Figure 12. Seasonal comparison of standard length of *Pogonias cromis* collected by trammel net in Baffin Bay.

reaches of Baffin Bay to search for more plentiful prey (crabs and shrimp) in the seagrass beds nearer the ICWW.

Cynoscion nebulosus.—A total of 820 *C. nebulosus* were collected by trammel net during the study, with similar numbers collected from reef sites (51 %) and non-reef control sites (48.8 %). More *C. nebulosus* (66.4 %) were collected from the patch reef area of the bay (Sites 1 and 2) while only 33.3 % were collected from the western reaches of the bay in the area of the reef fields.

The mean catch rate for *C. nebulosus* was not significantly different between reef and non-reef controls. The mean catch rate for eastern portions of the bay within the

patch reefs ($\bar{x} = 1.193$, SE = 0.157 fish/h) was significantly higher than for western bay samples ($\bar{x} = 0.497$, SE = 0.073 fish/h). Seasonal catch rates for *C. nebulosus* were not significantly different. The nested factor (site) was significant in the model (Table 9). In the Winter and Spring, Site 3 had significantly higher mean catch rates ($\bar{x} = 0.444$, SE = 0.153 and $\bar{x} = 0.986$, SE = 0.222 fish/h, respectively) than Site 4 ($\bar{x} = 0.042$, SE = 0.027 and $\bar{x} = 0.167$, SE = 0.070 fish/h, respectively). In no other seasons were catch rates found to be significantly different between sites. No significant interaction between factors was found.

Table 9. ANOVA table for the inverse of the *Cynoscion nebulosus* catch rate (fish/h) data.

Source	DF	MS	F	P
Location (east or west)	1	0.7531	7.1829	0.0169
Season (Fall 1990 - Fall 1991)	4	0.1827	1.8938	0.1771
Location * Season	4	0.0744	0.6856	0.6131
Site[Season,Location]	10	0.0927	8.7708	0.0061
Reef/non-reef[Site,Season,Location]	20	0.0155	0.3666	0.9931

Breuer (1957), Simmons and Huckabee (1971), and Tinnin (1974) describe *C. nebulosus* as a year-round resident of Baffin Bay. During this study *C. nebulosus* was also captured in all seasons, comprising 17.02 % of the total catch. Breuer (1957) found *C. nebulosus* conspicuously absent at salinities > 55 ppt. This may explain the significant difference in catch rates between east and west bay collections. Salinities at the west bay

sites ranged from 65 - 52 ppt during the first three seasons of the study (Fig. 2). Breuer (1957) reported that *C. nebulosus* was collected chiefly in the vicinity of the serpulid worm reefs. There was no evidence of concentration of *C. nebulosus* near the serpulid worm reefs found during my study. The major reason for the discrepancy between these studies is unclear, but it may be due to the increase of seagrass coverage in Baffin Bay. Breuer (1957) found no seagrass in Baffin Bay. Also Mackin (1971) made no mention of seagrass cover. Simmons and Huckabee (1971) found the Laguna Salada devoid of seagrass during Fall 1969, but by Spring 1970 *Halodule wrightii* and *Ruppia maritima* were becoming established. All studies since have reported the presence of seagrass cover in the Baffin Bay-complex (Fuls, 1974; Jensen, 1974; Tinnin, 1974; Krull, 1976; Cornelius, 1984). During my study, *H. wrightii* was well established from the Point of Rocks, through the Badlands, and extending along the margin of Baffin Bay to Alazan Bay. In fact, many areas of Baffin Bay < 1 m in depth and without caliche or serpulid worm reefs were covered with *H. wrightii*. There were also areas of scattered seagrass cover along the shore of the Laguna Salada near the pier at Site 55 (the Texas A&M University-Kingsville research station). *Cynoscion nebulosus* are known residents of seagrass beds (Pearson, 1928); therefore, the increase in seagrass cover may have allowed for a more uniform distribution of fishes throughout Baffin Bay. This would explain the discrepancy in *C. nebulosus* distribution between this study and Breuer's (1957).

Standard length of *C. nebulosus* ranged from 215 to 625 mm ($\bar{x} = 345$ mm) over the study period. Mean standard lengths of *C. nebulosus* varied significantly with location in the bay and season. The significance of location in the bay is dependent on

the season of collection as indicated by the significant season, location interaction (Table 10). Factorial ANOVA indicates the nested factor reef/non-reef was significant. In Spring 1991, the standard length of *C. nebulosus* was significantly greater for the reef (\bar{x} = 346 mm, SE = 7.02 mm) than the non-reef control (\bar{x} = 318 mm, SE = 7.86 mm) at Site 3. During Summer and Fall 1991 at Site 2 the standard length of *C. nebulosus* was significantly larger (\bar{x} = 385 mm, SE = 17.45 and \bar{x} = 353 mm, SE = 6.81 mm, respectively) than at the control site (\bar{x} = 332 mm, SE = 6.93 mm and \bar{x} = 336 mm, SE = 4.22 mm, respectively). The standard length of *C. nebulosus* was not significantly different between reef and non-reef control for any other sites or seasons. The standard length of *C. nebulosus* was significantly greater at east bay sites during Fall 1990 and Winter 1991. During Spring and Summer there were no significant differences between locations in the bay, but in Fall 1991 west bay sites produced significantly larger fish (Fig. 13).

No strong evidence was found to support the hypothesis that larger *C. nebulosus* congregate near serpulid worm reefs. The minor evidence found in support of the previously mentioned hypothesis was limited to two reefs; Site 3 in Spring, and Site 2 in Summer and Fall 1991. These two reefs are of different types and located at opposite ends of the bay; therefore, it is inappropriate to conclude that larger *C. nebulosus* always concentrate around the serpulid worm reefs; in fact, the occurrence of significantly larger fish around the serpulid worm reefs appears random.

Cynoscion nebulosus are known to move to deeper (warmer) waters during cold events in winter months (Pearson, 1928). Because the ICWW is the closest relatively

Table 10. ANOVA table for the standard length of *Cynoscion nebulosus*

Source	DF	MS	F	P
Location (east or west)	1	20493.5	7.5729	0.0136
Season (Fall 1990 - Fall 1991)	4	11004.9	3.3338	0.0394
Location * Season	4	10635.2	3.5741	0.0431
Site[Season,Location]	10	4359.41	1.3394	0.2843
Reef/non-reef[Site,Season,Location]	19	3175.89	1.6298	0.0437

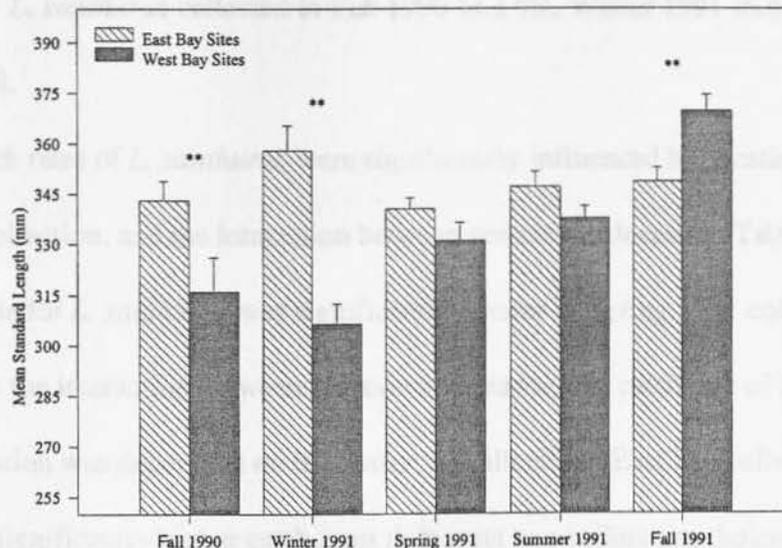


Figure 13. Seasonal comparison of the standard length of *Cynoscion nebulosus* between east and west bay collections. (** = Significantly different $P < 0.05$)

deep water, larger trout may move from the shallow upper reaches of Baffin Bay to the deeper more protected areas near the junction of the bay with the upper Laguna Madre. This movement to the eastern portion of the bay may account for the significantly larger individuals that were collected at east bay sites during Fall 1990 and Winter 1991.

Leiostomus xanthurus.—A total of 653 *L. xanthurus* (13.6 % of the total catch) were collected by trammel net making it the fourth most abundant species observed during this study. Three hundred eighty three (58.6 %) were collected adjacent to serpulid worm reefs and 270 (41.3 %) were collected at non-reef control sites. The overwhelming majority were collected at east bay locations (73.5 %) compared to 26.5 % collected at west bay sites. *Leiostomus xanthurus* were most abundant during Spring and Summer 1991 with 65.5 % and 20.7 % collected in these seasons, respectively. There were similar numbers of *L. xanthurus* collected in Fall 1990 (4.1 %), Winter 1991 (6.6 %), and Fall 1991 (3.1 %).

Catch rates of *L. xanthurus* were significantly influenced by location in the bay, season of collection, and the interaction between season and location (Table 11). Overall, the catch rate for *L. xanthurus* was significantly greater in Spring 1991 collections (Fig. 14). Due to the interaction between location and season, the catch rate of *L. xanthurus* at a given location was dependent on the season of collection. East bay collections (Sites 1 and 2) had significantly higher catch rates than west bay collections during Fall 1990, Winter 1991, and Spring 1991, while Summer and Fall 1991 catch rates did not significantly differ between locations (Fig. 15).

Spring peaks in occurrence of *L. xanthurus* have been noted by various authors (Pearson, 1928; Gunter, 1945; Breuer, 1957; Simmons, 1957; Simmons and Huckabee; 1971; Tinnin, 1974). Tinnin also reported a sharp increase in abundance of *L. xanthurus* in the summer during a trammel net survey of Laguna Salada. During my study an increased abundance of *L. xanthurus* was also observed at west bay sites in the summer.

Table 11. ANOVA table for the inverse of the *Leiostomus xanthurus* catch rate (fish/h) data.

Source	DF	MS	F	P
Location (east or west)	1	0.30975	5.0672	0.0416
Season (Fall 1990 - Fall 1991)	4	0.48738	8.4435	0.0020
Location * Season	4	0.22022	3.5132	0.0383
Site[Season,Location]	10	0.05619	2.5465	0.0650
Reef/non-reef[Site,Season,Location]	20	0.02408	0.6869	0.8269

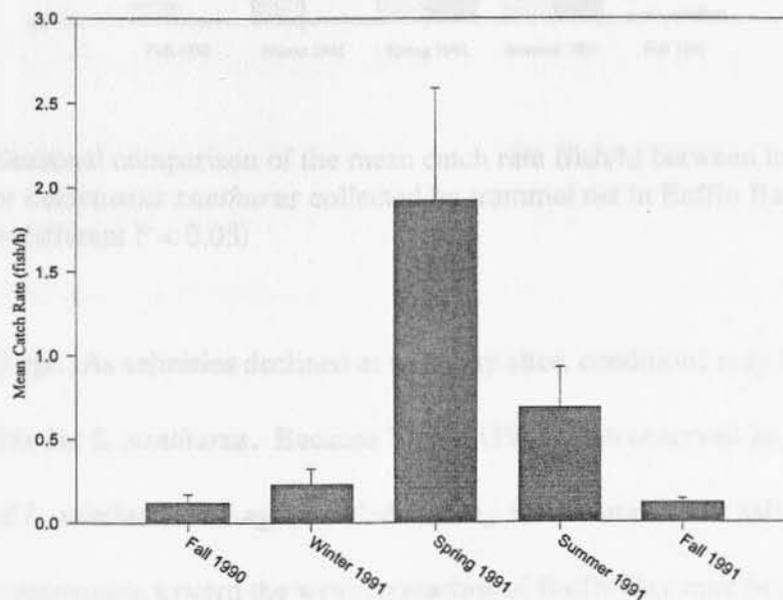


Figure 14. Seasonal comparison of the catch rate (fish/h) of *Leiostomus xanthurus* collected by trammel net in Baffin Bay.

The increased summer abundance of *L. xanthurus* at west bay sites relative to east bay sites caused the significant interaction observed in the model. The movement of *L. xanthurus* into west bay sites may have been salinity-related, or due to yearly migration patterns. Simmons (1957) found the abundance of *L. xanthurus* to decrease as salinities

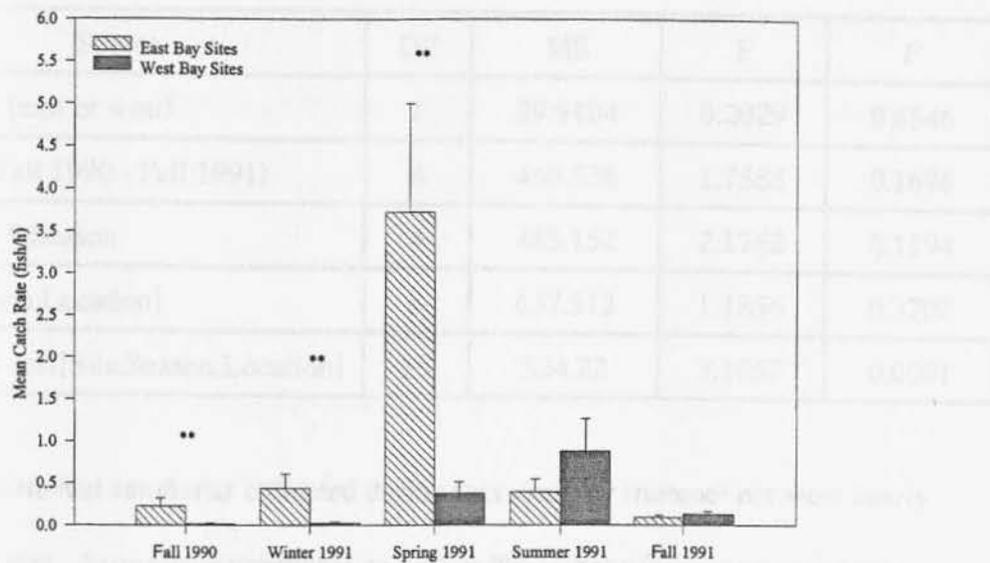


Figure 15. Seasonal comparison of the mean catch rate (fish/h) between locations of collection for *Leiosomus xanthurus* collected by trammel net in Baffin Bay. (** = Significantly different $P < 0.05$)

became > 50 ppt. As salinities declined at west bay sites, conditions may have become more favorable for *L. xanthurus*. Because Tinnin (1974) also observed an increase in the abundance of *L. xanthurus* in Laguna Salada during the summer when salinities were much lower, movement toward the western reaches of Baffin Bay may be part of the annual migration pattern.

Leiosomus xanthurus ranged in standard length from 108 - 250 mm ($\bar{x} = 184$ mm, $SE = 0.54$ mm) throughout the study. Factorial ANOVA indicates only the nested factor reef/non-reef significantly influenced the standard length of *L. xanthurus* (Table 12). Only in Spring 1991 (Site 1) was standard length significantly greater for reef collections ($\bar{x} = 186$ mm, $SE = 1.75$ mm) compared to non-reef controls ($\bar{x} = 178$ mm, $SE = 1.32$ mm).

Table 12. ANOVA table for the standard length of *Leiostomus xanthurus*.

Source	DF	MS	F	P
Location (east or west)	1	39.9104	0.2029	0.6546
Season (Fall 1990 - Fall 1991)	4	460.538	1.7568	0.1696
Location * Season	4	485.152	2.1762	0.1194
Site[Season,Location]	8	637.513	1.1856	0.3702
Reef/non-reef[Site,Season,Location]	15	524.22	3.1057	0.0001

Leiostomus xanthurus collected during this study by trammel net were nearly uniform in size. *Leiostomus xanthurus* remain in Texas bays for two years prior to migrating to the Gulf to spawn (Pearson, 1928). Pearson found *L. xanthurus* to attain a length of approximately 140 mm during the first year and 210 mm in the second. The December 1989 freeze that killed many fish on the Texas coast (McEachron *et al.*, 1994; Martin and McEachron, 1995) probably eliminated most of the *L. xanthurus* from Baffin Bay; therefore, *L. xanthurus* collected during my study were probably of one age class which explains their uniform size distribution.

Limited evidence indicates that significantly larger *L. xanthurus* concentrate near serpulid worm reefs. Only one site (Site 1) during one season (Spring 1991) displayed a significant difference in the standard length of *L. xanthurus*, so it is likely a random occurrence and does not accurately reflect a true difference.

Arius felis.—A total of 604 (12.01 % of the total catch) *A. felis* were collected by trammel net during the study making it the fifth most abundant species collected. Serpulid worm

reef sites produced 46.9 % of the *A. felis*, while 53.1 % were collected in non-reef control areas. Eastern bay collections produced 86.8 % of the *A. felis* compared to only 13.9 % collected in the western reaches of the bay. *Arius felis* were most abundant in Spring (46.3 %) and Summer (28.3 %) and less frequent in Fall 1991 (3.9 %) and Winter 1991 (4.1 %).

Factorial ANOVA of mean catch rates reveals no significant difference between reef and non-reef control collections; however, location of collection in the bay, season of collection, and the location by season interaction were significant (Table 13).

Throughout all seasons, the catch rate for *A. felis* was greater in the eastern portion of the bay ($\bar{x} = 1.04$ SE = 0.18 fish/h) compared to the western portions ($\bar{x} = 0.13$, SE = 0.03 fish/h). Although the east bay (Sites 1 and 2) catch rate for *A. felis* was greater in all seasons, it was only significantly so in Fall 1990, Spring 1991, and Summer 1991 (Fig. 16). Spring and Summer 1991 had significantly higher ($P < .05$) catch rates ($\bar{x} = 1.10$, SE = 0.26 and $\bar{x} = 0.87$, SE = 0.32 fish/h, respectively) than Fall and Winter 1991 ($\bar{x} = 0.11$, SE 0.04 and $\bar{x} = 0.09$, SE = 0.04 fish/h, respectively).

Arius felis move to deeper waters of the bay or to the Gulf of Mexico during winter months (Gunter, 1945; Breuer, 1957; Hellier, 1962; Zimmerman, 1969; Simmons and Huckabee, 1971; Tinnin, 1974). These seasonal movements away from shallow waters have been linked to declines in water temperature. Because high numbers of *A. felis* were collected by Simmons and Huckabee (1971) during hypersaline conditions and by Tinnin (1974) following a "freshnet" event, Tinnin (1974) concluded salinity was not a controlling factor for *A. felis*. The overwhelming majority of *A. felis* during my study

Table 13. ANOVA table for the inverse of the *Arius felis* catch rate (fish/h) data.

Source	DF	MS	F	P
Location (east or west)	1	1.5748	58.889	0.0000
Season (Fall 1990 - Fall 1991)	4	0.4295	11.207	0.0006
Location * Season	4	0.1361	3.2932	0.0480
Site[Season,Location]	10	0.0373	2.0136	0.1222
Reef/non-reef[Site,Season,Location]	20	0.0197	0.7474	0.7647

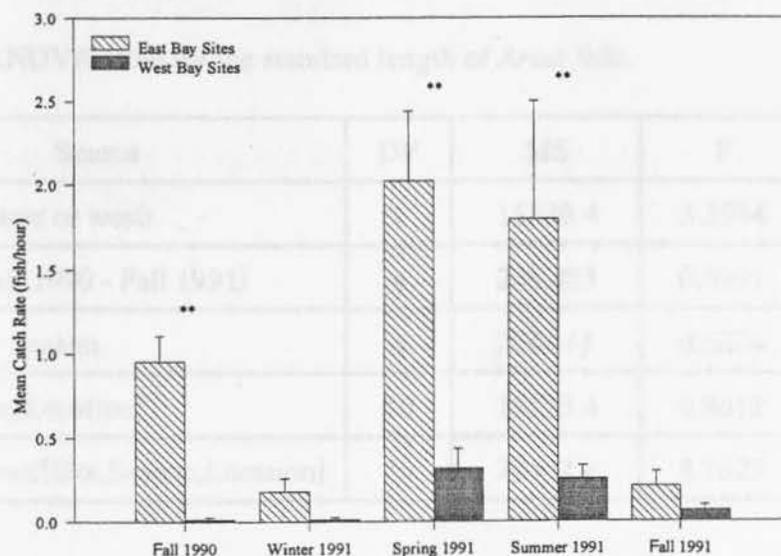


Figure 16. Seasonal comparison of *Arius felis* catch rates (fish/h) between east and west Baffin Bay collections. (** = Significant difference $P < 0.05$)

were collected from east bay sites. East bay sites had significantly lower salinities than west bay sites, suggesting that salinities > 50 ppt may control movements of this species.

Arius felis ranged in size from 85 - 385 mm ($\bar{x} = 242$ mm, SE = 2.53 mm)

throughout the study. Factorial ANOVA indicates the standard length of *A. felis* varies

significantly with season and the nested factor reef/non-reef (Table 14). Summer 1991 produced significantly smaller *A. felis* than all other seasons while Spring and Fall 1991 yielded significantly larger fish than Fall 1990 or Summer 1991 (Fig. 17). During Winter and Summer 1991 (Site 1) non-reef control site samples produced significantly larger ($\bar{x} = 254$ mm, SE = 11.00 mm and $\bar{x} = 249$ mm, SE = 9.53 mm, respectively) *A. felis* than did reef collections ($\bar{x} = 205$ mm, SE = 8.15 mm and $\bar{x} = 158$ mm, SE = 4.98 mm, respectively).

Table 14. ANOVA table for the standard length of *Arius felis*.

Source	DF	MS	F	P
Location (east or west)	1	15830.4	3.3594	0.7663
Season (Fall 1990 - Fall 1991)	4	248.385	0.0901	0.0360
Location * Season	4	2041.61	0.6224	0.6629
Site[Season,Location]	10	15535.4	0.8612	0.5683
Reef/non-reef[Site,Season,Location]	20	20402.4	8.7625	0.0000

Large numbers of small *A. felis* were collected during Summer 1991 causing the significant decrease in average size. My data suggest that the *A. felis* which remain in the bay in the Winter months are of a larger size and most of the smaller fish move to deeper water or the Gulf of Mexico. In Summer these smaller fish return to the bays in large numbers resulting in the observed significant decrease in standard length.

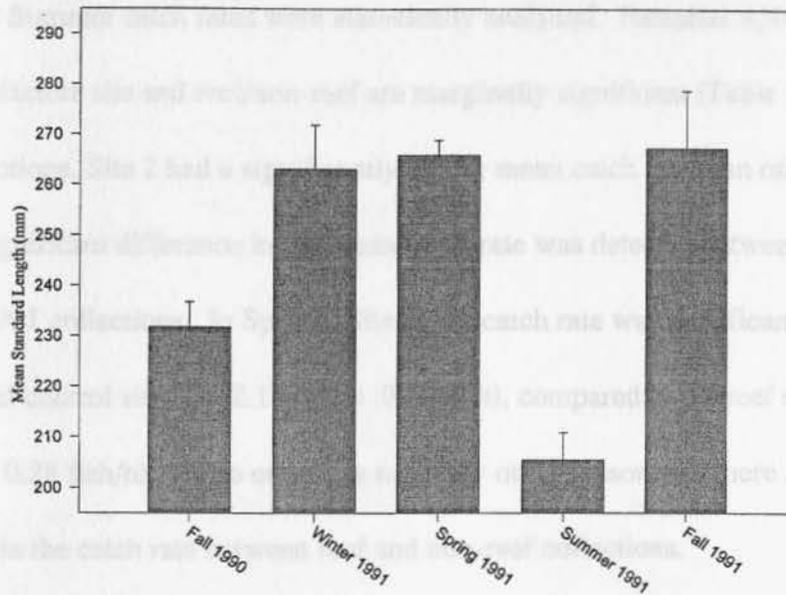


Figure 17. Seasonal comparison of the standard length of *Arius felis* collected by trammel net in Baffin Bay.

Lagodon rhomboides.—A total of 120 *L. rhomboides* (2.6 % of the total catch) were collected by trammel net during the study of which 45.8 % were collected adjacent to serpulid worm reefs and 54.2 % were collected at non-reef control sites. The overwhelming majority were collected at east bay locations within the area of the patch reefs and patch reef controls (76.7 %) compared to 23.3 % collected at western bay locations. *Lagodon rhomboides* were most abundant in Spring and Summer 1991 with 50.8 % and 34.2 % collected in these seasons, respectively. Winter 1991 showed the lowest abundance of *L. rhomboides* with only three individuals collected while in Fall 1990 nine individuals were collected and six were collected in Fall 1991 samples.

Because so few individuals were collected in Fall and Winter collections, only Spring and Summer catch rates were statistically analyzed. Factorial ANOVA indicates the nested factors site and reef/non-reef are marginally significant (Table 15). In Spring 1991 collections, Site 2 had a significantly higher mean catch rate than other sites (Fig. 18). No significant difference in the mean catch rate was detected between sites in the Summer 1991 collections. In Spring (Site 2) the catch rate was significantly higher for the non-reef control site ($\bar{x} = 2.19$, SE = .07 fish/h), compared to the reef collection ($\bar{x} = 0.63$, SE = 0.28 fish/h). At no other site or in any other season was there a significant difference in the catch rate between reef and non-reef collections.

Table 15. ANOVA table for the inverse of the *Lagodon rhomboides* catch rate (fish/h) data.

Source	DF	MS	F	P
Location (east or west)	1	0.34234	2.6770	0.1907
Season (Fall 1990 - Fall 1991)	1	0.00216	0.0159	0.9060
Location * Season	1	0.01565	0.1224	0.7473
Site[Season,Location]	4	0.15316	4.0765	0.0502
Reef/non-reef[Site,Season,Location]	8	0.03459	2.3143	0.0458

The migration patterns of *L. rhomboides* likely explains the strong seasonal shift in abundance observed during my study. *Lagodon rhomboides* spawn offshore and enter estuaries as juveniles (15 - 100 mm) in the spring and summer (Muncy, 1984). When water temperatures decrease in late fall, *L. rhomboides* migrate from the estuaries

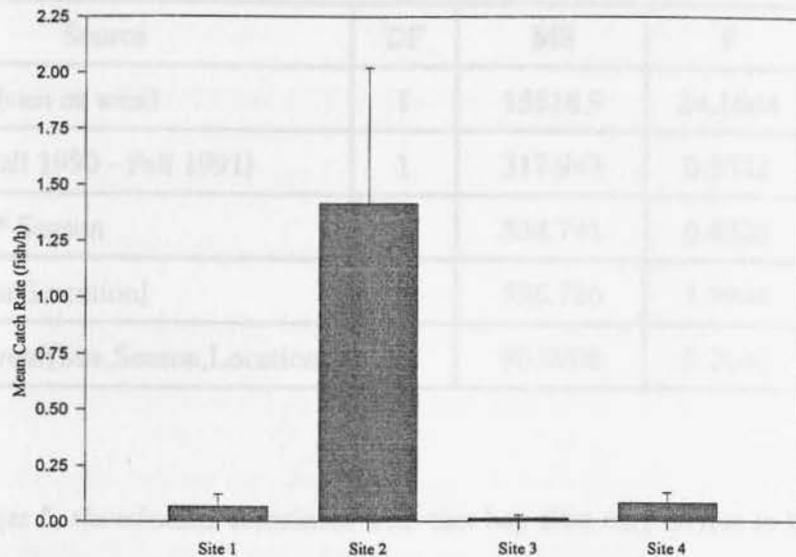


Figure 18. Comparison of the mean catch rate (fish/h) between sites for *Lagodon rhomboides* observer during the Spring 1991 trammel net collection in Baffin Bay.

(Weinstein et al., 1977; Wang and Kernegan, 1979). The dominance of the catch at east bay sites (Sites 1 and 2) might be explained by seagrass cover. *Lagodon rhomboides* prefer vegetated bottoms (Reid, 1954; Gunter and Hall, 1965; Coen et al., 1981). Site 2 was nearly surrounded by seagrass beds while the bottom, shoreward of Site 1, was also dominated by seagrass.

The standard length of *L. rhomboides* ranged from 80 - 175 mm (\bar{x} = 140 mm, SE = 2.16 mm) during the study. Factorial ANOVA indicates that only location in the bay was significant in the model (Table 16). The standard length of *L. rhomboides* was significantly greater for east bay collections (\bar{x} = 146 mm, SE = 1.77 mm) compared to west bay collections (\bar{x} = 109 mm, SE = 4.84 mm).

Table 16. ANOVA table for the standard length of *Lagodon rhomboides*.

Source	DF	MS	F	P
Location (east or west)	1	15518.9	24.1604	0.0097
Season (Fall 1990 - Fall 1991)	1	317.943	0.5522	0.5118
Location * Season	1	534.741	0.8325	0.4171
Site[Season,Location]	3	556.726	1.9944	0.1214
Reef/non-reef[Site,Season,Location]	5	90.8908	0.2102	0.9574

Larger *L. rhomboides* associated with east bay sites may be due to the greater percentage of seagrass cover there. The food habits of *L. rhomboides* change as the fish matures and grows. Mature *L. rhomboides* may be strict herbivores, grazing on seagrass and epiphytes (Stoner, 1982).

Sciaenops ocellatus.—A total of 117 (2.1 % of the total catch) *S. ocellatus* were collected by trammel net during the study of which 41.9 % were collected adjacent to serpulid worm reefs and 58.1 % were collected at non-reef control sites. Overall, collections made at east bay locations (Sites 1 and 2) produced twice as many *S. ocellatus* (66.7 %) as did west bay collections (33.3 %).

Because there were insufficient numbers of *S. ocellatus* collected to analyze with a factorial design, catch rates for each factor (location in the bay, season of collection, sites, and reef/non-reef) were analyzed independently. The mean catch rate of east bay collections ($\bar{x} = 0.069$, SE = 0.024 fish/h) was not significantly different than west bay

collections ($\bar{x} = 0.064$, $SE = 0.019$ fish/h). Fall 1991 showed a significantly greater mean catch rate than Spring 1991 (Fig. 19). The catch rate comparison between sites was not significantly different nor was the comparison between reef and non-reef controls.

Approximately 15,400 *S. ocellatus* were killed during the December 1989 freeze (McEachron *et al.*, 1994). The increase in catch rate from Fall 1990 - Fall 1991 is likely a result of increasing populations following the December 1989 freeze.

The standard length of *S. ocellatus* ranged from 175 - 692 mm ($\bar{x} = 334$ mm, $SE = 8.88$ mm) throughout the study. Because only one fish was collected in Spring 1991 this season was not included in the individual statistical comparisons of standard length between seasons. Overall, *S. ocellatus* were significantly larger in east bay collections (Sites 1 and 2) ($\bar{x} = 349$ mm, $SE = 11.93$ mm), compared to west bay collections (Sites 3 and 4) ($\bar{x} = 304$ mm, $SE = 10.62$ mm). The mean standard length of *S. ocellatus* was significantly greater in Winter 1991 than in Summer 1991 (Fig. 20). Overall, the mean standard length of *S. ocellatus* was significantly greater for Site 1 than Site 4 (Fig. 21) but the reef/non-reef mean standard lengths ($\bar{x} = 331$ mm, $SE = 14.693$ mm and $\bar{x} = 336$ mm, $SE = 11.086$ mm, respectively) were not significantly different.

Tinnin (1974) reported similar seasonal variation in the standard length of *S. ocellatus*. Tinnin concluded that an influx of smaller fish in spring and summer and emigration of these individuals in fall and winter resulted in the observed seasonal pattern. The significant difference observed between east and west bay sites may be a function of salinity. Simmons and Breuer (1962) found reduced abundance in areas > 50 ppt.

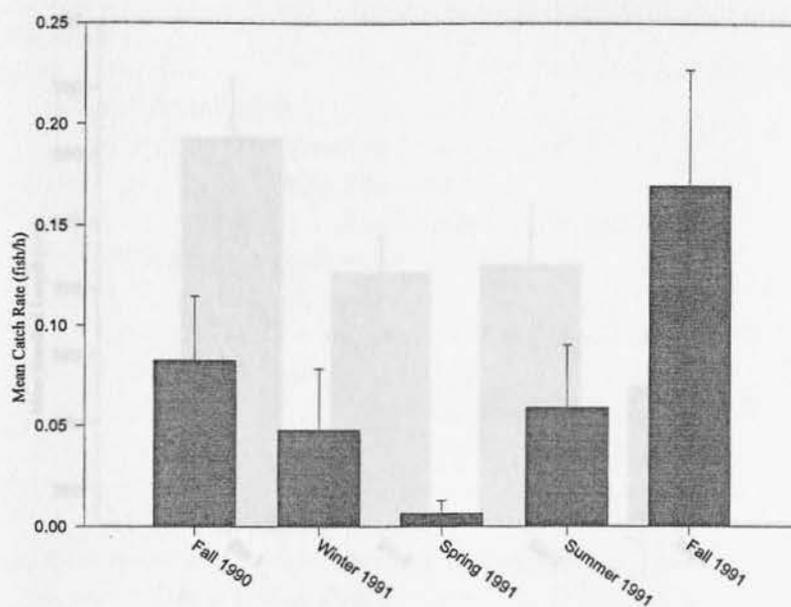


Figure 19. Seasonal comparison of the mean catch rate (fish/h) of *Sciaenops ocellatus* collected by trammel net from Baffin Bay.

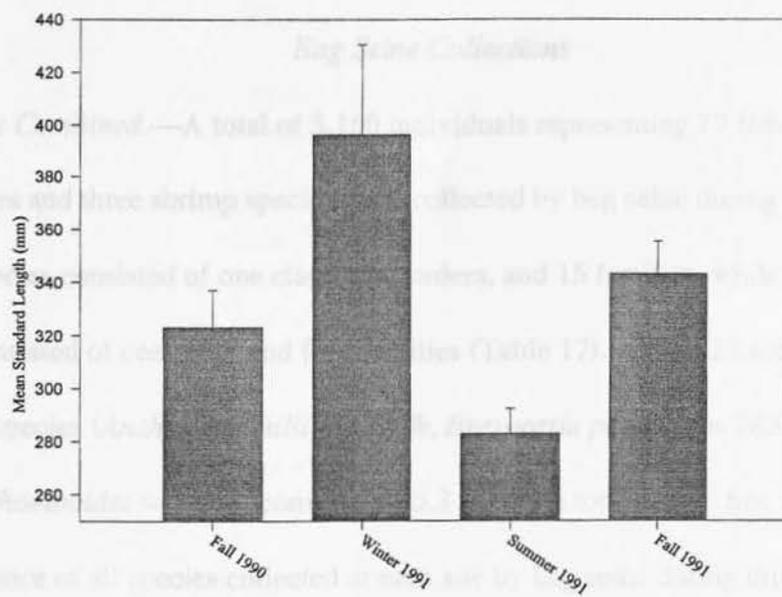


Figure 20. Seasonal comparison of the standard length of *Sciaenops ocellatus* collected by trammel net from Baffin Bay.

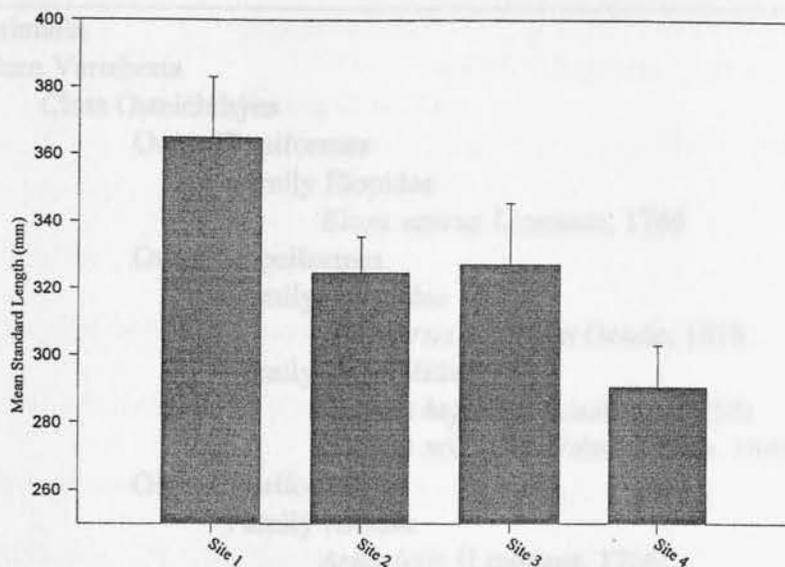


Figure 21. Comparison of standard length of *Sciaenops ocellatus* between sites collected by trammel net from Baffin Bay.

Bag Seine Collections

All Species Combined.—A total of 3,150 individuals representing 19 fish species, one crab species and three shrimp species were collected by bag seine during the study. The 19 fish species consisted of one class, nine orders, and 15 families, while the crabs and shrimp consisted of one order and four families (Table 17). Of the 23 species collected, three fish species (*Anchoa mitchilli* = 47.6 %, *Brevoortia patronus* = 38.9 %, and *Lagodon rhomboides* = 8.8 %) comprised 95.3 % of the total catch. See Appendix 2 for the abundance of all species collected at each site by bag seine during this study.

Overall there was no significant difference in the number of individuals of all species combined per bag seine sample between reef and non-reef areas. Factorial

Table 17. List of species collected by bag seine from Baffin Bay.

Kingdon Animalia			
Phylum Vertebrata			
Class Osteichthyes			
Order Elopiformes			
Family Elopidae			
			<i>Elops saurus</i> Linnaeus, 1766
Order Clupeiformes			
Family Clupeidae			<i>Brevoortia patronus</i> Goode, 1878
Family Engraulidae			<i>Anchoa hepsetus</i> (Linnaeus, 1758)
			<i>Anchoa mitchilli</i> (Valenciennes, 1848)
Order Siluriformes			
Family Ariidae			<i>Arius felis</i> (Linnaeus, 1766)
Order Batrachoidiformes			
Family Batrachoididae			<i>Opsanus beta</i> (Goode and Bean, 1879)
Order Beloniformes			
Family Belonidae			<i>Strongylura marina</i> (Walbaum, 1792)
Family Exocoetidae			<i>Hyporhamphus unifasciatus</i> (Ranzani, 1842)
Order Cyprinodontiformes			
Family Cyprinodontidae			<i>Lucania parva</i> (Baird and Girard, 1853)
Order Atheriniformes			
Family Atherinidae			<i>Menidia beryllina</i> (Cope, 1866)
Order Gasterosteiformes			
Family Syngnathidae			<i>Syngnathus louisianae</i> Gunther, 1870
			<i>Syngnathus scovelli</i> (Evermann and Kendal, 1896)
Order Perceformes			
Family Gerreidae			<i>Eucinostomus</i> sp.
Family Sparidae			<i>Lagodon rhomboides</i> (Linnaeus, 1766)
Family Sciaenidae			<i>Bairdiella chrysoura</i> (Lacepede, 1802)
			<i>Leiostomus xanthurus</i> Lacepede, 1802

Table 17. continued

Pogonias cromis (Linnaeus, 1766)
 Family Mugilidae
Mugil cephalus Linnaeus, 1758
 Family Gobiidae
Gobiosoma robustum Ginsburg, 1933

ANOVA indicates season, and the nested factor (site) significantly influenced the number of individuals collected per bag seine sample (Table 18). Significantly more individuals were collected per bag seine sample in Spring, Summer, and Fall 1991 than in Fall 1990 or Winter 1991 (Fig. 22). The significance of the nested factor (site) varied with season and location. In Winter, Spring, and Summer 1991 Site 4 had significantly higher numbers of individuals per bag seine sample, ($\bar{x} = 8.0$ SE = 3.22 individuals/sample, $\bar{x} = 116.4$ SE = 41.63 individuals/sample and $\bar{x} = 50.1$ SE = 8.37 individuals/sample, respectively), compared to Site 3 ($\bar{x} = 0.3$ SE = 0.21 individuals/sample, $\bar{x} = 9.7$ SE = 3.29 individuals/sample, and 19.8 SE = 10.81 individuals/sample, respectively).

Table 18. ANOVA table for number of individuals of all species combined per bag seine sample.

Source	DF	MS	F	P
Location (east or west)	1	0.0009	0.0013	0.9719
Season (Fall 1990 - Fall 1991)	4	4.7692	5.9520	0.0109
Location * Season	4	0.5416	0.7137	0.6043
Site[Season,Location]	10	0.8614	2.9397	0.0269
Reef/non-reef[Site,Season,Location]	20	0.2747	1.5193	0.0986

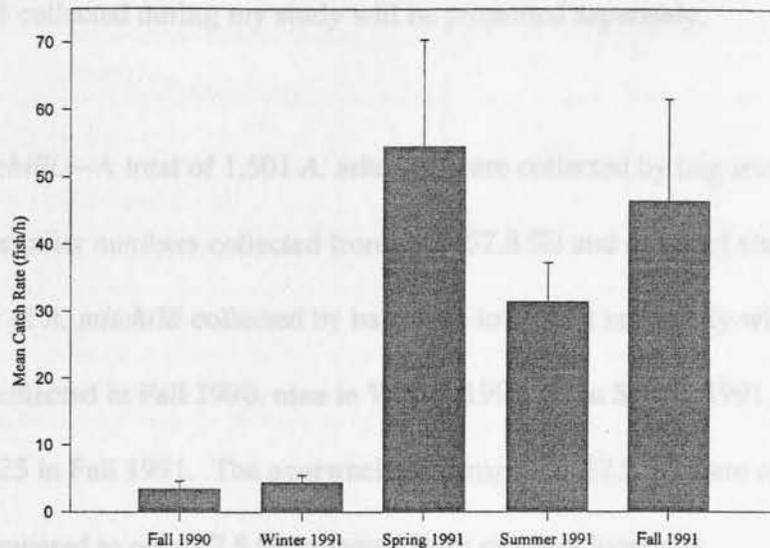


Figure 22. Seasonal comparison of the mean number per sample of all species combined collected by bag seine from Baffin Bay.

Spring peaks in abundance of organisms collected by bag seine were reported by Krull (1976) during a study of the small fish fauna of Laguna Salada when salinities ranged from 3.3 - 27.8 ppt. Krull (1976) reported collecting 26 species of which three (*A. mitchilli* 61.6 %, *Menidia beryllina* 15.6 %, and *B. patronus* 9.9 %) comprised 86 % of the total catch.

The significant differences found in the catch rates between Sites 3 and 4 may be explained by amount of seagrass cover associated with each site. Site 3 had a caliche bottom devoid of vegetation. At Site 4 seagrass was found in small patches just landward of the reef near the TAMU-Kingsville research station pier.

The results for the three dominant fish species (*A. mitchilli*, *B. patronus*, and *L. rhombioides*) collected during my study will be presented separately.

Anchoa mitchilli.—A total of 1,501 *A. mitchilli* were collected by bag seine during the study, with similar numbers collected from reef (57.8 %) and non-reef sites (42.2 %).

The number of *A. mitchilli* collected by bag seine increased seasonally with one individual collected in Fall 1990, nine in Winter 1991, 73 in Spring 1991, 593 in Summer 1991, and 825 in Fall 1991. The overwhelming majority (82.5 %) were collected at west bay sites compared to only 17.5 % collected from east bay locations.

Factorial ANOVA indicates season of collection and the nested factor reef/non-reef significantly influenced the catch of *A. mitchilli*/bag seine sample (Table 19). Summer and Fall 1991 had significantly higher mean abundance of *A. mitchilli*/sample than all other seasons (Fig. 23). The abundance of *A. mitchilli*/sample was significantly higher for the non-reef collections ($\bar{x} = 5.6$, SE = 1.33) compared to reef collections ($\bar{x} = 1.3$, SE = 0.33) in Spring 1991 at Site 2. At no other time was there a significant difference in the abundance of *A. mitchilli* between reef and non-reef collections.

Krull (1976) reported *A. mitchilli* to be the most abundant species taken by bag seine in Laguna Salada when salinity ranged from 3.3 - 27.8 ppt. Krull (1976) found the abundance of *A. mitchilli* was positively correlated with rising water temperature. Salinity is believed to have little influence on the distribution of *A. mitchilli* (Gunter, 1945; Reid, 1954; Kilby, 1955; Springer and Woodburn, 1960). Krull (1976) also found no relationship between salinity and abundance of *A. mitchilli*. During my study as

Table 19. ANOVA table for the inverse of the number of *Anchoa mitchilli* collected per bag seine sample from Baffin Bay.

Source	DF	MS	F	P
Location (east or west)	1	0.0518	0.8836	0.4039
Season (Fall 1990 - Fall 1991)	4	2.7379	34.4941	0.0000
Location * Season	4	0.3479	5.9322	0.0732
Site[Season,Location]	10	0.0917	0.8149	0.6195
Reef/non-reef[Site,Season,Location]	20	0.1035	1.7982	0.0354

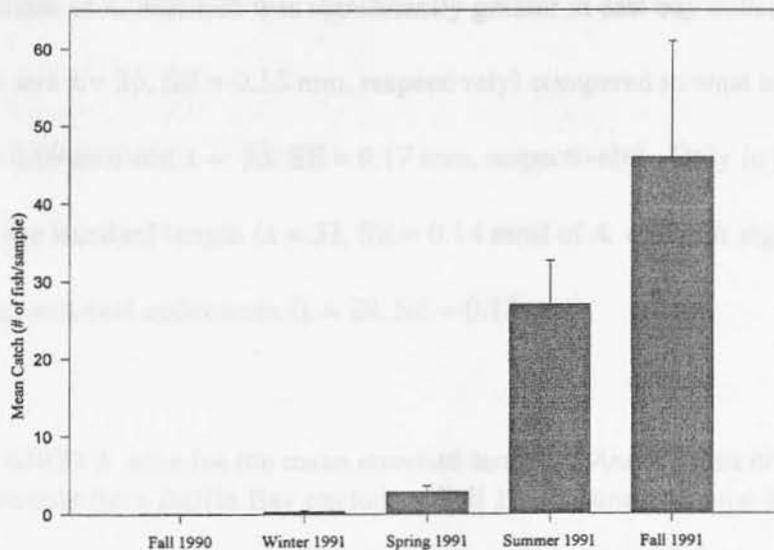


Figure 23. Seasonal comparison of the mean number of *Anchoa mitchilli* per sample collected from Baffin Bay.

salinity decreased the abundance of *A. mitchilli* increased, suggesting that salinities > 65 ppt might limit the distribution of this species.

The standard length of *A. mitchilli* ranged from 26 - 58 mm (33, SE = 0.17 mm) throughout the study. Because only one individual was collected in Fall 1990, this season was eliminated prior to factorial analysis. Factorial ANOVA indicates the standard length of *A. mitchilli* collected by bag seine was significantly influenced by the season of collection. The location, season interaction indicates the significance level of location is dependent on the season of collection. The nested factor reef/non-reef was also significant (Table 20). The standard length of *A. mitchilli* was significantly greater in Winter and Spring than in Summer or Fall 1991 (Fig. 24). In Summer and Fall 1991 the standard length of *A. mitchilli* was significantly greater in east bay collections ($\bar{x} = 33$, SE = 0.35 mm and $\bar{x} = 36$, SE = 0.55 mm, respectively) compared to west bay collections ($\bar{x} = 30$, SE = 0.09 mm and $\bar{x} = 33$, SE = 0.17 mm, respectively). Only in Summer 1991 at Site 4 was the standard length ($\bar{x} = 33$, SE = 0.14 mm) of *A. mitchilli* significantly greater for reef than non-reef collections ($\bar{x} = 29$, SE = 0.13 mm).

Table 20. ANOVA table for the mean standard length of *Anchoa mitchilli* collected per bag seine sample from Baffin Bay excluding Fall 1990 because of the lack of fish.

Source	DF	MS	F	P
Location (east or west)	1	0.1305	0.0150	0.9026
Season (Fall 1990 - Fall 1991)	3	1907.24	194.2276	0.0000
Location * Season	3	38.7969	4.6840	0.0172
Site[Season,Location]	7	12.9584	0.7042	0.6689
Reef/non-reef[Site,Season,Location]	12	23.8139	2.7129	0.0013

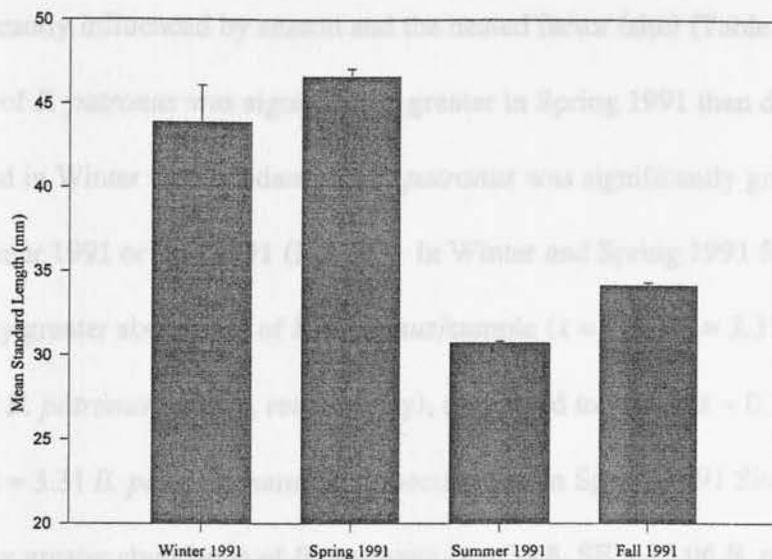


Figure 24. Seasonal comparison of the mean standard length of *Anchoa mitchilli* collected by bag seine from Baffin Bay.

Because the standard length of *A. mitchilli* was significantly greater at east bay sites, and at Site 4 in Summer, there may be a preference by larger individuals for seagrass beds.

Brevoortia patronus.—A total of 1,227 *B. patronus* were collected by bag seine during the study with the majority (75.1 %) collected from non-reef sites. Spring 1991 produced the greatest abundance of *B. patronus* (93.6 %) collected by bag seine. The majority (81.3 %) of *B. patronus* were collected by bag seine at west bay sites compared to 18.7 % from east bay sites.

Factorial ANOVA indicates the abundance of *B. patronus* collected by bag seine was significantly influenced by season and the nested factor (site) (Table 21). The abundance of *B. patronus* was significantly greater in Spring 1991 than during other seasons, and in Winter the abundance of *B. patronus* was significantly greater than in Fall 1990, Summer 1991 or Fall 1991 (Fig. 25). In Winter and Spring 1991 Site 4 yielded a significantly greater abundance of *B. patronus*/sample ($\bar{x} = 7.3$, SE = 3.31 and $\bar{x} = 110.3$, SE = 42.39 *B. patronus*/sample, respectively), compared to Site 3 ($\bar{x} = 0.3$, SE = 0.21 and $\bar{x} = 8.5$, SE = 3.31 *B. patronus*/sample, respectively). In Spring 1991 Site 1 yielded a significantly greater abundance of *B. patronus* ($\bar{x} = 34.8$, SE = 23.06 *B. patronus*/sample) than Site 2 ($\bar{x} = 0.8$, SE = 0.65 *B. patronus*/sample).

Table 21. ANOVA table for the inverse of the number of *Brevoortia patronus* collected per bag seine sample from Baffin Bay.

Source	DF	MS	F	P
Location (east or west)	1	0.4407	2.1136	0.1704
Season (Fall 1990 - Fall 1991)	4	2.0066	9.8446	0.0012
Location * Season	4	0.1829	0.8435	0.5233
Site[Season,Location]	10	0.2062	12.2731	0.0011
Reef/non-reef[Site,Season,Location]	20	0.0224	0.4377	0.9802

The Spring peak in abundance of *B. patronus* observed during my study agrees well with abundance data collected by Krull (1976) and Zimmerman (1969). Krull (1976) found 96 % of the *B. patronus* collected by bag seine in Laguna Salada occurred

from February through April. Spring seasonal peaks in abundance of *B. patronus* < 100 mm in length were also observed by Zimmerman (1969) during a study of fauna associated with seagrass beds in Redfish Bay, Texas.

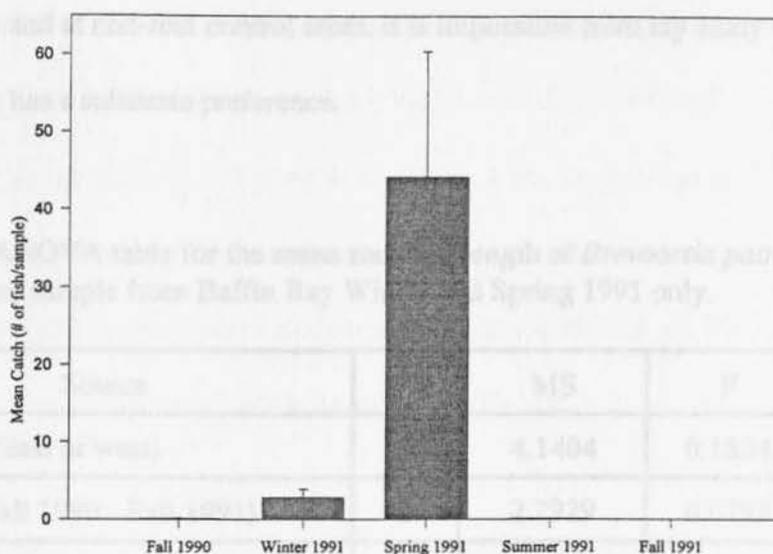


Figure 25. Seasonal comparison of the mean number of *Brevoortia patronus* per sample collected by bag seine from Baffin Bay

The standard length of *B. patronus* ranged from 25 - 72 mm ($\bar{x} = 32$, SE = 0.18 mm) throughout the study. Only Winter and Spring were used in factorial analyses of standard length for *B. patronus* because so few individuals were collected in other seasons. Factorial ANOVA indicates only the nested factor (reef/non-reef) significantly influenced the standard length of *B. patronus* (Table 22). The significance level of the nested factor (reef/non-reef) depended on the season and location of collection. In Spring 1991 at Site 1, the reef collections had significantly larger *B.*

patronus ($\bar{x} = 35$, SE = 0.72 mm) than non-reef collections ($\bar{x} = 33$, SE = 0.38 mm), while at Site 3 the non-reef had significantly larger fish ($\bar{x} = 37$, SE = 1.86 mm) than reef sites ($\bar{x} = 30$, SE = 0.32 mm).

Because *B. patronus* in Baffin Bay occurred in larger sizes both near serpulid worm reefs and at non-reef control areas, it is impossible from my study to determine if this species has a substrate preference.

Table 22. ANOVA table for the mean standard length of *Brevoortia patronus* collected per bag seine sample from Baffin Bay Winter and Spring 1991 only.

Source	DF	MS	F	P
Location (east or west)	1	4.1404	0.1534	0.7125
Season (Fall 1990 - Fall 1991)	1	2.2929	0.0753	0.7928
Location * Season	1	9.6398	0.3571	0.5779
Site[Season,Location]	4	117.191	2.3151	0.1279
Reef/non-reef[Site,Season,Location]	8	107.27	11.2378	0.0000

Lagodon rhomboides—A total of 276 (8.8 % of the total catch) *L. rhomboides* were collected by bag seine during the study, 64.5 % of which were collected adjacent to serpulid worm reefs leaving 35.5 % collected at non-reef control sites. The number of *L. rhomboides* collected varied seasonally with the greatest number (52.5 %) collected in Spring 1991 and the fewest (1.1 %) collected in Fall 1991. Similar numbers (22.8 %, 10.5 %, and 13.0 %) of *L. rhomboides* were collected in Fall 1990, Winter, and Summer

1991, respectively. The overwhelming majority of *L. rhomboides* (89.1 %) were collected at east bay sites compared to 10.9 % from west bay sites.

Factorial ANOVA reveals that location in the bay, and the nested factor reef/non-reef significantly influence the mean number of *L. rhomboides*/bag seine sample (Table 23). East bay collections ($\bar{x} = 4.731$, SE = 1.047 *L. rhomboides*/sample) were significantly greater than west bay collections ($\bar{x} = 0.455$, SE = 0.166 *L. rhomboides*/sample). Only in Spring 1991 at Site 4 was the number of *L. rhomboides*/sample significantly different between reef and non-reef comparisons. This was because the catch per sample at the reef averaged 4.500 SE = 1.708 *L. rhomboides*, compared to the non-reef area where none were collected.

Table 23. ANOVA table for the inverse of the number of *Lagodon rhomboides* collected per bag seine sample from Baffin Bay.

Source	DF	MS	F	P
Location (east or west)	1	3.6188	29.4054	0.0040
Season (Fall 1990 - Fall 1991)	4	0.2992	1.8229	0.2157
Location * Season	4	0.1249	0.9883	0.5000
Site[Season,Location]	10	0.1904	1.1803	0.3661
Reef/non-reef[Site,Season,Location]	20	0.1449	2.3710	0.0037

Lagodon rhomboides is one of the most abundant fish found in seagrass beds of the Laguna Madre (Hellier, 1962). Vegetated bottoms are preferred by *L. rhomboides* throughout its geographic range (Reid, 1954; Gunter and Hall, 1965; Zilberberg, 1966;

Clark, 1970; Hansen, 1970; Coen *et al.*, 1981). The preference by this species for vegetated bottoms may explain the significant difference in the abundance per sample between east and west bay collections. As previously discussed, seagrass cover is a dominant feature of east bay sites while in comparison there is relatively little seagrass in the upper western reaches of Baffin Bay. At Site 4 the serpulid worm reef is bordered to the landward side by seagrass beds while the non-reef control area was devoid of vegetation. The absence of seagrass at the control area of Site 4 probably explains the significant difference in abundance of *L. rhomboides* at this site.

The standard length of *L. rhomboides* ranged from 28 - 117 mm ($\bar{x} = 54$, SE = 1.09 mm) throughout the study. Because so few (2) *L. rhomboides* were collected in Fall 1991, this season was eliminated prior to factorial analyses. Factorial ANOVA indicates the size of *L. rhomboides* collected by bag seine was significantly influenced by location in the bay and season of collection (Table 24). The standard length of *L. rhomboides* collected by bag seine was significantly larger at west bay sites ($\bar{x} = 81$, SE = 3.08 mm) compared to east bay sites ($\bar{x} = 51$, SE = 0.98 mm). In Fall 1990 and Spring 1991 significantly smaller *L. rhomboides* were collected than during other seasons (Figure 26).

Invertebrate Collections

Diversity.—Reef substrate samples ranged in size from 57 - 228 ml displacement ($\bar{x} = 130.20$, SE = 11.59 ml displacement) throughout the study (Table 25).

A total of 29 species of invertebrates were collected from the serpulid worm reefs during the study (Table 26). Of the 29 species, eight (*Corophium louisianum* 70.45 %,

Table 24. ANOVA table for the mean standard length of *Lagodon rhomboides* collected per bag seine sample from Baffin Bay excluding Fall 1991 because of the lack of fish.

Source	DF	MS	F	P
Location (east or west)	1	6567.33	30.1786	0.0000
Season (Fall 1990 - Fall 1991)	3	793.515	3.3182	0.0401
Location * Season	3	742.473	3.2066	0.0500
Site[Season,Location]	5	390.413	1.7301	0.2037
Reef/non-reef[Site,Season,Location]	9	235.605	1.3527	0.2103

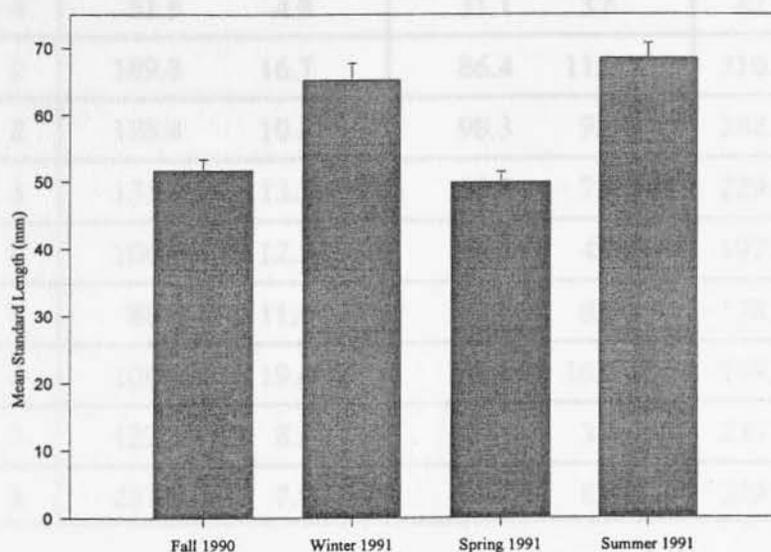


Figure 26. Seasonal comparison of the mean standard length of *Lagodon rhomboides* collected by bag seine from Baffin Bay.

Hargeria rapax 11.66, Syllidae 3.16 %, *Naineris laevigata* 2.95 %, *Polydora ligni* 2.72 %, *Nereis rissei* 1.93 %, *Balanus eburneus* 0.93% and Anemone 2.4%) comprised 96.2 % of the total abundances/liter of water displaced.

Table 25. Average size (displacement in ml, exposed surface area in cm, and wet weight in g) of the five serpulid worm reef samples collected from each site seasonally.

	Site	\bar{x} ml,	SE	\bar{x} cm,	SE	\bar{x} g wet	SE
Winter 1991	1	254.4	30.5	107.4	9.7	390.15	46.7
	2	393.8	54.4	193.2	25.6	573.61	83.66
	3	259.0	24.6	125.8	10.5	479.58	49.19
	4	252.6	25.2	117.2	5.7	467.33	48.38
Spring 1991	1	234.2	19.2	108.0	5.5	354.80	30.39
	2	184.0	21.1	122.2	16.1	287.24	27.10
	3	203.6	15.4	97.0	6.2	394.23	31.80
	4	51.8	4.8	31.1	3.6	82.23	8.31
Summer 1991	1	189.8	16.7	86.4	11.0	310.31	22.14
	2	128.4	10.5	98.3	9.9	202.32	14.84
	3	131.4	13.3	59.0	7.1	229.06	26.23
	4	106.8	12.2	53.6	4.6	197.22	24.84
Fall 1991	1	88.8	11.6	49.4	8.2	128.96	18.03
	2	106.8	19.4	55.5	10.9	159.54	30.26
	3	122.2	8.6	48.5	3.1	235.61	19.85
	4	203.0	7.7	89.0	8.8	329.96	34.64

Cole (1981) reported a total of 39 different species associated with the serpulid worm reefs in Baffin Bay when salinities ranged from 26 - 29 ppt and water temperature ranged from 16 - 23 °C. Cole (1981) used a Petersen dredge to sample the reefs. The discrepancy between the species list produced by Cole (1981) and the current list may result from the difference in collection techniques. According to Cole (1981), the

Table 26. Phylogenetic list of invertebrate species collected from the serpulid worm reefs in Baffin Bay, February - November 1991.

Phylum Cnidaria	
Class Hydrozoa	
Subclass Leptomedusa	
Order Thecata	
Family Campanularidae	
Subfamily	<i>Obelia bidentata</i> Clarke, 1875
Class Anthozoa	
Order Actinostolidae	
Class	Unknown anemone cf. <i>Cyrtasia pallida</i>
Phylum Nemertea	
Order	Unknown nemertean
Phylum Annelida	
Class Polychaeta	
Subclass Errantia	
Family Syllidae	
Subfamily	<i>Syllis</i> sp.
Family Nereidae	
Subfamily	<i>Nereis rissei</i> Grube 1856
Subfamily	<i>Platynereis drumerili</i> (Audouin and Milne Edwards) 1833
Subclass Sedentaria	
Family Orbiniidae	
Subfamily	<i>Naineris laevigata</i> (Grube) 1855
Family Spionidae	
Subfamily	<i>Paraprionospio</i> sp.
Subfamily	<i>Polydora ligni</i> Webster 1879
Family Cirratulidae	
Subfamily	<i>Dodecaceria concharum</i> Oersted 1843
Family Capitellidae	
Subfamily	<i>Capitella capitata</i> (Fabricius) 1780
Family Dorvilleidae	
Subfamily	<i>Dorvillea rubra</i> (Grube) 1865
Family Terebellidae	
Subfamily	unknown species
Family Serpulidae	
Subfamily	<i>Hydroides dianthus</i> (Verrill) 1873
Class Oligochaeta	
Order	Unknown oligochaete
Phylum Mollusca	
Class Gastropoda	
Subclass Prosobranchia	

Table 26. Continued.

Order Neogastropoda
Family Columbellidae
<i>Anachis avara</i> (Say, 1882)
Order Mesogastropoda
Family Caecidae
<i>Caecum</i> sp.
Subclass Opisthbranchia
Order Nudibranchia
Unknown Nudibranch
Class Bivalvia
Subclass Pteriomorpha
Order Mytiloidea
Family Mytilidae
<i>Branchidontes exustus</i> (Linnaeus, 1758)
Phylum Arthropoda
Class Crustacea
Subclass Malacostraca
Order Mysidacea
Family Mysidae
<i>Mysidopsis</i> sp.
Order Tanaidacea
Family Partanaidae
<i>Leptochelia rapax</i> (Harger, 1879)
Order Amphipoda
Family Corophiidae
<i>Corophium louisianum</i> Shoemaker, 1934
<i>Corophium</i> sp.
Family Aoridae
<i>Grandidierella bonnieroides</i> Stephensen, 1948
Order Caprellidea
Family Caprellidae
<i>Caprella</i> sp.
Order Decopoda
Family Xanthidae
<i>Neopanope texana</i> Stimpson, 1859)
Subclass Cirripedia
Order Thoracia
Family Balanidae
<i>Balanus eburneus</i> Gould, 1841

Petersen dredge sampled clumps of worm tubes, shell hash, and sandy clay. Because the Peterson dredge collected substrate other than serpulid worm reef, many of the organisms listed by Cole (1981) may not be directly associated with the reefs.

Salinity may also partially explain the difference between the results of my study and Cole's (1981) earlier findings. Salinity, during my study, ranged from 40 - 65 ppt. Because hypersaline conditions have been shown to support fewer species (Simmons, 1957) it is not surprising I collected ten fewer species than reported by Cole (1981).

Shannon diversity of reef substrate samples varied between location in the bay and seasonally. East bay locations (Sites 1 and 2) had significantly greater diversity than west bay locations (Sites 3 and 4) in all seasons except Fall 1991 (Fig. 27). Species richness was significantly affected by location in the bay while season of collection and

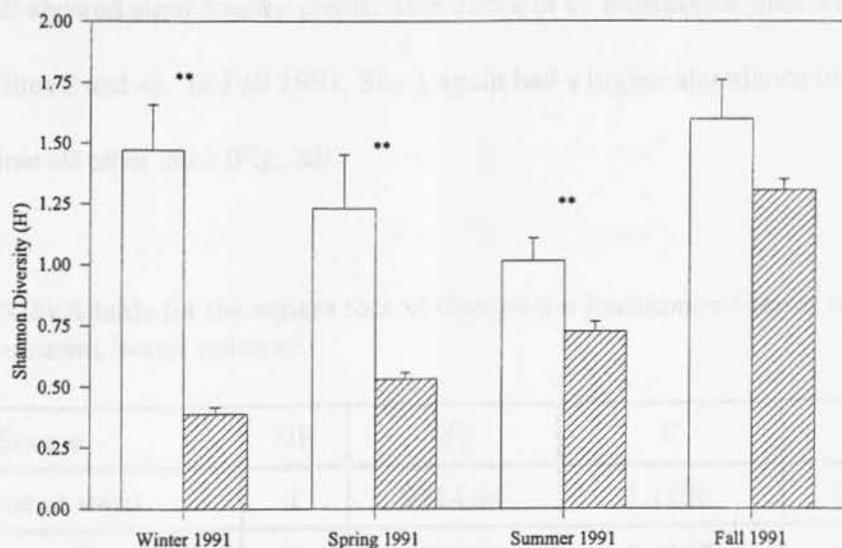


Figure 27. Comparison of Shannon diversity (H') (base e) between east and west bay reef locations (** = $P < .05$).

the interaction between location and season were not significant. East bay sites averaged 11.88 SE = 0.63 individuals/liter compared to west bay sites which averaged 5.35 SE = 0.18 individuals/liter, throughout the study. The results for the eight dominant species are reported individually in order of decreasing abundance.

Corophium louisianum—The amphipod *C. louisianum* was the most abundant species collected, comprising 70.44 % of the total organisms/liter. Factorial ANOVA indicates only the nested factor (site) was significant in the model (Table 27). The number of *C. louisianum*/liter varied between sites seasonally. Winter 1991 (Site 1) had a significantly higher abundance of *C. louisianum*/liter than other sites. In Spring 1991, Site 1 again had a significantly greater abundance of *C. louisianum* than other sites and Site 4 showed significantly higher abundance than Sites 2 or 3. Summer 1991 east bay collections (Sites 1 and 2) showed significantly greater abundance of *C. louisianum* than west bay collections (Sites 3 and 4). In Fall 1991, Site 1 again had a higher abundance of *C. louisianum* than all other sites (Fig. 28).

Table 27. ANOVA table for the square root of *Corophium louisianum*/liter of reef sample displacement (water volume).

Source	DF	MS	F	P
Location (east or west)	1	9514.64	1.1286	0.3191
Season (Winter - Fall 1991)	3	20542.3	2.4367	0.1396
Location * Season	3	1866.97	0.2215	0.8789
Site[Season,Location]	8	8430.35	69.2025	0.0000

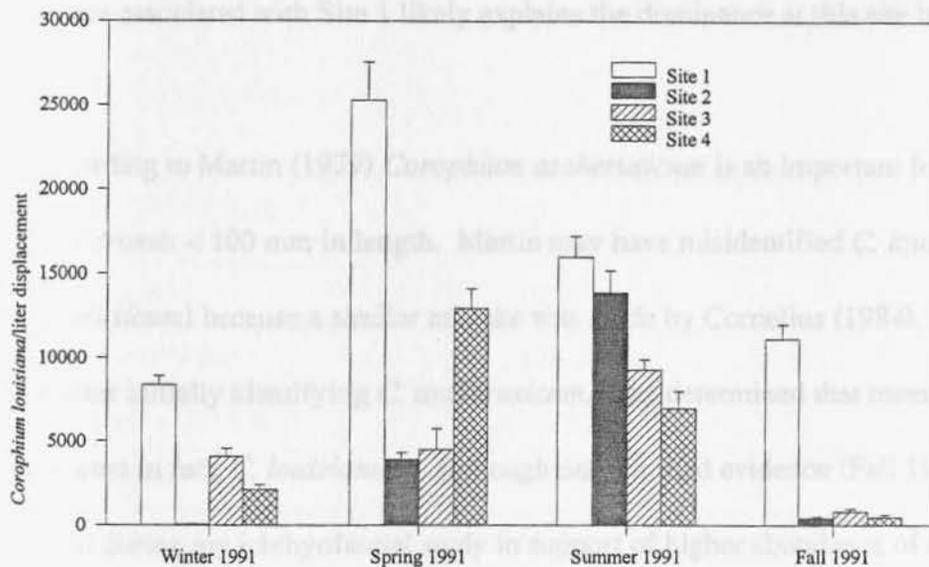


Figure 28. Comparison of the abundance of *Corophium louisianum*/liter of reef sample displacement between sites. (error bars represent standard error)

Cornelius (1984) found *C. louisianum* to be the second most abundant amphipod in Alazan Bay; therefore, it is interesting that Cole (1981) makes no mention of this species. During my study *C. louisianum* formed dense mats of mud tubes usually 1 - 2 cm thick, often giving the serpulid worm reef a spongy texture. The surface of the *C. louisianum* mats were usually covered with algal epiphytes giving the reefs a green appearance. The dense occurrence of *C. louisianum* at Site 1 probably excluded many other epifaunal species because of the lack of suitable hard substrate for attachment.

The southeast side of Site 1, the most centrally located reef of the study, was in a water depth of almost 2 m while the top of the reef at low tide was just below the water surface. Consequently during high southeast winds this reef was pounded by rough wave

conditions. *Corophium louisianum* is a suspension feeder (Gaston and Nasci, 1988), so the turbulence associated with Site 1 likely explains the dominance at this site by this species.

According to Martin (1979) *Corophium ascherusicum* is an important food item of *Pogonias cromis* < 100 mm in length. Martin may have misidentified *C. louisianum* (as *C. ascherusicum*) because a similar mistake was made by Cornelius (1984). Cornelius after initially identifying *C. ascherusicum*, later determined that most of these specimens were in fact, *C. louisianum*. Although only limited evidence (Fall 1991 at Site 4) was found during my ichthyofaunal study in support of higher abundance of *P. cromis* near the serpulid worm reefs, the dominance of these structures by a proven food source is a compelling argument for the importance of the serpulid worm reefs in the Baffin Bay-complex.

Hargeria rapax.—The tanaid *H. rapax* was the second most abundant invertebrate collected from the serpulid worm reefs, comprising 11.66 % of the total catch/liter. Factorial ANOVA indicates only the nested factor (site) was significant (Table 28). The number of *H. rapax* varied significantly seasonally between sites. In Winter 1991, Site 1 had a significantly greater abundance of *H. rapax*/liter than all other sites and Sites 3 and 4 had a greater abundance than Site 2. In Spring 1991, Site 1 had a greater abundance of *H. rapax*/liter than all other sites. In Summer 1991, Sites 1 and 3 had a significantly greater abundance of *H. rapax* than Sites 2 and 4. In Fall 1991, Site 1 had a significantly greater abundance of *H. rapax* than all other sites while Site 3 had a significantly greater

abundance than Sites 2 and 4. Site 2 had a significantly greater abundance of *H. rapax* than Site 4 (Fig. 29).

Table 28. ANOVA table for the square root of *Hargeria rapax*/liter of reef sample displacement (water volume).

Source	DF	MS	F	P
Location (east or west)	1	3346.56	1.4759	0.2591
Season (Winter - Fall 1991)	3	858.295	0.3785	0.7712
Location * Season	3	465.484	0.2053	0.8899
Site[Season,Location]	8	2267.5	64.9463	0.0000

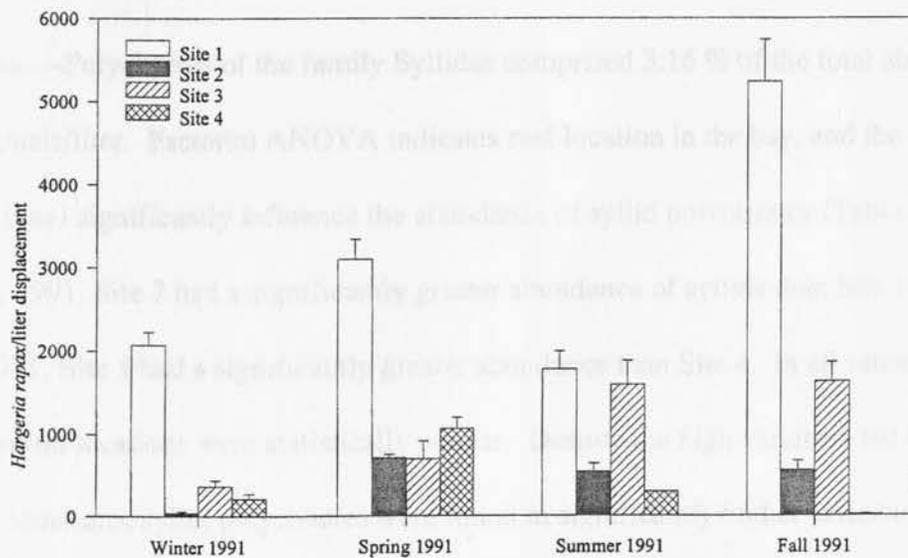


Figure 29. Comparison of the mean abundance of *Hargeria rapax*/liter of reef sample displacement between sites. (error bars represent standard error)

Hargeria rapax, commonly found during this study, was not listed by Cole (1981) as being associated with the serpulid worm reefs. Perhaps variation in salinity between the two studies caused this discrepancy.

Hargeria rapax, like *C. louisianum*, is also a suspension feeder (Gaston and Nasci, 1988) and probably benefitted from the usually rough wave conditions associated with Site 1. Site 3 is also unprotected from wave energy generated by strong southeast winds and also had a large population of *H. rapax*.

Hargeria rapax has also been determined to be an important food item for *P. cromis* (Martin, 1979). *Hargeria rapax* ranked second in abundance behind *C. louisianum* in the stomach contents of *P. cromis* < 100 mm in length (Martin, 1979).

Syllidae.—Polychaetes of the family Syllidae comprised 3.16 % of the total abundance of individuals/liter. Factorial ANOVA indicates reef location in the bay, and the nested factor (site) significantly influence the abundance of syllid polychaetes (Table 29). In Spring 1991, Site 2 had a significantly greater abundance of syllids than Site 1, while in Fall 1991, Site 3 had a significantly greater abundance than Site 4. In all other seasons, sites within locations were statistically similar. Despite the high variation between sites within locations, syllid polychaetes were found in significantly higher abundance at east bay stations (Sites 1 and 2) (Fig. 30).

Reef type and salinity strongly influenced the distribution and abundance of syllid polychaetes during this study. Large numbers of syllids were associated with the patch

reef sites in all seasons. The increasing trend in sylliid abundance over the duration of the study correlates to decreasing salinity.

Table 29. ANOVA table for the square root of Syllidae/liter of reef sample displacement (water volume).

Source	DF	MS	F	P
Location (east or west)	1	7387.91	26.4833	0.0009
Season (Winter - Fall 1991)	3	495.517	1.7763	0.2293
Location * Season	3	182.071	0.6527	0.6033
Site[Season,Location]	8	278.965	8.1989	0.0000

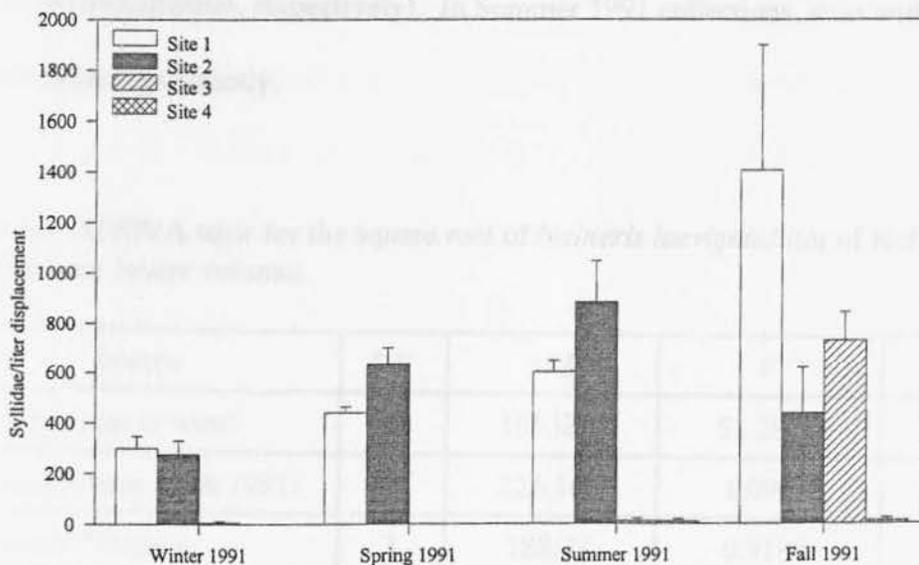


Figure 30. Comparison of the mean abundance of polychaetes family Syllidae/liter of reef sample displacement between sites. (error bars represent standard error)

Naineris laevigata.—The polychaete *N. laevigata* was commonly collected at east bay locations (Sites 1 and 2). *Naineris laevigata* comprised 2.95 % of the total number of

invertebrates collected/liter. Factorial ANOVA indicates location in the bay significantly influenced the number of *N. laevigata*/liter (Table 30). East bay collections (Sites 1 and 2) had a significantly greater abundance ($\bar{x} = 1,059.78$, SE = 182.81 individuals/liter) compared to west bay Sites 3 and 4 ($\bar{x} = 4.15$, SE = 4.15 individuals/liter). The nested factor (site) was significant. Even though the variation between sites within a location was large, the difference between locations was greater. In Winter, Spring, and Fall 1991 collections, Site 2 had a significantly greater abundance ($\bar{x} = 540.37$, SE = 51.45; $\bar{x} = 854.64$, SE = 173.01; $\bar{x} = 1405.10$, SE = 279.96 individuals/liter, respectively) of *N. laevigata* than Site 1 ($\bar{x} = 186.97$ SE = 60.76, $\bar{x} = 76.23$ SE = 26.05, $\bar{x} = 714.45$ SE = 113.31 individuals/liter, respectively). In Summer 1991 collections, sites within locations did not differ significantly.

Table 30. ANOVA table for the square root of *Naineris laevigata*/liter of reef sample displacement (water volume).

Source	DF	MS	F	P
Location (east or west)	1	10532.1	51.2821	0.0001
Season (Winter - Fall 1991)	3	225.161	1.0963	0.4051
Location * Season	3	188.73	0.9189	0.4742
Site[Season,Location]	8	205.377	14.3035	0.0000

No previous reference to this species was found for Baffin Bay. The preference of east bay sites by this species may be a function of salinity or proximity to the ICWW.

East bay sites had lower salinities compared to west bay sites. Site 2 was closer to the

ICWW than any other study sites. Larvae of this species may have been transported to the area via the ICWW but poor circulation in Baffin Bay and the salinity gradient may have prevented recruitment by this species to the more western reaches of the bay system.

Polydora ligni.—The polychaete *P. ligni* was common on all the reefs sampled comprising 2.72 % of the total abundance of all individuals collected/liter. Factorial ANOVA indicates only the nested factor (site) was significant (Table 31). The abundance of *P. ligni* varied significantly between sites within seasons. In Winter 1991, at Site 1 the abundance of *P. ligni* was significantly greater than at all other sites and the abundance at Site 2 was greater than at Sites 3 and 4. In Spring 1991, the abundance of *P. ligni* was significantly greater at Sites 1, 2, and 4 than at Site 3, and Site 4 had a significantly greater abundance than did Site 2. In Summer 1991, Site 4 had a significantly greater abundance of *P. ligni* than did all other sites. In Fall 1991, Site 4 had a significantly greater abundance of *P. ligni* than did Site 1 (Fig. 31).

Table 31. ANOVA table for the square root of *Polydora ligni*/liter of reef sample displacement (water volume).

Source	DF	MS	F	P
Location (east or west)	1	30.7416	0.0761	0.7896
Season (Winter - Fall 1991)	3	78.7544	0.1950	0.8969
Location * Season	3	347.58	0.8605	0.4998
Site[Season,Location]	8	403.915	9.4324	0.0000

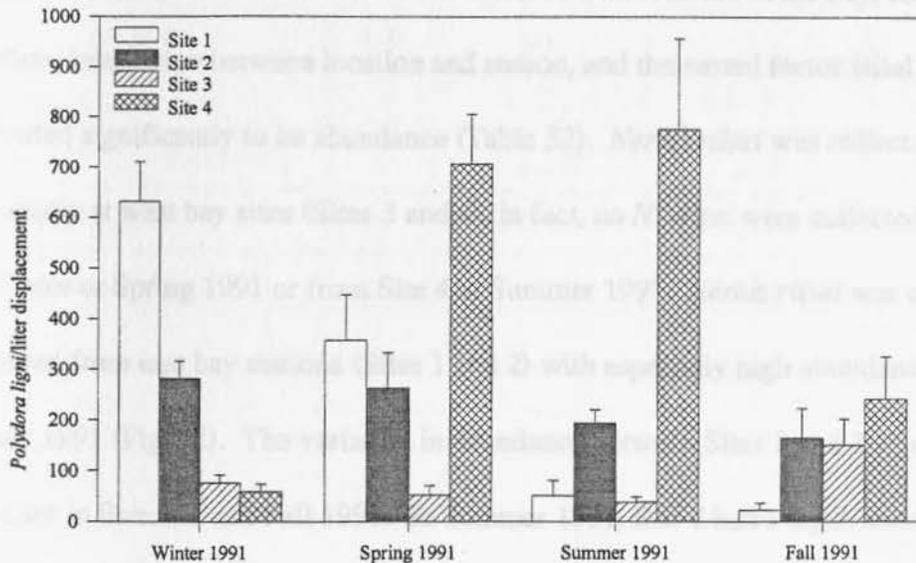


Figure 31. Comparison of the mean abundance of *Polydora ligni*/liter of reef sample displacement between sites. (error bars represent standard error)

Polydora ligni is a euryhaline, shallow water species (Foster, 1971). Cole (1981) found *Polydora* associated with three of four reefs sampled when salinities ranged from 26 - 29 ppt. The euryhaline nature of this species was evident during the current study as no trend was observed in the abundance of *P. ligni* with fluctuating salinity. Seasonal trends in temperature also had little effect on the abundance of this species.

Polydora ligni may be free living or commensal and often constructs thin mud tubes on tunicates, shells, wharf pilings, and in crevices (Foster, 1971). The empty serpulid worm tubes and the interstitial areas between serpulid worm tubes is ideal habitat for *P. ligni*.

Nereis riisei.—The nereid polychaete *N. riisei* comprised 1.93 % of the total abundance of all individuals/liter. Factorial ANOVA indicates reef location in the bay, season of collection, interaction between location and season, and the nested factor (site) all contributed significantly to its abundance (Table 32). *Nereis riisei* was collected infrequently at west bay sites (Sites 3 and 4), in fact, no *N. riisei* were collected from Site 3 in Winter or Spring 1991 or from Site 4 in Summer 1991. *Nereis riisei* was collected in all seasons from east bay stations (Sites 1 and 2) with especially high abundance in Summer 1991 (Fig. 32). The variation in abundance between Sites 1 and 2 was significant in Summer and Fall 1991. In Summer 1991, Site 2 had a significantly greater abundance of *N. riisei* than Site 1, while in Fall 1991 the opposite was observed. Although variation between these sites (1 and 2) was large, the difference in abundances between locations of collection was greater, yielding the significant location effect in the model. The interaction between location and season is probably due to an increase in the abundance of *N. riisei* at Sites 3 and 4 (Fall 1991) while at the same time the abundance decreased slightly at east bay sites (1 and 2).

Although no previous mention of this species was found for Baffin Bay, Simmons (1957) reported a similar species, *Nereis pelagica occidentalis*, to be abundant among barnacles, worm tubes, shell, and roots of vegetation during an ecological survey of the upper Laguna Madre, Texas, when salinities ranged from 29 - 77 ppt. Because decreasing salinities at west bay sites had little effect on the abundance of *N. riisei*, other factors probably controlled the abundance and distribution of this species in Baffin Bay. Reef type and season of collection may be the most important factors controlling the

Table 32. ANOVA table for the square root of *Nereis riisei*/liter of reef sample displacement (water volume).

Source	DF	MS	F	P
Location (east or west)	1	4665.24	58.3931	0.0001
Season (Winter - Fall 1991)	3	416.125	5.2085	0.0276
Location * Season	3	406.561	5.0888	0.0293
Site[Season,Location]	8	79.8936	7.0944	0.0000

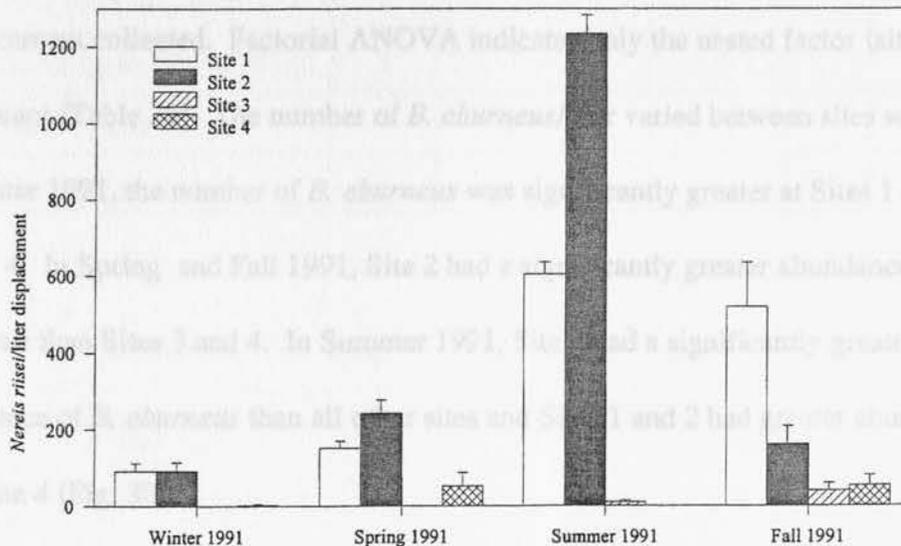


Figure 32. Comparison of the mean abundance of *Nereis riisei*/liter of reef sample displacement between sites. (error bars represent standard error)

distribution of *N. riisei* in Baffin Bay. Patch reefs (Sites 1 and 2) with their associated random and oriented growth patterns, have greater amounts of interstitial space between serpulid worm tubes compared to the random growth associated with reef field sites. The increased surface area of patch reefs probably affords a higher degree of protection from predators. The abundance of *N. riisei* at east bay sites also positively correlated with

water temperature, with least abundance occurring in Winter and the highest occurring in the Summer. No polychaetes in the family Nereidae were listed by Cole (1981) when salinities were < 30 ppt, possibly indicating that the salinity requirements of *N. riisei* may be more oceanic.

Balanus eburneus.—The barnacle *B. eburneus* was occasionally found on the serpulid worm reefs, comprising 0.93 % of the total number of invertebrates/liter of reef substrate displacement collected. Factorial ANOVA indicates only the nested factor (site) was significant (Table 29). The number of *B. eburneus*/liter varied between sites seasonally. In Winter 1991, the number of *B. eburneus* was significantly greater at Sites 1 and 2 than at Site 4. In Spring and Fall 1991, Site 2 had a significantly greater abundance of *B. eburneus* than Sites 3 and 4. In Summer 1991, Site 3 had a significantly greater abundance of *B. eburneus* than all other sites and Sites 1 and 2 had greater abundance than Site 4 (Fig. 30).

Balanus eburneus was also not listed by Cole (1981) but was found throughout Baffin and Alazan Bays by Breuer (1957) wherever places for attachment occurred. *Balanus eburneus* is a euryhaline species (Gittings *et al.*, 1986). This current study substantiates its euryhaline characteristic as no relationship in abundance was found with fluctuating salinities. The limiting factor for *B. eburneus*, as noted by Breuer (1957), is probably suitable hard substrate for settlement. Site 1 had relatively few *B. eburneus* probably due to the high concentration of *C. louisianum*. The widespread coverage of Site 1 by the mud tube mats of *C. louisianum* eliminates most of the available substrate

necessary for attachment by *B. eburneus*. Sites 2 and 3 had less dense *C. louisianum* populations so consequently there was more suitable habitat for *B. eburneus* at these locations.

Table 33. ANOVA table for the square root of *Balanus eburneus*/liter of reef sample displacement (water volume).

Source	DF	MS	F	P
Location (east or west)	1	216.51	0.9042	0.3695
Season (Winter - Fall 1991)	3	173.852	0.7260	0.5645
Location * Season	3	167981	0.7015	0.5772
Site[Season,Location]	8	239.451	16.5607	0.0000

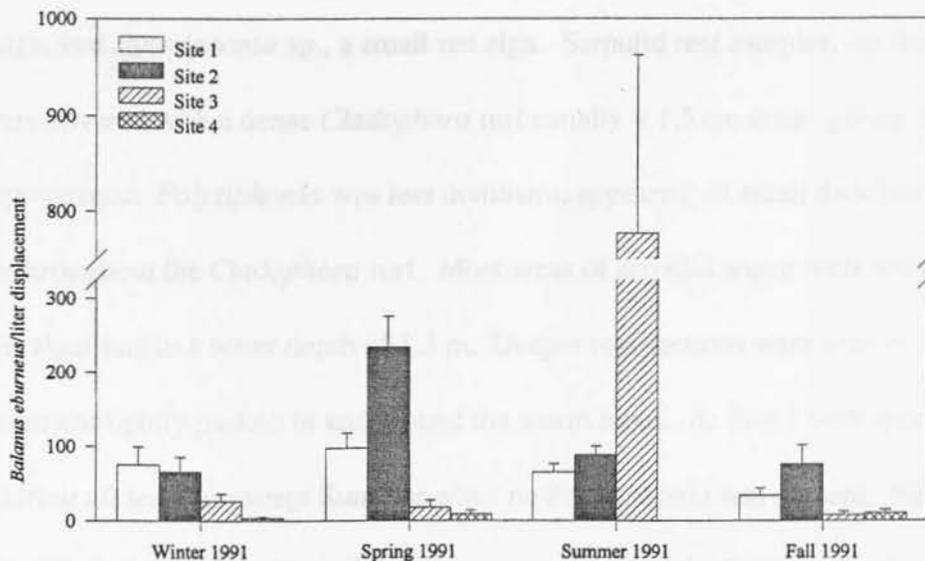


Figure 33. Comparison of the mean abundance of *Balanus eburneus*/liter of reef sample displacement between sites. (error bars represent standard error)

Unknown Anemones.—All anemones (cf. *Cyrtasia pallida*) collected were juveniles (< 2 mm) and all were collected from Site 2. One-way ANOVA of the abundance of *C. pallida* at Site 2 reveals Winter 1991 produced a significantly lower abundance of *C. pallida* than other seasons (Fig. 34).

The close proximity of Site 2 to the ICWW probably influenced the abundance of anemones. Cole (1981) reported anemones on all reefs sampled except at Site 55 (Site 4 in this study). The decrease in distribution of anemones between Cole's (1981) study and this study is probably related to the hypersaline condition of Baffin Bay during this study.

Primary Productivity

During the two years of quarterly observations of the serpulid worm reefs in Baffin Bay only two genera of algae were identified, *Cladophora* sp., a small branching green alga, and *Polysiphonia* sp., a small red alga. Serpulid reef samples, for the most part, were covered with a dense *Cladophora* turf usually < 1.5 cm thick, giving the reefs a green appearance. *Polysiphonia* was less dominant, appearing as small dark brown patches throughout the *Cladophora* turf. Most areas of serpulid worm reefs were covered with this algal turf to a water depth of 1.3 m. Deeper reef sections were grey in color from sediment tightly packed in and around the worm tubes. At Site 1 both species were found during all seasons except Summer when no *Polysiphonia* was present. Because of the lack of *Polysiphonia*, no P vs. I curves were produced in the Summer for this species. No effort was made to separate biomass by algal species because so little *Polysiphonia* was found. The dominant *Cladophora* was assumed to make up the biomass. The

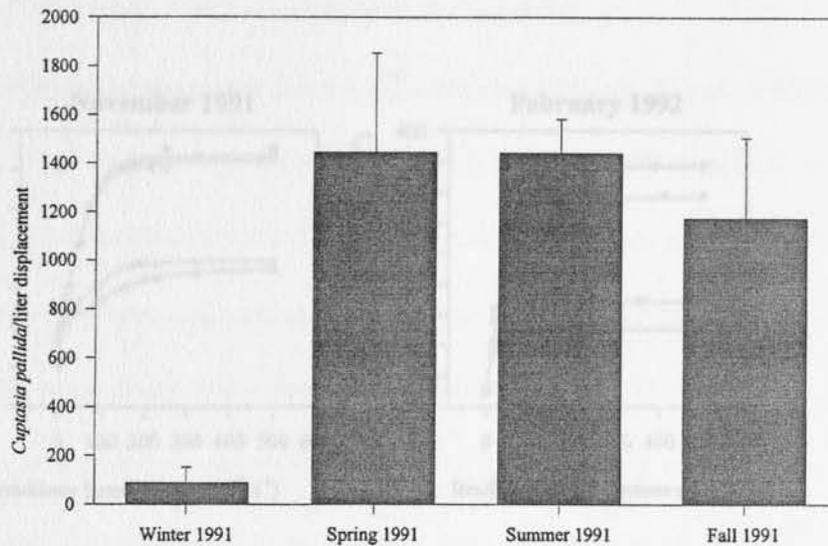


Figure 34. Seasonal comparison of the mean abundance of *Cuptasia pallida*/liter of reef sample displacement collected at Site 2. (error bars represent standard error).

photosynthetic parameters used in the H_{sat} model of production are based on *Cladophora* only.

The hyperbolic tangent function of Jassby and Platt (1976) explains the photosynthetic relationships well, with all P vs. I curves exhibiting an $r^2 > 0.95$ (Fig. 35). P_{max} for both species was highest in May 1992. Respiration for both species was affected by water temperature, being lowest in Winter and highest in Summer. No strong seasonal trend was evident in α for either species. P_{max} and α were both significantly higher in all seasons for *Cladophora*. Respiration was significantly higher for *Cladophora* during November 1991 and May 1992, while no difference between the two species was

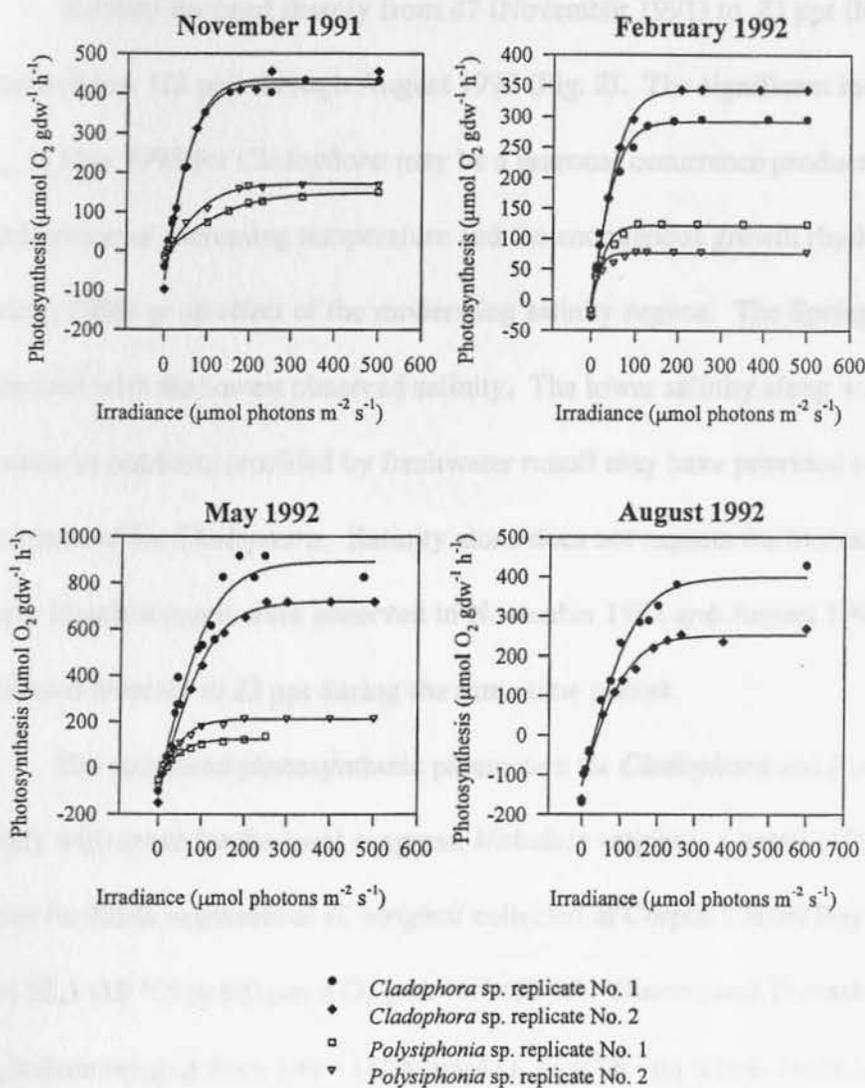


Figure 35. Seasonal comparison of laboratory generated photosynthesis vs. irradiance curves for Baffin Bay serpulid worm reef algal epiphytes, *Cladophora* and *Polysiphonia*. (November 1990 curves at 20 °C and 47 ppt, February curves at 10 °C and 31 ppt, May curves at 20 °C and 21 ppt, August curves at 30 °C and 23 ppt)

detected in February 1992 (Fig. 36). Empirically derived I_k ranged from 32.3 - 136.6 for *Polysiphonia* and 63.8 - 126.1 for *Cladophora* (Table 34).

Salinity declined sharply from 47 (November 1991) to 21 ppt (May 1992) and remained low (23 ppt) through August 1992 (Fig. 2). The significant increase in P_{max} in May 1992 for *Cladophora* may be a seasonal occurrence produced by a combination of increasing temperature and the endogenous growth rhythms of the algae (Dring, 1988) or an effect of the moderating salinity regime. The Spring peak in P_{max} coincided with the lowest observed salinity. The lower salinity along with a probable increase in nutrients provided by freshwater runoff may have provided a more conducive environment for *Cladophora*. Salinity alone does not explain the increase in P_{max} because nearly identical levels were observed in November 1991 and August 1992 while salinity decreased from 47 to 23 ppt during the same time period.

The measured photosynthetic parameters for *Cladophora* and *Polysiphonia* agree closely with those for the local seagrass, *Halodule wrightii*. Czerny (1994) reported P_{max} values for blade segments of *H. wrightii* collected in Corpus Christi Bay, Texas, ranged from 52.3 (10 °C) to 621 $\mu\text{mol O}_2 \text{gdw}^{-1} \text{h}^{-1}$ (30 °C). Dunton and Tomasko (1994) reported P_{max} values ranging from 140 - 1104 $\mu\text{mol O}_2 \text{gdw}^{-1} \text{h}^{-1}$ for whole *Halodule wrightii* plants incubated *in situ* in the upper Laguna Madre. Assuming a photosynthetic quotient of 1.0, the epiphytic algae associated with the serpulid worm reefs are as productive (on a tissue weight basis) as local seagrasses.

Ash free dry weight biomass ranged from 0.4132 - 0.7286 g/25cm² (Figure 37). A significant increase in biomass occurred in February 1992 following a sharp decline in

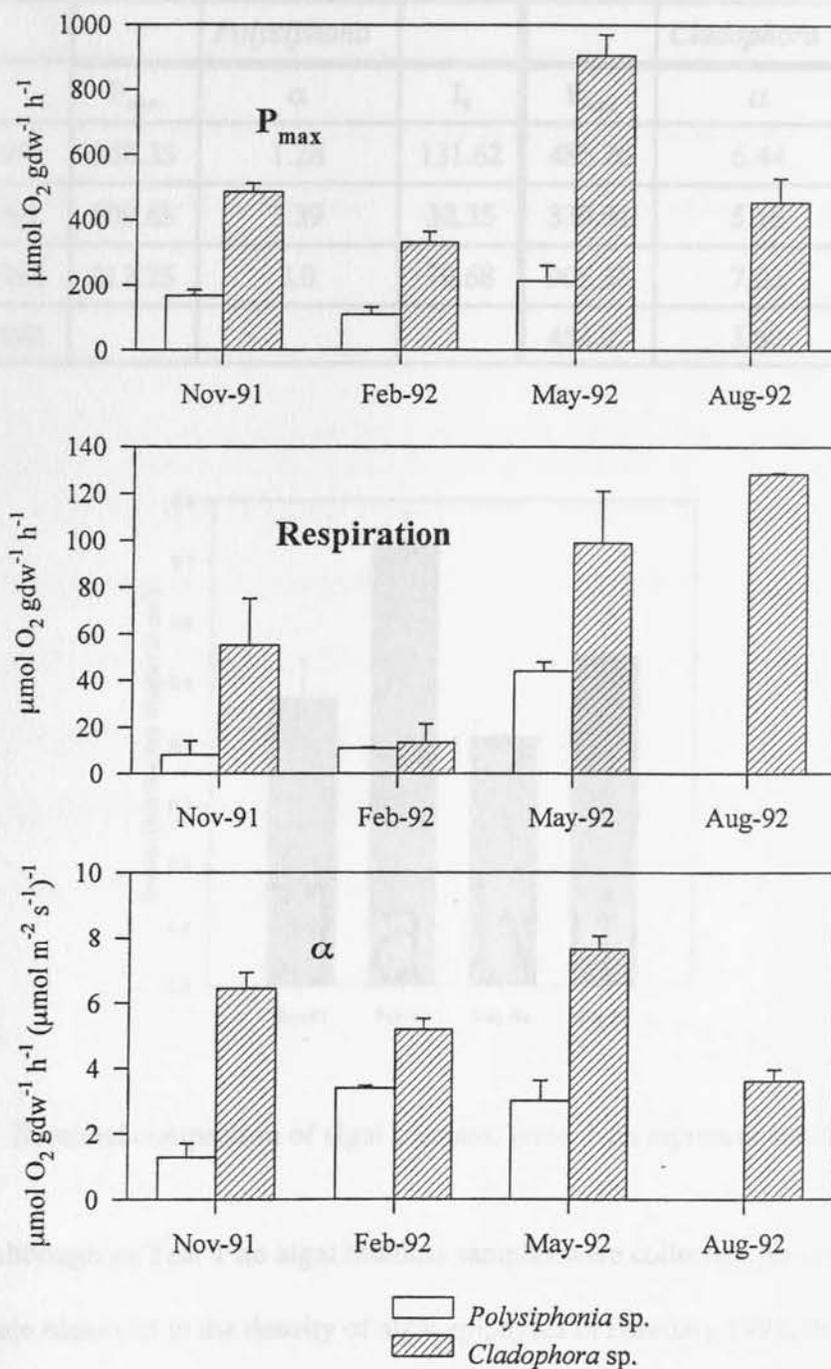


Figure 36. Seasonal comparison of gross photosynthetic parameters $P_{max(gross)}$, R and α , between *Polysiphonia* and *Cladophora*.

Table 34. Seasonal comparison of photosynthetic parameters (P_{\max} (gross), α , I_k) for algae associated with the serpulid worm reefs of Baffin Bay.

	<i>Polysiphona</i>			<i>Cladophora</i>		
	P_{\max}	α	I_k	P_{\max}	α	I_k
Nov - 1991	168.35	1.28	131.62	485.26	6.44	75.36
Feb - 1992	109.65	3.39	32.35	330.51	5.18	63.75
May - 1992	212.25	3.0	70.68	905.25	7.63	118.6
Aug - 1992				454.07	3.60	126.1

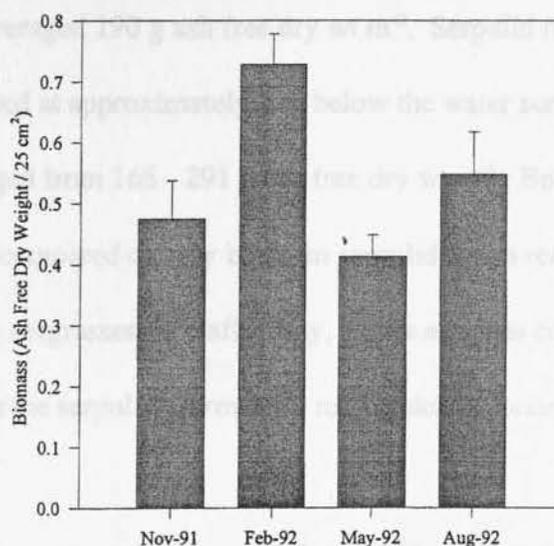


Figure 37. Seasonal comparison of algal biomass. (error bars represent standard error)

salinity. Although in Year 1 no algal biomass samples were collected, no dramatic changes were observed in the density of algal epiphytes in February 1991; therefore, the significant increase in biomass during Year 2 was probably due to nutrient input from freshwater runoff events and is not a seasonal occurrence. By May 1992, when P_{\max} was

at its highest, biomass levels were at their lowest, possibly indicating that cropping of the algae had taken place. Respiration rates may also explain why less algal biomass was observed when photosynthetic rates were at their maximum. Respiration for *Cladophora* in February 1992 was 4.0 % of gross P_{\max} while in May 1992 respiration was 10.9 % of gross P_{\max} ; therefore, comparatively less energy could be spent adding new plant material in May 1992.

Onuf (pers. comm.) reported whole plant ash free dry weight of seagrasses in the upper Laguna Madre to be as high as 496 g ash free dry wt m^{-2} , but in water depths between 1 - 1.2 m averaged 190 g ash free dry wt m^{-2} . Serpulid reef algal epiphyte samples were collected at approximately 1 m below the water surface and the average ash free dry weights ranged from 165 - 291 g ash free dry wt m^{-2} . Because biomass and photosynthetic rates compared closely between serpulid worm reef algal epiphytes and upper Laguna Madre seagrasses, in Baffin Bay, where seagrass coverage is minimal, turf algae associated with the serpulid worm reefs may make important contributions to the carbon pool.

Surface irradiance from 20 May - 19 June 1990 reached a maximum of 1,847 $\mu\text{mol photons } m^{-2} s^{-1}$ while at a depth of 2.4 m maximum irradiance was 167 $\mu\text{mol photons } m^{-2} s^{-1}$ and maximum predicted irradiance at a depth of 1 m was 340 $\mu\text{mol photons } m^{-2} s^{-1}$ (Fig. 38). Based on this light data and the I_k values, *Cladophora* was light saturated 8.9 h/day in May 1992 (Table ?). Areal gross H_{sat} production estimates for *Cladophora* in May 1992 were about 16.1 g C $m^{-2} \text{ day}^{-1}$. Although this May 1992 rate is

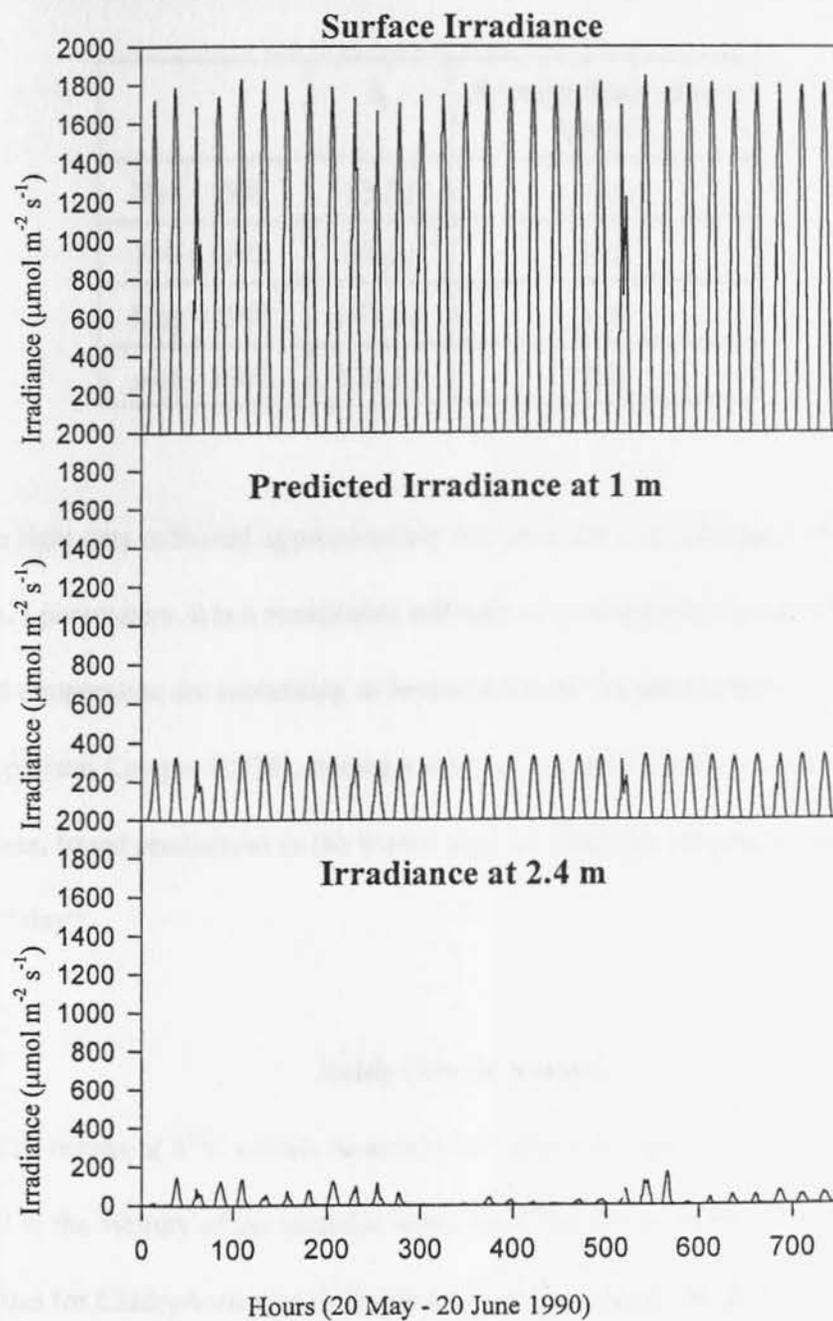


Figure 38. Predicted irradiance based on the Bouguer-Lambert Law of light attenuation for Baffin Bay sites at a water depth of 1 m along with surface irradiance (provided by Dr. Dunton, UTMSI) and irradiance at a depth of 2.4 m (provided by Dr. Montagna UTMSI).

Table 35. Average number of daily hours above saturation irradiance (I_k) for *Cladophora*. Values based on continuous light data collected from 20 May to 20 July 1990.

	I_k	Average Daily Hours Above I_k
Nov - 1991	75.36	10.8
Feb - 1992	63.76	10.9
May - 1992	118.63	8.9
Aug - 1992	126.12	8.8

based on light data collected approximately one year prior to collection of the biomass and P vs. I parameters, it is a reasonable estimate of productivity for late Spring when light and temperature are increasing to levels optimum for photosynthesis and growth. For comparison Cowper (1978), during a study of the drift algae community of Redfish Bay, Texas, found production in the brown alga *Dictyota* sp. ranging as high as $9 \text{ g C m}^{-2} \text{ day}^{-1}$

Stable Carbon Isotopes

The results of $\delta^{13}\text{C}$ values measured for epiphytic algae, local consumers, and fish collected in the vicinity of the serpulid worm reefs are in presented in Table 36. The $\delta^{13}\text{C}$ values for *Cladophora* and *Polysiphonia* were averaged for 28 February 1991 to use in the mixing model of Dunton and Schell (1987). A significant ($P < .05$) shift in the $\delta^{13}\text{C}$ between 28 February 1991 and 4 May 1992 was indicated by paired samples t-test. This shift caused invertebrate consumers to be isotopically lighter (-23 to -24.4) than the

Table 36. The $\delta^{13}\text{C}$ values, trophic levels and the change (Delta) in isotopic composition of selected samples. Dashed lines indicated no data. Parentheses indicate number sampled, others are one sample comprised of many individuals.

	Species	Trophic level	28-Feb-91	18-May-91	4-May-92	Delta
Algae	<i>Cladophora</i> <i>sp.</i>	0	-16.0	-	-19.9	-3.9
	<i>Polysiphonia</i> <i>sp.</i>	0	-15.5	-	-21.9	-6.4
Invertebrate	<i>Corophium</i> <i>louisianum</i>	2	-19.6	-	-24.4	-4.8
	<i>Neris</i> <i>riisei</i>	2	-19.9	-	-23.4	-3.5
	<i>Neopanope</i> <i>texana</i>	3	-20.0	-	-23.0	-3.0
Fish	<i>Lagodon</i> <i>rhomboides</i>	1-3	-	-15.6 (2)	-	-
	<i>Cynoscion</i> <i>nebulosus</i>	2-4	-	-15.3 (2)	-	-
	<i>Pogonias</i> <i>cromis</i>	2-4	-	-18.0 (2)	-	-

estimated value of -22‰ for phytoplankton. Therefore, only the isotopic data from 1991 was used in the mixing model.

The mixing model of Dunton (1987) indicates that the selected invertebrates living on the serpulid worm reefs were probably not utilizing the algal epiphytes as a primary food source or through a detrital food web (Table 37.) *Corophium louisianum*, a suspension feeder, *N. riisei* a surface deposit feeder (Gaston and Nasci, 1988), and *Neopanope texana*, a carnivore (Whorff, 1992), all live directly on the surface of the

Table 37. Percent contribution of epiphytic algae and phytoplankton to the $\delta^{13}\text{C}$ values of local consumers. Values were calculated from the mixing equation of Dunton (1987) using the data in Table 1. Ranges are given for species possibly occupying more than one trophic level.

Species	Percent Contribution to the $\delta^{13}\text{C}$ of consumers by:	
	Epiphytic Algae	Phytoplankton
<i>Corophium louisianum</i>	12.8	87.2
<i>Nereis riisei</i>	8.0	92.0
<i>Neopanope texana</i>	0.0	100.0
<i>Lagodon rhomboides</i>	64.0-89.6	10.4-36.0
<i>Cynoscion nebulosus</i>	56.0-81.6	18.4-44.0
<i>Pogonias cromis</i>	12.8-38.4	61.6-87.2

serpulid worm reefs and all show a decidedly phytoplankton $\delta^{13}\text{C}$ signature (Tables 36 and 37). This is not surprising, considering the dominance of the system by a "Brown Tide" algal bloom originating in Baffin Bay in January 1990 and persisting throughout this study. The rain of phytoplankton litter is probably much greater than that occurring under more normal conditions. The isotopically lighter consumers reflect a phytoplankton-based food web. The algal turf sampled on 28 February 1991 exhibited similar $\delta^{13}\text{C}$ values as epiphytes on seagrasses in the upper Laguna Madre, Texas, reported by Fry and Sherr (1984). Those authors also reported that consumers within seagrass beds in the upper Laguna Madre, Texas, ranged from -10.7 to -15.3 which are substantially isotopically heavier than those reported here. The $\delta^{13}\text{C}$ values reported by Fry and Sherr (1984) are indicative of "clear water" conditions (low phytoplankton

densities) and high seagrass biomass, the condition present in the upper Laguna Madre prior to the "Brown Tide" bloom. Baffin Bay in comparison has comparatively little seagrass cover; therefore, under normal conditions (no "Brown Tide") the algal epiphytes associated with the serpulid worm reefs may play a much greater role as a carbon source in the system.

The pinfish, *Lagodon rhomboides*, may be the greatest avenue through which carbon fixed by the epiphytic algae is passed through the food web. *Lagodon rhomboides* are known to change their diets between planktivory, omnivory, strict carnivory, and strict herbivory at different times, locations, and stages of development (Stoner, 1982). The mixing model of Dunton and Schell (1987) indicates that substantial levels of *L. rhomboides* carbon could be derived from the algal epiphytes (Table 35). The spotted seatrout, *Cynoscion nebulosus*, is a strict carnivore and feeds heavily on *L. rhomboides* (Moody, 1950; Breuer, 1962; Seagle, 1969, Muncy, 1984). It is not surprising that the $\delta^{13}\text{C}$ of *C. nebulosus* is close to that of *L. rhomboides* (Table 36). The black drum, *Pogonias cromis*, has been shown to feed heavily on the small clam, *Mulinia lateralis*, which is abundant in Baffin Bay (Pearson, 1928; Breuer, 1957; Simmons and Breuer 1962, Martin, 1979). Although Montagna *et al.* (1993) found decreased numbers of *M. lateralis* throughout 1990 and 1991, feeding experiments using "Brown Tide" as a food source produced no significant ill effects on *M. lateralis* in the laboratory; therefore, the $\delta^{13}\text{C}$ values observed for *P. cromis* are probably indicative of "Brown Tide" (Tables 36 and 37).

It is surprising that the mixing model indicates a significant (12.8 - 89.6) portion

of the $\delta^{13}\text{C}$ of fish tissue could come from the epiphytic algae, especially when invertebrate consumers living on the reefs have phytoplankton based signatures. It is likely that the fish are showing $\delta^{13}\text{C}$ ratios related to seagrasses. The fish may be more actively feeding on organism living in adjacent seagrass beds than on organisms living on the serpulid worm reefs.

The "simple" (two sources of carbon: algal epiphytes and phytoplankton) mixing model utilized here probably does not accurately portray isotope mixing in an estuary because other potential sources of carbon are present (seagrass and terrestrially-derived carbon introduced during freshwater inflow). Studying multiple isotopic tracers such as $\delta^{34}\text{S}$, $\delta^{13}\text{C}$, and $\delta^{15}\text{N}$, concurrently could help to determine more precisely the carbon source in an estuarine system (Fry and Sherr, 1984). Although such multiple tracers were beyond the scope of this study, the current two-carbon-source model of Dunton and Schell (1987) does demonstrate the current utilization of phytoplankton as the major source of carbon in the Baffin Bay system.

A paired t-test indicates a significant ($P < 0.05$) shift in the $\delta^{13}\text{C}$ values between 28 February 1991 and 4 May 1992 (Table 36). This significant decrease in the $\delta^{13}\text{C}$ values may be explained by either an influx of phytoplankton ("Brown Tide") or an input of terrestrial organic carbon during freshwater runoff. Salinity decreased from 50 (February 1991) to 21.0 ppt (May 1992) resulting from above normal precipitation early in 1992. Runoff from these rains probably resulted in higher loading of terrestrial organic carbon to the Baffin Bay-complex. The "Brown Tide" bloom was well established (one year) prior to the collection of $\delta^{13}\text{C}$ samples in February 1991; therefore, it seems

unlikely that a shift in the isotopic composition of the magnitude reported here would occur after two years' exposure.

Conclusion

Environmental conditions between reef and non-reef areas within sites and seasons were similar; therefore, any differences between reefs and non-reefs within sites and seasons were probably not a result of differences in water depth, temperature, or salinity. A salinity gradient existed throughout most of the study, with higher salinities occurring at west bay sites (3 and 4). Unfortunately, reef type (patch reef or reef field) was confounded with location in the bay, with patch reefs located in the eastern section of Baffin Bay, and reef fields located in western sections of the bay. Because of the salinity gradient and the confounded nature of reef type and location in the bay it is impossible to determine to what extent faunal abundance and diversity are independently controlled by reef type or position in the bay.

Ichthyofaunal diversity was not significantly different between reef and non-reef areas, but there were seasonal differences and differences between east and west bay sites. The differences between east and west bay sites were probably salinity-related because diversity remained stable at east bay sites while there was increasing diversity at west bay sites. At west bay sites diversity highly correlated with salinity (Pearson correlation = -0.81) and to a lesser degree, with water temperature (Pearson correlation = 0.51). Highest ichthyofaunal diversity during this study was at salinities between 41 - 52 ppt.

The overall ichthyofaunal catch rate was not significantly different between reef and non-reef sites; only a seasonal effect in the catch rate data was observed. Seasonal differences can be explained by the recruitment of fish into the bay in Spring and Summer. These seasonal peaks can be attributed to three species: *Arius felis*, *Pogonias cromis*, and *Leiostomus xanthurus*.

A total of 5,396 individuals representing 35 fish species, two crab species, and one shrimp species were collected by trammel net during the study. Of the 38 species collected seven fish species (*Arius felis* = 10.7 %, *Lagodon rhomboides* = 2.3 %, *Cynoscion nebulosus* = 15.2 %, *Leiostomus xanthurus* = 12.1 %, *Pogonias cromis* = 20.2 %, *Sciaenops ocellatus* = 1.1 %, and *Mugil cephalus* = 27.3 %) comprised 89.0 % of the total catch.

Little evidence was found in support of the hypothesis that fish congregate and are larger near the serpulid worm reefs of Baffin Bay; therefore, either fish are truly not congregating around the reefs, or the sampling technique used was not appropriate. The trammel nets were statically set; therefore, for a fish to be caught it must have been moving. Fish congregating around the reefs may be moving comparatively less than fish living in non-reef areas; therefore, the trammel net catches may not have been representative of fish abundance.

Despite "Brown Tide," the serpulid worm reefs exhibited a rich and diverse invertebrate assemblage. A total of 29 species of invertebrates were collected from the serpulid worm reefs during the study. Of the 29 species, eight (*Corophium louisianum* 70.45 %, *Hargeria rapax* 11.66 %, Syllidae 3.16 %, *Naineris laevigata* 2.95 %, *Polydora*

ligni 2.72 %, *Nereis rissei* 1.93 %, *Balanus eburneus* 0.93% and Anemone 2.4%)

comprised 96.2 % of the total abundance per liter of water displacement. There were significant differences in invertebrate diversity between east and west bay sites.

Corophium louisianum and *Hargeria rapax* are important food items for black drum (*P. cromis*) < 100 mm length, and were found in high abundance on the serpulid worm reefs. The dominance of these structures by a proven food source is a compelling argument for the importance of the serpulid worm reefs in the Baffin Bay-complex.

Biomass and photosynthetic rates compared closely between serpulid worm reef algal epiphytes and upper Laguna Madre seagrasses. Therefore, in Baffin Bay where seagrass coverage is minimal, the turf algae associated with the serpulid worm reefs may make important contributions to the carbon pool.

Limited $\delta^{13}\text{C}$ analyses of invertebrates inhabiting the serpulid worm reefs indicates a phytoplankton-based food web. This is not surprising considering the dominance of the system by a "Brown Tide" algal bloom originating in Baffin Bay in January 1990 and persisting throughout the study. The pinfish, *Lagodon rhomboides*, may be the primary avenue through which carbon fixed by the epiphytic algae is passed through the food web. The spotted seatrout, *Cynoscion nebulosus*, is a strict carnivore and feeds heavily on *L. rhomboides*. It is not surprising that the $\delta^{13}\text{C}$ of *C. nebulosus* is similar to that of *L. rhomboides*.

Although this study provides new information on the flora and fauna associated with the serpulid worm reefs of Baffin Bay, Texas, the reefs themselves remain poorly understood. Comparison of tube diameter and wall thickness between several possible

reef forming polychaetes indicates a tube morphology that more closely resembles *Hydroides dianthus* than others (ten Hove and van den Hurk, 1993). During this study *H. dianthus* was found only at east bay sites (primarily at Site 2). The serpulid worm reefs are a unique feature of Baffin Bay, and their formation is probably linked to the unusual environmental conditions associated with the area. It has been speculated that reef formation took place when salinities in Baffin Bay were more moderate (Andrews, 1964). Texas has other less saline bays, yet no known serpulid reef formation has taken place in them; therefore, it seems likely that reef formation is tied to the unique location of Baffin Bay on the Texas coast. The upper Laguna Madre has limited tidal exchange and no significant freshwater inputs other than infrequent rainfall and the resultant runoff; consequently, hypersalinity is the "normal" condition. Baffin Bay has several small creeks that flow, for the most part, only after rains. Because of these creeks, Baffin Bay is subject to a rapid large fluctuations in salinity even when salinity in the upper Laguna Madre remains fairly stable. The hypersaline condition of the upper Laguna Madre may act as an isolating buffer, preventing possible predators from reaching the serpulid worms in Baffin Bay. This possible barrier to predator populations may allow the reefs to flourish when conditions are favorable, such as lowered salinity.

The serpulid worm reefs of Baffin Bay are the only naturally occurring hard substrate on the Texas coast, other than oyster reefs and coquina "beach rock". During this study the reefs were not growing as in the past when they produced large areas of oriented growth. In my opinion, based on personal observations made during this study, there are fewer reefs than were previously reported by Brown *et al.* (1977). Breuer

(1957) reported Alazan Bay was nearly blocked from boat traffic by Center Reef, and only three entrances could be navigated. I had no trouble entering Alazan Bay, and in fact, had difficulty finding reef growth at the mouth of Alazan Bay. If reef growth has slowed or ceased, perhaps the reefs are slowly being destroyed. Relentless wave energy generated by seasonally strong southeast winds along with increased boat traffic (prop damage) and fishermen (trampling) may be breaking down the reefs. Although I found no increase in fish abundance near the serpulid worm reefs, Baffin Bay has historically produced some of the highest catch rates for commercially sought species in Texas; therefore, the entire system (reef and non-reef areas) may be more productive because of the reefs. Large scale definitive mapping of the reefs is necessary before the extent of loss or gain of the reefs can be determined. The serpulid worm reefs appear to be a fragile and important component of the Baffin Bay-complex that merit protection from anthropogenic degradation.

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Appendix 1. Total number of fish and the average standard length collected by seasonal trammel net surveys (Species are listed in alphabetical order). Patch Reef = Sites 1 and 2, Reef Field = Sites 3 and 4.

		<i>Archosargus probatocephalus</i>		<i>Arius felis</i>		<i>Astroscopus y-graecum</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	353	54	213.69	0	-
	Patch Reef Control	3	204.33	49	252.78	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	1	240.00	1	180.00	0	-
Winter 1991	Patch Reef	2	314.50	9	257.22	0	-
	Patch Reef Control	4	221.25	15	262.67	1	330.00
	Reef Field	2	211.50	0	-	0	-
	Reef Field Control	1	210.00	1	322.00	0	-
Spring 1991	Patch Reef	1	225.00	95	254.11	0	-
	Patch Reef Control	2	230.00	144	272.60	0	-
	Reef Field	0	-	10	319.50	0	-
	Reef Field Control	0	-	31	270.00	0	-
Summer 1991	Patch Reef	0	-	96	173.70	0	-
	Patch Reef Control	6	253.50	40	245.63	0	-
	Reef Field	1	205.00	10	201.50	0	-
	Reef Field Control	0	-	25	264.60	0	-
Fall 1991	Patch Reef	0	-	8	286.13	0	-
	Patch Reef Control	2	233.00	10	258.10	0	-
	Reef Field	0	-	1	189.00	0	-
	Reef Field Control	1	212.00	5	271.60	0	-

Appendix 1. continued.

		<i>Bagre marinus</i>		<i>Bairdiella chrysoura</i>		<i>Brevoortia patronus</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-	0	-	6	208.33
	Patch Reef Control	0	-	1	150.00	1	215.00
	Reef Field	0	-	0	-	2	185.00
	Reef Field Control	0	-	2	140.00	1	155.00
Winter 1991	Patch Reef	0	-	0	-	2	202.50
	Patch Reef Control	0	-	0	-	1	205.00
	Reef Field	0	-	0	-	1	230.00
	Reef Field Control	0	-	0	-	9	164.44
Spring 1991	Patch Reef	0	-	0	-	5	216.00
	Patch Reef Control	0	-	1	160.00	6	199.17
	Reef Field	0	-	0	-	7	160.00
	Reef Field Control	0	-	0	-	18	162.78
Summer 1991	Patch Reef	0	-	0	-	7	168.57
	Patch Reef Control	5	224.00	0	-	46	191.16
	Reef Field	0	-	0	-	14	167.14
	Reef Field Control	0	-	0	-	16	189.37
Fall 1991	Patch Reef	0	-	0	-	5	190.80
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	60	169.55
	Reef Field Control	0	-	0	-	22	170.45

Appendix 1. continued.

		<i>Caranx hippos</i>		<i>Chaetodipterus faber</i>		<i>Cynoscion arenarius</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-	0	-	1	254.00
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	2	255.00
	Reef Field Control	0	-	0	-	1	255.00
Winter 1991	Patch Reef	0	-	0	-	1	305.00
	Patch Reef Control	0	-	0	-	1	295.00
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	1	270.00
Spring 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Summer 1991	Patch Reef	1	105.00	0	-	0	-
	Patch Reef Control	1	110.00	0	-	0	-
	Reef Field	1	110.00	0	-	3	188.33
	Reef Field Control	0	-	0	-	5	193.00
Fall 1991	Patch Reef	0	-	0	-	19	293.68
	Patch Reef Control	0	-	1	95.00	0	-
	Reef Field	0	-	1	160.00	1	280.00
	Reef Field Control	0	-	0	-	1	220.00

Appendix 1. continued.

		<i>Cynoscion nebulosus</i>		<i>Dasyatis sabina</i>		<i>Dorosoma cepedianum</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	49	340.88	0	-	0	-
	Patch Reef Control	34	346.39	0	-	1	455.00
	Reef Field	12	310.83	0	-	0	-
	Reef Field Control	7	329.00	0	-	0	-
Winter 1991	Patch Reef	44	345.57	0	-	0	-
	Patch Reef Control	49	369.21	0	-	0	-
	Reef Field	9	294.56	0	-	0	-
	Reef Field Control	17	313.31	0	-	0	-
Spring 1991	Patch Reef	85	344.46	1	625.00	0	-
	Patch Reef Control	99	336.84	0	-	6	379.17
	Reef Field	25	342.71	0	-	0	-
	Reef Field Control	26	320.00	0	-	0	-
Summer 1991	Patch Reef	29	357.62	0	-	0	-
	Patch Reef Control	56	342.91	0	-	0	-
	Reef Field	53	338.77	0	-	0	-
	Reef Field Control	31	335.33	0	-	0	-
Fall 1991	Patch Reef	46	359.63	0	-	2	385.00
	Patch Reef Control	50	338.28	0	-	0	-
	Reef Field	58	369.52	0	-	0	-
	Reef Field Control	25	369.68	0	-	0	-

Appendix 1. continued.

		<i>Elopsaurus</i>		<i>Lagodon rhomboides</i>		<i>Larimus fasciatus</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	5	350.80	3	167.33	0	-
	Patch Reef Control	1	263.00	1	180.00	0	-
	Reef Field	0	-	3	125.00	0	-
	Reef Field Control	3	216.67	2	140.00	0	-
Winter 1991	Patch Reef	0	-	3	141.67	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Spring 1991	Patch Reef	3	406.67	13	145.77	0	-
	Patch Reef Control	10	398.33	43	149.77	0	-
	Reef Field	8	396.88	3	98.33	0	-
	Reef Field Control	3	450.00	2	100.00	1	90.00
Summer 1991	Patch Reef	6	388.00	12	136.25	0	-
	Patch Reef Control	7	372.14	17	145.59	0	-
	Reef Field	11	265.00	12	113.75	0	-
	Reef Field Control	23	320.65	0	-	0	-
Fall 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	1	217.00	0	-	0	-
	Reef Field	0	-	6	100.67	1	150.00
	Reef Field Control	0	-	0	-	0	-

Appendix 1. continued.

		<i>Leistomus xanthurus</i>		<i>Menticirrhus americanus</i>		<i>Micropogonias undulatus</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	12	186.92	0	-	0	-
	Patch Reef Control	14	198.36	0	-	0	-
	Reef Field	1	205.00	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Winter 1991	Patch Reef	26	180.08	0	-	0	-
	Patch Reef Control	13	182.31	0	-	0	-
	Reef Field	1	178.00	0	-	0	-
	Reef Field Control	3	180.00	0	-	0	-
Spring 1991	Patch Reef	265	189.08	0	-	3	180.00
	Patch Reef Control	114	183.10	0	-	1	270.00
	Reef Field	26	173.27	0	-	1	230.00
	Reef Field Control	23	170.00	0	-	0	-
Summer 1991	Patch Reef	13	186.15	1	285.00	3	232.50
	Patch Reef Control	16	180.63	0	-	4	236.25
	Reef Field	26	178.46	0	-	0	-
	Reef Field Control	80	178.04	0	-	0	-
Fall 1991	Patch Reef	4	176.00	1	254.00	4	225.25
	Patch Reef Control	3	221.00	0	-	1	225.00
	Reef Field	9	176.11	2	253.00	0	-
	Reef Field Control	4	184.50	0	-	0	-

Appendix 1. continued.

		<i>Mugil cephalus</i>		<i>Orthopristis chrysoptera</i>		<i>Paralichthys lethostigma</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	60	277.45	0	-	7	293.29
	Patch Reef Control	68	274.68	2	195.00	5	319.00
	Reef Field	242	270.37	1	185.00	2	172.50
	Reef Field Control	206	271.09	2	175.00	2	177.50
Winter 1991	Patch Reef	9	275.00	0	-	1	187.00
	Patch Reef Control	28	276.86	0	-	2	260.50
	Reef Field	115	270.61	0	-	1	204.00
	Reef Field Control	64	267.52	0	-	0	-
Spring 1991	Patch Reef	39	271.92	0	-	1	325.00
	Patch Reef Control	38	288.16	0	-	5	267.00
	Reef Field	175	277.54	0	-	0	-
	Reef Field Control	246	270.83	0	-	0	-
Summer 1991	Patch Reef	6	311.25	0	-	2	335.00
	Patch Reef Control	16	311.25	0	-	0	-
	Reef Field	20	287.25	0	-	1	415.00
	Reef Field Control	77	282.92	0	-	0	-
Fall 1991	Patch Reef	5	278.00	2	202.50	7	375.00
	Patch Reef Control	16	322.25	1	192.00	1	386.00
	Reef Field	31	285.94	0	-	0	-
	Reef Field Control	24	273.17	0	-	5	362.40

Appendix 1. continued.

		<i>Peprilus alepidotus</i>		<i>Peprilus burti</i>		<i>Pogonias cromis</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	353	0	-	16	379.06
	Patch Reef Control	1	130.00	0	-	17	326.82
	Reef Field	0	-	0	-	2	135.00
	Reef Field Control	0	-	0	-	7	286.43
Winter 1991	Patch Reef	0	-	0	-	50	257.78
	Patch Reef Control	0	-	0	-	43	304.54
	Reef Field	0	-	0	-	4	155.50
	Reef Field Control	1	130.00	0	-	10	195.50
Spring 1991	Patch Reef	2	112.00	0	-	77	221.27
	Patch Reef Control	0	-	0	-	63	200.54
	Reef Field	15	114.00	2	100.00	171	180.70
	Reef Field Control	14	110.36	0	-	116	171.36
Summer 1991	Patch Reef	0	-	0	-	52	322.96
	Patch Reef Control	0	-	0	-	53	212.92
	Reef Field	1	130.00	0	-	169	183.43
	Reef Field Control	0	-	0	-	84	182.32
Fall 1991	Patch Reef	1	140.00	0	-	18	232.22
	Patch Reef Control	0	-	0	-	8	253.38
	Reef Field	4	149.75	1	140.00	113	189.13
	Reef Field Control	2	146.50	1	130.00	41	213.66

Appendix 1. continued.

		<i>Polydactylus octonemus</i>		<i>Pomatomus saltatrix</i>		<i>Prinotus tribulus</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	353	0	-	1	176.00
	Patch Reef Control	3	204.33	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	1	240.00	0	-	0	-
Winter 1991	Patch Reef	2	314.50	0	-	0	-
	Patch Reef Control	4	221.25	0	-	0	-
	Reef Field	2	211.50	0	-	0	-
	Reef Field Control	1	210.00	0	-	1	180.00
Spring 1991	Patch Reef	1	225.00	0	-	1	200.00
	Patch Reef Control	2	230.00	0	-	0	-
	Reef Field	0	-	0	-	3	187.50
	Reef Field Control	0	-	0	-	6	194.17
Summer 1991	Patch Reef	0	-	0	-	1	225.00
	Patch Reef Control	6	253.50	0	-	0	-
	Reef Field	1	205.00	1	316.00	0	-
	Reef Field Control	0	-	0	-	0	-
Fall 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	2	233.00	0	-	0	-
	Reef Field	0	-	0	-	2	200.00
	Reef Field Control	1	212.00	0	-	2	187.50

Appendix 1. continued.

		<i>Rhinoptera bonasus</i>		<i>Sciaenops ocellatus</i>		<i>Scomberomorus maculatus</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-	5	297.40	0	-
	Patch Reef Control	0	-	10	321.00	0	-
	Reef Field	0	-	1	510.00	0	-
	Reef Field Control	0	-	1	285.00	0	-
Winter 1991	Patch Reef	0	-	1	456.00	0	-
	Patch Reef Control	0	-	7	386.33	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Spring 1991	Patch Reef	1	420.00	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	1	260.00	0	-
	Reef Field Control	0	-	0	-	0	-
Summer 1991	Patch Reef	2	424.00	0	-	0	-
	Patch Reef Control	7	426.50	3	276.67	10	296.88
	Reef Field	0	-	13	284.23	2	322.50
	Reef Field Control	0	-	15	370.60	0	-
Fall 1991	Patch Reef	0	-	37	352.19	0	-
	Patch Reef Control	0	-	13	327.15	0	-
	Reef Field	0	-	10	288.40	0	-
	Reef Field Control	0	-			0	-

Appendix 1. continued. Number of fish and the average standard length collected by season and site for three species (Species are listed in alphabetical order). Patch Reef = Sites 1 and 2, Reef Field = Sites 3 and 4.

		<i>Trachinotus carolinus</i>		<i>Trichiurus lepturus</i>		<i>Trinectes maculatus</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Winter 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Spring 1991	Patch Reef	0	-	0	-	3	123.33
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Summer 1991	Patch Reef	4	160.00	0	-	1	140.00
	Patch Reef Control	6	160.00	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Fall 1991	Patch Reef	0	-	3	969.33	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-

Appendix 2. Total number of fish and the average standard length collected by seasonal bag seine surveys (Species are listed in alphabetical order). Patch Reef = Sites 1 and 2, Reef Field = Sites 3 and 4.

		<i>Anchoa hepsetus</i>		<i>Anchoa mitchelli</i>		<i>Arius felis</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	2	110.5
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	1	31.0	0	-
Winter 1991	Patch Reef	0	-	2	36.0	0	-
	Patch Reef Control	0	-	5	46.6	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	1	46.0	0	-
Spring 1991	Patch Reef	1	47.0	1	49.0	0	-
	Patch Reef Control	0	-	45	46.6	0	-
	Reef Field	0	-	11	47.4	0	-
	Reef Field Control	0	-	1	46.0	0	-
Summer 1991	Patch Reef	0	-	41	33	0	-
	Patch Reef Control	0	-	76	33.1	0	-
	Reef Field	0	-	215	30.1	0	-
	Reef Field Control	0	-	294	30.1	0	-
Fall 1991	Patch Reef	0	-	42	36.6	0	-
	Patch Reef Control	0	-	33	35.3	0	-
	Reef Field	0	-	534	34.2	0	-
	Reef Field Control	0	-	92	33.7	0	-

Appendix 2. continued.

		<i>Bairdiella chrysoura</i>		<i>Brevoortia patronus</i>		<i>Esops saurus</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	3	62.3	1	38.0	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	1	72.0	0	-
Winter 1991	Patch Reef	0	-	13	33.1	0	-
	Patch Reef Control	0	-	2	33.5	0	-
	Reef Field	0	-	17	32.5	0	-
	Reef Field Control	0	-	44	33.3	0	-
Spring 1991	Patch Reef	0	-	62	35.4	0	-
	Patch Reef Control	0	-	143	33.0	0	-
	Reef Field	0	-	211	30.1	1	61.0
	Reef Field Control	0	-	724	31.6	0	-
Summer 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	1	57.0	0	-
	Reef Field Control	0	-	0	-	0	-
Fall 1991	Patch Reef	1	75.0	0	-	5	190.80
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	60	169.55
	Reef Field Control	0	-	0	-	22	170.45

Appendix 2. continued.

		<i>Eucinostomus</i> <i>sp.</i>		<i>Gobiosoma</i> <i>robustum</i>		<i>Hyporhamphus</i> <i>unifasciatus</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	2	30.5	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Winter 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Spring 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	1	37.0	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Summer 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	1	102.0
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Fall 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-

Appendix 2. continued.

		<i>Lagodon rhomboides</i>		<i>Leiostomus xanthurus</i>		<i>Lucania parva</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	27	48.4	0	-	0	-
	Patch Reef Control	29	49.9	1	59.0	0	-
	Reef Field	5	69.6	0	-	0	-
	Reef Field Control	2	77.5	0	-	0	-
Winter 1991	Patch Reef	15	65.8	0	-	0	-
	Patch Reef Control	2	33.5	0	-	0	-
	Reef Field	3	79.3	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Spring 1991	Patch Reef	82	45.9	0	-	0	-
	Patch Reef Control	45	43.3	1	43.0	0	-
	Reef Field	18	84.1	3	64.0	0	-
	Reef Field Control	0	-	3	56.3	0	-
Summer 1991	Patch Reef	28	67.1	0	-	1	23.0
	Patch Reef Control	6	67.3	0	-	1	24.0
	Reef Field	0	-	0	-	0	-
	Reef Field Control	2	91.5	0	-	0	-
Fall 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	3	58.0	0	-	1	21.0
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-

Appendix 2. continued.

		<i>Menidia beryllina</i>		<i>Mugil cephalus</i>		<i>Opsanus beta</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	1	52.0	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	1	25.0	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Winter 1991	Patch Reef	7	57.9	0	-	0	-
	Patch Reef Control	1	49.0	0	-	0	-
	Reef Field	0	-	1	119.0	0	-
	Reef Field Control	0	-	0	-	0	-
Spring 1991	Patch Reef	0	-	0	-	1	90.0
	Patch Reef Control	0	-	0	-	1	102.0
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Summer 1991	Patch Reef	1	38.0	0	-	0	-
	Patch Reef Control	1	37.0	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Fall 1991	Patch Reef	1	32.0	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-

Appendix 2. continued.

		<i>Pogonias cromis</i>		<i>Strongylura marina</i>		<i>Syngnathus louisiana</i>	
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-	1	285.0	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Winter 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Spring 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	9	49.4	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Summer 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	1	167.0
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-
Fall 1991	Patch Reef	0	-	0	-	0	-
	Patch Reef Control	0	-	0	-	0	-
	Reef Field	0	-	0	-	0	-
	Reef Field Control	0	-	0	-	0	-

Appendix 2. continued.

		<i>Syngnathus scovelli</i>					
		No.	\bar{x} SL	No.	\bar{x} SL	No.	\bar{x} SL
Fall 1990	Patch Reef	0	-				
	Patch Reef Control	0	-				
	Reef Field	0	-				
	Reef Field Control	0	-				
Winter 1991	Patch Reef	0	-				
	Patch Reef Control	0	-				
	Reef Field	0	-				
	Reef Field Control	0	-				
Spring 1991	Patch Reef	0	-				
	Patch Reef Control	0	-				
	Reef Field	0	-				
	Reef Field Control	0	-				
Summer 1991	Patch Reef	0	-				
	Patch Reef Control	1	80.0				
	Reef Field	0	-				
	Reef Field Control	0	-				
Fall 1991	Patch Reef	0	-				
	Patch Reef Control	0	-				
	Reef Field	0	-				
	Reef Field Control	0	-				