THE INFLUENCE OF PHYSICOCHEMICAL FACTORS AND WIND-INDUCED RESUSPENSION ON MICROALGAL AND ZOOPLANKTON COMMUNITY ASSEMBLAGES IN A SHALLOW COASTAL EMBAYMENT, SOUTH BAY, TX, USA

A Thesis

by

JENNIFER SUE STONE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2006

Major Subject: Biology

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Approved by:

Chair of Committee,	Donald Harper
Committee Members,	James L. Pinckney
	Antonietta Quigg
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ABSTRACT

The Influence of Physicochemical Factors and Wind-induced Resuspension on Microalgal and Zooplankton Community Assemblages in a Shallow Coastal Embayment, South Bay, TX, USA. (May 2006)

Jennifer Sue Stone, B.S., Ohio University

Chair of Advisory Committee: Dr. Donald Harper

Plankton communities are important members of the food web in coastal systems and are regulated by top-down and bottom-up controls. This study examined the influence of bottom-up controls, such as physicochemical factors, and top-down controls, such as predation, on the plankton communities in South Bay, Texas. Microalgal photopigments were ascertained by high-performance liquid chromatography (HPLC) to determine the relative abundances of major algal classes. Zooplankters were identified to the lowest possible taxon and enumerated. No spatial trends were observed for the physicochemical factors. The northern bay sections exhibited significantly higher phytoplankton and microphytobenthic diatom biomass, probably due to their proximity to the bay inlet. Copepod, gastropod veliger and brachyuran zoea abundances were also higher in this area, albeit insignificantly. The southern bay sections experienced significantly higher cyanobacterial, euglenophyte and chlorophyte biomass, and polychaete larval abundances. Total zooplankton and nauplii abundances were also higher in the southern areas, albeit insignificantly. Sampling the inaccessible areas of the bay in the future may reveal spatial variability among the physicochemical factors which could be influencing the distribution of plankton. Temporal variation for the physicochemical factors followed a typical trend for subtropical climates and influenced the seasonality of the plankton communities. Phytoplankton biomass peaked in February, August and October but these maximums were not significantly different from the other months sampled. Microphytobenthic biomass peaked during the summer months, while diatom biomass also peaked in February. Zooplankton abundances peaked in October, while nauplii and polychaete larvae also peaked in February.

Relationships between wind speed, turbidity and the microalgal pigments were assessed to determine if wind-induced resuspension influenced the location of the major algal classes within the water column compared to the sediments. Wind speed and turbidity were directly related to each other, albeit insignificantly. Some phytoplankton and microphytobenthos were considered tychopelagic because wind-induced resuspension increased their biomass in the water column compared to the sediments. The physicochemical factors exerted bottom-up control of plankton community dynamics in this study, while top-down controls, such as predation, require further investigation. Future studies should focus on which of these controls have more influence on plankton community dynamics in South Bay.

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INTRODUCTION

Plankton community dynamics can play a major role in the overall productivity of marine communities. Microalgae are just one of several potential primary producers in coastal ecosystems. Other primary producers include marsh plants, seagrass meadows, mangroves, and macroalgae (Cloern, 1987; Page, 1997). In nearshore systems, microalgal assemblages can be further subdivided into phytoplankton, microphytobenthos and epiphytes on seagrasses and mangroves. The degree of contribution to the overall productivity from these assemblages varies across systems. However, benthic microalgae and phytoplankton combined contribute significantly to the net carbon production in coastal waters (Duarte and Cebrián, 1996; Perissinotto *et al.*, 2000, 2002; Gilabert, 2001). Plankton community dynamics were examined in this study in order to identify and assess the strength of various bottom-up and top-down controls on these trophic levels. Therefore, the effects of various biological and physicochemical factors on microalgal and zooplankton community dynamics were investigated in South Bay, Texas. South Bay is located in southern Texas and was once part of the lower Laguna Madre until 1938 when the Brownsville Ship Channel was completed. The spoil from dredging this channel was deposited along most of the northern edge of what is now South Bay, thereby separating it from the lower Laguna Madre (Breuer, 1962; Hook, 1991). A small inlet remains along the northeastern edge of the bay (Figure I).

Biological Factors

Potential biological factors that regulate microalgal biomass and productivity include the species composition of the phytoplankton and microphytobenthic community, the species composition of the herbivorous community and the associated predation rates upon these primary producers. Because microalgae are easily assimilated when compared to other vascular plants, they are the preferred prey for many estuarine species. Thus, grazing has a considerable impact on microalgal biomass and production rates (Duarte and Cebrián, 1996; Fejes *et al.*, 2005). Grazing rates may vary on different

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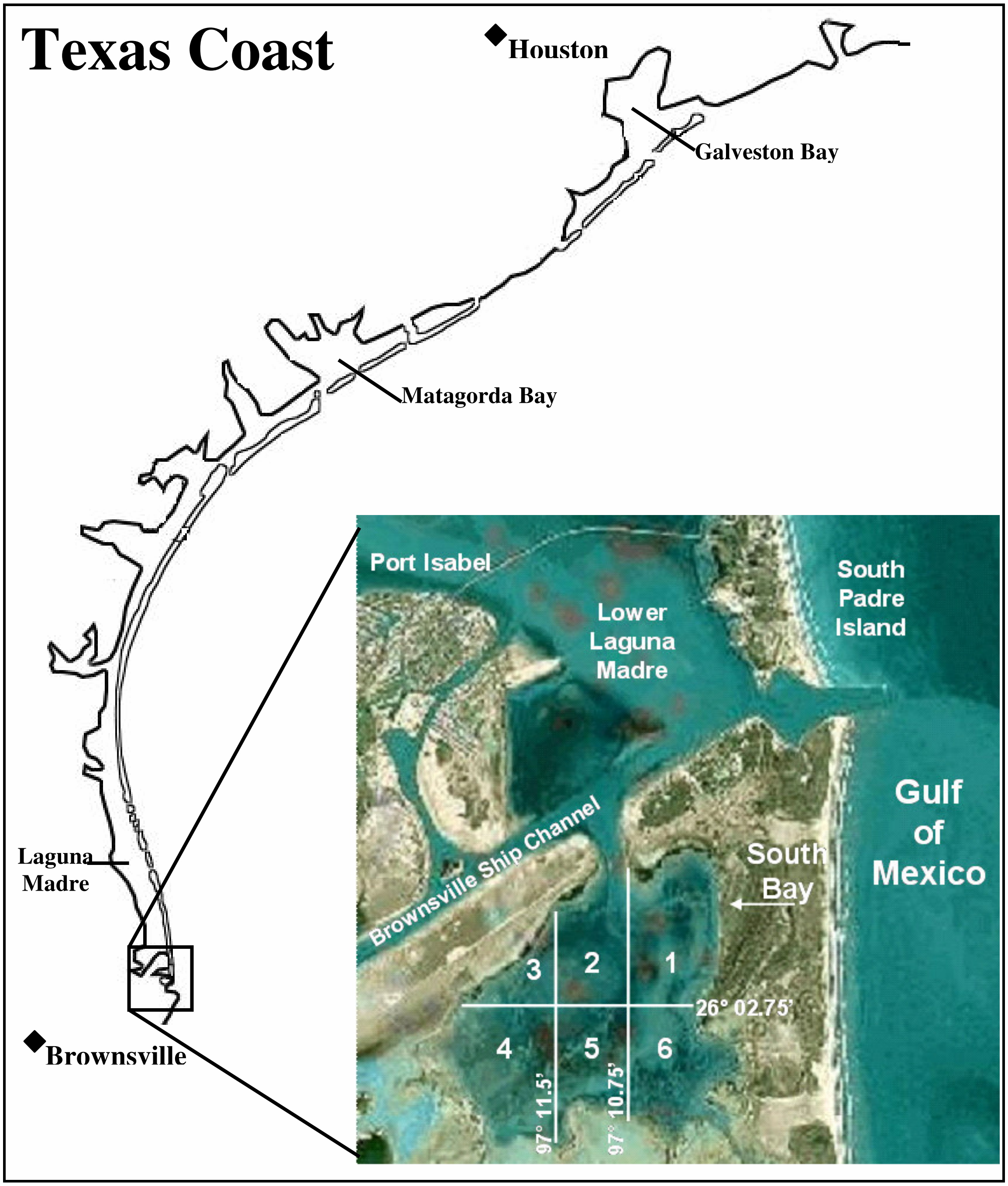


Figure I. Map of South Bay, Lower Laguna Madre, Texas, USA. The bay is divided up into six strata represented by the numbered areas above.

time scales ranging from seasonal to hourly which could result in changes in the microalgal biomass along these same time scales (Fulton, 1984; Litaker *et al.*, 1987;

Pennock and Sharp, 1994). Grazers may prefer easily captured or assimilated species over others. This preference would result in species compositional changes within the microalgal community (Gaul and Antia, 2001; Caron *et al.*, 2004; Fejes *et al.*, 2005). In the Laguna Madre of Texas, decreases in grazer populations have resulted in phytoplankton blooms that have altered the trophic structure of the system (Buskey *et al.*, 1997). These algal blooms may then out compete other phytoplankton resulting in a shift in the phytoplankton community composition (Buskey *et al.*, 1997; Buskey *et al.*, 2001). Given this variability in plankton assemblages over various time scales, the pigment composition and relative abundance of the phytoplankton and the benthic microalgal community, as well as the species composition and abundance of the zooplankton community were monitored in this study to assess the potential biological factors controlling these communities. This information provided some insight into the overall food web dynamics for the lower trophic levels in this shallow coastal embayment.

Physicochemical Factors

Microalgal and zooplankton biomass and diversity can be affected by seasonal variations in physicochemical factors. From preliminary observations within South Bay, drastic seasonal changes in salinity range from 15 ppt to 70 ppt (personal observation) with hypersalinity being a common occurrence in surrounding waters throughout the year (Sherrod and McMillan, 1981). Hypersalinity results from evaporation rates that exceed inputs of fresh water via precipitation and runoff (Largier *et al.*, 1997; Hiney, 2000). Seasonal changes in salinity and temperature in a hypersaline lagoon in the Mediterranean, the Mar Menor, resulted in strong seasonal trends in the taxonomic composition of the phytoplankton and zooplankton communities (Gilabert, 2001). Microalgal biomass and productivity have been shown to be higher in the warmer summer seasons of the northern hemisphere when compared with winter biomass and productivity values (Boynton *et al.*, 1982; Wang *et al.*, 1999). Additionally, during an open phase associated with the winter season in a temporarily-open estuary in South Africa, an increase in salinity and turbulence occurred concurrently with an increase in zooplankton diversity and a decrease in zooplankton abundances (Kibirige and Perissinotto, 2003).

Non-seasonal variation in physicochemical factors may also exert control over plankton community dynamics. Potential physicochemical factors include light attenuation and intensity, photoinhibition, temperature, salinity, dissolved oxygen, water movements, and available nutrients (Fogg, 1991). Phytoplankton photopigment and species distribution have been shown to correlate with salinity and seston in a microtidal estuary in Argentina (Calliari *et al.*, 2005). Phytoplankton biomass and its associated productivity can be regulated by light availability (Boynton *et al.*, 1982; Cloern, 1987) and limited under hypersaline (>35 ppt) conditions (Robblee *et al.*, 1989). The majority of the primary production in a hypersaline lagoon in Brazil originated more from the benthic microalgae than the phytoplankton (Souza *et al.*, 2003). A shift in the phytoplankton community composition along with significant decreases in zooplankton abundances were observed in the permanent hypersaline regions of Shark Bay, Australia. The shifts in phytoplankton community composition and decreased zooplankton abundances were attributed to the hypersalinity tolerance for the individual species and lower nutrient availability in this region of Shark Bay (Kimmerer *et al.*, 1985).

Because these physicochemical factors have been shown to affect plankton abundances, species distribution, biomass, and productivity, this study tested the effects of various physicochemical factors on plankton community dynamics in South Bay. Determining which physicochemical factors had an effect on plankton community dynamics thereby revealed some of the bottom-up controls on these trophic levels.

Wind-induced Resuspension

The microphytobenthic community is a contributor to the overall productivity of shallow water embayments. Temporarily-open, subtropical estuaries have limited tidal exchange, are shallow and scarcely inundated with fresh water during the dry season. The microphytobenthic biomass is up to several orders of magnitude higher than the phytoplankton biomass in these systems (MacIntyre and Cullen, 1995; Perissinotto *et al.*, 2000, 2002; Safi, 2003; Froneman, 2004). Therefore, the microphytobenthos is an important contributor to the primary production of the estuary and probably serve as an important link for benthic-pelagic coupling of food webs and biogeochemical cycling. Because of the similarities in climatic and hydrological regimes of other subtropical estuaries and the lower Laguna Madre, the assessment and comparison of microphytobenthic assemblages with phytoplankton assemblages is necessitated for this study area to compare the phytoplankton, benthic microalgal and zooplankton dynamics in this estuary with other subtropical lagoons. This will also provide insight on the relative contribution of planktonic assemblages to the productivity and overall food web dynamics in this estuary.

During wind-induced resusupension events in shallow coastal systems, the distinction between the phytoplankton and microphytobenthic assemblages may become unclear. Wind has been shown to control sedimentation and resuspension events in shallow, coastal bodies along the Texas gulf coast (Shideler, 1984). During wind-induced resuspension events, chlorophyll *a* concentrations and turbidity increase within the water column due to resuspension of the microphytobenthos and sediment in shallow, microtidal systems (Demers *et al.*, 1987; Garcia-Soto *et al.*, 1990; Arfi *et al.*, 1993). The resuspended microphytobenthos usually originate from the top few millimeters of the sediment (MacIntyre and Cullen, 1995). Since these organisms occupy both the water column and the benthos, they can be considered tychopelagic. Tychopelagic organisms are at the mercy of physical forces, such as wind-induced resuspension, that control their location within the water column or the sediments (Cahoon and Laws, 1993; Safi, 2003). These organisms are ubiquitous in shallow systems and can only be classified as members of the phytoplankton or the microphytobenthos based upon their preference of a pelagic or benthic habitat (MacIntyre *et al.*, 1996).

During wind-induced resuspension events, sediments may be suspended in the water column for an extended period of time during which the resultant turbidity may limit microalgal growth and productivity in the water column (Pennock and Sharp, 1994; Blanchard and Montagna, 1995; MacIntyre and Cullen, 1995). On the other hand, extended periods of calm conditions in shallow coastal systems may result in high light levels that actually limit microalgal growth and production via photoinhibition (MacIntyre and Cullen, 1996; MacIntyre and Geider, 1996). Additionally, elevated levels of regenerated nutrients, such as ammonia and phosphate, have been observed in the water column during resuspension events and may fuel microalgal growth and production (Simon, 1989; Arfi *et al.*, 1993; Arfi and Bouvy, 1995). Grazing rates could increase during these events due to the increased prey availability in the water column which would result in a reduction of microalgal biomass and productivity. However, the suspended sediments would most likely hinder the ability of the organism to locate and graze on edible food particles. Subsequently, all of these processes can result in sporadic changes in microalgal biomass and primary and secondary productivity.

Because wind-induced resuspension events are erratic, fine-scale changes in microalgal biomass and primary production rates may occur. Chlorophyll *a* concentrations are usually directly related to primary production rates, but this is not always the case (Pennock and Sharp, 1994, MacIntryre and Cullen, 1996). Increases in chlorophyll *a* within the water column have been shown to be directly related to diel changes in wind activity in a shallow tropical lagoon (Arfi *et al.* 1993). Additionally, chlorophyll *a* concentrations in the water column may be affected by horizontal transport of patches of phytoplankton, microalgal growth rates, and grazing rates (MacIntyre and Cullen, 1996). All of these factors affect phytoplankton biomass on short-term time scales. Chlorophyll *a* concentrations in the sediment have also been shown to be highly variable on hourly and daily time scales. This variation may be due to the vertical migration of the microphytobenthos within the sediment, physical forces stirring the sediment, or a combination of both (Pinckney and Zingmark, 1991; MacIntyre and Cullen, 1995). The short-term variations observed in both the phytoplankton and microphytobenthic biomass are not always reflected in the productivity values. Primary production rates have been shown to remain relatively stable despite this short-term variability in biomass within the water column and sediments (MacIntryre and Cullen, 1996). Microalgal pigment concentrations within the water column and the sediment were measured in the current study in order to assess the effects of wind-induced resuspension on the location of specific microalgal taxonomic groups during these events. The results from this study provide an evaluation of factors affecting the productivity in shallow, microtidal embayments such as in this study area.

Study Area

South Bay, which is located in southern Texas, was once part of the lower Laguna Madre (Figure I). Prior to the completion of the Brownsville Ship Channel in 1938, the water used to flow from the Gulf into the lagoon via Boca Chica Pass which was located in the southeastern corner of South Bay. This direction of flow was due to the dominance of southerly winds during most of the year. In winters, northerly winds dominated, the flow reversed, and water entered the Gulf via Boca Chica Pass. During dredging of the ship channel, spoil was deposited along the northern edge of what is now known as South Bay. Only a small inlet remained along the northeastern edge to permit water exchange between the bay and the lagoon. Water exchange between the Gulf and the lower Laguna Madre then took place via the ship channel instead of Boca Chica Pass. This shift in water exchange and sedimentation patterns led to shallower depths, the permanent closure of Boca Chica Pass, and minimal circulation within South Bay (Breuer, 1962).

Because South Bay was once part of the lower Laguna Madre, it shares many characteristics with this lagoon (Hook, 1991). The Laguna Madre is one of the largest hypersaline systems in the world (Quammen and Onuf, 1993; Hiney, 2000). Hypersalinity within the lagoon is due to high evaporation rates, its shallow depth (ca. 1-2 m), reduced fresh water inflow, and limited tidal exchange with the Gulf of Mexico waters (Onuf, 1996; Hiney, 2000). Tropical cyclones occasionally deliver fresh water via precipitation and salt water from storm surge into the lagoon. The major rainfall events associated with tropical cyclones flush the lagoon and result in lowered salinities (Hiney, 2000; Buskey *et al.*, 2001).

During non-cyclonic periods, a combination of dredging and the persistence of hypersalinity in the Laguna Madre have led to reduced light attenuation, loss and compositional changes of seagrass beds, and the persistence of harmful algal bloom species such as the Texas brown tide species, *Aureoumbra lagunensis*. Brown tide blooms have altered trophic interactions in the food web and could lead to changes in primary production (Onuf, 1994; Blanchard and Montagna, 1995; Buskey *et al.*, 1997, 1998, 2001; Rhudy *et al.*, 1999). *Aureoumbra lagunensis* blooms have been shown to destroy seagrass beds which are areas of significant primary productivity and important habitat for commercial fin and shellfish species (Quammen and Onuf, 1993). The brown tide blooms clearly have a significant impact upon the ecosystem of the lagoon and illustrate how changes in the microalgal community composition can alter food web dynamics (Street *et al.*, 1997; Buskey *et al.*, 1998, 2003; Rhudy *et al.*, 1999).

Additionally, few studies have investigated the effects of physicochemical factors upon plankton communities in this region. The South Texas Outer Continental Shelf (STOCS) environmental survey was conducted from 1975-1977 on the nearby shelf and revealed strong seasonal trends in the plankton community which corresponded to variation in some of the physicochemical factors (Berryhill, 1975; Flint and Rabalais, 1980). A study done in the lower Laguna Madre of Texas revealed that phytoplankton abundances are regulated by changes in salinities (Withers, 2002). Few studies have been conducted in South Bay. Of these, only one has focused on the ecology of the system, but this was just part of a larger ecological survey of the entire lower Laguna Madre (Breuer, 1962). The other studies in South Bay have focused on fish community dynamics (Hook, 1991) and black mangrove stands (Sherrod and McMillan, 1981; Everitt and Judd, 1989; Everitt *et al.*, 1996). Because of the paucity of data on plankton community dynamics in this region, microalgal and zooplankton assemblages in South Bay were examined in this study to identify the major components of the planktonic food web, their relative abundances, and the primary factors controlling these abundances.

The dominant substratum types of South Bay are the same as the lower Laguna Madre and consist of seagrass beds and adjacent non-vegetated patches. The vegetated areas consist of four seagrass species: *Halodule wrightii*, *Syringodium filiforme*, *Thalassia testudinum*, and *Halophila engelmannii* (Onuf, 1996). The non-vegetated areas consist of soft mud (Breuer, 1962). Oyster reefs also cover parts of the substratum and black mangroves, *Avicennia germinans*, are located along some of the edges of South Bay (Sherrod and McMillan, 1981; Everitt and Judd, 1989; Hook, 1991; Everitt *et al.*, 1996). South Bay is microtidal (Shideler, 1984), is surrounded by tidal flats, has a mean depth of approximately .5 m (Hook, 1991), and occupies an area of approximately 14 km^2 (Figure I).

Objectives

The overall objective of this study was to determine the effects of various biological and physicochemical factors on plankton community dynamics by identifying the major components of the community and their relative abundances. From this information, top-down and bottom-up controls can be identified for the planktonic food web. Based upon previous studies of how significant seasonal trends and spatial distribution are evident in plankton communities in similar systems to South Bay, this study tested the following null hypotheses to determine the primary factors controlling the plankton distributions:

- No significant spatial differences exist for the microalgal pigment concentrations and composition and zooplankton species abundances and composition within South Bay.
- No significant temporal differences exist in the microalgal pigment concentrations and composition and zooplankton species abundances and composition within South Bay.
- No significant relationships exist between salinity, water temperature, air temperature, dissolved oxygen and turbidity with microalgal pigment concentrations and composition and zooplankton species abundances and composition.
- No significant differences exist in phytoplankton and benthic microalgal pigment concentrations and compositions between high turbidity episodes associated with wind-induced resuspension events and static, low turbidity episodes.

METHODS

Sampling Stations

Sampling was conducted bimonthly (every other month) in 2004 to determine temporal trends in the microalgal pigment concentrations and the zooplankton abundances. To determine spatial trends throughout the year, South Bay was divided into six strata of similar size (Figure I). The latitude 26° 01.75’ split the bay in half creating a northern and southern section. The longitudes 97° 11.5’ and 97° 10.75’ split the bay into three sections creating a western, central, and eastern section. This resulted in a total of six strata with the geographic location and areas displayed in Table I. An X-Y coordinate system was developed for each stratum in which coordinates were selected by a random number generator in Microsoft Excel©. These coordinates were transformed by a formula into corresponding latitude and longitude positions within each stratum. The exact position of each sampling site was recorded using a GPS unit.

Table I. The geographic locations and areas (km^2) for each of the strata in South Bay, TX.

Stratum #	Geographic Location	Area (km^2)
1	Northeast	2.2
2	North Central	2.6
3	Northwest	2.4
4	Southwest	2.2
5	South Central	2.5
6	Southeast	1.8

Physicochemical Factors

Physicochemical characteristics such as salinity, water and air temperature, dissolved oxygen, and conductivity were measured at each station with a YSI 85 multi-parameter probe. Approximately 20 mL of mid-water column seawater was collected for turbidity measurements which were determined in the laboratory by using a LaMotte 2020 turbidimeter. This turbidimeter was calibrated with an AMCO^{TM} 10.0 NTU turbidity standard. Historical tidal data were obtained from NOAA’s CO-OPS website for station #8779770 which is located in Port Isabel, TX, and is the closest station to South Bay (http://www.co-ops.nos.noaa.gov/index.html, 2004). Hourly water level heights were obtained for the week prior to the sampling date. Water level heights were also obtained for six-minute intervals on the day sampled. Historical wind speed and wind direction data were also obtained from NOAA's CO-OPS website for the Port Isabel, TX station. The hourly wind speed and wind direction data were obtained for the week prior to the sampling date and the day sampled. Precipitation data were obtained from NOAA's National Climatic Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html, 2005). Hourly precipitation data for each of the months sampled were analyzed in this study.

Phytoplankton

High-performance liquid chromatography (HPLC) was used to determine chemosystematic photosynthetic pigment concentrations for the phytoplankton community of South Bay. Three replicate phytoplankton pigment samples were collected from each sampling site. Seawater (200 mL) was filtered through a Gelman filter funnel onto 47 mm Whatman GF/F filters using a vacuum pump at a pressure of 130 kPa or less. The filters were placed in polypropylene microcentrifuge tubes (2 mL) which were wrapped in aluminum foil and stored in the dark on dry ice for transport back to the laboratory. Twenty-four hours prior to HPLC analysis, the filters were sonicated with approximately one mL of 100 % acetone for pigment extraction. The microcentrifuge tubes containing the filters and acetone were kept in the dark and stored at -20°C until extraction was complete. After extraction, the supernate was filtered through a 0.45 µm PTFE filter (Gelman Acrodisc). A known volume of the extract, usually 0.5 to 0.75 mL, was dispensed into two mL amber glass autosampler vials. Just prior to the HPLC run, an ion-pairing (IP) solution (1.00 M ammonium acetate) was added to the vial in a ratio of three parts extract to one part ammonium acetate. The HPLC vials were sealed with teflon-lined caps and placed in the refrigerated (2°C) autosampler rack. The sample (375 µL) was injected into a Shimadzu HPLC equipped with a monomeric (Rainin Microsorb-MV, 0.46 x 10 cm, 3 µm) and a polymeric (Vydac 201TP, 0.46 x 25 cm, 5 µm) reverse-phase C_{18} column in series. A nonlinear binary gradient was used for pigment separations (for details, see Pinckney *et al*., 1996).

Absorption spectra and chromatograms (440 nm) were acquired using a Shimadzu SPD-M10av photodiode array detector. Pigment peaks were identified by comparison of retention times and absorption spectra with pure crystalline standards, including chlorophylls *a*, *b*, beta-carotene (Sigma Chemical Company), fucoxanthin, and zeaxanthin (Hoffman-LaRoche and Company). Other pigments were identified by comparison to extracts from phytoplankton cultures and quantified using the appropriate extinction coefficients (Jeffrey *et al.*, 1997).

Unfortunately, the photodiode array detector was not functioning optimally due to a failing tungsten lamp, so the resultant chromatograms had some baseline noise. Therefore, the chromatograms were analyzed conservatively, and only the fucoxanthin and chlorophyll *a* pigments with peak areas in excess of 50,000 were quantified and further analyzed.

Benthic Microalgae

Chemosystematic photosynthetic pigment concentrations for the benthic microalgal community of South Bay were determined in a similar manner to the phytoplankton pigment concentrations. Five replicate sediment cores were collected from the designated sampling sites within each of the strata. One core was taken from each of the five replicate benthic grabs randomly selected in approximately a five square meter area. Butyrate tubing of one cm diameter was used as a core to collect the top few cm of sediment and the benthic microalgae. The cores were stored in the dark on dry ice during transport back to the laboratory. The upper three mm of each of the cores was extruded, sectioned, placed in microcentrifuge tubes (2 mL) and stored at -80 °C. For HPLC analyses, sediment samples were placed in two mL of 100% acetone, sonicated, and extracted at -20 °C for 18 to 20 h. Filtered extracts (300 µL) were injected into the Shimadzu HPLC and analyzed as described previously for the phytoplankton pigment analyses. However, the resultant chromatograms did not have as much baseline noise as the chromatograms for the phytoplankton samples. The benthic microalgal pigment peaks were identified by comparison of retention times and absorption spectra to standards and cultures.

Only four of the benthic microalgal pigments were analyzed in this study because they represented the algal groups of interest. Chlorophyll *a* concentrations represented the total biomass of all major microalgal groups. Fucoxanthin concentrations represented the diatom biomass, zeaxanthin concentrations represented the cyanobacterial biomass, and chlorophyll *b* concentrations represented the euglenophyte and chlorophyte biomass (Piippola and Kononen, 1995; Pinckney *et al.*, 1999).

The percentages of the phytoplankton to microphytobenthic photopigment concentrations were calculated to compare the biomass of each of these communities and determine their relative importance in the food web. In order to do this, the phytoplankton concentrations (µg/L, which is equal to mg/m^3) were converted into units of mg/m^2 by multiplying by the water depth. Since water depth was not one of the physicochemical factors measured in this study, an average water depth of one meter was used for this conversion. The microphytobenthic concentrations (ng/cm^2) were multiplied by 10 to convert the units into mg/m^2. Fucoxanthin and chlorophyll *a* concentrations were the only two photopigments that were analyzed for both the phytoplankton and microphytobenthos, so these were the only two used in this biomass comparison. The percentages were averaged for each stratum and month sampled. Additionally, the overall mean percentage for all locations and sampling months was calculated to compare the phytoplankton to the microphytobenthic biomass.

Zooplankton

Three replicate samples of seawater (100 L) were collected at each sampling site using a 10 L bucket. The water was filtered through a zooplankton net having an approximate mesh size of 500 µm. The captured zooplankton were fixed with five percent buffered formalin. In the laboratory, samples were filtered through a 63 µm mesh sieve and preserved in alcohol.

All zooplankters were identified to species level where possible. Some specimens could not be identified to this level because they were either too small, too mangled, or a juvenile that did not exhibit enough adult characteristics to be correctly identified. Therefore, these specimens were identified to the lowest possible taxon. The number of individuals per 100 L was converted to the number of individuals per cubic meter in order to compare results with the literature. The least abundant specimens which were those with total abundances less than 1,000 individuals per cubic meter for all replicates and dates sampled were not used in the statistical analyses. The most abundant groups of zooplankton (those with total abundances exceeding 1,000 individuals per cubic meter for all replicates and dates sampled) and the total number of zooplankton were used in statistical analyses to determine if and where significant spatial and temporal differences existed.

The copepod abundances were further divided into their respective orders: Calanoida, Cyclopoida, and Harpacticoida. The abundances for these three orders and their juvenile counterparts were examined statistically to see if and where significant spatial and temporal trends occurred. Additionally, the percentages of the individual taxa abundance to the total copepod abundance and the total order abundance were calculated. This provided an estimate of the contribution of each individual species or taxonomic group to the total abundances. Furthermore, sex was determined where possible for the copepods. The percentage of males and females for the individual species were compared.

Statistical Analyses

Several statistical analyses were performed by the use of SPSS 11.0 software to test the null hypotheses. Univariate and multivariate analysis of variance (ANOVA and MANOVA) tests were performed on the physicochemical factors (air and water temperatures, salinity, dissolved oxygen and turbidity) and the biological data (microalgal pigment concentrations and composition and zooplankton species abundances and composition) to determine if and where significant spatial differences existed across strata and if and where significant temporal differences existed over the sampling period of one year. For these ANOVAs, the month sampled was one of the fixed factors with six levels (February, April, June, August, October, and December) and stratum was the other fixed factor with six levels (Strata 1, 2, 3, 4, 5, and 6). Kolmogorov-Smirnov (K-S) tests were conducted on all variables to test for normality with a p-value set at 0.05. The K-S test with a p-value set at 0.05 was also used to determine if the residuals were normally distributed for each variable. If there was more than one value for each factor level combination, Levene's test was utilized to determine if variances were homogeneous. In cases where variables were not normal, variances were heterogeneous and/or residuals were not normally distributed, the more conservative Dunnett's T3 nonparametric *post hoc* test was utilized to determine where significant differences existed. In other cases where the assumptions of the ANOVA were satisfied, the Bonferroni *post hoc* test was used to indicate where significant differences existed.

Nonparametric Spearman's rank order correlation analyses were conducted on the physicochemical factors and the biological data to determine if any significant relationships existed between them. Replicates for the physicochemical factors were not collected, but the biological data had replication. The phytoplankton pigment concentrations and the zooplankton abundances had three replicates, while the benthic microalgal pigment concentrations had five replicates. The mean of these replicates was calculated and used with the physicochemical factors to produce bivariate data for the correlation analyses. Correlation analyses were performed on the biological data to determine if and where significant relationships existed among the plankton abundances.

In order to test if wind-induced resuspension had a significant effect upon the location of microalgae in the water column compared to the sediments, the nonparametric Spearman's rank order correlation analysis between turbidity and the historical wind speed data was performed. This correlation indicated if turbidity was related to wind speed and, if so, in what capacity.

Ratios of microalgal pigments to chlorophyll *a* concentrations were calculated and compared to the turbidity and wind speed data. The ratio of fucoxanthin to chlorophyll *a* was calculated for the phytoplankton and used to represent the concentration of diatoms in the water column. The ratios of benthic microalgal fucoxanthin, zeaxanthin, and chlorophyll *b* to chlorophyll *a* were calculated. These ratios were representative of benthic diatom, cyanobacteria, and chlorophyte and euglenophyte concentrations, respectively. These ratios were then used in a nonparametric Spearman's correlation analysis to determine if these algal groups were related to the turbidity and the historical wind speed data. The locations of these algal groups in the water column compared to the sediments during wind-induced resuspension events was inferred from the significant relationships with turbidity and wind speed as revealed by the correlation analyses.

RESULTS

Physicochemical Data

Salinities, air and water temperatures, and dissolved oxygen concentrations varied seasonally during 2004 in South Bay (Table II). Hypersaline conditions occurred during August and October (Figure II a). The ANOVA revealed that August salinity values were significantly different than all other months sampled except October ($p<0.05$, Table II). Significantly warmer water and air temperatures were observed during the summer and fall months of June, August and October (Figure II b & c, respectively). The dissolved oxygen levels were significantly higher in the winter months of February and December than levels in the other months sampled. The only exception is that October dissolved oxygen levels were not significantly different from February dissolved oxygen levels (Figure II d). Conversely, turbidity values did not exhibit a significant seasonal trend, but were variable throughout the year (Figure II e).

Table II. Homogeneous groups across sampling month and strata for the physicochemical factors as indicated by the Bonferroni multiple comparisons test.

Physicochemical Factor	**Homogeneous Groups for Sampling Month and for Strata** (indicated by an underline)					
Salinity (ppt)	Aug	Oct	Jun	Apr	Dec	Feb
	____	____				
		____	____	____	____	____
	4	6	3	5	1	2
	____	____	____	____	____	____
Water Temperature (°C)	Aug	Jun	Oct	Apr	Dec	Feb
	____	____	____			
	4	5	6	3	1	2
	____	____	____	____	____	____
Air Temperature (°C)	Aug	Jun	Oct	Dec	Apr	Feb
	____	____	____			
				____	____	
	3	4	5	6	2	1
	____	____	____	____	____	____
Dissolved Oxygen (mg/L)	Dec	Feb	Oct	Apr	Jun	Aug
	____	____				
		____	____			
			____	____	____	____
	4	5	2	1	6	3
	____	____	____	____	____	____
Turbidity (NTU)	Aug	Feb	Jun	Dec	Apr	Oct
	____	____	____	____	____	____
	6	2	3	1	4	5
	____	____	____	____	____	____

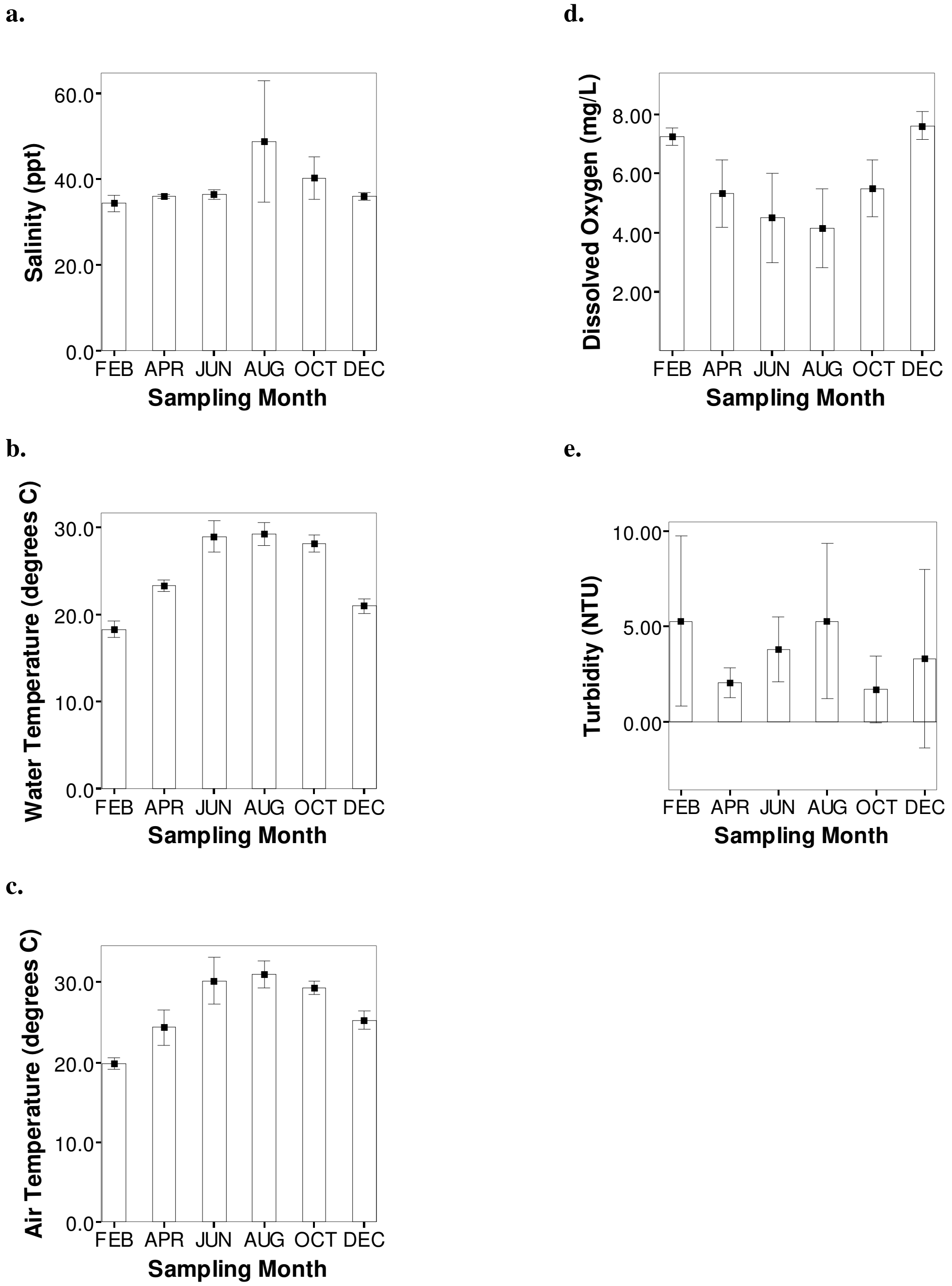


Figure II. Means of the physicochemical variables salinity (**a**), water temperature (**b**), air temperature (**c**), dissolved oxygen (**d**), and turbidity (**e**) observed during bimonthly sampling in 2004. Error bars represent the 95% confidence intervals.

Salinity, water and air temperatures, dissolved oxygen, and turbidity values did not differ spatially across South Bay (Figure III). The ANOVA further revealed that location within South Bay did not have a significant effect upon the physicochemical variables (p>0.05, Table II).

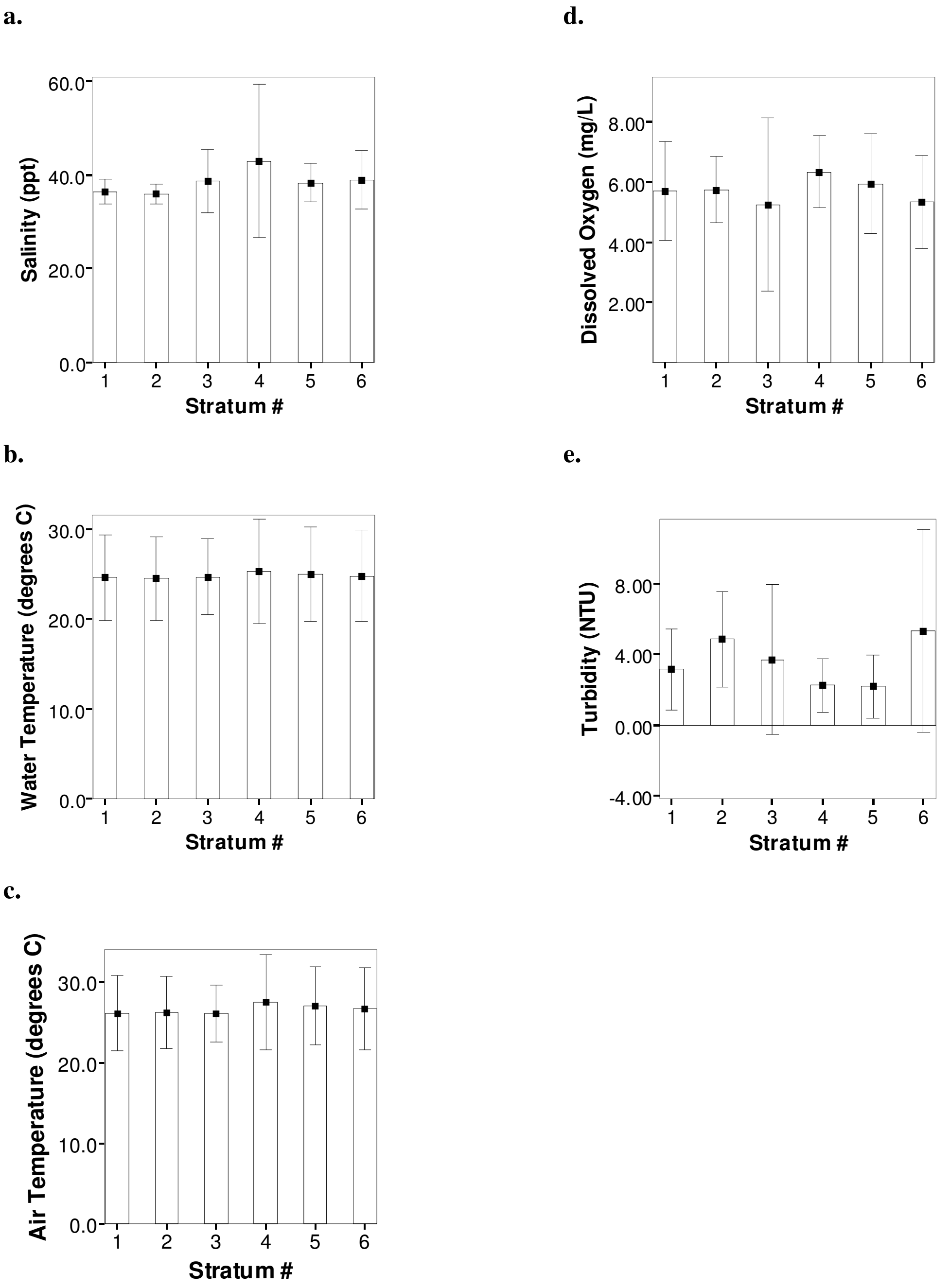


Figure III. Means of the physicochemical variables salinity (**a**), water temperature (**b**), air temperature (**c**), dissolved oxygen (**d**), and turbidity (**e**) observed across strata in South Bay, TX, USA. Error bars represent the 95% confidence intervals.

Several significant relationships existed between the physicochemical factors ($p<0.05$, Table III). Salinity exhibited a significant positive correlation with both water and air temperature, while water and air temperature were also positively correlated with each other (Figure IV a-c). Salinity, water temperature and air temperature were all negatively correlated with dissolved oxygen (Figure IV d-f). The salinity value of 74.6 ppt that appeared as an outlier was a real value obtained during an extreme high tide in August over the shallower shoal areas that were not normally accessible by boat (Figure IV a, b and d).

Table III. Results of the nonparametric Spearman's rank order correlation analyses between the physicochemical factors and the mean phytoplankton pigment concentrations.

	r_s and p	**Salinity (ppt)**	**Water Temperature (°C)**	**Air Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**Turbidity (NTU)**	**Fucoxanthin (µg/m^3)**
Salinity (ppt)	r_s						
	p						
Water Temperature (°C)	r_s	.697					
	p	.000*					
Air Temperature (°C)	r_s	.722	.942				
	p	.000*	.000*				
Dissolved Oxygen (mg/L)	r_s	-.441	-.585	-.438			
	p	.007*	.000*	.008*			
Turbidity (NTU)	r_s	-.053	.089	.040	-.152		
	p	.759	.604	.815	.376		
Fucoxanthin (µg/L)	r_s	.206	.145	.132	-.106	.393	
	p	.229	.398	.442	.537	.018*	
Chlorophyll *a* (µg/L)	r_s	.008	-.020	-.067	-.064	.374	.940
	p	.965	.908	.697	.710	.025*	.000*

* denotes significance with a p-value ≤ 0.05

Tides in South Bay varied from diurnal to semidiurnal to mixed for all of the weeks prior to the sampling dates. For the week of February 21-28, the tides shifted from a mixed semidiurnal tide to a diurnal tide on the day sampled (Figure V a). During the week of April 21-28, a steady diurnal tide persisted for the entire week prior to the sampling date (Figure V b). The tides shifted from a slightly mixed semidiurnal tide to a steady diurnal tide prior to the sampling date for the week of June 12-19 (Figure V c). For the week of August 12-19, the tides changed from a steady diurnal tide to a mixed semidiurnal tide on the day sampled (Figure V d). The tides shifted from a diurnal to a mixed semidiurnal tide prior to the sampling date during the week of October 20-27 (Figure V e). For the week of November 28-December 5, the tides changed from diurnal to a slightly mixed semidiurnal tide on the date sampled (Figure V f).

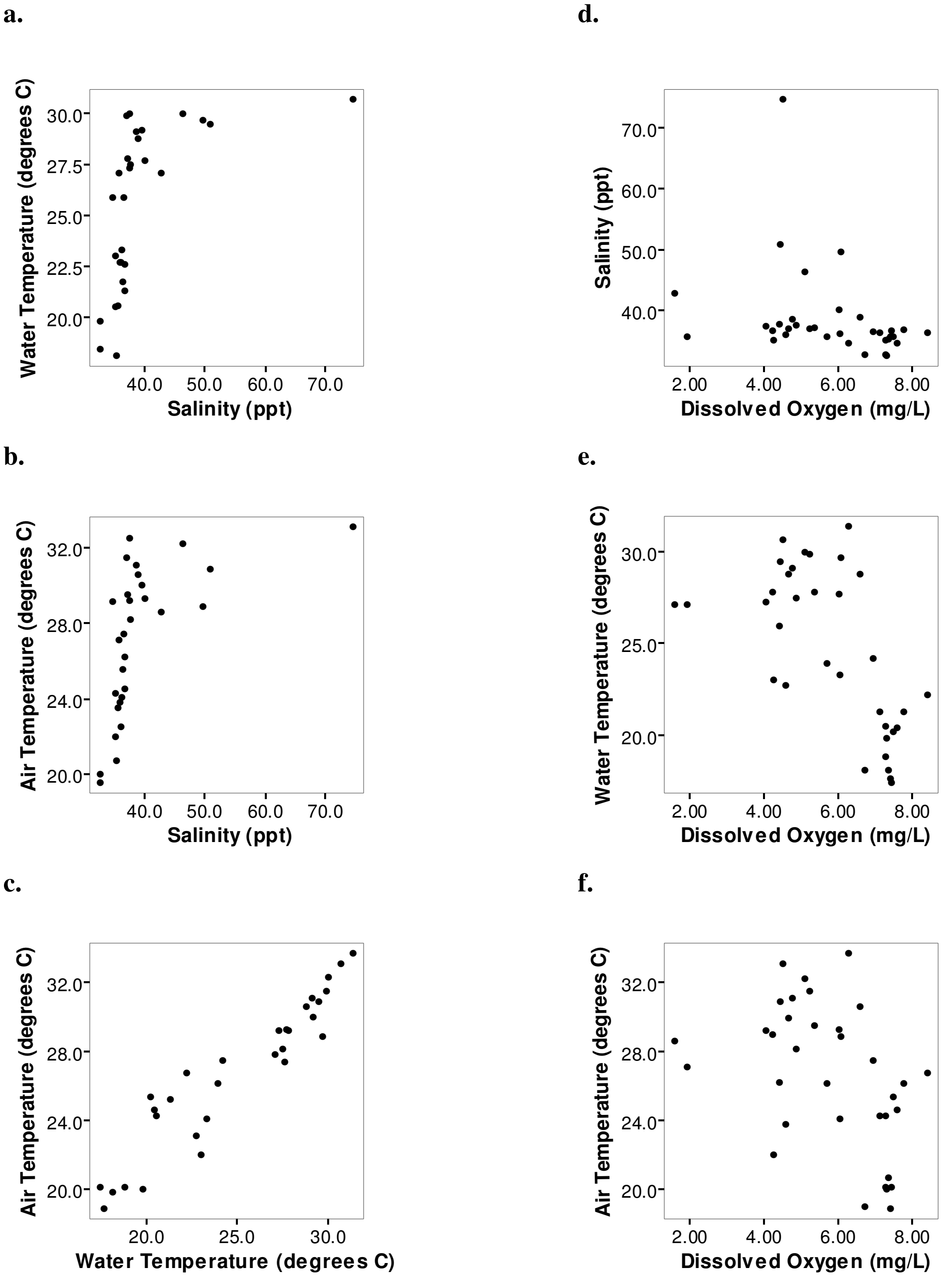


Figure IV. Significant correlations among the physicochemical factors. Salinity vs. water temperature (**a**), salinity vs. air temperature (**b**), water temperature vs. air temperature (**c**), salinity vs. dissolved oxygen (**d**), water temperature vs. dissolved oxygen (**e**), and air temperature vs. dissolved oxygen (**f**).

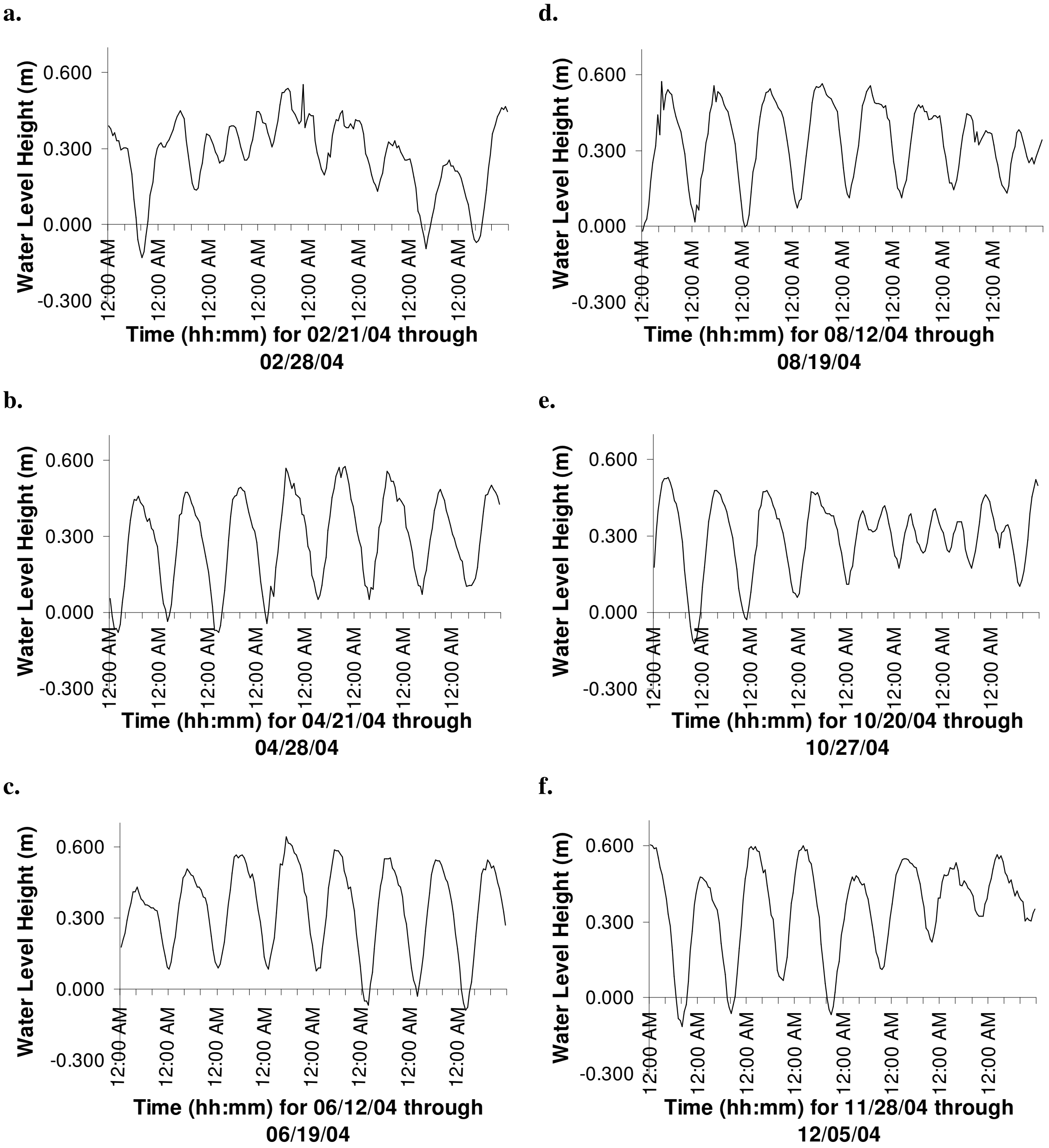


Figure V. Hourly tidal data from the NOAA CO-OPS Port Isabel, TX station for one week prior to the sampling dates. February 21-28, 2004 (**a**), April 21-28, 2004 (**b**), June 12-19, 2004 (**c**), August 12-19, 2004 (**d**), October 20-27, 2004 (**e**), and November 28-December 5, 2004 (**f**).

Both diurnal and mixed semidiurnal tides were observed on the days sampled. Diurnal tides occurred on the day sampled for February, April and June (Figure VI a-c). A slightly mixed semidiurnal tide occurred on the December sampling date (Figure VI f). Definitive mixed semidiurnal tides occurred on the sampling dates for August and October (Figure VI d and e).

The magnitude of the high and low tides for each sampling date were approximately the same given a few exceptions. The high tides for all sampling dates were approximately 0.5 m except the August 19th high tide which was slightly lower at approximately 0.4 m (Figure VI d). The low tides for almost all sampling dates were approximately 0.1 m. However, February and June low tides were quite a bit lower in magnitude at approximately -0.1 m (Figure VI a and c). Additionally, the low tide for December 5th was considerably higher at 0.3 m (Figure VI f).

Over the course of the year sampling was conducted during both flooding and ebbing tides of the tidal cycle. Not all areas of the bay were navigable by boat due to the shallow depths during ebbing tides, so the shallower sampling locations were usually sampled during the flooding tides. Some areas of the bay experienced shallow depths that were inaccessible by boat during both phases of the tidal cycle. Therefore, the first sampling location for each stratum chosen by the random number generator was not always used. In that case, the next possible location listed by the random number generator for that particular stratum was used as the sampling site. For February 28th and April 28th, sampling began at approximately the slack low tide and continued on through the flooding tide (Figure VI a-b). On June 19th and August 19th , sampling commenced during the flooding tide and ended around slack high tide for the June sampling date (Figure VI c), but continued on through the slack high tide and ceased during the beginning of the ebbing tide for the August sampling date. Sampling was conducted during the larger magnitude tide of the two tidal cycles that comprised the mixed semidiurnal tide on the August sampling date (Figure VI d). For October 27th, sampling was conducted during the lesser magnitude tide of the two tidal cycles that comprised the mixed semidiurnal tide on this day. Sampling commenced during the ebbing tide, continued on through the slack low tide, and ended during the beginning of the flooding tide (Figure VI e). Sampling on December 5th was conducted during a progressively ebbing tide. However, slight flooding may have occurred during sampling at Strata 1, 4 and 6 (Figure VI f).

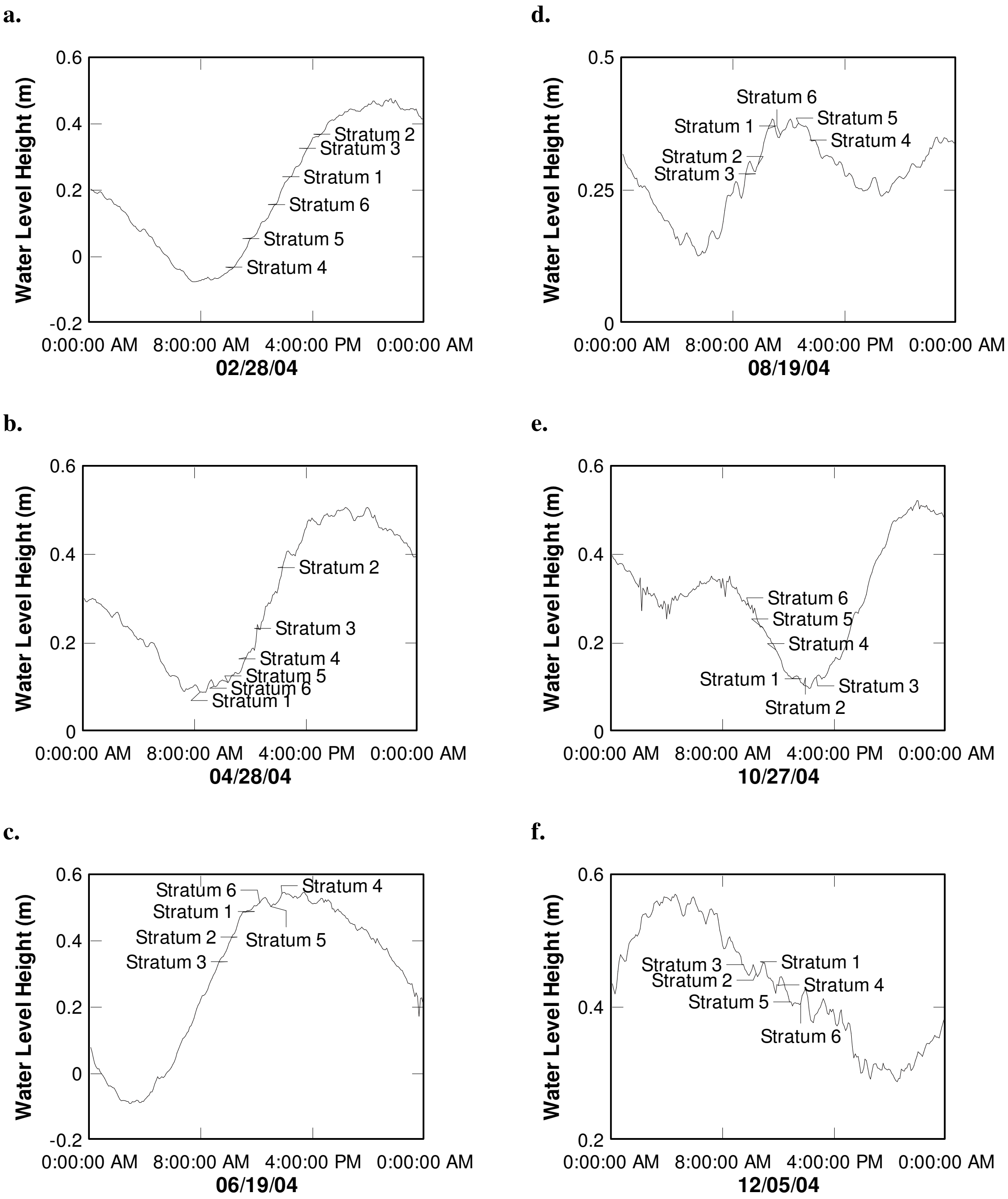


Figure VI. Six-minute tidal data from the NOAA CO-OPS Port Isabel, TX station for the sampling dates of February 28, 2004 (**a**), April 28, 2004 (**b**), June 19, 2004 (**c**), August 19, 2004 (**d**), October 27, 2004 (**e**), and December 5, 2004 (**f**).

Hourly wind speed data obtained from the NOAA CO-OPS Port Isabel, TX station for the week prior to the sampling date were variable. No consistent trends were observed when comparing the weekly data. Both increases and decreases in wind speeds were variable throughout the week prior to the date sampled for all sampling months (Figure VII).

Wind directions were variable for the week prior to the dates sampled. Consistent southeast winds were observed several days prior to the sampling dates in June and August (Figure VII c and d), and throughout the entire week prior to the sampling date in October (Figure VII e). Southeast winds were also observed one day prior to the sampling date in February (Figure VII a). The wind directions fluctuated for the day prior to the sampling date in April. These winds shifted from a northwest wind, to a northeast wind, and then to a southeast wind on the day sampled (Figure VII b).

a.

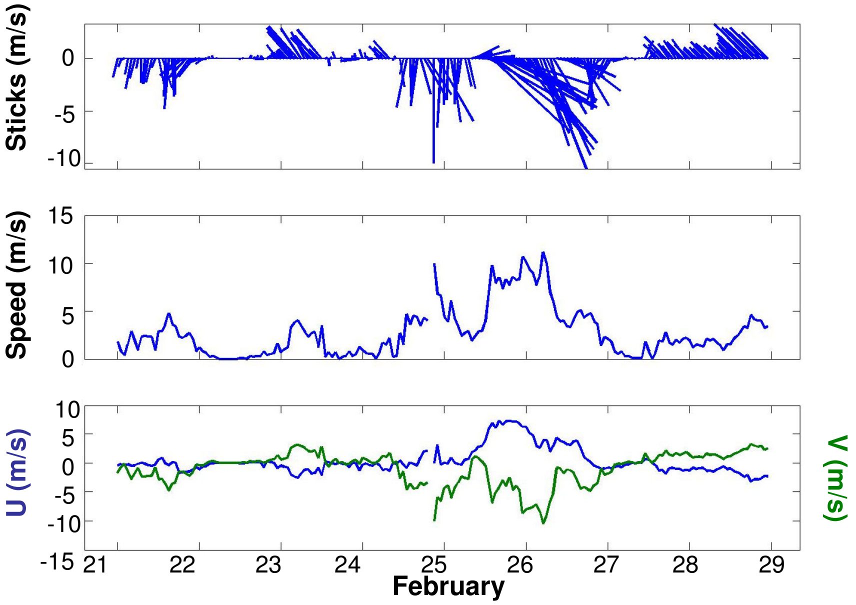


Figure VII. Hourly wind speed (m/s) and wind direction data from the NOAA CO-OPS Port Isabel, TX station for one week prior to the sampling dates. February 21-28, 2004 (**a**), April 21-28, 2004 (**b**), June 12-19, 2004 (**c**), August 12-19, 2004 (**d**), October 20-27, 2004 (**e**), and November 28-December 5, 2004 (**f**). U and V represent the east-west and the north-south component, respectively. A positive U indicates a west wind, a negative U indicates an east wind, a positive V indicates a south wind and a negative V indicates a north wind.

Northwest winds dominated the day prior to the sampling date in December. Southwest winds were observed at the beginning of the day sampled, but these shifted to northwest winds temporarily, and then to southeast winds at the end of the day (Figure VII f).

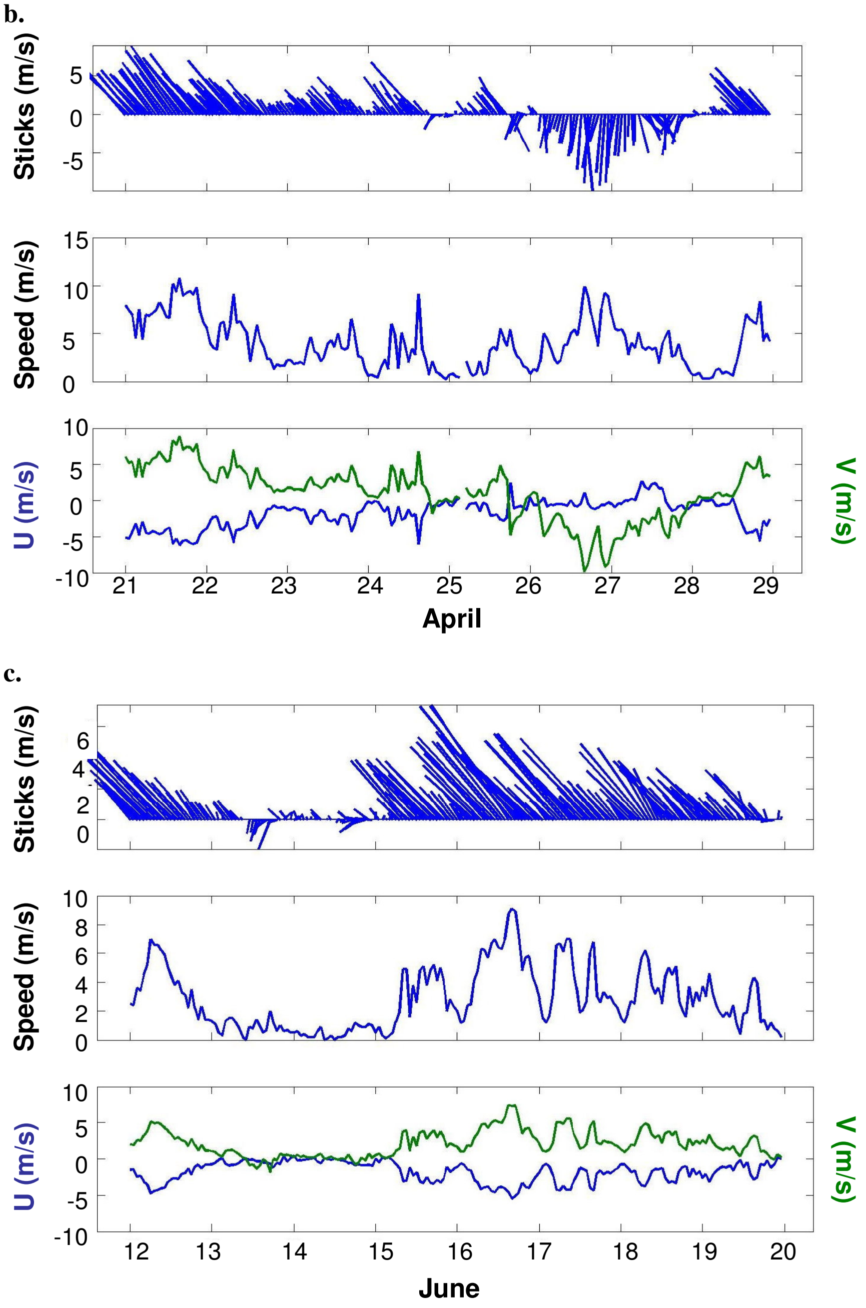
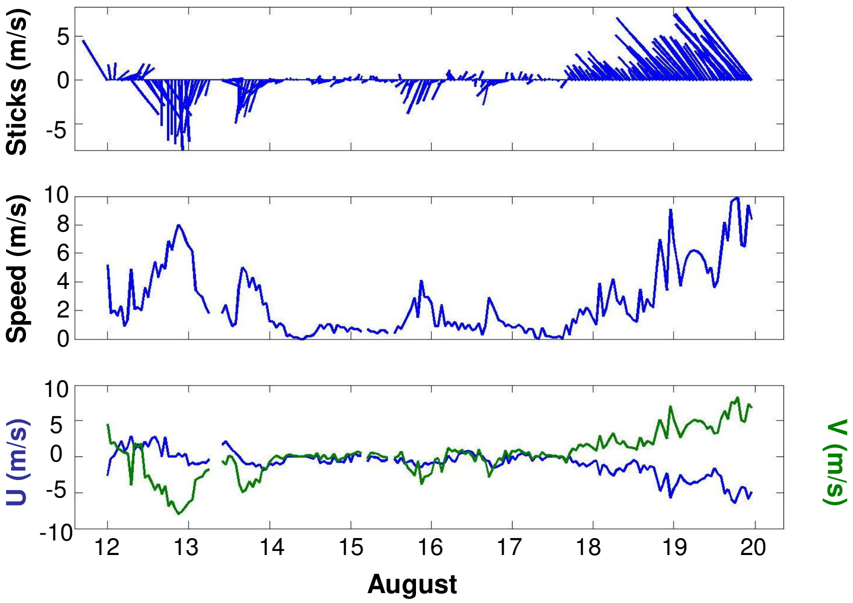


Figure VII. Continued.

d.



e.

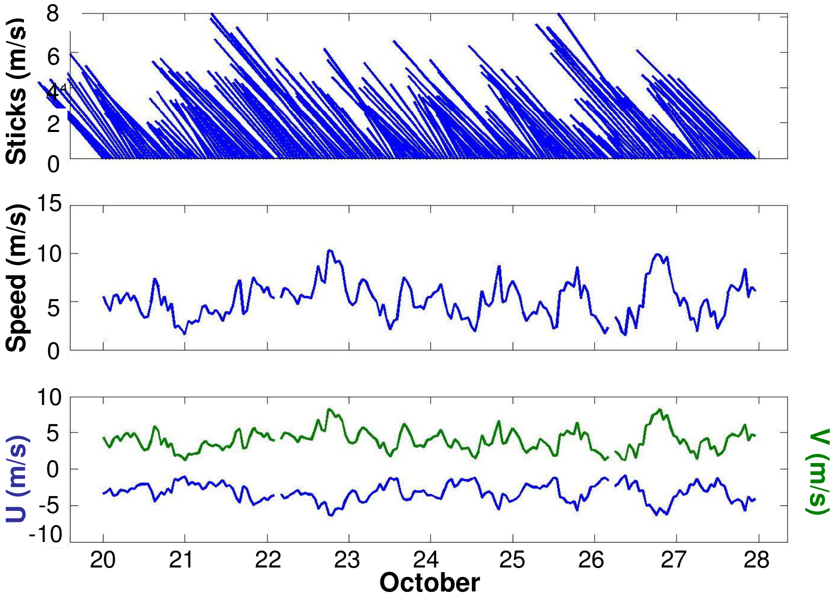


Figure VII. Continued.

f.

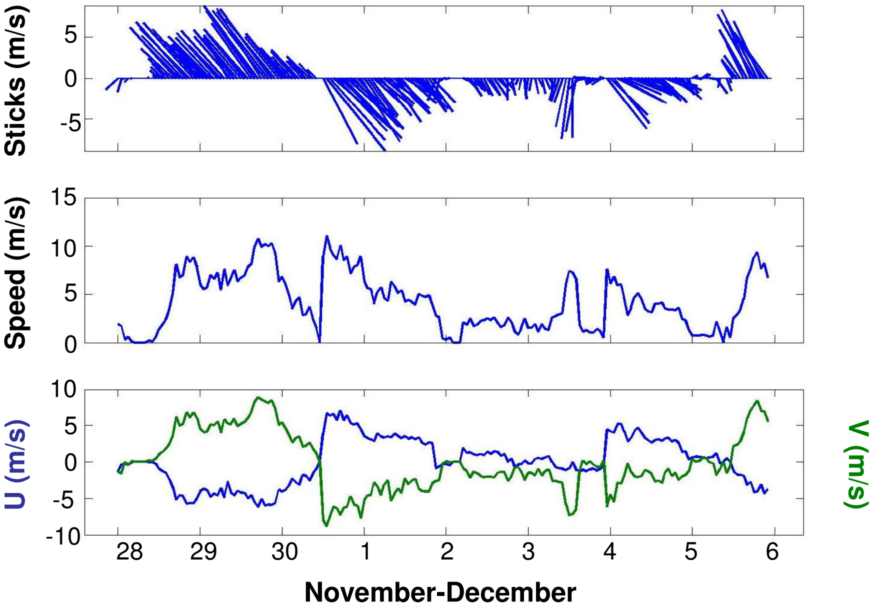
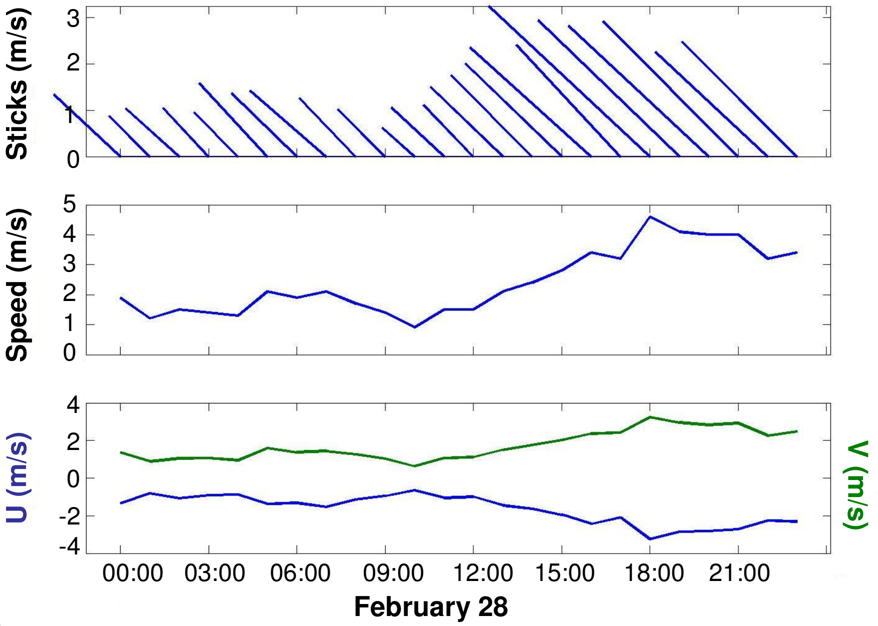


Figure VII. Continued.

The hourly wind speed data for each date sampled revealed a consistent increase in the wind speed in the afternoon. Wind speeds were variable in the mornings. August 19th and October 27th morning wind speeds were higher than morning wind speeds in the other months sampled (Figure VIII). The highest overall wind speeds were observed in the afternoons of August 19th and December 5th, 2004 (Figure VIII d and f).

Wind directions for every sampling date were predominately southeast winds (Figure VIII). The winds in the early morning of April 28th were more variable and shifted from northeast to southeast winds (Figure VIII b). The winds in the early morning of December 5th shifted from northwest to north, then to southeast winds (Figure VIII f). Winds in the evening of June 19th were out of the southeast, but began to shift to easterly winds and then to southerly winds (Figure X c). Because all field surveys were conducted between 8:00am and 4:00pm, these deviations from the dominant southeast winds did not occur during the times sampled.

a.



b.

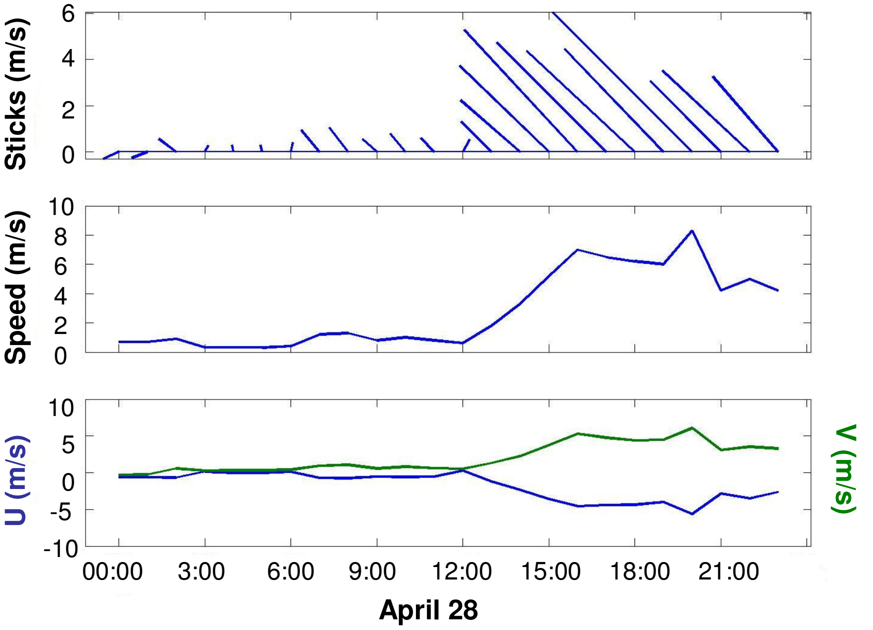


Figure VIII. Hourly wind speed (m/s) and wind direction recorded from the NOAA CO-OPS Port Isabel, TX station for the sampling dates of February 28, 2004 (**a**), April 28, 2004 (**b**), June 19, 2004 (**c**), August 19, 2004 (**d**), October 27, 2004 (**e**), and December 5, 2004 (**f**). U and V represent the east-west and the north-south component, respectively. A positive U indicates a west wind, a negative U indicates an east wind, a positive V indicates a south wind and a negative V indicates a north wind.

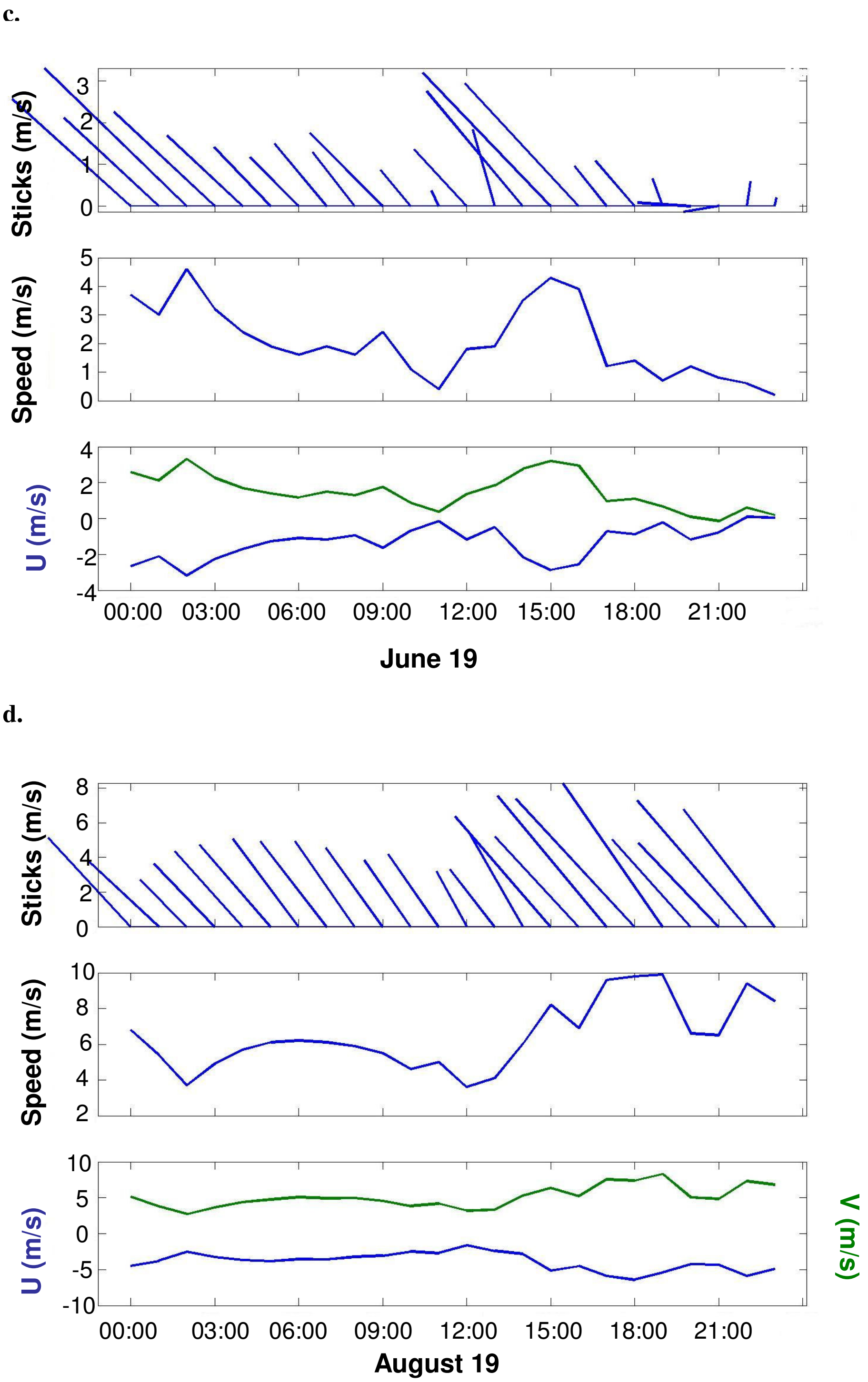
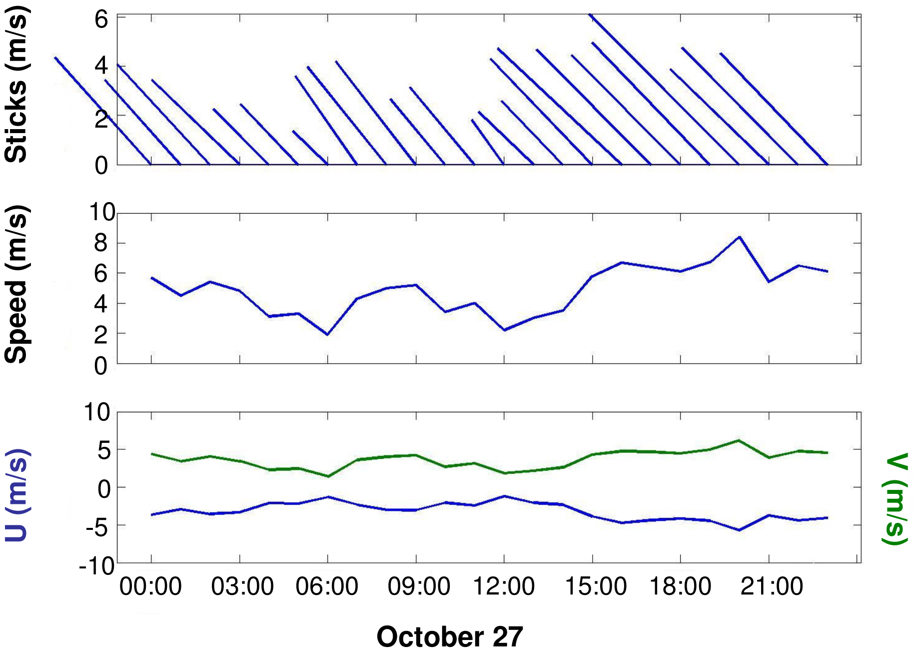


Figure VIII. Continued.

e.



f.

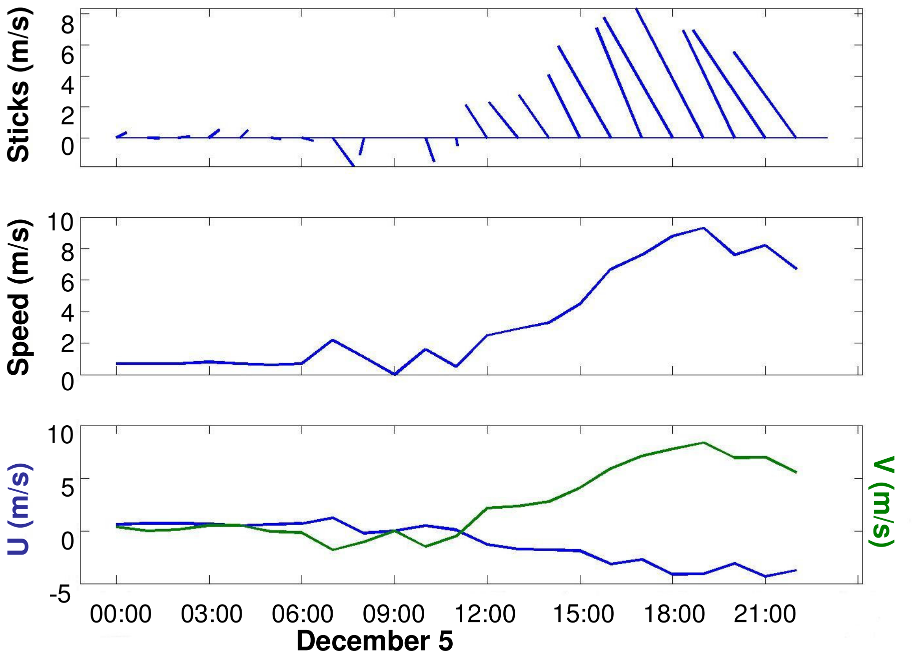


Figure VIII. Continued.

Only a few of the dates sampled experienced precipitation during the week prior to field surveys. Slight precipitation occurred the week prior to the February 28th sampling date (Figure IX a). About one centimeter of precipitation fell three days prior to the April 28th sampling date and about one-half of a centimeter of rain fell on the sampling date (Figure IX b). Almost one-half of a centimeter of rain fell the day before the October 27th sampling date (Figure IX e). The week prior to the sampling dates for June, August, and December experienced no precipitation (Figure IX c, d and f). An atypical snowfall occurred on December 25th, but because it occurred after the December sampling date, it had no bearing on this study (Figure IX f).

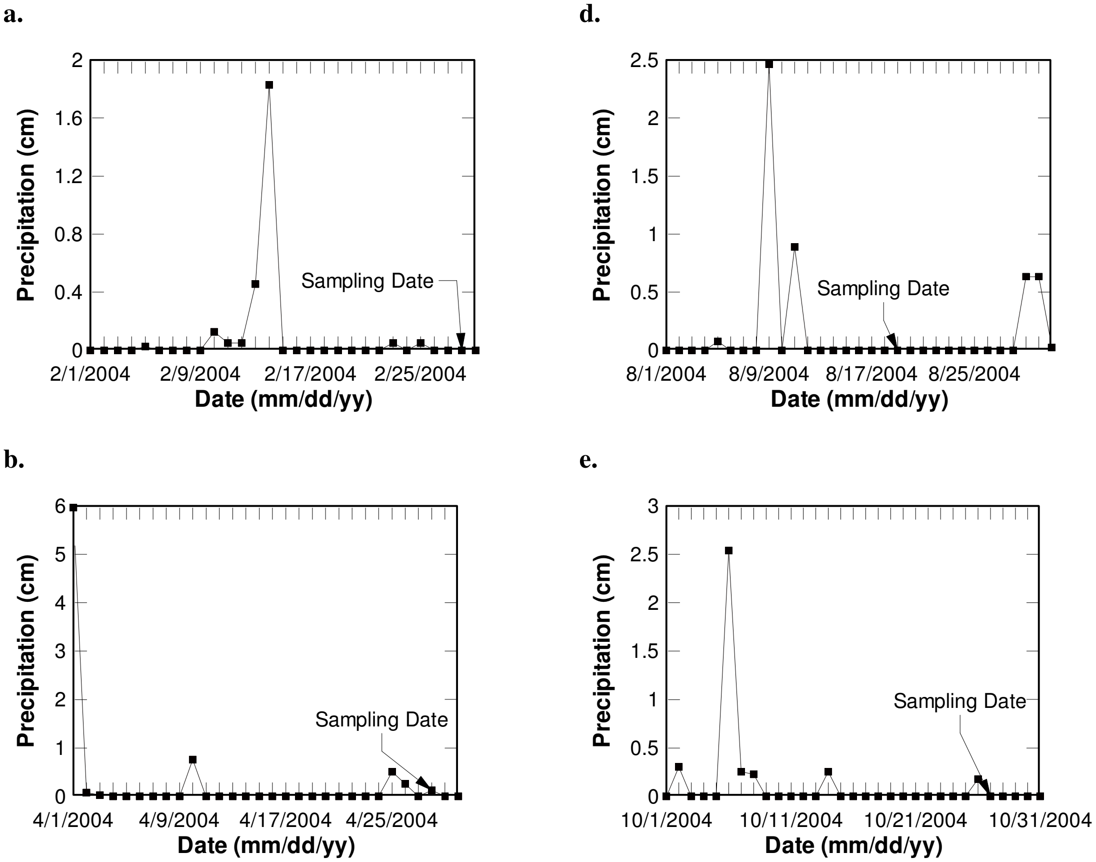


Figure IX. Hourly precipitation data (cm) from the NOAA NCDC Port Isabel, TX station during the sampling months of February (**a**), April (**b**), June (**c**), August (**d**), October (**e**), and December (**f**).

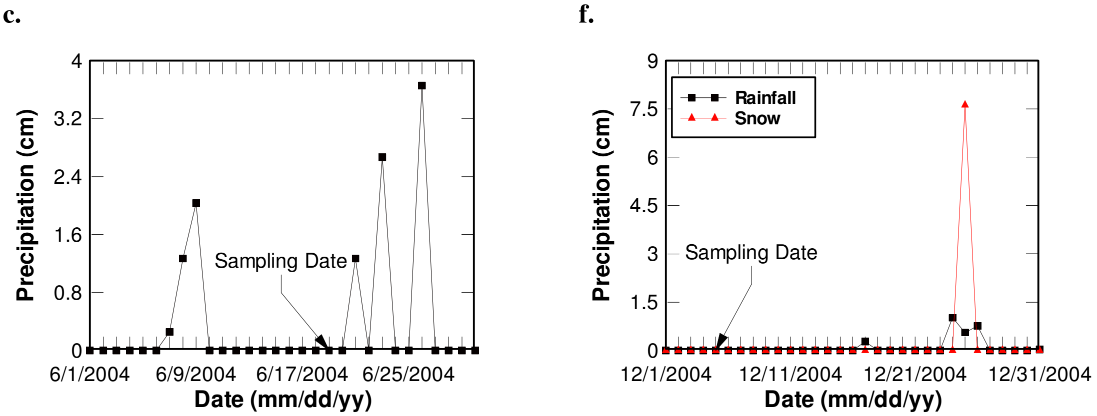


Figure IX. Continued.

Phytoplankton Pigment Data

Chlorophyll *a* concentrations (µg/L) represented all phytoplankton biomass and varied across sampling months with higher values observed during August and October (Figure X a). The ANOVA further supported this by indicating that sampling month had a significant effect on chlorophyll *a* concentrations ($p<0.05$). Chlorophyll *a* concentrations peaked in February, albeit insignificantly, declined in spring and early summer, peaked again in August and October, then declined again in December (Figure X a). August and October chlorophyll *a* concentrations were significantly higher than concentrations observed in April, but not significantly higher than concentrations during the other months sampled (Table IV, $p<0.05$).

Chlorophyll *a* concentrations exhibited a distinct spatial pattern across South Bay. Strata 1 and 2 had significantly higher chlorophyll *a* concentrations than the other strata of the bay ($p<0.05$, Figure X b). Stratum 2 encompasses the opening of the bay and Stratum 1 is just east of this inlet (Figure I).

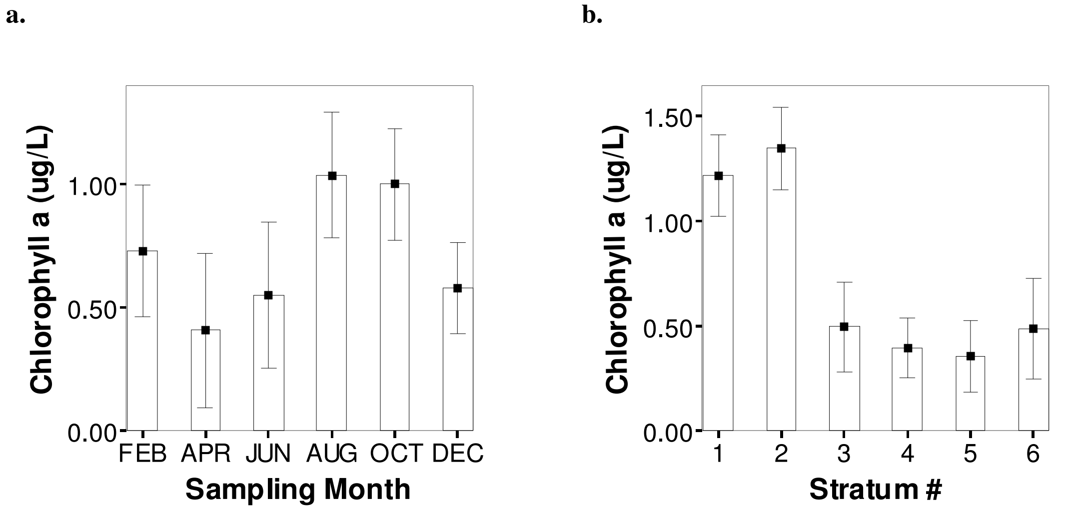


Figure X. Mean phytoplankton chlorophyll *a* concentrations (µg/L) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent the 95% confidence intervals.

Table IV. Homogeneous groups across sampling month and strata for the phytoplankton pigments fucoxanthin and chlorophyll *a* as indicated by the Dunnett's T3 multiple comparisons test.

Phytoplankton Pigment (µg/L)	**Homogeneous Groups across Sampling Month and Strata** (indicated by an underline)					
Fucoxanthin	Feb	Oct	Aug	Jun	Dec	Apr
	1	2	3	6	5	4
Chlorophyll *a*	Aug	Oct	Feb	Dec	Jun	Apr
	2	1	3	6	4	5

Chlorophyll *a* concentrations varied both as a function of location within South Bay and the time of year (Figure XI). For example, chlorophyll *a* concentrations for Stratum 2 were the highest for April, August and October, but lower than chlorophyll *a* concentrations for Stratum 1 in February, June and December. The ANOVA indicated a significant interaction term which further supported that chlorophyll *a* concentrations varied as a function of strata and sampling month ($p<0.05$).

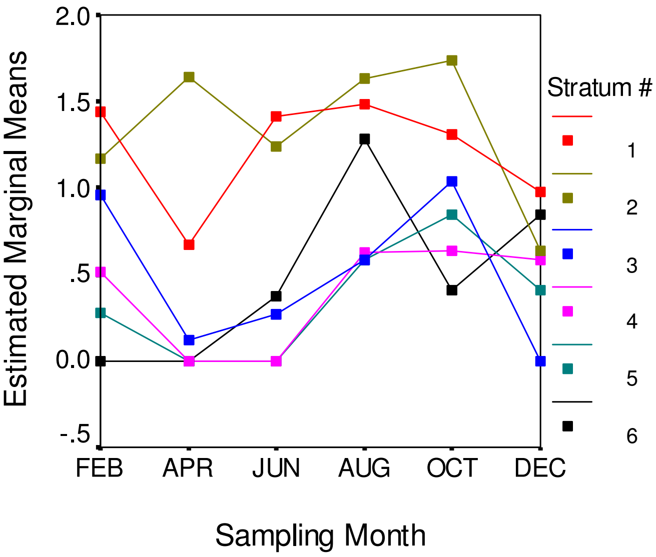


Figure XI. The estimated marginal means of phytoplankton chlorophyll *a* concentrations (µg/L) across strata for all sampling months.

Phytoplankton fucoxanthin concentrations (µg/L) represented diatom biomass and peaked in February, August and October (Figure XII a). The ANOVA results indicated that time of year had a significant effect on fucoxanthin concentrations ($p < 0.05$). However, the Dunnett's T3 nonparametric *post hoc* test revealed that fucoxanthin concentrations were homogeneous across all sampling months ($p > 0.05$, Table IV). Because the nonparametric test is more conservative than the ANOVA, the fucoxanthin pigment concentrations observed over the year were considered homogeneous, at least statistically. Even though no significant temporal variation existed, a seasonal trend in fucoxanthin concentrations was evident over the year and was similar to the seasonal trends in chlorophyll *a* concentrations. Fucoxanthin concentrations tended to be higher in February, declining in the spring and early summer, higher in August and October, and declining again in December (Figure XII a).

Fucoxanthin concentrations exhibited the same spatial pattern as chlorophyll *a* concentrations across strata. Strata 1 and 2, the northeastern and north central sections of South Bay, respectively, exhibited higher fucoxanthin concentrations than the other four strata (Figure XII b). Stratum 2 encompasses the opening of the bay, while Stratum

1 is in closest proximity to this inlet (Figure I). These results concurred with the ANOVA in that strata had a significant effect on fucoxanthin concentrations ($p<0.05$, Table IV).

The fucoxanthin pigment concentrations for a particular month were not always the highest across all strata, just as the concentrations for a particular stratum were not always the highest for all sampling months (Figure XIII). For example, fucoxanthin concentrations for Stratum 1 were highest in February and June through December, but lower than fucoxanthin concentrations for Stratum 2 in April. This indicated that fucoxanthin concentrations were significantly affected by a combination of location within South Bay and the time of year. Furthermore, the ANOVA indicated that the interaction term was significant ($p <0.05$).

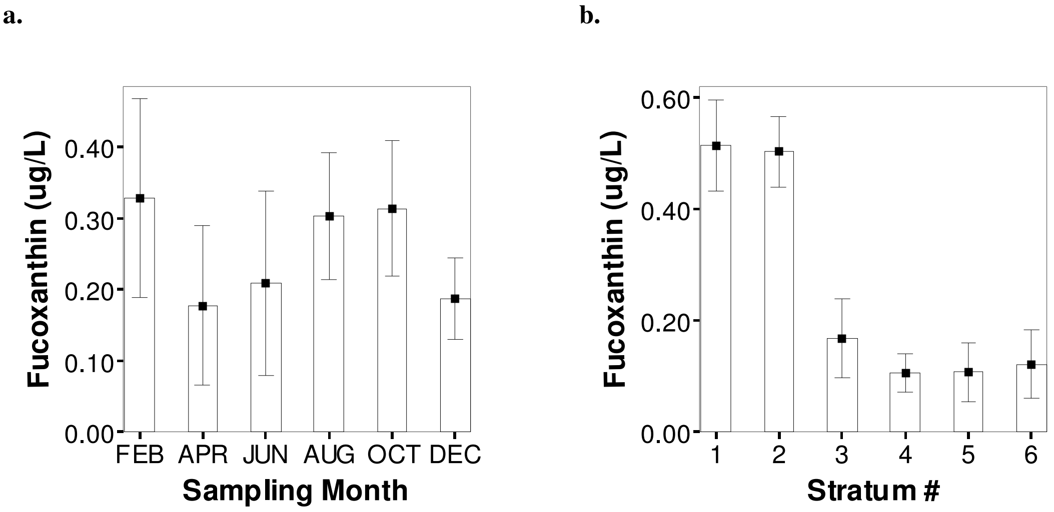


Figure XII. Mean phytoplankton fucoxanthin concentrations (µg/L) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent the 95% confidence intervals.

Mean fucoxanthin and chlorophyll *a* concentrations exhibited a significant correlation with only one of the physicochemical factors, turbidity ($p<0.05$, Table III). Both mean fucoxanthin and chlorophyll *a* concentrations were positively correlated with turbidity (Figure XIV a-b). Additionally, mean fucoxanthin concentrations were directly correlated with mean chlorophyll *a* concentrations ($p<0.05$, Table III, Figure XV).

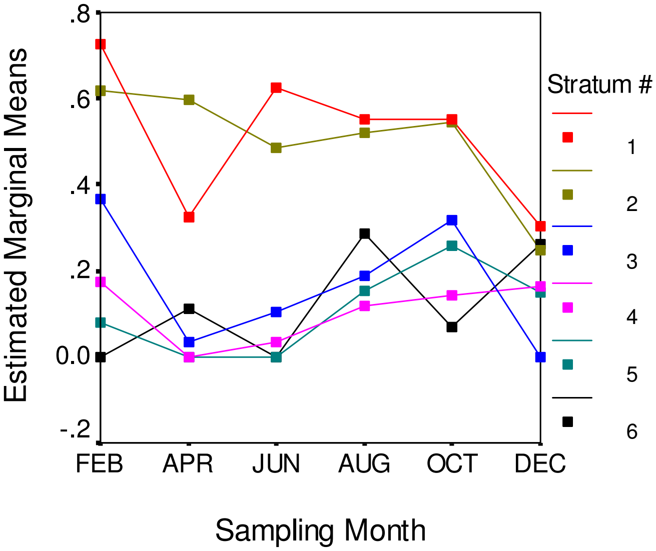


Figure XIII. The estimated marginal means of phytoplankton fucoxanthin concentrations (µg/L) across strata for all sampling months.

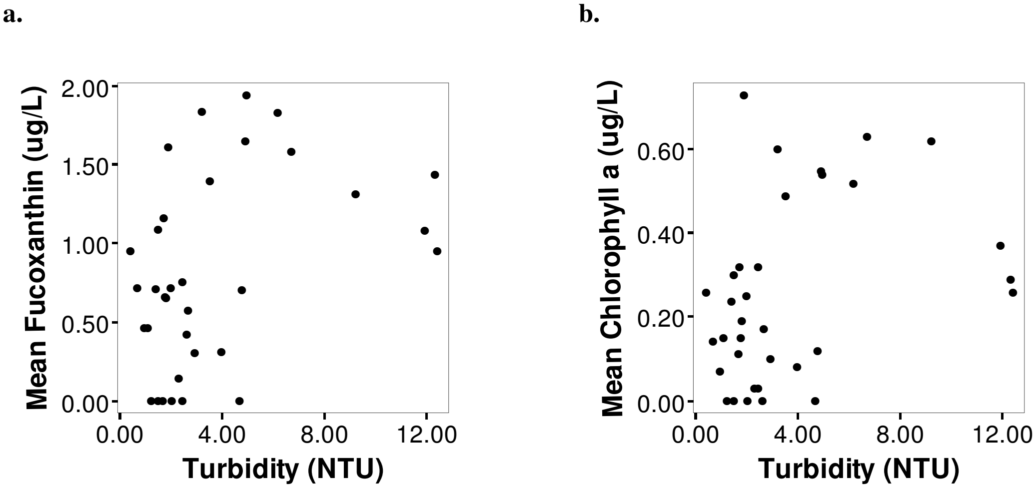


Figure XIV. Mean phytoplankton fucoxanthin (**a**) and chlorophyll *a* (**b**) concentrations (µg/L) as a function of turbidity (NTU) illustrating the significant correlations ($p<0.05$).

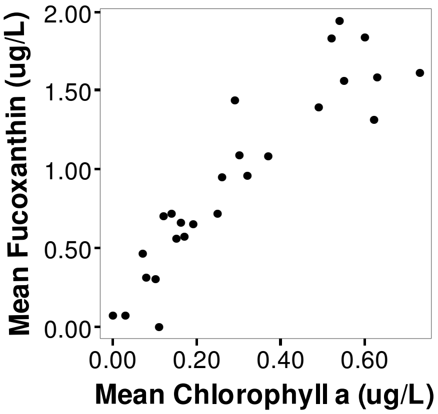


Figure XV. Mean phytoplankton fucoxanthin as a function of mean chlorophyll *a* concentrations (µg/L) illustrating the significant correlation ($p<0.05$).

Benthic Microalgae Pigment Data

The chlorophyll *a* concentrations which represented all of the benthic microalgal biomass varied significantly due to the time of year ($p<0.05$, Figure XVI a). The summer month of August exhibited significantly higher concentrations of chlorophyll *a* than the February and October chlorophyll *a* concentrations (Table V).

Benthic microalgal chlorophyll *a* concentrations were uniform across South Bay (Figure XVI b). However, the MANOVA indicated that strata had a significant effect on chlorophyll *a* concentrations ($p<0.05$). This contradicted the results of the Dunnett's T3 *post hoc* test. Because this test is more conservative than the MANOVA, the chlorophyll *a* concentrations were considered homogeneous across South Bay for the benthic microalgae (Table V).

The chlorophyll *a* concentrations varied as a function of both location and time of year. For example, the chlorophyll *a* concentrations for Stratum 6 were lowest in February, April and June; highest in August and October; and intermediate in December (Figure XVII). The mean chlorophyll *a* concentrations were dependent upon location within South Bay and the time of year as indicated by the previous example and the significant interaction term revealed by the MANOVA ($p<0.05$).

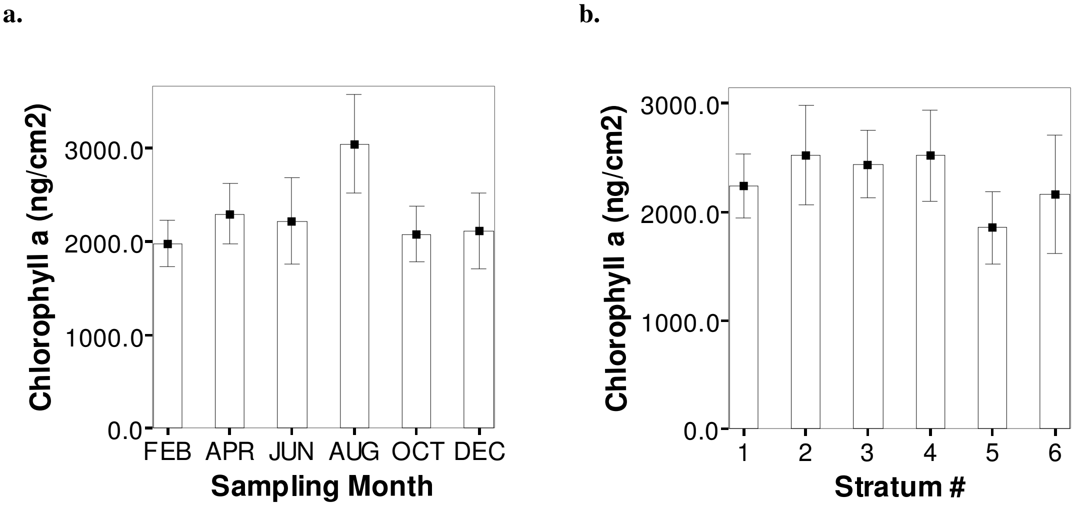


Figure XVI. Chlorophyll *a* pigment concentrations (ng/cm^2) for benthic microalgae across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent the 95% confidence intervals.

Table V. Homogeneous groups across sampling month and strata for the benthic microalgal pigments as indicated by the Dunnett's T3 multiple comparisons test.

Benthic Microalgal Pigment (ng/cm^2)	**Homogeneous Groups across Sampling Month and Strata** (indicated by an underline)					
Fucoxanthin	Aug	Feb	Oct	Apr	Dec	Jun
	———	———	———	———	———	———
	2	1	3	6	5	4
	———	———	———			
			———	———	———	
				———	———	———
Zeaxanthin	Aug	Oct	Jun	Dec	Apr	Feb
	———	———	———	———		
		———	———	———	———	———
	4	5	6	3	1	2
	———	———	———		———	———
			———	———		
Chlorophyll *b*	Jun	Aug	Apr	Oct	Feb	Dec
	———	———				
		———	———			
			———	———	———	———
	6	5	4	1	3	2
	———	———	———	———	———	———
Chlorophyll *a*	Aug	Apr	Jun	Dec	Oct	Feb
	———	———	———	———		
		———	———	———	———	———
	2	4	3	1	6	5
	———	———	———	———	———	———

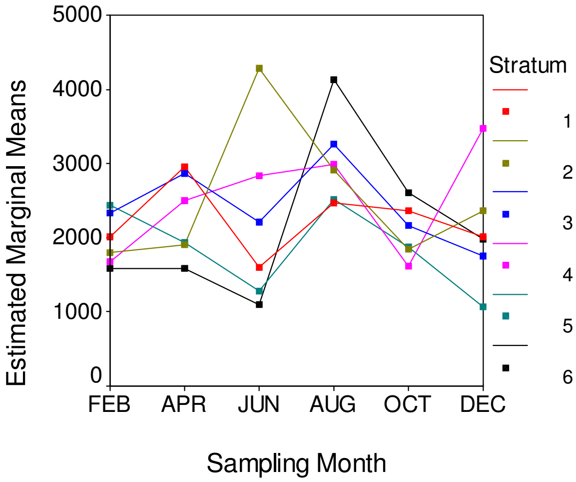


Figure XVII. The estimated marginal means of chlorophyll *a* concentrations (ng/cm^2) for benthic microalgae across sampling months for all strata.

Fucoxanthin pigment concentrations which represented the benthic diatom biomass did not vary significantly during the year ($p>0.05$, Figure XVIII a). However, the benthic fucoxanthin pigment concentrations varied significantly across strata ($p<0.05$, Figure XVIII b). In general, the northern sections had significantly higher fucoxanthin concentrations than the southern sections of the bay. Strata 1 and 2 exhibited significantly higher fucoxanthin concentrations than the rest of the strata except Stratum 3 (Table V).

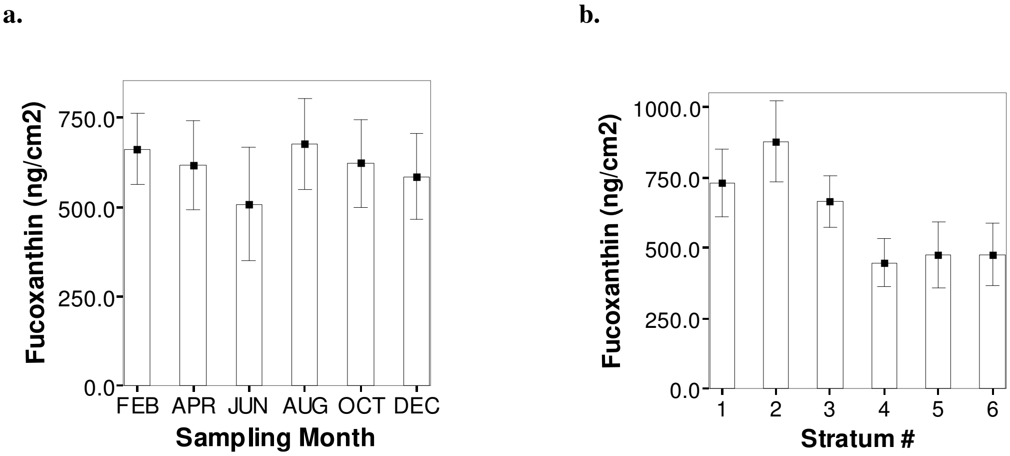


Figure XVIII. Fucoxanthin pigment concentrations (ng/cm^2) for benthic microalgae across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent the 95% confidence intervals.

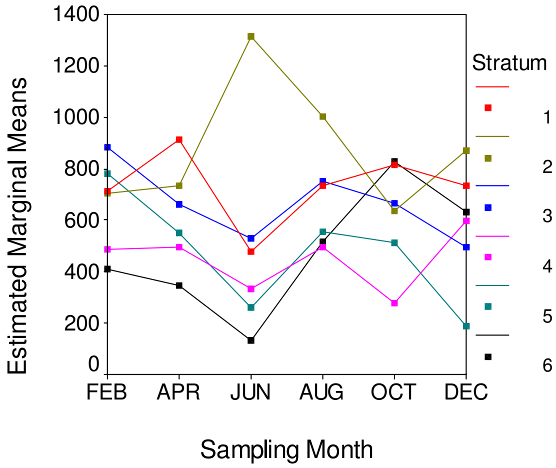


Figure XIX. The estimated marginal means of fucoxanthin concentrations (ng/cm^2) for benthic microalgae across sampling months for all strata.

The benthic zeaxanthin pigment concentrations, which represented the cyanobacteria, varied significantly due to the time of year and the location within South Bay (Figure XX). The August zeaxanthin concentrations were significantly higher than February and April concentrations ($p<0.05$, Table V). In general, the zeaxanthin concentrations for the southern sections of South Bay were significantly higher than the northern sections. Strata 4, 5 and 6 had significantly higher zeaxanthin concentrations than Strata 1, 2 and 3 with the exception that Statum 6 had homogeneous zeaxanthin concentrations with Stratum 3. Stratum 3 also had significantly higher zeaxanthin concentrations than concentrations for Strata 1 and 2 (Table V).

Benthic microalgal zeaxanthin concentrations were also shown to vary significantly as a function of season and location within South Bay (Figure XXI). For example, zeaxanthin concentrations for Stratum 2 were the lowest in all months except for June. A significant interaction term for strata and sampling month was revealed by the MANOVA ($p<0.05$).

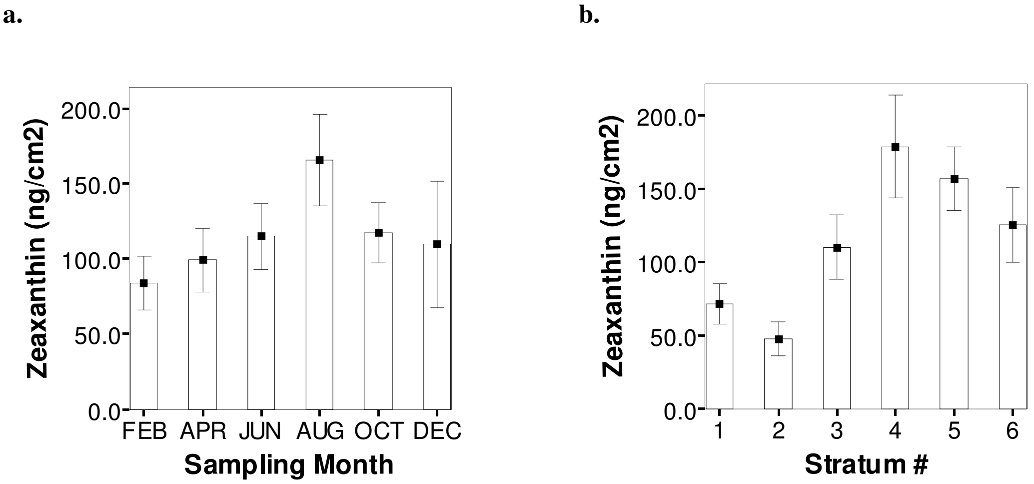


Figure XX. Zeaxanthin pigment concentrations (ng/cm^2) for benthic microalgae across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent the 95% confidence intervals.

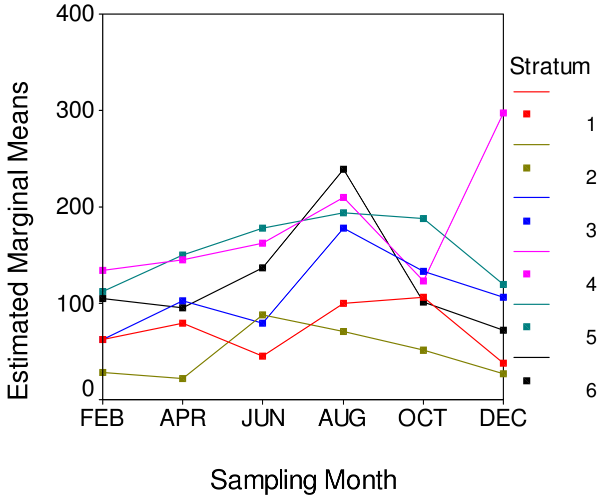


Figure XXI. The estimated marginal means of zeaxanthin concentrations (ng/cm^2) for benthic microalgae across sampling months for all strata.

The chlorophyll *b* concentrations which represented the benthic euglenophytes and chlorophytes varied significantly depending on the time of year sampled (Figure XXII a). The chlorophyll *b* concentrations were higher in the summer months of June and August when compared to all the other months sampled with one exception. Chlorophyll *b* concentrations were homogeneous for August and April (Table V).

Chlorophyll *b* concentrations did not vary spatially across South Bay (Table V). However, the MANOVA indicated that location had a significant effect on chlorophyll *b* concentrations for the benthic microalgae. Because the Dunnett's T3 *post hoc* test is more conservative than the MANOVA, the chlorophyll *b* concentrations across South Bay were considered homogeneous (Figure XXII b). A general spatial trend was observed in the chlorophyll *b* concentrations. The concentrations in the southern sections of the bay tended to be higher even though this trend was found to be statistically insignificant (Figure XXII b).

Chlorophyll *b* concentrations varied significantly due to location and time of year. For example, the chlorophyll *b* concentrations for Stratum 2 were lowest in February, April and October; highest in June; and intermediate in August (Figure XXV). This example illustrated how both location and time of year were responsible for the variation in chlorophyll *b* concentrations in South Bay. This was further supported by the significant interaction term revealed by the MANOVA ($p<0.05$).

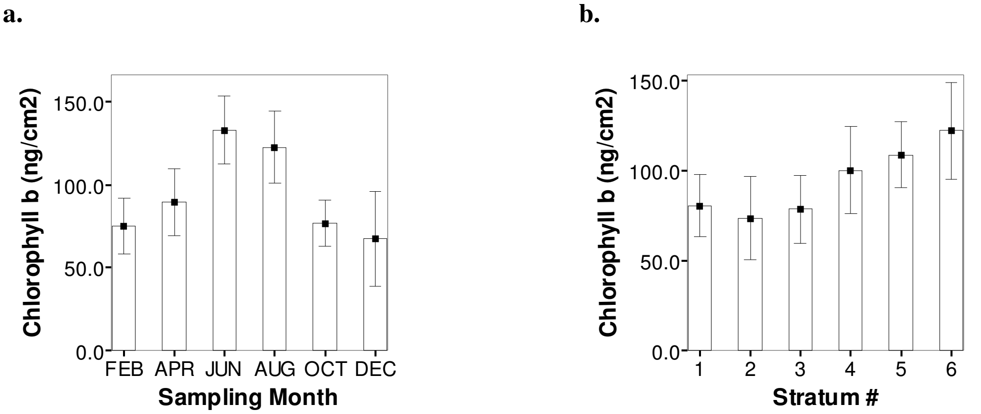


Figure XXII. Chlorophyll *b* pigment concentrations (ng/cm^2) for benthic microalgae across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent the 95% confidence intervals.

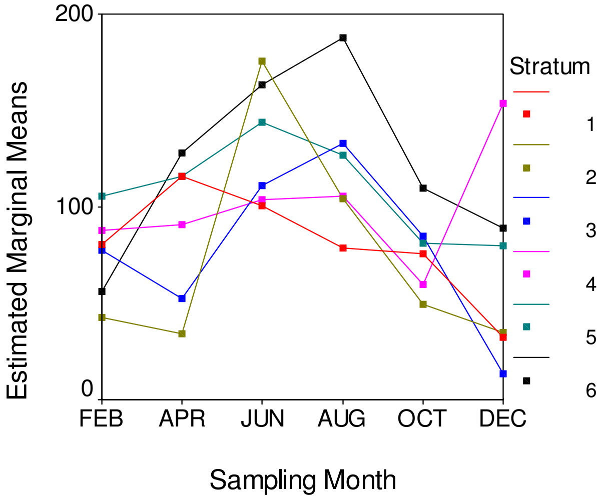


Figure XXIII. The estimated marginal means of chlorophyll *b* concentrations (ng/cm^2) for benthic microalgae across sampling months for all strata.

Several significant correlations existed between the physicochemical factors and the means of the benthic microalgal pigments of interest ($p<0.05$, Table VI). Salinity and water temperature were positively correlated with mean zeaxanthin and chlorophyll *b* concentrations. Mean zeaxanthin concentrations and mean chlorophyll *b* concentrations were also positively correlated with air temperature and dissolved oxygen, respectively. Additionally, turbidity was negatively correlated with mean zeaxanthin concentrations (Figure XXIV).

Table VI. Results of the nonparametric Spearman's rank order correlation analyses between the physicochemical factors and mean benthic microalgal pigment concentrations (ng/cm^2).

Benthic Microalgal Pigment (ng/cm^2)	**r_s and p**	**Salinity (ppt)**	**Water Temperature (°C)**	**Air Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**Turbidity (NTU)**
Fucoxanthin	r_s	-.066	-.194	-.203	-.058	.182
	p	.700	.257	.235	.736	.289
Zeaxanthin	r_s	.537	.397	.398	-.087	-.333
	p	.001*	.017*	.016*	.612	.047*
Chlorophyll b	r_s	.402	.394	.297	-.547	.084
	p	.015*	.018*	.078	.001*	.624
Chlorophyll *a*	r_s	.269	.232	.218	-.240	.111
	p	.112	.173	.201	.159	.520

* denotes significance with a p-value ≤ 0.05

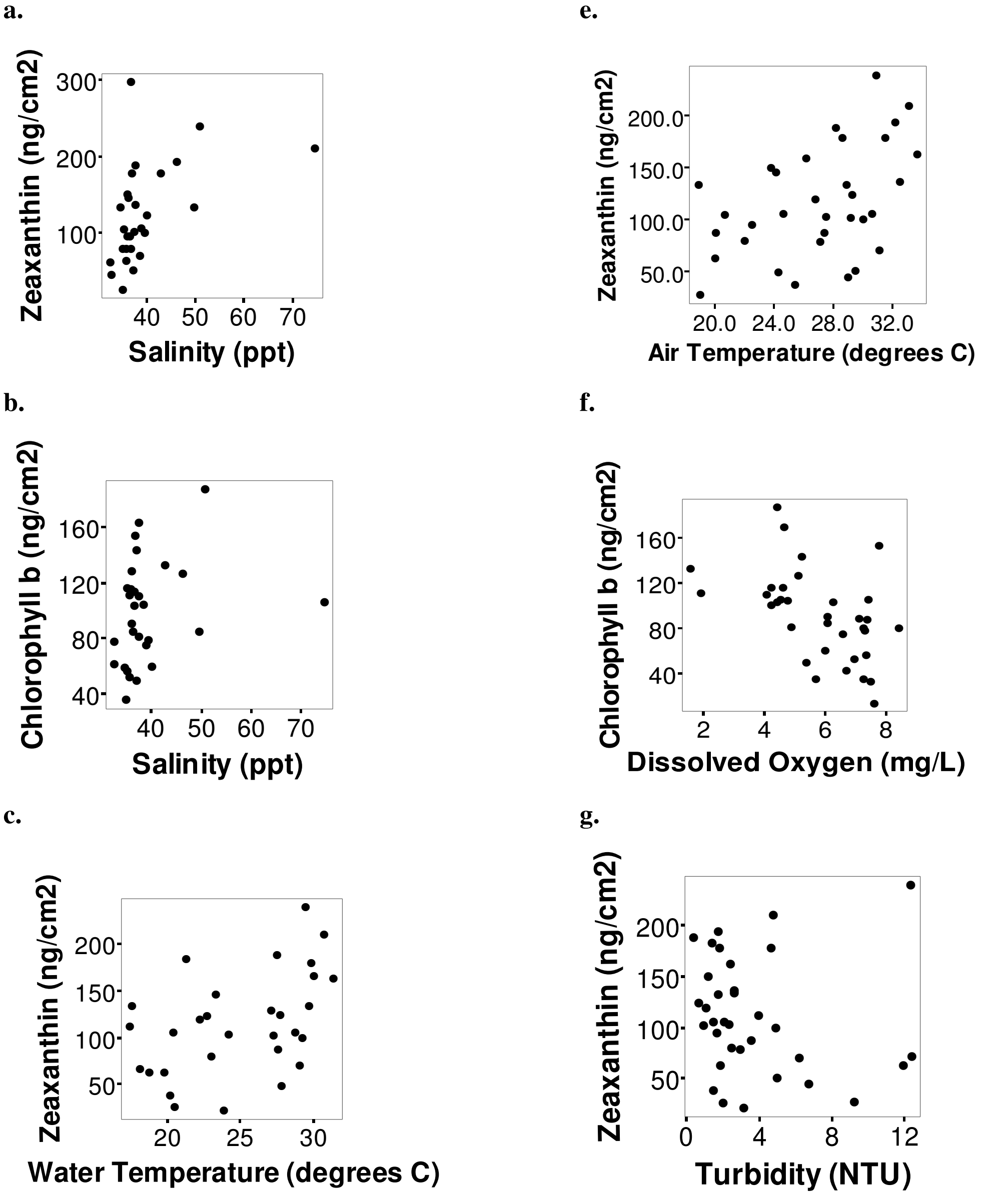


Figure XXIV. Mean benthic microalgal pigment concentrations (ng/cm^2) as a function of the physicochemical factors that they were significantly correlated with ($p<0.05$).

d.

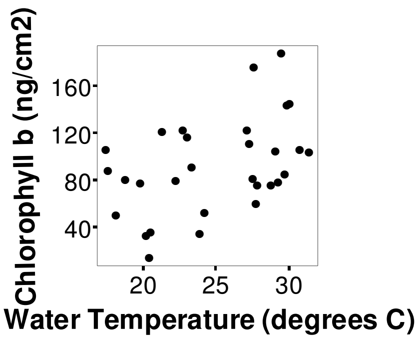


Figure XXIV. Continued.

Some of the benthic microalgal pigments of interest were also significantly correlated with each other ($p<0.05$, Table VII). Mean fucoxanthin values were negatively correlated with mean zeaxanthin concentrations and positively correlated with mean chlorophyll *a* concentrations (Figure XXV a and b). Mean zeaxanthin concentrations were positively correlated with mean chlorophyll *b* concentrations (Figure XXV c). Additionally, mean chlorophyll *b* values were positively correlated with mean chlorophyll *a* concentrations (Figure XXV d).

Table VII. Results of the nonparametric Spearman's rank order correlation analyses between the mean benthic microalgal pigment concentrations (ng/cm^2).

Benthic Microalgal Pigment (ng/cm^2)	**r_s and p**	Fucoxanthin	Zeaxanthin	Chlorophyll b	Chlorophyll *a*
Fucoxanthin	r_s				
	p				
Zeaxanthin	r_s	-.466			
	p	.004*			
Chlorophyll b	r_s	-.114	.551		
	p	.509	.000*		
Chlorophyll *a*	r_s	.600	.210	.351	
	p	.000*	.218	.036*	

* denotes significance with a p-value ≤ 0.05

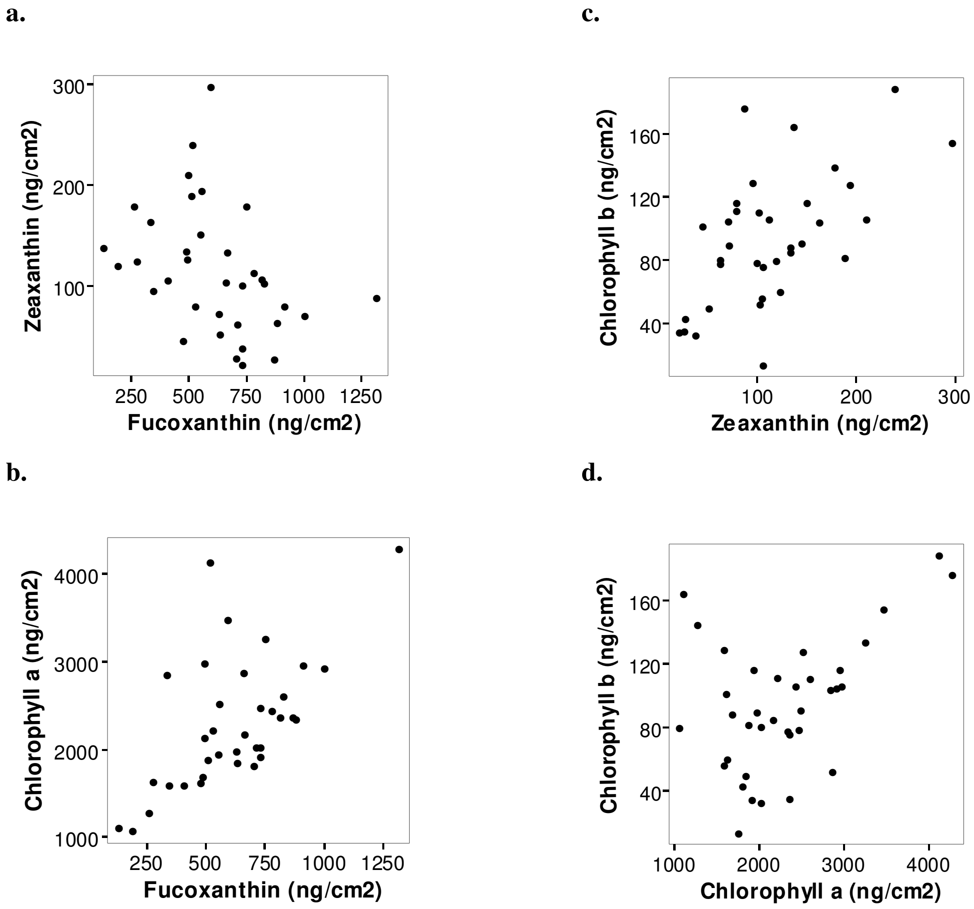


Figure XXV. Mean benthic microalgal pigment concentrations versus other mean benthic microalgal pigment concentrations (ng/cm^2) that they were significantly correlated with ($p<0.05$).

When the phytoplankton biomass and microphytobenthic biomass were converted to the same units and compared, the phytoplankton biomass was diminutive when weighted against the microphytobenthic biomass for all strata and sampling months (Table VIII). The percentage of the phytoplankton fucoxanthin and chlorophyll *a* biomass was slightly higher in Strata 1 and 2 than the other strata. This percentage was also slightly higher in February and October when compared to the other sampling months. The overall mean percentage of phytoplankton to microphytobenthic fucoxanthin concentrations was 3.93 %, while the overall mean percentage of phytoplankton to microphytobenthic chlorophyll *a* concentrations was 3.27 % (Table VIII).

Table VIII. The mean percentages of phytoplankton fucoxanthin and chlorophyll *a* concentrations (mg/m^2) to microphytobenthic fucoxanthin and chlorophyll *a* concentrations (mg/m^2).

Strata or Sampling Month	**% of Phytoplankton to Microphytobenthic Fucoxanthin Concentrations**	**% of Phytoplankton to Microphytobenthic Chlorophyll *a* Concentrations**
1	7.55	5.77
2	6.19	5.96
3	2.31	2.06
4	2.47	1.80
5	2.78	1.98
6	2.28	2.06
FEB	4.61	3.65
APR	2.56	1.88
JUN	3.30	2.72
AUG	4.30	3.49
OCT	5.18	4.97
DEC	3.62	2.91
Overall Mean	3.93	3.27

Zooplankton Data

The total zooplankton abundances varied temporally during this study (Figure XXVI a). The October abundances of total zooplankton were significantly higher than the abundances observed during all other sampling months ($p<0.05$, Table IX).

The total zooplankton abundances did not exhibit a spatial trend across South Bay (Figure XXVI b). Even though the ANOVA indicated that strata had a significant effect upon total zooplankton abundances ($p<0.05$), the Dunnett's T3 *post hoc* test revealed that abundances were not significantly different across strata ($p>0.05$, Table IX). Because the Dunnett's T3 *post hoc* test is more conservative than the ANOVA, the total zooplankton abundances were considered to not differ spatially, at least statistically. Total zooplankton abundances tended to be lower in Stratum 2 than other strata but this relationship was found to be insignificant (Figure XXVI b).

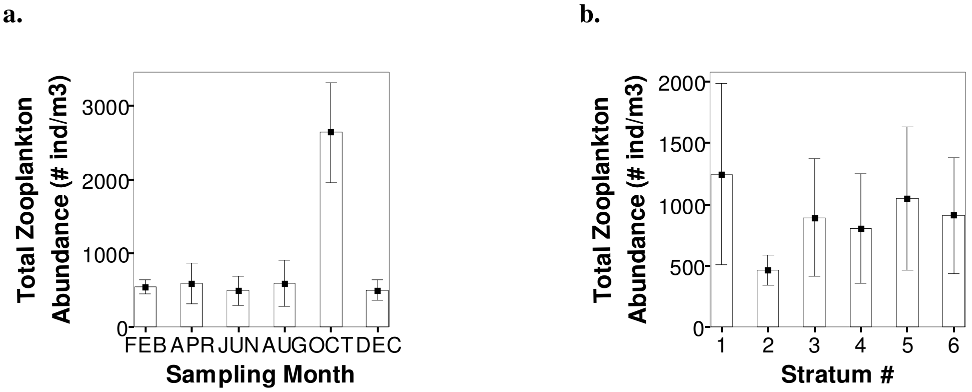


Figure XXVI. Total zooplankton abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

Table IX. Homogeneous groups across sampling month and strata for the zooplankton groups as indicated by the *post hoc* test.

Zooplankton Group Abundances (# ind/m^3)	**Homogeneous Groups for Sampling Month and Strata** (indicated by an underline)					
Total Zooplankton	Oct	Apr	Aug	Feb	Dec	Jun
	1	5	6	3	4	2
Nauplii	Oct	Feb	Dec	Apr	Jun	Aug
		———	———			
			———	———	———	———
	5	4	6	3	1	2
Gastropod Veligers	Oct	Aug	Apr	Jun	Dec	Feb*
	1	3	5	6	4	2
Polychaete Larvae	Oct	Dec	Feb	Apr	Jun	Aug
				———	———	———
	5	6	3	1	4	2
			———	———	———	———
Brachyuran Zoea Larvae	Aug	Apr	Oct	Dec	Jun	Feb*
		———	———	———	———	———
	1	2	3	6	5	4
Copepods	Oct	Feb	Jun	Dec	Aug	Apr
			———	———	———	———
	1	2	3	5	4	6

* Bonferroni's *post hoc* test was used to establish homogeneous groups for these instances. All other homogeneous groups were determined by the nonparametric Dunnett's T3 *post hoc* test.

The total zooplankton abundances were controlled by both location and the time of year (Figure XXVII). For example, total zooplankton abundances for Stratum 1 were higher than all other strata in April, August and October, but were not higher than abundances of other strata in the remaining months sampled. This illustrated that total zooplankton abundances were varying as a function of both sampling month and strata. This is evidenced by the significant interaction term revealed by the ANOVA ($p<0.05$).

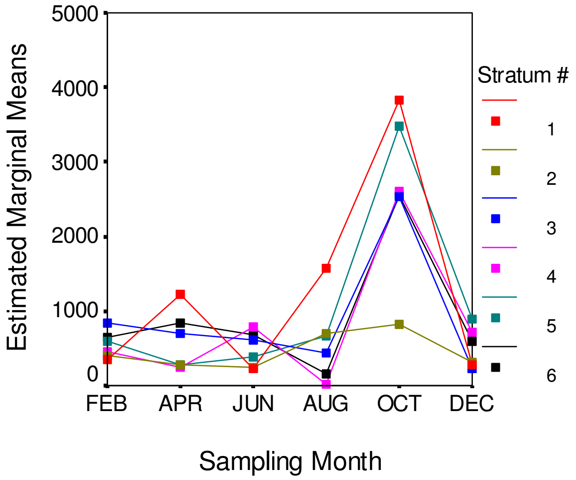


Figure XXVII. The estimated marginal means of total zooplankton abundances (# individuals/m^3) across sampling months for all strata.

The nauplii group included all nauplii except barnacle nauplii as these were easily distinguished due to the presence of rostral horns and placed in a separate group. The nauplii abundances were generally higher in the fall and winter months than the spring and summer months (Figure XXVIII a). February and October nauplii abundances were significantly higher than abundances in all other sampling months ($p<0.05$), with the exception that February abundances were not significantly higher than December abundances ($p>0.05$, Table IX).

Nauplii abundances exhibited no spatial trend across South Bay (Figure XXVIII b). Even though the ANOVA indicated that location had a significant effect on nauplii abundances ($p<0.05$), the Dunnett's T3 *post hoc* test revealed that nauplii abundances across strata did not differ significantly (Table IX). Because the *post hoc* test is more conservative than the ANOVA, the nauplii abundances were considered to not vary significantly across the bay. The nauplii abundances tended to be lower in the northern sections of the bay versus the southern sections of the bay, but this observation was statistically insignificant (Figure XXVIII b).

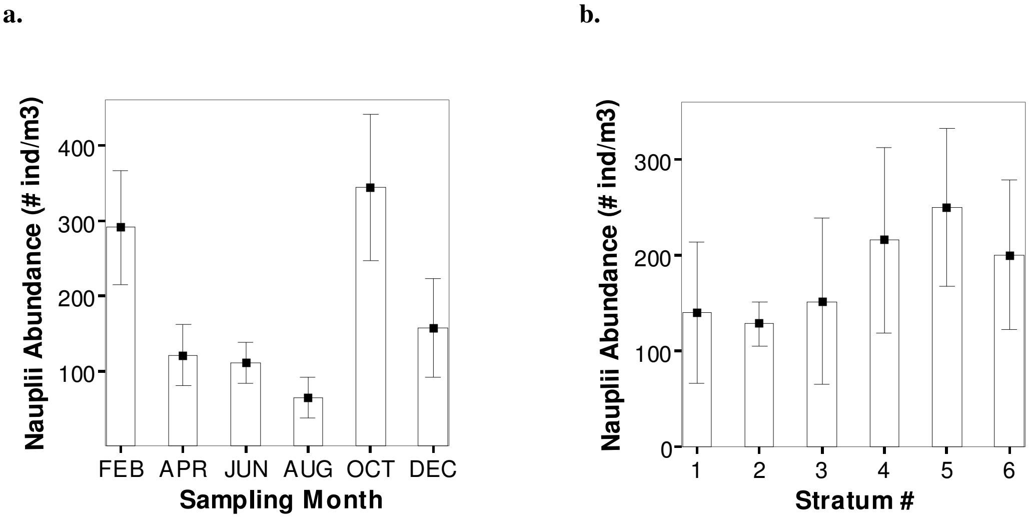


Figure XXVIII. Nauplii abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

Nauplii abundances varied significantly as a function of location and time of year (Figure XXIX). For example, Stratum 4 had the lowest nauplii abundances in June and August, but not in other sampling months. This indicated that the nauplii abundances were controlled by a combination of location within South Bay and the time of year which was supported by the significant interaction term of the ANOVA ($p<0.05$).

Gastropod veliger abundances peaked in October and were extremely low in the winter months of February and December (Figure XXX a). October abundances were significantly higher than abundances in all other sampling months ($p<.05$, Table IX).

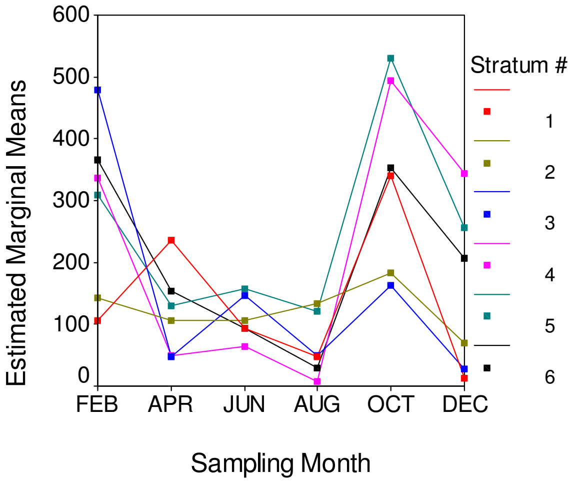


Figure XXIX. The estimated marginal means of nauplii abundances (# individuals/m^3) across sampling months for all strata.

Gastropod veliger abundances appeared to be lower in Stratum 2 compared with the other sections of South Bay (Figure XXX b). According to the ANOVA, strata had a significant effect on gastropod veliger abundances (p<0.05). However, the Dunnett's T3 *post hoc* test revealed that the gastropod veliger abundances did not exhibit a significant spatial variation (p>0.05, Table IX). Because this test is more conservative than the ANOVA, the spatial distribution of gastropod veliger abundances did not vary significantly.

Gastropod veliger abundances were controlled by the combination of location and time of year (Figure XXXI). For example, the gastropod veliger abundances for Stratum 1 were higher than the abundances for other strata in April, August and October, but lower than the abundances for the other strata in the remaining months. Furthermore, the ANOVA indicated a significant interaction term that supported the variation in gastropod veliger abundances as a function of both strata and sampling month (p<0.05).

Polychaete larval abundances exhibited a slight seasonal trend (Figure XXXII a). The abundances in August were significantly lower than the fall and winter abundances in February, October and December (p<0.05, Table IX). April and June polychaete larval abundances were not significantly different from the abundances for all other sampling months ($p>0.05$, Table IX).

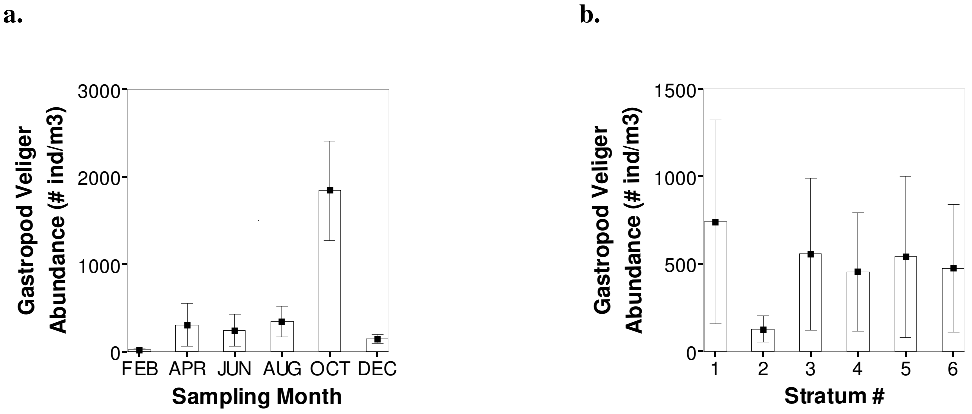


Figure XXX. Gastropod veliger abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent the 95% confidence intervals.

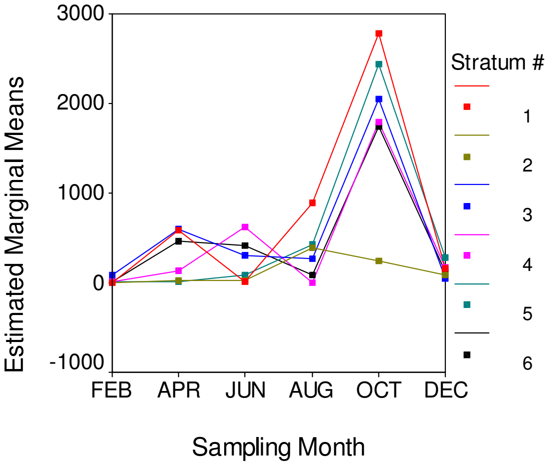


Figure XXXI. The estimated marginal means of gastropod veliger abundances (# individuals/m^3) across sampling months for all strata.

Polychaete larval abundances exhibited spatial variation across South Bay (Figure XXXII b). The abundances were significantly higher in Strata 5 and 6 when compared with Strata 2 and 4. Polychaete larval abundances within Strata 1 and 3 were not significantly different than abundances within the other strata ($p>0.05$, Table IX).

Polychaete larval abundances were controlled by both location and time of the year (Figure XXXIII). For example, polychaete larval abundances for Stratum 5 were highest in February, October and December, but were not the highest in other months sampled. This indicated that both location and time of year were controlling polychaete larval abundances and this was supported by the significant interaction term of the ANOVA ($p<0.05$).

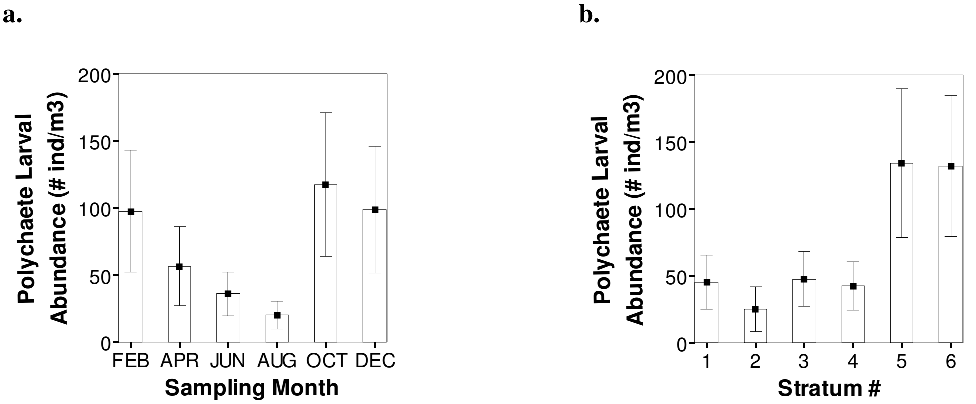


Figure XXXII. Polychaete larval abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

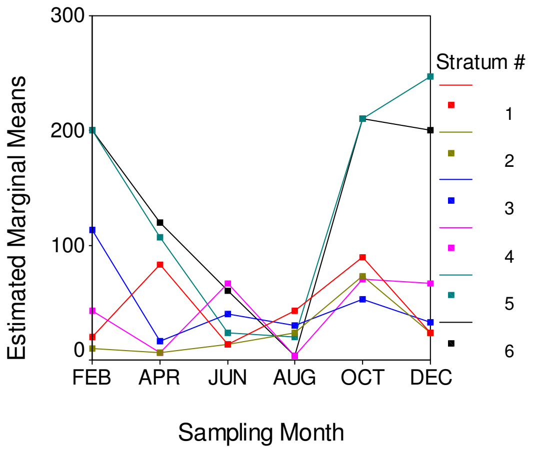


Figure XXXIII. The estimated marginal means of polychaete larval abundances (# individuals/m^3) across sampling months for all strata.

Brachyuran zoea larval abundances in August were higher than the other months sampled (Figure XXXIV a). Time of year was shown to have a significant effect on brachyuran zoea larval abundances as indicated by the ANOVA ($p<0.05$). August abundances were significantly higher than all other sampling months except April and October brachyuran zoea larval abundances ($p<0.05$, Table IX).

Brachyuran zoea larval abundances tended to be higher in Stratum 1 (Figure XXXIV b). The ANOVA indicated that location had a significant effect on brachyuran zoea larval abundances ($p<0.05$). However, the results of the Dunnett's T3 *post hoc* test were contradictory and indicated that brachyuran zoea larval abundances did not exhibit significant spatial variation. Because this test is more conservative than the ANOVA, the brachyuran zoea larval abundances were considered to not differ with respect to location within the bay ($p<0.05$, Table IX).

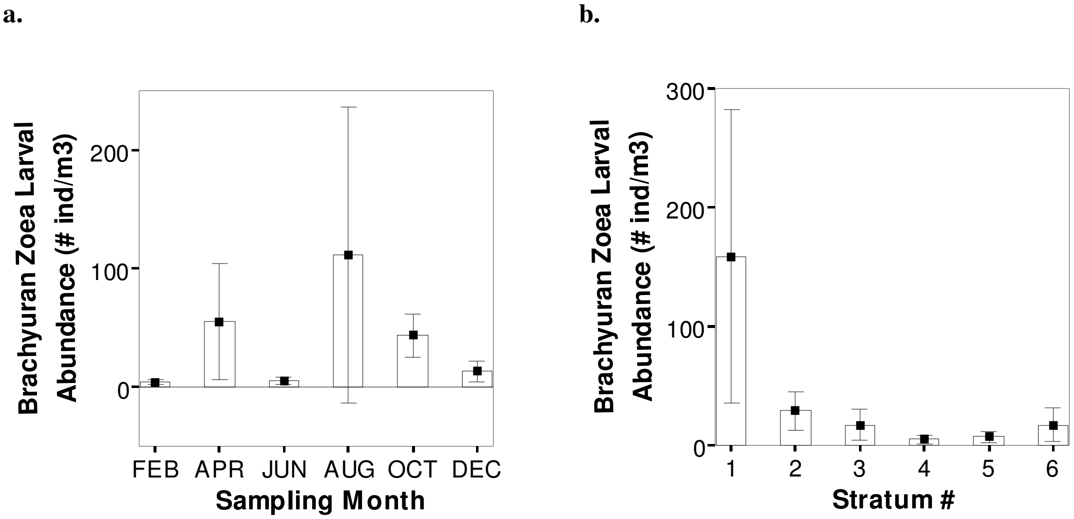


Figure XXXIV. Brachyuran zoea larval abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

Brachyuran zoea larval abundances varied significantly as a function of location and time of year (Figure XXXV). For example, brachyuran zoea larval abundances for Stratum 1 were significantly higher in all months sampled except December. This indicated that location and time of year were both controlling brachyuran zoea larval abundances. The significant interaction term revealed by the ANOVA further supported the control that both of these factors had upon brachyuran zoea larval abundances ($p<0.05$).

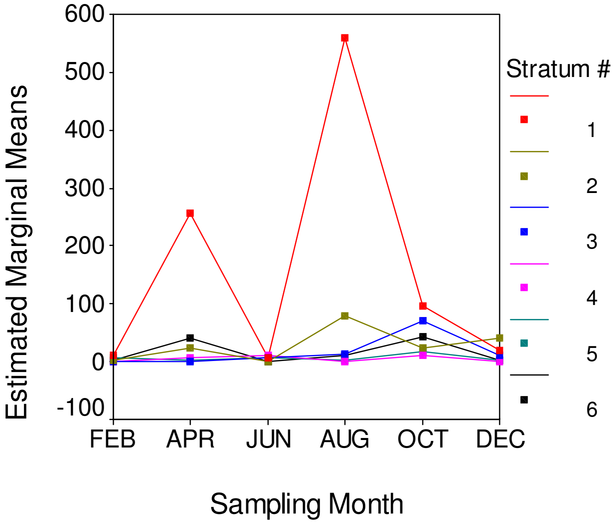


Figure XXXV. The estimated marginal means of brachyuran zoea larval abundances (# individuals/m^3) across sampling months for all strata.

Copepod abundances did not exhibit much of a seasonal trend, but peaked sporadically throughout the year (Figure XXXVI a). October copepod abundances were significantly higher than all other months sampled. February abundances were also significantly higher than April and August abundances ($p<0.05$, Table IX).

Copepod abundances did not exhibit significant spatial variation across South Bay. Although the ANOVA indicated that strata had a significant effect on copepod abundances ($p<0.05$), the more conservative Dunnett's T3 *post hoc* test revealed that no significant differences existed across strata (Table IX). Therefore, the copepod abundances across South Bay did not exhibit significant spatial variation. However, the copepod abundances tended to decline slightly in the southern sections of the bay (Strata 4, 5 and 6) when compared with the northern sections of the bay (Strata 1, 2 and 3), but this observation was statistically insignificant (Figure XXXVI b).

Copepod abundances varied as a function of both location and time of year (Figure XXXVII). For example, Stratum 1 exhibited much higher copepod abundances during October than the other strata. In all other months, copepod abundances in Stratum 1 were not the highest. This indicated that copepod abundances were varying significantly as a function of both location and time of year. The influence of both of these factors upon copepod abundances is evident in the significant interaction term revealed by the ANOVA ($p<0.05$).

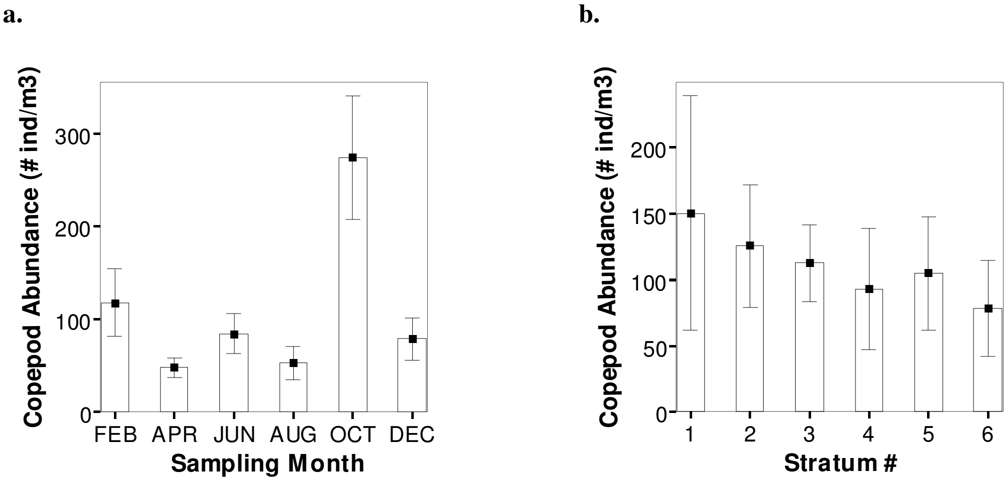


Figure XXXVI. Copepod abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

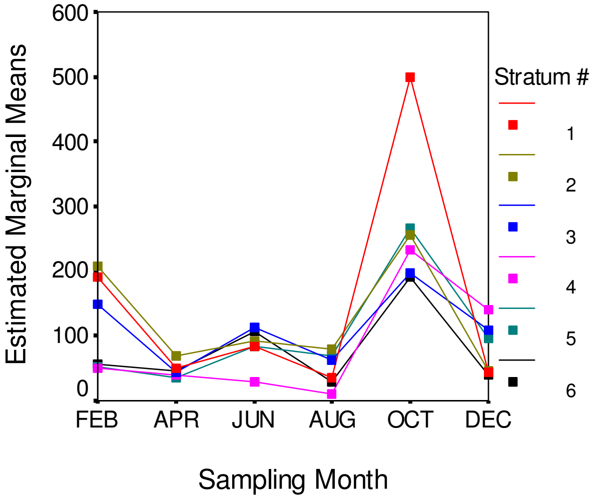


Figure XXXVII. The estimated marginal means of copepod abundances (# individuals/m^3) across sampling months for all strata.

The copepods were classified into three orders: Calanoida, Cyclopoida and Harpacticoida. These abundances along with the abundances of the juveniles were analyzed and several temporal and spatial trends emerged. Calanoid abundances peaked in October (Figure XXXVIII a), and were significantly higher than calanoid abundances in other months sampled ($p<0.05$, Table X). The ANOVA further supported this by indicating that time of year had a significant effect on calanoid abundances ($p<0.05$). The ANOVA also indicated that strata had a significant effect on calanoid abundances ($p<0.05$), but the more conservative Dunnett's T3 *post hoc* test revealed that no significant spatial variation occurred for the calanoid abundances across strata ($p>0.05$, Table X). Despite this insignificant variation, calanoid abundances tended to be higher in the northern sections of the bay when compared to the southern sections of the bay (Figure XXXVIII b).

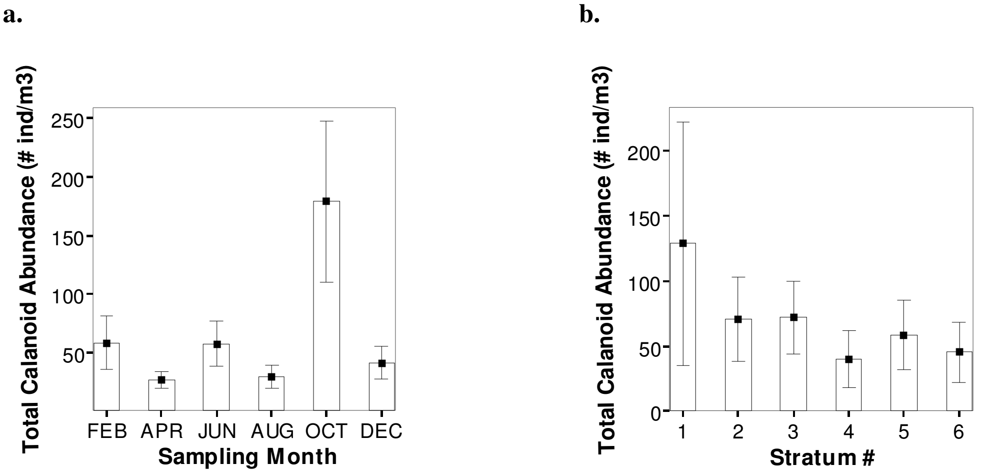


Figure XXXVIII. Total calanoid abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

Calanoid abundances varied as a function of location and time of year. For example, Stratum 1 had the highest calanoid abundances in February and October but not in the other months sampled (Figure XXXIX). Furthermore, the interaction term of the ANOVA was significant ($p<0.05$).

Table X. Homogeneous groups across sampling month and strata for the copepod order abundances and the juvenile abundances for each of these orders as indicated by the Dunnett's T3 *post hoc* test.

Copepod Order Abundances (# ind/m^3)	**Homogeneous Groups for Sampling Month and Strata** (indicated by an underline)					
Total Calanoids	Oct	Jun	Feb	Dec	Aug	Apr
	1	2	3	5	6	4
Juvenile Calanoids	Oct	Jun	Feb	Aug	Dec	Apr
	1	5	2	6	4	3
Total Cyclopoids	Oct	Feb	Jun	Dec	Apr	Aug
	1	3	5	6	4	2
Juvenile *Oithona* spp.	Oct	Feb	Jun	Aug	Apr	Dec
	4	2	3	1	5	6
Total Harpacticoids	Dec	Aug	Apr	Feb	Jun	Oct
	3	4	6	5	1	2
Juvenile Harpacticoids	Dec	Feb	Apr	Aug	Jun	Oct
	4	3	5	6	1	2

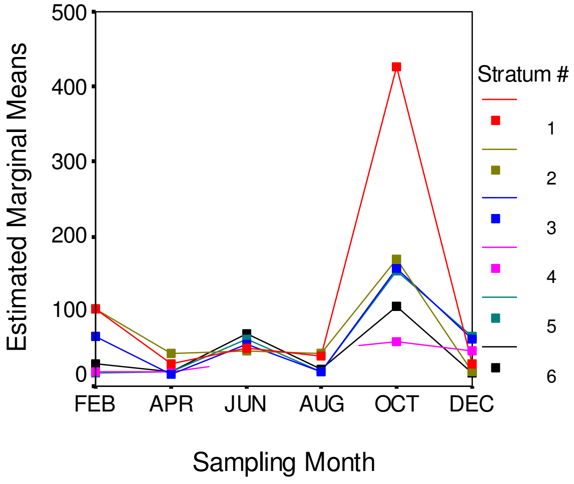


Figure XXXIX. The estimated marginal means of calanoid copepod abundances (# individuals/m^3) across sampling months for all strata. Non-estimable means were not plotted.

Juvenile calanoid abundances were highest in October with secondary peaks occurring in February and June (Figure XL a). October abundances were significantly higher than August, December and April abundances ($p<0.05$), but were not significantly higher than the abundances in February and June ($p>0.05$, Table X). The ANOVA supported this temporal trend by indicating that time of year had a significant effect on juvenile calanoid abundances ($p<0.05$). Juvenile calanoid abundances were uniform across strata as indicated by the ANOVA ($p>0.05$, Table X). The juvenile calanoid abundances tended to be slightly lower in Strata 3 and 4, but this observation was statistically insignificant (Figure XL b).

Juvenile calanoid abundances were controlled by both strata and sampling month. For instance, the juvenile calanoid abundances for Stratum 5 were highest in October and December, but not during the other months sampled (Figure XLI). This indicated that location and time of year were both controlling the juvenile calanoid abundances and is further supported by the slightly significant interaction term of the ANOVA ($p<0.05$).

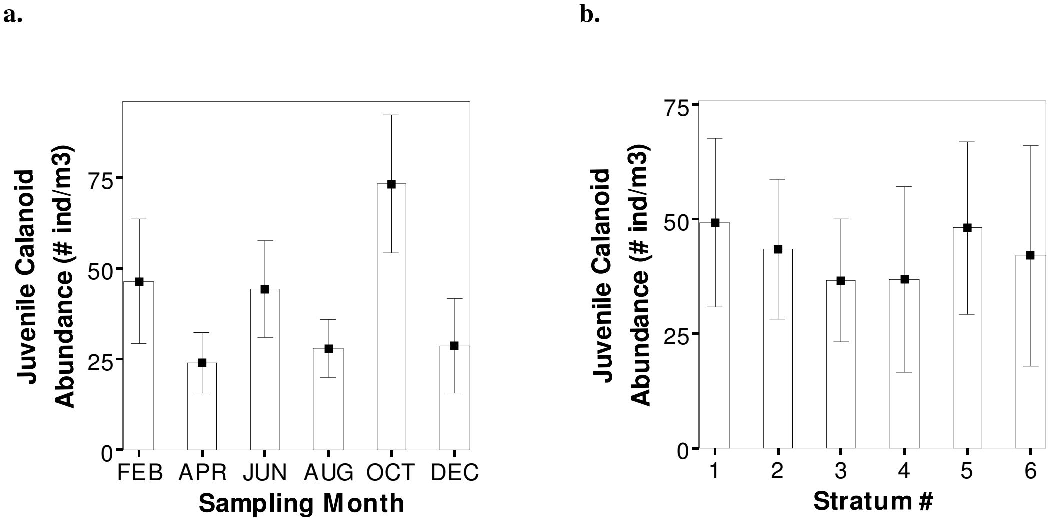


Figure XL. Juvenile calanoid abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

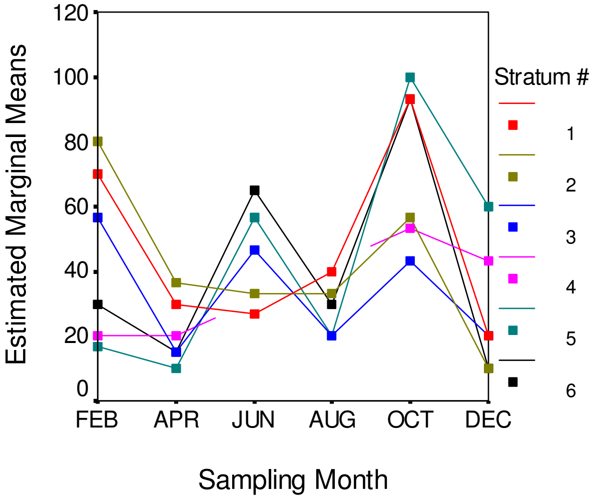


Figure XLI. The estimated marginal means of juvenile calanoid abundances (# individuals/m^3) across sampling months for all strata. Non-estimable means were not plotted.

The total calanoid abundances consisted of several species of copepods. These were *Centropages* sp., *Labidocera* spp., *Paracalanus quasimodo*, *Parvocalanus crassirostris*, *Temora turbinata*, *Tortanus setacaudatus*, juvenile calanoids and unidentified calanoids. Of these, the juvenile calanoids comprised the majority of both the total copepod abundances and the calanoid abundances (Table XI). The abundances of *Labidocera* spp. and *Parvocalanus crassirostris* followed slightly behind the juvenile calanoid abundances in terms of percentage composition of the total calanoids. The abundances for the rest of the calanoids were minimal, comprising less than one percent of the total calanoid and the total copepod abundances (Table XI).

Female calanoids were more prevalent than male calanoids. The majority, if not all, of *Centropages* sp., *Labidocera* spp., *Paracalanus quasimodo*, *Parvocalanus crassirostris* and *Temora turbinata* were female. The only exception was *Tortanus setacaudatus* in which only one male was collected during the entire study (Table XI). The female abundances for *Paracalanus quasimodo* and *Temora turbinata* were also only based on one female that was collected during this study (Table XI). Sex was not determined for the juvenile and unidentified calanoids (Table XI).

Table XI. The percentage composition of the total copepod abundance, the total order abundance, and the males vs. females for the individual species of Copepoda.

Order	**Species**	**% of Total Copepod Abundance**	**% of Order Abundance**	**% Male**	**% Female**
Calanoida	*Centropages* sp.	0.26	0.46	33.3	66.7
	Labidocera spp.	14.6	26.3	14.7	85.3
	Paracalanus quasimodo	0.09	0.15	0.00	100
	Parvocalanus crassirostris	7.53	13.6	29.5	70.5
	Temora turbinata	0.17	0.31	0.00	100
	Tortanus setacaudatus	0.09	0.15	100	0
	Juvenile calanoids	32.2	58.2	N/A	N/A
	Unidentified Calanoida	0.51	0.93	N/A	N/A
Cyclopoida	*Hemicyclops* spp.	2.91	7.85	N/A	N/A
	Oithona colcarva	12.8	34.4	17.4	82.6
	Oithona hebes	2.65	7.16	0.00	100
	Juvenile *Oithona* spp.	17.7	47.8	N/A	N/A
	Oncaea sp.	0.09	0.23	N/A	N/A
	Unidentified Corycaeidae	0.17	0.46	N/A	N/A
	Unidentified Cyclopoida	0.34	0.92	N/A	N/A
Harpacticoida	*Microsetella norvegica*	1.71	22.7	N/A	N/A
	Microsetella rosea	0.09	1.14	N/A	N/A
	Oculosetella gracilis	0.09	1.14	N/A	N/A
	Juvenile harpacticoids	4.02	53.4	N/A	N/A
	Unidentified Harpacticoida	1.80	23.9	N/A	N/A

Cyclopoid copepod abundances peaked in October and February (Figure XLII a). October and February abundances were significantly higher than the other months sampled ($p<0.05$), except that February abundances were not significantly higher than the June abundances ($p>0.05$, Table X). The ANOVA supported this trend by indicating that time of year had a significant effect on cyclopoid abundances ($p<0.05$). Cyclopoid abundances did not vary across strata ($p>0.05$, Table X, Figure XLII b).

Cyclopoid abundances were controlled by both strata and sampling month. Stratum 4 had the highest cyclopoid abundance in October, but the lowest in December (Figure XLIII). The control that both of these factors had on cyclopoid abundances is further supported by the significant interaction term of the ANOVA ($p<0.05$).

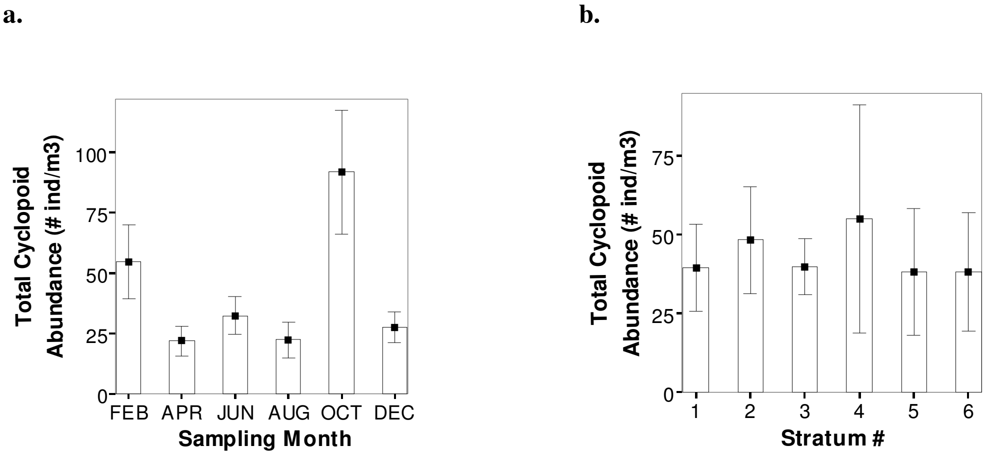


Figure XLII. Total cyclopoid abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

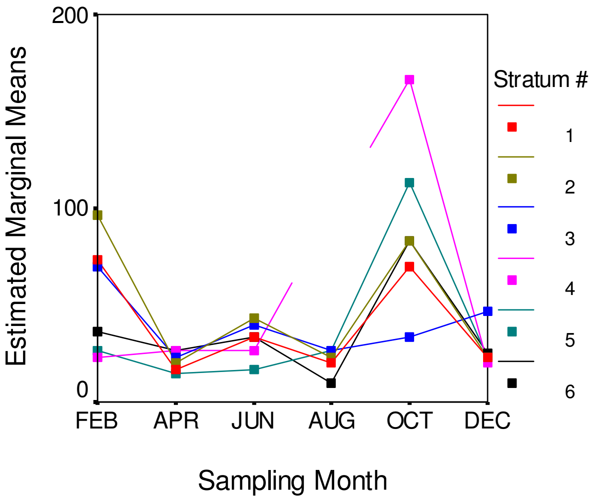


Figure XLIII. The estimated marginal means of cyclopoid copepod abundances (# individuals/m^3) across sampling months for all strata. Non-estimable means were not plotted.

All of the juvenile cyclopoids were juveniles of the genus *Oithona*, so these were used in the analyses. Juvenile *Oithona* spp. abundances peaked sporadically throughout the year (Figure XLIV a). October and February abundances were significantly higher than the other months sampled ($p<0.05$), with the exception that February abundances were not significantly higher than the juvenile *Oithona* spp. abundances during June and

August (p>0.05, Table X). The ANOVA also concurred that time of year had a significant effect on juvenile *Oithona* spp. abundances (p<0.05). Location within South Bay had no significant effect on juvenile *Oithona* spp. abundances (p>0.05, Table X, Figure XLIV b).

Juvenile *Oithona* spp. abundances did not vary significantly as a function of location and time of year. Juvenile *Oithona* spp. abundances in Stratum 3, for instance, were highest in June and lowest in August, and were varying as a function of location and time of year (Figure XLV). However, this variation is statistically insignificant as revealed by the interaction term of the ANOVA (p>0.05).

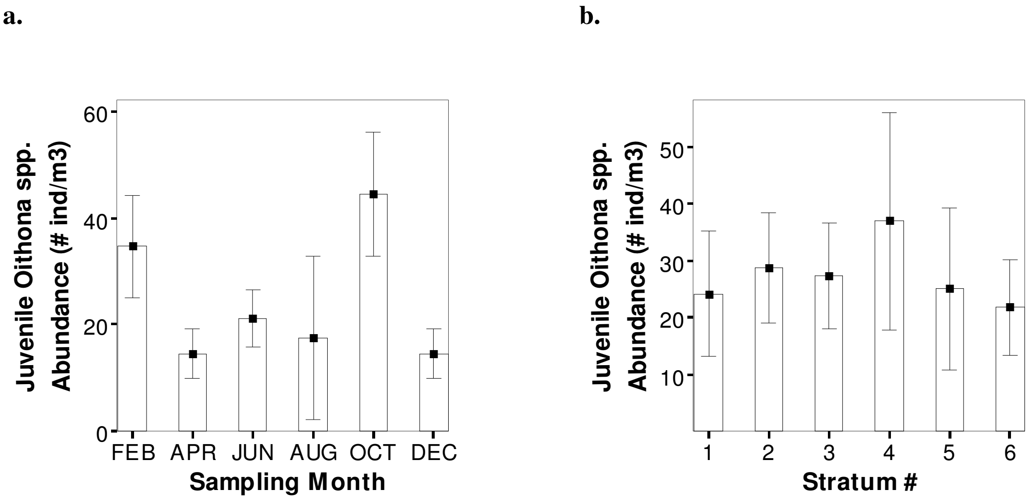


Figure XLIV. Juvenile *Oithona* spp. abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

The total cyclopoid abundances were comprised of *Hemicyclops* sp., *Oithona colcarva*, *Oithona hebes*, juvenile *Oithona* spp., *Oncaea* sp., unidentified Corycaeidae, and unidentified Cyclopoida. Juvenile *Oithona* spp. and *Oithona colcarva* were the second and fourth most abundant copepod, respectively (Table XI). Juvenile *Oithona* spp. abundances were also the highest out of all of the cyclopoids. *Oithona colcarva*, *Hemicyclops* sp. and *Oithona hebes* abundances followed shortly behind abundances of juvenile *Oithona* spp. Percentage compositions for *Oncaea* sp., unidentified

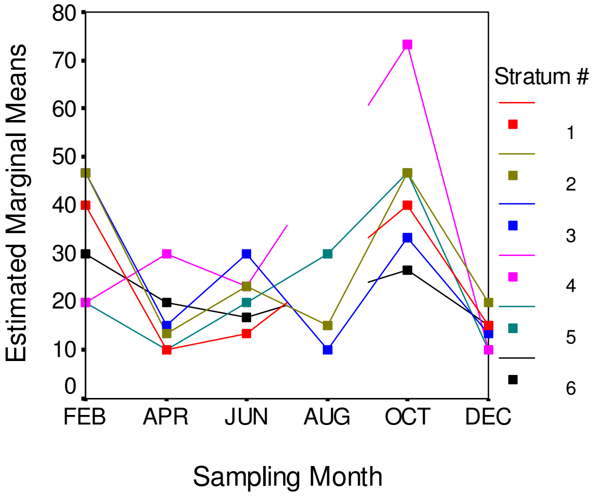


Figure XLV. The estimated marginal means of juvenile *Oithona* spp. abundances (# individuals/m^3) across sampling months for all strata. Non-estimable means were not plotted.

Corycaeidae, and unidentified Cyclopoida were negligible for both the total copepod and total cyclopoid abundances (Table XI).

Sex could not be determined for most of the cyclopoids except *Oithona colcarva* and *Oithona hebes*. Females were more numerous for both *Oithona colcarva* and *Oithona hebes*. In fact, no male *Oithona hebes* were collected during this study (Table XI).

The total harpacticoid abundances did not vary spatially or temporally during this study (Figure XLVI). Although the ANOVA indicated that both location and time of year had a significant effect on harpacticoid abundances, the Dunnett's T3 *post hoc* test revealed that no significant differences existed over the year or across strata ($p>0.05$, Table X). Because this test is more conservative than the ANOVA, the harpacticoid abundances were considered uniform across the bay and over the course of the year.

Harpacticoid abundances varied as a function of location and time of year. For example, Stratum 3 exhibited the highest harpacticoid abundances in most months sampled, but Stratum 4 had higher harpacticoid abundances in December (Figure XLVII). The control that both location and time of year have on harpacticoid abundances is evident in the significant interaction term of the ANOVA ($p<0.05$).

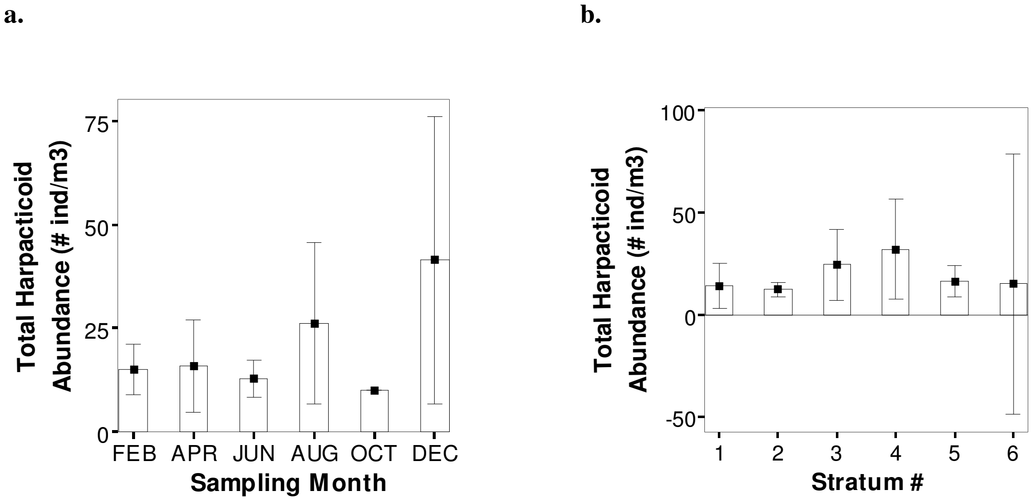


Figure XLVI. Total harpacticoid abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

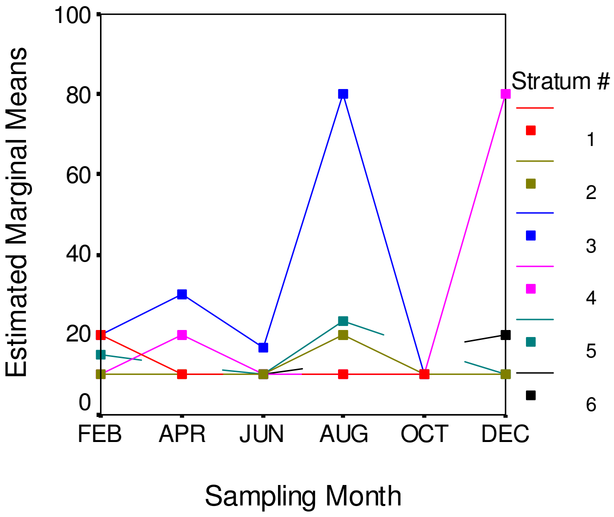


Figure XLVII. The estimated marginal means of harpacticoid copepod abundances (# individuals/m^3) across sampling months for all strata. Non-estimable means were not plotted.

Juvenile harpacticoid abundances tended to be higher in December than the other months sampled (Figure XLVIII a). The ANOVA supported this by indicating that time of year had a significant effect on juvenile harpacticoid abundances ($p<0.05$). However, the more conservative Dunnett's T3 *post hoc* test revealed that juvenile harpacticoid abundances were uniform over the course of the year (p>0.05, Table X). Therefore the juvenile harpacticoid abundances were considered to not differ seasonally. The juvenile harpacticoid abundances tended to be higher in Stratum 4 (Figure XLVIII b). However, the abundances across strata did not differ significantly from each other (p>0.05, Table X).

Juvenile harpacticoid abundances exhibited variation as a function of location and time of year. For example, the juvenile harpacticoid abundances in Stratum 4 were highest in April and December, but not during the other months sampled (Figure XLIX). However, this variation was statistically insignificant as indicated by the interaction term of the ANOVA (p>0.05). Therefore the juvenile harpacticoid abundances were not controlled by both location and time of year.

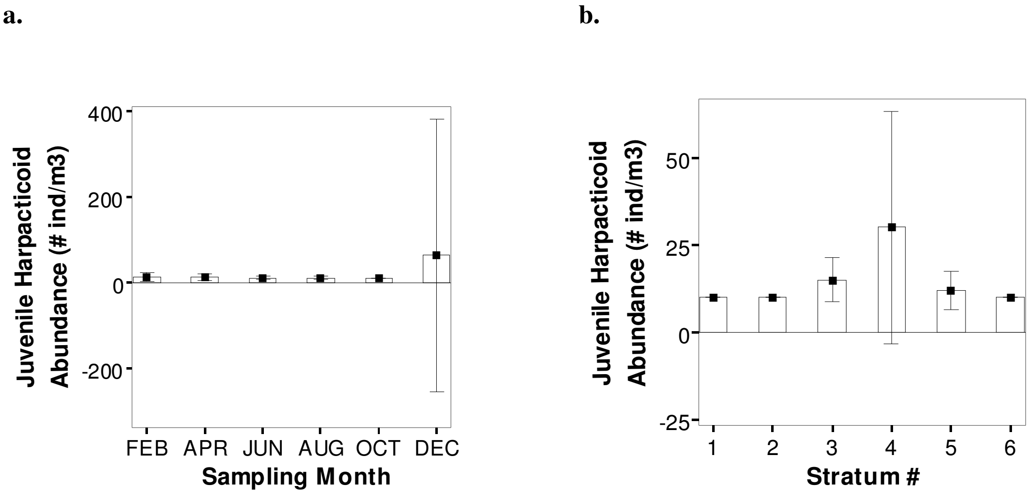


Figure XLVIII. Juvenile harpacticoid abundances (# individuals/m^3) observed across sampling month (**a**) and strata (**b**) in South Bay, TX, USA. Error bars represent 95% confidence intervals.

The total harpacticoid abundances consisted of *Microsetella norvegica*, *Microsetella rosea*, *Oculosetella gracilis*, juvenile harpacticoids and unidentified Harpacticoida. Juvenile harpacticoids comprised the majority of the harpacticoid abundances and comprised about four percent of the total copepod abundances (Table XI). All of the other harpacticoids encompassed less than two percent of the total copepod abundances. The abundances for the unidentified harpacticoids and *Microsetella norvegica* were the next highest in percentage composition of the harpacticoid abundances (Table XI). The percentage composition of the harpacticoid abundances for *Microsetella rosea* and *Oculosetella gracilis* were trivial in comparison (Table XI). Sex was not determined for the harpacticoids, so no comparison of the percent females to percent males could be made for these species (Table XI).

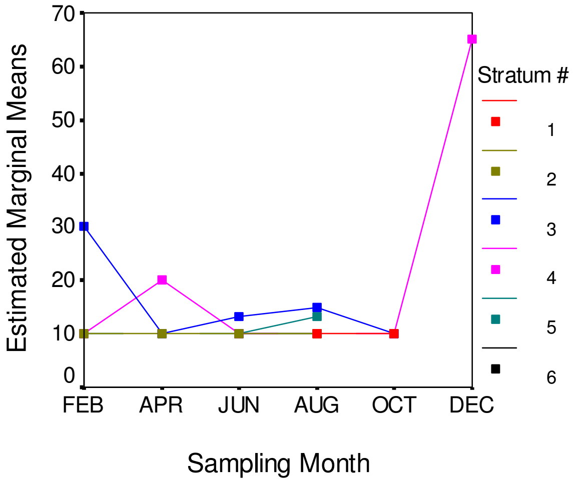


Figure XLIX. The estimated marginal means of juvenile harpacticoid abundances (# individuals/m^3) across sampling months for all strata. Non-estimable means were not plotted.

The remaining zooplankters that had abundances less than 1,000 individuals per cubic meter and were not used in any statistical analyses are listed in Table XII. The abundances reported in this table were not converted to units of individuals per cubic meter, but were in units of the raw data which were # individuals per 100 L of seawater. *Caligus* sp. were present only during April. The one anomuran zoea larva was present in June. *Acetes americanus* was collected only during December. *Lucifer faxoni* was present only in June, while zoeae of this species were observed in the August and December samples. A cyphonaute larva was collected in December and an ascidian tadpole was observed in the April samples. An unidentified Ostracoda was present in only the June samples. An unidentified thaliacean was present during August only.

Nematodes, bivalve veligers, and echinoderm pluteus larvae appeared in samples sporadically throughout the year. The majority of the unidentified hydromedusae were found in the winter months. The cladoceran, *Penilia avirostris*, was more abundant during June. Barnacle nauplii were more common in the October and December samples. The unidentified Amphipoda occurred intermittently throughout the year with higher abundances in the April samples. Penaeid zoea were collected throughout the year, but were more numerous in the summer and fall months. The *Penaeus setiferus* postlarval forms were found only in the earlier months of the year, February and April. The chaetognath, *Adhesisagitta hispida*, was observed throughout the year, but was more prevalent in the October samples. The appendicularian, most likely of the genus *Oikopleura*, was collected in the earlier months of the year with higher abundances in February. One unknown organism was observed in February and April that had a tadpole body shape, but could not be identified (Table XII).

For the most part, the less abundant zooplankton showed no preference for specific areas of the bay. However, some groups were restricted to particular areas within the bay. The bivalve veligers were only observed in Strata 3, 4 and 5. The cladoceran, *P. avirostris*, and the echinoderm pluteus larvae were only observed near the opening of the bay in Strata 1 and 2. The majority of the appendicularians occurred in the northern sections of the bay. The remaining zooplankton groups either were evenly distributed across the bay or there were too few to infer a spatial preference within the bay (Table XII).

Several significant correlations existed between the more abundant zooplankton groups and the physicochemical factors ($p<0.05$, Table XIII). Mean gastropod veliger abundances had a slight positive correlation with the physicochemical factors of salinity, water temperature, and air temperature (Figure L a-c). Mean gastropod veliger abundances exhibited a slight negative correlation with turbidity as did mean polychaete larval abundances (Figure L d and e). Nauplii, copepods, brachyuran zoea larvae, and total zooplankton abundances did not exhibit significant correlations with any of the physicochemical factors (Table XIII).

Table XII. The occurrence and the location of the less abundant zooplankton (abundances < 1,000 individuals per cubic meter) observed during bimonthly sampling in South Bay, TX, USA.

Phylum	Species	Sampling Month	Stratum #	Abundance (# individuals per 100 L)
Cnidaria	Unidentified Hydromedusa	Feb	2	3
		Aug	3	1
		Dec	6	1
Nematoda	Male nematode	Feb	4	1
		Feb	6	1
		Jun	5	2
		Dec	2	1
Mollusca	Bivalve Veliger	Jun	3	1
		Jun	5	1
		Oct	4	1
Arthropoda	*Penilia avirostris*	Apr	2	1
		Jun	2	3
		Dec	1	1
Arthropoda	Unidentified Ostracoda	Jun	4	1
Arthropoda	*Caligus* sp.	Apr	3	1
Arthropoda	Barnacle Nauplii	Feb	3	1
		Apr	2	2
		Jun	5	2
		Aug	2	1
		Oct	1	2
		Oct	2	4
		Oct	5	1
		Oct	6	3
		Dec	1	1
		Dec	2	2
		Dec	5	2
		Dec	6	2
Arthropoda	Unidentified Amphipoda	Feb	5	1
		Apr	1	2
		Apr	5	1
		Oct	6	1
		Dec	1	1
Arthropoda	Penaeid zoea	Apr	2	1
		Apr	6	2
		Jun	3	1
		Jun	5	4
		Aug	5	4
		Aug	6	1
		Oct	2	2
		Oct	3	2
		Oct	5	2
		Dec	2	1
Arthropoda	*Penaeus setiferus* postlarvae	Feb	5	1
		Apr	2	1
Arthropoda	*Lucifer faxoni* zoea	Aug	1	1
		Dec	3	1
Arthropoda	*Lucifer faxoni*	Jun	1	1
Arthropoda	Anomuran Zoea	Jun	2	1

Table XII. Continued.

Phylum	Species	Sampling Month	Stratum #	Abundance (# individuals per 100 L)
Chaetognatha	*Adhesisagitta hispida*	Feb	2	1
		Feb	3	1
		Apr	1	1
		Apr	2	3
		Apr	5	1
		Jun	1	1
		Jun	5	1
		Aug	5	1
		Oct	1	2
		Oct	2	9
		Oct	3	1
		Oct	4	1
		Oct	5	3
		Oct	6	1
		Dec	2	1
		Dec	4	1
Echinodermata	Pluteus larvae	Jun	1	1
		Dec	1	1
		Dec	2	1
Bryozoa	Cyphonaute larva	Dec	1	1
Chordata	*Oikopleura* spp.	Feb	1	5
		Feb	2	9
		Feb	3	3
		Feb	5	1
		Apr	2	4
		Jun	1	3
Chordata	Unidentified Thaliacea	Aug	3	1
Chordata	Ascidian Tadpole	Apr	1	1
Unknown 1		Feb	6	1
		Apr	5	3

Table XIII. Results of the nonparametric Spearman's rank order correlation analyses between the physicochemical factors and mean zooplankton abundances (# individuals/m^3).

Zooplankton Abundances (# ind/m^3)	r_s and p	Salinity (ppt)	Water Temperature (°C)	Air Temperature (°C)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
Nauplii	r_s	-.016	-.210	-.222	.169	-.189
	p	.928	.219	.193	.326	.269
Gastropod Veligers	r_s	.402	.459	.452	-.230	-.425
	p	.015*	.005*	.006*	.176	.010*
Polychaete Larvae	r_s	-.063	-.213	-.169	.167	-.341
	p	.716	.212	.323	.329	.042*
Copepods	r_s	.068	.006	.029	.111	-.213
	p	.695	.972	.866	.518	.213
Brachyuran Zoea Larvae	r_s	.164	.241	.216	-.304	-.138
	p	.340	.157	.206	.071	.421
Total Zooplankton	r_s	.219	.205	.193	-.030	-.318
	p	.200	.229	.260	.863	.059

* denotes significance with a p-value ≤ 0.05

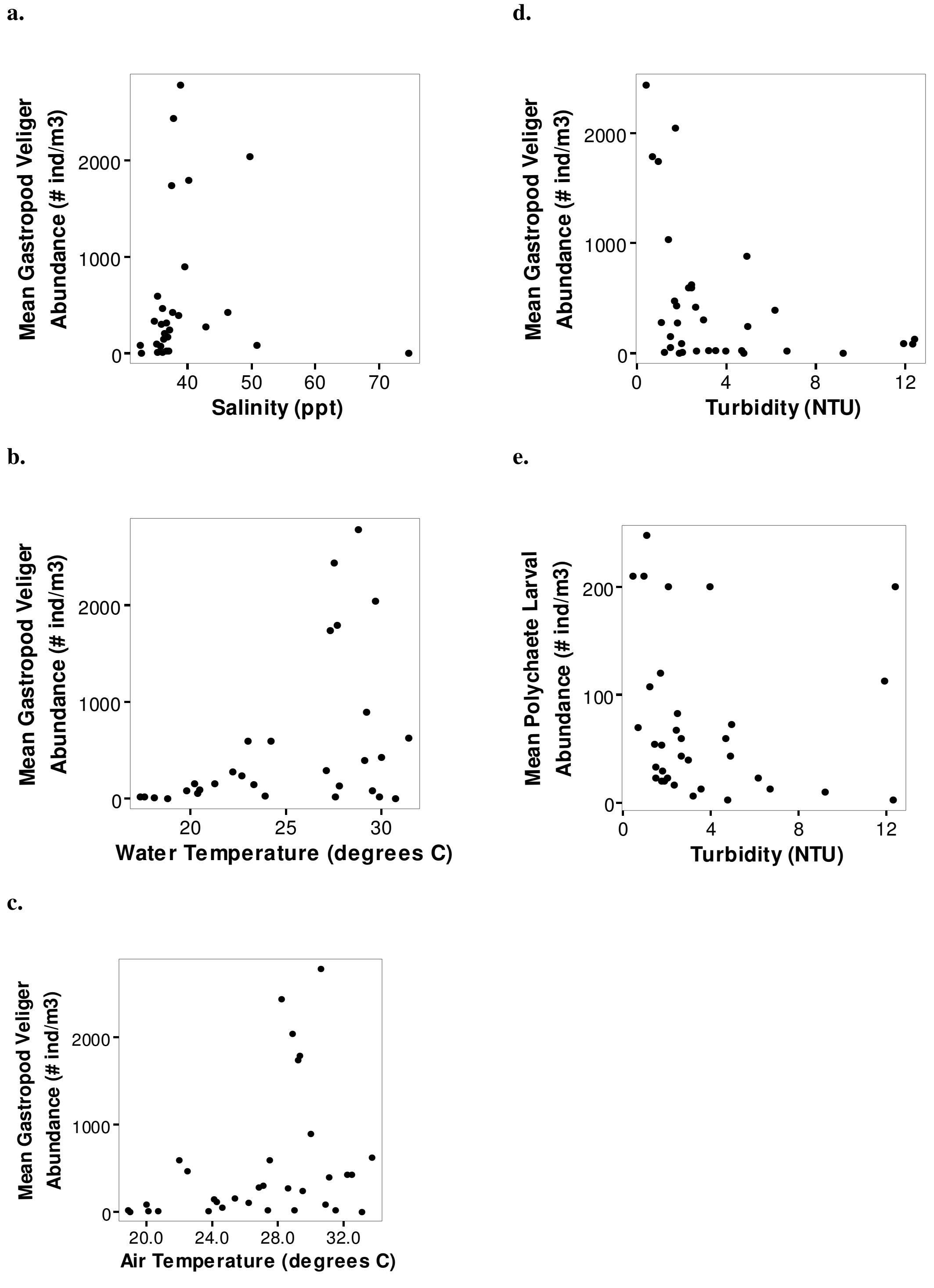


Figure L. Mean zooplankton abundances (# individuals/m^3) versus the physicochemical factors that they were significantly correlated with ($p<0.05$).

Only one of the zooplankton group abundances exhibited a significant correlation with the microalgal pigment data ($p<0.05$, Table XIV). Polychaete larval abundances were negatively correlated with benthic microalgal chlorophyll *a* concentrations (Figure LI).

Table XIV. Results of the nonparametric Spearman's rank order correlation analyses between the mean zooplankton abundances (# individuals/m^3) and the microalgal pigment concentrations.

Variable	**r_s and p**	Nauplii abundance (# ind/m^3)	Gastropod Veliger Abundance (# ind/m^3)	Polychaete Larval Abundance (# ind/m^3)	Copepod Abundance (# ind/m^3)	Brachyuran Zoea Larval Abundance (# ind/m^3)	Total Zooplankton Abundance (# ind/m^3)
Phytoplankton Fucoxanthin (µg/m^3)	r_s	-.021	-.029	-.267	.282	.290	.023
	p	.904	.866	.115	.096	.086	.893
Phytoplankton Chlorophyll *a* (µg/m^3)	r_s	-.063	.023	-.301	.282	.299	.016
	p	.713	.892	.075	.095	.076	.924
Benthic Microalgal Fucoxanthin (ng/cm^2)	r_s	-.037	.046	-.114	.081	.303	.025
	p	.830	.790	.510	.641	.072	.887
Benthic Microalgal Zeaxanthin (ng/cm^2)	r_s	.055	.166	.098	-.146	-.242	.095
	p	.748	.332	.571	.395	.155	.580
Benthic Microalgal Chlorophyll *b* (ng/cm^2)	r_s	.040	.024	.007	-.188	-.156	-.036
	p	.817	.891	.966	.272	.362	.833
Benthic Microalgal Chlorophyll *a* (ng/cm^2)	r_s	-.325	.146	-.341	-.306	.031	-.127
	p	.053	.396	.042*	.070	.857	.461

* denotes significance with a p-value ≤ 0.05

Some of the zooplankton group abundances were significantly correlated with other zooplankton group abundances ($p<0.05$, Table XV). Mean nauplii abundances were positively correlated with mean polychaete and mean copepod abundances (Figure LII a and b). Mean gastropod veliger abundances exhibited a slight positive correlation with mean polychaete and mean brachyuran zoea larval abundances (Figure LII c and d). Considering that the total zooplankton abundances are derived from abundances of each composite group, total zooplankton abundances were significantly correlated with means for all of the five zooplankton groups. These correlations were positive, and in the order of strongest to weakest are: gastropod veligers, polychaete larvae, nauplii, copepods, and brachyuran zoea larvae ($p<0.05$, Table XV).

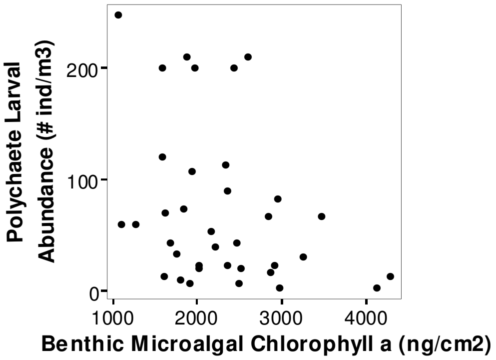


Figure LI. Polychaete larval abundances (# individuals/m^3) plotted against benthic microalgal chlorophyll *a* concentrations (ng/cm^2) to illustrate the significant correlation between them.

Table XV. Results of the nonparametric Spearman's rank order correlation analyses amongst the mean zooplankton abundances (# individuals/m^3).

Zooplankton Abundances (# ind/m^3)	**r_s and p**	Nauplii	Gastropod Veligers	Polychaete Larvae	Copepods	Zoea Larvae
Nauplii	r_s					
	p					
Gastropod Veligers	r_s	.185				
	p	.279				
Polychaete Larvae	r_s	.727	.356			
	p	.000*	.033*			
Copepods	r_s	.592	.236	.261		
	p	.000*	.165	.124		
Zoea Larvae	r_s	.033	.469	.129	.148	
	p	.849	.004*	.454	.390	
Total Zooplankton	r_s	.664	.766	.697	.484	.390
	p	.000*	.000*	.000*	.003*	.019*

* denotes significance with a p-value ≤ 0.05

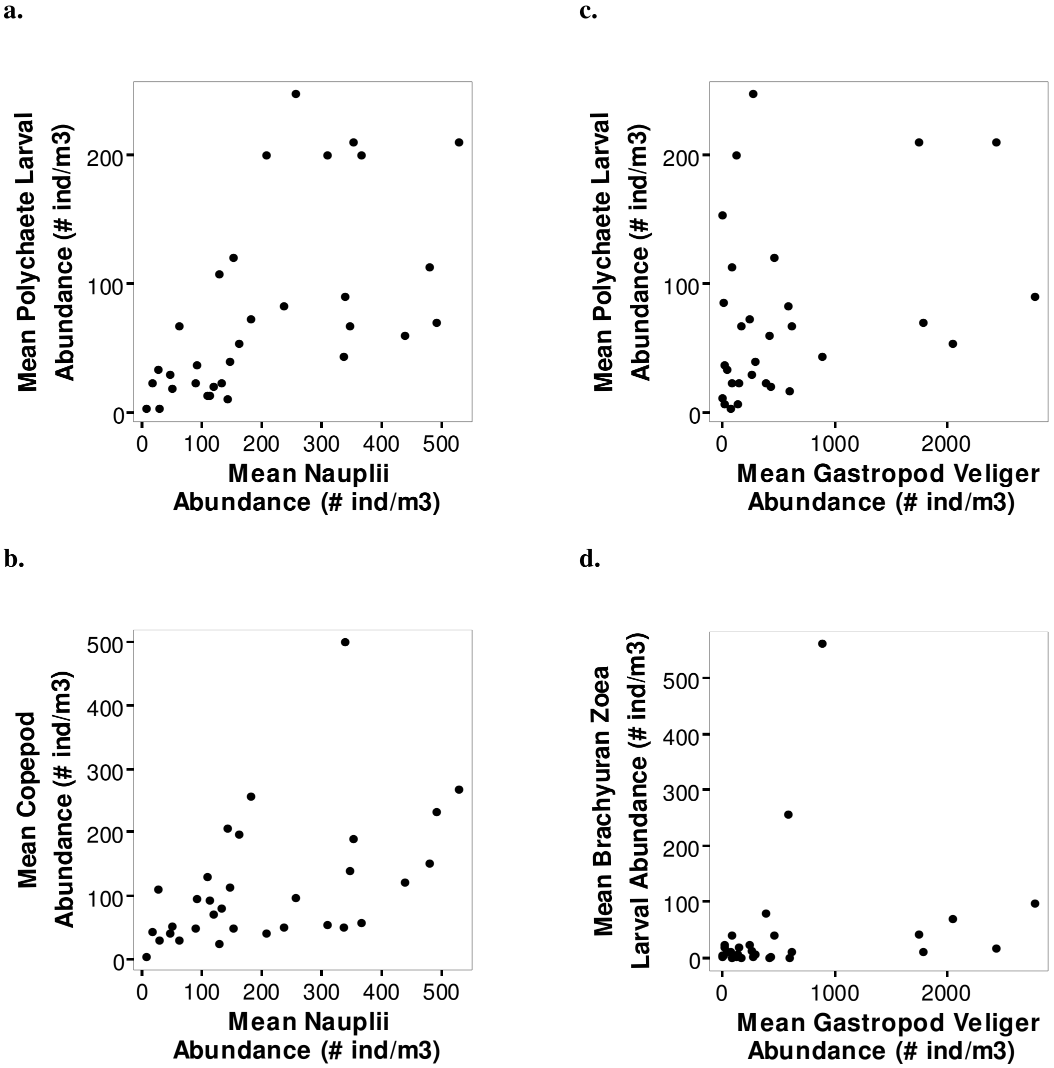


Figure LII. Mean zooplankton abundances that were significantly correlated ($p<0.05$) with other mean zooplankton abundances (# individuals/m^3).

The abundances of all replicates for each of the five most abundant zooplankton groups were added together. This summation was plotted with the total zooplankton abundances versus sampling month and strata in order to determine which zooplankton group was driving the spatial and temporal trends observed for the total zooplankton abundances. When the total abundances for each of the five most abundant groups are compared with the total zooplankton abundances, the strong correlation between gastropod veliger abundances and total zooplankton abundances was visually apparent. The gastropod veliger abundance curve mirrors the total zooplankton abundance curve when plotted against both sampling month and strata. Both the polychaete larval and nauplii abundance curves are also similar to the total zooplankton abundance curve, but not to the same magnitude as the gastropod veliger abundance curve (Figure LIII).

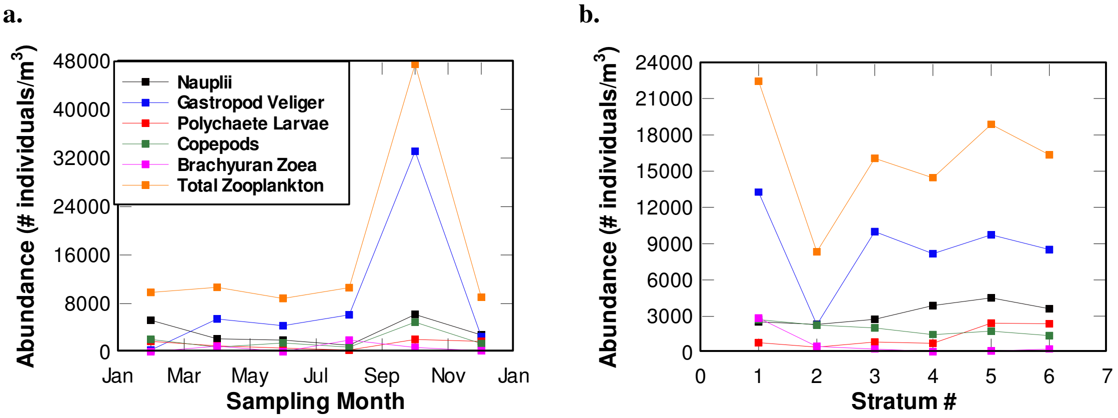


Figure LIII. Total nauplii, gastropod veliger, polychaete larval, copepod, brachyuran zoea larval, and zooplankton abundances (# individuals/m^3) for all replicates across sampling month (**a**) and strata (**b**) in South Bay, TX, USA.

Wind-induced Resuspension Data

To determine if wind-induced resuspension had a significant effect upon the location of microalgae in the water column versus the sediments, a relationship between wind speed and turbidity had to be established. Wind speed and turbidity were found to not be significantly correlated with each other ($p>0.05$, Table XVI). When wind speed and turbidity were plotted together, a slight trend emerged indicating that as wind speed increased, turbidity also increased (Figure LIV). Although the correlation was insignificant, Figure LIV illustrated that increases in wind speed had a tendency to increase turbidity values in South Bay waters.

Table XVI. Results of the nonparametric Spearman's rank order correlation analysis between wind speed (m/s) and turbidity (NTU).

Wind-induced resuspension variables	Wind Speed (m/s)	Turbidity (NTU)
Wind Speed (m/s)		
Turbidity (NTU)	$r_s = .178$ $p = .306$	

* denotes significance with a p-value ≤ 0.05

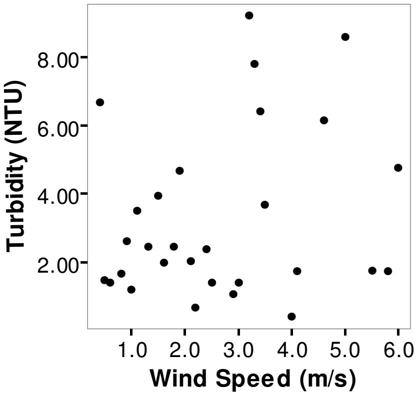


Figure LIV. Turbidity values (NTU) as a function of wind speed (m/s) in South Bay, TX, USA.

Turbidity exhibited significant relationships with some of the microalgal pigments of interest. Turbidity exhibited a significant positive correlation to the phytoplankton pigments, chlorophyll *a* and fucoxanthin (Table III). Additionally, the benthic microalgal pigment zeaxanthin exhibited a significant negative correlation with turbidity (Table VI).

The correlation analyses between the pigment ratios and the turbidity and wind speed values revealed few significant relationships. None of the ratios were significantly correlated with wind speed, and only the mean benthic microalgal ratio of zeaxanthin to chlorophyll *a* was significantly correlated with turbidity (Table XVII). As turbidity increased, the mean zeaxanthin to chlorophyll *a* ratio decreased (Figure LV a). Additionally, the ratio of phytoplankton fucoxanthin to chlorophyll *a* was positively correlated with the ratio of benthic microalgal fucoxanthin to chlorophyll *a*. (Figure LV b). The phytoplankton ratio of fucoxanthin to chlorophyll *a* was negatively correlated with the benthic microalgal ratio of zeaxanthin to chlorophyll *a* concentrations (Figure LV c). The benthic microalgal ratio of fucoxanthin to chlorophyll *a* was negatively correlated with the benthic microalgal ratios of zeaxanthin to chlorophyll *a* and chlorophyll *b* to chlorophyll *a* concentrations (Figure LV d and e). Additionally, the benthic microalgal ratio of zeaxanthin to chlorophyll *a* was positively correlated with the benthic microalgal ratio of chlorophyll *b* to chlorophyll *a* concentrations (Figure LV f).

Table XVII. Results of the nonparametric Spearman's rank order correlation analyses for turbidity, wind speed, and the microalgal pigment ratios.

Variable	r_s and p	Turbidity	Wind Speed	Phytoplankton Ratio of Fucoxanthin to Chlorophyll *a*	Benthic Microalgal Ratio of Fucoxanthin to Chlorophyll *a*	Benthic Microalgal Ratio of Zeaxanthin to Chlorophyll *a*
Wind Speed	r_s p	.178 .306				
Phytoplankton Ratio of Fucoxanthin to Chlorophyll *a*	r_s p	.289 .092	.033 .849			
Benthic Microalgal Ratio of Fucoxanthin to Chlorophyll *a*	r_s p	.239 .167	-.049 .778	.651 .000*		
Benthic Microalgal Ratio of Zeaxanthin to Chlorophyll *a*	r_s p	-.403 .016*	.050 .773	-.662 .000*	-.797 .000*	
Benthic Microalgal Ratio of Chlorophyll *b* to Chlorophyll *a*	r_s p	-.041 .815	-.131 .448	-.303 .073	-.569 .000*	.602 .000*

* denotes significance with a p-value ≤ 0.05

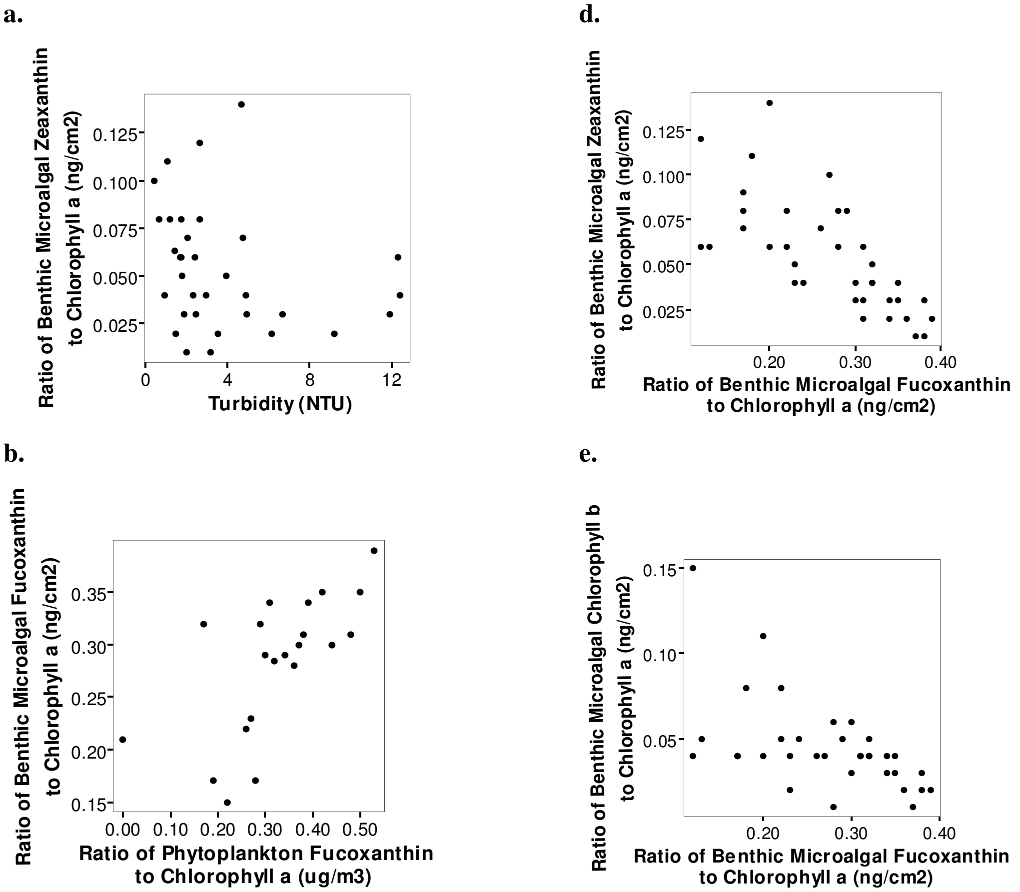


Figure LV. The significant correlations of the ratios of the microalgal pigments with turbidity and with themselves. The ratios of benthic microalgal zeaxanthin : chlorophyll *a* concentrations (ng/cm^2) plotted against turbidity (NTU) (**a**), the ratios of phytoplankton fucoxanthin : chlorophyll *a* concentrations (µg/m^3) plotted against the ratios of benthic microalgal fucoxanthin : chlorophyll *a* concentrations (ng/cm^2) (**b**), the ratios of phytoplankton fucoxanthin : chlorophyll *a* concentrations (µg/m^3) plotted against the ratios of benthic microalgal zeaxanthin : chlorophyll *a* concentrations (ng/cm^2) (**c**), the ratios of benthic microalgal fucoxanthin : chlorophyll *a* concentrations (ng/cm^2) plotted against the ratios of benthic microalgal zeaxanthin : chlorophyll *a* concentrations (ng/cm^2) (**d**), the ratios of benthic microalgal fucoxanthin : chlorophyll *a* concentrations (ng/cm^2) plotted against the ratios of benthic microalgal chlorophyll *b* : chlorophyll *a* concentrations (ng/cm^2) (**e**), and the ratios of benthic microalgal zeaxanthin : chlorophyll *a* concentrations (ng/cm^2) plotted against the ratios of benthic microalgal chlorophyll *b* : chlorophyll *a* concentrations (ng/cm^2) (**f**).

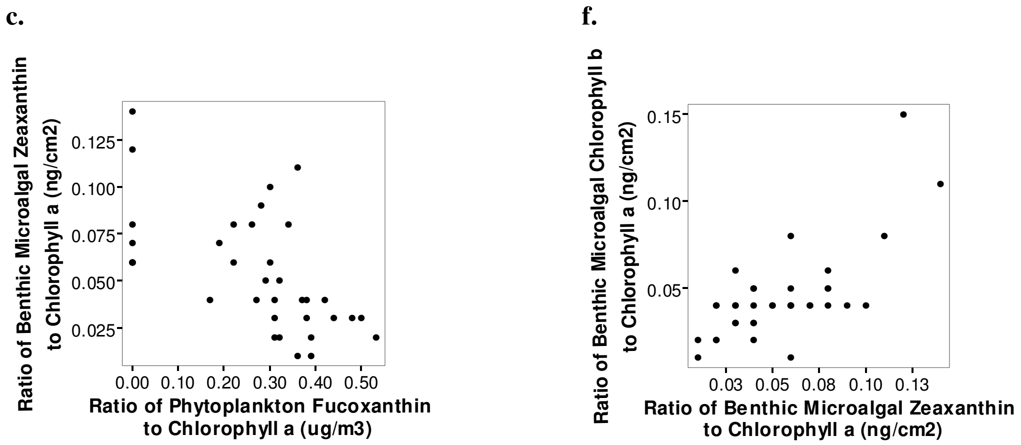


Figure LV. Continued.

DISCUSSION

Spatial Patterns

Physicochemical Factors

The physicochemical factors of salinity, water and air temperature, dissolved oxygen, and turbidity did not vary significantly across strata (Table II). This spatial homogeneity could be explained by the circulation patterns in South Bay. Prior to the dredging of the Brownsville Ship Channel, water flowed from the Gulf into South Bay and the lower Laguna Madre via Boca Chica Pass which was located in the southeastern corner of the bay. This direction of flow was due to the dominance of southerly winds during most of the year. In winters, northerly winds dominated, the flow reversed, and water entered the Gulf via Boca Chica Pass. This permitted an annual scouring of Boca Chica Pass. Upon completion of the ship channel in 1938, the northern edge of the bay was partly blocked off by a wall of dredge spoil (Breuer, 1962). Water exchange between the lagoon and the Gulf then took place through the Brownsville Ship Channel, not Boca Chica Pass. This change in the water circulation pattern and subsequent sand movement led to the closure of Boca Chica Pass, shallower depths and little to no circulation within South Bay (Breuer, 1962). This description is also supported by personal observation of recent water circulation within the bay which was observed to be minimal. The water entered South Bay between Strata 1 and 2, propagated through several deeper channels that headed toward the southern and eastern sections of the bay and along the northern edge of the bay during flooding tides. This water then dispersed out onto the shallower, adjacent shoals fringing South Bay (Figure 1). No definitive clockwise or counterclockwise circulation pattern was observed during this study. The circulation pattern throughout the channels and adjacent shoals may permit sufficient horizontal movement of water masses across South Bay, thereby resulting in spatial homogeneity among the physicochemical factors.

The dominant circulation pattern throughout the channels and adjacent shoal areas is largely regulated by tidal forces. Sampling was conducted during both diurnal and semidiurnal tidal regimes during the weeks prior to sampling and on the dates sampled (Figure V and Figure VI). Sampling was also conducted during both flood and ebb tides throughout the year (Figure VI). It is unlikely that the variation in these tidal regimes during sampling resulted in spatial homogeneity of the physicochemical factors. However, the magnitude of the high and low tides on the dates sampled remained fairly consistent and may help to explain the static physicochemical factors (Figure VI). Having tides of the same magnitude would allow for consistent horizontal exchange of water masses between the outside and the inside of the bay and between the channels and adjacent shoal areas. Horizontal exchanges of water masses can be controlled by tidal effects (Arfi and Bouvy, 1995). This exchange could contribute to the even distribution of salinities, water temperatures, dissolved oxygen levels, and turbidity values observed across South Bay.

Variations in wind direction and wind speeds may impact circulation patterns. Strong winds persisting in a particular direction could push waters toward one section of the bay in shallow systems such as this study area. These winds could enhance or be detrimental to horizontal mixing depending on whether they were forcing waters in the normal or opposite direction of the predominant circulation patterns. Additionally, calm winds occurring over long periods of time could result in more or less horizontal mixing. Again this depends on the direction of the predominant circulation pattern and the magnitude of tidal circulation. Both wind speed and wind direction are variable on fine time scales within South Bay. Wind speeds were shown to vary throughout the days sampled with increased wind speeds in the late afternoon (Figure VIII). Wind directions were shown to be fairly consistent on the days sampled (Figure VIII), but were variable the week prior to the sampling date for all months except October (Figure VII). The observed variation in wind speed and direction may have had a profound effect on the horizontal mixing in South Bay. These winds could have perturbed the circulation pattern and affected horizontal mixing of water masses on variable time scales. The variable winds in this study must have partially contributed to the observed spatial homogeneity of the physicochemical factors throughout South Bay.

Many other factors could influence the spatial distribution of each of the physicochemical factors. Increases in precipitation rates could lower salinities across the bay through direct input or along the edges of South Bay due to additional fresh water runoff, which has occurred in the past (Hook, 1991). Precipitation during the week prior to the sampling dates was minimal (Figure IX), so decreases in salinities due to precipitation were not observed. This minimal precipitation could have promoted to the spatial homogeneity of the salinity values. On the other hand, localized increases in evaporation rates that exceed the precipitation and runoff rates could increase the salinities to the point of hypersaline conditions in certain areas. Hypersaline conditions were more common along the shallower edges of South Bay, especially edges along Strata 3 and 4, that were only accessible during high tides by boat (pers. obs.). Hook (1991) also observed more hypersaline conditions for the shallower sites in his study that were along the edges of South Bay. Water temperatures could also be higher in these areas due to the shallower depth, solar heating and the evaporation rates (Millan-Nuñez *et al.*, 1982). Water temperatures in this study were approximately of the same magnitude as those from Hook's (1991) study in South Bay. Because the solubility of oxygen is inversely proportional to water temperature (D'Autilia *et al.*, 2004), localized increases in water temperature may result in decreased dissolved oxygen levels over these shoal areas. Dissolved oxygen levels could also vary spatially due to patchiness in the microalgal community and their associated primary production rates (Sandulli and Pinckney, 1999). Because these shoal areas were only accessible during high tide, sampling may be biased toward the deeper, nonvegetated, cooler, lower salinity channels in South Bay. Therefore this sampling protocol could have missed significant spatial patterns that really do exist among the physicochemical characteristics of South Bay. Sampling should be carried out along these fringing shoals in future studies in order to determine if these areas really do differ physicochemically. This difference could ultimately affect the distribution of plankton and other organisms within the bay. Additional studies on the controls of South Bay circulation patterns are also needed in order to assess the impacts of circulation on not just the physicochemical factors, but also on the biological factors.

Phytoplankton

High-performance liquid chromatography (HPLC) was used in this study to distinguish between specific chlorophylls, chlorophyll derivatives, carotenoids, phaeopigments, and phycobilins. HPLC is used in many studies to detect the presence or absence of these pigments in the water column and sediment (Millie *et al.*, 1993; Jeffrey *et al.*, 1997). The composition of the microalgae at the class level can be determined by the pigments revealed from the HPLC analysis (Tester *et al.*, 1995).

The phytoplankton pigments of chlorophyll *a* and fucoxanthin, which represented the total phytoplankton biomass and the diatom biomass, respectively (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999), exhibited a distinct spatial pattern across South Bay. Significantly higher concentrations of fucoxanthin and chlorophyll *a* were observed in Strata 1 and 2, the two strata that are immediately adjacent to and encompass the opening of the bay, respectively (Table IV, Figure I). This higher biomass could be due to the presence of the channel that connects the lower Laguna Madre with South Bay. Phytoplankton may be transported into the bay via this channel. However, Pennock (1985) and Cloern (1987) have shown that phytoplankton biomass in multiple estuarine systems is higher on adjacent shoal areas versus the central channel during certain periods of the year. South Bay may not follow this paradigm because it is not a typical estuarine system with strong riverine input and a classic salt wedge, it is a shallow microtidal embayment with physicochemical factors that are homogeneous throughout (Table II). In a coastal lagoon in Baja California, Mexico, the phytoplankton abundances were higher in the mouth of the bay and lower at the bay extremes (Millan-Nuñez *et al.*, 1982). This lagoon is more similar in structure to South Bay and the phytoplankton abundances in South Bay follow the pattern to those observed in the Baja California lagoon.

Tidal inundation may better explain the higher fucoxanthin and chlorophyll *a* concentrations in Strata 1 and 2. For Strata 1 and 2, the tide was rising during the times that phytoplankton pigments were collected in every month except October and December (Figure VI). This incoming tide may have delivered phytoplankton to this area and resulted in the significantly higher observed pigment concentrations near the entrance to South Bay. An analysis of these pigments over several days of uninterrupted sampling that encompassed varying tidal regimes would help determine if this is the reason for the higher pigment concentrations observed in these areas of South Bay.

The higher fucoxanthin concentrations observed in Strata 1 and 2 could also be due to higher diatom biomass. The elevated diatom biomass in this area would contribute to a higher chlorophyll *a* biomass because the chlorophyll *a* concentrations are indicative of all microalgae present in the water column. These diatoms could have been entrained in this area due to the flooding and ebbing tides or they may have been resuspended from sediments. Boat traffic is common in these two strata because they encompass the entrance of the bay and contain deeper channels that extend out to other sections of the bay. Boat traffic has been shown to increase turbidity and resuspension in shallow systems (Anderson, 1976; Garrad and Hey, 1987). Due to the lack of submerged vegetation and the boat traffic in these channels, resuspension of benthic diatoms is a likely contributor to the observed increases in fucoxanthin and chlorophyll *a* concentrations in this area of South Bay.

Benthic Microalgae

The benthic microalgal chlorophyll *a* concentrations, which represented all the microphytobenthic biomass (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999), did not exhibit the same spatial trend as these concentrations for the phytoplankton. Benthic microalgal chlorophyll *a* concentrations did not vary significantly across South Bay (Table V). Benthic microalgae have been shown to vary spatially on fine scales, but also some consistency has been reported on much larger scales on the order of kilometers (MacIntyre *et al.*, 1996; Sandulli and Pinckney, 1999; Safi, 2003). Given the lack of spatial variation in chlorophyll *a* concentrations, the total microphytobenthic biomass was considered similar throughout South Bay.

Although the chlorophyll *a* concentrations revealed that the total microphytobenthic biomass did not vary spatially, the concentrations of the other benthic microalgal pigments revealed that the major algal classes differed spatially across the bay. The benthic diatom biomass, represented by fucoxanthin concentrations (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999), was significantly higher in Strata 1 and 2 which are immediately adjacent to and encompass the opening of the bay, respectively (Table V, Figure I). The elevated diatom biomass for the microphytobenthos was observed in the exact same area as the elevated phytoplankton diatom biomass. This refutes the possibility that diatoms are being removed from the sediment and resuspended into the water column creating a higher phytoplankton biomass in this area, because a lower diatom biomass would have been observed in the sediments. A more likely explanation could be that tidal inundation and nutrient availability are controlling the higher diatom biomass observed both in the water column and in the sediments. Because taxonomic identification of these diatoms was not performed, the classification of these diatoms as part of the microphytobenthos versus the phytoplankton was impossible. The diatoms in this area of the bay could be tychopelagic, in which they are at the mercy of physical forces that control their location in the water column versus the sediments (Cahoon and Laws, 1993; Safi, 2003). If these diatoms are tychopelagic, they may be responsible for the higher biomass observed both in the water column and in the sediments. The mechanism controlling the higher diatom biomass in this area could be tidal inundation and nutrient availability, but this is still unclear and requires further investigation.

The benthic cyanobacterial biomass which was represented by zeaxanthin pigment concentrations (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999) was significantly higher in the southern sections of the bay than the northern sections (Figure XX b). Chlorophyll *b* concentrations were found to not differ significantly across South Bay (Table V), but a general spatial trend was observed in which chlorophyll *b* concentrations were higher in the southern sections of the bay (Figure XXII b). This trend was similar to zeaxanthin concentrations. Because chlorophyll *b* concentrations are representative of euglenophytes and chlorophytes (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999), these organisms along with the cyanobacteria are thought to dominate the microphytobenthic community of the southern portions of South Bay. This observation may be due to spatial distribution of various nutrients and physicochemical factors. Higher silica concentrations which diatoms prefer (Sommer, 1996) may be characteristic of the northern sections of the bay. The southern sections of the bay may have lower silica concentrations that cyanobacteria and chlorophytes prefer (Sommer, 1996).

The spatial variation of the benthic microalgae was further supported by the ratios of the various benthic microalgal pigments to chlorophyll *a* concentrations. The ratio of fucoxanthin to chlorophyll *a* concentrations increased as the ratios of zeaxanthin to chlorophyll *a* and chlorophyll *b* to chlorophyll *a* concentrations in the sediments decreased (Table XVII). This suggested that as benthic diatom biomass increased, the cyanobacterial, euglenophyte and chlorophyte biomass decreased in the sediments. A significant positive correlation between the ratio of zeaxanthin to chlorophyll *a* and chlorophyll *b* to chlorophyll *a* in the sediments was also observed (Table XVII). This correlation indicated that as benthic cyanobacterial biomass increased, so did euglenophyte and chlorophyte biomass. The relationships observed between these organisms supported the north to south transition in the composition of the benthic microalgal communities within the bay. Benthic diatom biomass dominated the northern sections of the bay, while cyanobacteria, euglenophyte and chlorophyte biomass dominated the southern sections of the bay. Another possible mechanism responsible for this spatial variation could be allelopathy. Allelopathy is the release of extracellular substances that hinder the growth of other microorganisms such as phytoplankton (Suikkanen *et al.*, 2004). This process may permit the cyanobacteria to outcompete the diatoms by releasing this extracellular substance. On the other hand, nutrient dynamics can result in the diatoms outcompeting the cyanobacteria. When N : P levels are not limiting or high, diatoms dominate over the cyanobacteria. When N : P levels are low, cyanobacteria will thrive over the diatoms because they are capable of fixing nitrogen while the diatoms have to rely on external sources of nitrogen for growth (Pinckney *et al.*, 1995; Sommer, 1996). Future studies in South Bay should examine nutrient availability to determine if this could be influencing the spatial variation of the microalgal communities. Nutrient bioassays would also be beneficial in determining whether the microalgal species of South Bay follow the same nutrient limitations as the microalgae in other studies (Pinckney *et al.*, 1995; Sommer, 1996). Additional studies into species identification of the microalgal benthic community are also needed in order to definitively conclude that a dominance of diatoms exists along the northern portions of South Bay and cyanobacteria, euglenophytes and chlorophytes dominated the southern portions of South Bay.

Zooplankton

Zooplankton distributions within South Bay exhibited little spatial variability. This observation may be due to dominant circulation patterns, tidal patterns and wind forces that provided sufficient horizontal mixing of waters resulting in a uniform distribution of zooplankton across the bay. Total zooplankton, nauplii, total copepod, adult and juvenile calanoid, adult and juvenile cyclopoid, adult and juvenile harpacticoid, and brachyuran zoea larval abundances were found to be evenly distributed across the bay (Table IX, Table X). Although the uniformity was significant, several statistically insignificant trends in these abundances were observed. Total zooplankton abundances were slightly lower in Stratum 2 than the other strata (Figure XXVI b). Nauplii abundances tended to be lower in the northern sections of the bay versus the southern sections (Figure XXVIII b). Brachyuran zoea larval abundances in Stratum 1 tended to be higher than other strata (Figure XXXIV b). Copepod abundances exhibited a slight decreasing trend in the southern sections of the bay (Figure XXXVI b). On the other hand, gastropod veliger and polychaete larval abundances significantly varied across South Bay. Gastropod veligers exhibited significantly lower abundances in Stratum 2 versus the other strata (Figure XXX b). Polychaete larvae exhibited a slight spatial difference with Strata 5 and 6 exhibiting significantly higher abundances than Strata 2 and 4 (Figure XXXII b). From these trends a gradient emerged in abundances along a north to south transect. Total zooplankton, nauplii, gastropod veligers and polychaete larval abundances were lower in all or some of the northern sections of the bay versus the southern sections. This distribution could be due to prey preference. If the benthic microalgae in the southern portions of South Bay are tychopelagic and available to pelagic predators, then the larvae found in the southern portions of the bay may prefer the cyanobacteria, euglenophyte and chlorophyte assemblages that are characteristic of this area. Additionally, the polychaete larval abundances were negatively correlated with the benthic microalgal chlorophyll *a* concentrations (Table XIV). This meant that as the polychaete larval abundances increased, the benthic microalgal chlorophyll *a* concentrations which were representative of all benthic microalgal biomass decreased (Figure LI). The nauplii abundances also exhibited an inverse relationship with the benthic microalgal chlorophyll *a* concentrations, but this relationship was just slightly insignificant ($p = 0.051$, Table XIV). This could be indicative of predation by the polychaete larvae, and possibly the nauplii, on the benthic microalgae. In turn, the copepods and brachyuran zoea larvae may prefer the diatom assemblage that is characteristic of the northern Strata 1 and 2. This would explain the tendency for the higher copepod and brachyuran zoea larval abundances observed in the northern sections of the bay. Because not all phytoplankton pigments were examined in this study, it is important to bear in mind that other phytoplankton may be present in the water column. These phytoplankton may be available to the herbivorous zooplankton, thereby possibly influencing their spatial distribution.

Prey availability is not the only factor that could be responsible for the spatial variation in the zooplankton. Other possible factors that may regulate spatial variation in zooplankton abundances are the tidal, the wind-driven or the predominant circulation patterns of South Bay. These physical forces may be transporting larvae to certain areas of the bay. Conditions in various areas may be more favorable for larval development and subsequent settlement than other areas of the bay. Zooplankton have also been shown to be closely associated with seagrass beds during the day and then migrate up into the water column at night. Because sampling took place during the day, the abundances and composition of the zooplankton assemblage may not be an accurate representation of their community (Fulton, 1984). Additionally, the estimated mesh size of the zooplankton net was 500 µm. This size is larger than the nets typically used in zooplankton collection (Kimmerer *et al.*, 1985; Gordon, 2000). Using this larger mesh size may have prevented capture of important members of the zooplankton community. This may have resulted in an inaccurate depiction of the zooplankton abundances and community composition. Therefore, future studies should utilize an appropriately sized mesh net for zooplankton collection. Furthermore, grazing by predators can have an influence on zooplankton abundances and distribution. In summary, habitat requirements for larval settlement, diel vertical migration of zooplankton, utilization of a zooplankton net with a smaller mesh size, and the predator community composition and distribution should be the focus of future studies concerned with zooplankton community dynamics in South Bay. Additionally, future studies examining tidal, wind-driven and predominant circulation patterns in South Bay are necessary in determining their impact upon the spatial distribution of plankton communities.

Temporal Patterns

Physicochemical Factors

All of the physicochemical variables except turbidity followed a seasonal pattern (Table II). Salinity was significantly higher in August and October when compared to the other sampling months and was even hypersaline in some areas of the bay (Figure II a). These higher salinities can be attributed to solar heating, higher evaporation rates during the summer and lack of precipitation in this arid region (Figure IX). Both air and water temperatures were significantly higher in the summer and fall months of June, August, and October which is expected for these months in subtropical regions of the northern hemisphere (Figure II b and c). Salinities and water temperatures were in the same range and followed similar seasonal trends as another study done in the nearby hypersaline Laguna Madre of Texas (Buskey *et al.*, 2001). Dissolved oxygen concentrations were significantly higher during the winter months of February and December (Figure II d). This follows the typical pattern in that dissolved oxygen levels are higher in winter months due to the higher solubility of oxygen in colder waters (D'Autilia *et al.*, 2004). Unlike the previously mentioned physicochemical factors, turbidity did not exhibit a seasonal trend (Figure II e). Therefore, turbidity can be considered random throughout the year and not controlled by seasonal effects.

Phytoplankton

No significant seasonal trend was observed for the phytoplankton fucoxanthin pigment concentrations (Table IV). However, further examination yielded a tendency for fucoxanthin concentrations to peak in February, decline in spring and early summer, peak again in August and October, and then decline again in December (Figure XII a). This insignificant seasonal trend for fucoxanthin concentrations was similar to the significant seasonal trend indicated for phytoplankton chlorophyll *a* concentrations (Table IV). Chlorophyll *a* concentrations peaked in August and October and were significantly higher than April concentrations. An insignificant peak was also observed in February (Figure X a). This seasonal trend is similar to that in other studies that have shown higher chlorophyll *a* values during both winter and summer months in the northern hemisphere (Wang *et al.*, 1999). Cell counts paired with microscopic identification would reveal species composition and diversity and how this relates to this seasonal trend. Measurements of primary production, and pigment and nutrient analysis with shorter sampling intervals than the present study would also be beneficial in clarifying the seasonal distribution of phytoplankton biomass within South Bay.

Benthic Microalgae

All of the benthic microalgal groups of interest had pigment concentrations that varied seasonally. Chlorophyll *a* concentrations, which were representative of all benthic microalgal biomass (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999), exhibited a slight seasonal trend with higher biomass observed during August than the winter months (Figure XVI a). Diatom biomass, as represented by fucoxanthin concentrations (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999), peaked twice throughout the year despite the lack of a significant temporal variation revealed by the ANOVA (Table V). Diatom biomass peaked in February and declined through June, and peaked again in August and declined through December (Figure XVIII a). The cyanobacterial biomass, which was represented by zeaxanthin concentrations (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999), exhibited one peak during the summer and lower values during the winter (Figure XX a). Euglenophyte and chlorophyte biomass, which was represented by chlorophyll *b* concentrations (Piippola and Kononen, 1995; Tester *et al.*, 1995; Pinckney *et al.*, 1999), exhibited the same pattern as the cyanobacterial biomass with one peak during the summer (Figure XXII a). The warmer water and higher salinities associated with the summer season appear to have favored benthic microalgal biomass for all of the algal classes in this study and agreed with seasonal trends observed in other studies (MacIntyre *et al.*, 1996). The seasonal trends were further supported by the significant relationships between various physicochemical factors and zeaxanthin and chlorophyll *b* concentrations (Figure XXIV). This is in direct opposition to a similar study performed in a southeastern Texas marsh which indicated extreme hypersaline conditions had a negative impact on microalgal biomass and primary production (Fejes *et al.*, 2005). However, the majority of the salinities in the Fejes *et al.* (2005) study approached saturation levels and ranged from 100-300 parts per thousand, while this study only observed hypersaline conditions around 50 to 75 parts per thousand. The hypersaline conditions observed within South Bay may not be extreme enough to cause the detrimental effects to the microalgae observed by Fejes *et al.* (2005).

Zooplankton

Most of the zooplankton abundances varied seasonally with a peak in August or October. Total zooplankton and gastropod veliger abundances peaked only once throughout the year in October (Figure XXVI a and XXX a). October and February nauplii and polychaete larval abundances were higher than some of the other months sampled (Figure XXVIII a and XXXII a). Brachyuran zoea larval abundances were higher in August, but this was statistically insignificant (Figure XXXIV a). However, the October brachyuran zoea larval abundances were significantly higher than February and June abundances (Table IX). The seasonal trend observed in zooplankton abundances in this study contradicts seasonal trends observed in a similar hypersaline system in the Mediterranean, the Mar Menor. In the Mediterranean system, higher zooplankton abundances were observed during the warmer, summer months (Gilabert, 2001). In this study, the zooplankton exhibited higher abundances during the fall and winter months of October and February. However, salinities and temperatures in October closely resemble those values observed during the summer in South Bay (Table II). Therefore, the higher zooplankton abundances in October did correspond to the higher zooplankton abundances observed in the Mar Menor during warmer, higher salinity periods (Gilabert, 2001).

The fall peak in zooplankton abundances observed in this study does not necessarily correspond with seasonal trends in zooplankton abundances along the Texas coast. The STOCS data indicated a peak in total zooplankton abundances in the spring along their northernmost transect off San Antonio Bay (Berryhill, 1975). Berryhill (1975) also examined historical data from a nearshore location off of Port Aransas along the central Texas coast which indicated a peak in total zooplankton abundances in the late summer and early fall. Unfortunately, the STOCS survey did not sample in the fall, so the zooplankton peak that occurred in the fall in this study cannot be directly compared to the STOCS survey. However, a trend can be inferred from the data in this study and the STOCS data in regards to zooplankton abundances along the Texas coast. Peaks in zooplankton abundances tend to occur in the spring along the northern stretches of the coast, transition to a summer peak along the central portions of the coast, and then exhibit a fall peak along the southern sections of the coast. Thus future studies on seasonal distributions of zooplankton along the Texas coast would be beneficial in determining the validity of this inferred trend.

In addition to this fall peak in zooplankton abundances, nauplii and polychaete larval abundances also exhibited a peak during February. These meroplankton may prefer to reproduce during the cooler periods of the year in addition to the summer months. Another possibility is that the nauplii and polychaete larval abundance peak observed during February may be due to a different species that prefers to reproduce during the winter months.

Copepod abundances were significantly higher in October than any other months following the same trend as the other zooplankton. However, February copepod abundances were also significantly higher than those in April. The higher abundances of holoplanktonic copepods in these months follows the same trend observed for holoplankton in the hypersaline system of the Mar Menor in that holoplankton exhibited several peaks throughout the winter and spring with no real seasonal trend (Gilabert, 2001). Copepod abundances in the Mar Menor declined in late summer months, but began to increase in October which is when the highest copepod abundances were observed in South Bay (Gilabert, 2001; Figure XXXVI a). Copepod abundances have also been shown to increase with water temperature and have higher abundances during the summer (Fulton, 1984). Although copepod abundances were not significantly correlated with water temperature in this study, copepod abundances were highest in one of the warmer months of the year, October (Table IX, Figure II b).

The adult and juvenile calanoid and cyclopoid copepods were responsible for the peak in October copepod abundances, while the harpacticoids were not. The percentages of each of the order abundances to the total copepod abundances are similar to those percentages observed in another study. The calanoid and cyclopoid abundances contributed more to the total copepod abundances when compared to the harpacticoids in this study and elsewhere (Grice, 1956). In this study, the harpacticoid abundances in October were the lowest compared to the other months sampled (Table X). The adult and juvenile calanoid and cyclopoid copepod abundances in October were significantly higher than most, if not all, of the other months sampled (Table X). Juvenile calanoids and juvenile *Oithona* spp. were the most numerous calanoid and cyclopoid, respectively (Table XI). Despite the juvenile abundances, *Labidocera* spp. was the second most abundant calanoid, while *Oithona colcarva* was the second most abundant cyclopoid (Table XI). These dominate species and the less numerous calanoids such as *Parvocalanus crassirostris* and *Temora turbinata* and the cyclopoid *Oithona hebes* are typical copepod species found in similar subtropical environments (Woodmansee, 1958; Grice, 1960; Breuer, 1962; Cuzon Du Rest, 1963; Reeve, 1964; Kimmerer *et al.*, 1985).

Making a direct comparison of zooplankton abundances between two studies is difficult due to the varied collection techniques (Mallin, 1991). However, looking at the percentages of each species or taxonomic group to the total copepod abundances alleviates this problem (Wilson, 1932). The October peak in zooplankton abundances observed during this study was also common in similar coastal systems (Wilson, 1932; Woodmansee, 1958; Reeve, 1964; Mallin, 1991). Reeve (1964) and Woodmansee (1958) observed a peak in total zooplankton abundance and volume in October in Florida. Copepods comprised the majority of the October peak in the Florida studies. This contradicts the composition of the October peak in total zooplankton abundances observed in this study. Gastropod veliger abundances were highest in October and were mostly responsible for the increase in total zooplankton abundances (Figure XLIII). The copepods and the nauplii followed the same trend, but not to the same magnitude. However, Woodmansee (1958) indicated that the gastropod veligers comprised the majority of the total zooplankton abundance and volume during other times of the year. Therefore, some similarities exist between these two systems and common factors could be driving the total zooplankton abundances. Woodmansee (1958) found some evidence that the October rise in zooplankton numbers could be due to a previous phytoplankton bloom. This bloom served as a food resource and fueled zooplankton productivity. Increases in phytoplankton biomass occurred prior to the October zooplankton bloom in this study and could be a driving force for this observation. Chlorophyll *a* concentrations were significantly higher in August and October which is indicative of higher phytoplankton biomass (Table IV). If the herbivorous zooplankton community responds to such increases in phytoplankton biomass, then their abundances would thrive shortly after this increase in food availability. This is a definite possibility given that increases in zooplankton abundances occurred in October immediately following peak phytoplankton biomass in August and October. Additionally, the negative correlation of the polychaete larval abundances with the benthic microalgal chlorophyll *a* concentrations were indicative of possible predation upon the benthic microalgae which exhibited peak biomass in August (Table XIV, Figure XVI). This example illustrates that predation by the zooplankton on the microalgae was occurring and could be a possible top-down regulation of microalgal biomass.

Some of the less abundant zooplankton exhibited similar seasonal trends as those in other studies. The chaetognath *Adhesisagitta hispida* occurred throughout the year just as in the Florida study (Table XII, Woodmansee, 1958). The seasonal distribution of *Lucifer faxoni* followed similar trends as those observed in Chicken Key, Florida, and along the Texas coast. Only one adult *L. faxoni* was collected in this study along with one zoea of this species during the summer. This agrees with the same late summer and early fall peak in nearshore populations of *L. faxoni* observed by Harper (1968) along the Texas coast. Another *L. faxoni* zoea was collected in December (Table XII). This concurs with the continuous, yet reduced, occurrence of *L. faxoni* larvae throughout the year in Chicken Key, Florida and along the Texas coast (Woodmansee, 1958; Harper, 1968). In this study, the majority of the hydromedusae occurred during the winter months (Table XII), which is similar to the seasonal distribution in a Louisiana marsh (Cuzon Du Rest, 1963), but differs from the sporadic seasonal occurrence observed in Chicken Key (Woodmansee, 1958). The irregular distribution of echinoderm pluteus larvae throughout the year (Table XII) concurred with the Woodmansee (1958) study, but differed from the Cuzon Du Rest (1963) study which showed a summer peak in echinoderm pluteus larvae. The penaeid postlarvae follow a similar seasonal trend as the shrimp larvae of the Louisiana marsh. The shrimp larvae in the marsh were more prevalent in April, while the penaeid postlarvae in South Bay were only found during February and April (Table XII). Given these differences and similarities between the seasonal distributions of the less abundant zooplankton taxa in this study and those in other studies, a more frequent sampling regime is suggested for future studies wanting to identify the true seasonal distribution of the less abundant zooplankton in South Bay. As stated previously, sampling with a zooplankton net that has a finer mesh size will yield a more accurate portrayal of the zooplankton community and would aid in depicting definitive seasonal trends among the less abundant zooplankton taxa.

Relationships between the Biological Data and the Physicochemical Factors

Phytoplankton pigment concentrations did not correlate with any of the physicochemical factors except turbidity. Both fucoxanthin and chlorophyll *a* concentrations exhibited a slight positive correlation with turbidity (Table III). Phytoplankton biomass has been shown to be significantly correlated with turbidity in coastal ecosystems around the world (Calliari *et al.*, 2005). An increase in phytoplankton biomass within the water column will in itself increase the turbidity as there are more algal cells present, so light penetration will decrease. The direct relationship between chlorophyll *a* concentrations and turbidity suggests that all microalgae within the water column were experiencing either increases in growth rates or some benthic microalgae were resuspended into the water column along with the sediments. The direct relationship between fucoxanthin concentrations and turbidity suggests that diatoms were either partially or wholly responsible for the increases in algal cells within the water column via either increases in growth rates or resuspension of benthic diatoms. This relationship is most likely attributable to wind-induced resuspension and is discussed in more detail in the following section.

Three of the physicochemical factors exhibited a direct relationship with benthic microalgal zeaxanthin and chlorophyll *b* concentrations. Salinity values and water temperatures were positively correlated with zeaxanthin and chlorophyll *b* concentrations. Air temperatures were significantly correlated with zeaxanthin concentrations (Table VI). These relationships indicated that the benthic cyanobacteria, euglenophytes and chlorophytes represented by these pigments preferred the higher salinity waters during the warmer months of the year.

Dissolved oxygen levels were negatively correlated with chlorophyll *b* concentrations (Table VI). This relationship concurred with significant relationships described previously for the euglenophytes and chlorophytes. These algal groups were found to prefer higher salinity and warmer waters during this study. Given that dissolved oxygen levels are indirectly related to water temperature, the negative correlation observed between chlorophyll *b* concentrations and dissolved oxygen levels is logical due to autocorrelation.

Turbidity values were negatively correlated with zeaxanthin concentrations (Table VI). These pigments are indicative of cyanobacteria, blue-green algae, and diatoms amongst other algae (Jeffrey *et al.*, 1997). Because turbidity values were loosely associated with wind speeds, then members of the benthic cyanobacteria community were probably resuspended into the water column during higher turbidity episodes (Table XVI). The wind-induced resuspension events would result in reduced concentrations of benthic cyanobacteria within the top few millimeters of the sediment.

Few significant correlations existed between the zooplankton abundances and the physicochemical factors. Gastropod veligers exhibited slight positive correlations with salinity, water temperature, and air temperature (Table XIII). These correlations may indicate that gastropod veligers were abundant during times of higher salinity and warmer waters, which in South Bay would be indicative of the late summer and early fall months. These correlations concur with the ANOVA in that October abundances of gastropod veligers were significantly higher than all the other months (Table IX). This may be the ideal time of the year for gastropod veligers to grow and develop prior to settlement.

In similar hypersaline systems, the extreme salinities usually limit zooplankton abundances and either increase or decrease zooplankton diversities (Kimmerer *et al.*, 1985; Kibirige and Perissinotto, 2003). The dominant zooplankton taxa observed in the hypersaline reaches of Shark Bay, Australia, were very similar to the taxa observed in this study (Kimmerer *et al.*, 1985). No direct evidence for decreased zooplankton abundances due to hypersaline conditions existed for South Bay. However, only one copepod was collected at Stratum 4 during August when salinity values reached a peak of 74.6 ppt. This may infer that these extreme salinities are resulting in decreased zooplankton abundances in South Bay. Because hypersalinity is speculated to occur on the shallower shoal areas that are not normally accessible by boat, the effect of hypersalinity on zooplankton assemblages was not justly assessed. Further examination of the physicochemical characteristics and the zooplankton assemblages in these shallower areas of the bay may reveal that salinity may exert some control of the zooplankton community.

Both gastropod veliger and polychaete larval abundances exhibited a slight negative correlation with turbidity (Table XIII). This indicated that periods of higher turbidity that are associated with phytoplankton blooms or wind-induced resuspension were not favorable for gastropod veligers and polychaete larvae. During episodes of high turbidity that are a result of wind-induced resuspension, nutrients, sediments, and benthic microalgae are mixed up into the water column (Arfi *et al.*, 1993). These mixing processes may have contributed to the lower abundances of gastropod veligers and polychaete larvae by displacing them to unfavorable habitats. Changes in zooplankton abundances have also been attributed to their ability to move away from turbulent waters to more favorable areas (Garcia-Soto *et al.*, 1990). Therefore the gastropod veligers and polychaete larvae may have moved away from areas in South Bay associated with higher turbidity. However, large-scale movements for gastropod veligers and polychaete larvae are impractical. The decreased zooplankton abundances observed during high turbidity episodes could also have been due to lack of prey availability. During open phases of South African estuaries, ocean water enters the system creating higher salinities and more turbulent conditions. Zooplankton abundances have been shown to decrease during these open phases (Kibirige and Perissinotto, 2003). The turbulent conditions observed in the South African estuary and during periods of high wind in South Bay may reduce light levels low enough that phytoplankton cannot survive. Therefore the decrease in zooplankton abundances may be attributed to a lack of prey availability for the herbivorous zooplankton.

Wind-induced Resuspension

To determine if wind-induced resuspension of benthic microalgae was occurring, signficant relationships of wind speed with turbidity and turbidity with the phytoplankton and benthic microalgal pigment data had to be established. The correlation analysis between wind speed and turbidity indicated that these two variables were not significantly correlated with each other (Table XVI). Therefore, wind speed was not dictating turbidity within South Bay, at least statistically. Other factors such as the presence of seagrasses help stabilize the sediment and can result in lower turbidity values (Koch, 1999). Turbidity values in South Bay were typically lower than other hypersaline bays in Texas (Blanchard and Montagna, 1995) and could be due to the presence of seagrasses. Given the patchiness of seagrasses within South Bay, turbidity values may have varied spatially due to the presence or absence of these seagrass beds. The spatial variability of these seagrass beds was not accounted for in this study and could be the reason why no significant relationship was found between wind speed and turbidity values. To control for this variation, turbidity could be measured in areas with similar benthic vegetation and those without vegetation. Then these turbidity measurements could be compared separately with wind speed data in order to determine if wind speed does control turbidity. Another reason that turbidity was not correlated with wind speed could be that higher salinities can increase flocculation of suspended sediments which would result in lower turbidity values (Fisher *et al.*, 1988). These higher salinities may induce variability in the turbidity values which could result in an insignificant correlation with wind speed. An additional reason that no significant correlation was found between wind speed and turbidity could be due to the fine-scale variability in wind speeds observed during this study (Figure VIII; MacIntyre and Cullen, 1995). Sampling wind speed and turbidity values on shorter time scales throughout the day would help to control for the fine-scale variability in wind speeds and may yield a significant relationship between these two variables that was overlooked in this study. Wind speeds have also been shown to vary seasonally resulting in more frequent resuspension during fall, winter and early spring in a similar system in Louisiana (Booth *et al.*, 2000). Therefore, more frequent sampling of wind speeds on shorter time scales throughout the year would help in determining a significant correlation between wind speed and turbidity within South Bay.

Despite the lack of a significant correlation between wind speed and turbidity, the scatterplot of turbidity plotted against wind speed indicated a tendency for wind speed to have some influence on turbidity (Figure LIV). Turbidity values did increase as wind speed values increased even though this relationship was found to not be statistically significant. Given that this trend was observed in this study and other studies, wind speed was considered to have some control over turbidity values in South Bay (Arfi and Bouvy, 1995; MacIntyre *et al.*, 1996; Booth *et al.*, 2000). Foam slicks were observed across South Bay during times of high wind speeds (pers. obs.). These foam slicks are formed by Langmuir circulation near the surface of the water that is created by wind. These convection cells penetrate to a depth that is half the distance between the foam slicks (Fogg, 1991). Given the distance observed between the foam slicks in South Bay, the Langmuir convection cells would have penetrated all the way down to the sediment-water interface. This circulation pattern would result in resuspension of bottom sediments and benthic microalgae thereby permitting a tychopelagic lifestyle for the microalgae.

The tychopelagic lifestyle proposed for the phytoplankton and benthic microalgal communities was further supported by the pigment data. Both phytoplankton chlorophyll *a* and fucoxanthin pigment concentrations were positively correlated with turbidity (Table III). These correlations may be explained by one of two processes. First, the increase in abundance of algal cells within the water column such as during phytoplankton blooms could have in itself accounted for the higher turbidity values. Secondly, these correlations may have been an indication that benthic microalgae were indeed being resuspended during higher turbidity episodes. This explanation is further supported by the negative correlations of the benthic microalgal zeaxanthin pigment concentrations with turbidity (Table VI, Table XVII). These negative correlations have indicated that benthic cyanobacteria were being removed from the sediment during higher turbidity episodes and thus being resuspended into the water column. Benthic cyanobacteria have been shown to be one of the first algal groups removed from the sediments during wind-induced resuspension (Arfi and Bouvy, 1995).

When the ratios of fucoxanthin to chlorophyll *a* concentrations for the phytoplankton and microphytobenthos were compared in a correlation analysis, a significant positive correlation was revealed (Table XVII). This correlation is somewhat contradictory to the resuspended, tychopelagic lifestyle proposed for the microalgae in this study. If wind-induced resuspension was occurring, then a reduction in the ratio of fucoxanthin to chlorophyll *a* concentrations in the sediments and an increase in the ratio of fucoxanthin to chlorophyll *a* concentrations in the water column should have been observed. This would have indicated that benthic diatoms were being removed from the sediment and being resuspended into the water column. However, a significant positive correlation was found between these two ratios which indicated that diatom biomass was concurrently increasing in the water column and the sediments. The increases in diatom biomass in both compartments could have been due to the resuspension of benthic diatoms that resided deeper in the sediment than the top few millimeters (MacIntyre and Cullen, 1995). Benthic diatoms are capable of vertical migration within the sediment (Pinckney and Zingmark, 1991). Because only the top few millimeters of sediment was collected in this study and the oxic zone extended deeper than this, the diatoms may have vertically migrated to sediments deeper than the top few millimeters (Barranguet *et al.*, 1997). These diatoms may have been resuspended into the water column if the wind forces were strong enough to resuspend sediments that were deeper than just the top few millimeters. The resuspension of these deeper diatoms would have resulted in increases in diatom biomass for both the water column and the top few millimeters of the sediment which would be confirmed by increases in the ratios of fucoxanthin to chlorophyll *a* concentrations for both the phytoplankton and the microphytobenthos as observed in this study.

A significant negative correlation was also observed between the phytoplankton ratio of fucoxanthin to chlorophyll *a* concentrations and the benthic microalgal ratio of zeaxanthin to chlorophyll *a* concentrations (Table XVII). This correlation suggested that as phytoplankton diatom biomass increased, the benthic cyanobacteria biomass decreased. This relationship could also be indicative of wind-induced resuspension. If the benthic diatoms and benthic cyanobacteria were resuspended, then an increase in the phytoplankton ratio of fucoxanthin to chlorophyll *a* concentrations would have been observed, which it was. A concurrent decrease in the benthic microalgal ratio of zeaxanthin to chlorophyll *a* concentrations would also have been observed, which indicated removal of benthic cyanobacteria from the sediment. An increase in the phytoplankton ratio of zeaxanthin to chlorophyll *a* concentrations would have further supported the resuspension of benthic cyanobacteria into the water column. Unfortunately, the zeaxanthin concentrations in the water column were not measured in this study and this ratio was not calculated. From the significant relationships that were observed between these pigment ratios, wind-induced resuspension was likely a mechanism controlling the location of microalgae within the water column compared to the sediments.

Wind-induced resuspension has significant implications for food web dynamics. Wind-induced resuspension may be beneficial to the benthic microalgae. Although they are being removed from their habitat, they are being transported to the water column where light and nutrient levels may be superior (Arfi and Bouvy, 1995). Therefore the benthic microalgae are important contributors to the overall water column productivity (MacIntyre and Cullen, 1995; MacIntyre *et al.*, 1996). On the other hand, some microalgae could be accustomed to lower light levels associated with a benthic existence so that when they are resuspended, they may undergo photoinhibition (MacIntyre and Geider, 1996). Additionally, the benthic microalgae that remain in the top layers of the sediment would not benefit from wind-induced resuspension events. The reduced light levels due to resuspension of sediments and algal cells at the sediment-water interface could result in lower benthic primary production available to higher trophic levels (Blanchard and Montagna, 1995; MacIntyre and Cullen, 1996; MacIntyre *et al.*, 1996; Fejes *et al.*, 2005). The temporal variation of wind-induced resuspension may also result in temporal changes in the water column and sediment primary production rates (Blanchard and Montagna, 1995; MacIntyre and Cullen, 1995). This could also affect grazers that rely on the benthic microalgae as a food source. Therefore, the benthic microalgae may prefer a tychopelagic lifestyle in order to ensure sufficient nutrients and light levels for growth and proliferation.

The magnitude of wind-induced resuspension directly relies on the strength of the wind speeds. Wind speeds as low as 4-6 m/s have been shown to induce resuspension of at least 50 percent of the sediments in similar systems such as this study area (Arfi and Bouvy, 1995; Booth *et al.*, 2000). Wind speeds in this study obtained these levels at least part of the time (Figure VII). Some microalgae such as cyanobacteria are more easily resuspended than others due to their size. Because of this and temporal variation in wind speeds, wind-induced resuspension can affect different microalgae on varying time scales (MacIntyre *et al.*, 1996; Safi, 2003). Different microalgae would be resuspended into the water column and available to predators on varying time scales (Arfi and Bouvy, 1995). This temporal variation in prey availability could affect predator community abundances and composition. Predators such as zooplankton may not be able to respond to such fine-scale changes in prey availability and energy would not be transferred throughout the trophic levels. However, some predators may be able to respond to these short-term changes in prey availability. This would result in efficient energy transfers within the food web (Arfi and Bouvy, 1995).

The phytoplankton microalgal biomass was minuscule compared to the benthic microalgal biomass (Table VIII). The benthic microalgal biomass was similar to values reported elsewhere (MacIntyre and Cullen, 1995; Nozais *et al.*, 2005). However, the phytoplankton biomass was about one order of magnitude lower than those reported in similar coastal systems (Millan-Nuñez *et al.*, 1982; Litaker *et al.*, 1987; MacIntyre and Cullen, 1996; Pinckney *et al.*, 1997; Perissinotto *et al.*, 2000). The overall mean percentage of phytoplankton to benthic microalgal fucoxanthin was approximately four percent, while the comparison of total biomass of the phytoplankton to the total microphytobenthic biomass was only about three percent (Table VIII). These percentages indicate that microphytobenthic biomass is an order of magnitude higher than the phytoplankton biomass in South Bay. This has important implications for carbon cycling. Because of these low percentages, the productivity of the system relies more heavily on the benthic microalgae compared to the phytoplankton. The benthic microalgae play a greater role in the carbon fixation in this system compared to the phytoplankton. The microphytobenthos are important contributors to new production of organic matter in South Bay. Additionally, these wind-induced resuspension events are critical to the microphytobenthos because they enhance the availability of the microphytobenthos to consumers and are critical in the transfer of energy to higher trophic levels in the food web of South Bay.

CONCLUSIONS

The overarching goal of this study was to determine the dynamics of the plankton community in the food web of South Bay by determining spatial and temporal trends in microalgal and zooplankton abundances and composition. Various physicochemical factors were measured in order to assess their bottom-up control on plankton community dynamics. The physicochemical factor results failed to reject the null hypothesis that there was no significant spatial variability; however, this null hypothesis was rejected for the phytoplankton biomass, benthic microalgal biomass and zooplankton abundances. The spatial homogeneity for the physicochemical factors was attributed to sufficient horizontal mixing of water masses due to tidal and/or wind-driven circulation patterns in South Bay. Sampling protocol in this study may have been biased toward the deeper, more turbulent channels in the bay due to the physical incapabilities of sampling the shallower, shoal areas with a boat. By not sampling the shallower, shoal areas, significant spatial variability in the physicochemical factors could have been overlooked. Phytoplankton biomass was found to be significantly higher in the northern sections of the bay that encompassed the entrance to the lower Laguna Madre. The higher biomass in this area was attributed to the delivery of more phytoplankton biomass to this area via tidal inundation or due to resuspension of benthic microalgae from increases in boat traffic, currents, or wind speeds. Benthic microalgal biomass remained fairly consistent throughout the bay as indicated by the homogeneity in chlorophyll *a* concentrations, but the composition of the benthic microalgal community was spatially variable. The northern sections of the bay exhibited higher diatom biomass than the southern sections, while the southern sections exhibited higher cyanobacterial, euglenophyte and chlorophyte biomass than the northern sections of the bay. Possible mechanisms influencing this distribution included spatial variation in nutrient availability and the physicochemical factors and allelopathy. Zooplankton distributions also exhibited a north to south transition in community composition. Copepods, gastropod veligers and brachyuran zoea larval abundances tended to be higher in the northern sections of the bay, while the nauplii, polychaete larval and total zooplankton abundances were generally higher in the southern sections of the bay. This spatial variability was statistically insignificant for all zooplankton groups except the polychaete larvae. However, the tendency for differences in community composition within the bay does exist and requires further investigation. This distribution may be due to prey preference associated with the spatial variability among the benthic microalgal community compositions in the northern versus the southern sections of the bay. The zooplankton distribution could also be attributed to circulation patterns, habitat preferences, and variability in the physicochemical environment.

The second null hypothesis that there was no significant temporal variability was rejected for the physicochemical factors, the phytoplankton, the benthic microalgal and the zooplankton communities. Warmer water and air temperatures, higher salinities and lower dissolved oxygen levels were observed during summer months. The exception among the physicochemical factors was that no seasonal trend was detected for turbidity levels. Total phytoplankton biomass as indicated by chlorophyll *a* concentrations was significantly higher in late summer and early fall months and also peaked in February, albeit insignificantly. Phytoplankton diatom biomass followed the same seasonal trend, but no significant temporal variation was detected. Therefore, the phytoplankton diatom biomass results failed to reject the hypothesis that there was no significant temporal variation. Benthic microalgal biomass was generally higher in the summer months with an additional peak in diatom biomass during February. Nutrient analyses, primary production rates, cell counts, and microscopic identification of species should also be examined in future studies to determine the influence of these factors upon the seasonal distribution of microalgal biomass in South Bay. The zooplankton abundances generally increased in late summer or early fall. This increase was attributed to reproduction and growth rates that could have occurred in response to increases in microalgal biomass, to an association with tidal cycles, and to an association with the physicochemical factors.

The third null hypothesis stated that the physicochemical factors and the biological data were not significantly related to each other. This null hypothesis was rejected based on several significant relationships that were observed between these factors and the microalgal biomass and zooplankton abundances. Clearly the seasonal changes in the physicochemical factors are partially responsible for some of the bottom-up control exerted on the plankton communities of South Bay.

The last null hypothesis stated that no significant difference existed in phytoplankton and benthic microalgal pigment concentrations and compositions between high turbidity episodes associated with wind-induced resuspension events and static, low turbidity episodes. When wind speeds increased, turbidity values typically increased indicating a possible relationship, albeit statistically insignificant, between these two variables. This poor correlation could be due to variable wind directions that occurred on the days sampled. Changes in wind direction could result in intermittent, calmer conditions with lower turbidity before wind speeds gather enough strength in another direction to resume resuspension. This weak correlation may also be due to the ability of weaker winds which produce smaller waves to reach the sediments during ebbing tides (Green and MacDonald, 2001). This would result in higher turbidity values observed at relatively lower wind speeds.

Despite the lack of a statistically significant correlation between wind speed and turbidity, sufficient evidence was gathered for the occurrence of wind-induced resuspension. Phytoplankton biomass was positively correlated with turbidity indicating that benthic microalgae could have been resuspended during these higher turbidity episodes. Benthic cyanobacterial biomass decreased during the higher turbidity episodes indicating that they were being removed from the sediment by resuspension forces. Increases in the fucoxanthin to chlorophyll *a* ratios for the phytoplankton and benthic microalgae indicated that deeper benthic diatoms may have been resuspended into the water column or moved to the upper layers of the sediment. The negative correlation for the ratio of phytoplankton fucoxanthin to chlorophyll *a* with the ratio of benthic microalgal zeaxanthin to chlorophyll *a* indicated that benthic cyanobacteria could have been removed from the sediments and resuspended as diatom biomass in the water column increased. However, the negative correlation between the phytoplanktonic diatoms and the microphytobenthic cyanobacteria may be attributed to allelopathy or to differences in nutrient uptake and requirements between the two algal groups. In spite of these mechanisms, all of this evidence suggested that wind-induced resuspension was occurring in South Bay. Therefore, the null hypothesis that no significant difference existed in microalgal pigment concentrations and composition between high turbidity episodes associated with wind-induced resuspension and low turbidity episodes was rejected. A more thorough analysis on shorter time scales of wind speed, turbidity, and pigment data would help to resolve whether the higher turbidity episodes are controlled by wind-induced resuspension.

The distinction between the phytoplankton and microphytobenthic communities became unclear as benthic microalgae were easily resuspended into the water column. Members of the phytoplankton and microphytobenthic community may be considered tychopelagic. Cell counts and species identification studies would help determine which species are part of the true phytoplankton, part of the true microphytobenthos, and which are tychopelagic. The microalgae are important sources of organic carbon to higher trophic levels such as the zooplankton in this study. Wind-induced resuspension of benthic microalgae permits different prey to be available at different times due to which microphytobenthic species are resuspended and how strong the forces are controlling resuspension (Arfi and Bouvy, 1995). Hypersaline systems usually rely more on benthic microalgal productivity rather than water column productivity because the benthic microalgal productivity is higher (Souza *et al.*, 2003). The benthic microalgal biomass has been shown to be an order of magnitude higher than that of the phytoplankton and is probably responsible for the majority of the productivity in this system. When compared to the phytoplankton, the microphytobenthos are more important players in the carbon cycle because they are most likely responsible for the majority of carbon fixation and production of new organic matter (Barranguet *et al.*, 1997). Therefore, the resuspension of the benthic microalgae in this study was critical in transferring energy to higher trophic levels. Primary production rates for the phytoplankton and the microphytobenthos should be measured in future studies to determine if they follow the same pattern as the relative biomass values for these compartments.

Future research has a lot of potential and should be directed toward several different topics concerning the food web dynamics of South Bay. Determining the members of the microbial loop would be beneficial in assessing the productivity of South Bay. Using a net with a smaller mesh size to collect plankton would be beneficial in identifying potentially important members of the microbial loop such as the ciliates, microzooplankton, rotifers, and heterotrophic flagellates (Fogg, 1991). Using a net with a smaller mesh net size would also be beneficial in determining seasonal and spatial distributions of the less abundant zooplankton observed in this study. More frequent sampling throughout the year would also aid in detecting short-term variability of plankton populations in South Bay. Species identification of the phytoplankton and microphytobenthos is essential in pinpointing which species are responsible for the primary production within this system. Analysis of all nutrient cycling will aid in primary production studies and may also help to explain the spatial and temporal variation in the phytoplankton and microphytobenthic communities observed in this study. Isotopic analyses would also help determine how the phytoplankton and microphytobenthos compare with each other and with other primary producers in this system such as the seagrasses and mangroves. This comparison would reveal which primary producers are essential to commercially and recreationally important fin and shellfish species within the bay. South Bay is an important nursery ground for these species so monitoring the productivity of this coastal embayment is highly suggested for future studies (Hook, 1991).

This study determined important spatial and temporal trends in the plankton communities that were attributable to bottom-up control of various physicochemical and meteorological factors and top-down control such as predation. The findings presented here can be used as a baseline for future studies concerned with the food web dynamics in South Bay and to compare with other studies performed in similar shallow, coastal embayments.

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