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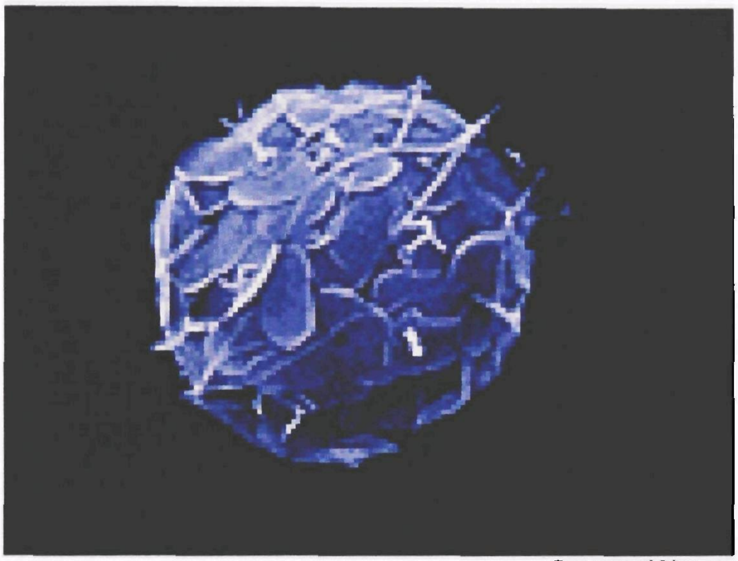
MONITORING *Pfiesteria* IN TEXAS ESTUARIES

Project Report



Cyst stage of *Pfiesteria*

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By

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Notice

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Abstract

A two-year monitoring program examined the Texas coast for the presence/absence of *Pfiesteria piscicida* and *P. shumwayae*. The sampling included a variety of bays and estuaries with differing degrees of nutrient input, sewage treatment outfalls, and heavily urbanized channels. In 2000, nine stations were monitored monthly and eight stations were monitored on a bi-monthly basis from April through September. In 2001, a selected set of stations was monitored at two-week intervals. Water samples were collected for nutrient and chlorophyll analyses. Two polymerase chain reaction (PCR) assays were used in the study. A conventional PCR assay for detection of a large amplified fragment was less sensitive than a second assay using a fluorogenic probe and quantitative PCR (Q-PCR). Despite evidence of DNA degradation after prolonged storage at -20° C, the follow-up Q-PCR technique yielded substantially more positives. Using this method, we found both *Pfiesteria* species occurred at some time during 2001 at every station sampled. Water collected after a fish kill in Dickinson Bayou, Texas tested positive for *Pfiesteria*, but there is no supporting data to indicate that this was the cause of the fish kill. The two species occurred at a wide range of chlorophyll and nutrient concentrations. They appear to be common and widely distributed members of the Texas coastal dinoflagellate community.

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Acknowledgments

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Cover photo courtesy of JoAnn Burkholder, North Carolina State University, Center for Applied Aquatic Ecology

Chapter 1
Introduction

Concern has grown nationwide about the possible presence and impacts of toxic algae on coastal ecosystems and human health. During the mid to late 90's, awareness has increased about the group of toxic dinoflagellates referred to as *Pfiesteria* and *Pfiesteria*-like organisms (PLO). These recently discovered organisms have been found to cause massive fish kills, outbreaks of fish disease and some neurological effects in humans in coastal ecosystems.

Pfiesteria has been implicated in both fish kills and human health issues along the eastern U.S. coast (Burkholder et al. 2001). In response, significant resources have been devoted to understanding the nature of its toxicity, response to environmental variables, geographic distribution and importance in estuarine environments.

The *Pfiesteria* species complex comprises two described species, *P. piscicida* (Steidinger et al 1996) and *P. shumwayae* Glasgow et Burkholder (Glasgow et al 2001b). Both species have complex life cycles and may occur in three functional types or toxicity states as: (1) highly toxic or TOX-A (actively toxic, requiring the presence of live finfish or other fish tissues and excreta), (2) temporarily non-toxic in the absence of fish or TOX-B; and (3) non-inducible, apparently unable to produce toxin in response to fish (Burkholder et al 2001b).

Pfiesteria Steidinger et Burkholder (Dinamoebales; Pfiesteriaceae) is a heterotrophic dinoflagellate with planktonic zoospore populations sourced from seed beds of cysts and amoebae in sediments (Steidinger et al 1996; Burkholder et al 1992; Burkholder and Glasgow 1997). *Pfiesteria* exhibits "ambush predator" behavior in the presence of fish (Burkholder et al 1998), which may lead to non-focal as well as deep-focal, ulcerous lesions and death, as demonstrated in laboratory experiments (Burkholder et al 1992, 1995, 2001a; Noga et al 1996). The fish attacks are non-specific and more than 20 native and exotic species tested in the U.S. have proven to be vulnerable to these attacks (Burkholder et al 1997). Many of these species are common to the estuarine waters of Texas, including redfish (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), catfish, striped mullet (*Mugil cephalus*), blue crab (*Callinectes sapidus*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*) (Glasgow et al. 2001). Although the Atlantic menhaden (*Brevoortia tyrannus*), the species most commonly killed in the *Pfiesteria* attacks, is not found along the Texas coast, there are two species of menhaden that do occur in abundance along the Texas coast, those being the Gulf menhaden (*Brevoortia patronus*) and the finescale menhaden (*Brevoortia gunteri*) (Hoese and Moore, 1977).

Pfiesteria spp. can consume small photosynthetic microalgae and retain their chloroplasts in an active state, presumably utilizing their photosynthetic products (Glasgow et al. 1999, 2001b; Lewitus et al 1999). Experiments show that *Pfiesteria piscicida* zoospores aggressively feed on and consume the soft tissues of larval bay scallops and eastern oysters (*Crassostrea virginica*) (Springer et al 2002).

Exposure to the dinoflagellate *Pfiesteria* causes skin ulcers in fish. Skin damage begins as epithelial erosion, which progresses to complete epithelial loss. Fish that recover from the acute toxic exposure develop bacterial and/or fungal infected skin ulcers that are typical of many spontaneous skin ulcer epidemics occurring in estuarine fish species along the Atlantic coast of the U.S. (Noga et al 1996).

Much research has been devoted to ascertaining the environmental conditions under which *Pfiesteria* and PLO can survive and thrive. While it has been determined that *Pfiesteria* and PLO are found in a wide range of salinities, from 0 to 35 ppt, the preferred range is from 5 to 20 ppt, with the optimum condition being found at salinities of 10 to 15 ppt (Burkholder et al. 2001a; Glasgow et al. 2000; Glasgow et al. 2001a). Furthermore, *Pfiesteria* and PLO have been found at a temperature range between 12 and 33 deg C, although the optimal range is 20 to 30 deg C, with best results at temperatures greater than 26 deg C. Although *Pfiesteria* and PLO appear to tolerate a wide range of temperatures and salinities, the conditions required to trigger a "bloom" and "predatory attack on fish" are much less well understood. Research indicates that the excreta from live fish, and possibly high levels of nutrients are required to trigger the ambush predatory behavior. Both N and P (organic and inorganic) have been shown experimentally to directly and indirectly stimulate toxic *Pfiesteria* strains (Glasgow et al. 2001).

Other research has demonstrated that when certain flagellated algal prey are present, *Pfiesteria* and PLO predominate as planktonic zoospores, but if non-motile prey such as the coccoid unicellar cyanobacterium *Cyanothece* or the diatom *Thalassiosira* are abundant, a higher proportion of the *Pfiesteria* population can consist of benthic lobose amoebae (Burkholder et al. 2001).

Nutrient enriched waters appear to be a preferred habitat for *Pfiesteria* and PLO (Glasgow et al. 2001a). The nutrient regime that appears to be conducive to *Pfiesteria* cell production is >> 100 ug/L DIN and 100 ug/L DIP. In addition, pH conducive to zoospore cell production ranges from 6.6 to 8.6 with an optimum pH at 7.5. *Pfiesteria* appears to prefer a sea state of low turbulence and light levels at 0 to 300 umol photons/m/s, with negligible or slow cell production above that light level. The preferred algal prey for zoospores and amoebae are cryptomonads, while finfish prey for the zoospores are many (Glasgow et al. 2001).

In addition, laboratory experiments have shown comparatively higher P stimulation of *P. piscicida* zoospores, and higher N stimulation of *P. shumwayae* (Glasgow et al. 2001a). There is also evidence suggesting that *P. shumwayae* may have improved mechanisms for survival of flooding/scouring events relative to *P. piscicida*, as there was a shift in dominance to *P. shumwayae* following several hurricanes that hit the North Carolina coast between 1996 and 1999 (Glasgow et al. 2001a).

There is no evidence to date that human illnesses result from eating fish or shellfish that have been exposed to a *Pfiesteria* event. Recent research by Springer et al (2002) has demonstrated that toxic *Pfiesteria* cells can be concentrated by some shellfish (for example, the sub-adult eastern oyster, *Crassostrea virginica* Gmelin). Thus, risks to humans from seafood cannot be ruled out until the *Pfiesteria* toxin can be identified, so that their presence/absence in fish tissue can be conclusively determined and quantified (Fairey et al 1999; Kimm-Brinson et al 2001; Samet et al 2001).

P. piscicida has been linked to measurable neurotoxic effects in humans, including central nervous system impairment (for example, mostly reversible short-term memory loss that can last for weeks to months, Glasgow et al. 1995; Gratten et al. 1998), as well as autonomic and peripheral nervous system dysfunction, skin lesions and other effects (Glasgow et al 1995).

Humans with environmental exposure to waterways in which *Pfiesteria* toxins are present are at risk of developing a reversible clinical syndrome characterized by difficulties with learning and high cognitive functions. Risk of illness is directly related to the degree of exposure, with the most prominent symptoms and signs occurring among people with chronic daily exposure to affected waterways (Gratten et al 1998).

The *Pfiesteria*-like complex appears to be broadly distributed and has been found at many locations within the U.S. and internationally. Outside of the U.S., *Pfiesteria* has been found in Scandinavia (Burkholder and Glasgow 2001), and New Zealand (Rhodes et al 2002). Both *P. piscicida* and *P. shumwayae* were found in Scandinavia, while only *P. shumwayae* was found in New Zealand.

Within the U.S., *Pfiesteria* has been found at many locations, particularly along the east coast. To date, it has been found in New York (Rublee et al 1999, 2001), New Jersey (Rublee et al 2001), Delaware (Burkholder et al 1995), Maryland (Lewitus et al. 1995; Burkholder et al. 1995; Gratten et al 1998), Virginia (Rublee et al 2001), North Carolina (Burkholder et al. 1992; Burkholder and Glasgow 1997, 2001), South Carolina (Rublee et al 2001), Georgia (Rublee et al 2001) and

Florida (Burkholder and Glasgow 1997; Glasgow et al 2001a). Within the Gulf of Mexico, *Pfiesteria* has been found in Florida (Burkholder and Glasgow 1997a; Glasgow et al 2001a) and Alabama (Burkholder and Glasgow 2001).

Along the eastern U.S. seaboard, *Pfiesteria* is considered to be a major cause of fish mortality (Glasgow et al. 2001). Fish kills are common along the Texas coast, and while there is no evidence to suggest *Pfiesteria* has been a causative agent, information on its distribution and occurrence in these waters is an important part of the state's overall resource management program.

The economic costs related to *Pfiesteria* have been high. In Maryland the presence of the dinoflagellate in association with the death of about 50,000 Atlantic menhaden (*Brevoortia tyranus* Latrobe) was responsible for an estimated cost of $65 million (Epstein 1998; Lipton 1998). This was due to indirect market effects based on provocative media reports and public perception rather than particularly heavy fish losses (Anderson et al 2000; Burkholder and Glasgow 2002).

Texas has experienced massive toxic blooms of *Karenia brevis* which have killed over 40 million fish along the Texas coast in the past 13 years. Toxic blooms of the dinoflagellate, *Alexandrium monilata*, have also occurred along the Texas coast. Texas has never had a documented incident caused by *Pfiesteria* or *Pfiesteria*-like organisms.

The Texas coast appears to be a likely habitat for *Pfiesteria* but there have been no attempts to determine if the species is present on this coast. The shallow, estuarine systems typical of the Texas coast are similar to *Pfiesteria* habitat along the eastern U.S. coast and the records of this species from the eastern Gulf of Mexico suggest it is likely to be present. We report here the results of two years of sampling using two different gene assays for both *Pfiesteria piscicida* and *P. shumwayae*.

Chapter 2
Study Design

The population of possible sampling sites considered for year one (2000) of the project encompassed the entire Texas coast. All bays, estuaries, tidal rivers, bayous and streams were considered. The research team selected sites based on the following selection criteria: logistics, other ongoing sampling programs, equitability of sampling distribution, possible nutrient sources, and degree of human impact. An attempt was made to select some stations that were considered to be degraded, and others that were considered to be minimally impacted by humans. Sampling was conducted for six months, from April through October. Samples sites that were difficult to access were sampled every other month. In some cases sites were sampled every other month to balance the sampling program. A total of 17 stations were selected (Table 2-1). Nine of the stations were sampled every month, while eight were sampled every other month.

In year two (2001) of the study, a different approach was taken. The population of sample sites was selected from the 17 stations sampled during 2000. Six stations were selected, two in the northern third, two in the central part of the coast and two in the southern third of the coast (Table 2-1). Sampling was again conducted from April through September, with each station sampled twice a month, once in the first half of the month, the other in the second half of the month.

Table 2-1. Sampling Locations and Schedule for *Pfiesteria* Monitoring in Texas for 2000 and 2001

System	Minor system	Sampling Scheme for 2000	Sampling Scheme for 2001
Sabine Lake	Sabine Pass	Monthly	
Galveston Bay	Tabbs Bay	Bi-monthly	
Galveston Bay	Clear Lake	Monthly	Semi-monthly
Galveston Bay	Dickinson Bayou	Bi-Monthly	Semi-monthly
Galveston Bay	Moses Bayou	Bi-monthly	
Galveston Bay	Jamaica Beach Canal	Monthly	
Brazos River	Freeport North	Bi-monthly	
Brazos River	Freeport South	Bi-monthly	
Matagorda Bay	Caney Creek	Monthly	Semi-monthly
Matagorda Bay	Colorado River	Bi-monthly	
Matagorda Bay	Lavaca Bay	Monthly	Semi-monthly
Aransas Bay	Mesquite Bay	Bi-monthly	
Corpus Christi Bay	Nueces River	Monthly	
Corpus Christi Bay	Port Aransas	Monthly	Semi-monthly
Corpus Christi Bay	Oso Bay	Monthly	
Upper Laguna Madre	Baffin Bay	Monthly	
Lower Laguna Madre	Arroyo Colorado	Bi-monthly	Semi-monthly

Chapter 3
Methods

Field Methods

Water samples were collected in 2000 and 2001. During each field season, samples were collected in the months of April through October. Samples were collected from small boats, bridges, fishing piers and bankside.

Upon arriving at each sampling site the date, time, air temperature, cloud cover, wind speed, wind direction, and sea state were noted and recorded. The latitude and longitude of each site was determined using a Global Positioning System hand held unit. Names of personnel involved in the sampling were also recorded along with the name of the location sampled.

Water quality parameters were measured using a Hydrolab unit. The Hydrolab unit measured depth (meters), temperature (degrees Celsius), specific conductivity (mS/cm), salinity (ppt), dissolved oxygen (mg/L), percent saturation of oxygen, and pH. Hydrolab measurements were taken at the surface and at one-meter intervals throughout the water column and recorded. A Secchi disk was used to measure turbidity of the water.

Water samples for chlorophyll analysis were collected at each site using a syringe and filter system. A water sample was taken at the surface using a container that had been rinsed two to three times with site water. A GF-75 glass fiber filter was used to filter the water. The volume of water filtered varied depending on water turbidity. In some cases, less than 40 ml was drawn so the water sample would not burst the filter while being pushed through. The syringe was then turned to have the opening face up while drawing another 10 ml of air. The water sample was forced through the filter by gently pushing the plunger with all the air being expelled at the end of the sample. Once the water sampled was expelled out of the syringe, the filter was removed with forceps, folded in half, placed in aluminum foil, labeled, and frozen on dry ice.

Four 10 ml vials of nutrient samples were collected at every site. While handling materials for the nutrient samples, latex gloves were worn. A pre-combusted filter was placed on the syringe head using forceps. Extreme care was used during sampling since ammonia is easy to contaminate. The filter, filter head surface, or the inside of the nutrient vial was never touched while sampling. Each of the four vials were filled with 10 ml each of filtered water. The vials were then labeled and frozen on dry ice. Occasionally the sampling process would require more than one filter if the water sampled was turbid. Blank samples were also sent to the lab. Deionized water was taken into the field and two vials were run through the filtration procedure.

Samples were taken at each site for gene probe analyses. A 2.5 cm GFC filter was placed in the filter head using forceps. The syringe was used to draw 50 ml of water from a rinsed container. The filter head was then placed on the syringe and 50 ml of water was pushed through the GFC filter. The filter was then removed from the filter head using forceps and immersed in the CTAB buffer in a micro-centrifuge vial. The vials were stored at room temperature until shipped to the lab.

Sediment samples were taken at a few pre-selected locations. A Van Dorn water sampler was used to collect the top layer of sediment from the bottom of the water column. Approximately 0.5-1.0 g of sediment was collected and placed in a micro-centrifuge vial. The vial was stored in a cool or ambient temperature and sent to the lab via overnight express.

Laboratory Methods

At each station, water samples were collected for chlorophyll a (Welschmeyer 1994)) and automated nutrient analysis (Lachat Quikchem 8000) for nitrate+nitrite, silicate, phosphate, ammonium and dissolved organic nitrogen. Nutrient analysis was conducted at UTMSI using a LaChat QC 8000 ion analyzer with computer controlled sample selection and peak processing. Chemistries are as specified by the manufacturer and have ranges as follows: nitrate+nitrate (0.03-5.0 μM; Quikchem method 31-107-04-1-A), silicate (0.03-5.0 μM; Quikchem method 31-114-27-1-B), ammonium (0.1-10 μM; Quikchem method 31-107-06-5-A) and phosphate (0.03-2.0 μM; Quikchem method 31-115-01-3-A). Chlorophyll was extracted overnight and read fluorometrically on a Turner Model 10-AU using a non-acidification technique (Welschmeyer, 1994; EPA method 445.0). Assays were performed in duplicate. Dissolved organic nitrogen and dissolved organic phosphorus was conducted by simultaneous persulfate digestion (Raimbault et al. 1999) and then assayed for nitrate+nitrite and phosphate by the above listed protocols.

Presence/absence of *P. piscicida* and *P. shumwayae* was determined using gene assays. Between 40 and 100 ml of water were filtered and returned to UNC, Greensboro for processing. Initially, samples were analyzed by a conventional PCR approach (M1) using probes for *P. piscicida* from Rublee, et al. (1999) and for *P. shumwayae* by Oldach, et al. (2000). Samples were later re-assayed by real-time PCR (M2) using primers and Taqman probes (Bowers et al. 2000) on a Cepheid Smart Cycler. The M2 assay was not available until 6 months after all samples were run using M1. Although the real-time PCR assay is more sensitive, storage of samples at –20 °C and additional freezing and thawing of samples prior to this second assay may have resulted in some degradation of DNA between assays.

The *Pfiesteria* and *Pfiesteria*-like genes assays were conducted by Dr. Parke Rublee at the UNCG. DNA is purified using chloroform purification (Schaefer 1997). If samples had high suspended sediment loads, an additional clean up step was used (DNeasy Plant Kit, Qiagen). Purified DNA was dissolved in sterile ddH_2O and stored at -20°C. 50 μl PCR reactions are following standard protocols (Innis, et al. 1995). Both positive (template from confirmed *Pfiesteria piscicida*, species "B" or *Cryptoperidiniopsis brodyi* culture) and negative controls (no template) were carried through each PCR run. PCR products were visualized by electrophoresis and ethidium bromide staining. For each sample, at least two primer sets specific for *Pfiesteria piscicida*, and single primer sets for each of the other two organisms were run. If no test reactions were positive, a control reaction was run using generic eukaryotic primers to confirm that amplifiable DNA had been extracted from the sample.

Data Analysis

Wind data for both years was converted to a Beaufort number using the Beaufort wind scale (Lincoln et al. 1982) for consistency. Where ranges were recorded the mid point was used to determine the Beaufort number. Means for stations were calculated, and then an approximate average wind speed was back calculated. The same approach was used with sea state, as data was recorded using both verbal descriptions or wave heights or wave height ranges were recorded. Based on the verbal description, a corresponding Beaufort number was applied so that an approximate average sea state could be calculated. Cloud cover data was recorded as a percentage in 2000, while in 2001 a coded pick list was developed, each code representing a range of percent cloud cover. All data was converted to the code system, and an approximate cloud cover back calculated from those means.

Data manipulation, graphics and statistical analysis was performed using MS Excel 2000, Sigma Plot 8.0 and Statview 5.01. Homogeneity of variance was tested using an F test, while differences between means was tested using a t-test.

Chapter 4
Results

Sampling Locations

In 2000, a total of 76 samples were collected for *Pfiesteria*, chlorophyll and nutrient analysis (Table 4-1). The sites were distributed along the entire Texas coast (Figure 4-1), with an attempt to sample as many of the major bay systems and as many different habitats as was logistically feasible. Following is a short description of all sampling locations. In Appendix A a more detailed description, plus a satellite image for all locations and ground photos for many of them are provided.

In the northeast part of the state, samples were collected at the Sabine Pass Swing Bridge (Figures A-1, A-2, A-3), at the same location where the Texas Water Development Board (TWDB) and TPWD maintain and monitor a datasonde.

Within the Galveston Bay system, there were six different areas where sampling was conducted. The Tabbs Bay station is located in north Galveston Bay, just south of Baytown (Figure A-4). In the Clear Lake area, samples were collected on two tributaries of Clear Lake: Armand Bayou, at a site within the Armand Bayou Nature Preserve (Figures A-5, A-6, A-7), and at a site on Clear Creek (Figures A-5, A-8, A-9, A-10, A-11). In addition, samples were collected from a pier at a park on Clear Lake (Figure A-5, A-12, A-13). There were two sample locations in Dickinson Bayou (Figure A-14), indicated as Dickinson Bayou 1 (Figures A-15, A-16) and Dickinson Bayou 2 (Figures A-17, A-18). There was a fish kill occurring at the Dickinson Bayou 2 station at the time of *Pfiesteria* sample collection. Further south in the Galveston Bay system were the Moses Bayou (Figures A-19, A-20, A-21) and Moses Lake (Figure A-19) stations. And across West Bay there was a station located at a boat ramp in the canals of the community of Jamaica Beach (Figures A-22, A-23, A-24).

Further down the coast in the Brazosport area, located near the Brazos River, were the Freeport North and South sampling locations (Figure A-25). Samples were collected in Oyster Creek (Figures A-26, A-27) and Swan Lake for the Freeport North locations, while Jones Creek and the ICWW (Figures A-28, A-29) were sampled for the Freeport South location.

Moving further south, was the Caney Creek station which is a tributary of East Matagorda Bay (Figures A-30, A-31, A-32) and the Colorado River station, which drains into Matagorda Bay (Figure A-33). Further up the Matagorda Bay system were the Lavaca Bay stations (Figure A-34). In 2000 the Pfiesteria samples were collected along the Lavaca Bay causeway where TWDB and TPWD monitored and maintained a datasonde, while in 2001 samples were collected from the Port Lavaca Fishing Pier (Figures A-35, A-36).

A site in a relatively unimpacted area was located in Mesquite Bay (Figure A-37). Another station was located in the marsh at the Port Aransas Birding Center (Figures A-38, A-39). This marsh is used in the treatment of water coming from the Port Aransas STP. Also located within the Corpus Christi Bay system is a station on the Nueces River (Figure A-40), located just downstream of the Allison Sewage Treatment Plant (Figure A-41, A-42), which treats wastewater from Corpus Christi. There were also three sites sampled in the Oso Bay system, a sub-system of Corpus Christi Bay (Figure A-43). Oso Bay 1 was located at the mouth of the Oso Bay (Figures A-44, A-45). Oso Bay 2 was located on the Yorktown Rd. bridge where it crosses the upper reaches of Oso

Bay (Figures A-46, A-47). Finally, the Oso Creek station was located on the Staples Rd. bridge that crosses over Oso Creek (Figures A-48, A-49). The Oso Bay system is heavily influenced by inputs from STPs and the discharges from the Barney-Davis power plant.

Along the lower Texas coast, samples were collected in Baffin Bay, a sub-estuary of the Upper Laguna Madre (Figure A-50) and the Arroyo Colorado, a major tributary of the Lower Laguna Madre (Figure A-55). Baffin Bay samples were collected at the Bayview Campground (Figures A-51, A-52) and at Kraatz Pier (Figures A-53, A-54). The Arroyo Colorado samples were collected from a pier at the Adolph Tomae Jr. County Park (Figures A-56, A-57, A-58). The Arroyo is a conduit for much of the wastewater from the city of Harlingen. In addition, two large shrimp farms in Arroyo City discharge wastes into the Arroyo Colorado.

In 2001, 67 samples were collected (Table 4-2) at only six locations. These six locations, Clear lake, Dickinson Bayou, Caney Creek, Lavaca Bay, Port Aransas and Arroyo Colorado (Figure 4-2), were selected from the sites sampled in 2000, but with a more intensive sampling regime, that being twice a month, rather than the monthly or bi-monthly sampling performed in 2000. All stations remained at the same location except for the Lavaca Bay station, which was moved from the Lavaca Bay causeway to the Port Lavaca Fishing Pier for easier access. Several samples were not collected from the Lavaca Bay site due to logistical and communication problems. Two samples were not collected at Arroyo Colorado because of logistical problems.

The sites sampled represented a wide variety of environments in relation to salinity, water body type, possible nutrient sources, and proximity to population centers. Table 4-3 lists all the stations and general characteristics such as the salinity regime, nutrient sources, land use in the watershed and type of water body where the sample was collected.

A total of 27 different locations were sampled during the two-year study. There were three oligohaline sites, two being upper reaches of tidal creeks (Dickinson Bayou, Oso Creek) and the other was the marsh of the Port Aransas Birding Center. There were 11 mesohaline sites, these typically being tidal creeks (Armand Bayou, Dickinson Bayou 1, Oyster Creek) and rivers (Colorado River, Nueces River, Arroyo Colorado), and bays (Tabbs Bay, Clear Lake, Port Lavaca Fishing Pier (Lavaca Bay)) in the upper end of the estuary. There were eight polyhaline sites, with these also including tidal creeks (Moses Bayou, Jones Creek, Caney Creek), passes and canals (Sabine Pass Swing Bridge, ICWW) and bays (Moses Lake, Lavaca Bay Causeway, Oso Bay 2), generally in closer proximity to the Gulf of Mexico. There were four marine sites (Jamaica Beach Canal (West Bay), Mesquite Bay, Oso Bay 1, Kraatz Pier (Baffin Bay)) and one hypersaline site (Bayview Campground (Baffin Bay)), with one of the marine sites (Kraatz Pier) likely to typically be hypersaline.

The water body types ranged from small tidal creeks and bayous, passes, canals, tidal rivers, open bays and a marsh. The land use/land cover surrounding and upstream of the sites varied considerably, from sites in industrial to urban settings to locations surrounded by a Wildlife Management Area (Jones Creek) or adjacent to a National Wildlife Refuge (Mesquite Bay). The sediment types found at most of the stations was predominantly silt and clay, as ten of the stations (Tabbs Bay, Clear Creek, Dickinson Bayou 1, Moses Bayou, Caney Creek, Colorado River, Lavaca Bay Causeway, Port Lavaca Fishing Pier, Nueces River, and Adolph Tomae Jr. County Park) consisted of greater than 85% silt/clay (Table 4-3). There were two stations (Moses Lake and Oso Bay 1) that had greater than 80% sand, while the Sabine Pass Swing Bridge and Mesquite Bay stations had greater than 10% gravel (White et al., 1983, 1985, 1986, 1987, 1988, 1989a, 1989b).

Potential pollution and nutrient sources for the sites also varied considerably (Table 4-4). Nutrient concentrations of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) as determined by TCEQ's Surface Water Quality Monitoring program from January 1970 through December 2004 varied greatly at the *Pfiesteria* sampling stations (Table 4-4). The greatest mean DIN concentrations were found at the Clear Creek (1.386 mg/L) station (Segment 1101) and the Adolph Tomae

Jr. County Park (2.310 mg/L) station (Segment 2201). at the Caney Creek (0.890 mg/L) station (Segment 1304) and the Jones Creek (0.805 mg/L) station (Segment 1201). The mean concentration of DIP was greatest at the Clear Creek (0.831 mg/L) station. Other stations with relatively high mean DIP concentrations included Tabbs Bay with 0.436 mg/L (Segment 2426), Armand Bayou and Clear Lake with 0.356 mg/L (Segment 2425) and the Adolph Tomae Jr. County Park with 0.336 mg/L (Segment 2201) (Table 4-4). Thirteen of the sites were located in Texas

In addition, mean DIN concentrations were fairly high Commission of Environmental Quality (TCEQ) segments that appear on the 1998 303(d) listing (Table 4-4). Of these 13, seven were listed for "organic enrichment/low dissolved oxygen". Many of the sites are likely to be affected by non-point source pollution from industrial, agricultural, urban or suburban land uses upstream of the site. In addition, several locations are on watercourses affected by STP outfalls. It is likely that leachate from septic systems could also affect several of the sites.

Table 4-1. Stations Sampled for the Texas *Pfiesteria* Monitoring Program in 2000 (nc=not collected).

Minor System	Sampling locations	April		May		June		July		August		September	
		Planned	Date Collected	Planned	Date Collected	Planned	Date Collected	Planned	Date Collected	Planned	Date Collected	Planned	Date Collected
Sabine Lake	Sabine Pass Swing Bridge	X	25-Apr	X	nc	X	23-Jun	X	12-Jul	X	2-Aug	X	15-Sep
Galveston Bay	Tabb's Bay	X	26-Apr			X	23-Jun			X	10-Aug		
Clear Lake	Clear Lake, Clear Creek, Armand Bayou	X	26-Apr	X	11-May	X	21-Jun	X	10-Jul	X	7-Aug	X	20-Sep
Dickinson Bay	Dickinson Bayou	X	19-Apr			X	nc		26-Jul	X	7-Aug		20-Sep
Moses Lake	Moses Bayou, Moses Lake			X	11-May			X	7-Jul			X	20-Sep
West Bay	Jamaica Beach Canal	X	19-Apr	X	15-May	X	21-Jun	X	27-Jul	X	9-Aug	X	4-Oct
Freeport (north)	Oyster Creek, Swan Lake			X	30-May			X	20-Jul			X	4-Oct
Freeport (south)	Jones Creek, Intracoastal Waterway			X	30-May			X	20-Jul			X	4-Oct
East Matagorda Bay	Caney Creek	X	19-Apr	X	nc	X	23-Jun	X	26-Jul	X	15-Aug	X	22-Sep
Colorado River	Colorado River			X	26-May			X	26-Jul			X	22-Sep
Lavaca Bay	Lavaca Bay Causeway	X	13-Apr	X	17-May	X	30-Jun	X	25-Jul	X	nc	X	29-Sep
Mesquite Bay	Mesquite Bay			X	17-May			X	24-Jul			X	10-Oct
East Flats	Port Aransas Birding Center	X	18-Apr	X	24-May	X	21-Jun	X	12-Jul	X	14-Aug	X	3-Oct
Nueces Bay	Nueces River	X	19-Apr	X	16-May	X	14-Jun	X	12-Jul	X	8-Aug	X	7-Sep
Oso Bay	Oso Bay, Oso Creek	X	13-Apr	X	30-May	X	20-Jun	X	12-Jul	X	8-Aug	X	15-Sep
Baffin Bay	Bayview Campground, Kraatz Pier	X	27-Apr	X	31-May	X	21-Jun	X	28-Jul	X	24-Aug	X	28-Sep
Arroyo Colorado	Adolph Tomae Jr. County Park	X	6-Apr			X	13-Jun			X	9-Aug		
Total		12	12	14	12	12	11	14	15	12	11	14	15

Table 4-2. Stations Sampled for the Texas *Pfiesteria* Monitoring Program in 2001 (nc=not collected).

Minor system	Sampling locations	April		May		June		July		Aug		Sept	
		Date collected: first half	Date collected: second half	Date collected: first half	Date collected: second half	Date collected: first half	Date collected: second half	Date collected: first half	Date collected: second half	Date collected: first half	Date collected: second half	Date collected: first half	Date collected: second half
Clear Lake	Clear Lake	10-Apr	25-Apr	9-May	24-May	5-Jun	20-Jun	3-Jul	19-Jul	3-Aug	17-Aug	4-Sep	28-Sep
Dickinson Bay	Dickinson Bayou	10-Apr	25-Apr	9-May	24-May	5-Jun	20-Jun	3-Jul	19-Jul	3-Aug	17-Aug	4-Sep	18-Sep
East Matagorda Bay	Caney Creek	10-Apr	25-Apr	9-May	24-May	5-Jun	20-Jun	3-Jul	19-Jul	3-Aug	17-Aug	31-Aug	18-Sep
Lavaca Bay	Port Lavaca Fishing Pier	nc	19-Apr	nc	nc	10-Jun	28-Jun	11-Jul	nc	6-Aug	15-Aug	19-Sep	27-Sep
East Flats	Port Aransas Birding Center	10-Apr	25-Apr	8-May	24-May	12-Jun	26-Jun	10-Jul	31-Jul	14-Aug	30-Aug	14-Sep	27-Sep
Arroyo Colorado	Adolph Tomae Jr. County Park	9-Apr	23-Apr	9-May	24-May	7-Jun	19-Jun	10-Jul	24-Jul	13-Aug	29-Aug	12-Sep	nc
Total		5	6	5	5	6	6	6	5	6	6	6	5

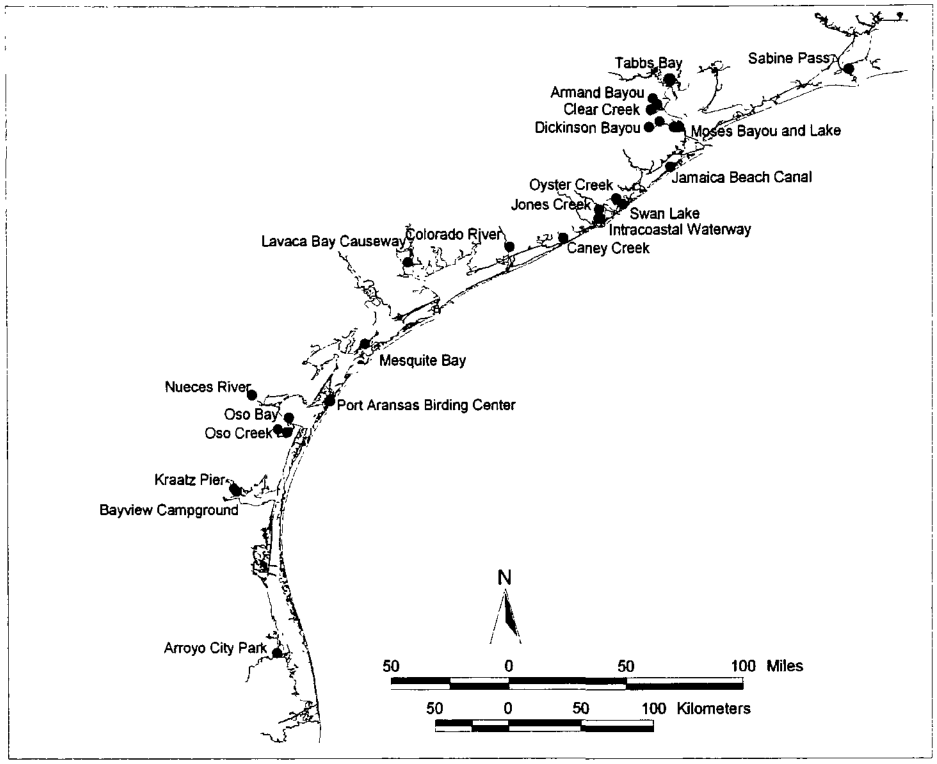

Figure 4-1. Location of stations sampled for *Pfiesteria* in 2000.

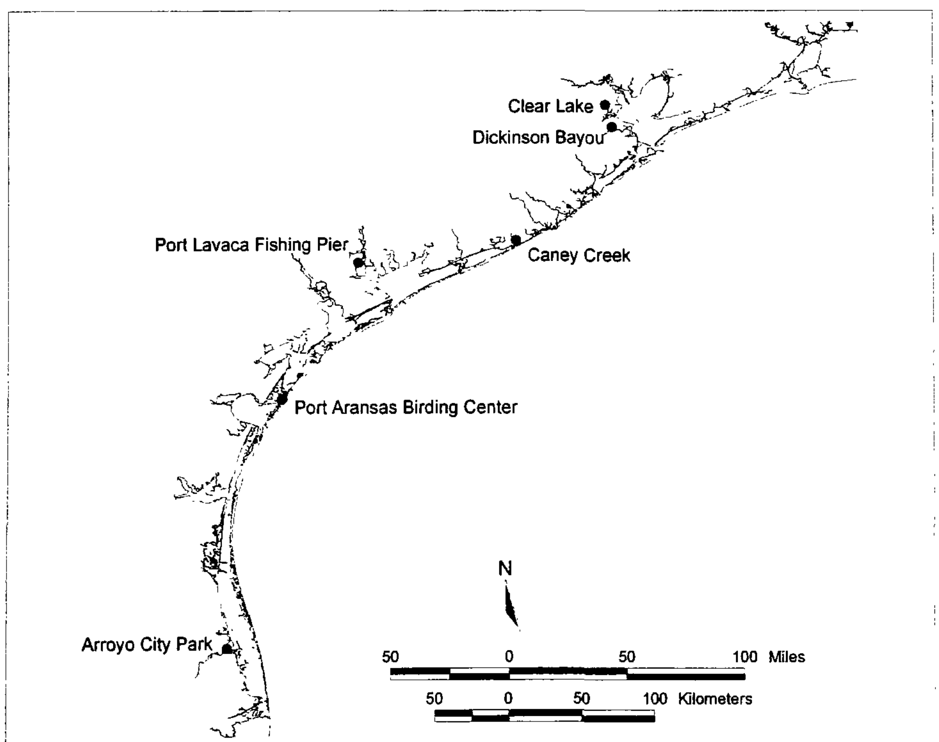

Figure 4-2. Location of stations sampled for *Pfiesteria* in 2001.

Table 4-3. Characteristics of the Water Bodies and Adjacent Watersheds for the *Pfiesteria* sampling locations in 2000 and 2001. (nd=no data).

Location	Salinity Regime[1]	Water Body Type	Nearby Predominant Landuse/Landcover[2]	Sediment Types[3] Gravel (%)	Sand (%)	Silt/Clay (%)
Sabine Pass Swing Bridge	polyhaline	pass	ind, marsh	10.7	26.17	63.13
Tabbs Bay	mesohaline	open bay	ind, forest, resid, marsh, comm.	0.49	5.76	93.75
Armand Bayou	mesohaline	bayou	forest, resid, abnp, marsh	0	0	98
Clear Lake	mesohaline	open bay	resid, comm., park	0	0	98
Clear Creek	mesohaline	bayou	resid, ind, marsh	0.94	12.69	86.38
Dickinson Bayou 1	mesohaline	bayou	resid, park, forest	0	12.43	87.56
Dickinson Bayou 2	oligohaline	bayou	forest, resid, agric	nd	nd	nd
Moses Bayou	polyhaline	bayou	golf course, resid, prairie	1.66	5.36	92.98
Moses Lake	polyhaline	open bay	resid, marsh, prairie	0.21	82.85	16.94
Jamaica Beach Canal	marine	canal	resid	nd	nd	nd
Oyster Creek	mesohaline	tidal creek	forest, prairie, resid	nd	nd	nd
Swan Lake	mesohaline	tidal lake	marsh, prairie	nd	nd	nd
Jones Creek	polyhaline	tidal creek	forest, wma	nd	nd	nd
Intracoastal Waterway	polyhaline	canal	forest, brush	nd	nd	nd
Caney Creek	polyhaline	tidal creek	resid, forest, brush, marsh	0.1	0.1	99.8
Colorado River	mesohaline	tidal river	forest	0	9.95	90.05
Lavaca Bay Causeway	polyhaline	open bay	ind, marsh, agric	0.05	6.73	93.21
Port Lavaca Fishing Pier	mesohaline	open bay	rv park, comm., agric	0.3	3.59	96.1
Mesquite Bay	marine	open bay	nwr, oil/gas, marsh, prairie	14.15	35.75	50.1
Nueces River	mesohaline	tidal river	ind, resid, marsh, agric	0	11.3	88.75
Port Aransas Birding Center	oligohaline	marsh	marsh, resid	nd	nd	nd
Oso Creek	oligohaline	tidal creek	resid, agric	nd	nd	nd
Oso Bay 1	marine	open bay	univ, naval base, marsh, resid	0.06	98.7	1.29
Oso Bay 2	polyhaline	open bay	resid, agric, range	0.36	1.65	98
Kraatz Pier	marine	open bay	agric, ranch	1.94	35.54	62.51
Bayview Campground	hypersaline	open bay	rv park, agric, ranch	1.67	37.29	61.04
Adolph Tomae Jr. County Park	mesohaline	tidal river	agric, ranch, aquacult	0	2.32	97.68

1. oligohaline= 0.6-3.0 ppt, mesohaline=3.1-16.5 ppt, polyhaline=16.6-30.0 ppt,.marine=30.1-40.0, hypersaline>40.0 ppt (from Stickney 1984).
2. ind=industrial, resid=residential, comm.=commercial, abnp=Armand Bayou Nature Preserve, wma=Wildlife Management Area, nwr=National Wildlife Refuge, univ=university, aquacult=aquaculture.
3. Sediment types from Bureau of Economic Geology, (White et al, 1983,1985,1986,1987,1988,1989a, 1989b).

Table 4-4. Potential Pollution Sources and Historic Nutrient Characteristics of the Water Bodies and Adjacent Watersheds for the *Pfiesteria* sampling locations in 2000 and 2001. (nd=no data)

Location	TCEQ Segment	DIN (mg/L)	DIP (mg/L)	Nearby Potential Nutrient Sources[1]	1998 303d Listed Parameters of Concern[2]
Sabine Pass Swing Bridge	2411	0.219	0.035	ind waste, NPS	
Tabbs Bay	2426	0.584	0.436	ind waste, urban NPS	1,2
Armand Bayou	2425	0.363	0.356	resid NPS	2,7
Clear Lake	2425	0.363	0.356	resid NPS	
Clear Creek	1101	1.386	0.831	resid, comm., ind NPS	2,3,4,5,6
Dickinson Bayou 1	1103	0.362	0.136	resid NPS	7
Dickinson Bayou 2	1103	0.362	0.136	agric NPS	7
Moses Bayou	2431	0.223	0.212	golf course	
Moses Lake	2431	0.223	0.212	resid, comm. NPS	
Jamaica Beach Canal[3]	2424	0.121	0.096	resid NPS, septic syst	2,8,9
Oyster Creek	1109	0.470	0.285	septic syst	2
Swan Lake	nd	nd	nd		
Jones Creek[3]	1201	0.805	0.162		
Intracoastal Waterway	nd	nd	nd		
Caney Creek	1304	0.890	0.244	septic syst	2
Colorado River	1401	0.571	0.153	agric NPS	
Lavaca Bay Causeway	2453	0.175	0.068	agric, ind NPS	
Port Lavaca Fishing Pier	2453	0.175	0.068	comm., agric NPS	2
Mesquite Bay	2463	0.169	0.097		
Nueces River	2101	0.307	0.267	STP, resid, ind NPS	
Port Aransas Birding Center	2481	0.213	0.079	STP, resid NPS	
Oso Creek	2485	0.423	0.169	STP, agric, resid NPS	2,7
Oso Bay 1	2485	0.423	0.169	resid NPS	2,7
Oso Bay 2	2485	0.423	0.169	STP, resid NPS	2,7
Kraatz Pier	2492	0.172	0.075	agric NPS	
Bayview Campground	2492	0.172	0.075	septic syst, agric NPS	
Adolph Tomae Jr. County Park	2201	2.310	0.336	shrimp farm, STP, agric NPS	7

1. ind=industrial, NPS=non point source, resid=residential, comm.=commercial, agric=agriculture, STP=sewage treatment plant
2. 1=dioxin, 2=pathogens, 3=dichloroethane, 4=trichloroethane, 5=carbon disulfide, 6=chlordane, 7=organic enrichment/low dissolved oxygen, 8=copper, 9=mercury.
3. The TCEQ segment data for these stations is not likely to be indicative of the local conditions at the *Pfiesteria* sampling station.

Meteorological Conditions

Mean monthly air temperatures during both sampling seasons followed a typical seasonal pattern, with a mean maximum temperature of 34.1 °C in August 2000 (Figure 4-3) and 30.3 °C in August of 2001 (Figure 4-4). In both years, the mean minimum temperatures were recorded on April, with 27.4 °C in 2000 (Figure 4-3) and 24.3 °C in 2001 (Figure 4-4).

The highest mean air temperature at any station in 2000 was 35 °C and was recorded at the Jones Creek station, while the lowest mean of 25.56 °C was found at Oso Bay 1 (Table 4-5). In 2001, the highest mean air temperature of 32.38 °C was recorded at the Port Lavaca Fishing Pier, while the lowest mean was 27.87 °C at Clear Lake (Table 4-6).

The mean monthly cloud cover in 2000 was quite variable and had a minimum value of 2.0 (10-25%) in July (Table 4-5, Figure 4-5). By station, the lowest cloud cover of 1.0 (0-9%) was recorded at Kraatz Pier on Baffin Bay, while the highest value of 6.0 (91-100%) was recorded at Oso Bay 1 (Table 4-5). In 2001, the mean monthly cloud cover was again quite variable, with the smallest mean of 2.1 (11.5%) occurring in May (Table 4-6, Figure 4-6). By station, the lowest mean cloud cover of 2.5 was recorded at Lavaca Bay Fishing Pier, while the highest value of 4.0 was recorded at Adolph Tomae Jr. County Park (Table 4-6).

In 2000 the mean monthly wind speed was greatest during the spring months with a mean 3.8 (12.5 kts) in April and 3.1 (9.0 kts) in May, and was lowest during the late summer months with a mean of 2.4 (6.4 kts) in August and 2.7 (7.5 kts) September (2.7) (Figure 4-7).

The corresponding sea state values show great variability. The highest mean sea state of 2.1 (distinct wavelets, small and short but not breaking) was recorded in August. The calmest mean sea state of 0.7 (only ripples or small wavelets, no foam crests) was recorded in September (Figure 4-8).

In 2000, the highest mean wind speed of 5.0 (19.0 kts) was recorded at Kraatz Pier on Baffin Bay, while the lowest value of 1.0 (2.0 kts) was recorded at Moses Lake (Table 4-5). The highest mean sea state of 5.0 (pronounced waves, distinctly elongated with many white horses, perhaps isolated spray) was also recorded at Kraatz Pier, while there were 10 stations with a mean sea state of 0.0 (water surface smooth, mirror-like) (Table 4-5).

For 2001 the highest mean monthly wind speed of 2.6 (7.1 kts) was recorded in April, and generally showed a progression of decreases through a low in July Of 1.75 (4.25 kts) followed by slight increases in August and September (Figure 4-9). Mean sea state appears to correspond much better with wind speed in 2001. The highest mean sea state of 2.4 (distinct wavelets, small and short but not breaking) was recorded in April and the lowest 0.6 (only ripples or small wavelets, no foam crests) in July (Figure 4-8).

The highest mean wind speed at a station in 2001 was 3.29 (9.95 kts), recorded at Lavaca Bay Fishing Pier, while the lowest mean wind speed of 1.42 (3.3 kts) was found at Clear Lake (Table 4-6). The highest mean sea state of 2.71 (distinct wavelets, small to medium but not breaking) was recorded at the Port Lavaca Fishing Pier, while Clear Lake had a mean sea state of 0.00 (water surface smooth, mirror-like) (Table 4-6).

Table 4-5. Means (Stdev, N) for Meteorological Parameters at *Pfiesteria* Sampling Locations for 2000.

Minor System	Location	Air temperature (degrees C)	Wind speed code (Beaufort)	Approximate average wind speed (kts)	Cloud cover code	Approximate average cloud cover (%)	Sea state code (Beaufort)	Approximate average sea state
Sabine Lake	Sabine Pass	32.69 (2.091, 6)	2.17 (0.753, 6)	5.6	3.00 (1.673, 6)	38.5	0 (0.000, 6)	Smooth
Galveston Bay	Tabbs Bay	32.41 (4.979, 3)	3.00 (1.000, 3)	8.5	2.00 (0.000, 3)	17.5	2.33 (2.082, 3)	Wavelets
Clear Lake	Clear Lake	29.44 (0, 1)	3.00 (0, 1)	8.5	2.00 (0, 1)	17.5	2.00 (0, 1)	Wavelets
Clear Lake	Clear Creek	30.28 (1.179, 2)	3.50 (0.707, 2)	11.0	4.00 (2.828, 2)	63.0	1.50 (2.121, 2)	Ripples to small wavelets
Clear Lake	Armand Bayou	33.15 (1.604, 3)	3.33 (1.528, 3)	10.2	3.00 (1.000, 3)	38.5	2.00 (1.732, 3)	Wavelets
Dickinson Bay	Dickinson Bayou 1	30.00 (4.747, 3)	2.67 (0.577, 3)	7.3	3.33 (1.528, 3)	46.6	3.00 (3.000, 3)	Large wavelets
Dickinson Bay	Dickinson Bayou 2	33.61 (1.964, 2)	2.00 (1.414, 2)	5.0	2.50 (0.707, 2)	28.0	0.00 (0.000, 2)	Smooth
Moses Lake	Moses Bayou	31.67 (0.786, 2)	3.00 (1.414, 2)	8.5	4.50 (2.121, 2)	72.8	1.50 (2.121, 2)	Ripples to small wavelets
Moses Lake	Moses Lake	32.22 (0, 1)	1.00 (0, 1)	2.0	2.00 (0, 1)	17.5	0.00 (0, 1)	Smooth
West Bay	Jamaica Beach Canal	31.57 (1.424, 6)	3.17 (0.753, 6)	9.4	2.00 (1.000, 5)	17.5	0.00 (0.000, 6)	Smooth
Freeport South	Intracoastal Waterway	32.22 (0.000, 2)	2.50 (0.707, 2)	6.8	2.50 (0.707, 2)	28.0	1.50 (2.121, 2)	Ripples to small wavelets
Freeport South	Jones Creek	35 (0, 1)	2 (0, 1)	5.0	2 (0, 1)	17.5	0 (0, 1)	Smooth
Freeport North	Oyster Creek	32.22 (0.000, 2)	2.00 (1.414, 2)	5.0	2.50 (0.707, 2)	28.0	0.00 (0.000, 2)	Smooth
Freeport North	Swan Lake	33.33 (0, 1)	3.00 (0, 1)	8.5	2.00 (0, 1)	17.5	0.00 (0, 1)	Smooth

East Matagorda Bay	Caney Creek	31.56	2.80	7.8	3.00	38.5	1.20	Ripples
		(2.466, 5)	(0.837, 5)		(1.414, 4)		(1.643, 5)	
Matagorda Bay	Colorado River	32.59	2.66	7.3	2.33	24.4	0.00	Smooth
		(0.642, 3)	(0.760, 3)		(0.577, 3)		(0.000, 3)	
Lavaca Bay	Lavaca Bay Causeway	30.78	3.80	12.5	3.00	38.5	3.20	Large wavelets with white horses
		(3.656, 5)	(1.142, 5)		(1.871, 5)		(1.643, 5)	
Mesquite Bay	Mesquite Bay	31.30	4.00	13.5	3.00	38.5	3.00	Large wavelets with white horses
		(3.208, 3)	(1.732, 3)		(1.732, 3)		(3.000, 3)	
Nueces Bay	Nueces River	31.11	4.33	15.3	2.67	31.6	0.80	Smooth to small wavelets
		(4.052, 6)	(0.816, 6)		(2.251, 6)		(1.304, 5)	
Corpus Christi Bay	Port Aransas Birding Center	27.81	4.00	13.5	1.50	11.0	0.00	Smooth
		(4.007, 3)	(0.000, 3)		(0.707, 2)		(0.000, 2)	
Oso Bay	Oso Bay 1	25.56	3.00	8.5	6.00	95.5	3.00	Large wavelets with white horses
		(0, 1)	(0, 1)		(0, 1)		(0, 1)	
Oso Bay	Oso Bay 2	30.05	3.00	8.5	2.50	28.0	2.25	Distinct wavelets
		(2.262, 4)	(1.414, 4)		(1.732, 4)		(1.500, 4)	
Oso Bay	Oso Creek	32.22	2.00	5.0	2.00	17.5	0.00	Smooth
		(0, 1)	(0, 1)		(0, 1)		(0, 1)	
Baffin Bay	Kraatz Pier	31.11	5.00	19.0	1.00	4.5	5.00	Pronounced waves, many white horses
		(0, 1)	(0, 1)		(0, 1)		(0, 1)	
Baffin Bay	Bayview Campground	30.46	4.00	13.5	1.60	12.3	3.80	Large wavelets, some waves, some white horses
		(2.101, 5)	(1.581, 5)		(0.894, 5)		(0.837, 5)	
Arroyo Colorado	Arroyo City Park	29.91	2.66	7.3	2.67	31.6	2.00	Distinct wavelets
		(5.852, 3)	(1.075, 3)		(2.082, 3)		(2.828, 3)	
Grand Mean		31.29	3.12		2.64		1.50	
(Stdev, N)		(5.189, 75)	(1.208, 75)		(1.476, 72)		(1.854, 72)	
(Min, Max)		(24.4, 36.7)	(1.0, 6.0)		(1.0, 6.0)		(0.0, 6.0)	

Table 4-6. Means (Stdev, N) for Meteorological Parameters at *Pfiesteria* Sampling Locations for 2001.

Minor System	Location	Air temperature (degrees C)	Wind speed code (Beaufort)	Approximate average wind speed (kts)	Cloud cover code	Approximate average cloud cover (%)	Sea state code (Beaufort)	Approximate average sea state
Clear Lake	Clear Lake	27.87	1.42	3.3	2.75	33.3	0.00	Smooth
		(2.761, 12)	(1.084, 12)		(2.094, 12)		(0.000, 12)	
Dickinson Bay	Dickinson Bayou	28.33	1.92	4.8	3.42	48.8	0.75	Smooth to small ripples
		(2.333, 12)	(0.669, 12)		(1.730, 12)		(1.357, 12)	
East Matagorda Bay	Caney Creek	28.33	2.17	5.6	3.08	40.5	1.08	Ripples to small wavelets
		(2.024, 12)	(0.577, 12)		(1.505, 12)		(1.621, 12)	
Lavaca Bay	Lavaca Bay	32.38	3.29	9.9	2.50	28.0	2.71	Distinct to large wavelets
		(3.219, 7)	(1.266, 7)		(1.690, 8)		(2.215, 7)	
Corpus Christi Bay	Port Aransas Birding Center	25.02	2.75	7.6	2.75	33.3	0.50	Smooth to small ripples
		(2.745, 12)	(0.754, 12)		(1.960, 12)		(0.707, 2)	
Arroyo Colorado	Arroyo City Park	30.35	3.18	9.4	4.00	63.0	2.27	Distinct wavelets
		(3.411, 8)	(1.168, 11)		(1.789, 11)		(1.737, 11)	
Grand Meam		28.32	2.35		3.10		1.20	
(Stdev, N)		(3.352, 63)	(1.143, 66)		(1.810, 67)		(1.699, 56)	
(Min, Max)		(19.7, 35.0)	(0.0, 6.0)		(1.0, 6.0)		(0.0, 6.0)	

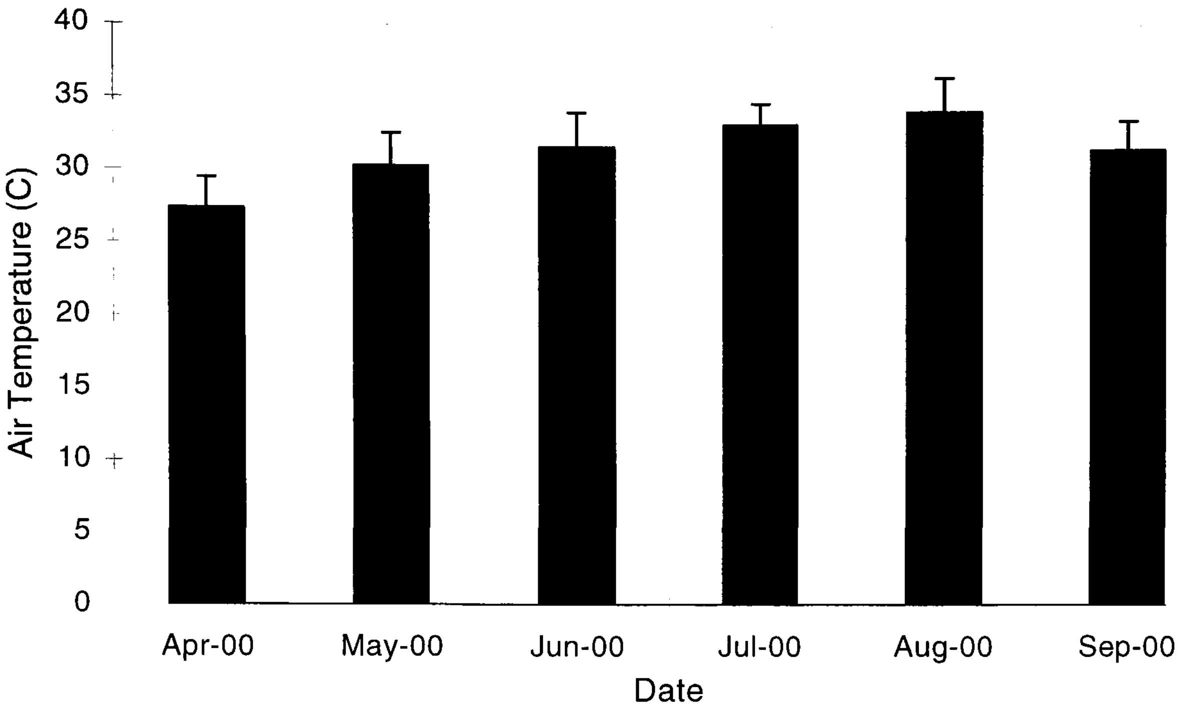

Figure 4-3. Mean monthly air temperature at *Pfiesteria* sampling stations in 2000.

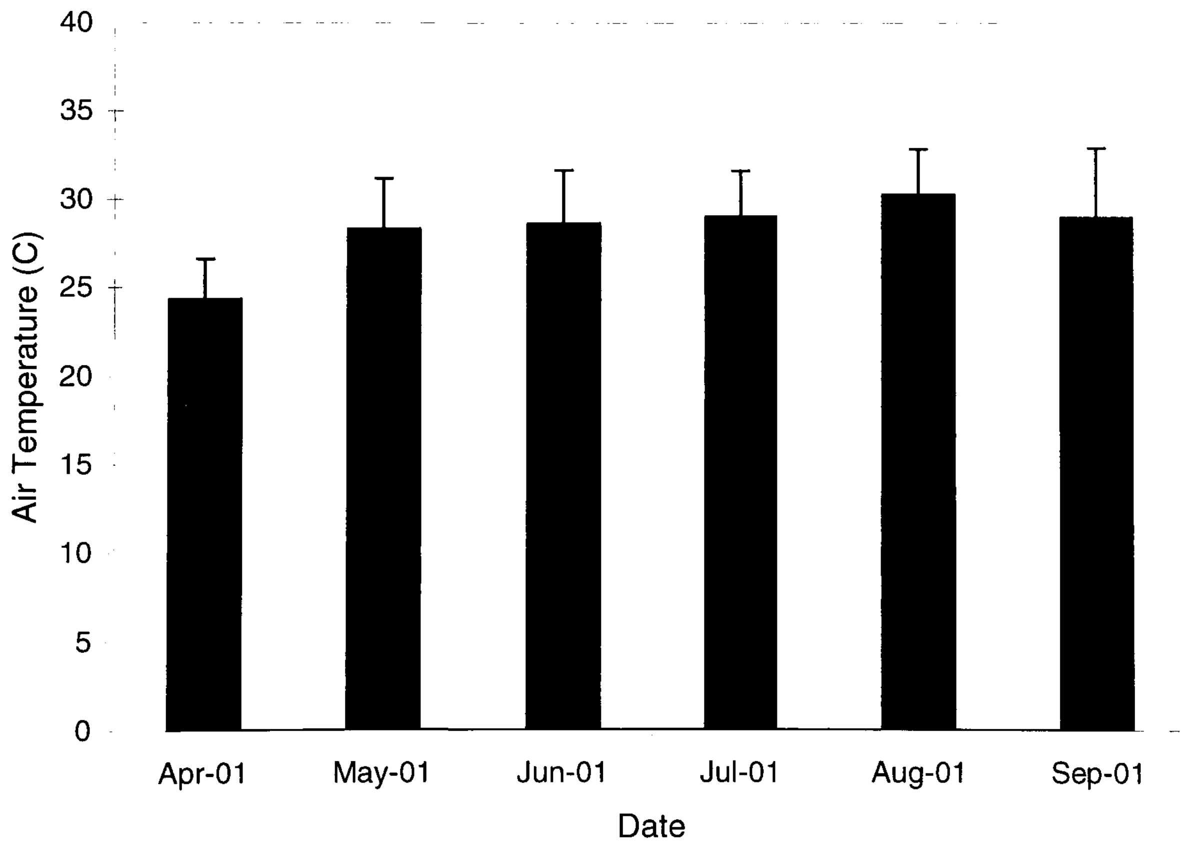

Figure 4-4. Mean monthly air temperature at *Pfiesteria* sampling stations in 2001.

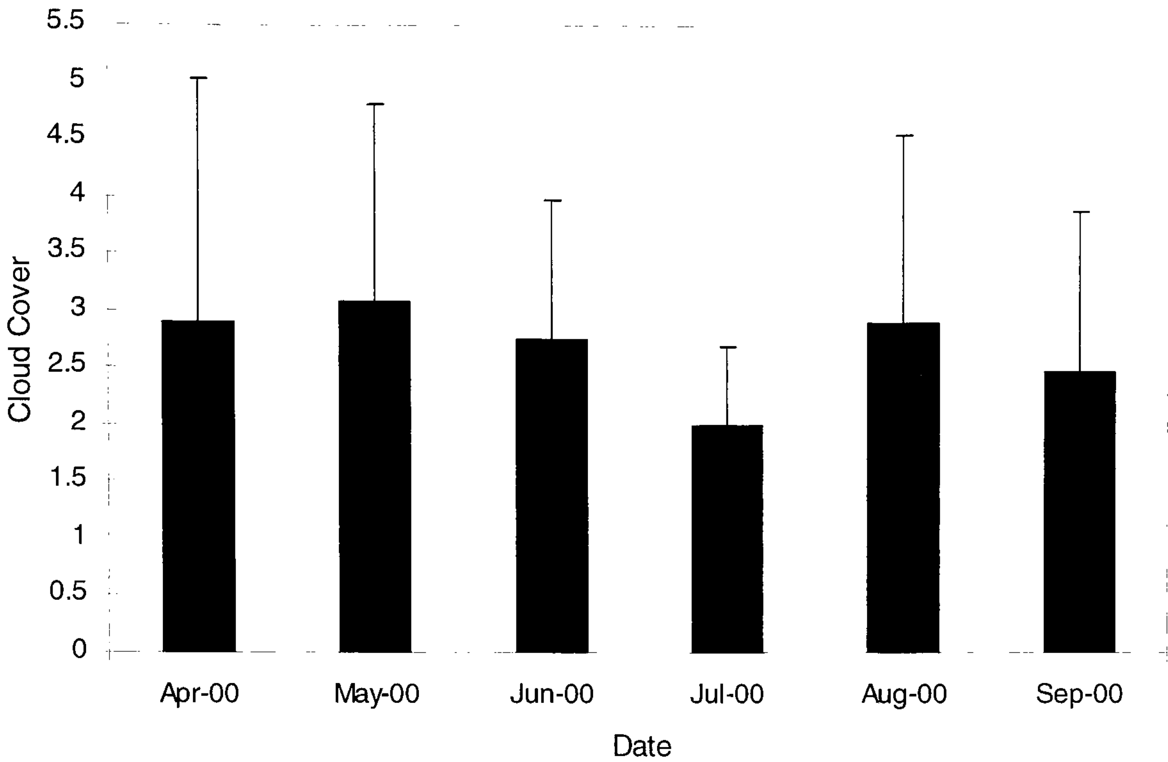

Figure 4-5. Mean monthly cloud cover at *Pfiesteria* sampling stations in 2000. Cloud cover code values: 1=0-9%, 2=10-25%, 3=26-50%, 4=51-75%, 5=76-90%, 6=91-100%.

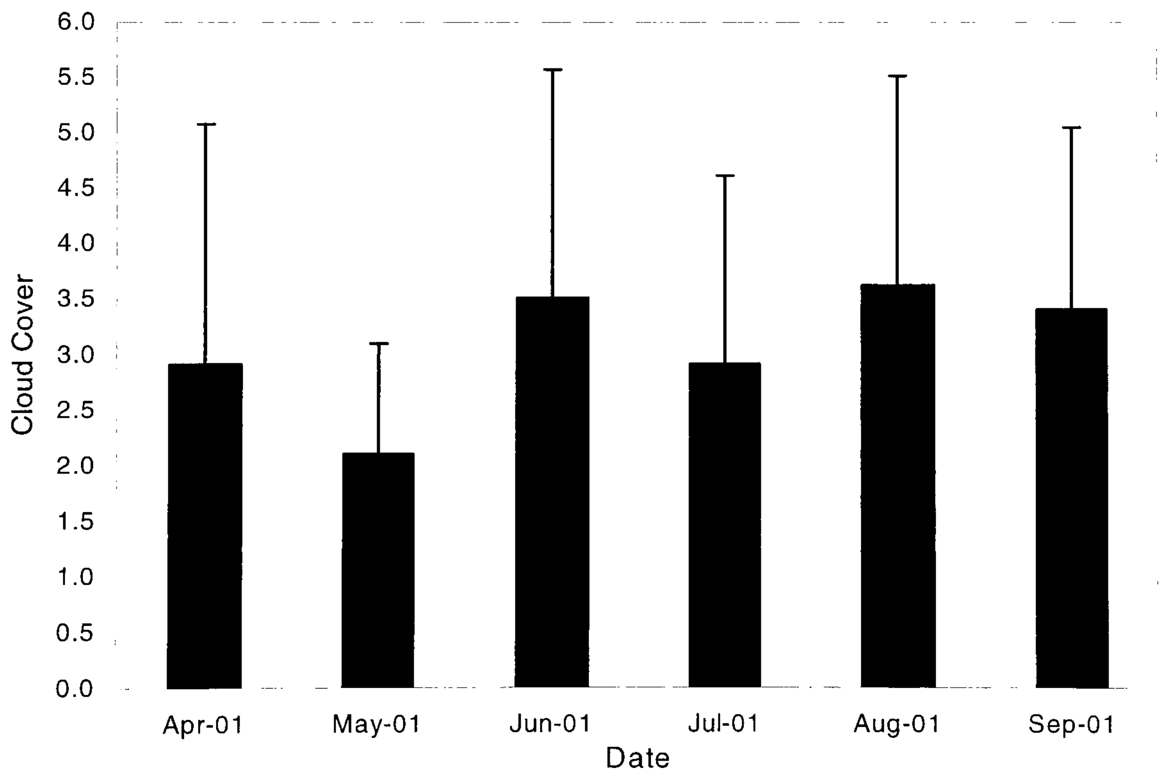

Figure 4-6. Mean monthly cloud cover at *Pfiesteria* sampling stations in 2001. Cloud cover code values: 1=0-9%, 2=10-25%, 3=26-50%, 4=51-75%, 5=76-90%, 6=91-100%.

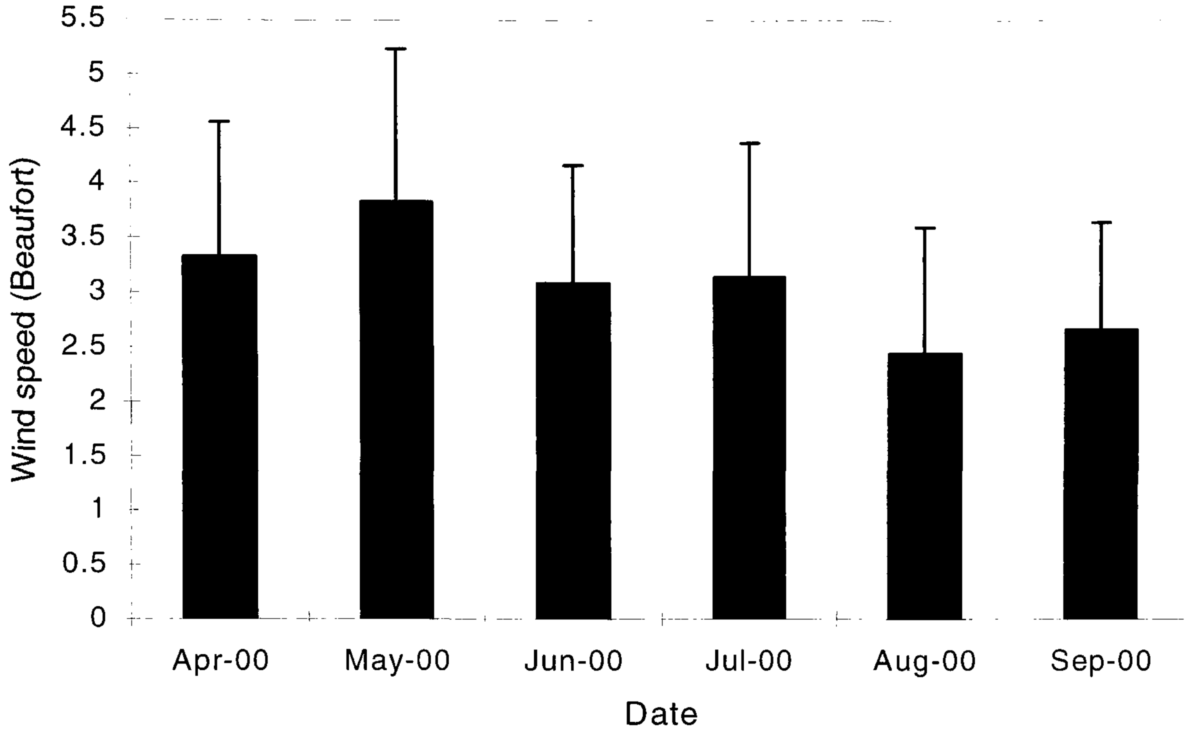

Figure 4-7. Mean monthly wind speed (Beaufort scale) at *Pfiesteria* sampling stations in 2000.

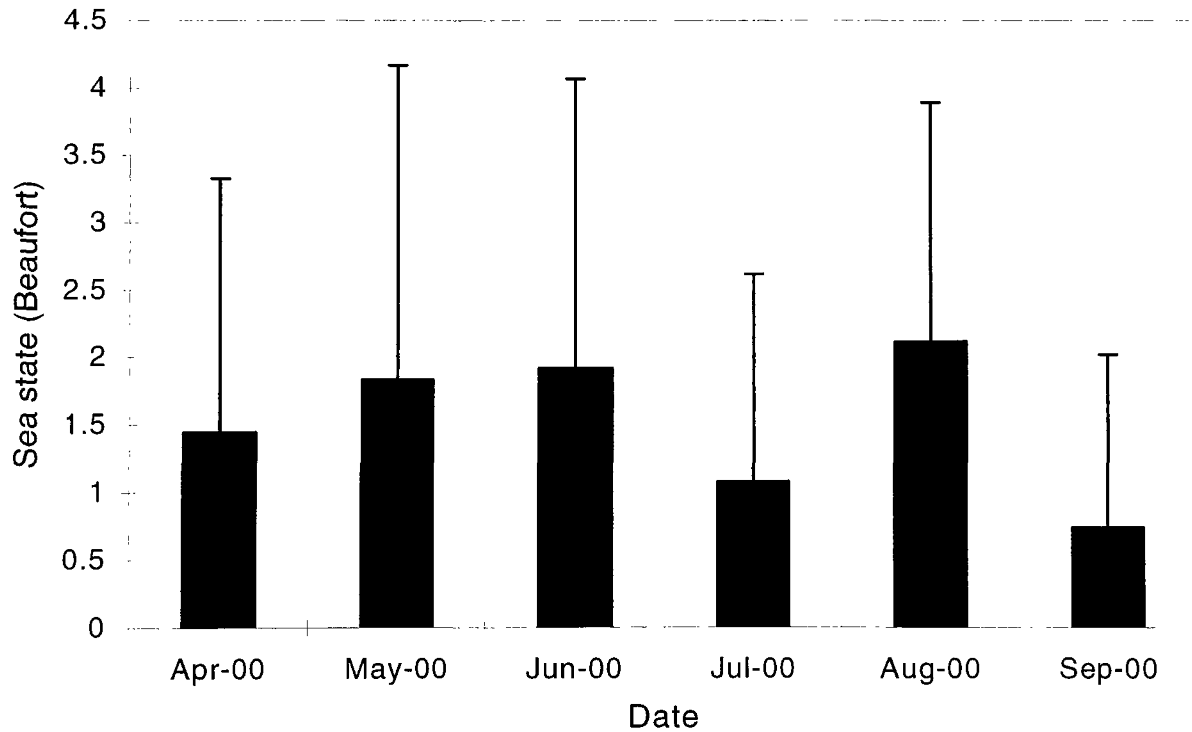

Figure 4-8. Mean monthly sea state (Beaufort scale) at *Pfiesteria* sampling stations in 2000.

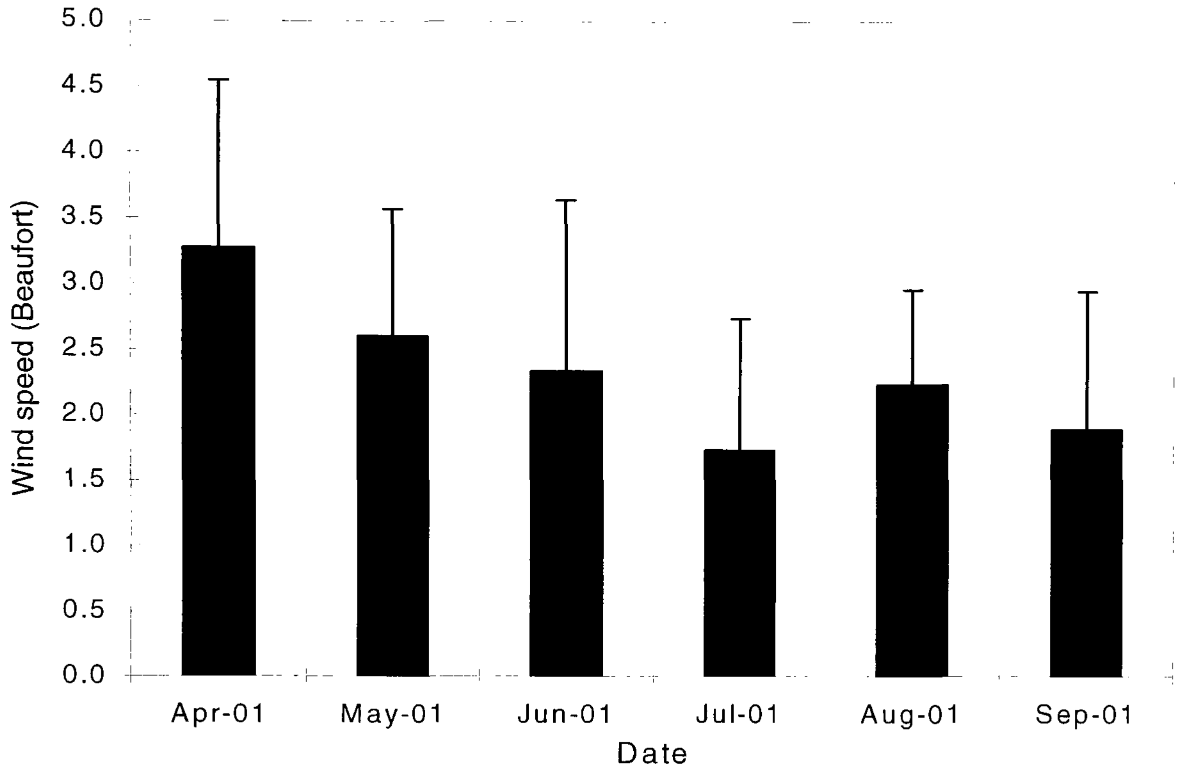

Figure 4-9. Mean monthly wind speed (Beaufort scale) at *Pfiesteria* sampling stations in 2001.

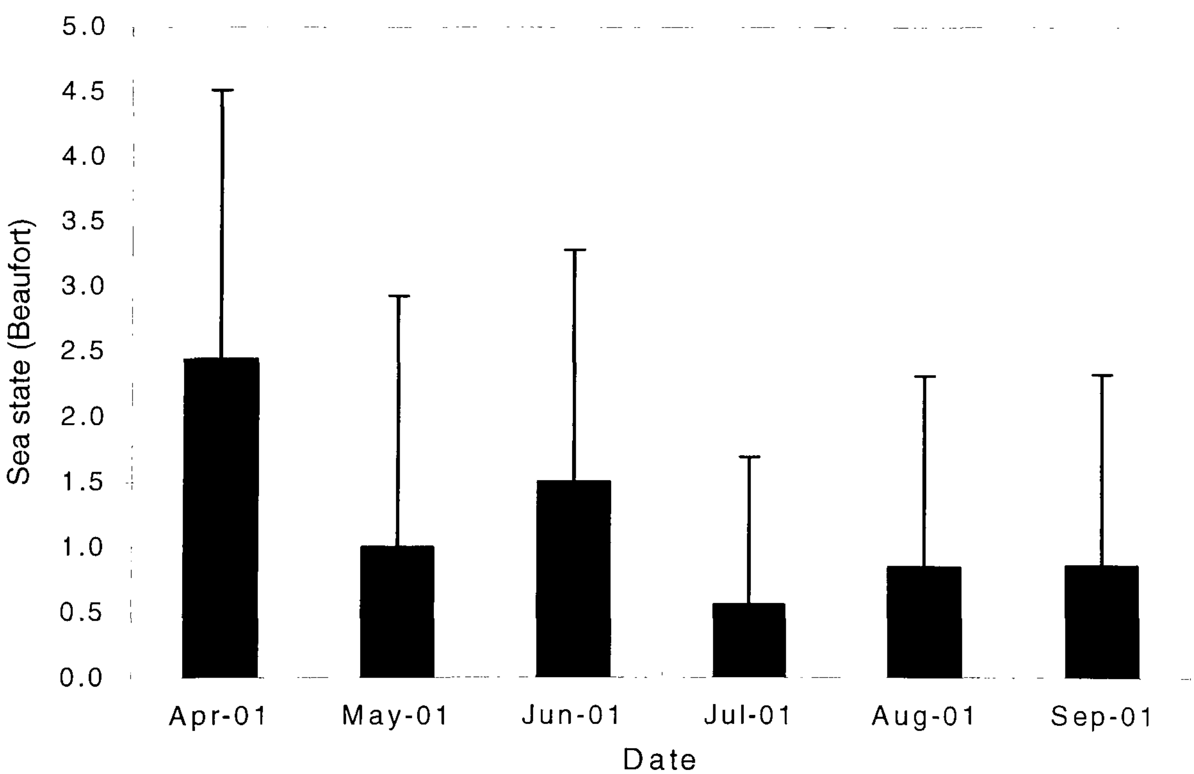

Figure 4-10. Mean monthly sea state (Beaufort scale) at *Pfiesteria* sampling stations in 2001.

Physicochemical Conditions

Measures of depth, water temperature, dissolved oxygen, salinity, conductivity, pH, percent saturation and Secchi depth were recorded on a fairly consistent basis at nearly all the sampling stations in both 2000 and 2001. At the Port Aransas Birding Center, typically, only depth, water temperature and salinity data were collected. In other occasions there were equipment failures or probe malfunctions that prevented collection of some or all of the suite of parameters. It should be noted that some care should be taken in the interpretation of the monthly mean data in 2000, as not all of the stations were sampled each month.

The mean water temperature at the 26 sites sampled in 2000 was 29.04 °C and ranged from 20.4 °C to 33.8 °C (Table 4-6). On a monthly basis the water temperature followed the same pattern as the air temperature, with the highest mean water temperature of 31.21 °C recorded in August (Figure 4-14). Surface and bottom temperatures varied little in relation to each other in all months, with the surface temperatures only slightly higher than bottom temperatures (Figure 4-14).

The mean dissolved oxygen in 2000 was 6.91 mg/L, with a range from 1.37 to 13.86 mg/L (Table 4-6). On a monthly basis, the mean surface and bottom dissolved oxygen was greatest in April and May, decreased to a low in June, then steadily increased to a high of 8.07 mg/L in September (Figure 4-15). Surface and bottom dissolved oxygen differed by about 1 mg/L, with the bottom values always being lower than the surface values (Figure 4-15). Armand Bayou (11.91 mg/L) and the Port Aransas Birding Center (13.86 mg/L) had the highest mean surface dissolved oxygen, while the lowest mean values were recorded at Dickinson Bayou 2 (2.93 mg/L) and Oso Creek (1.37 mg/L) (Table 4-6, Figure 4-11).

The mean salinity and conductivity in 2000 was 19.5 ppt and 32.86 mS/cm, respectively (Table 4-6). The salinity ranged from 0.00 to 60.0 ppt (Table 4-6). The highest mean salinities were recorded at the Bayview Campground (49.34 ppt) and Oso Bay 1 (45.5 ppt) sampling locations, while the lowest salinities were recorded in the upper reaches of creeks such as Dickinson Bayou (2.00 ppt), Oso Creek (2.20 ppt), Clear Creek (5.73 ppt) and at the Port Aransas Birding Center (0.65 ppt) (Table 4-6, Figure 4-12). On a monthly basis, the highest mean surface salinities were observed in September (23.94 ppt), followed closely by July (20.55 ppt) and August (23.26 ppt), while the lowest mean salinity was recorded in June (12.96 ppt) (Figure 4-16). In all cases, the mean bottom salinity was greater than the surface salinity, with the greatest differences being in July and September (Figure 4-16).

The mean pH recorded along the coast in 2000 was 8.11, with a range from 7.15 to 9.54 (Table 4-6). On a monthly basis, the pH was very similar, with June being slightly lower that the other months (Figure 4-17). Surface and bottom pHs showed almost no difference (Figure 4-17).

The mean Secchi depth for the 26 sites sampled in 2000 was 45.88 cm, with a range from 10 to 100 cm (Table 4-6). The highest mean Secchi depths were recorded at the Sabine Pass Swing Bridge (70.17 cm) and Dickinson Bayou 2 (80.0 cm) (Table 4-6, Figure 4-13). On a monthly basis, the mean Secchi depth varied greatly month to month, with the highest Secchi depths occurring in July (49.79 cm) and September (50.77 cm) and the lowest in May (35.91 cm) (Figure 4-18).

The mean water temperature at the six sites sampled in 2001 was 28.17 °C and ranged from 21.91 to 32.95 °C (Table 4-7). On a monthly basis, water temperatures followed the typical seasonal pattern, with the highest mean temperature of 30.18 °C recorded in August, and the lowest mean temperature of 24.74 °C occurring in April (Figure 4-22). Surface and bottom temperatures varied only slightly in relation to each other, with the bottom temperatures usually slightly lower than the surface (Figure 4-22).

The mean dissolved oxygen in 2001 was 7.17 mg/L, with a range from 2.05 to 19.15 mg/L (Table 4-7). The lowest mean dissolved oxygen was recorded at Caney Creek (4.52 mg/L) and the highest at the Port Aransas Birding Center (10.28 mg/L) (Table 4-7). On a monthly basis, the mean surface dissolved oxygen was highest during the months of April (8.95 mg/L) and May (8.72 mg/L), then dipped to a low of 5.98 mg/L in June (Figure 4-23). The dissolved oxygen then showed a slight increase, and was fairly consistent for the months of July, August and September (Figure 4-23).

The mean salinity in 2001 was 8.67 ppt with a range from 0.1 to 30.8 ppt (Table 4-7). The six sites sampled in 2001 were distinctly divided into three very low salinity, oligohaline sites, all with mean salinities below 4.0 ppt (Clear Lake, Dickinson Bayou and Port Aransas Birding Center) and three mesohaline sites, Caney Creek, Port Lavaca Fishing Pier and Arroyo City Park, with mean salinities between 15 and 20 ppt (Figure 4-20). On a monthly basis, mean salinities generally increased from April to August, then showed precipitous decline in September (Figure 4-24). Surface and bottom showed very little difference in relation to each other, with the mean bottom salinities in all months, slightly higher than the surface (Figure 4-24).

The mean pH for the six sampling sites in 2001 was 8.36, with a range from 7.19 to 10.81 (Table 4-7). The Port Aransas Birding Center had the highest mean pH at 9.35, while the lowest mean pH of 7.81 was recorded at Caney Creek (Table 4-7). On a monthly basis, the mean pH was very similar from month to month, and there was little difference between the surface and bottom pHs in each month (Figure 4-25). The highest monthly mean pH of 8.78 was recorded in August, the lowest, 8.04, was recorded in September (Figure 4-25).

The mean Secchi depth for all sites in 2001 was 35.8 cm, with a range from 15 to 71 cm (Table 4-7). Secchi depth was not recorded at the Port Aransas Birding Center. At the other five sites, the smallest mean Secchi depth of 25.0 cm was recorded at Clear Lake, while the greatest mean Secchi depth of 41.0 cm was recorded at the Port Lavaca Fishing Pier (Table 4-7, Figure 4-21). The mean monthly Secchi depth followed a pattern very similar to that of salinity, with the values increasing to a high of 47.78 cm in August, then dropping off to a low of 33.33 cm in September (Figure 4-26).

Table 4-7. Means (StdDev, N) for Physicochemical Parameters at *Pfiesteria* Sampling Locations for 2000 (nc=not collected)

Location	Temp (deg C)	DO (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	pH	Percent Saturation	Secchi Depth (cm)
Sabine Pass Swing Bridge	29.03	6.37	19.65	28.75	7.87	94.55	70.17
	(3.090, 6)	(0.924, 6)	(4.271, 6)	(5.265, 6)	(0.135, 6)	(15.303, 6)	(18.978, 6)
Tabbs Bay	29.19	7.00	15.53	24.70	8.13	98.87	36.67
	(3.728, 3)	(0.286, 30	(1.677, 3)	(2.970, 2)	(0.014, 2)	(8.010, 3)	(15.275, 3)
Armand Bayou	31.46	11.91	3.80	6.83	9.31	167.61	31.00
	(2.061, 3)	(0.491, 3)	(0.819, 3)	(1.468, 3)	(0.202, 3)	(12.843, 3)	(10.149, 3)
Clear Creek	29.03	7.53	5.73	10.69	8.35	99.95	27.50
	(0.325, 2)	(1.846, 2)	(0.304, 2)	(1.387, 2)	(0.014, 2)	(24.395, 2)	(3.536, 2)
Clear Lake	26.90	9.68	14.50	nc	nc	131.90	50.00
	(0, 1)	(0, 1)	(0, 1)	(0, 0)	(0, 0)	(0, 1)	(0, 1)
Dickinson Bayou 1	29.37	7.64	6.77	11.73	8.24	106.08	59.00
	(3.097, 4)	(2.665, 4)	(3.625, 4)	(5.865, 4)	(0.606, 3)	(42.384, 4)	(18.520, 3)
Dickinson Bayou 2	29.44	2.93	2.00	3.68	7.28	37.70	80.00
	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)
Moses Bayou	28.30	6.73	18.90	30.38	7.97	96.85	30.00
	(0.205, 2)	(1.358, 2)	(1.831, 2)	(2.793, 2)	(0.071, 2)	(20.577, 2)	(14.142, 2)
Moses Lake	30.92	6.52	22.60	36.00	7.97	103.40	50.00
	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)
Jamaica Beach Canal	28.24	5.46	33.34	50.48	7.95	84.83	46.00
	(1.592, 6)	(2.281, 6)	(2.491, 6)	(3.503, 6)	(0.178, 5)	(33.179, 6)	(13.416, 5)
Oyster Creek	29.68	6.72	10.30	17.23	8.01	94.85	40.00
	(2.864, 2)	(0.262, 2)	(8.627, 2)	(13.683, 2)	(0.148, 2)	(3.465, 2)	(14.142, 2)
Swan Lake	30.43	5.25	nc	nc	7.91	91.30	30.00
	(0, 1)	(0, 1)	(0, 0)	(0, 0)	(0, 1)	(0, 1)	(0, 1)
Intracoastal Waterway	30.67	6.64	21.85	34.30	7.88	102.10	35.00
	(3.995, 2)	(1.563, 2)	(14.071, 2)	(20.223, 2)	(0.148, 2)	(25.032, 2)	(35.355, 2)
Jones Creek	30.44	7.83	21.00	22.10	8.14	121.00	50.00
	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)
Caney Creek	29.10	5.20	20.01	31.51	8.09	76.68	56.50
	(1.734, 5)	(1.084, 5)	(12.143, 5)	(17.762, 5)	(0.101, 4)	(13.546, 5)	(21.502, 4)
Colorado River	30.43	9.17	3.20	5.81	8.48	125.57	41.67
	(0.756, 3)	(1.995, 3)	(2.406, 3)	(4.200, 3)	(0.267, 3)	(30.218, 3)	(12.583, 3)
Lavaca Bay Causeway	26.13	6.20	23.20	35.18	8.15	95.83	62.60
	(4.282, 5)	(1.239, 4)	(4.500, 5)	(4.712, 5)	(0.184, 4)	(6.801, 3)	(30.664, 5)
Mesquite Bay	27.87	6.18	34.46	55.35	8.01	94.95	53.00
	(2.091, 3)	(0.092, 2)	(5.159, 3)	(9.798, 3)	(0.205, 3)	(2.192, 2)	(2.828, 2)
Nueces River	28.56	8.24	7.30	12.24	8.59	112.08	31.50
	(2.076, 6)	(1.322, 6)	(8.459, 6)	(13.168, 6)	(0.210, 6)	(19.476, 6)	(5.683, 6)
Port Aransas Birding Center	30.22	13.86	0.65	21.46	9.35	196.90	15.00
	(2.980, 6)	(0.000, 1)	(0.811, 6)	(0.000, 1)	(0.000, 1)	(0.000, 1)	(0.000, 1)
Oso Bay 1	23.40	8.25	34.00	51.60	8.10	124.00	nc
	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 0)

Oso Bay 2	31.39	4.75	45.41	72.95	8.01	83.30	59.50
	(0.947, 4)	(2.064, 4)	(3.918, 4)	(8.953, 4)	(0.132, 3)	(36.210, 4)	(35.369, 4)
Oso Creek	26.65	1.37	2.20	4.55	7.13	16.70	28.00
	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)
Bayview Campground	28.57	6.94	49.34	73.49	7.90	113.92	30.90
	(3.536, 5)	(1.714, 5)	(9.096, 5)	(10.958, 5)	(0.299, 4)	(35.822, 5)	(10.249, 5)
Kraatz Pier	28.86	8.07	36.20	54.10	8.39	135.60	18.00
	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)	(0, 1)
Arroyo City Park	28.80	6.55	15.90	26.60	8.11	94.10	50.33
	(3.504, 3)	(3.757, 3)	(5.183, 3)	(6.759, 3)	(0.194, 3)	(51.895, 3)	(10.017, 3)
Grand mean	29.04	6.91	19.5	32.86	8.17	102.02	45.88
(Stdev, Count)	(2.678, 78)	(2.402, 71)	(15.384, 77)	(22.648, 70)	(0.441, 64)	(34.019, 70)	(21.405, 68)
(Min, Max)	(20.4, 33.8)	(1.37, 13.86)	(0, 60.6)	(0.88, 82.3)	(7.13, 9.54)	(16.7, 196.9)	(10, 100)

Table 4-8. Means (StdDev, N) for Physicochemical Parameters at *Pfiesteria* Sampling Locations for 2001

Location	Temp (deg C)	DO (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	pH	Percent Saturation	Secchi Depth (cm)
Clear Lake	27.66	7.66	0.81	1.55	8.70	89.86	25.00
	(3.510, 12)	(3.966, 12)	(0.760, 12)	(1.392, 12)	(0.624, 11)	(47.610, 11)	(7.071, 12)
Dickinson Bayou	28.82	6.21	2.79	5.09	7.94	82.73	37.50
	(3.043, 12)	(1.640, 12)	(3.336, 12)	(5.736, 12)	(0.363, 11)	(25.535, 12)	(10.766, 12)
Caney Creek	27.74	4.52	18.88	28.09	7.81	64.43	40.42
	(2.693, 12)	(1.195, 12)	(10.153, 12)	(14.237, 12)	(0.214, 11)	(15.870, 12)	(12.147, 12)
Port Lavaca Fishing Pier	28.49	6.99	15.50	24.38	8.17	102.58	41.00
	(3.824, 8)	(0.965, 7)	(7.954, 8)	(11.772, 8)	(0.154, 6)	(7.326, 6)	(17.680, 8)
Port Aransas Birding Center	26.95	10.28	1.58	2.13	9.35	129.52	nd
	(1.801, 12)	(5.019, 12)	(1.731, 12)	(0.398, 12)	(0.874, 7)	(64.883, 12)	nd
Arroyo City Park	29.62	7.28	15.27	26.45	8.52	111.84	37.57
	(2.011, 11)	(2.065, 10)	(5.456, 11)	(8.947, 7)	(0.269, 7)	(31.082, 7)	(4.315, 7)
Grand mean	28.17	7.17	8.67	13.05	8.36	95.12	35.8
(Stdev, Count)	(2.881, 67)	(3.432, 65)	(9.455, 67)	(14.392, 63)	(0.689, 60)	(44.135, 60)	(12.390, 51)
(Min, Max)	(21.91, 32.95	(2.05, 19.15)	(0.1, 30.8)	(0.19, 46.3)	(7.19, 10.81)	(30.3, 252.6)	(15, 71)

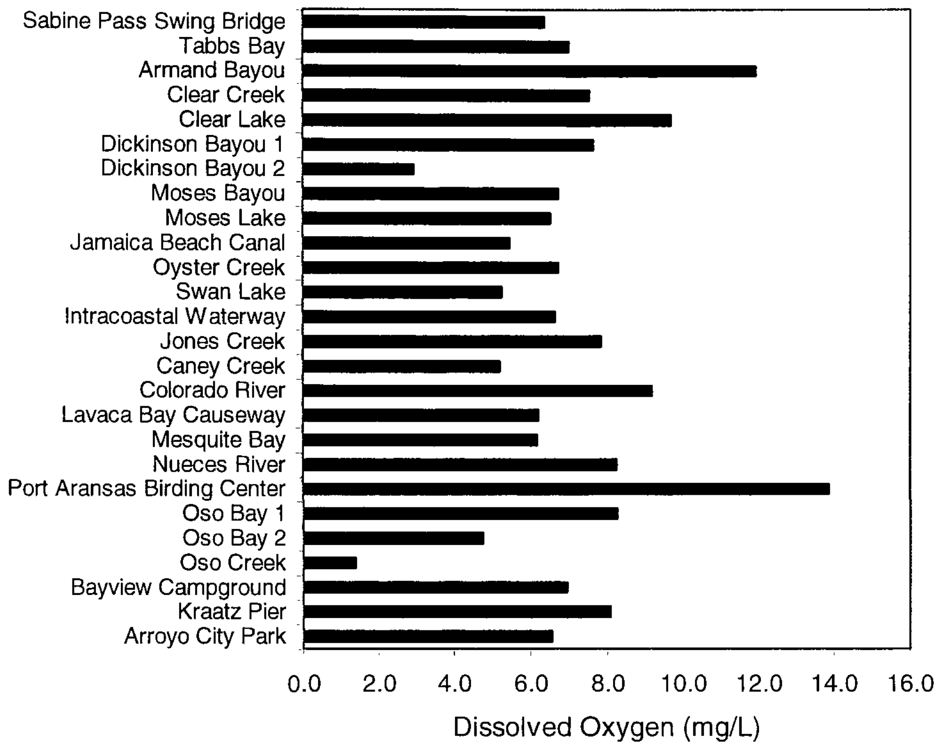

Figure 4-11. Mean dissolved oxygen at the *Pfiesteria* sampling stations in 2000.

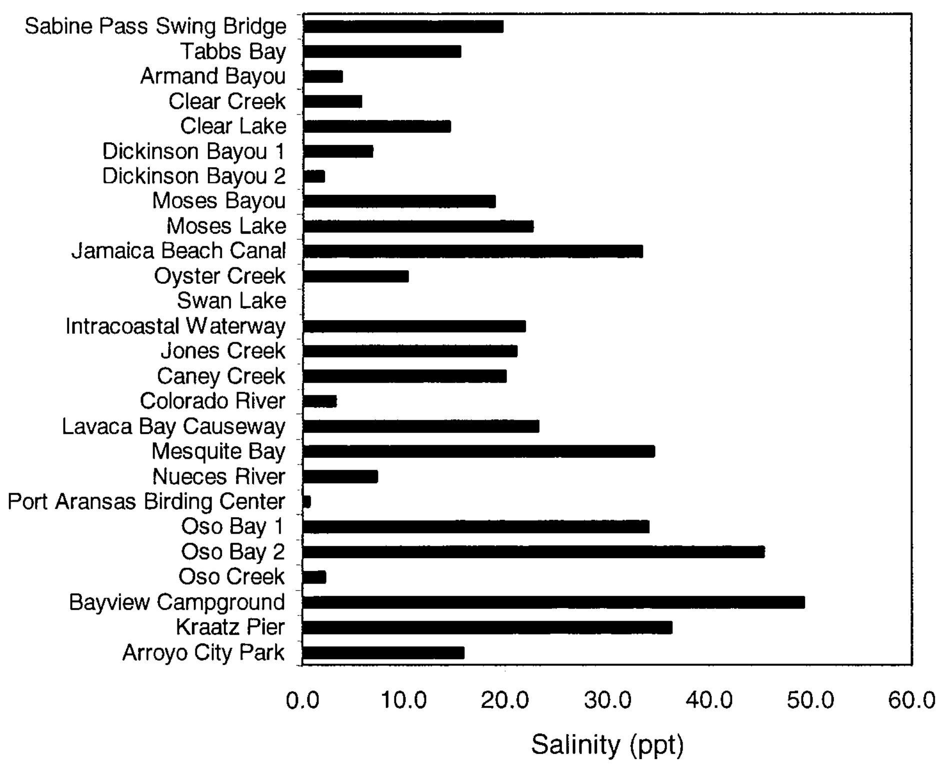

Figure 4-12. Mean salinity at the *Pfiesteria* sampling stations in 2000.

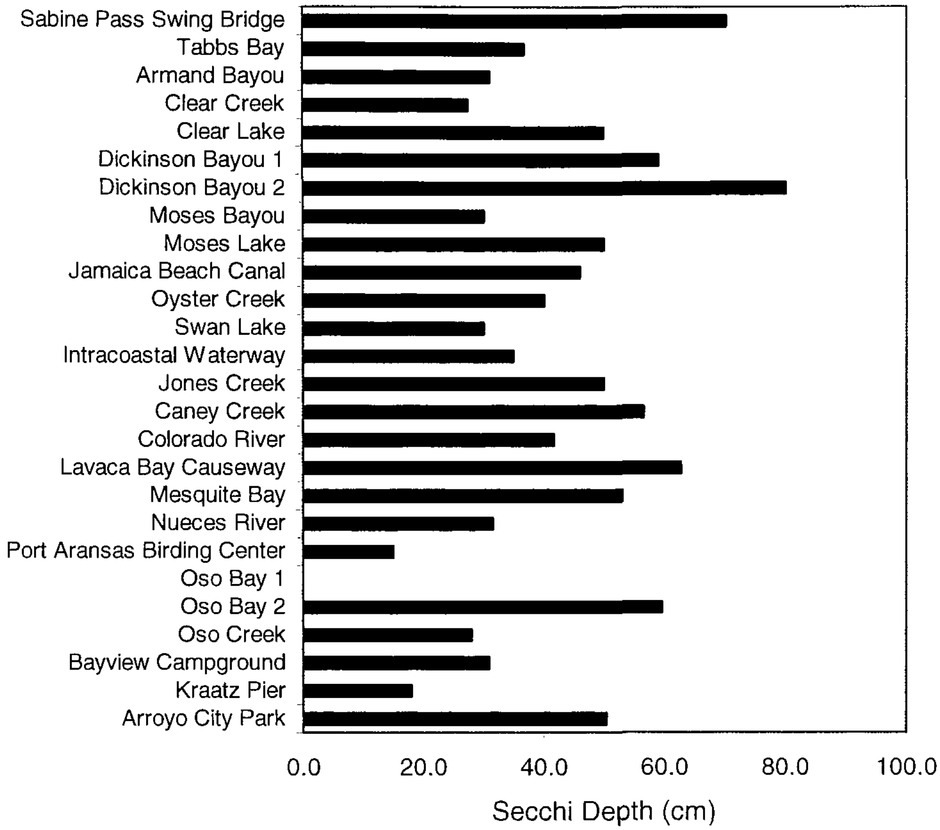

Figure 4-13. Mean Secchi depth at the *Pfiesteria* sampling stations in 2000.

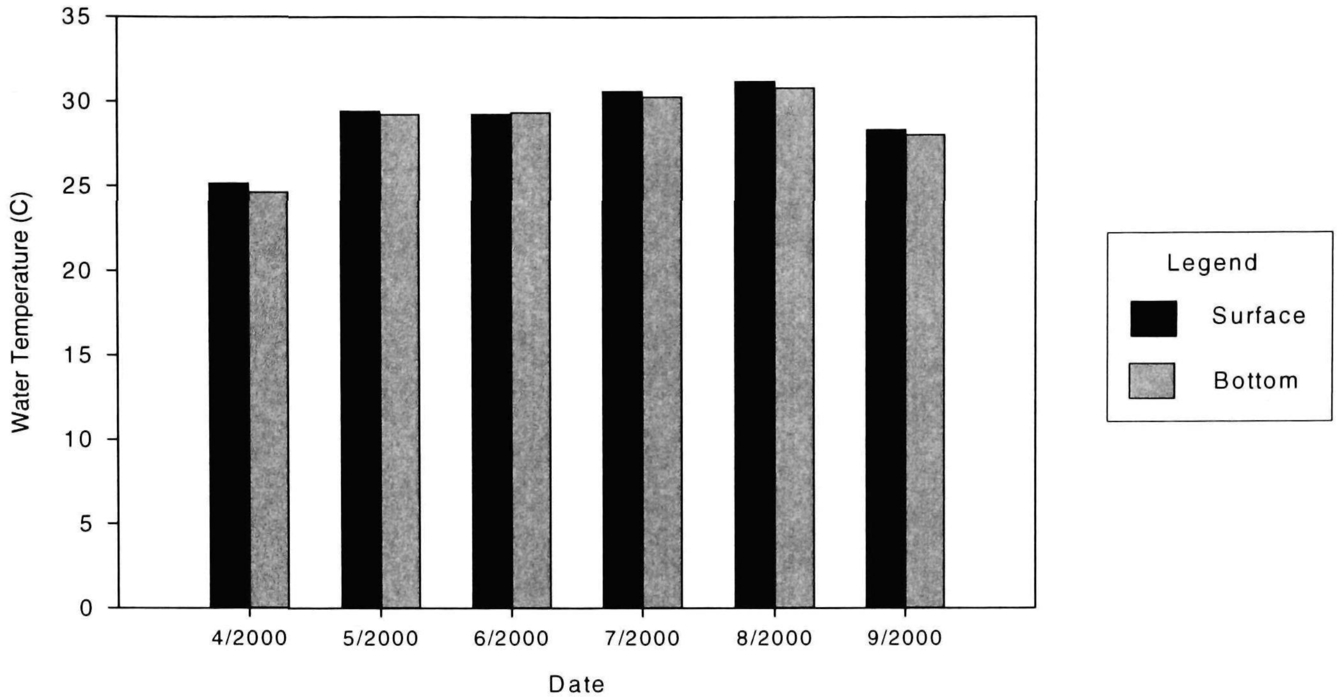

Figure 4-14. Mean monthly surface and bottom water temperature at *Pfiesteria* sampling stations for 2000.

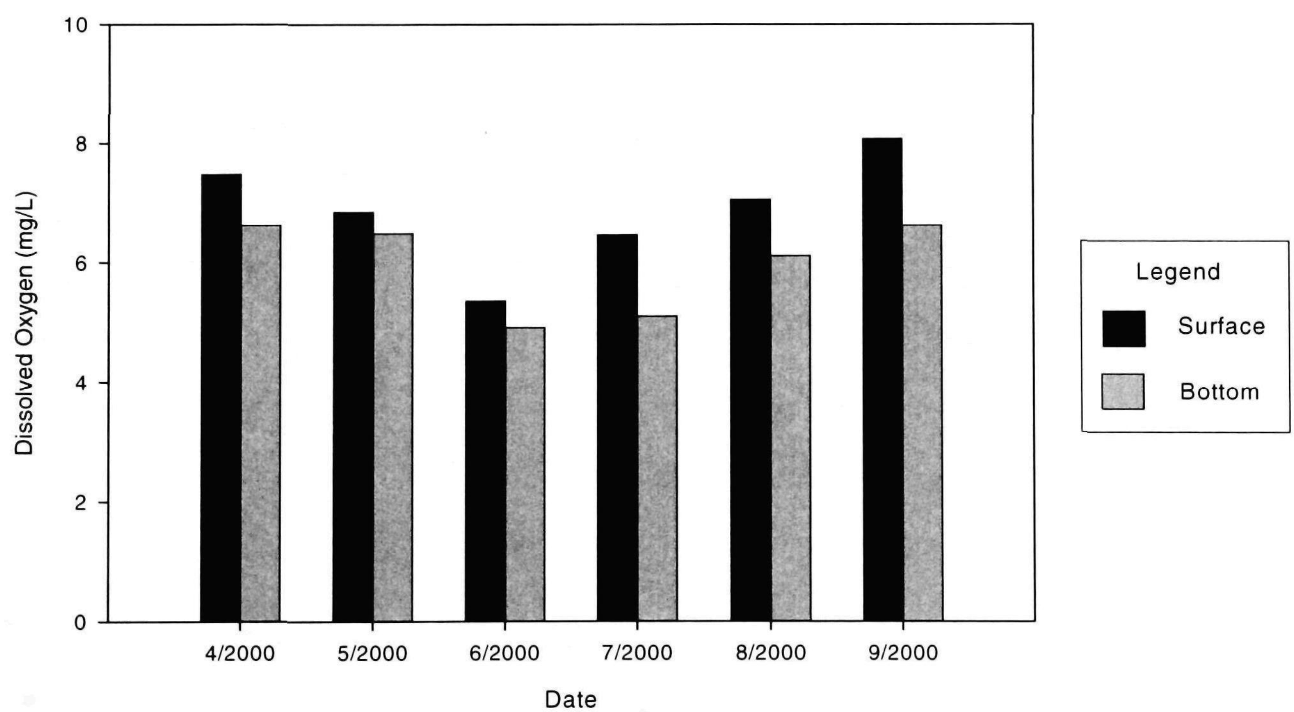

Figure 4-15. Mean monthly surface and bottom dissolved oxygen at *Pfiesteria* sampling stations for 2000.

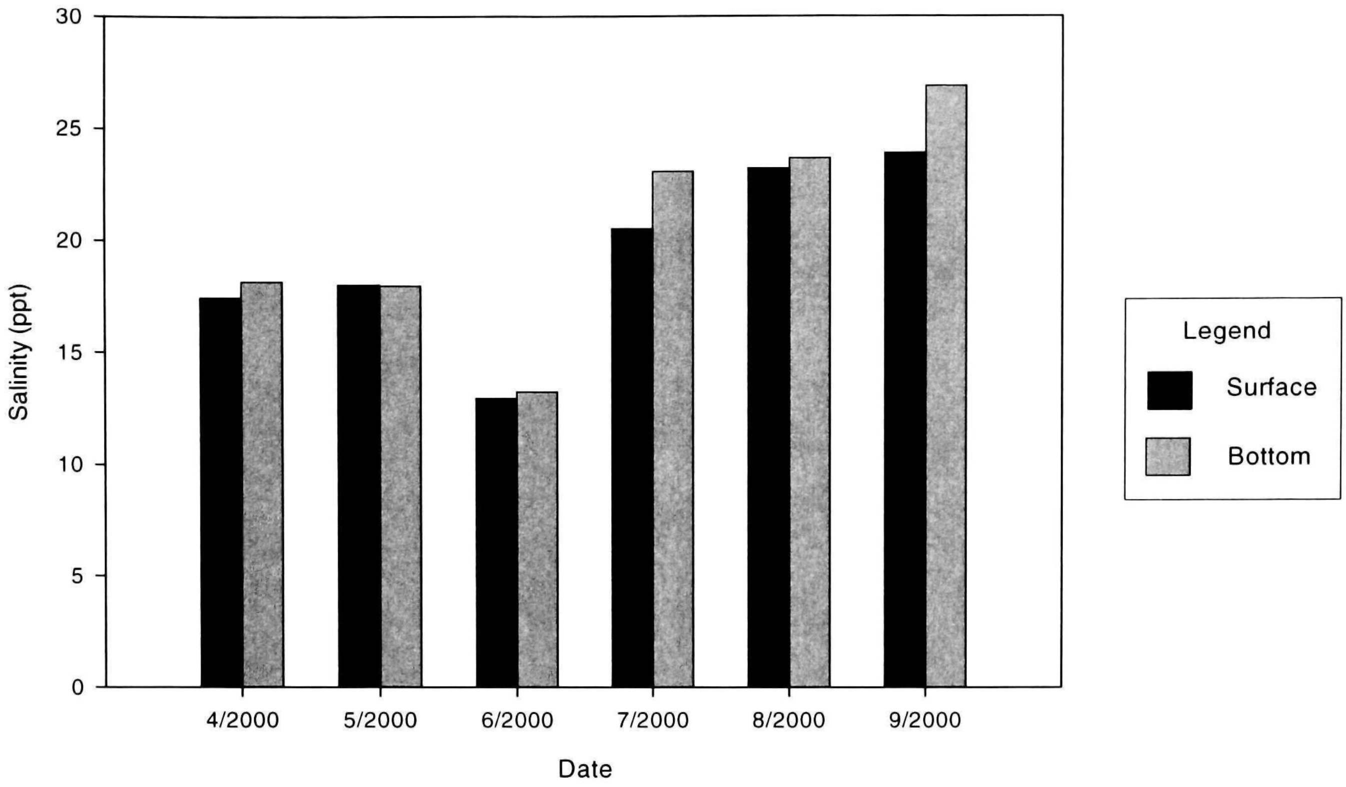

Figure 4-16. Mean monthly surface and bottom salinity at *Pfiesteria* sampling stations for 2000.

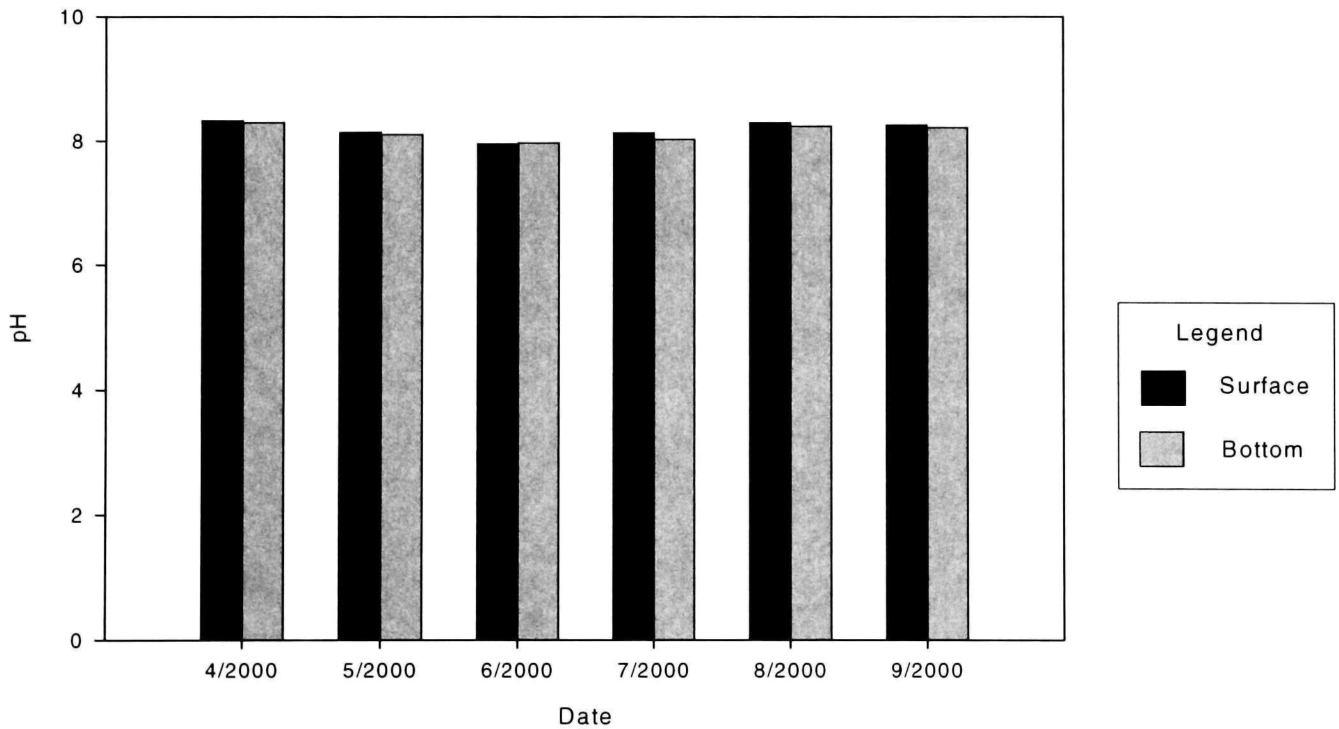

Figure 4-17. Mean monthly surface and bottom pH at *Pfiesteria* sampling stations for 2000.

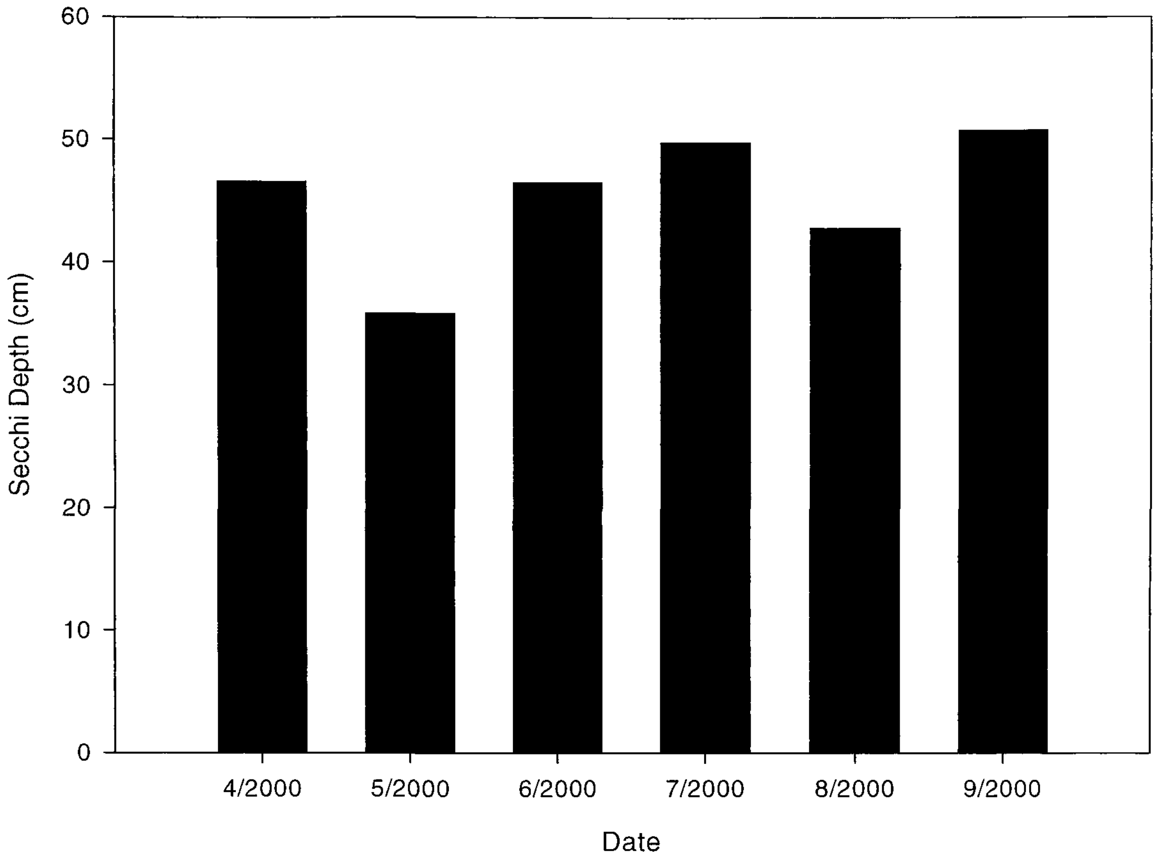

Figure 4-18. Mean monthly Secchi depth at *Pfiesteria* sampling stations for 2000.

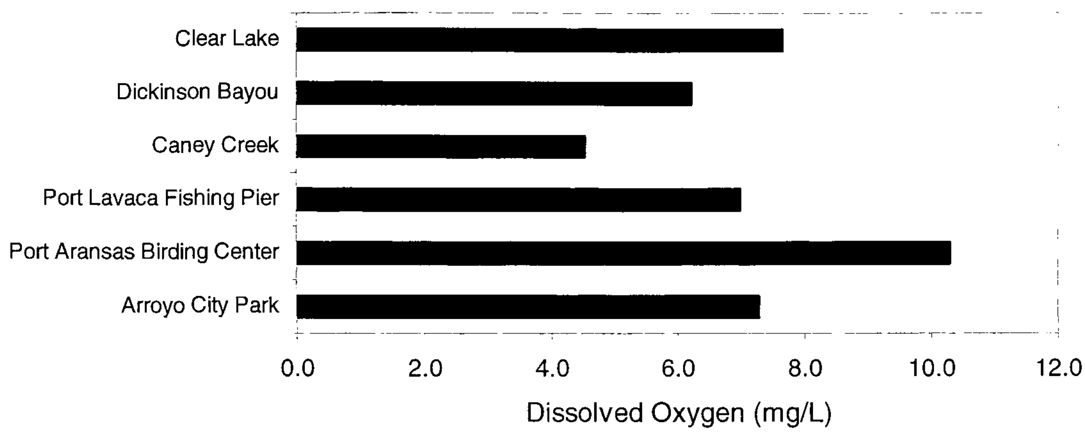

Figure 4-19. Mean dissolved oxygen at the *Pfiesteria* sampling stations in 2001.

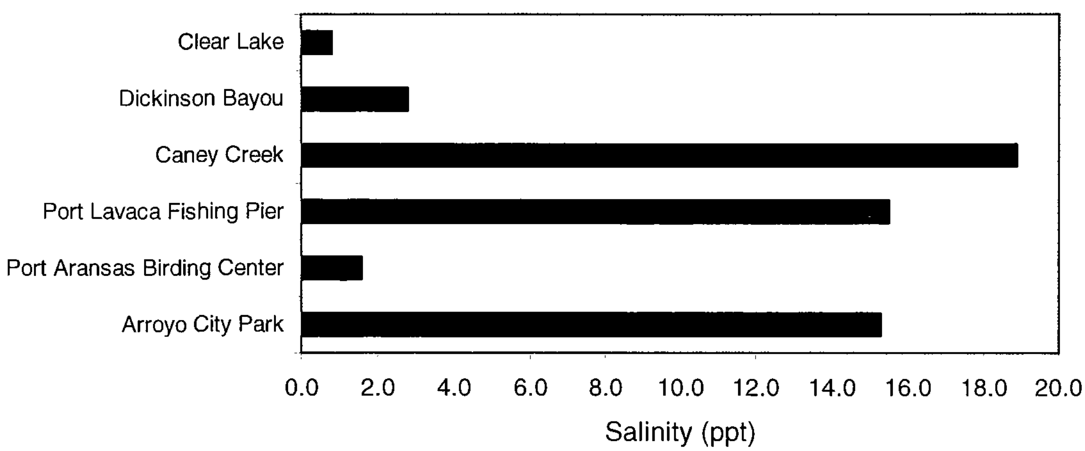

Figure 4-20. Mean salinity at the *Pfiesteria* sampling stations in 2001.

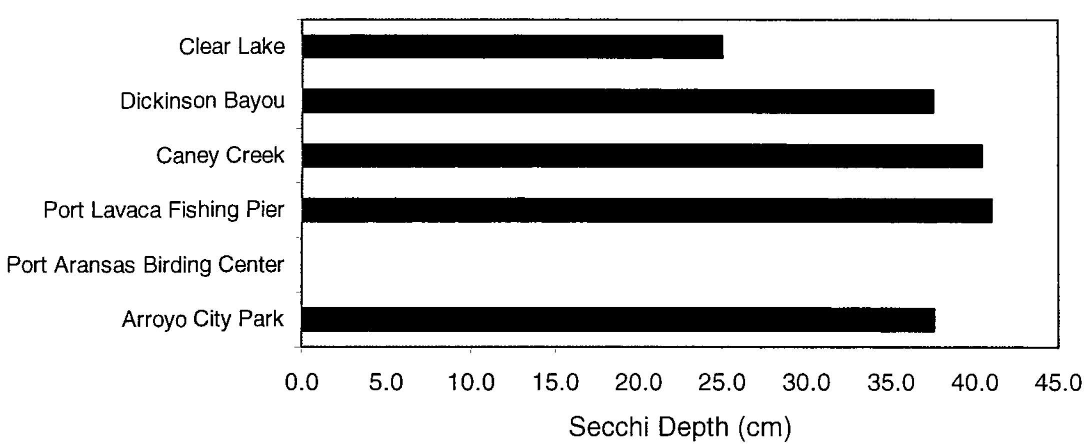

Figure 4-21. Mean Secchi depth at the *Pfiesteria* sampling stations in 2001.

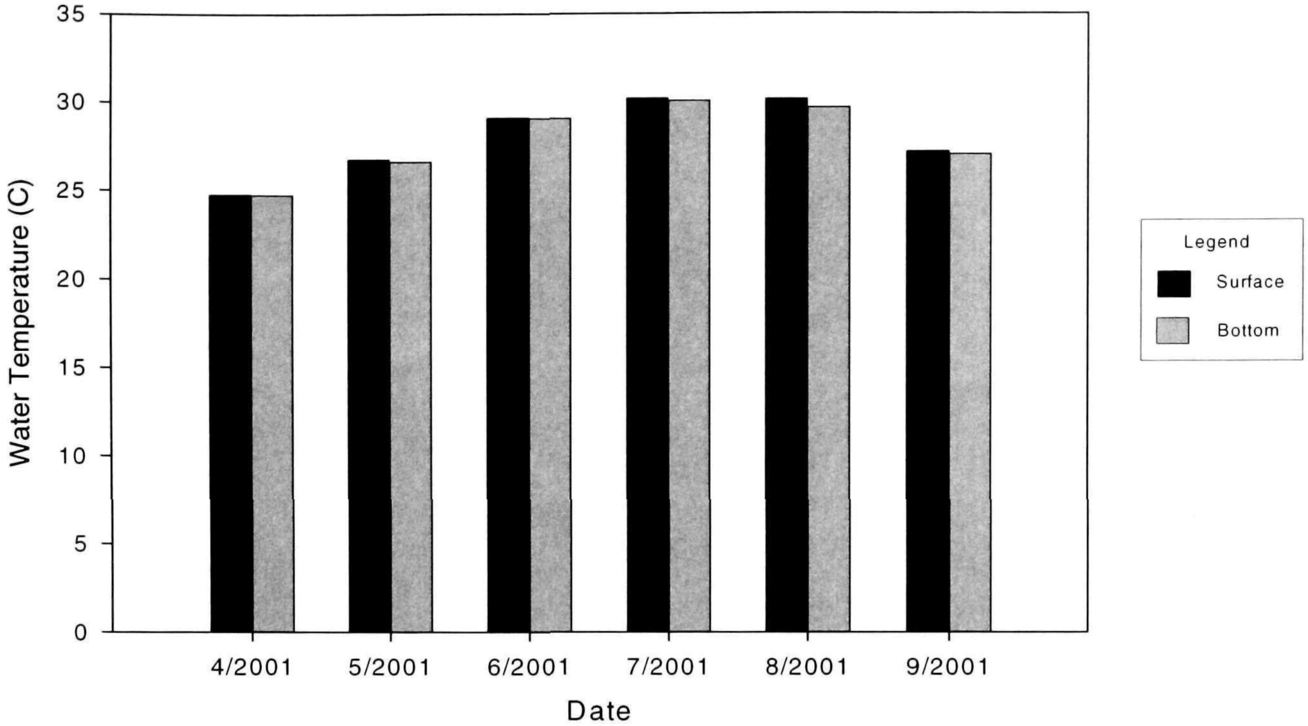

Figure 4-22. Mean monthly surface and bottom water temperature at *Pfiesteria* sampling stations for 2001.

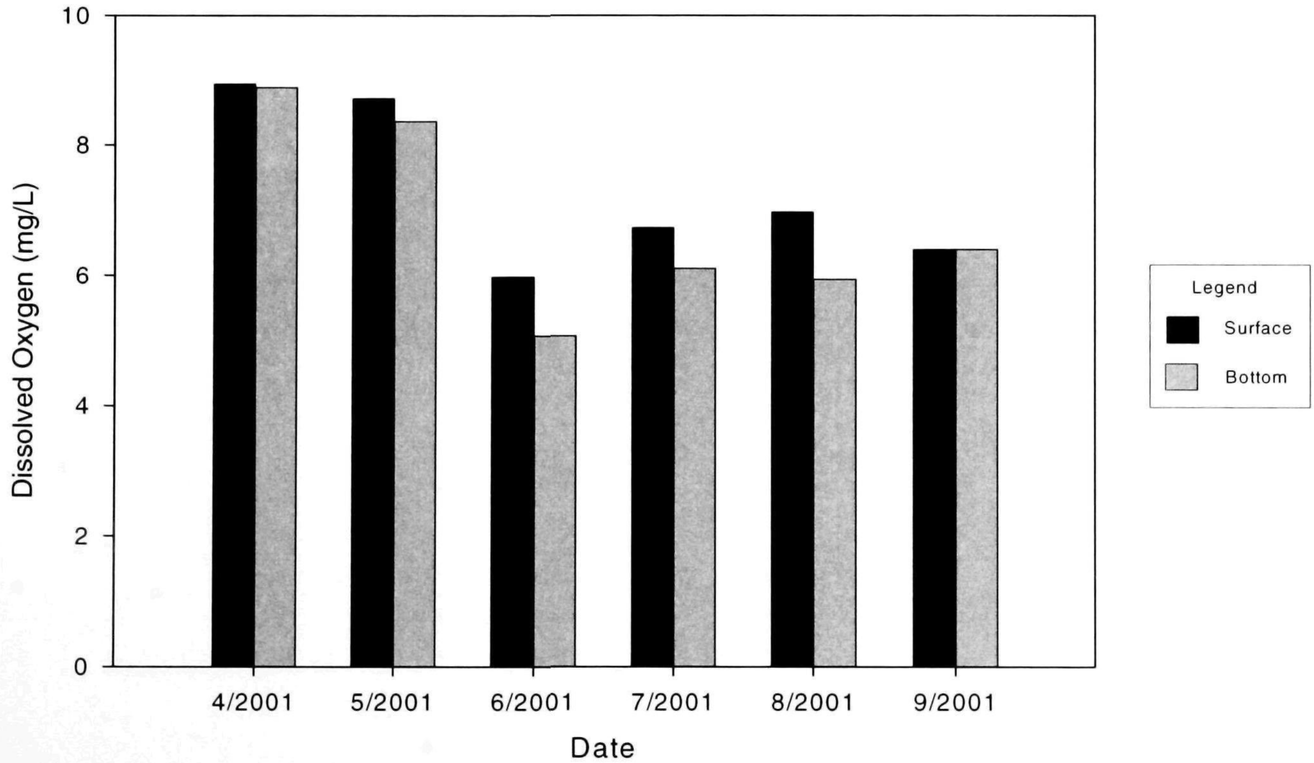

Figure 4-23. Mean monthly surface and bottom dissolved oxygen at *Pfiesteria* sampling stations for 2001.

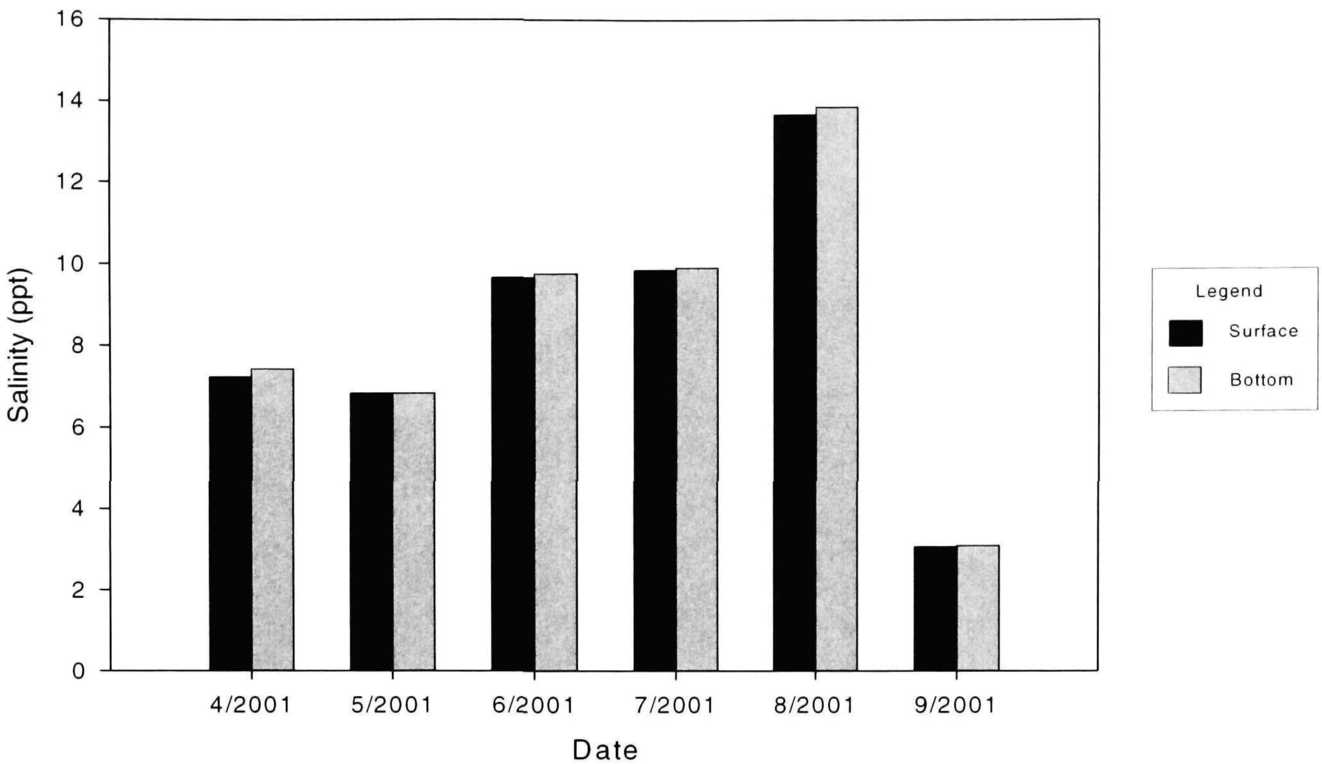

Figure 4-24. Mean monthly surface and bottom salinity at *Pfiesteria* sampling stations for 2001.

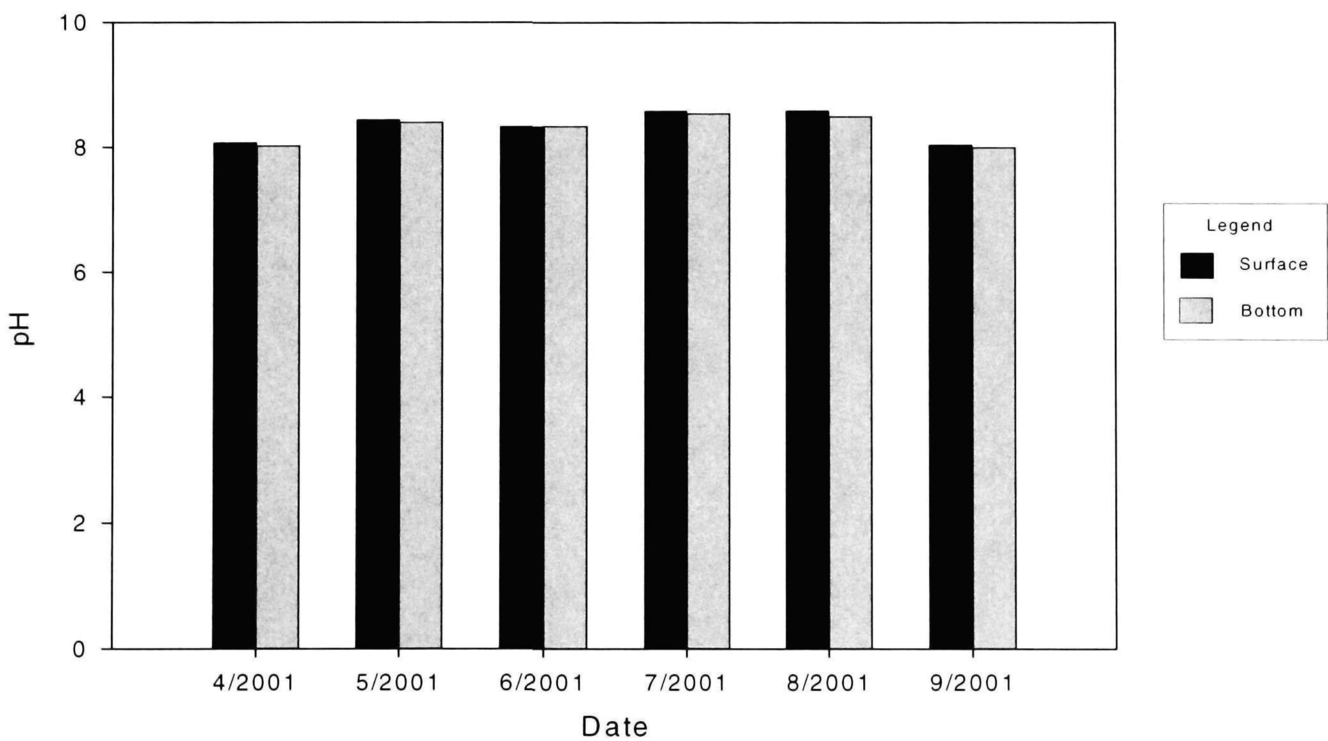

Figure 4-25. Mean monthly surface and bottom pH at *Pfiesteria* sampling stations for 2001

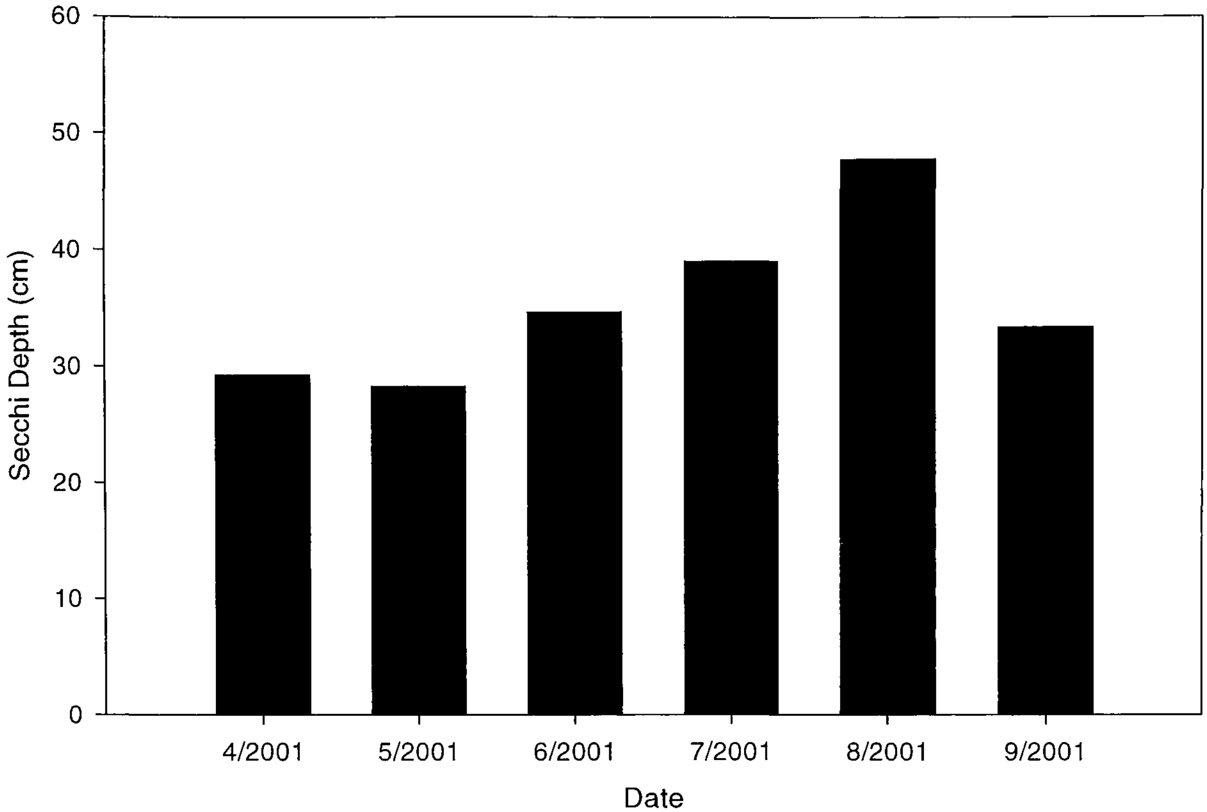

Figure 4-26. Mean monthly Secchi depth at *Pfiesteria* sampling stations for 2001

Chlorophyll a and Nutrients

The mean chlorophyll a concentration for the 26 sites in 2000 was 24.62 µg/L, with a range from 12 to 134 µg/L (Table 4-8). There was much variation among the sites, with mean values ranging from 4.10 ug/L (Oso Bay 2) to 73.92 µg/L (Armand Bayou) (Figure 4-27). The monthly mean chlorophyll a concentration showed a steady increase from April (13.67 µg/L) through September (39.97 µg/L), except for August, which had the lowest mean of 11.56 µg/L (Figure 4-33).

The mean silicate concentration was 109.04 ug/L, with a range from 11.12 to 347.19 ug/L (Table4-8). In general, the mean silicate at the sites increases as one moves south along the coast, with the highest levels recorded at the Nueces River (209.53 ug/L), Port Aransas Birding Center (202.24 µg/L), Oso Creek 260.28 ug/L), Kraatz Pier (201.98 µg/L) and Adolph Tomae Jr. County Park (239.90 µg/L) (Figure 4-28). On a monthly basis, the mean silicate concentration in the spring and early summer (April-June) of 132.49 µg/L was much greater than the 88.35 ug/L found in the late summer (July-September) (Figure 4-34).

The mean phosphate concentration for the 26 sites sampled in 2000 was 9.32 ug/L, with a range from 0.06 to 80.24 ug/L (Table 4-8). Phosphate did not show any trend along the coast (Figure 4-29). Highest values were recorded at the Port Aransas Birding Center (29.01 ug/L) and Adolph Tomae Jr. County Park (31.37 ug/L), while the lowest concentration of phosphate, by far, were recorded at Oso Bay 1 (0.235 ug/L) (Table 4-8, Figure 4-29). The vast majority of the values were between 1 to 15 ug/L. The monthly mean phosphate concentration did not show any clear trends, although the highest values were recorded in August (12.24 ug/L) and September(11.50 ug/L) (Figure 4-35).

The nitrogen species for the study were reported as nitrate+nitrite (NO_3+NO_2), ammonium NH4), dissolved organic nitrogen (DIN), dissolved organic nitrogen (DON) and total dissolved nitrogen (TDN). The mean DIN (NO_3+NO_2+NH_4) was 28.21 ug/L, with a range from 0.095 to 474.5 ug/L (Table 4-8). The majority of the DIN was the nitrate+nitrite component, which had a mean concentration of 24.39 ug/L. Nitrate+nitrite showed a great deal of variability along the coast (Figure 4-30), with very high values recorded at Port Aransas Birding Center (182.97 ug/L) and Adolph Tomae Jr. County Park (128.03 ug/L) (Table 4-8, Figure 4-30). Not surprisingly, DIN showed a similar pattern as that seen in nitrate+nitrite (Figure 4-31).

Mean DON concentration was 87.61 ug/L with a range from 17.29 to 1,191.16 ug/L (Table 4-8). There was no trend in DON concentrations along the coast (Figure 4-32). The highest mean values were recorded at Jones Creek (218.68 ug/L) and the Port Aransas Birding Center (609.66 ug/L) locations (Table 4-8, Figure 4-32).

Monthly mean values of nitrate+nitrite peaked in May (41.38 ug/L) and then trended downward to low values in August (11.48 ug/L) and September (11.94 ug/L) (Figure 4-36). DIN followed the same pattern Figure 4-37). On the other hand, DON showed a much different pattern, as the lowest means were recorded in June (80.63 ug/L) and July (53.77 ug/L), with the peak occurring in April (144.45 ug/L) (Figure 4-38).

In 2001, the mean chlorophyll a concentration at the six stations sampled was 57.57 ug/L with a range from 1.36 to 306.75 ug/L (Table 4-9). The mean values at Clear Lake (94.35 ug/L) and the Port Aransas Birding Center (117.86 ug/L) were by the far the highest, while the remaining four stations had mean chlorophyll a concentrations below 40 ug/L (Figure 4-39). On a monthly basis, the mean chlorophyll a concentration peaked in May (76.06 ug/L) and the showed a steady decline to a low value of 42.15 ug/L in September (Figure 4-45).

The mean silicate concentration in 2001 was 44.10 ug/L, with a range from 8.09 to 100.07 ug/L. (Table 4-9). Silicate means tended to be higher at the lower coast stations, with mean values of 69.02 ug/L at the Port Aransas Birding Center and 56.51 ug/L at Adolph Tomae Jr. County Park (Figure 4-40). The lowest mean silicate values were found in the central part of the coast, at Caney Creek (26.71 ug/L) and Port Lavaca (31.91 ug/L) (Table 4-9, Figure 4-40). On a monthly basis, the mean silicate concentration was higher in the latter four months (June-September) of the study (Figure 4-46).

The mean phosphate concentration in 2001 was 10.62 ug/L, with a range from 0.18 to 62.18 ug/L (Table 4-9). By far, the highest mean concentration of phosphate was found at the Port Aransas Birding Center (35.74 ug/L). All the rest of the sites had mean values below 10 ug/L (Table 4-9, Figure 4-41). On a monthly basis, phosphate concentrations showed a general increasing trend, from a low value of 5.71 ug/L in April to a high of 15.64 ug/L in September (Figure 4-47).

The mean DIN (NO_3+NO_2+NH_4) in 2001 was 34.07 ug/L, with a range from 0.14 to 191.56 ug/L (Table 4-9). The majority of the DIN was made up of nitrate+nitrite, but not nearly as high a percentage as in 2000, as it made up only about 2/3 of the DIN as compared to 4/5 in 2000. The highest mean concentration of DIN was found at the Port Aransas Birding Center (123.13 ug/L), while the rest of the coast was less than 30 ug/L (Table 4-9, Figure 4-43). As with DIN, the highest nitrate+nitrite concentration was found at the Port Aransas Birding Center (80.49 ug/L), while the remainder of the stations were below 25 ug/L (Table 4-9, Figure 4-42).

The mean DON was 174.88 ug/L, with a range from 8.62 to 1119.27 ug/L (Table 4-9). The mean DON concentration, like the DIN, was highest at the Port Aransas Birding Center (631.62 ug/L), while all other stations were less than 200 ug/L (Table 4-9, Figure 4-44). The DON also was higher at the three southern stations as compared to the northern stations (Figure 4-44).

On a monthly basis, nitrate+nitrite showed a steady decrease from April (35.59 ug/L) to August (26.19 ug/L), with a slight increase in September (35.33 ug/L) (Figure 4-48). On the other hand, DIN was fairly consistent during the six months, ranging between 25 to 40 ug/L (Figure 4-49). The monthly mean DON concentration increased from April (123.52 ug/L) to June (254.43 ug/L), then dropped in July (125.53 ug/L) to approximately the value in April, then increased again through September (194.70 ug/L) (Figure 4-50).

Table 4-9. Means (StdDev, N) for Chlorophyll a, Silicate (SIO3), Phosphate (PO_4), Nitrate+Nitrite ($NO_3 + NO_2$,) Ammonium (NH_4), Dissolved Inorganic Nitrogen (DIN), Dissolved Organic Nitrogen (DON) and Total Dissolved Nitrogen (TDN) for *Pfiesteria* Sampling Locations for 2000 (nd=no data).

Location	Chlorophyll a (ug/L)	Silicate (ug/L)	Phosphate (ug/L)	Nitrate+Nitrite (ug/L)	Ammonium (ug/L)	DIN [1] (ug/L)	DON [2] (ug/L)	TDN (ug/L)
Sabine Pass Swing Bridge	8.33 (4.876, 6)	48.49 (7.349, 6)	3.40 (3.408, 6)	2.46 (3.418, 6)	0.45 (0.455, 6)	2.91 (3.459, 6)	24.76 (9.600, 6)	27.67 (9.184, 6)
Tabbs Bay	6.66 (2.469, 3)	57.34 (19.186, 3)	9.87 (4.314, 3)	21.38 (19.647, 3)	4.13 (6.749, 3)	25.51 (25.249, 3)	30.88 (16.312, 3)	56.39 (40.180, 3)
Clear Lake	14.65 (0, 1)	51.155 (0, 1)	4.38 (0, 1)	15.82 (0, 1)	0.695 (0, 1)	16.515 (0, 1)	35.44 (0, 1)	51.955 (0, 1)
Clear Creek	51.09 (8.715, 2)	49.96 (13.124, 2)	10.79 (0.421, 2)	17.68 (17.398, 2)	0.27 (0.004, 2)	17.95 (17.402, 2)	31.64 (8.807, 2)	49.58 (26.209, 2)
Armand Bayou	73.92 (39.115, 3)	57.02 (21.752, 3)	14.03 (3.698, 3)	0.74 (0.694, 3)	0.24 (0.040, 3)	0.97 (0.687, 3)	51.33 (1.920, 3)	52.30 (2.603, 3)
Dickinson Bayou 1	18.39 (12.920, 4)	79.60 (37.877, 4)	4.92 (1.638, 4)	5.12 (8.835, 4)	5.79 (8.188, 4)	10.91 (16.903, 4)	45.08 (10.223, 3)	57.36 (22.883, 3)
Dickinson Bayou 2	11.625 (0, 1)	70.1 (0, 1)	1.98 (0, 1)	0.55 (0, 1)	0.27 (0, 1)	0.82 (0, 1)	28.65 (0, 1)	29.47 (0, 1)
Moses Bayou	21.19 (20.241, 2)	46.60 (15.295, 2)	3.65 (4.830, 2)	0.28 (0.099, 2)	0.46 (0.523, 2)	0.74 (0.424, 2)	33.77 (18.880, 2)	34.50 (18.459, 2)
Moses Lake	13.425 (0, 1)	66.08 (0, 1)	2.385 (0, 1)	0.085 (0, 1)	0.05 (0, 1)	0.135 (0, 1)	25.205 (0, 1)	25.34 (0, 1)
Jamaica Beach Canal	21.67 (12.768, 6)	60.67 (11.859, 6)	4.61 (6.583, 6)	0.11 (0.044, 6)	0.26 (0.094, 6)	0.37 (0.095, 6)	26.96 (5.286, 6)	27.32 (5.239, 6)
Oyster Creek	11.12 (2.837, 2)	89.67 (54.242, 2)	6.54 (4.978, 2)	10.96 (15.224, 2)	5.03 (6.749, 2)	15.99 (21.973, 2)	25.20 (5.636, 2)	41.19 (16.338, 2)
Swan Lake	8.325 (0, 1)	11.12 (0, 1)	12.27 (0, 1)	5.79 (0, 1)	0.44 (0, 1)	6.23 (0, 1)	41.205 (0, 1)	47.435 (0, 1)
Intracoastal Waterway	30.14 (34.807, 2)	79.00 (79.825, 2)	10.09 (1.587, 2)	22.37 (6.781, 2)	2.00 (2.450, 2)	24.37 (9.231, 2)	38.10 (16.469, 2)	62.47 (25.700, 2)
Jones Creek	69.75 (0, 1)	85.9 (0, 1)	19.79 (0, 1)	5.59 (0, 1)	0.51 (0, 1)	6.1 (0, 1)	218.675 (0, 1)	224.775 (0, 1)
Caney Creek	5.56 (3.855, 5)	78.85 (73.785, 5)	13.31 (3.632, 5)	12.81 (23.193, 5)	4.86 (8.033, 5)	17.67 (31.174, 5)	43.93 (34.509, 5)	61.59 (65.117, 5)
Colorado River	47.51 (51.164, 3)	123.88 (58.457, 3)	6.75 (3.397, 3)	23.84 (20.238, 3)	1.83 (2.668, 3)	25.67 (21.332, 3)	23.00 (7.989, 3)	48.67 (26.852, 3)
Lavaca Bay Causeway	10.64 (5.673, 5)	89.45 (25.069, 5)	2.62 (4.363, 5)	0.73 (0.616, 3)	0.58 (0.658, 5)	0.99 (1.250, 5)	32.34 (12.857, 4)	32.81 (12.489, 4)
Mesquite Bay	13.47 (8.789, 3)	86.58 (8.244, 3)	5.84 (8.486, 3)	0.68 (0.527, 3)	0.27 (0.446, 3)	0.94 (0.787, 3)	31.08 (16.925, 3)	32.02 (17.125, 3)
Nueces River	28.41 (17.291, 6)	209.53 (86.610, 6)	6.52 (2.976, 6)	2.18 (2.468, 6)	4.07 (7.261, 6)	6.25 (9.024, 6)	33.57 (7.767, 6)	39.81 (12.057, 6)
Port Aransas Birding Center	60.76 (53.339, 6)	202.24 (99.452, 6)	29.01 (26.776, 6)	182.97 (157.299, 6)	26.68 (49.248, 6)	209.65 (188.836, 6)	609.66 (376.607, 6)	819.31 (270.630, 6)
Oso Bay 1	6 (0, 1)	74.57 (0, 1)	0.235 (0, 1)	1.31 (0, 1)	4.025 (0, 1)	5.335 (0, 1)	33.15 (0, 1)	38.485 (0, 1)
Oso Bay 2	4.10 (1.551, 4)	89.12 (37.822, 4)	6.93 (7.900, 4)	0.64 (0.280, 4)	1.18 (0.919, 4)	1.82 (0.680, 4)	52.51 (9.353, 4)	54.33 (9.385, 4)
Oso Creek	25.93 (0, 1)	260.28 (0, 1)	8.64 (0, 1)	0.20 (0, 1)	0.71 (0, 1)	0.91 (0, 1)	48.50 (0, 1)	49.41 (0, 1)
Kraatz Pier	26.75 (0.000, 2)	201.98 (17.299, 2)	1.82 (0.209, 2)	1.53 (0.463, 2)	0.46 (0.654, 2)	2.00 (0.191, 2)	nd	nd
Bayview Campground	31.83	153.79	4.87	0.87	2.51	3.37	91.12	94.49

	(28.773, 5)	(44.372, 4)	(8.860, 4)	(0.836, 4)	(4.718, 4)	(5.530, 4)	(13.067, 4)	(8.787, 4)
Arroyo City Park	14.88	239.90	31.37	128.03	8.64	136.68	35.23	82.99
	(3.870, 3)	(59.223, 3)	(36.785, 3)	(173.848, 30	(14.163, 3)	(187.819, 3)	(1.015, 2)	(40.765, 3)
Grand mean	24.62	109.04	9.32	24.71	4.13	28.21	87.61	82.99
(Stdev, n)	(27.899, 79)	(77.785, 78)	(12.873, 78)	(72.913, 76)	(14.932, 78)	(82.491, 78)	(188.150, 73)	(40.765, 74)
(Min)	(12, 0)	(11.12)	(0.06)	(0.065)	(0.00)	(0.095)	(17.29)	(18.34)
(Max)	(134)	(347)	(80.24)	(418.02)	(126.85)	(474.5)	(1191.16)	(1304.37)

1. DIN=NO3+NO2+NH4
2. DON=TDN-DIN

Table 4-10. Means (StdDev, N) for Chlorophyll a, Silicate (SIO3), Phosphate (PO_4), Nitrate+Nitrite ($NO_3 + NO_2$,), Ammonium (NH_4), Dissolved Inorganic Nitrogen (DIN), Dissolved Organic Nitrogen (DON) and Total Dissolved Nitrogen (TDN) for *Pfiesteria* Sampling Locations for 2001 (nd=no data).

Location	Chlorophyll a (ug/L)	Silicate (ug/L)	Phosphate (ug/L)	Nitrate+Nitrite (ug/L)	Ammonium (ug/L)	DIN [1] (ug/L)	DON [2] (ug/L)	TDN (ug/L)
Clear Lake	94.35	34.27	9.58	15.52	4.23	19.75	33.24	52.98
	(54.985, 12)	(19.544, 12)	(4.193, 12)	(12.575, 12)	(5.080, 12)	(11.899, 12)	(15.337, 12)	(15.887, 12)
Dickinson Bayou	39.66	44.17	3.48	6.69	4.21	10.90	33.40	44.30
	(27.436, 12)	(31.986, 12)	(1.712, 12)	(5.745, 12)	(5.014, 12)	(9.969, 12)	(18.066, 12)	(23.170, 12)
Caney Creek	13.13	26.71	3.71	4.19	4.27	8.45	23.46	31.92
	(11.520, 12)	(15.631, 12)	(5.941, 12)	(6.162, 12)	(2.679, 12)	(7.278, 12)	(10.471, 12)	(12.459, 12)
Port Lavaca Fishing Pier	16.16	31.91	1.97	3.45	1.39	4.84	144.49	149.32
	(7.053, 6)	(13.698, 8)	(1.544, 8)	(4.841, 8)	(2.512, 8)	(5.118, 8)	(323.495, 8)	(322.136, 8)
Port Aransas Birding Center	117.86	69.02	35.74	80.49	42.65	123.13	631.62	754.75
	(70.952, 12)	(25.699, 12)	(18.788, 12)	(9.457, 12)	(36.666, 12)	(32.272, 12)	(319.289, 12)	(308.628, 12)
Arroyo City Park	36.53	56.51	5.50	23.46	2.86	26.31	172.53	198.84
	(27.347, 8)	(20.374, 10)	(2.328, 10)	(24.061, 10)	(4.014, 10)	(23.821, 10)	(311.168, 10)	(311.939, 10)
Grand mean	57.57	44.10	10.62	23.40	10.66	34.07	174.88	208.94
(Stdev, n)	(57.982, 62}	(26.436, 66)	(14,777, 66)	(30.305, 66)	(21.726, 66)	(46.31, 66)	(303.81, 66)	(334.16, 66)
(Min)	(1.36)	(8.09)	(0.18)	(0.11)	(0.00)	(0.14)	(8.62)	(18.40)
(Max)	(306.75)	(100.07)	(62.18)	(95.69)	(117.32)	(191.56)	(1119.27)	(1258.53)

1 DIN=NO3+NO2+NH4
2. DON=TDN-DIN

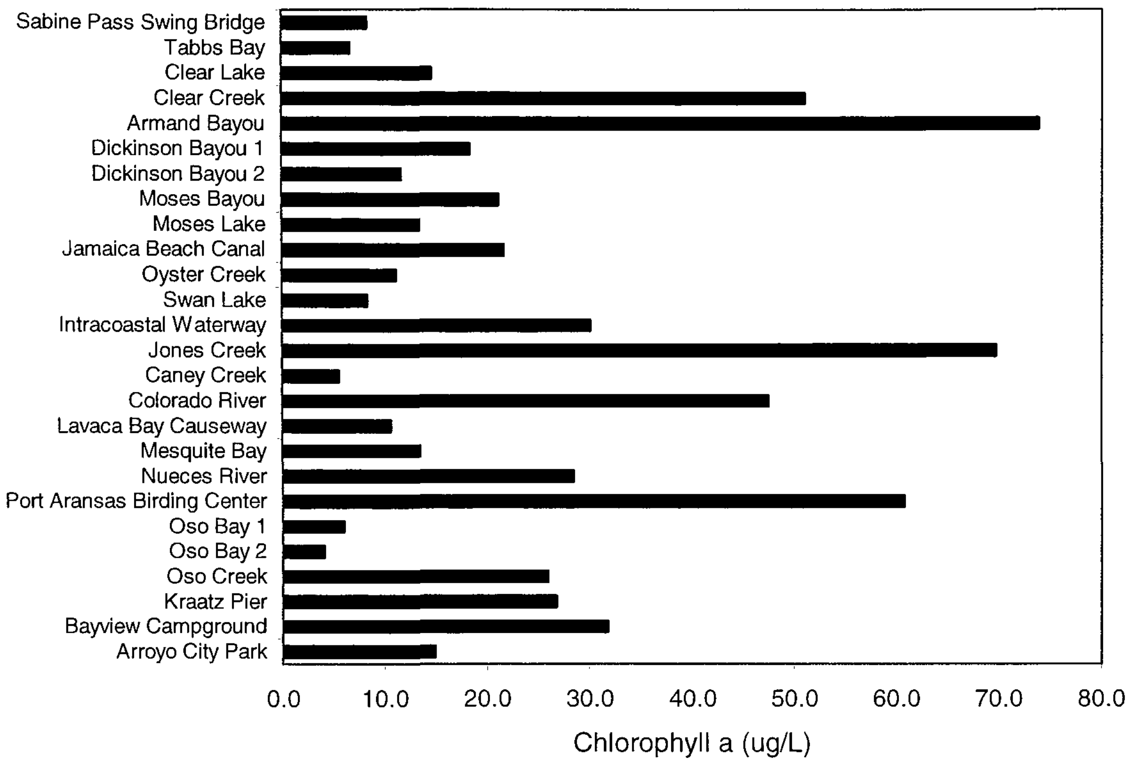

Figure 4-27. Mean chlorophyll a concentration at the *Pfiesteria* sampling stations in 2000.

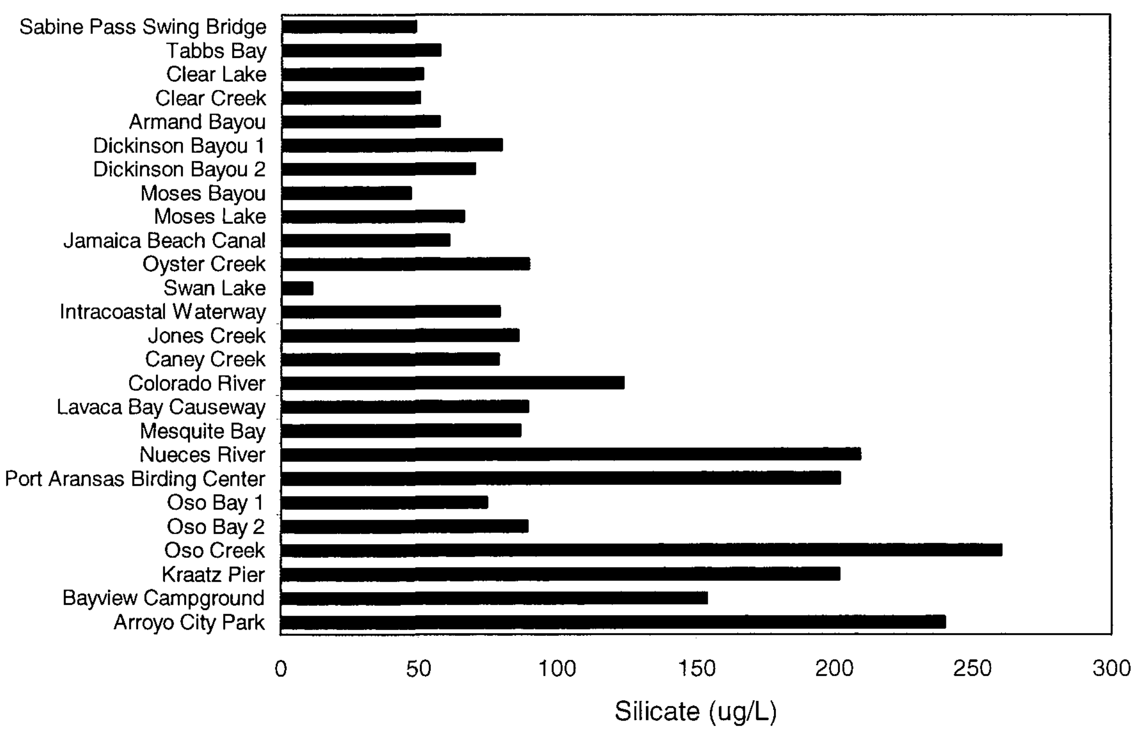

Figure 4-28. Mean silicate concentration at the *Pfiesteria* sampling stations in 2000.

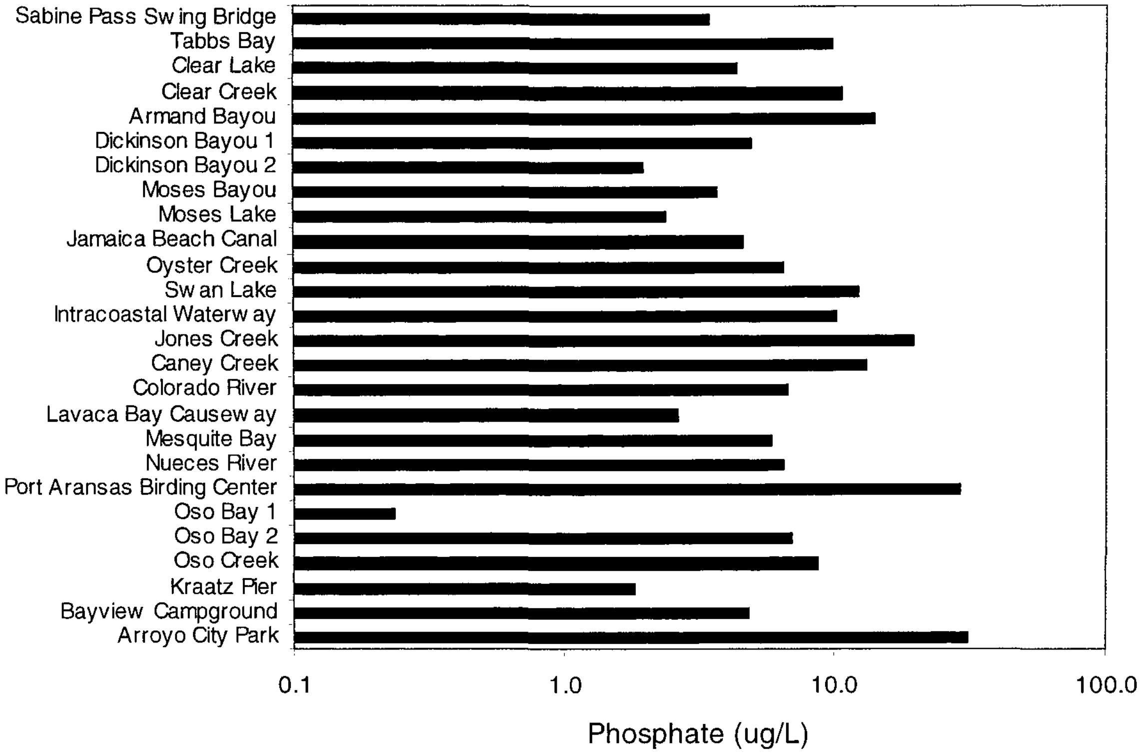

Figure 4-29. Mean phosphate concentration at the *Pfiesteria* sampling stations in 2000.

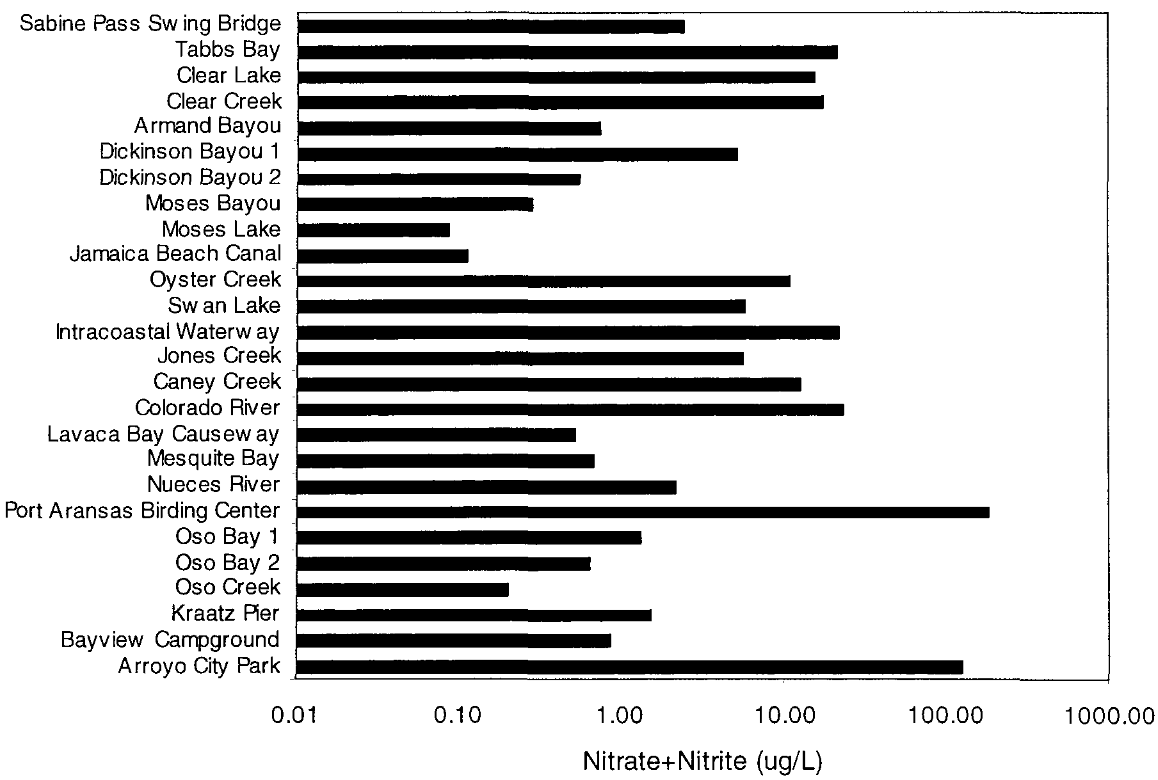

Figure 4-30. Mean nitrate+nitrite concentration at the *Pfiesteria* sampling stations in 2000.

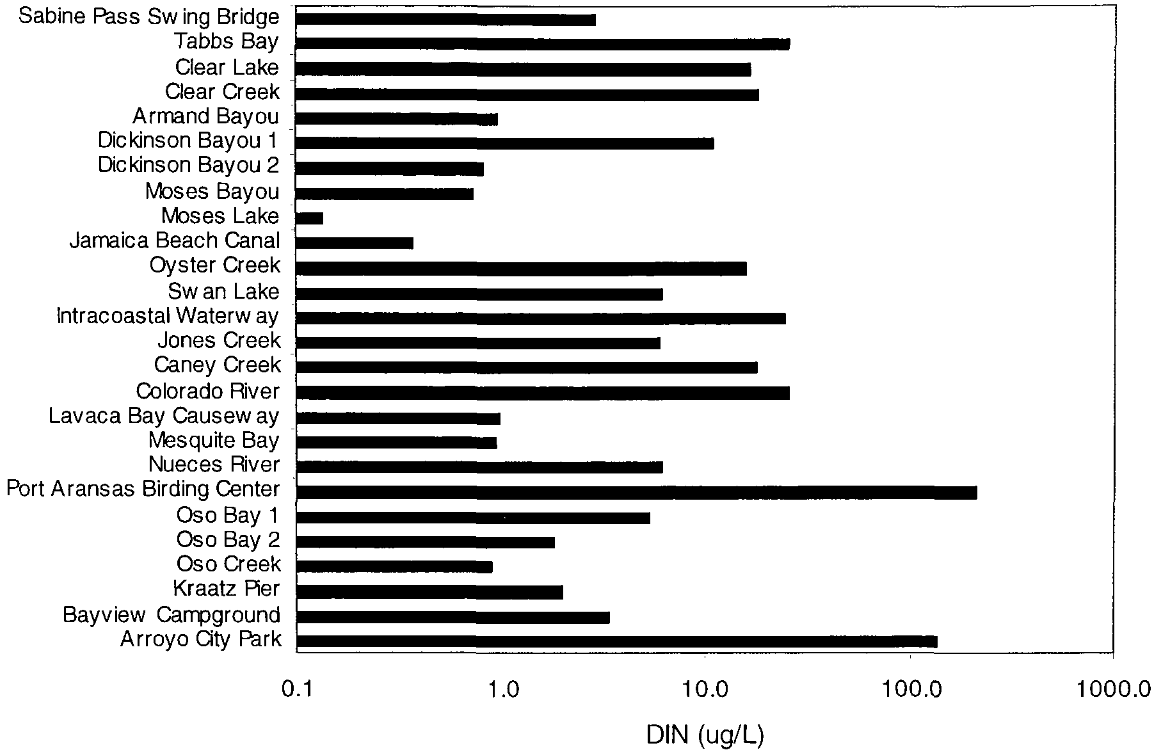

Figure 4-31. Mean dissolved inorganic nitrogen (DIN) concentration at the *Pfiesteria* sampling stations in 2000.

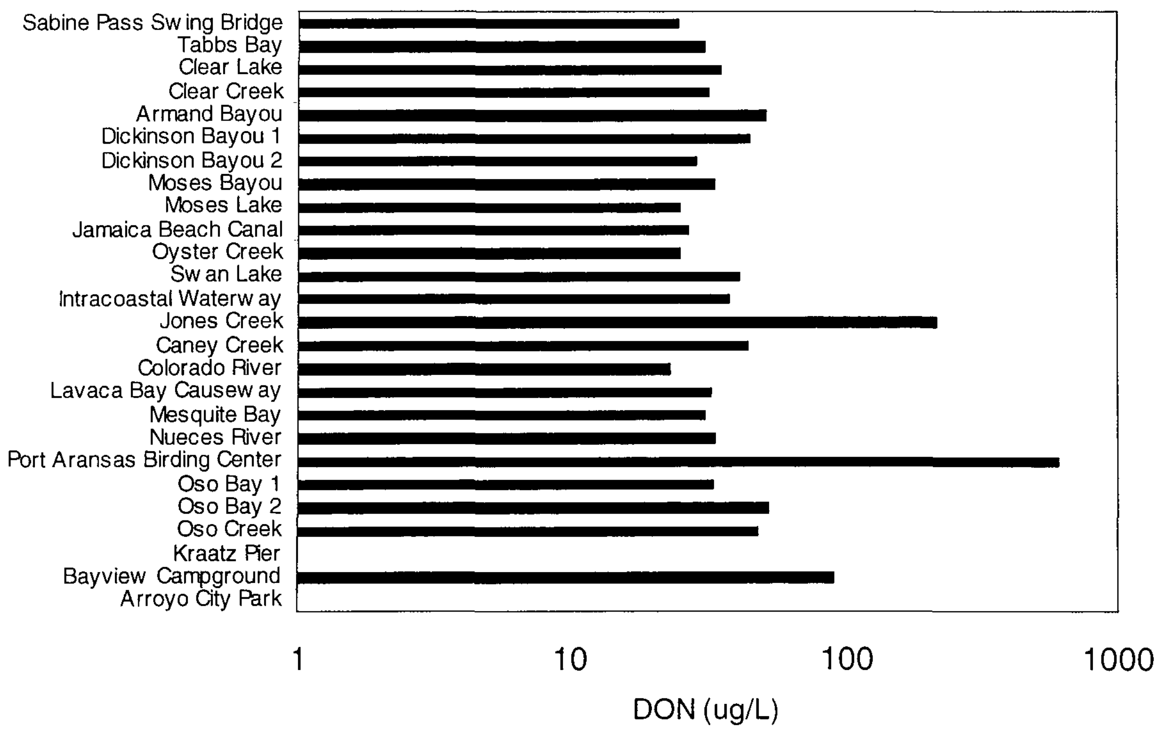

Figure 4-32. Mean dissolved organic nitrogen (DON) concentration at the *Pfiesteria* sampling stations in 2000.

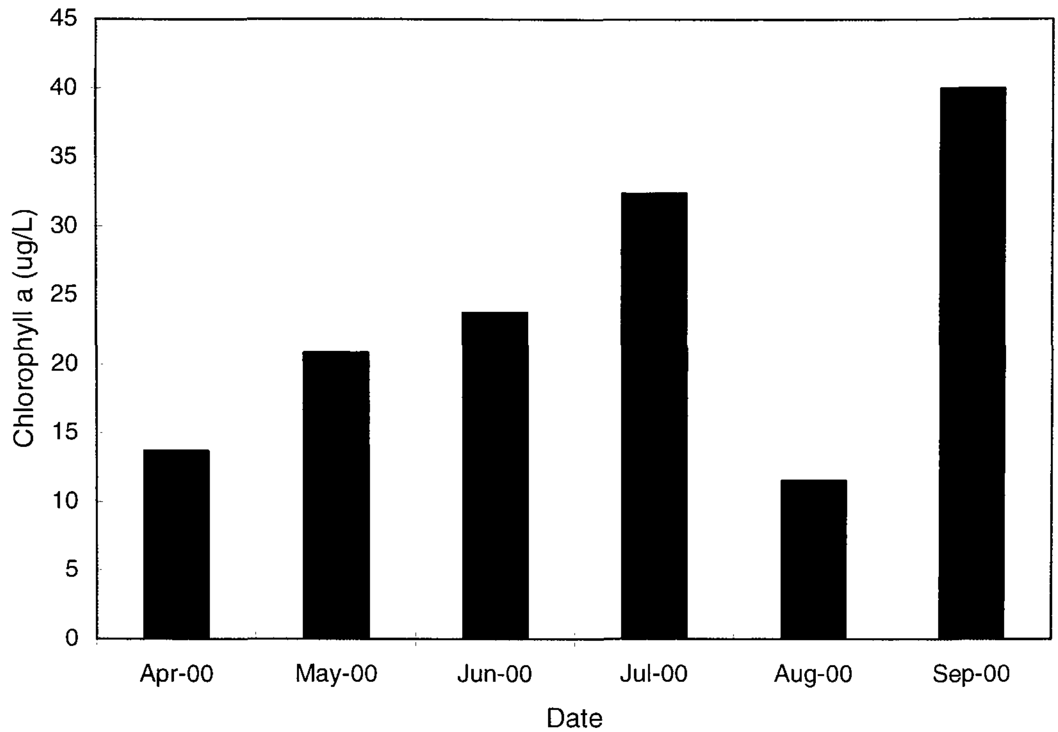

Figure 4-33. Mean monthly chlorophyll a concentration at the *Pfiesteria* sampling stations in 2000.

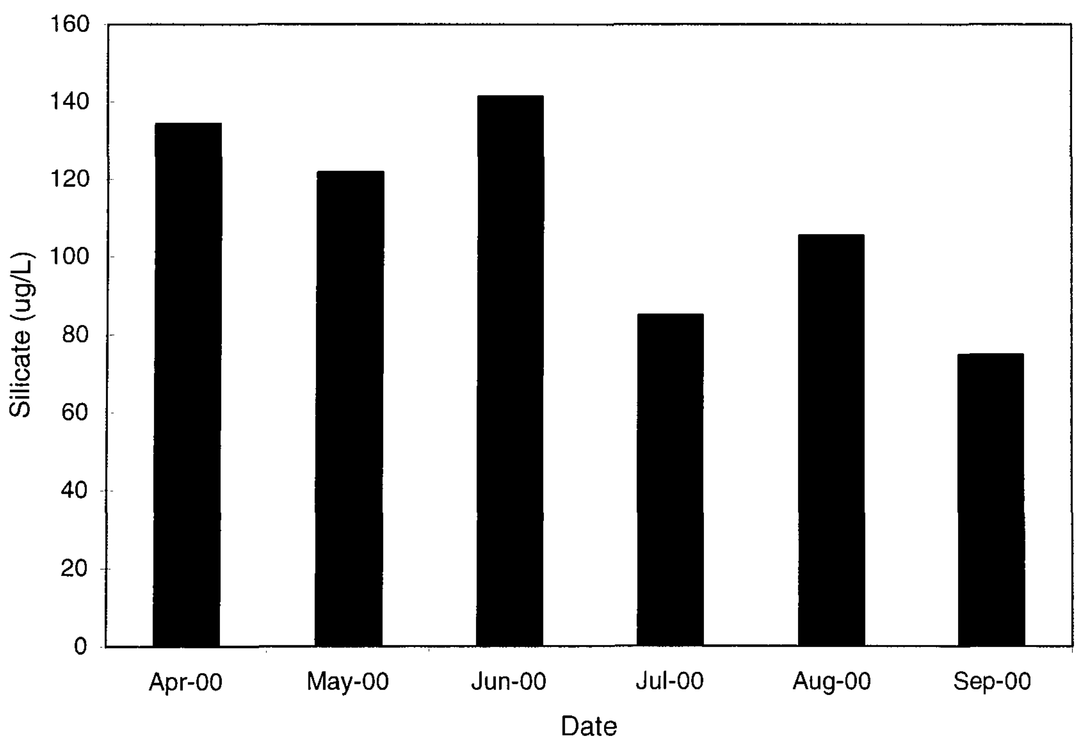

Figure 4-34. Mean monthly silicate concentration at the *Pfiesteria* sampling stations in 2000.

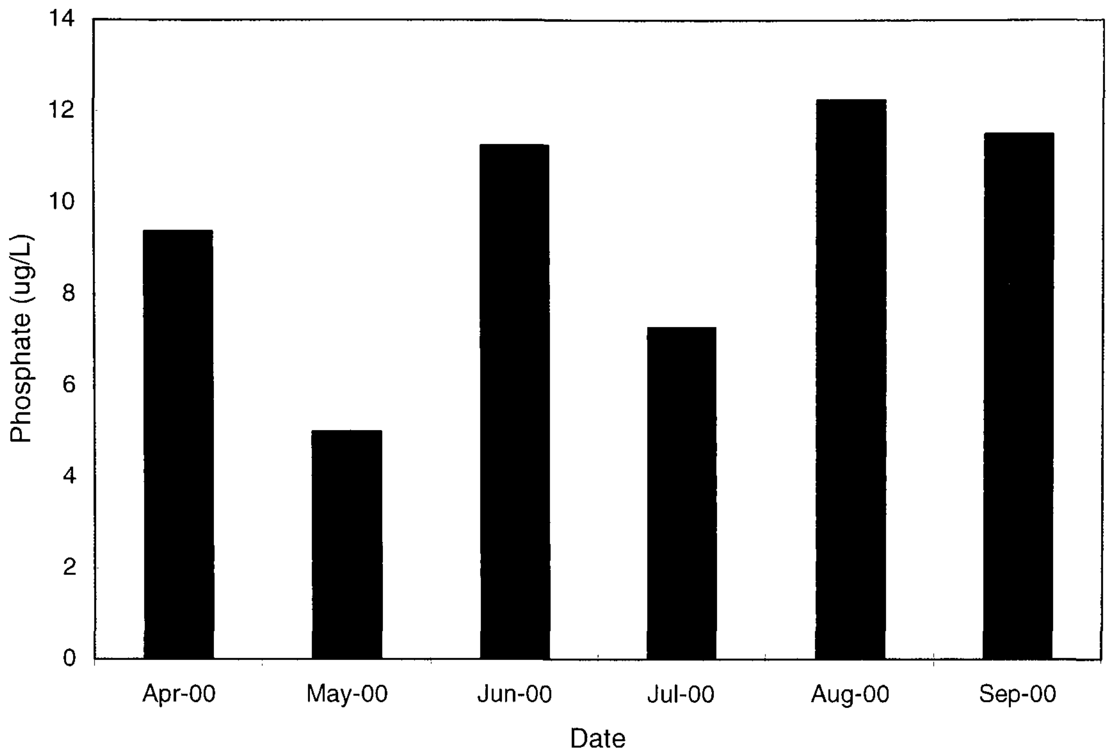

Figure 4-35. Mean monthly phosphate concentration at the *Pfiesteria* sampling stations in 2000.

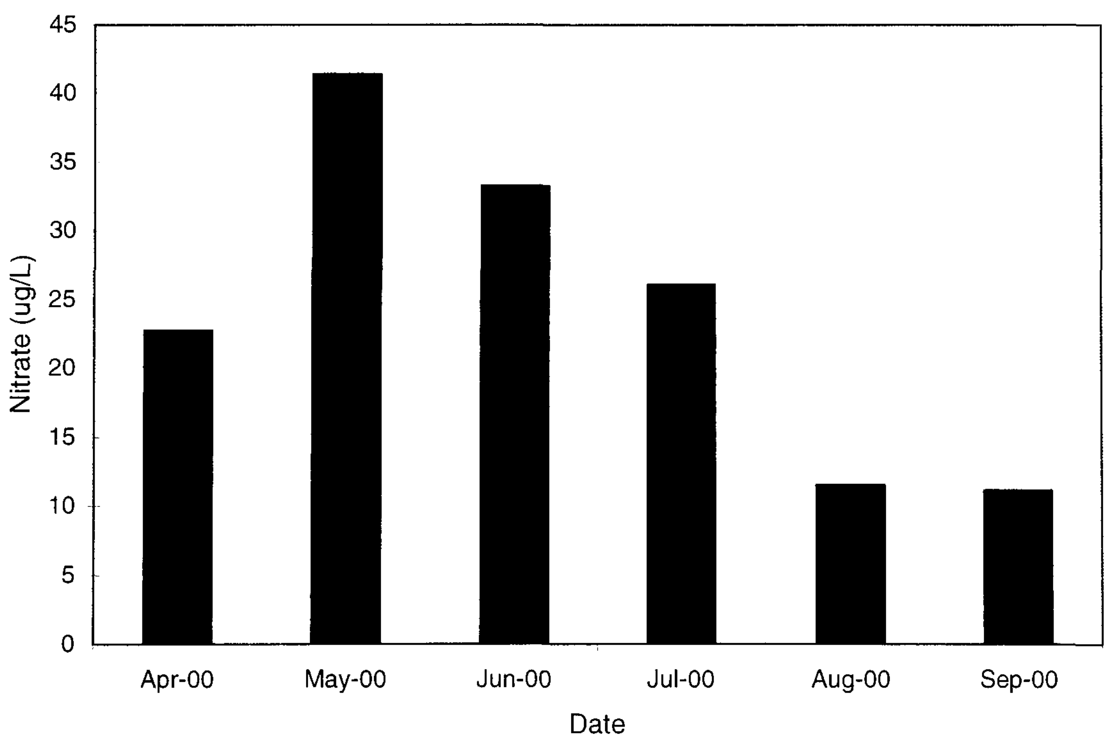

Figure 4-36. Mean monthly nitrate+nitrite concentration at the *Pfiesteria* sampling stations in 2000.

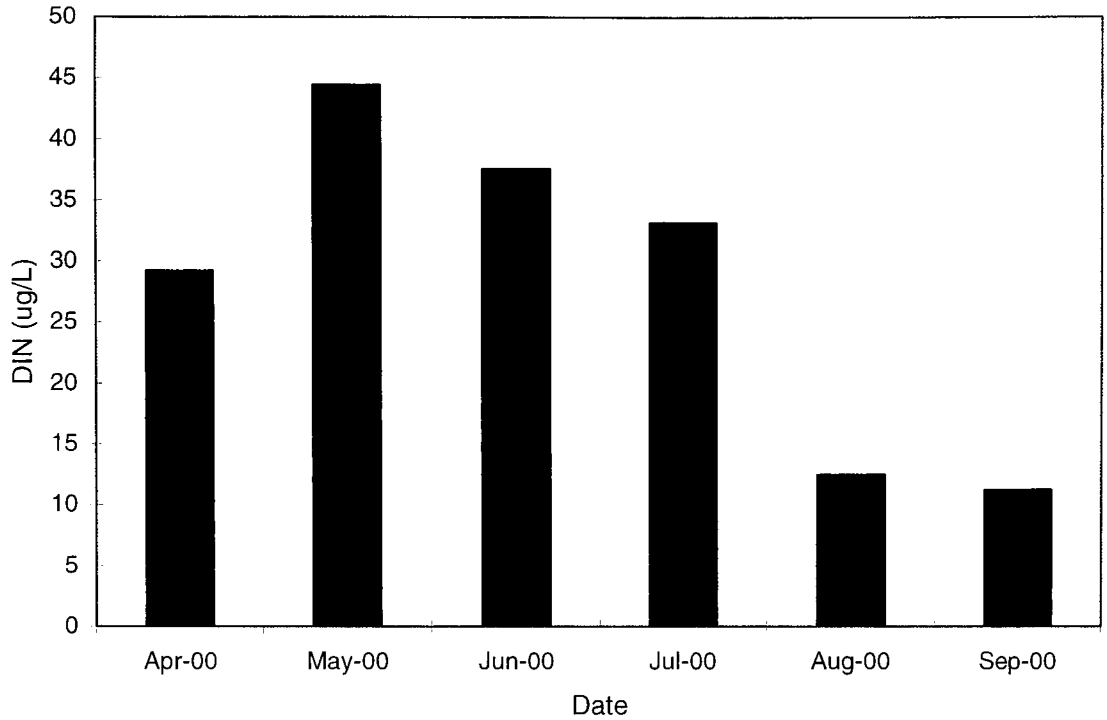

Figure 4-37. Mean monthly dissolved inorganic nitrogen (DIN) concentration at the *Pfiesteria* sampling stations in 2000.

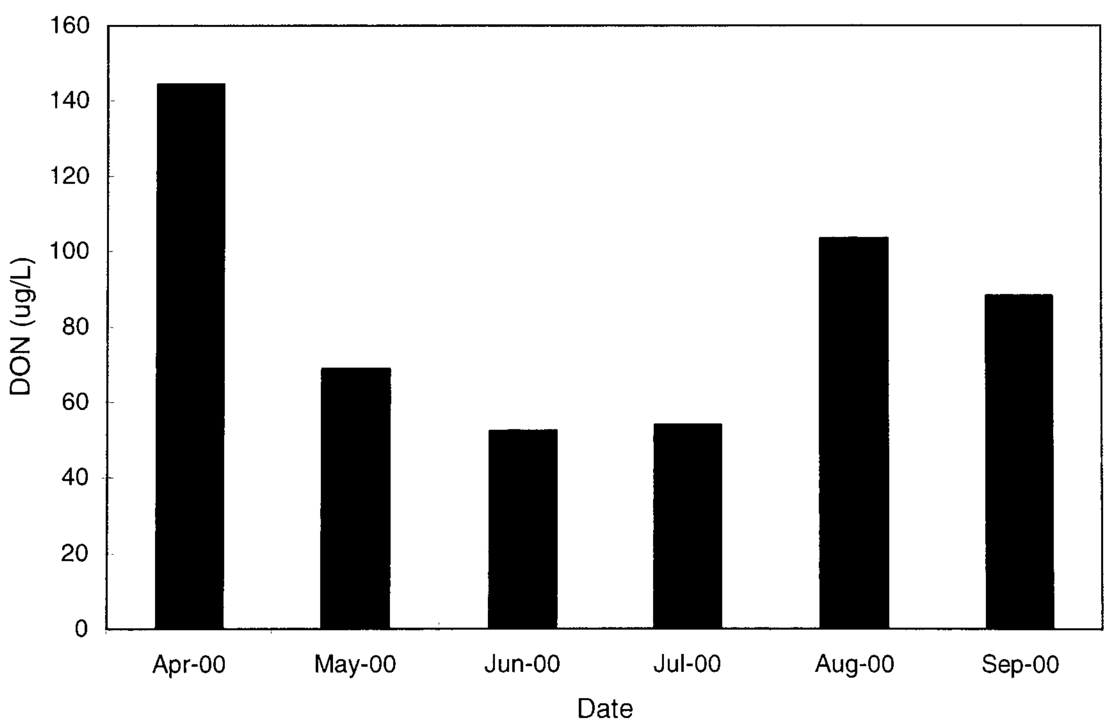

Figure 4-38. Mean monthly dissolved organic nitrogen (DON) concentration at the *Pfiesteria* sampling stations in 2000.

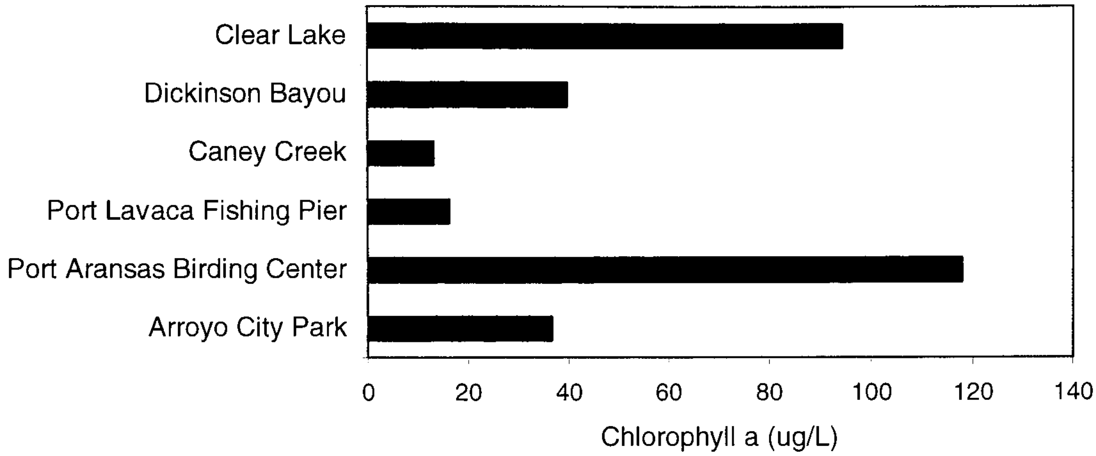

Figure 4-39. Mean chlorophyll a concentration at the *Pfiesteria* sampling stations in 2001.

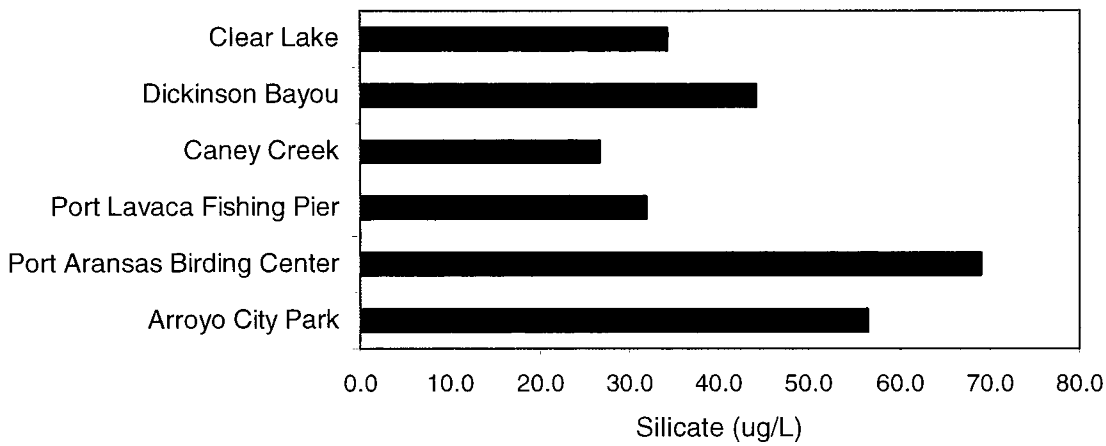

Figure 4-40. Mean silicate concentration at the *Pfiesteria* sampling stations in 2001.

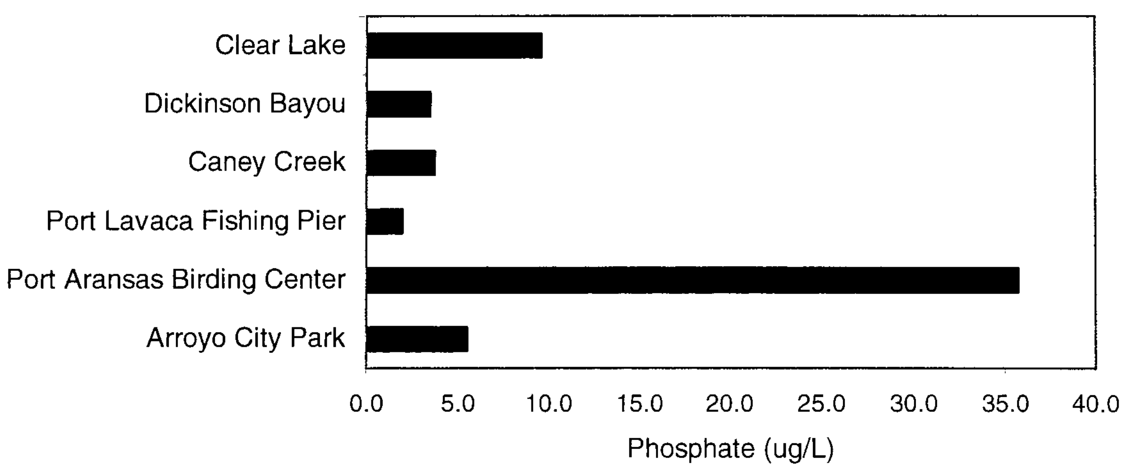

Figure 4-41. Mean phosphate concentration at the *Pfiesteria* sampling stations in 2001.

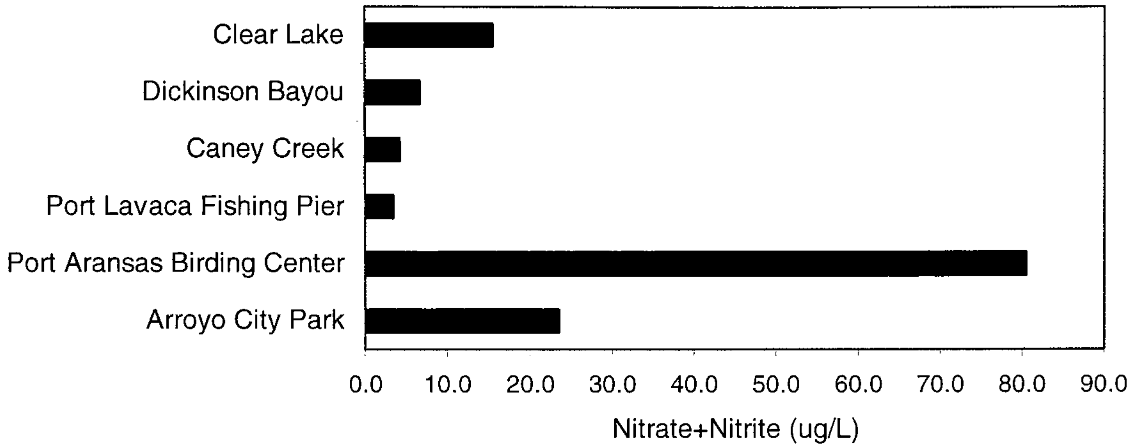

Figure 4-42. Mean nitrate+nitrite concentration at the *Pfiesteria* sampling stations in 2001.

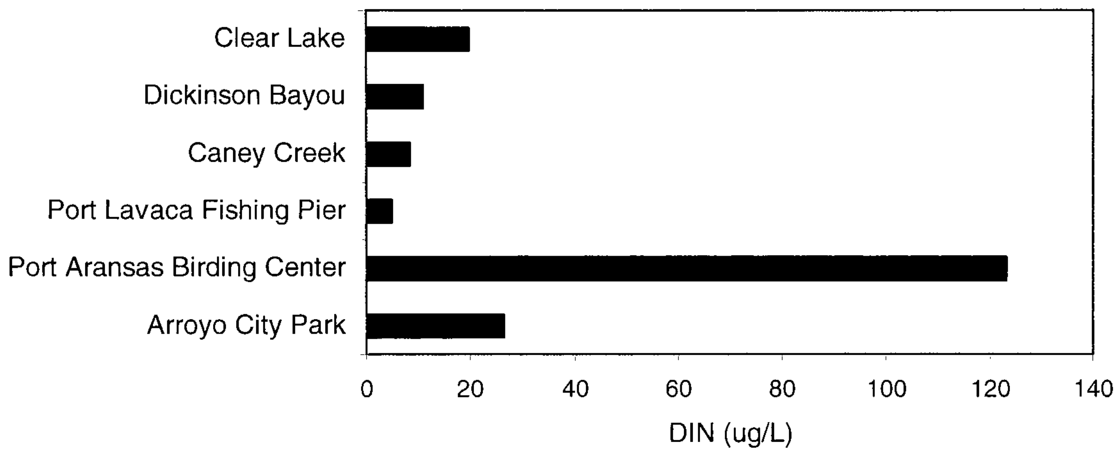

Figure 4-43. Mean dissolved inorganic nitrogen (DIN) concentration at the *Pfiesteria* sampling stations in 2001.

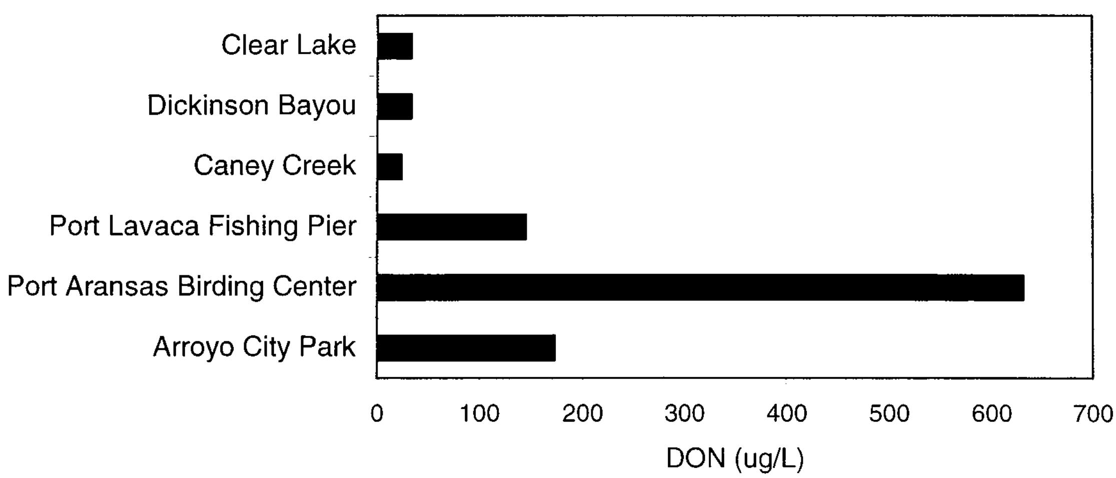

Figure 4-44. Mean dissolved organic nitrogen (DON) concentration at the *Pfiesteria* sampling stations in 2001.

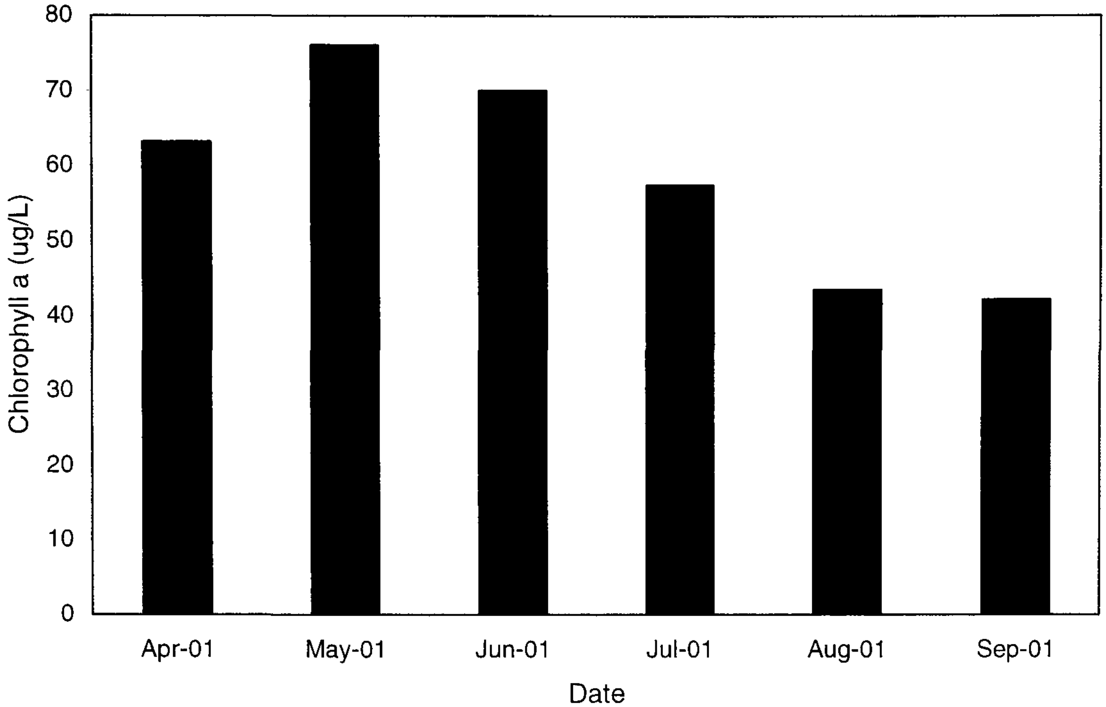

Figure 4-45. Mean monthly chlorophyll a concentration at the *Pfiesteria* sampling stations in 2001.

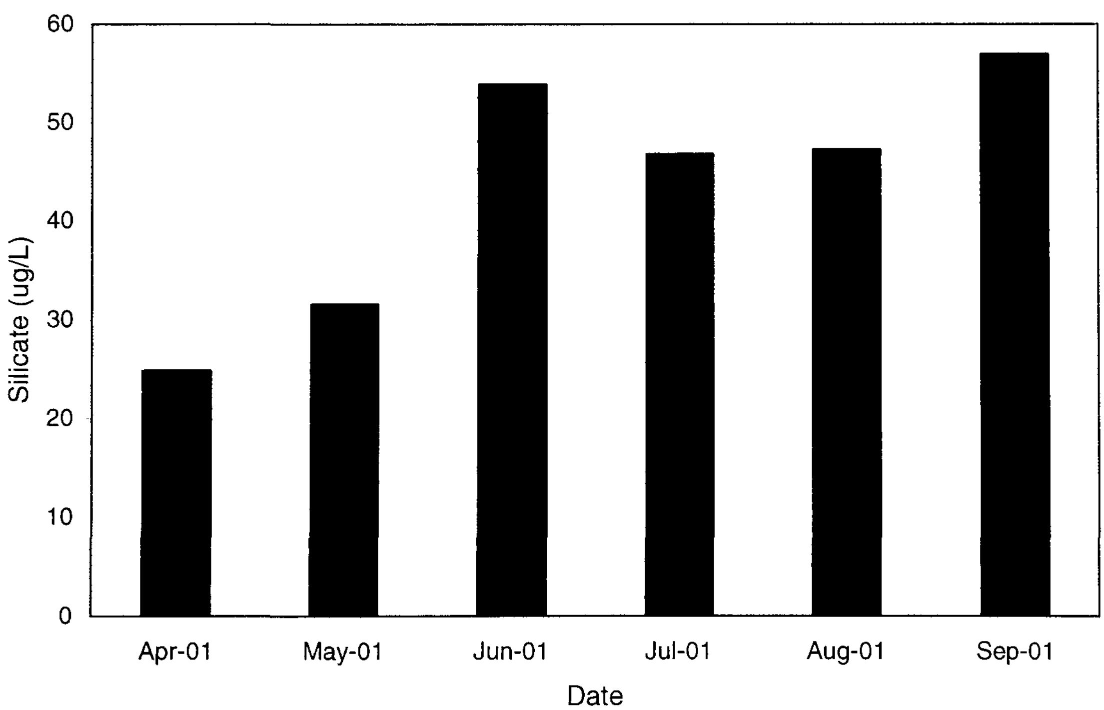

Figure 4-46. Mean monthly silicate concentration at the *Pfiesteria* sampling stations in 2001.

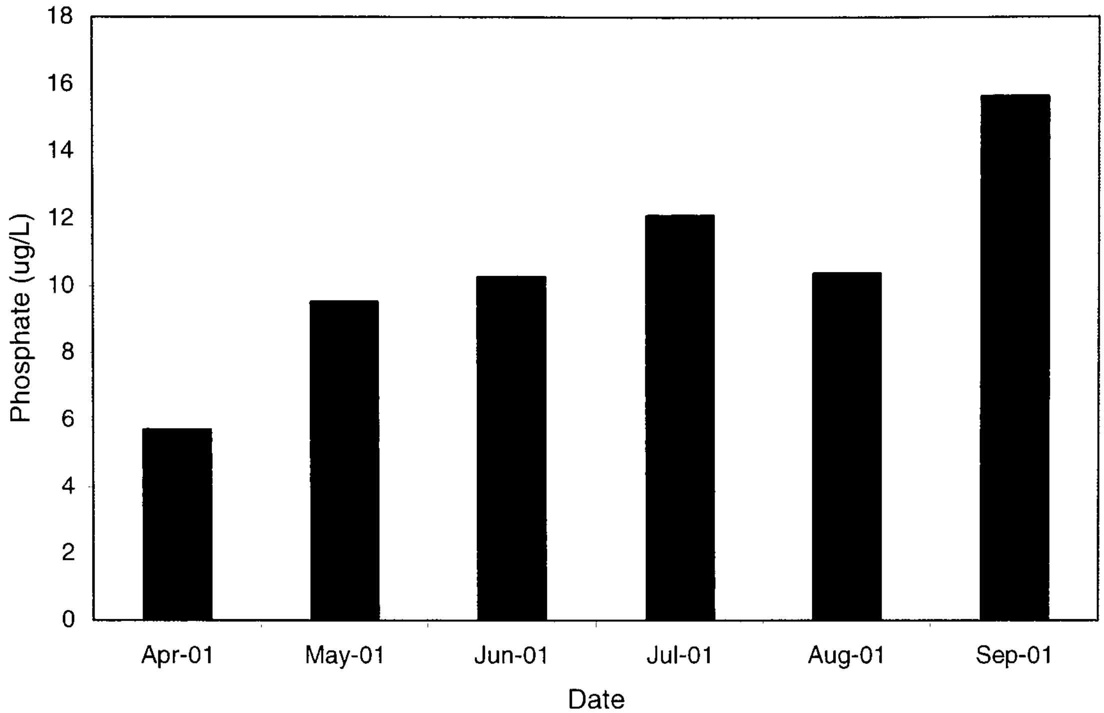

Figure 4-47. Mean monthly phosphate concentration at the *Pfiesteria* sampling stations in 2001.

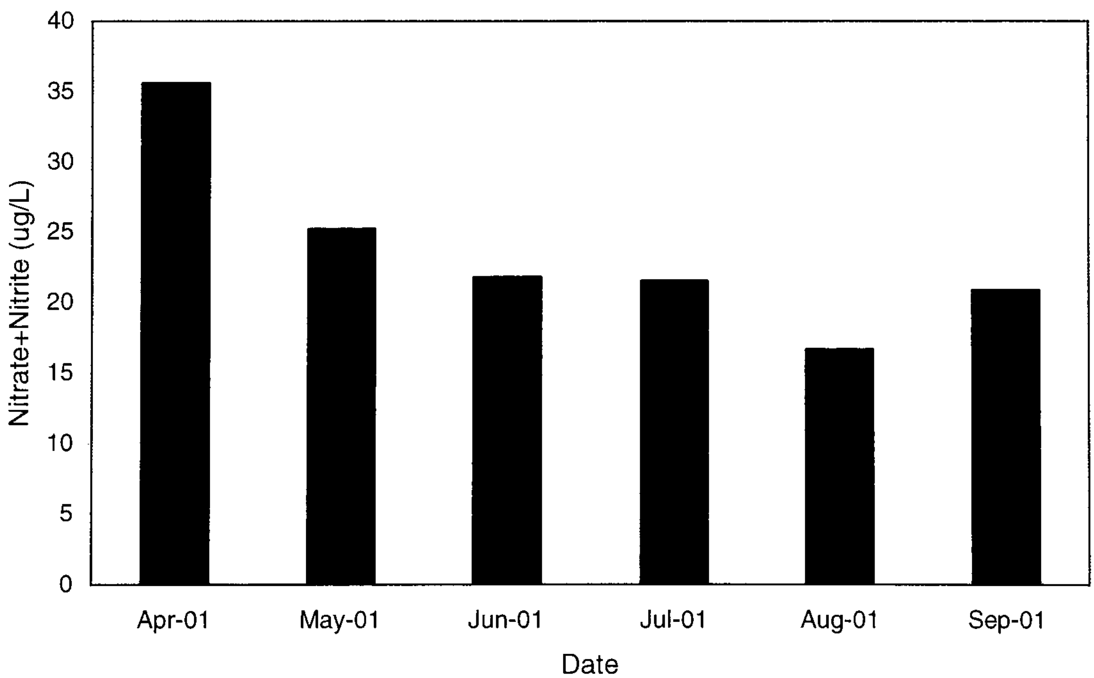

Figure 4-48. Mean monthly nitrate+nitrite concentration at the *Pfiesteria* sampling stations in 2001.

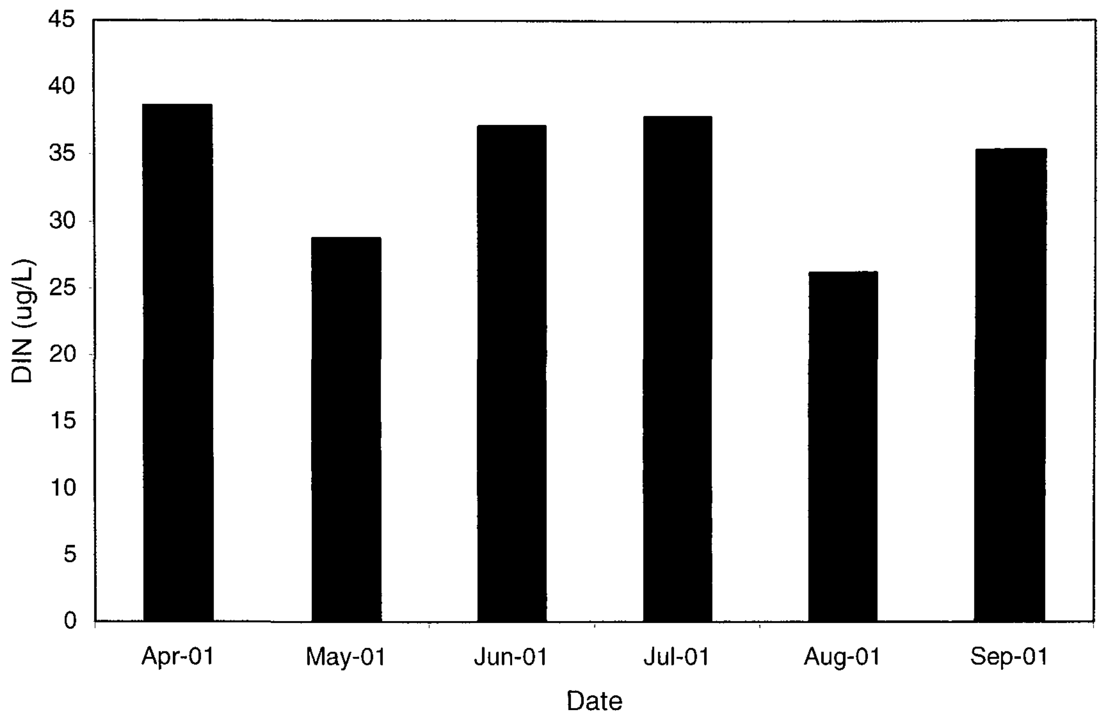

Figure 4-49. Mean monthly dissolved inorganic nitrogen (DIN) concentration at the *Pfiesteria* sampling stations in 2001.

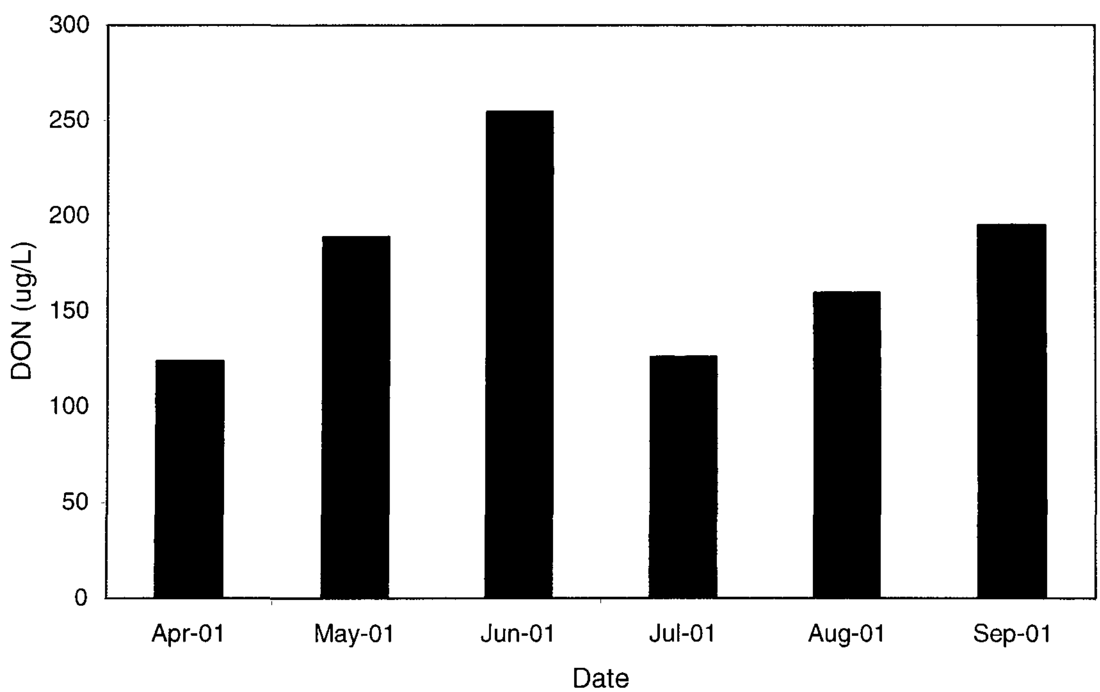

Figure 4-50. Mean monthly dissolved organic nitrogen (DON) concentration at the *Pfiesteria* sampling stations in 2001.

Pfiesteria Results

Samples for *Pfiesteria* analysis were collected at 27 different sites in the 2000 sampling season (Figure 4-1), while that was reduced to six stations in 2001 (Figure 4-2). At the 27 stations sampled in 2000 there were 83 water and 8 sediment samples collected (Table 4-1). In 2001, there were 67 water and 3 sediment samples collected (Table 4-2). For the 2000 and 2001 sampling seasons, the samples were initially tested using Method 1 (M1), which was not as sensitive as Method 2 (M2), which was developed later. Samples were re-tested later in 2001 or 2002, but testing was probably not as effective on the year 2000 samples as it may have been with samples collected in 2001, as they may have degraded over time with freezing and thawing.

Both *Pfiesteria* spp. were present along the coast in both years (Table 4-10, Figures 4-51, 4-52). Substantially more positives were found using the M2 assay, particularly in 2001 (Table 4-10). There were more positives in 2001 than 2000, probably due to sample degradation of the 2000 samples upon re-analysis.

Initial results from the sampling program did not take long to find a positive result, as the first sample collected in 2000, at Adolph Tomae Jr. County Park on the Arroyo Colorado, was positive for *P. piscicida*. Method 1 detected *P. piscicida* in five samples, *P. shumwayae* in 3 samples and one sample was positive for *Cryptoperidiniopsis* (Table 4-10). These were all water samples. The results of the eight sediment samples collected revealed two positives, both *P. shumwayae* (Table 4-10). Using the improved Method 2 there were 10 positive water samples (eight *P.* pisicicida and two *P.* shumwayae). These results added six *P. piscicida* and two *P. shumwayae* to the number of distinct positives for *Pfiesteria* found in 2000. Method 2 also resulted in one additional positive for *P. piscicida* in the sediment samples (Tables 4-10, 4-11).

The results of the sampling in 2001 using Method 1 detected only 12 positives (five *P. piscicida* and six *P. shumwayae*) in the water samples. Then using the improved Method 2 on much fresher samples than those of 2000, a total of 52 positives were detected (24 *P. piscicida* and 26 *P. shumwayae*). In addition, two *P. piscicida* were detected in the sediment samples with Method 2, while they were not detected using Method 1.

Looking at results of both methods combined in 2000, a total of 21 positive results were found, 12 *P. piscicida* and 8 *P. shumwayae* and one *Cryptoperidiniopsis* (Table 4-11). The only stations to record more than one positive in total were Adolph Tomae Jr. County Park (5), Armand Bayou (3) and Dickinson Bayou (3). The distribution of positives was spread out evenly along the Texas coast, from a positive in Sabine Pass at the Sabine Pass Swing Bridge to five positives in the Arroyo Colorado, sampled at the Adolph Tomae Jr. County Park. The two *Pfiesteria* species did show some differences in regional distribution in 2000, as all eight of the *P. shumwayae* were located at or south of the Lavaca Bay station, while 10 of the 12 *P. piscicida* were found at or north of the Colorado River station (Table 4-11).

In 2001, rather than looking for *Pfiesteria* in a comprehensive coast-wide approach, we concentrated on six stations, in a more intensive sampling scheme, that was spread evenly along the Texas coast. (Table 4-12). Results of the Method 1 and Method 2 combined revealed a total of 59 positives, 26 for *P. piscicida* and 33 for *P. shumwayae* (Table 4-12). The greatest number of total positives in 2001 were located at Adolph Tomae Jr. County Park with 14, followed closely by Clear Lake and Port Aransas Birding Center with 12 each. The smallest number of positives at any single station for *Pfiesteria* (4) was recorded at the Port Lavaca Fishing Pier. There were no patterns or trends apparent in the distribution of the species, as both species were commonly found at all six of the stations (Table 4-12).

On a monthly basis, the percentage of stations positive for *Pfiesteria* by Method 1, Method 2 and the two methods combined was examined (Figure 4-53). In 2000, the largest percentage of samples were positive in the months of May (0.50) and August (0.40). It was in these two months that Method 2 had the greatest impact on the number and percentage of positives (Figure 4-53). The smallest percentage of stations positive for *Pfiesteria* were recorded in July (0.07) and April (0.06) (Figure 4-53).

In 2001, the percentage of samples positive for *Pfiesteria* was much greater than in 2000 (Figure 4-54).

The use of Method 2 had a much greater impact in 2001, as it greatly increased the percentage of samples positive for *Pfiesteria* in all months (Figure 4-54). The month of June had the highest percentage of samples positive for *Pfiesteria* at 85%. The smallest percentage of samples positive for *Pfiesteria* occurred in April (0.45) and May (0.50) (Figure 4-54).

Meteorological conditions were measured or observed at each of the sampling locations in 2000 during most visits. Table 4-13 and Figure 4-55 summarize the results of these observations in relation to the presence or absence of *Pfiesteria*. Results of these analyses indicate that, in general, there were no clear relationships between meteorological parameters and positives for *Pfiesteria*. Means for air temperature (Figure 4-55a) and wind speed (Figure 4-55c) were nearly identical. There was significantly less cloud cover, on the average, at stations positive for *Pfiesteria* ($t=2.937$, $df=55$, $p=0.005$). In addition, the mean sea state at stations positive for *Pfiesteria* was higher than those that were negative, but was not significant (Figure 4-55d).

Comparisons of means for meteorological conditions at stations positive for *P. piscicida* or *P. shumwayae* were also examined (Table 4-13). There were significant differences in the mean air temperature ($t=3.585$, $df=14$, $p=0.003$) and the mean wind speed ($t=2.344$, $df=14$, $p=0.034$) at sites positive for *P. piscicida* versus those positive for *P. shumwayae*. The means for cloud cover and sea state were not significantly different.

Physicochemical parameters in 2000 at sites positive or negative for *Pfiesteria* show that mean water temperature, percent saturation and Secchi depth were greater at sites positive for all *Pfiesteria*, and while the mean salinity at sites positive for *Pfiesteria* was less than those sites negative for *Pfiesteria* (Table 4-14, Figure 4-52). None of the six means examined were significantly different. The mean values of physicochemical parameters at sites positive for only *P. shumwayae* or *P. piscicida* were also examined (Table 4-14). None of these means were significantly different.

Chlorophyll a and nutrient results in 2000 at the sites positive or negative for *Pfiesteria* indicate that mean chlorophyll a, silicate, nitrate+nitrite and DIN concentration was higher at sites positive for both *Pfiesteria*, while mean phosphate, ammonium and DON was lower at sites positive for *Pfiesteria* (Table 4-15, Figure 4-57). None of these means were significantly different. Means for stations positive for *P. piscicida* or *P. shumwayae* were also examined (Table 4-15). Although differences in the means of nitrate+nitrite, DIN, DON and TDN appear to be different, none of them were statistically significant. Only the means for silicate at stations positive for *P. piscicida* or *P. shumwayae* were significantly different ($t=3.091$, $df=14$, $p=0.008$).

Bivariate plots of physicochemical, chlorophyll a and nutrient parameters were constructed to explore relationships between these parameters and sites that were positive for *Pfiesteria*. The results of these plots show very few clear relationships, either between the two parameters, or their relationship to sites positive for *Pfiesteria* (Figures 4-58 to 4-71).

A plot of dissolved oxygen versus chlorophyll a reveals a dense clump of stations between 5 and 8 mg/L and chlorophyll a values generally below 20 mg/L (Figure 4-58). There appears to be a slight positive correlation between dissolved oxygen and chlorophyll a concentration. There does not appear to be any difference in the distribution of samples positive or negative for *Pfiesteria* (Figure 4-58).

A plot of silicate versus chlorophyll a concentrations (Figure 4-59) shows a tight cluster of points in a zone defined by chlorophyll a concentrations between 0 and 20 ug/L and silicate concentrations between 0 and 100 ug/L. Aside from that cluster, there is much scatter in the data, with no clear relationships apparent.

The plot of salinity versus chlorophyll a concentration displays a pattern similar to an inverse second or third order curve (Figure 4-60). There are very few positives for *Pfiesteria* above a salinity of 20 ppt.

The plot of Secchi depth versus chlorophyll a does suggest that Secchi depth increases as chlorophyll a concentrations decrease (Figure 4-61), although there does not appear to be any relationships between sites positive or negative for *Pfiesteria*.

The plot of nitrate+nitrate (log 10) versus chlorophyll a does not reveal any substantive patterns (Figure 4-62).

A plot of phosphate (log 10) versus chlrophyll a shows a rather dense swarm of points at chlorophyll a concentrations below 60 ug/L and phosphate concentrations from about 5 to 20 ug/L (Figure 4-63). Aside from this clump, there is an increase in chlorophyll a concentrations with an increase in phosphate. Distribution of points positive for *Pfiesteria* do not show any particular pattern

There appears to be a fairly strong relationship between nitrate+nitrite (log 10) and phosphate (log 10) concentrations (Figure 4-64) as they increase with each other. There does not appear to be any difference in the distribution of sites positive for *Pfiesteria* as compared to the sites that were negative (Figure 4-64).

There appears to be a slight trend toward higher mean nitrate+nitrite (log 10) at lower salinities, and nitrate+nitrite is generally lower at high salinities (Figure 4-65). The distribution of points positive for *Pfiesteria* shows no particular pattern.

The plot of nitrate+nitrite (log 10) and Secchi depth are scattered all over the landscape (Figure 4-64). The distribution of points positive for *Pfiesteria* is similar.

The plot between nitrate+nitrite and silicate (log 10) concentrations reveals a tight grouping of points, with silicate between 0.1 and 1.0 and nitrate+nitrite between about 10 and 100, but there are many other points scattered over the rest of the graph (Figure 4-67). The pattern of points positive for *Pfiesteria* closely follows that of those negative for *Pfiesteria.*

A plot of phosphate versus silicate concentrations reveals a slightly positive, linear relationship (Figure 4-68) with a tight grouping of points at phosphate concentrations between about 10 to 100 ug/L and silicate concentrations from about 5 to 20 ug/L. There does not appear to be any discernible relationship for points positive for *Pfiesteria*.

On a plot of Secchi depth versus phosphate (log 10), there does not appear to be any meaningful relationships revealed (Figure 4-69).

On a plot of silicate versus salinity (Figure 4-70), the bulk of the silicate is between 0 and 100 ug/L with most of the points positive for *Pfiesteria* found at salinities below 20 ppt. The general shape of the plot appears to loosely follow an inverse third order cruve.

The plot of Secchi depth versus salinity indicates that most of the *Pfiesteria* is found around or below a salinity of 20 ppt, but with no relationship to Secchi depth (Figure 4-71). In general, there is much scatter in the plot with no discernible pattern.

Meteorological conditions in 2001, like 2000, did not show any clear meaningful relationships (Table 4-16, Figure 4-72a-d). Mean air temperatures and wind speed were nearly identical for stations positive or negative for *Pfiesteria* (Figure 4-72a, 4-72c). Mean cloud cover and sea state were lower for stations positive for *Pfiesteria* (Figure 4-72b, 4-72d), but none of these results were statistically significant. Examination of meteorological conditions at stations positive for *P. piscicida* or *P. shumwayae* revealed no statistically significant differences (Table 4-16).

Physicochemical conditions in 2001 for sites positive or negative for *Pfiesteria* are summarized in Table 4-17 and Figure 4-73a-d. Mean water temperature varied little between positive or negative sites for *Pfiesteria* (Figure 4-73a). Mean dissolved oxygen and percent saturation were lower for sites negative for *Pfiesteria* (Figure 4-73b). The mean salinity and conductivity were higher for all stations positive for *Pfiesteria* (Table 4-17 and Figure 4-71c). The mean Secchi depth was greater for all the sites positive for *Pfiesteria* as compared to the sites negative for *Pfiesteria* (Table 4-17, Figure 4-73d). None of the above results were statistically significant. Mean pH at sites positive for *Pfiesteria* and those negative were identical (Table 4-17).

Results of chlorophyll a and nutrients analysis at stations positive or negative for *Pfiesteria* are summarized in Table 4-18 and Figure 4-74a-d. The mean chlorophyll a concentration of 67.14 ug/L at stations positive for *Pfiesteria* was higher than at those negative for *Pfiesteria* (43.41 ug/L) (Table 4.18, Figure 4-72a). There is also a difference in chlorophyll a concentrations at stations positive for *P. shumwayae* (70.56 ug/L) as compared to those positive for *P. piscicida* (58.35 ug/L).

There was little difference in mean silicate concentrations between stations positive (45.29 ug/L) or negative (42.14 ug/L) (Table 4-18, Figure 4-72b). There does appear to be a significant difference, though, between stations positive for *P. shumwayae* (38.32 ug/L) as compared to those positive for *P. piscicida* (55.18 ug/L) (Table 4.18).

The mean phosphate concentration at stations positive for *Pfiesteria* was only slightly higher (11.54 ug/L) as compared to those negative for *Pfiesteria* (9.12 ug/L) (Table 4-18). Mean phosphate was higher at stations that were positive for *P. piscicida* (11.43 ug/L) as compared to *P. shumwayae* (8.69 ug/L) (Table 4.18).

Nitrogen facies analyzed included nitrate (NO3), nitrite (NO2), ammonia (NH4), DIN and DON (Table 4-18). The mean DON concentration of 214.53 ug/L) at stations positive for *Pfiesteria* was nearly twice what it was at stations negative for *Pfiesteria* (109.84 ug/L) (Table 4.18, Figure 7-75f). For NO3+NO2 and DIN there was little difference between stations that were positive or negative for *Pfiesteria* (Table 4-18, Figure 4-72d-e). For all these facies, the mean value for those stations positive for *P. piscicida* were greater than those positive for *P. shumwayae* (Table 4-18).

Bivariate plots of several parameters were plotted with stations positive for *Pfiesteria* differentiated from those negative for *Pfiesteria* to examine relationships between the parameters and if this relationship differed for those stations negative or positive for *Pfiesteria.*

A plot of dissolved oxygen versus chlorophyll a concentrations indicates a fairly strong positive linear relationship between the two variables, although there does not appear to be any difference between stations negative or positive for *Pfiesteria* (Figure 4-75).

A plot of silicate versus chlorophyll a concentrations again reveals a positive relationship. Stations positive for *Pfiesteria* were distributed evenly with those negative for *Pfiesteria* (Figure 4-76).

A plot of chlorophyll a versus salinity appears to indicate an inverse third order relationship, with those stations negative for *Pfiesteria* spread evenly with those positive for *Pfiesteria* (Figure 4-77).

The plot Secchi depth versus chlorophyll a concentration indicates a weak negative relationship between the variables. There also are more points representing a positive result for *Pfiesteria* at higher combinations of the two variables plotted (Figure 4-78).

A plot of nitrate+nitrite (log10) versus chlorophyll a concetrations shows a positive relationship, with again no apparent difference in the relationship between those stations negative or positive for *Pfiesteria* (Figure 4-79).

The plot of phosphate (log10) versus chlorophyll a concentrations indicates a positive linear relationship between the two variates. There does not appear to be any difference between stations negative or positive for *Pfiesteria* (Figure 4-80).

There appears to be a fairly strong relationship between phosphate (log 10) and nitrate+nitrite (log 10) concentrations (Figure 4-81) as they increase with each other in a somewhat linear fashion. There does not appear to be any difference in the distribution of sites positive for *Pfiesteria* are located all along the plot (Figure 4-81).

The plot of salinity versus nitrate+nitrite (log 10) concentration appears to have an inverse second order distribution (Figure 4-82). The distribution of points positive for *Pfiesteria* shows no particular pattern.

The plot of Secchi depth versus nitrate+nitrite (log 10) concentration are fairly scattered although there does appear to a slight negative linear relationship, with decreasing nitrate+nitrate with increasing Secchi depth (Figure 4-83). The distribution of points positive for *Pfiesteria* is similar.

The plot between nitrate+nitrite (log 10) versus silicate concentrations reveals a generally very scattered distribution of points (Figure 4-84). There is not any pattern to the distribution of points positive for *Pfiesteria.*

A plot of phosphate (log 10) versus silicate concentrations reveals a slightly positive, linear relationship (Figure 4-85). There does not appear to be any discernible relationship for points positive for *Pfiesteria.*

On a plot Secchi depth versus phosphate, there appears to be a negative linear relationship, as phosphate concentrations appear to decrease as Secchi depth increases (Figure 4-86). There does not appear to be any apparent relationship for points positive for *Pfiesteria.*

On a plot of silicate versus salinity (Figure 4-87), there is much scatter to the distribution of points, with no particular pattern to the distribution of points positive for *Pfiesteria.*

In the plot of Secchi depth versus salinity (Figure 4-88) there appears to be a somewhat loose linear positive relationship. There does not appear to be any particular pattern to the points positive for *Pfiesteria.*

Table 4-11. Total Number of Occurrences of *Pfiesteria* and *Cryptoperidiniopsis* Using the Two Gene Probes. Repeated Positive Results Between the Two Methods are Included (N=number of samples, M1=method 1, M2=method 2, nr=not reported, nd=not done).

Year	Water Samples			Sediment Samples		
	N	M1	M2	N	M1	M2
			P. piscicida			
2000	83	5	8	8	0	1
2001	66	5	24	3	0	2
			P. shumwayae			
2000	83	3	2	8	2	0
2001	66	6	27	3	1	1
			Cryptoperidiniopsis			
2000	83	1	Nd	8	0	Nd
2001	66	nd	Nd	3	Nd	Nd

Table 4-12. Location and Number of Occurrences of *Pfiesteria* and *Cryptoperidiniopsi* in Water and Sediment Samples Collected along the Texas Coast in 2000 Using Results from Method 1 and Method 2, Ignoring Repeated Positive Results (N=number of samples, Numbers in parentheses are sediment samples).

Location	N	Number of Positive Samples	Species Identified *P. piscicida*	*P. shumwayae*	*Cryptoperidiniopsis*
Sabine Pass Swing Bridge	7 (1)	1 (0)	1	0	0
Tabbs Bay	3	0	0	0	0
Armand Bayou	3	2	2	0	1
Clear Lake	1	1	1	0	0
Clear Creek	2	0	0	0	0
Dickinson Bayou 1	5 (1)	3 (0)	3	0	0
Dickinson Bayou 2	1 (1)	1 (0)	1	0	0
Moses Bayou	2	0	0	0	0
Moses Lake	1	0	0	0	0
Jamaica Beach Canal	7 (1)	1 (0)	1	0	0
Oyster Creek	2	0	0	0	0
Jones Creek	1	0	0	0	0
Swan Lake	1	0	0	0	0
Intracoastal Waterway	2	0	0	0	0
Caney Creek	6 (1)	0 (0)	0	0	0
Colorado River	3	1	1	0	0
Lavaca Bay Causeway	5	1	0	1	0
Mesquite Bay	3	0	0	0	0
Nueces River	6	0	0	0	0
Port Aransas Birding Center	6	1	0	1	0
Oso Creek	1	0	0	0	0
Oso Bay 1	1	0	0	0	0
Oso Bay 2	4	1	0	1	0
Bayview Campground	5	1	0	1	0
Kraatz Pier	2	0	0	0	0
Adolph Tomae Jr. County Park	3 (3)	2 (2)	1 (1)	1 (2)	0
Total	83 (8)	16 (2)	11 (1)	5 (2)	1

Table 4-13. Location and Number of Occurrences of *Pfiesteria* and *Cryptoperidiniopsi* in Water and Sediment Samples Collected along the Texas Coast in 2001 Using Results from Method 1 and Method 2, Ignoring Repeated Positive Results (N=number of samples, Numbers in parentheses are sediment samples, nd=not done).

Location	N	Number of Positive Samples	Species Identified *P. piscicida*	*P. shumwayae*	*Cryptoperdiiniopsis*
Clear Lake	12	10	2	10	nd
Dickinson Bayou	12	5	5	3	nd
Caney Creek	12	7	4	5	nd
Port Lavaca Fishing Pier	7	4	1	3	nd
Port Aransas Birding Center	12	8	6	6	nd
Adolph Tomae Jr. County Park	11 (3)	7 (3)	6 (2)	5 (1)	nd
Total	66 (3)	41 (3)	24 (2)	32 (1)	nd

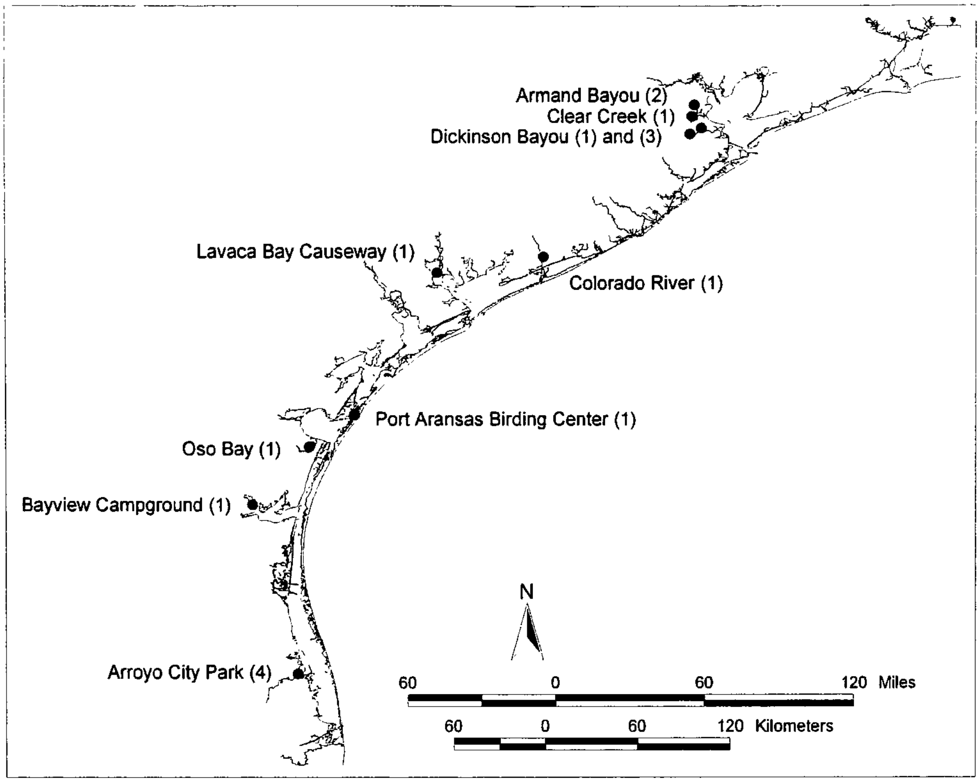

Figure 4-51. Location of sites positive for *Pfiesteria* in 2000. Number in parentheses indicates the number of positive results.

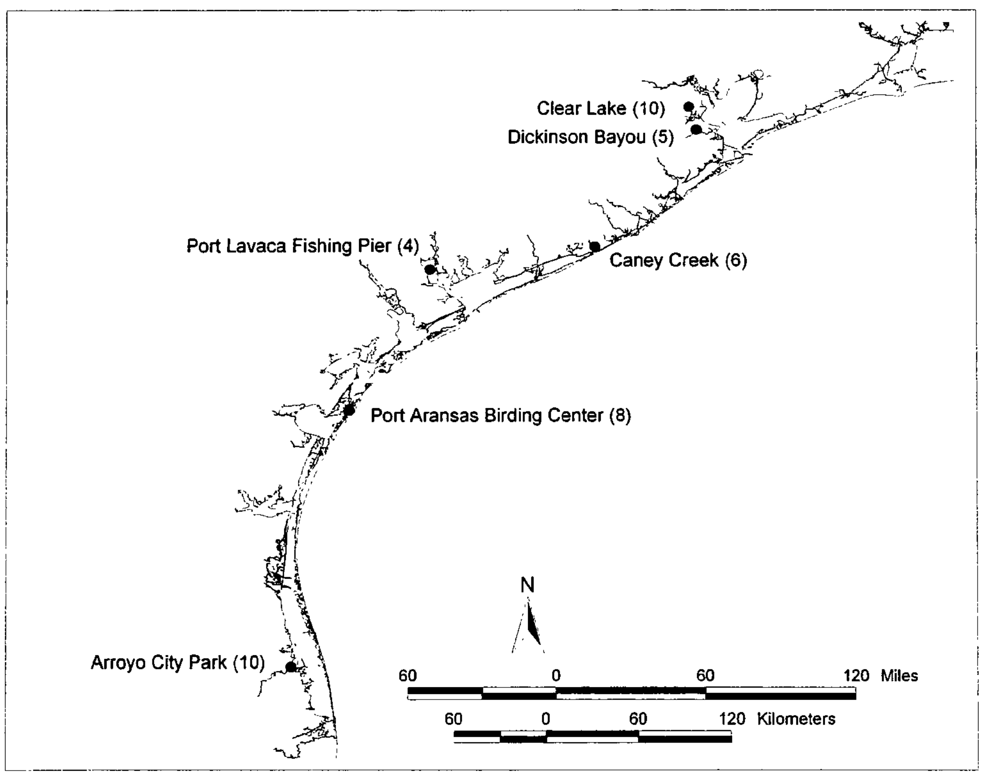

Figure 4-52. Location of sites positive for *Pfiesteria* in 2001. Number in parentheses indicates the number of positive results.

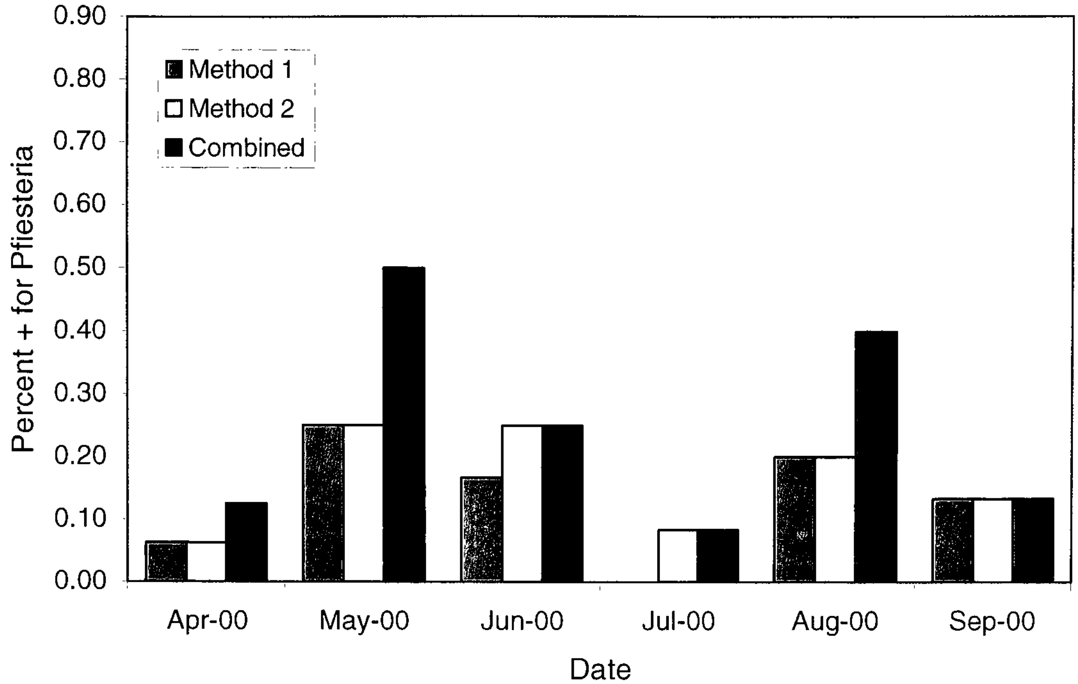

Figure 4-53. Percentage of stations by month that were found to be positive for *Pfiesteria* using Method 1, Method 2 and by combination of results from both methods in 2000.

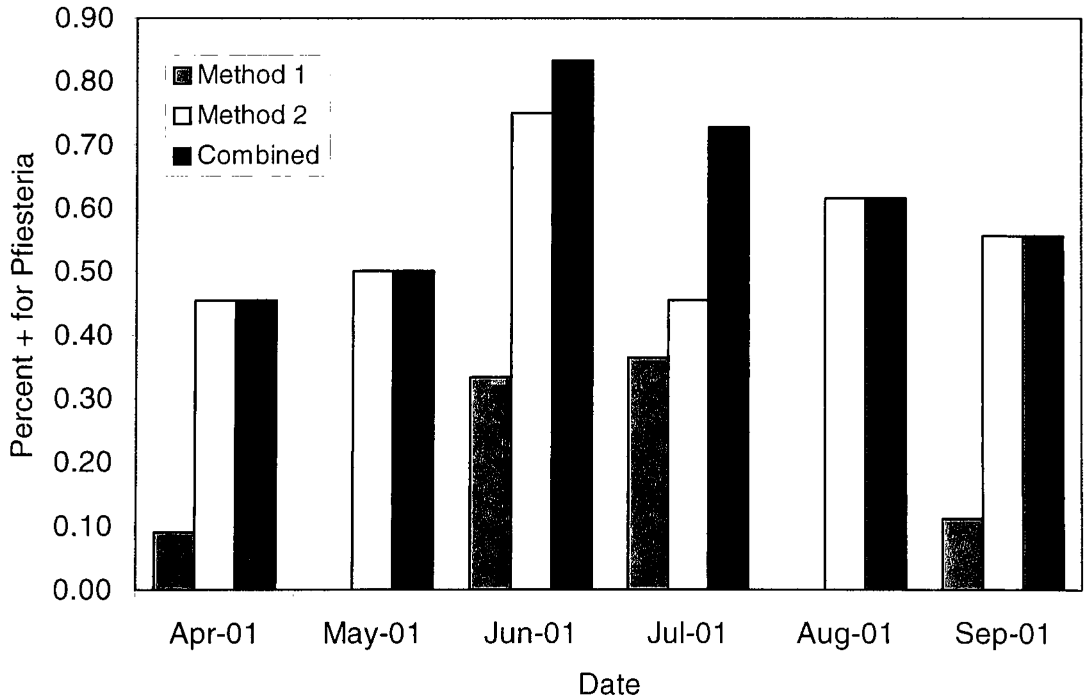

Figure 4-54. Percentage of stations by month that were found to be positive for *Pfiesteria* using Method 1, Method 2 and by combination of results from both methods in 2001.

Table 4-14. Mean, Standard Deviation, Sample Size (N), Minimum and Maximum Values for Meteorological Parameters Measured at Stations Negative and Positive for *Pfiesteria*, and those Positive of only *P. shumwayae*, and those Positive for only *P. piscicida*, in 2000.

Results of PCR		Air temperature (degrees C)	Wind speed code (Beaufort)	Cloud cover code	Sea state code (Beaufort)
Negative for *Pfiesteria*	Mean	31.24	3.12	2.82	1.42
	Stdev	2.778	1.233	1.585	1.841
	N	59	59	56	57
	Min	24.4	1	1	0
	Max	36.67	6	6	6
Positive for all *Pfiesteria*	Mean	31.13	3.20	2.07	1.64
	Stdev	3.140	1.146	0.704	1.906
	N	15	15	15	14
	Min	26.67	1	1	0
	Max	36.67	5	3	6
Positive for *P. shumwayae*	Mean	28.16	4.00	1.80	2.25
	Stdev	2.903	0.707	0.837	1.500
	N	5	5	5	4
	Min	26.67	3	1	0
	Max	33.33	5	3	3
Positive for *P. piscicida*	Mean	32.98	2.73	2.09	1.64
	Stdev	2.308	1.104	0.701	2.111
	N	11	11	11	11
	Min	29.44	1	1	0
	Max	36.67	5	3	6

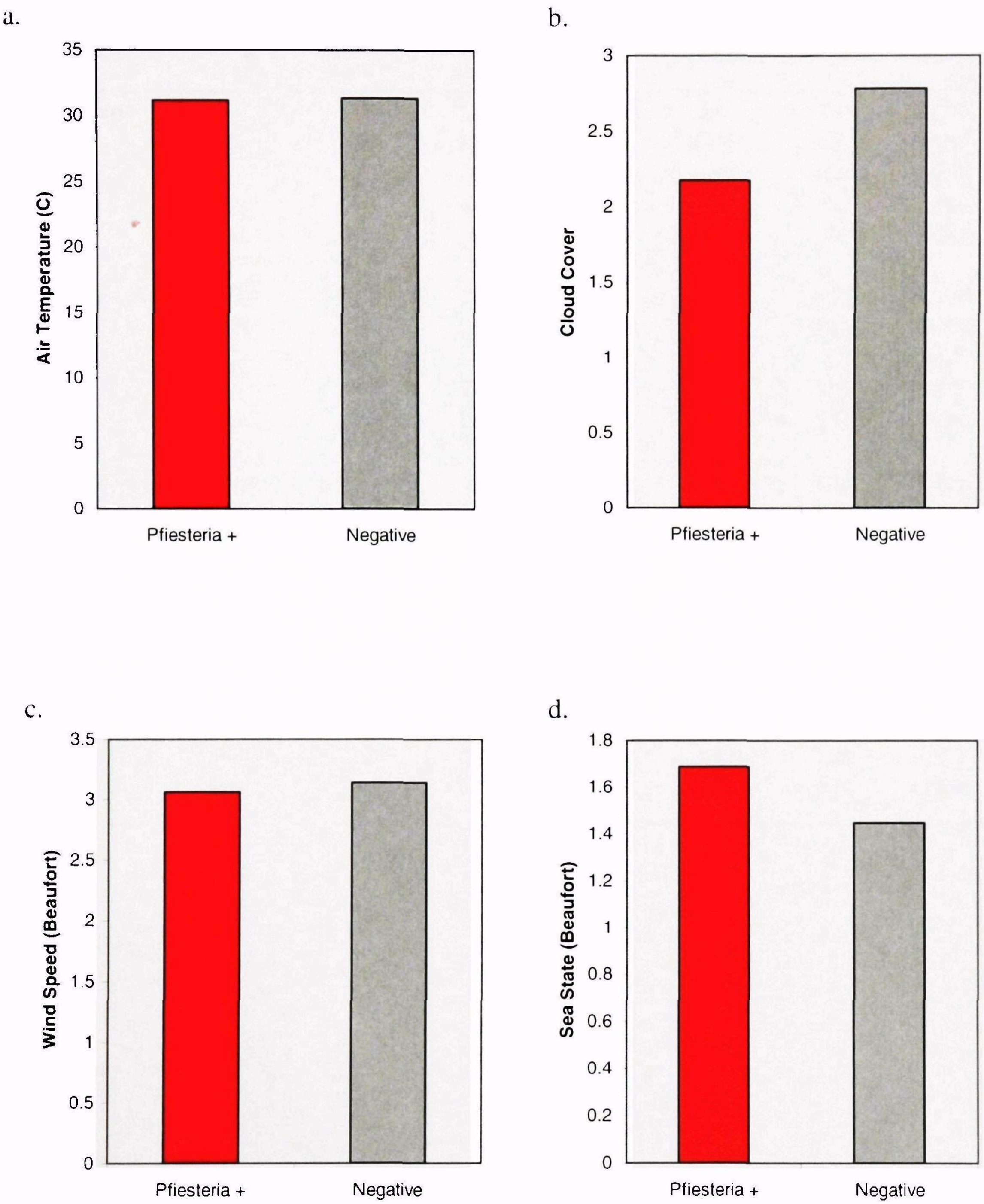

Figure 4-55. Mean values for meteorological parameters at sites positive and negative for *Pfiesteria* in 2000. (a) air temperature, (b) cloud cover, (c) wind speed, (d) sea state.

Table 4-15. Mean, Standard Deviation, Sample Size (N), Minimum and Maximum Values for Physicochemical Water Parameters Measured at Stations Negative and Positive for all *Pfiesteria*, those Positive for only *P. shumwayae*, and those Positive for only *P. piscicida*, in 2000.

Results of PCR		Water Temperature (deg C)	DO (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	pH	Percent Saturation	Secchi Disk (cm)
Negative for *Pfiesteria*	Mean	28.78	6.79	20.86	35.01	8.15	100.34	44.78
	Stdev	2.751	2.235	15.706	22.876	0.381	32.367	22.274
	N	62	56	61.00	56	52	56.0	53
	Min	20.42	1.37	0.00	0.875	7.13	16.7	10
	Max	33.8	13.86	60.59	82.284	9.35	196.9	100
Positive for all *Pfiesteria*	Mean	29.97	7.37	14.34	24.27	8.25	108.71	49.73
	Stdev	2.201	2.989	13.285	20.228	0.654	40.622	18.148
	N	16	15	16	14	12	14	15
	Min	24.78	2.48	0	1.427	7.28	37.7	20
	Max	33	11.88	40.09	60.18	9.54	170.6	80
Positive for *P. shumwayae*	Mean	29.78	6.62	22.64	43.55	8.13	110.87	47.25
	Stdev	3.367	2.456	16.650	17.476	0.212	24.000	9.179
	N	5	4	5.00	4	2	3.0	4
	Min	24.78	4.59	0.00	28.4	7.98	85.7	37
	Max	33	9.94	40.09	60.18	8.28	133.5	58
Positive for *P. piscicida*	Mean	30.05	7.64	10.57	16.56	8.28	108.12	50.64
	Stdev	1.646	3.223	10.185	16.067	0.717	45.036	20.796
	N	11	11	11.00	10	10	11.0	11
	Min	26.9	2.48	0.70	1.427	7.28	37.7	20
	Max	32.81	11.88	35.20	53.3	9.54	170.6	80

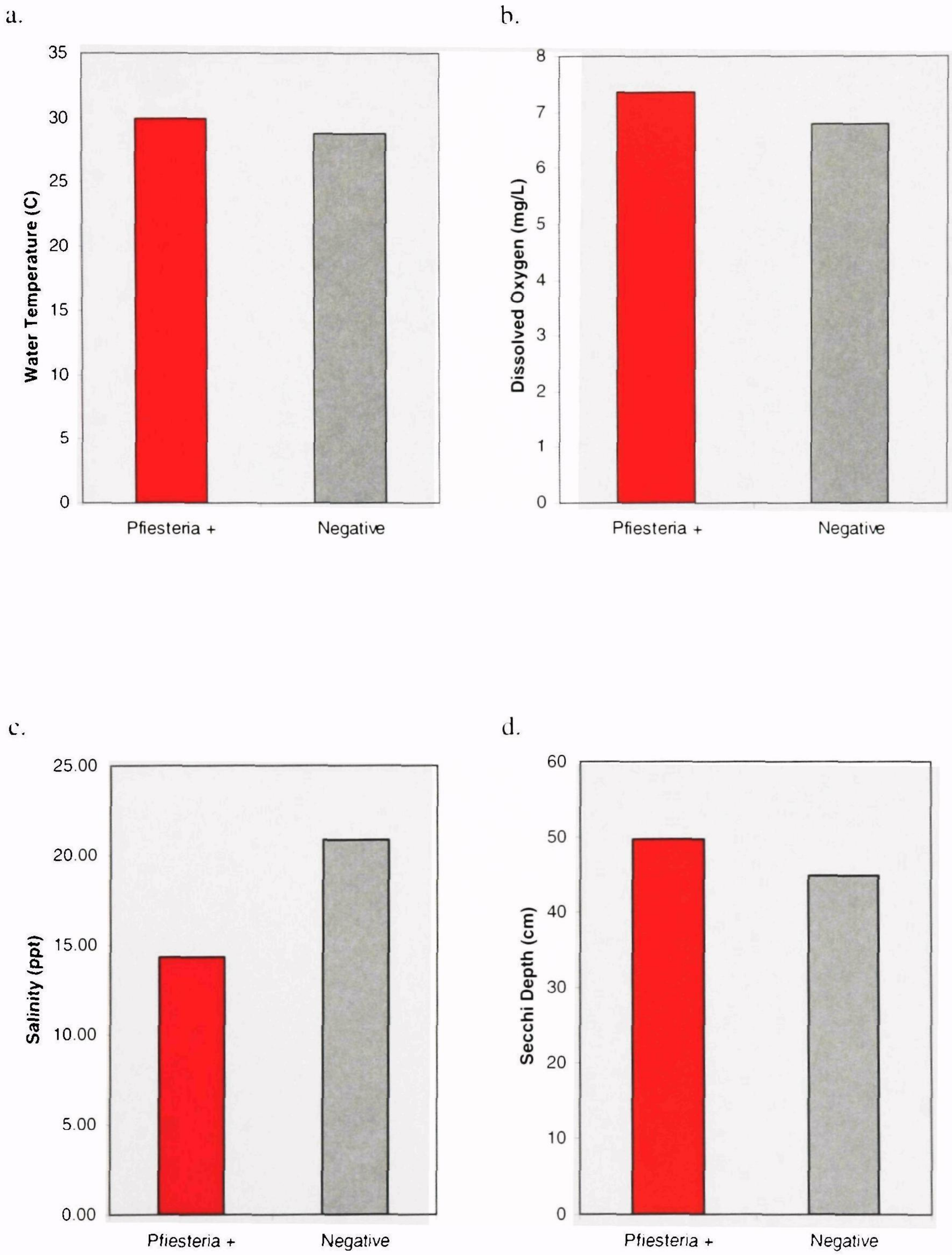

Figure 4-56. Mean values for physicochemical water parameters at sites positive and negative for *Pfiesteria* in 2000. (a) water temperature, (b) dissolved oxygen, (c) salinity, (d) Secchi depth.

Table 4-16. Mean, Standard Deviation, Sample Size (N), Minimum and Maximum Values for Chlorophyll a and Nutrient Parameters Measured at Stations Negative and Positive for all *Pfiesteria*, those Positive for only *P. shumwayae*, and those Positive for only *P. piscicida*, in 2000.

Results of PCR		Chlorophyll a (ug/L)	Silicate (ug/L)	Phosphate (ug/L)	Nitrate+Nitrite (ug/L)	Ammonium (ug/L)	DIN (ug/L)	DON (ug/L)	TDN (ug/L)
Negative for *Pfiesteria*	Mean	23.18	106.22	9.37	22.10	5.07	26.49	90.37	112.91
	Stdev	27.184	77.169	13.621	61.486	16.311	74.170	200.129	226.975
	N	66	66	66	64	66	66	62	63
	Min	1.20	11.12	0.06	0.07	0.00	0.10	17.29	18.34
	Max	134.13	347.20	80.24	347.65	126.85	474.50	1191.16	1304.37
Positive for all *Pfiesteria*	Mean	27.81	112.24	7.71	33.58	1.59	35.17	65.76	102.83
	Stdev	29.535	76.589	7.533	103.580	3.011	106.132	88.174	195.546
	N	16	16	16	16	16	16	15	15
	Min	6.11	32.46	0.13	0.13	0.06	0.24	18.02	27.22
	Max	119.00	272.18	29.41	418.02	11.04	429.05	376.21	805.26
Positive for *P. shumwayae*	Mean	28.08	80.39	7.79	5.88	1.20	7.09	37.65	44.76
	Stdev	33.267	52.634	4.687	10.092	1.948	11.264	11.287	13.184
	N	11	11	11	11	11	11	10	10
	Min	7.95	32.46	1.98	0.13	0.07	0.24	18.02	27.22
	Max	119.00	188.01	15.73	32.39	5.30	37.30	55.26	69.43
Positive for *P. piscicida*	Mean	27.21	182.29	7.54	94.52	2.45	96.97	121.98	218.95
	Stdev	22.447	78.412	12.562	182.282	4.813	187.027	144.906	328.873
	N	5	5	5	5	5	5	5	5
	Min	6.11	69.77	0.13	0.14	0.06	0.26	31.55	31.81
	Max	61.50	272.18	29.41	418.02	11.04	429.05	376.21	805.26

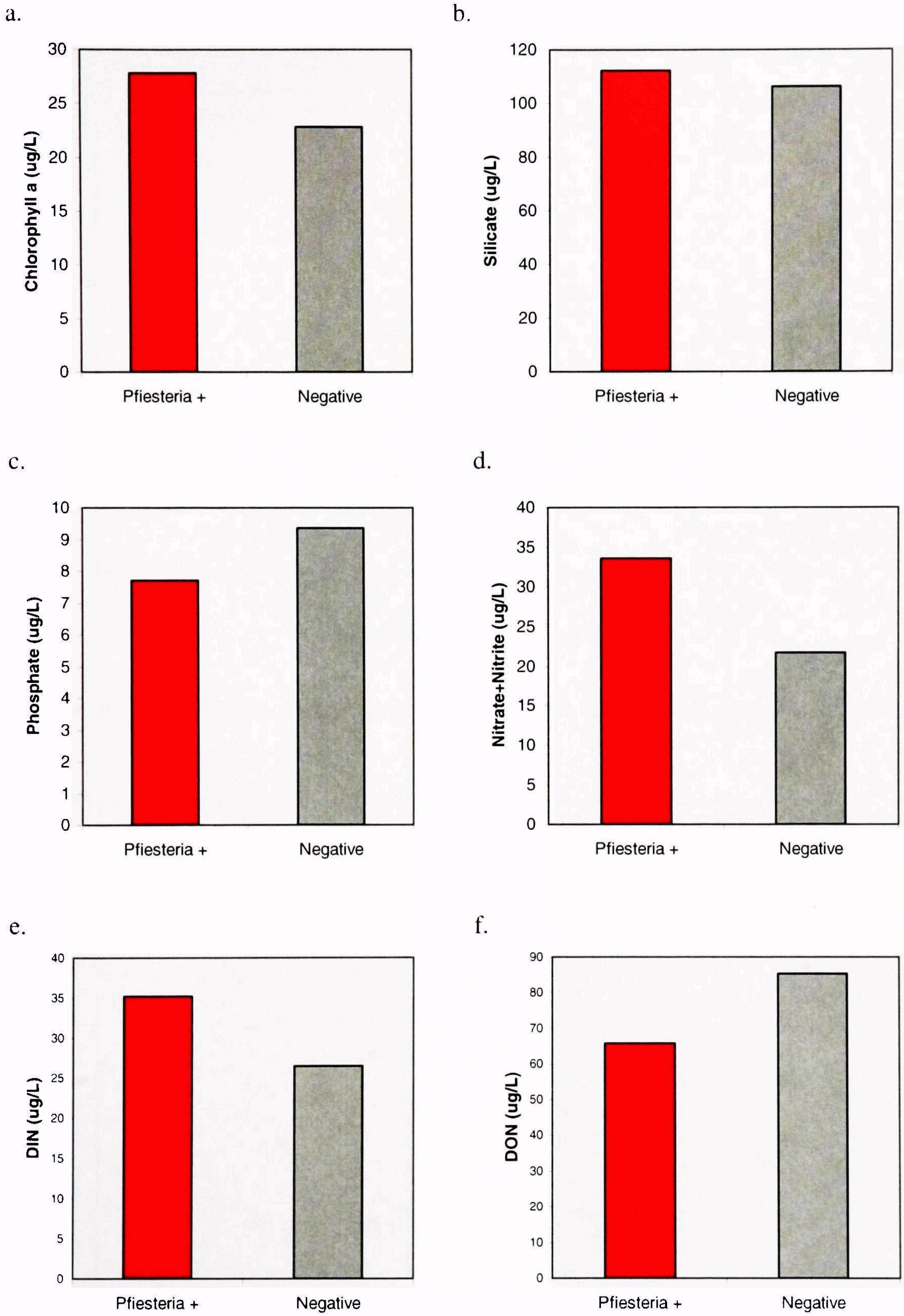

Figure 4-57. Mean values for chlorophyll a and nutrients at sites positive and negative for *Pfiesteria* in 2000. (a). chlorophyll a, (b) silicate, (c) phosphate, (d) nitrate+nitrite, (e) dissolved inorganic nitrogen (DIN), (f) dissolved organic nitrogen (DON).

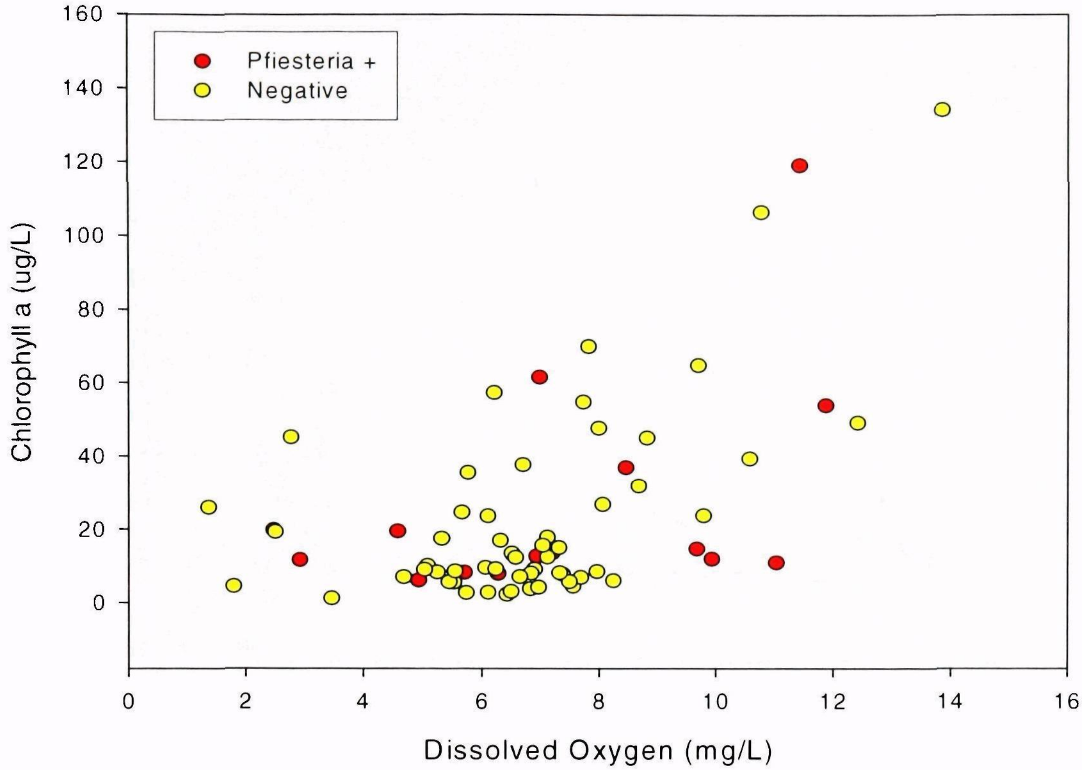

Figure 4-58. Relationship between chlorophyll a and dissolved oxygen for stations positive and negative for *Pfiesteria* in 2000.

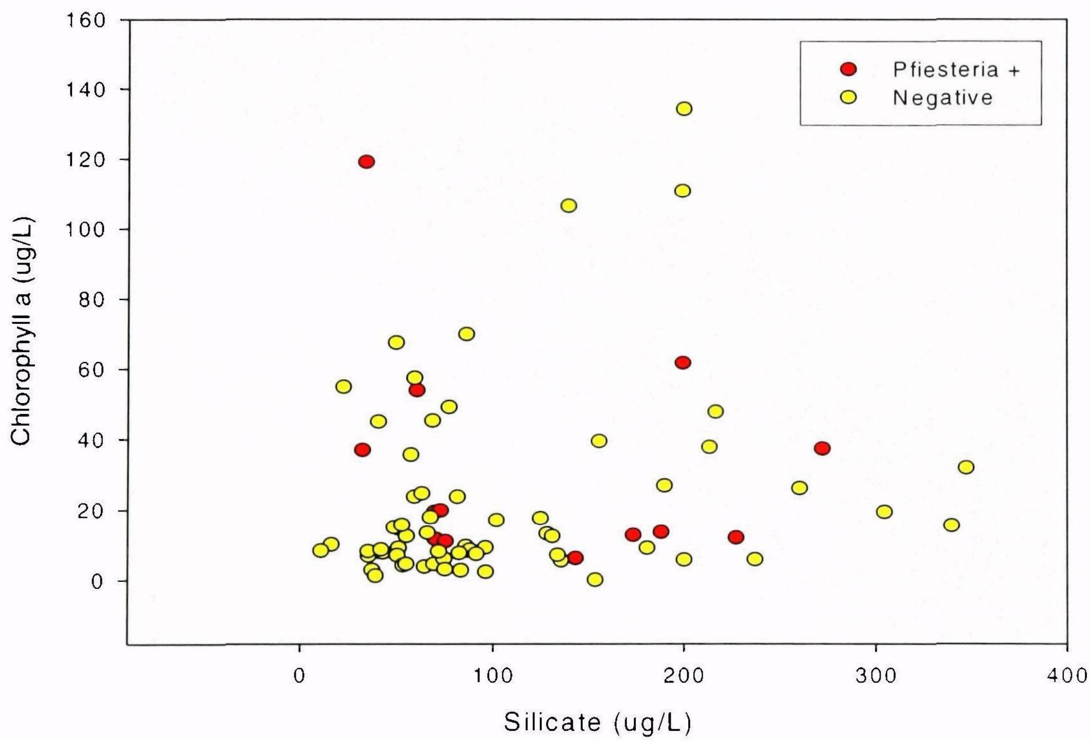

Figure 4-59. Relationship between chlorophyll a and silicate for stations positive and negative for *Pfiesteria* in 2000.

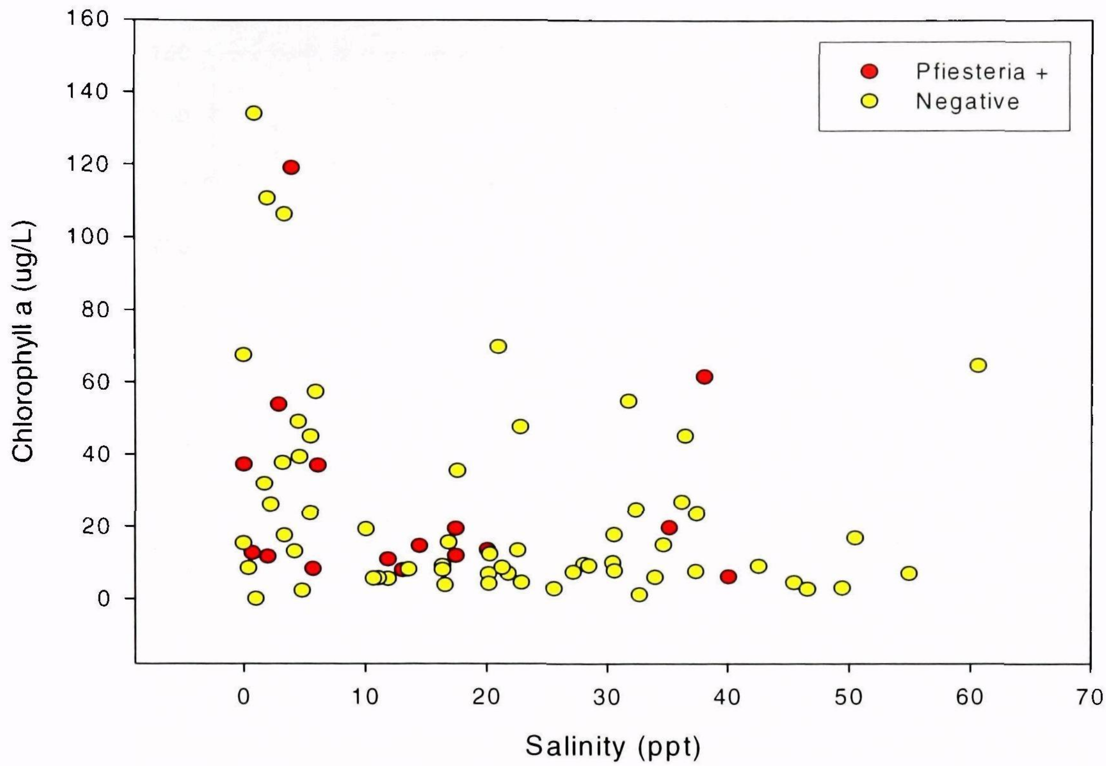

Figure 4-60. Relationship between chlorophyll a and salinity for stations positive and negative for *Pfiesteria* in 2000.

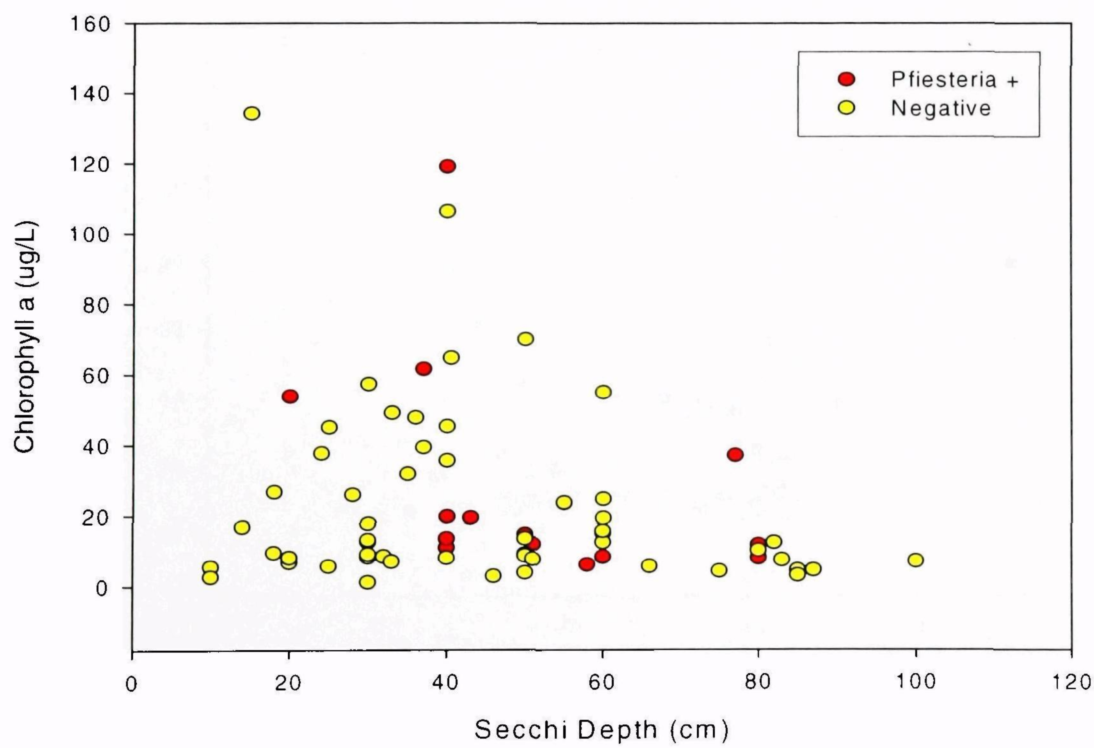

Figure 4-61. Relationship between chlorophyll a and Secchi depth for stations positive and negative for *Pfiesteria* in 2000.

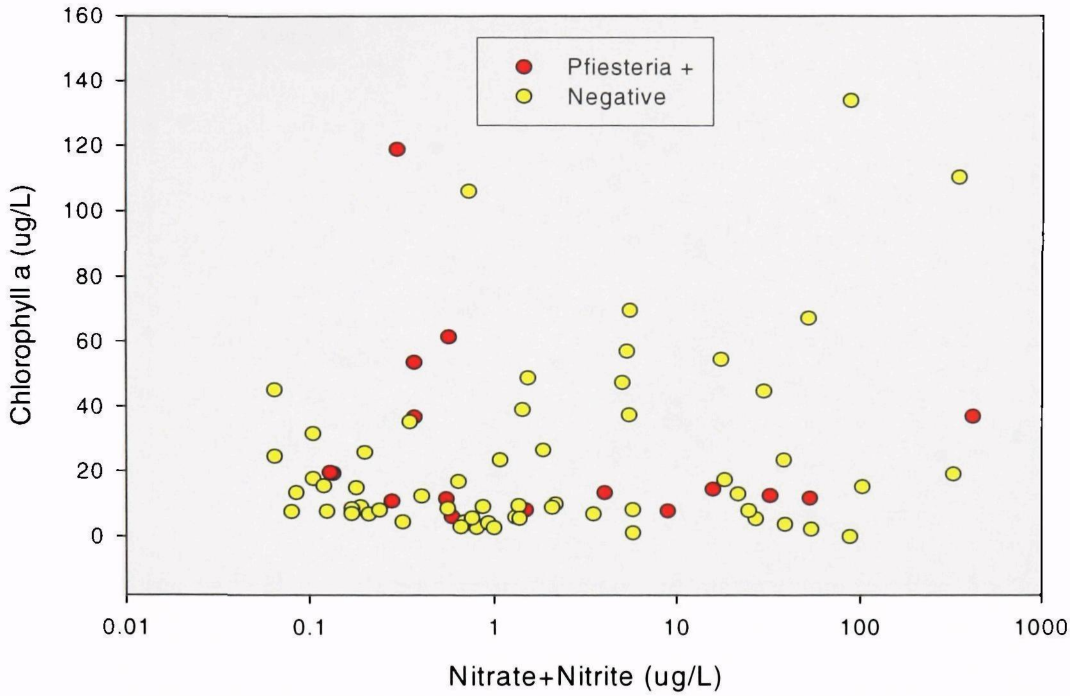

Figure 4-62. Relationship between chlorophyll a and nitrate+nitrite for stations positive and negative for *Pfiesteria* in 2000.

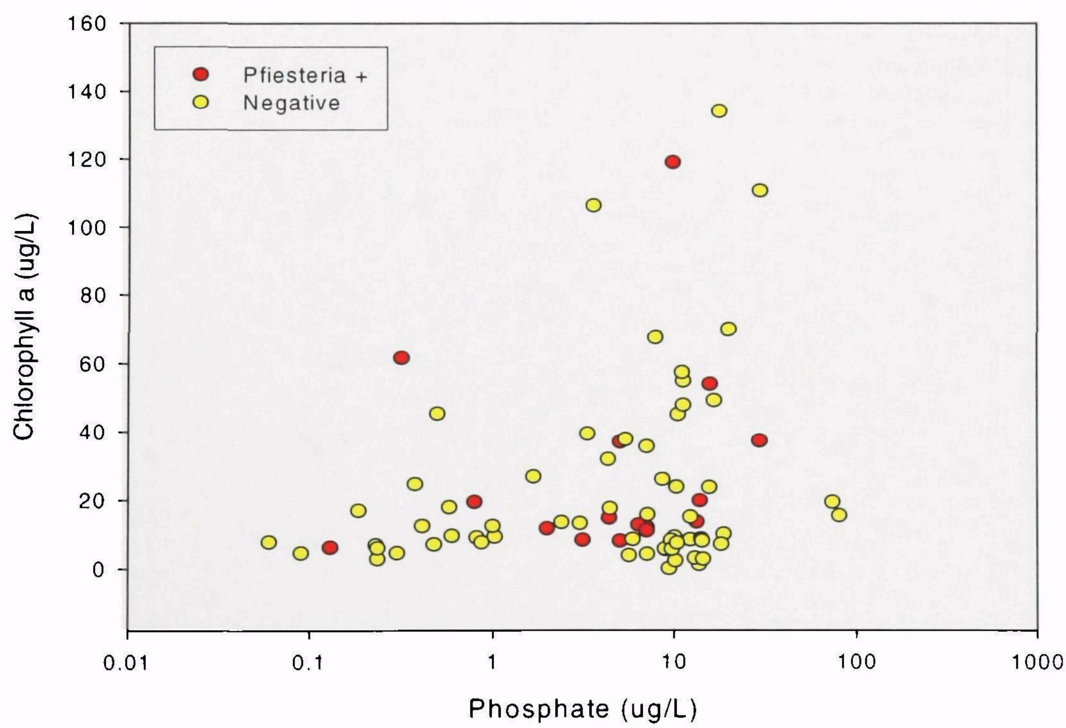

Figure 4-63. Relationship between chlorophyll a and phosphate for stations positive and negative for *Pfiesteria* in 2000.

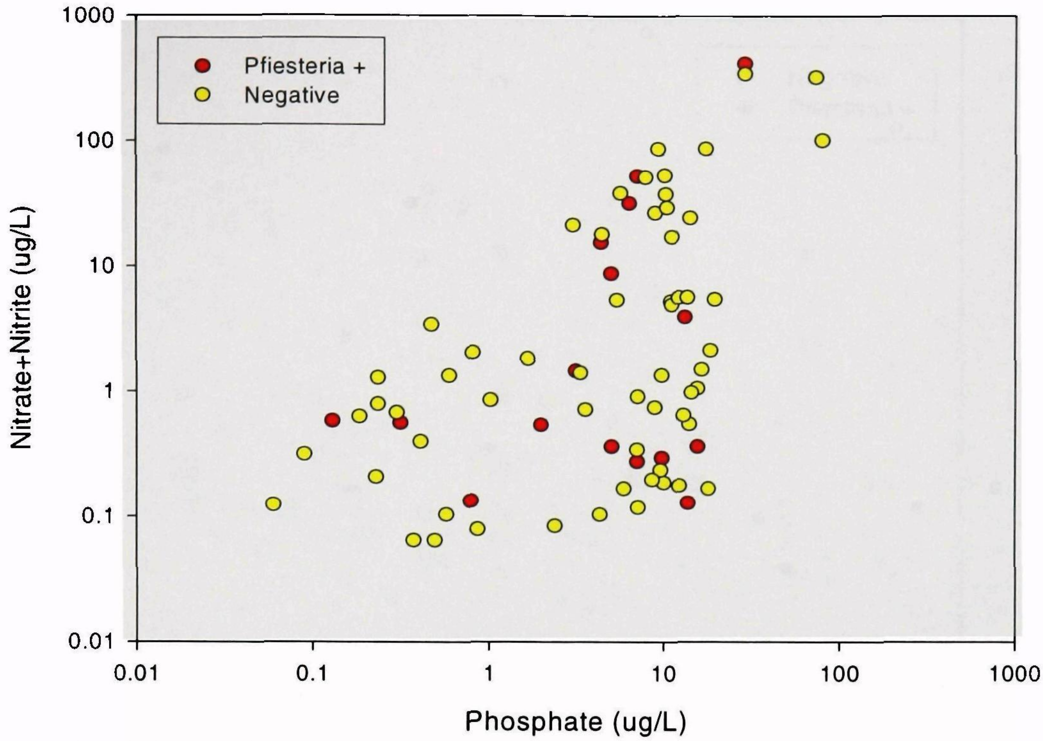

Figure 4-64. Relationship between nitrate+nitrite and phosphate for stations positive and negative for *Pfiesteria* in 2000.

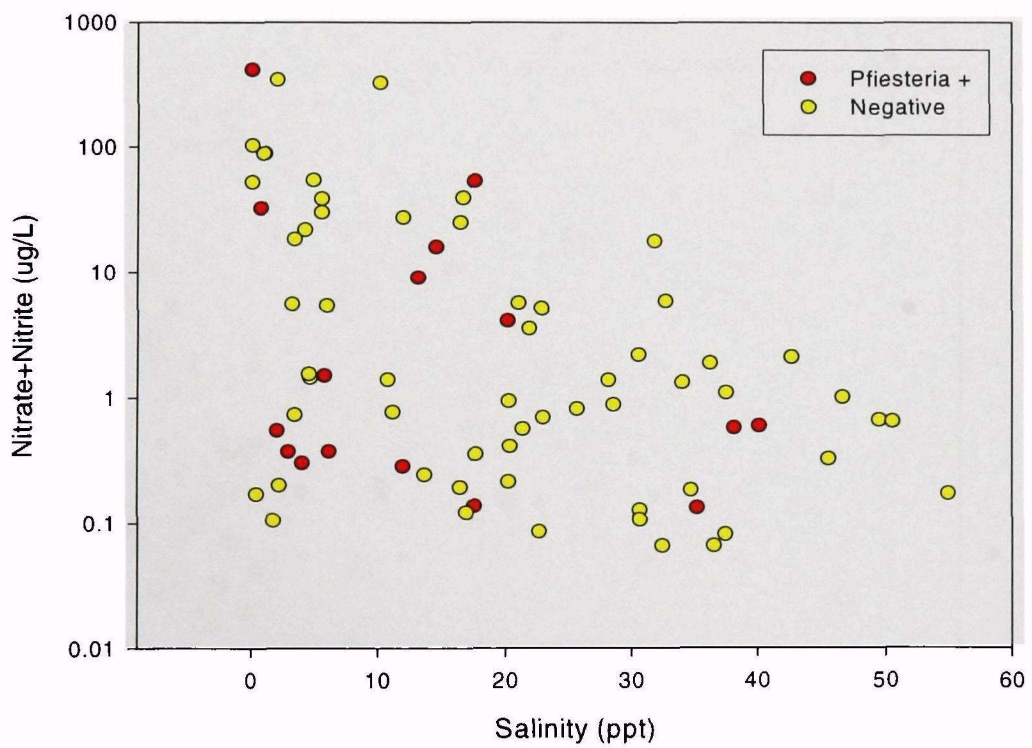

Figure 4-65. Relationship between nitrate+nitrite and salinity for stations positive and negative for *Pfiesteria* in 2000.

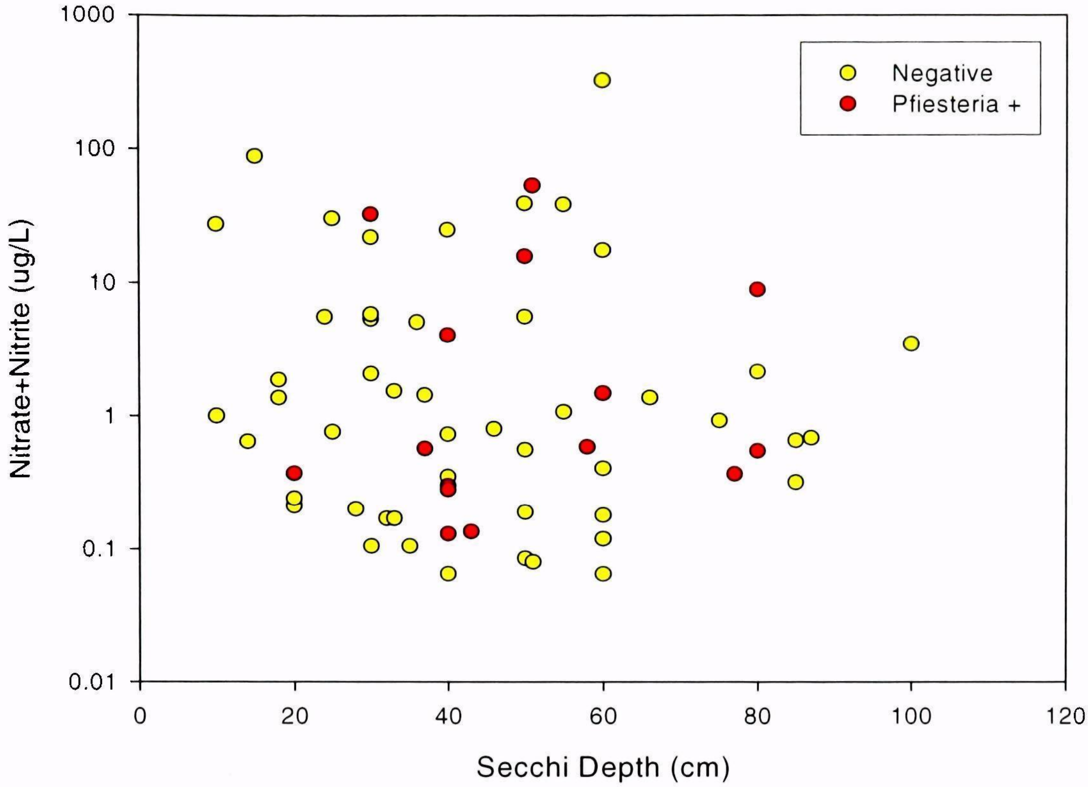

Figure 4-66. Relationship between nitrate+nitrite and Secchi depth for stations positive and negative for *Pfiesteria* in 2000.

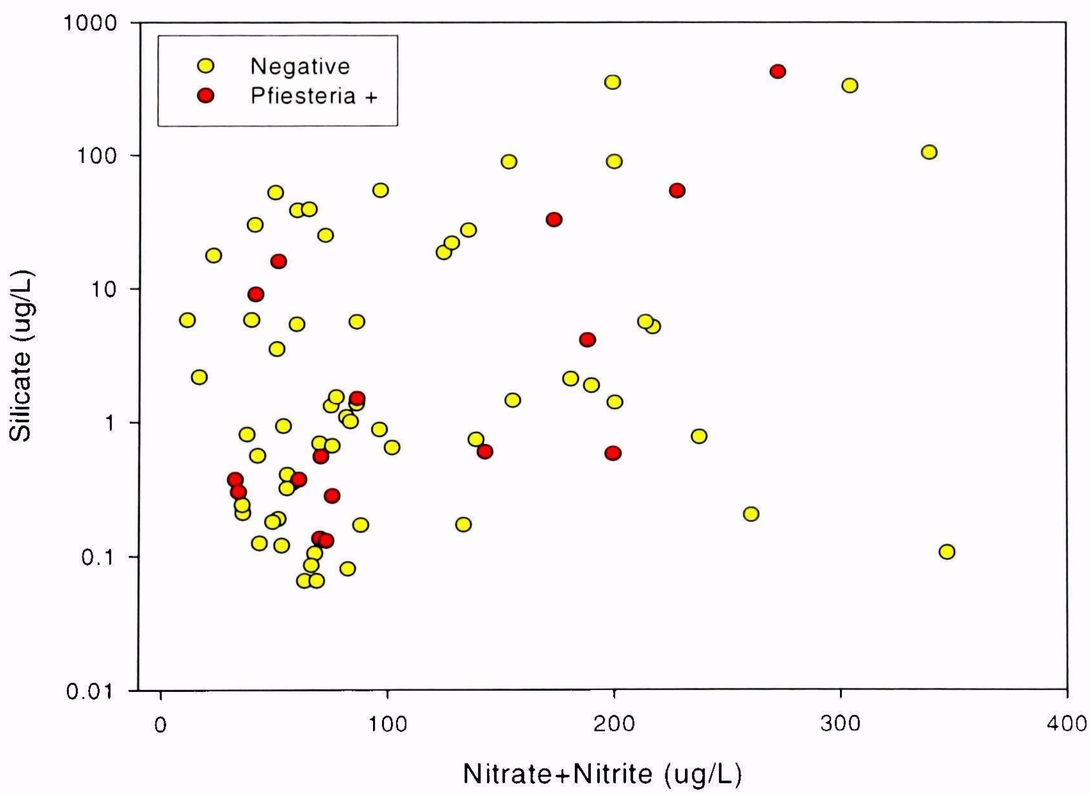

Figure 4-67. Relationship between silicate and nitrate+nitrite for stations positive and negative for *Pfiesteria* in 2000.

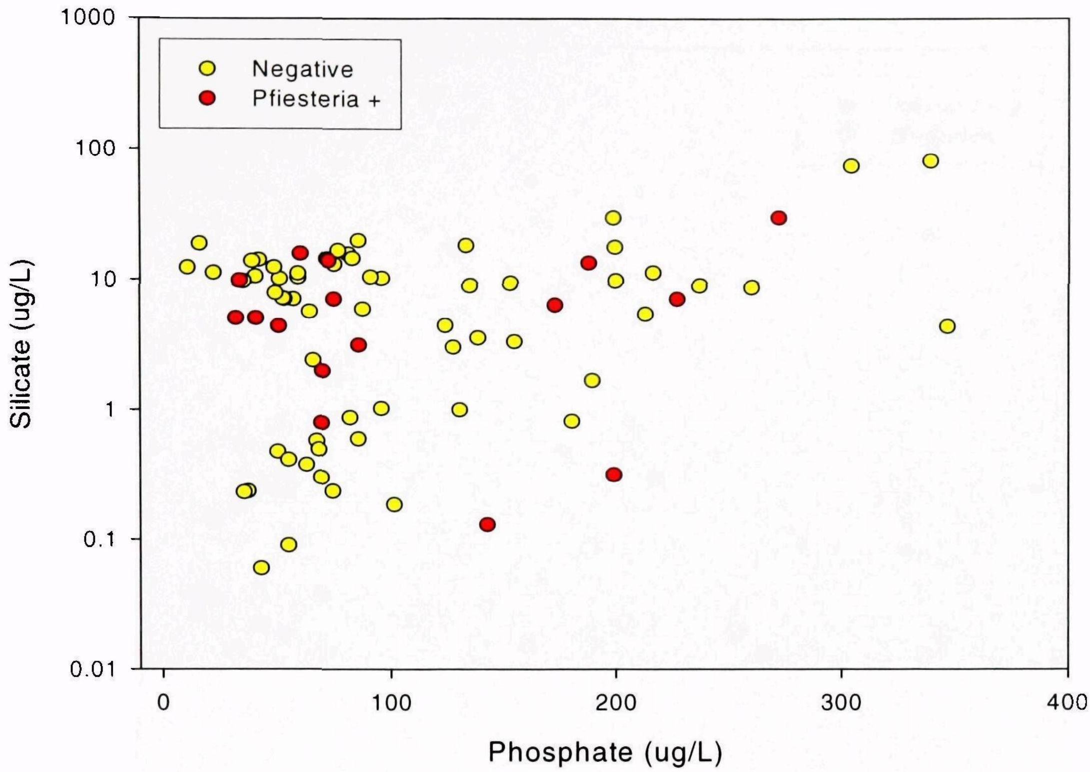

Figure 4-68. Relationship between silicate and phosphate for stations positive and negative for *Pfiesteria* in 2000.

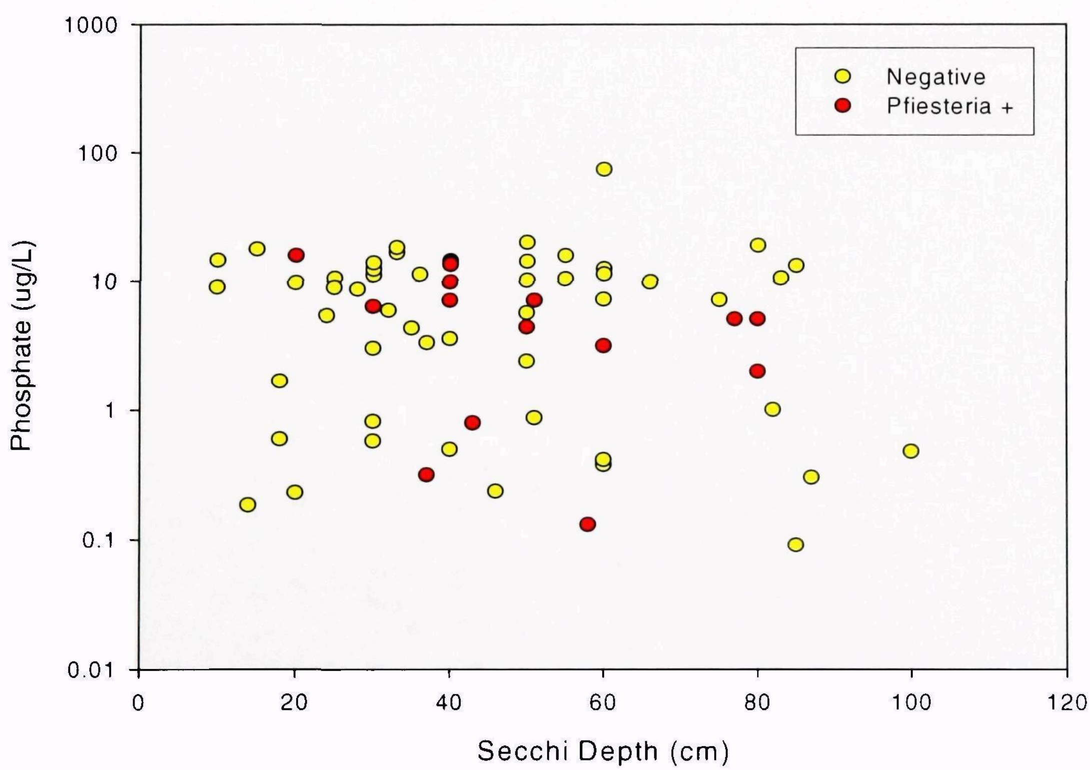

Figure 4-69. Relationship between phosphate and Secchi depth for stations positive and negative for *Pfiesteria* in 2000.

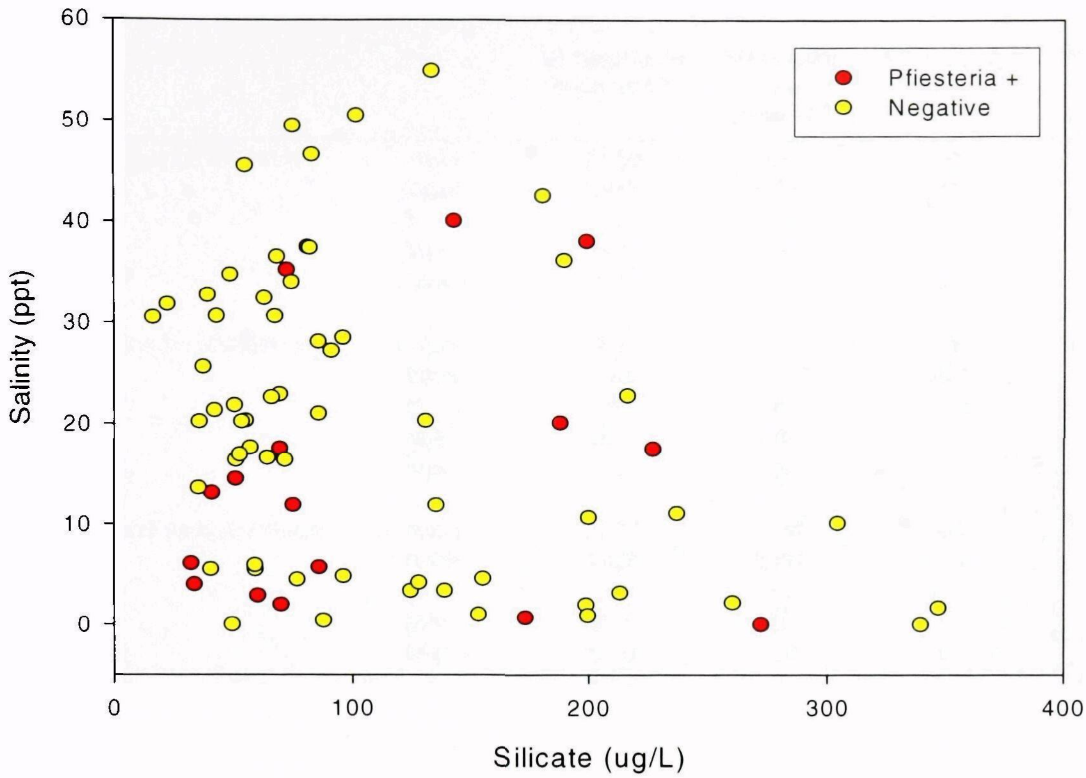

Figure 4-70. Relationship between salinity and silicate for stations positive and negative for *Pfiesteria* in 2000.

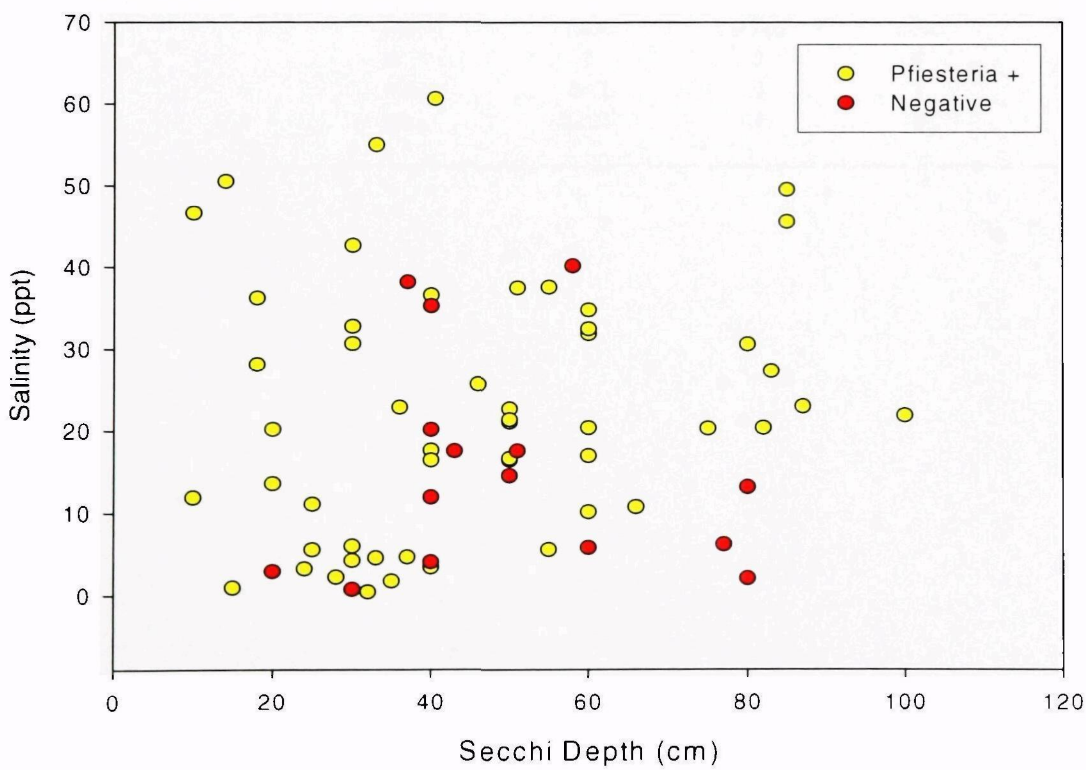

Figure 4-71. Relationship between salinity and Secchi depth for stations positive and negative for *Pfiesteria* in 2000.

Table 4-17. Mean, Standard Deviation, Sample Size (N), Minimum and Maximum Values for Meteorological Parameters Measured at Stations Negative and Positive for all *Pfiesteria*, those Positive for both *Pfiesteria*, those Positive of only *P. shumwayae*, and those Positive for only *P. piscicida*, in 2001.

Results of PCR		Air temperature (degrees C)	Wind speed code (Beaufort)	Cloud cover code	Sea state code (Beaufort)
Negative for *Pfiesteria*	Mean	28.28	2.36	3.42	1.65
	Stdev	3.389	1.350	2.023	1.968
	N	24	25	26	23
	Min	19.7	0	1	0
	Max	33.5	6	6	6
Positive for all *Pfiesteria*	Mean	28.34	2.34	2.90	0.88
	Stdev	3.374	1.015	1.655	1.431
	N	39	41	41	33
	Min	20.5	0	1	0
	Max	35	5	6	4
Positive for both *Pfiesteria*	Mean	27.77	2.64	3.00	1.30
	Stdev	3.468	0.842	1.664	1.703
	N	14	14	14	10
	Min	20.5	2	1	0
	Max	32.22	5	6	4
Positive for *P. shumwayae*	Mean	28.40	2.00	2.44	0.50
	Stdev	3.797	1.188	1.542	1.095
	N	16	18	18	16
	Min	23.89	0	1	0
	Max	35	4	6	3
Positive for *P. piscicida*	Mean	29.13	2.56	3.67	1.14
	Stdev	2.498	0.726	1.732	1.676
	N	9	9	9	7
	Min	25.2	2	1	0
	Max	32.22	4	6	4

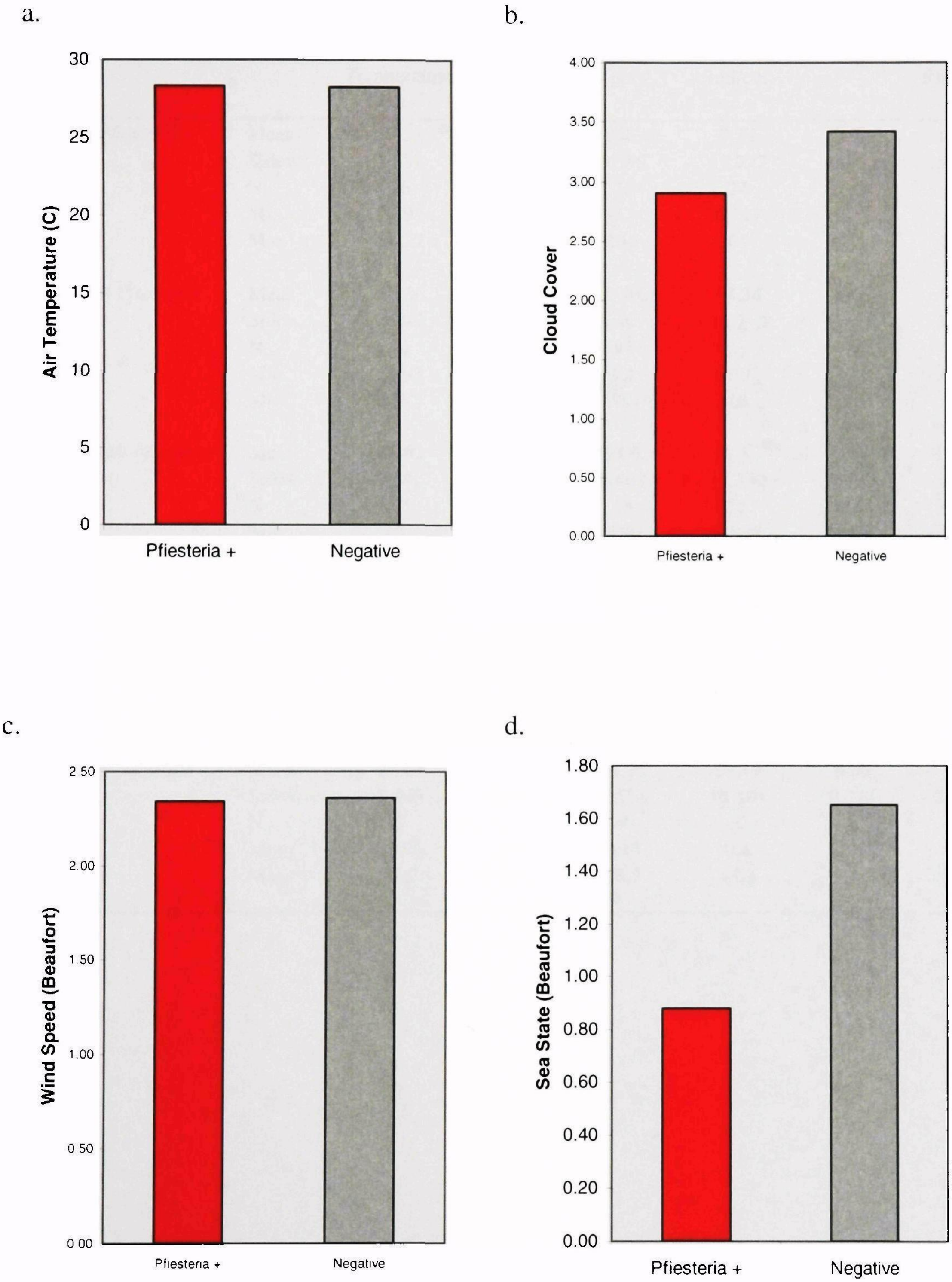

Figure 4-72. Mean values for meteorological parameters at sites positive and negative for *Pfiesteria* in 2001. (a) air temperature, (b) cloud cover, (c) wind speed, (d) sea state.

Table 4-18. Mean, Standard Deviation, Sample Size (N), Minimum and Maximum Values for Physicochemical Water Parameters Measured at Stations Negative and Positive for all *Pfiesteria*, those Positive for both *Pfiesteria*, those Positive for only *P. shumwayae*, and those Positive for only *P. piscicida*, in 2000.

Results of PCR		Water Temperature (deg C)	DO (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	pH	Percent Saturation	Secchi Depth (cm)
Negative for *Pfiesteria*	Mean	27.57	7.55	7.46	9.34	8.36	101.67	32.67
	Stdev	2.531	4.184	9.598	13.227	0.810	55.695	8.892
	N	26	25	26	24	19	23	18
	Min	21.96	2.05	0.1	0.197	7.19	30.3	20
	Max	31.27	19.15	30.8	45	10.81	252.6	53
Positive for all *Pfiesteria*	Mean	28.56	6.93	9.44	15.34	8.36	91.04	37.52
	Stdev	3.049	2.898	9.401	14.763	0.624	35.387	13.759
	N	41	40	41	39	34	37	33
	Min	21.91	2.53	0.1	0.193	7.19	32.5	15
	Max	32.95	14.4	30.4	46.3	10.37	179	71
Positive for both *Pfiesteria*	Mean	28.62	7.92	9.06	15.10	8.65	100.89	38.18
	Stdev	3.410	3.086	8.662	13.730	0.732	35.068	11.125
	N	15	14	15	15	12	13	11
	Min	22.7	4.75	0.96	1.827	7.68	61	15
	Max	32.95	14.4	27.1	42.4	10.37	179	55
Positive for *P. shumwayae*	Mean	27.85	6.69	8.77	12.64	8.28	88.46	35.47
	Stdev	3.258	2.988	10.346	15.426	0.514	39.383	16.374
	N	17	17	17	16	14	16	15
	Min	21.91	2.53	0.1	0.193	7.19	32.5	20
	Max	31.79	13.34	30.4	46.3	9.11	174	71
Positive for *P. piscicida*	Mean	29.81	5.82	11.32	21.19	8.06	80.19	40.86
	Stdev	1.445	2.097	9.552	15.501	0.497	26.044	12.389
	N	9	9	9	8	8	8	7
	Min	27.46	3.44	0.19	0.4	7.62	51.9	16
	Max	31.2	10.5	28.5	44.3	9.17	137.9	55

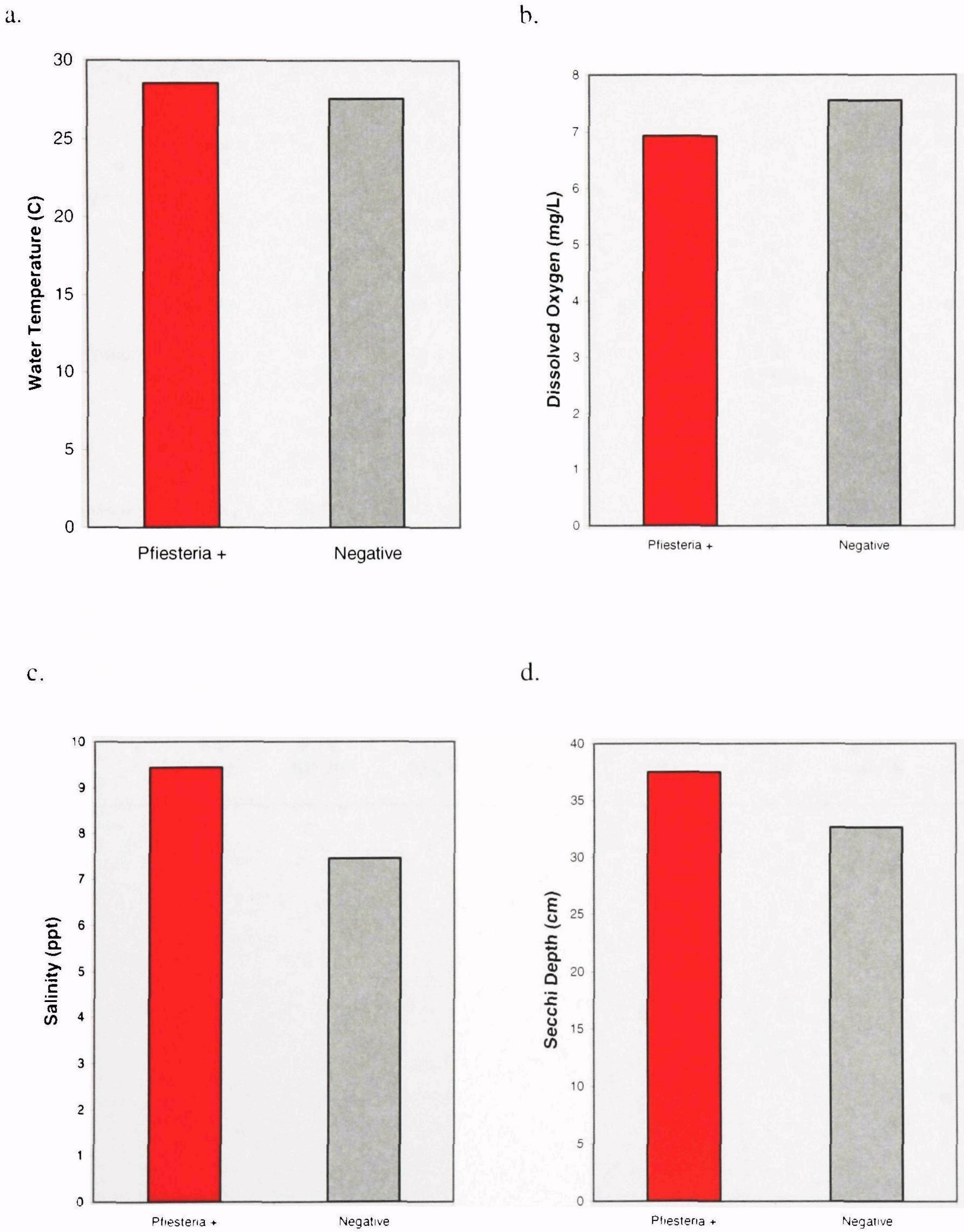

Figure 4-73. Mean values for physicochemical water parameters at sites positive and negative for *Pfiesteria* in 2001. (a) water temperature, (b) dissolved oxygen, (c) salinity, (d) Secchi depth.

Table 4-19. Mean, Standard Deviation, Sample Size (N), Minimum and Maximum Values for Chlorophyll a and Nutrient Parameters Measured at Stations Negative and Positive for all *Pfiesteria*, those Positive for both *Pfiesteria*, those Positive for only *P. shumwayae*, and those Positive for only *P. piscicida*, in 2001.

Results of PCR		Chlorophyll a (ug/L)	Silicate (ug/L)	Phosphate (ug/L)	Nitrate+Nitrite (ug/L)	Ammonium (ug/L)	DIN (ug/L)	DON (ug/L)	TDN (ug/L)
Negative for *Pfiesteria*	Mean	43.41	42.14	9.12	22.38	10.82	33.20	109.84	143.04
	Stdev	46.106	27.179	13.462	29.474	24.242	46.850	219.636	252.358
	N	25	25	25	25	25	25	25	25
	Min	1.36	8.09	0.51	0.83	0.00	0.96	9.03	18.95
	Max	161.00	100.07	45.56	93.52	117.32	191.56	869.52	972.36
Positive for all *Pfiesteria*	Mean	67.14	45.29	11.54	24.03	10.57	34.60	214.53	249.13
	Stdev	63.609	26.241	15.615	31.146	20.357	46.552	341.744	372.647
	N	37	41	41	41	41	41	41	41
	Min	1.85	8.24	0.18	0.11	0.00	0.14	8.82	18.40
	Max	306.75	98.37	62.18	95.69	88.09	161.90	1119.27	1258.53
Positive for both *Pfiesteria*	Mean	67.62	47.25	14.83	32.01	15.48	47.49	200.39	247.88
	Stdev	53.920	30.050	20.136	33.095	26.834	53.664	316.384	356.412
	N	14	15	15	15	15	15	15	15
	Min	5.12	13.36	1.45	0.70	0.00	1.77	13.75	24.00
	Max	158.00	98.37	62.18	87.58	88.09	161.90	1119.27	1258.53
Positive for *P. shumwayae*	Mean	70.56	38.32	8.69	17.70	3.94	21.65	180.75	202.39
	Stdev	81.391	22.026	10.275	27.289	5.328	28.759	337.036	354.692
	N	16	17	17	17	17	17	17	17
	Min	1.85	8.24	0.18	0.11	0.03	0.14	11.34	19.40
	Max	306.75	88.24	42.22	95.69	15.88	96.02	1044.29	1132.75
Positive for *P. piscicida*	Mean	58.35	55.18	11.43	22.67	14.90	37.57	301.93	339.51
	Stdev	35.979	25.926	16.153	35.180	24.406	58.852	412.542	454.513
	N	7	9	9	9	9	9	9	9
	Min	8.36	19.62	0.72	1.10	0.36	1.47	8.82	18.40
	Max	105.30	92.69	48.42	94.09	62.44	146.78	1014.57	1035.04

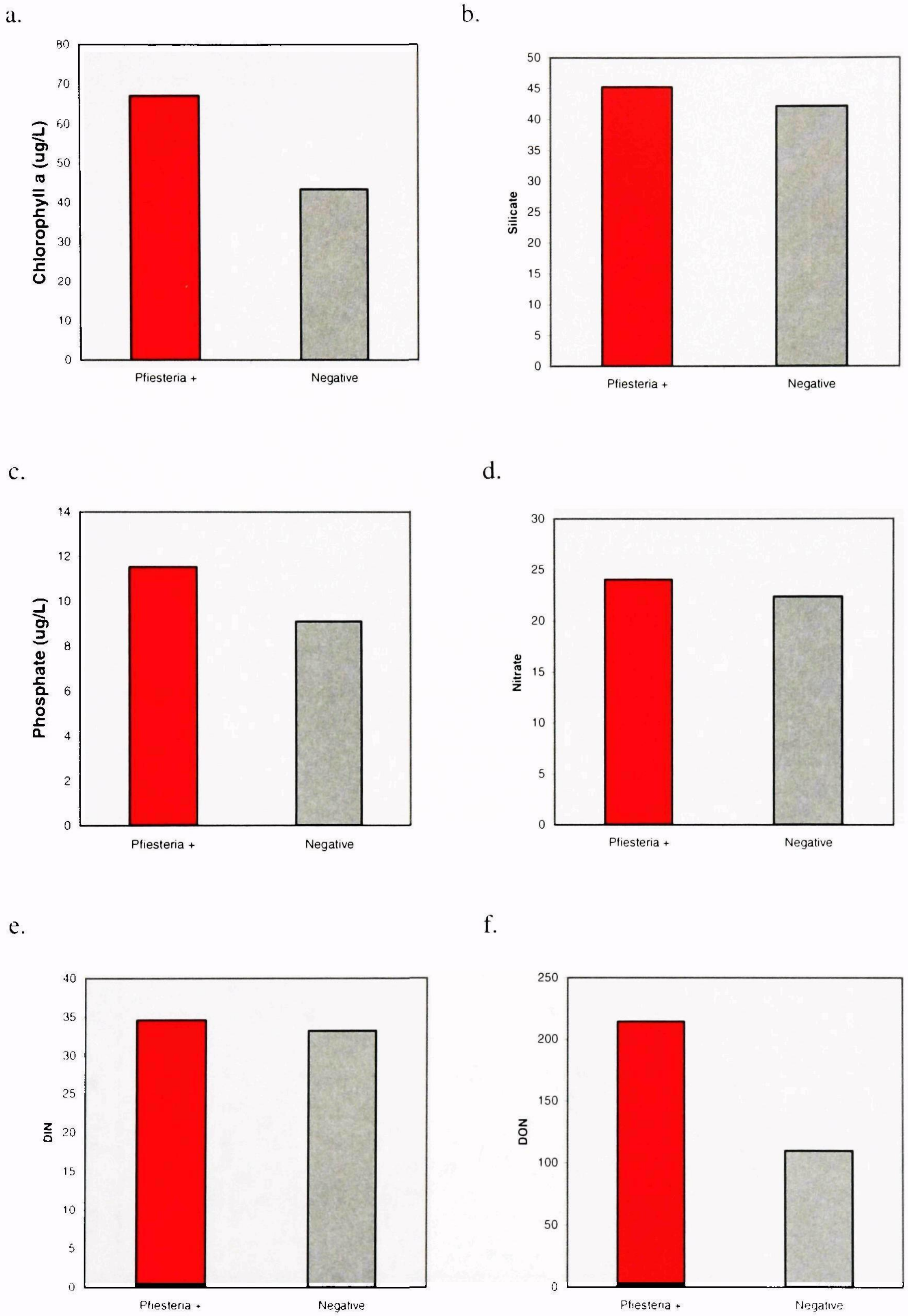

Figure 4-74. Mean values for chlorophyll a and nutrients at sites positive and negative for *Pfiesteria* in 2001. (a). chlorophyll a, (b) silicate, (c) phosphate, (d) nitrate, (e) dissolved inorganic nitrogen (DIN), (f) dissolved organic nitrogen (DON).

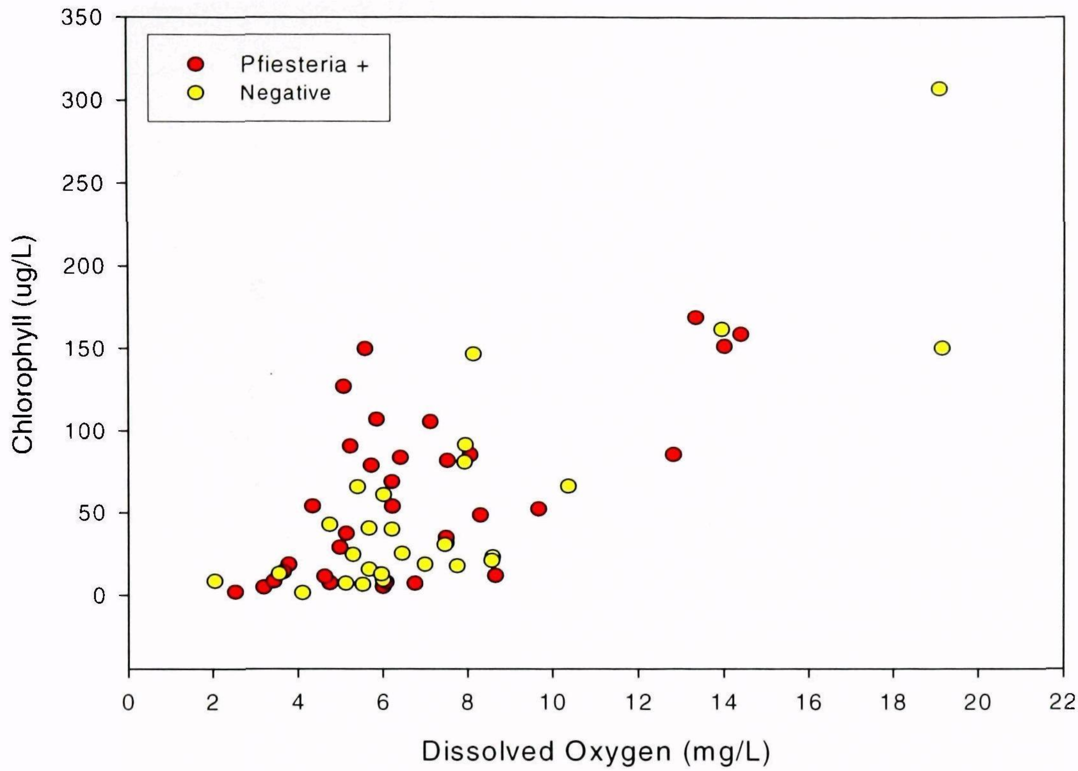

Figure 4-75. Relationship between chlorophyll a and dissolved oxygen for stations positive and negative for *Pfiesteria* in 2001.

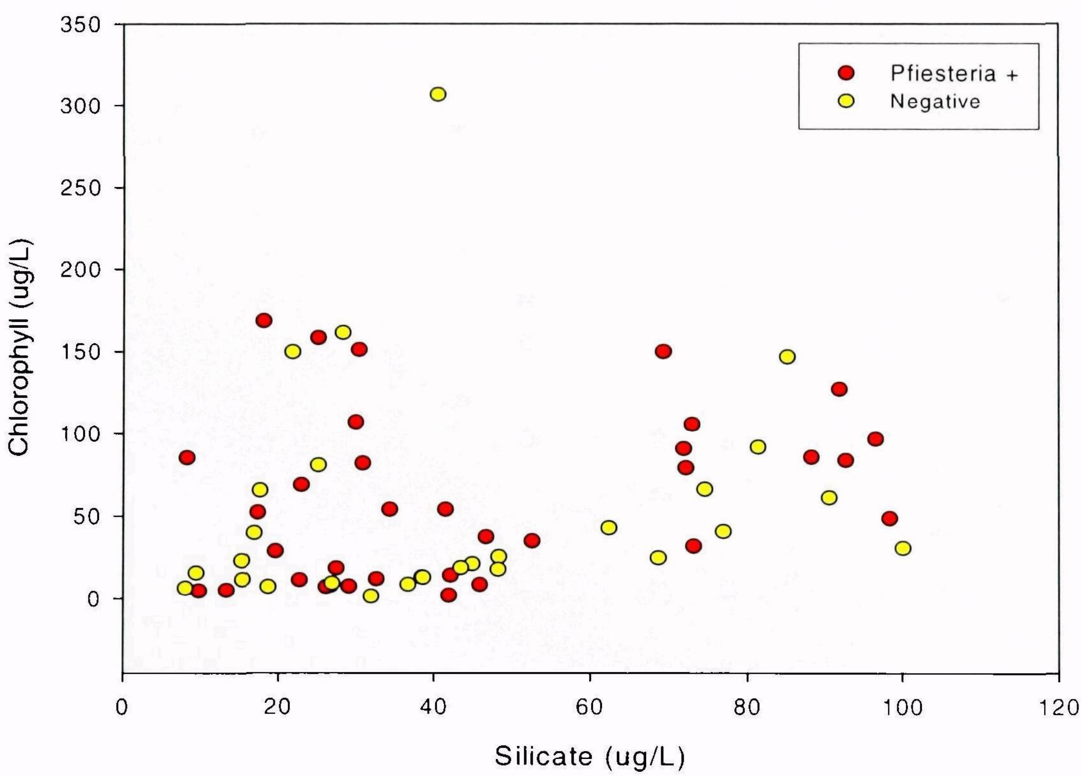

Figure 4-76. Relationship between chlorophyll a and silicate for stations positive and negative for *Pfiesteria* in 2001.

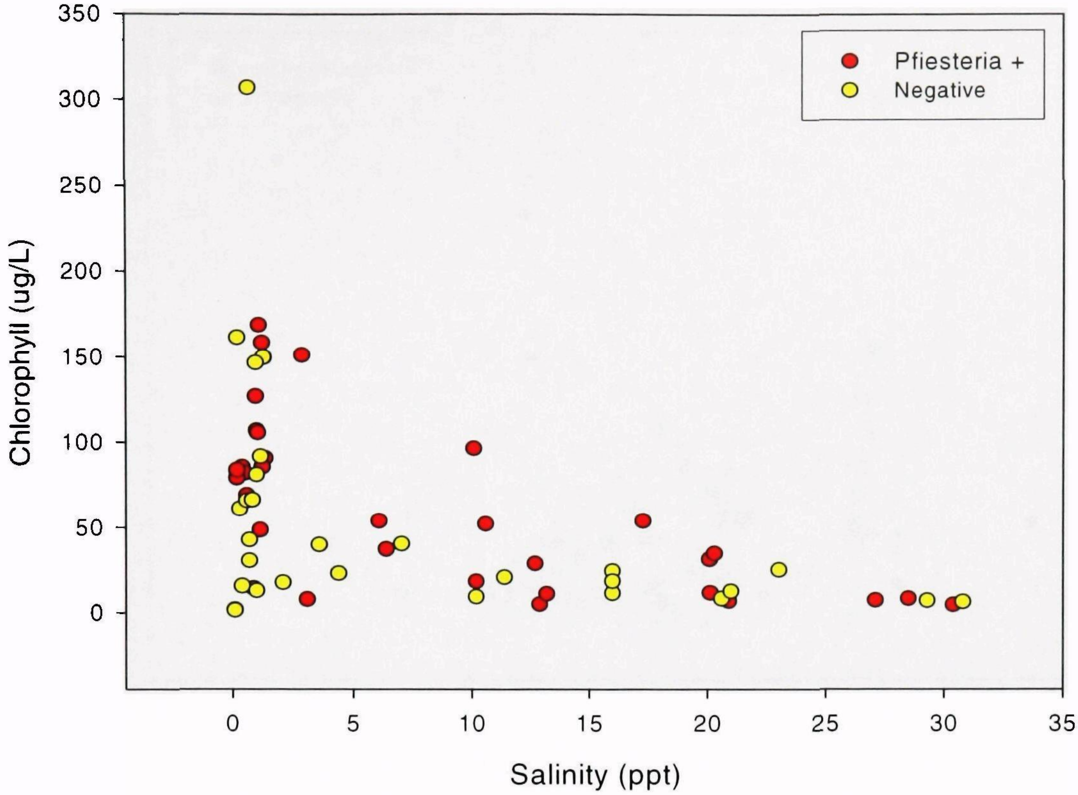

Figure 4-77. Relationship between chlorophyll a and salinity for stations positive and negative for *Pfiesteria* in 2001.

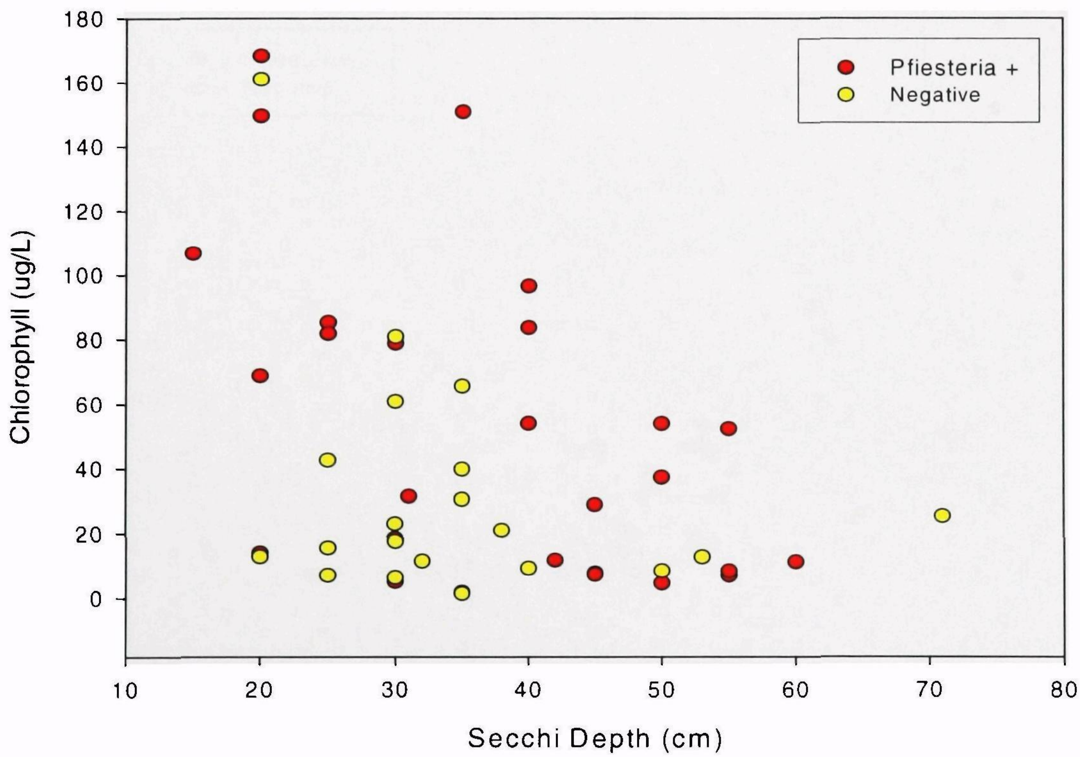

Figure 4-78. Relationship between chlorophyll a and Secchi depth for stations positive and negative for *Pfiesteria* in 2001.

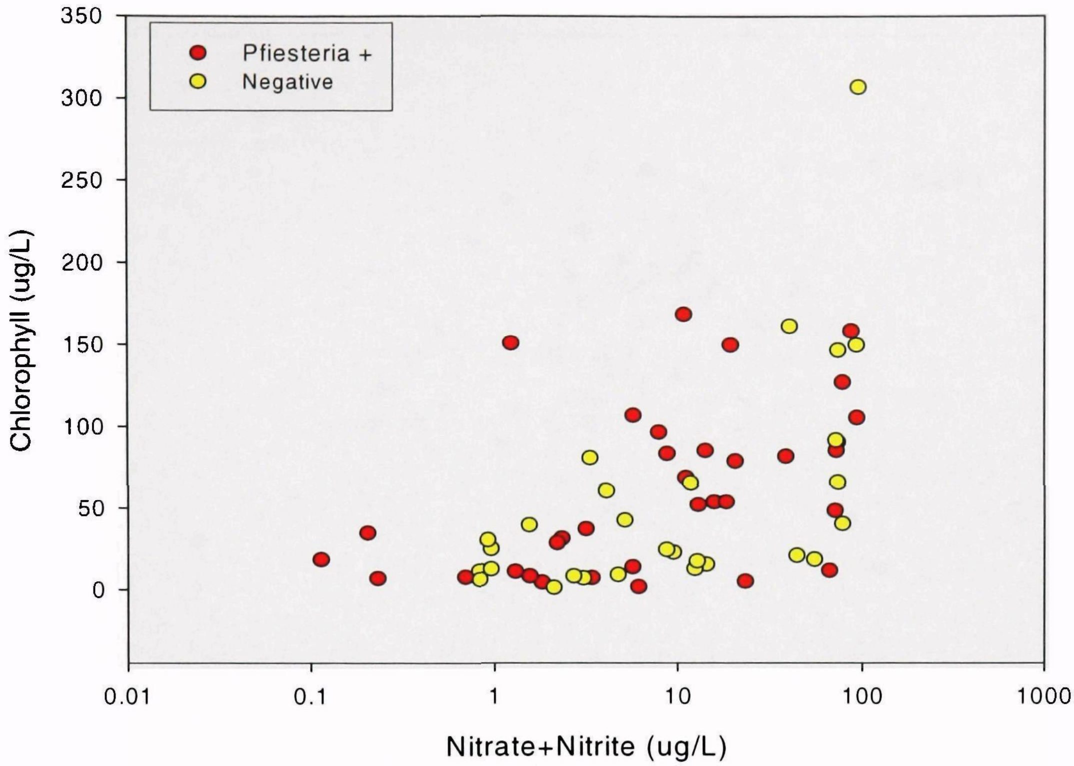

Figure 4-79. Relationship between chlorophyll a and nitrate+nitrite for stations positive and negative for *Pfiesteria* in 2001.

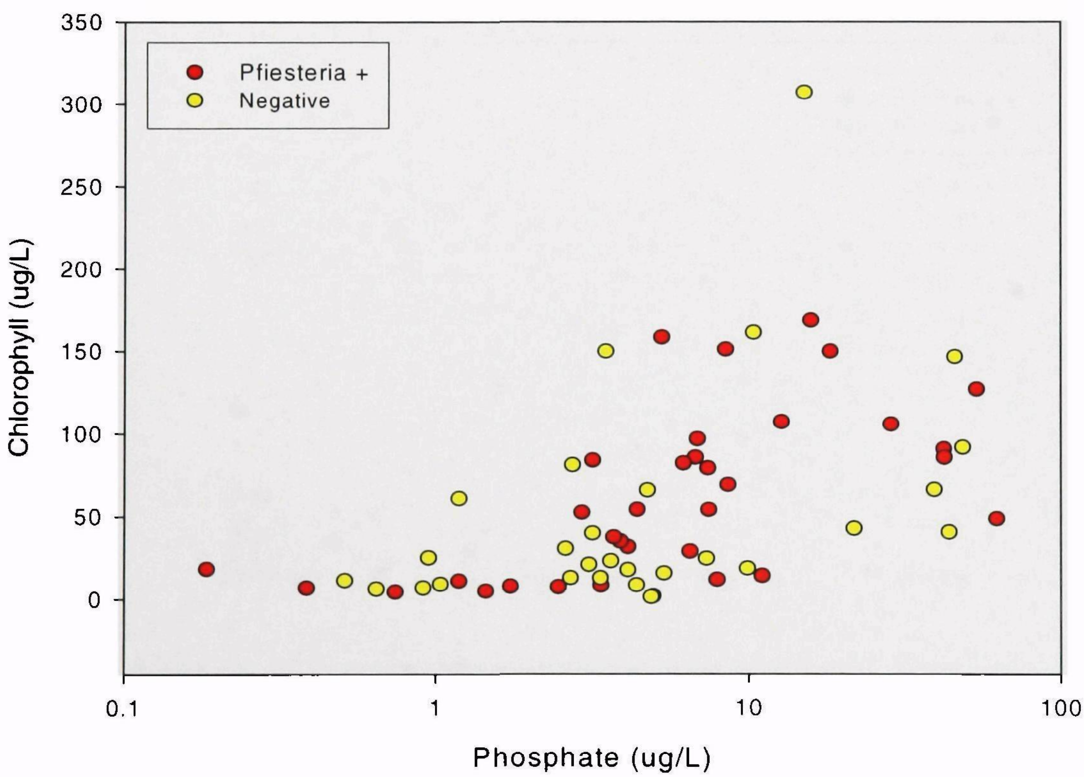

Figure 4-80. Relationship between chlorophyll a and phosphate for stations positive and negative for *Pfiesteria* in 2001.

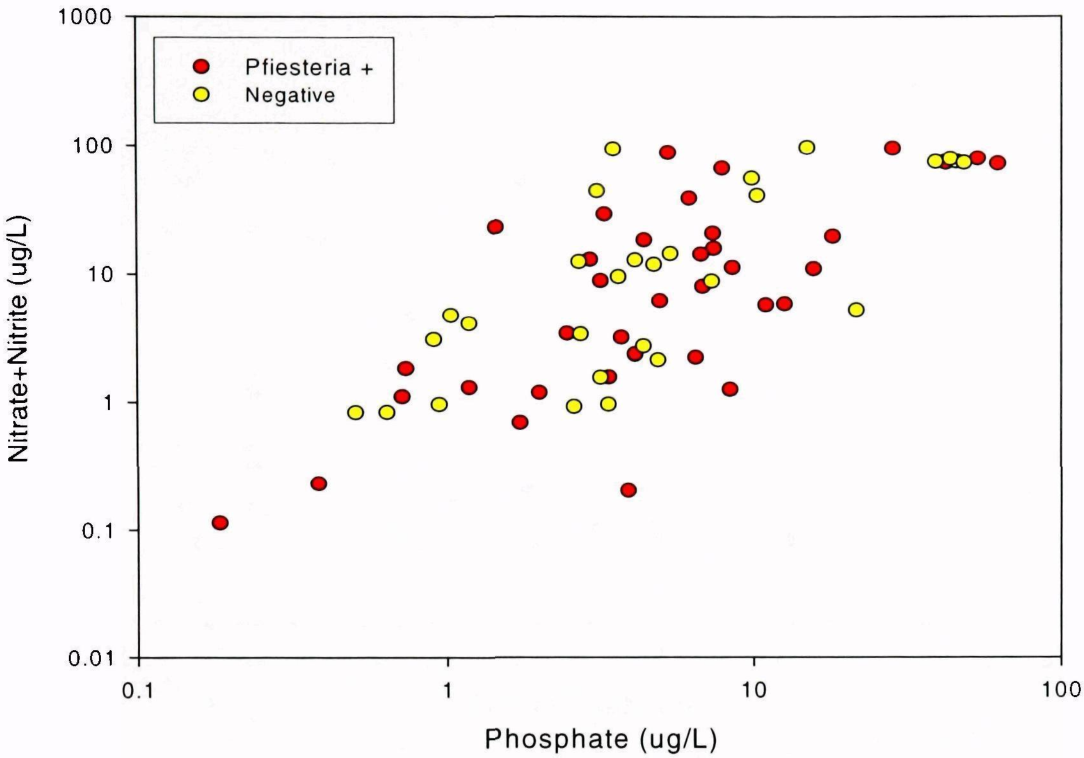

Figure 4-81. Relationship between nitrate+nitrite and phosphate for stations positive and negative for *Pfiesteria* in 2001.

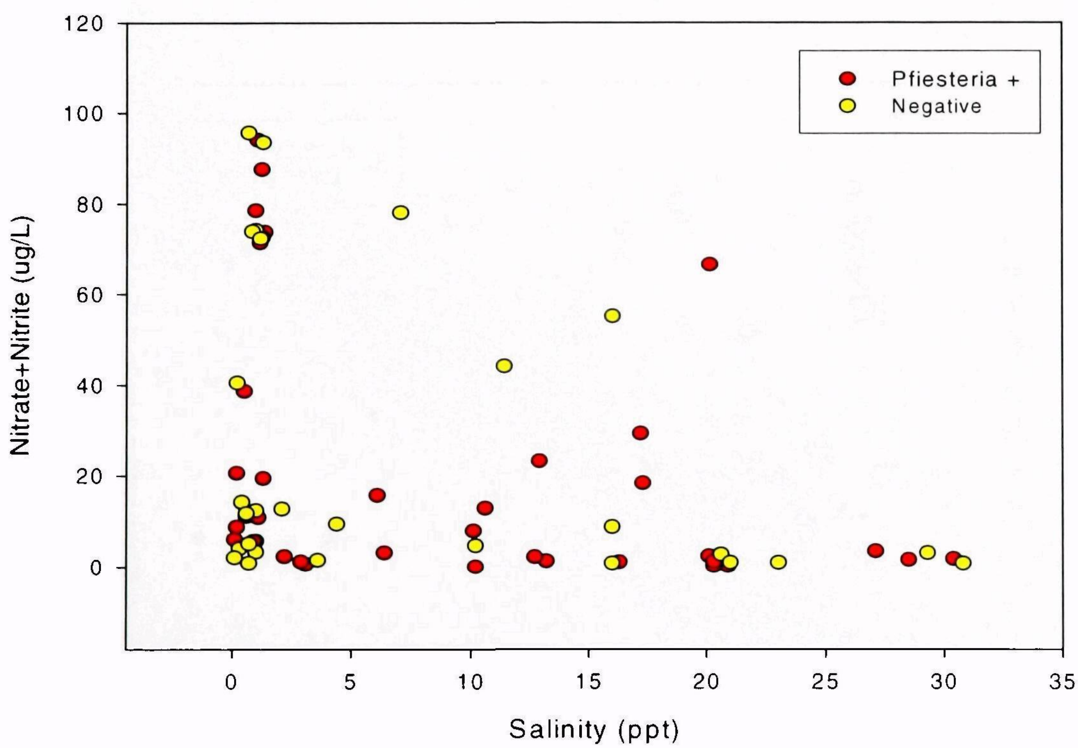

Figure 4-82. Relationship between nitrate and salinity for stations positive and negative for *Pfiesteria* in 2001.

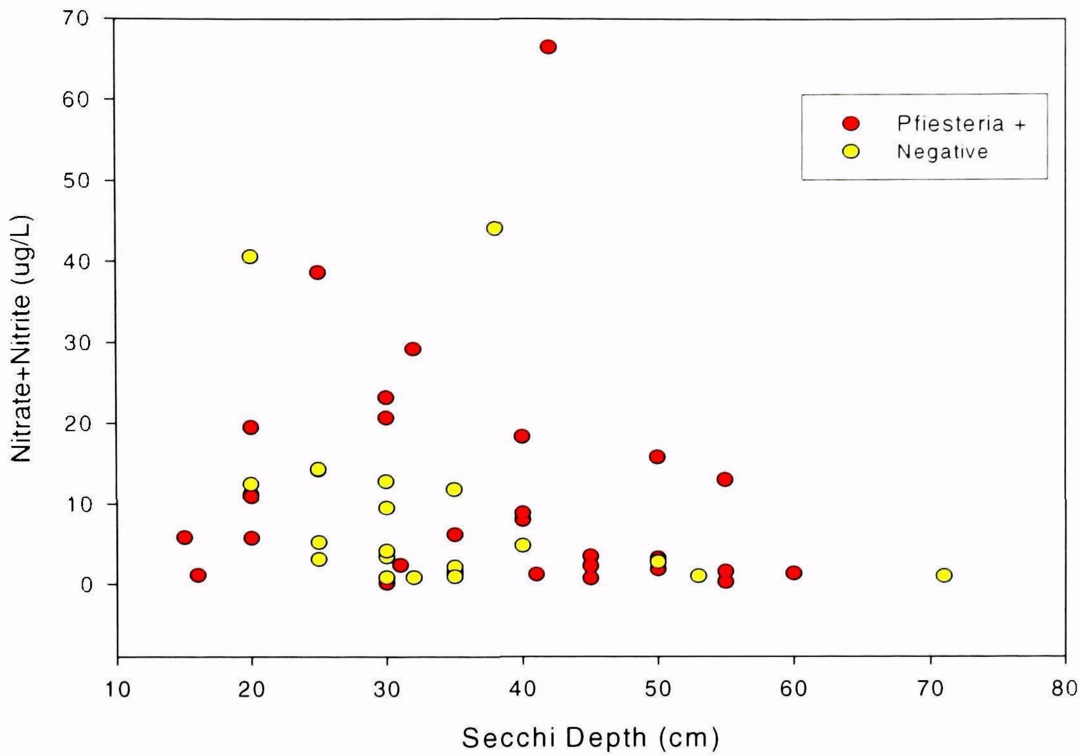

Figure 4-83. Relationship between nitrate and Secchi depth for stations positive and negative for *Pfiesteria* in 2001.

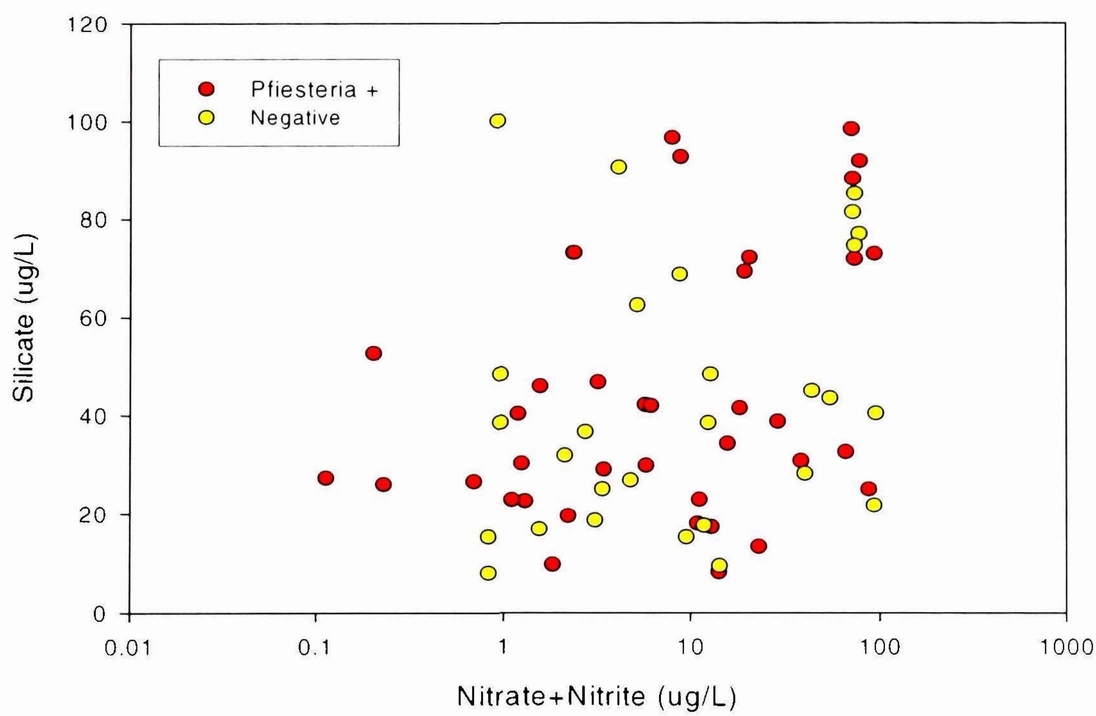

Figure 4-84. Relationship between silicate and nitrate for stations positive and negative for *Pfiesteria* in 2001.

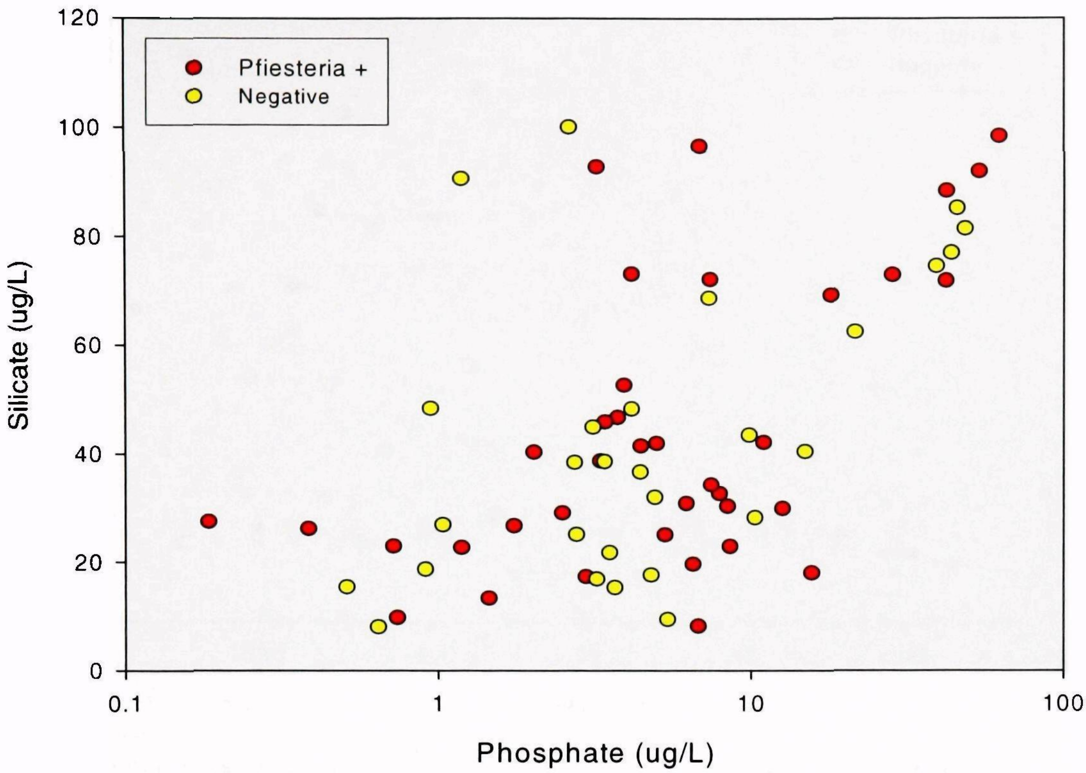

Figure 4-85. Relationship between silicate and phosphate for stations positive and negative for *Pfiesteria* in 2001.

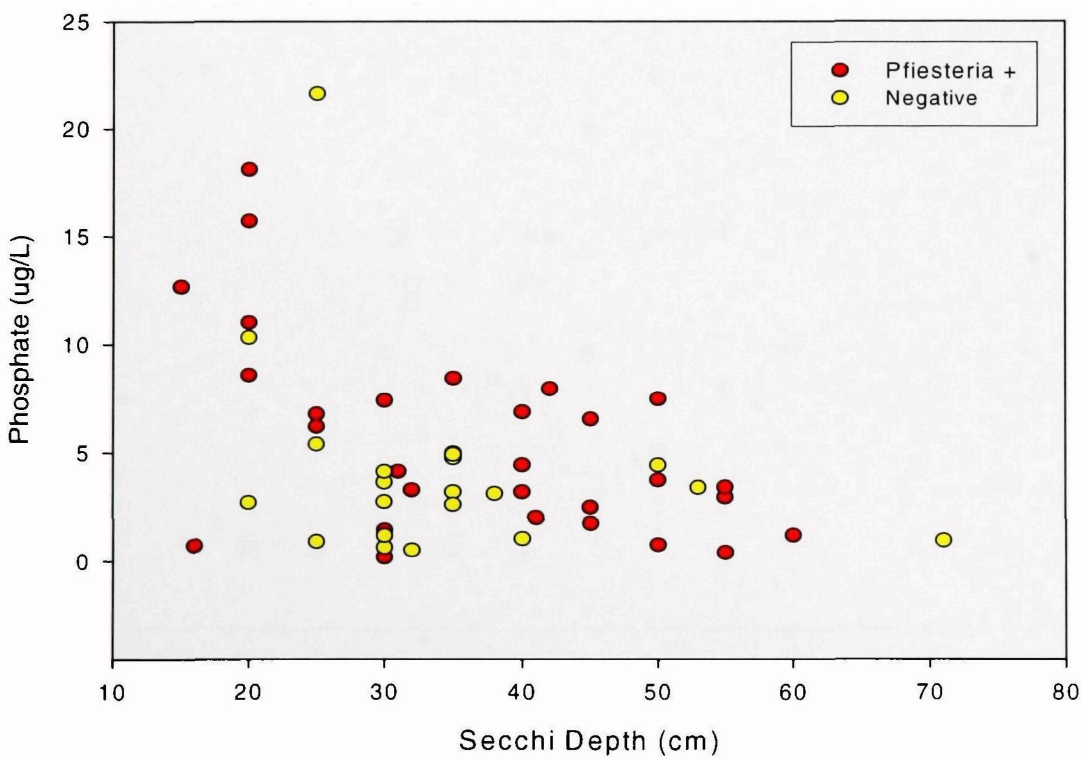

Figure 4-86. Relationship between phosphate and Secchi depth for stations positive and negative for *Pfiesteria* in 2001.

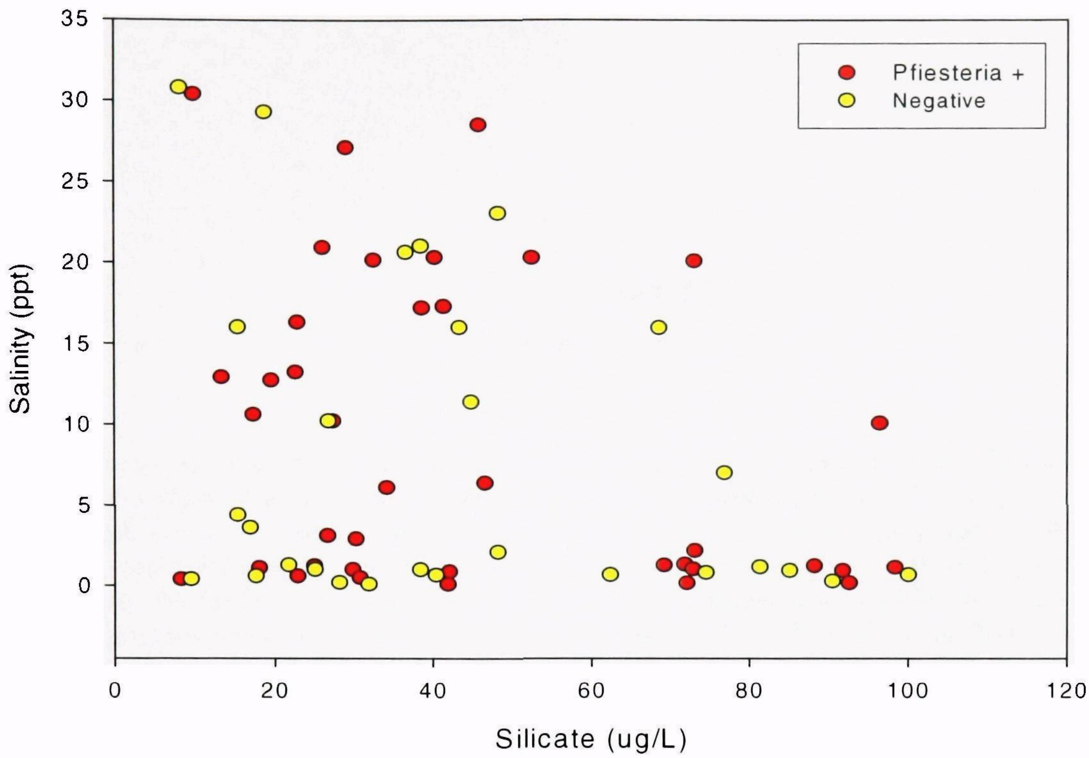

Figure 4-87. Relationship between salinity and silicate for stations positive and negative for *Pfiesteria* in 2001.

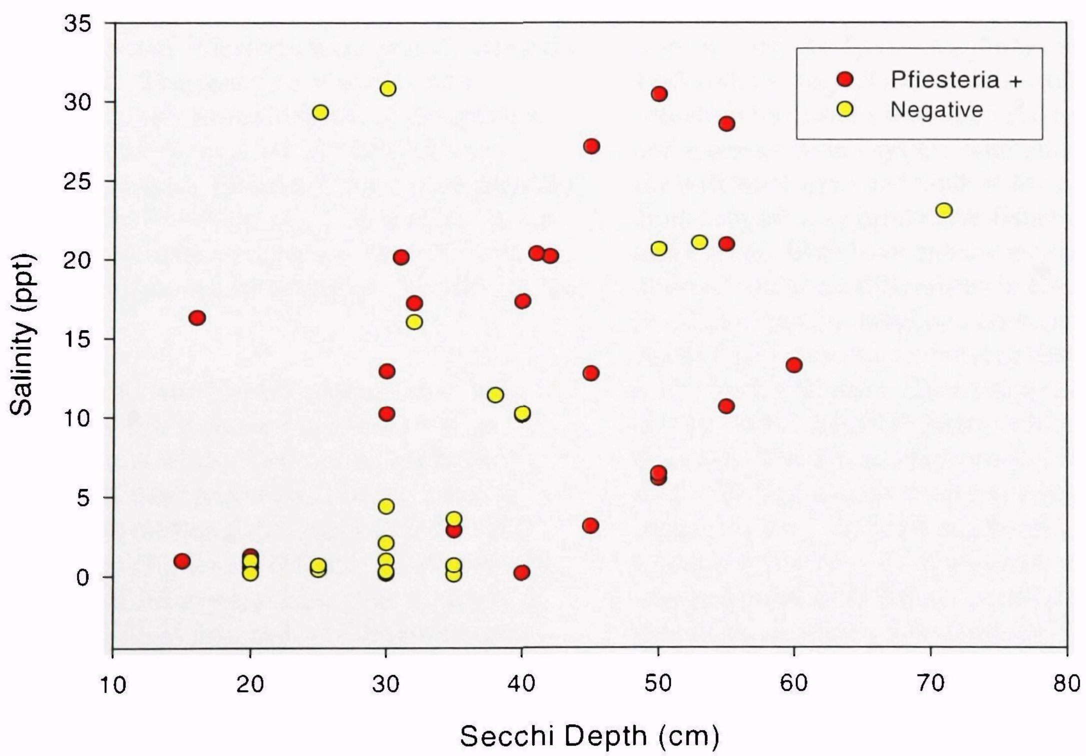

Figure 4-88. Relationship between salinity and Secchi depth for stations positive and negative for *Pfiesteria* in 2001.

Chapter 5
Discussion

It did not take long to establish that *Pfiesteria* was present on the Texas coast. The first station sampled in 2000, at the Adolph Tomae Jr. County Park on the Arroyo Colorado, produced a positive result for *Pfiesteria piscicida.* As the first sampling season proceeded, more positive results were found, but at a relatively low rate. By the end of the first sampling season a total of 18 positive results out of 91 samples (83 water and 8 sediment) for *Pfiesteria* had been found. By the end of the second year, that total had climbed to 62 positives from at total of 160 samples (149 water and 11 sediment) for the two years.

Pfiesteria spp. appear to be broadly distributed members of the coastal dinoflagellate community along the Texas coast. Both species of *Pfiesteria* were present along the entire Texas coast. The genetic test used cannot distinguish toxic from non-toxic forms of the species. Although one sample from a fish kill in Dickinson Bayou tested positive for *Pfiesteria*, there is no ancillary evidence to suggest *Pfiesteria* was responsible. Thus at this time, we cannot state whether we have TOX-A, TOX-B, non-inducible strains or any combination of the above.

The Texas coast, like the North Carolina coast, has experienced many fish kills over the past 13 years. Between 1991 and 2000 the Texas coast experienced 160 major (>1,000 dead fish) fish kills that killed approximately 150 million fish (Unpublished TPWD fish kill database). Of these 160 fish kills, 92 were the result of low dissolved oxygen, caused by a variety of reasons, including algal respiration. These 92 events killed approximately 127 million fish. There were five major kills of unknown cause that killed 1.83 million fish. In addition, there were 8 kills due to bacteria/virus that killed about 65,000 fish and one kill due to brevetoxin from a red tide that killed about 5,300 fish. As in North Carolina, many of these kills have occurred due to unknown causes. During the same time period there were 159 major fish kills in North Carolina, which killed approximately 1.02 billion fish, of which approximately 3.1 million were caused in non-*Pfiesteria* related kills (Glasgow et al. 2001). Of the 159 fish kills, 80 of them were the result of *Pfiesteria.* Seventy-eight of the 80 fish kills occurred in the Albemarle-Pamlico and Nuese River estuaries (Mallin et al. 2000). With our current knowledge of the rapidity of the *Pfiesteria* predatory activity and succeeding retreat to benthic cysts, it is understandable why the organism has remained so elusive.

There are many striking similarities between North Carolina and the Texas coastlines and coastal zones. Both exhibit very shallow, drowned river valley estuarine formations with lagoons, extensive wetlands and a barrier island system with only a few openings to the Atlantic Ocean and Gulf of Mexico, respectively. Both support very productive fisheries of shrimp, crabs and finfish. Both have extensive areas of agriculture, although there are differences in crops. Texas cropping consists of cotton, sorghum, corn and rice, while those in North Carolina supports tobacco and corn. But other differences also exist. Texas supports a rather extensive oil, gas and chemical industry, while North Carolina does not. The Texas coast is also home to offshore oil rigs. The Texas coastal zone also supports much open range ranching. In addition, North Carolina is home to millions of swine, tens of millions of turkeys and several hundred million chickens. In the past 15 years the swine industry has quadrupled, and has been loosely regulated in regards to environmental regulations. The swine and poultry operations tend to have large waste holding lagoons that are prone to floods in the low lying coastal plain of North Carolina (Pleasant, 2001).

Consideration of the characteristics of each sampling site takes into account the history of the site. Those in urbanized areas are likely to have experienced the insults of STP effluent releases, failing septic systems and general urban NPS pollution, while sites in rural and agricultural areas are likely to have received nutrient inputs from agricultural NPS pollution and to a lesser extent, failing septic systems and STP outfalls. Sites located in isolated rural areas or wilderness areas, such as special management areas are expected to be the most pristine (although no area on the Texas or North Carolina coast is pristine), thus less likely to experience a *Pfiesteria* bloom.

Most of the research on the ecological conditions supporting *Pfiesteria* have been aimed at establishing the conditions that support a *Pfiesteria* "bloom". In short, the basic factors necessary for a toxic *Pfiesteria* outbreak, other than a healthy *Pfiesteria* population, are: the presence of high density of fish prey, particularly large schools of oily fish; poorly flushed, shallow water that is over enriched in nutrients, warm and brackish; and abundant phytoplankton or other prey that serve as an alternate food source for *Pfiesteria* when live fish are not detected (Burkholder and Glasgow, 1997; Burkholder and Glasgow 2001).

The results of this study indicated that the presence of *Pfiesteria* was not correlated with any of the meteorological variables (air temperature, cloud cover, wind speed and sea state) measured (or estimated) during the two year study along the Texas coast. As these factors are not likely to influence the presence/absence of the dinoflagellate, this result is not surprising. Laboratory and field studies in North Carolina indicate that light levels from 0 to 300 umol photons/m/s are conducive to *Pfiesteria* zoospore production. Research on *Pfiesteria* induced fish kills indicates that quiet, shallow waters with low turbulence, gentle current or wave action are conditions necessary for a bloom of actively toxic (TOX-A) *Pfiesteria* in a fish kill event (Glasgow et al., 2001).

Salinity conditions at stations positive for *Pfiesteria* in Texas in 2000 and 2001 had mean values of 14.34 and 9.44 respectively, and ranged from 0.00 to 40.9 ppt. This compares very favorably to the optimal conditions of 10 to 15 ppt that were found from lab and field studies of conditions necessary for *Pfiesteria* zoospore "blooms" in North Carolina (Glasgow et al., 2001). In addition, a study of 90 fish kill events in North Carolina and 4 in the Chesapeake Bay region, the mean salinity was 9.2 ppt, with a range from 1 to 18 ppt (Glasgow et al., 2001).

Temperatures found at stations positive for *Pfiesteria* in Texas averaged 29.97 and 25.86 in 2000 and 2001, and ranged from 21.91 to 33.0 °C. These results compare well to a study of lab and field conditions necessary for *Pfiesteria* zoospore "blooms", that found optimal conditions at > 26 °C, with a range of 20 to 30 °C conducive to cell production (Glasgow et al., 2001). In a study of 90 fish kill events in North Carolina and 4 in the Chesapeake Bay region, the mean water temperature was 27.1 C, with a range from 18 to 33 C (Glasgow et al., 2001).

The pH values recorded at the Texas stations positive for *Pfiesteria* in 2000 and 2001 had means of 8.25 and 8.36, and ranged from 7.19 to 10.37. These results also compare very closely to the optimal pH of > 7.5 and range of 6.6 to 8.6 found necessary for *Pfiesteria* zoospore "blooms" in laboratory and field conditions found in North Carolina (Glasgow et al., 2001). In a study of 90 fish kill events in North Carolina and 4 in the Chesapeake Bay region, the mean low pH was 6.82 and the high mean was 8.74, with a range from 6.1 to 10.4 (Glasgow et al., 2001).

The mean dissolved oxygen at *Pfiesteria* monitoring stations in Texas in 2000 and 2001 were 6.93 and 7.37 ug/L, respectively, and ranged from 2.48 to 14.4 ug/L. In results from 90 North Carolina stations and four from the Chesapeake Bay region that experienced *Pfiesteria* blooms, the stations had a mean low dissolved oxygen of 4.9 and mean high of 9.4, and ranged from 3.8 to 10.4 ug/L (Glasgow et al., 2001).

The physicochemical conditions where *Pfiesteria* has been found in North Carolina spanned essentially the entire range found along the Texas coast during the April through September 2000 and 2001 sampling period. We found no evidence of preferred conditions although we recognize that presence/absence is not a useful indicator for biological response. Although no "blooms' of *Pfiesteria* were found along the Texas coast, the physicochemical conditions where *Pfiesteria* was found are very close to those conditions where blooms have occurred along the North Carolina coast and in the Chesapeake Bay.

The mean chlorophyll a concentrations at stations positive for *Pfiesteria* in Texas in 2000 and 2001 were 27.81 and 67.14 ug/L, respectively, with a range from 1.85 to 306.75 ug/L. In a study of 90 fish kill events in North Carolina and 4 in the Chesapeake Bay, the mean chlorophyll a concentration was 34 ug/L, with a range of 10 to 112 ug/L. These results indicate that the chlorophyll a concentrations in waters where *Pfiesteria* was found in Texas clearly bracket the mean and are well within the range of values found at fish kills caused by *Pfiesteria* in North Carolina and the Chesapeake Bay.

The mean DIP during the Texas study in 2000 and 2001 was 7.71 ug/L (range 0.13 to 29.41 ug/L), and for DIN a mean of 35.17 ug/L (range 0.24 to 429.05 ug/L). The research by Burkholder and others have indicated that the nutrient conditions present at *Pfiesteria* "blooms" is >> 100 ug/L for both DIP and DIN. These values are much higher than those found along the Texas coast during the two years of the monitoring project. A study of 90 fish kill events in North Carolina and 4 in the Chesapeake Bay region that were attributed to *Pfiesteria* the mean DIN was 443.2 ug/L, with a range of 10 to 1,300 ug/L, while mean DIP was 335.0 ug/L with a range of 70 to 1,200 ug/L (Glasgow et al., 2001). It is relevant to note that the distribution of either species was not statistically linked to any inorganic nutrient, DON or chlorophyll concentration.

A comparison of 25 years of DIN and DIP concentration data from the TCEQ's SWQM segments represented by sampling stations in this study was conducted. TCEQ Segment 2201, which had the highest mean DIN concentration of 2,310 ug/L, was represented by Adolph Tomae Jr. County Park in this study. This station had higher numbers of samples positive for *Pfiesteria* spp. and PLO in 2000 (4) and 2001 (10) than all other stations except Clear Lake in 2000, which also had 10 positive results for *Pfiesteria* spp. and PLO. Mean DIN concentrations in TCEQ segments with only one positive (554 ug/L) for *Pfiesteria* and those negative (435 ug/L) for *Pfiesteria* in 2000 were much lower. TCEQ Segment 2453, represented by the Port Lavaca Fishing Pier in 2001, had a mean DIN of 175 ug/L and the lowest number (4) and percentage (57%) of samples positive for *Pfiesteria* spp. and PLO in 2001. Mean DIP in 2000 in three TCEQ segments with more than one positive result for *Pfiesteria* spp. or PLO was 276 ug/L, while those segments with only one positive for *Pfiesteria* had a mean DIP of 253 ug/L, and those negative for *Pfiesteria* had a mean DIP of 251 ug/L. In 2001, the mean historic DIP in the two segments with the greatest number and percentage of positives for *Pfiesteria* and PLO was 346 ug/L, which is greater than the 224 ug/L found in the segments with the smallest percentages of positives for *Pfiesteria* spp. and PLO.

The above comparisons indicate that nutrient concentrations found along the Texas coast during this study are significantly less than those found during *Pfiesteria* "blooms" along the North Carolina coast and the Chesapeake Bay. On the other hand, the mean nutrient values for the TCEQ segments over the past 25 years that contain these stations, particularly the DIN at several stations, is of the same magnitude found at the "blooms" in North Carolina and the Chesapeake Bay.

Based on results in the United States and internationally, it appears that *Pfiesteria* spp. are a ubiquitous part of the dinoflagellate community. The jury is still out as to what triggers the *Pfiesteria* predatory ambush attacks, although high nutrient concentrations, substantially higher than those typically found along the Texas coast, are strongly implicated to be pivotal in triggering these attacks. Although it is possible that past fish kills of unknown cause in Texas were the result of *Pfiesteria* blooms, it appears to be unlikely. As more knowledge about *Pfiesteria* unfolds, cognizance of its presence will add it as an option to be investigated in the event of a fish kill. Should symptoms exist that would suggest such an event, i.e. ulcerous sores on fish such as menhaden, we need to be prepared to collect samples for further analysis and verification.

It is incumbent upon us, to the extent possible, to prevent our waters from duplicating the conditions that appear to be necessary for *Pfiesteria* blooms to occur. So far, the conditions on much of the Texas coast would appear to preclude such an event at present. Yet, as our population continues to grow on the Texas coast, we must be ever vigilant to the possibility of such conditions developing in the future. The vast numbers of fish killed in North Carolina as a result of these organisms and the potential for known health problems and negative impacts on local economies make it prudent that we be aware of the potential devastation that the *Pfiesteria* species can cause.

Chapter 6
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Appendices

Appendix A

Site Descriptions

This Appendix contains color-infrared Landsat images of all the *Pfiesteria* sampling stations for 2000 and 2001. Other identifying landmarks such as bays, towns and cities are annotated on each image. For many of the sites there are also ground photographs taken of the sampling site, and views upstream and downstream from the site. These aerial and ground images of the sites give a sense of place to the written descriptions and may help in the human interpretation of the data as to why *Pfiesteria* did or did not occur in a particular location.

Sabine Lake

Sabine Lake is at the confluence of the Sabine and Neches rivers on the border between Louisiana and Texas. In addition to the rivers, the lake has a number of wide bayous flowing into it. Sabine Lake has a 8.1 kilometer long tidal inlet, known as Sabine Pass, that connects the lake to the Gulf of Mexico. The Waterway connects an industrial complex of four ports (Port Arthur, Beaumont, Orange, and Sabine Pass) to the Gulf of Mexico, and along with canal systems, supplies water to municipal and industrial customers including petrochemical plants, a pulp and paper mill, a steel plant, and an electrical generating station (SRA, 2002). Water is also supplied for the purpose of rice irrigation, crawfish and catfish farming (SRA, 2002). The Sabine estuary has been made more saline by human actions, primarily by changes both upstream and at the mouth of the tidal lake (CRCL, 1999).

In 2001, data analyses by the Sabine River Authority (SRA) indicated water quality problems in three subwatersheds (Adams, Cow, and Little Cypress bayous) on the lower Sabine River. Impairments included low dissolved oxygen levels, high fecal coliforms, and high nutrients (TEP, 1998). Studies indicated the impairments were due to both point and non-point sources (SRA, 2000).

The *Pfiesteria* sampling was performed from a boat in Sabine Pass near the Sabine Pass Swing Bridge just below the confluence with Sabine Lake on the west side of the channel in 1.3 meters of water (Figures A-1, A-2, A-3).

Figure A-1. Color infra-red Landsat image showing the location of the Sabine Pass Swing Bridge *Pfiesteria* sampling location.

Figure A-2. View to the west from the location of the Sabine Pass Swing Bridge *Pfiesteria* sampling location.

Figure A.3. View to the south from the location of the Sabine Pass Swing Bridge *Pfiesteria* sampling location.

Tabbs Bay

Tabbs Bay is located at the northern end of the Galveston Bay estuary system, and receives water from the Houston Ship Channel. Along its length, the Houston Ship Channel receives treated wastewater from many industrial sites as well as nonpoint-source runoff from parts of metropolitan Houston. The San Jacinto River joins the Houston Ship Channel fifteen miles upstream from the point where the Houston Ship Channel empties into Tabbs Bay. Tabbs Bay and the San Jacinto State Park, which is just upstream of Tabbs Bay, both have many points of public access and support both recreational and subsistence fishing activities (Ward, 2001). In addition, the cities of Baytown and La Porte and their surrounding suburbs flank Tabbs Bay to the north and south. In 1990 the Texas Department of Health issued a consumption advisory for the Houston Ship Channel, the San Jacinto River and Tabbs Bay due to contamination of catfish and blue crabs with dioxins (Seafood Safety Division, 2001).

The Pfiesteria sampling was conducted from a boat in Tabbs Bay (Figure A-4)

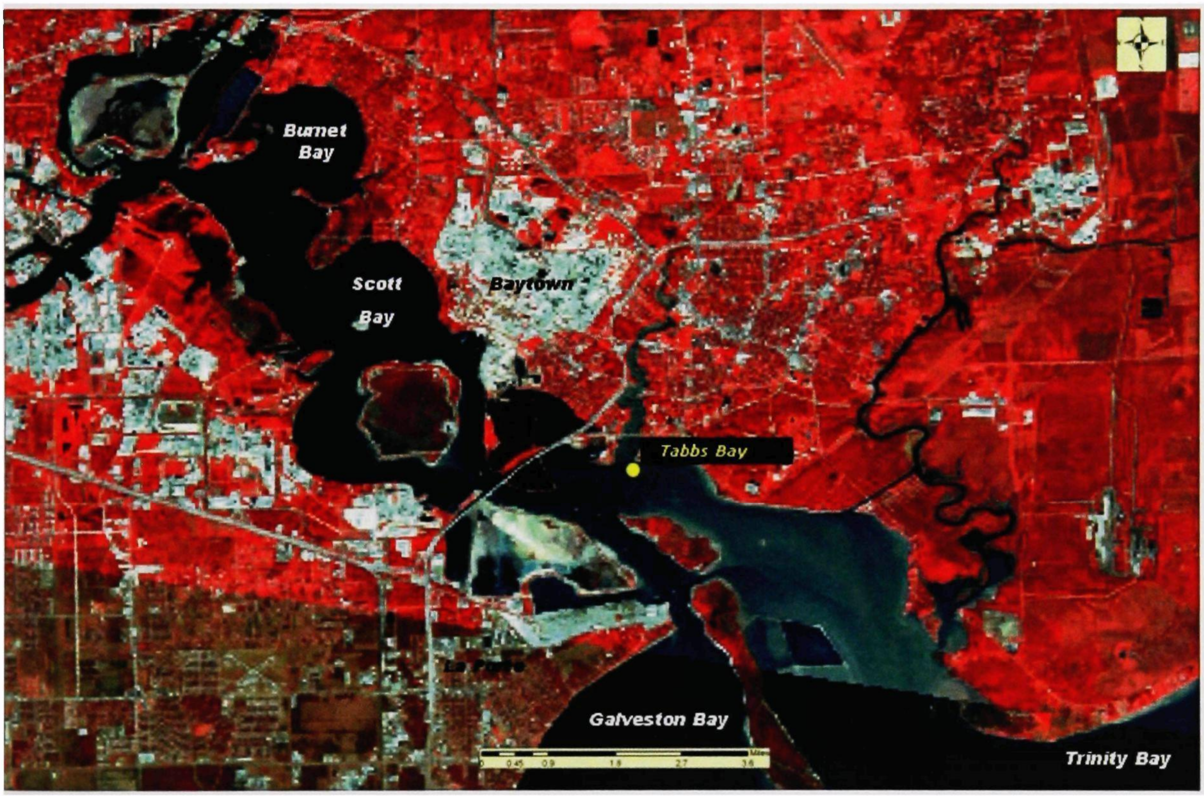

Figure A-4. Color infra-red Landsat image showing the location of the Tabbs Bay *Pfiesteria* sampling station.

Armand Bayou,

Armand Bayou is a coastal tributary of Clear Lake, a secondary bay in the Galveston Bay system in southern Harris County. The bayou consists of a tidal reach and a non-tidal reach with the tidal reach extending 12.9 kilometers north of Clear Lake. The bayou, which is also one of only four Texas coastal preserves, covers 121 hectares. Armand Bayou is one of the only bayous in the area not channelized in the tidal reach. The bayou flows over a muddy substrate within the San Jacinto-Brazos Coastal Basin. The depth of the bayou varies but is mostly very shallow with a mean width of 12.2 meters. The flow of Armand Bayou also varies with rain and tides. The upper reaches of Armand Bayou are highly urbanized with residential and some urbanized developments. The bayou also has a history of depressed oxygen levels and high level of fecal coliform bacteria and it appeared on the Texas 1998 303(d) list for pathogens and several toxic organics, including dichloroethane, trichloroethane, carbon disulfide and chlordane (TEP, 1998). The area has lost several marshes due to groundwater pumping causing subsidence. The bayou is rich in plant and animal life and is used by canoeists, kayakers, boaters, fishermen, birdwatchers, with a minimal amount of logging, and hay cutting occurring. The bayou serves as a nursery area for speckled trout, flounder, redfish, and shellfish.

The *Pfiesteria* sampling was performed from a pier at the Armand Bayou Nature Center Figures A-5, A-6, A-7).

Clear Creek

Clear Creek rises a mile west of the Blue Ridge oil field in the northeast corner of Fort Bend County (TSHS, 2002). Clear creek is a tidally influenced bayou that meanders 75.6 through Fort Bend, Brazoria , Harris and Galveston Counties before emptying into Clear Lake (American Rivers, 2000). It drains a 411,182 hectare watershed that contains flat to rolling terrain, surfaced by sandy and clay loam that supports mixed hardwoods and pines. Its floodplain is largely undeveloped, featuring green ash and towering oak trees. The creek and its floodplain support a wide variety of wildlife including wood ducks, spotted sandpipers, osprey, roseate spoonbills, more than fifty species of fish, including redfish and flounder, and three species of shrimp. Clear Creek is a vitally important and valuable watershed. Many of the species that spawn and feed in the watershed are important to the commercial fishing industry, and the area is a popular ecotourism and recreation destination. Unfortunately, human impacts including urban development, dredge and fill activities have degraded vital watershed habitats and water resources.

The *Pfiesteria* sampling was conducted from the Route 3 bridge that crosses over Clear Creek (Figures A-5, A-8, A-9, A-10, A-11)

Clear Lake

Clear Lake, which empties into Galveston Bay, supports twenty-one marinas and has the largest number of recreational boats on the Texas coast. Recreational fishers use approximately 6,000 boat slips on the lake. Several major boat refurbishment businesses are located on the shores of Clear Lake (Ward 2001). Clear Lake is the receiving body for Clear Creek, Aramand Bayou and Taylor Bayou/Taylor Lake, all of which drain watersheds that have moderate to heavily developed suburban and associated commercial developments.

The *Pfiesteria* sampling was conducted from a pier located in a park on Clear Lake (Figures A-5, A-12, A-13)

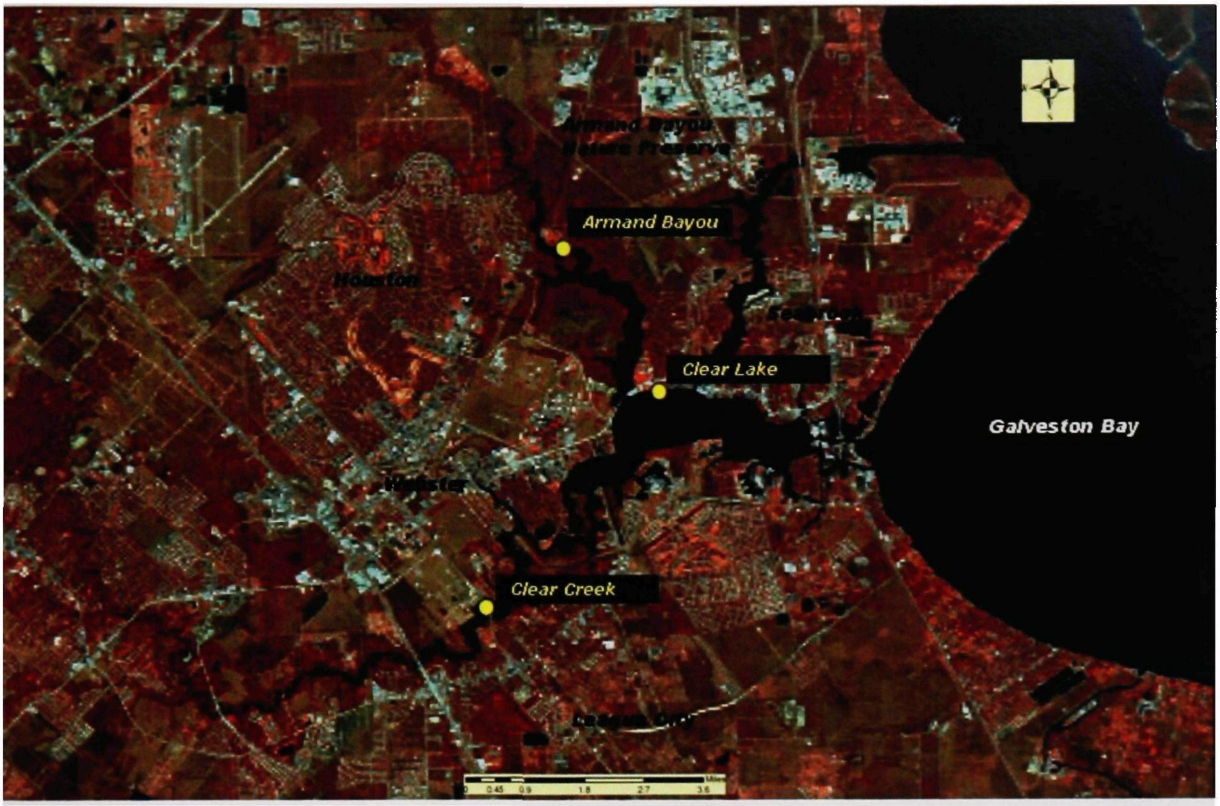

Figure A-5. Color infra-red Landsat image showing the location of the Armand Bayou, Clear Lake and Clear Creek *Pfiesteria* sampling locations.

Figure A-6. View upstream from the location of the Armand Bayou *Pfiesteria* sampling location.

Figure A-7. View downstream from the location of the Armand Bayou *Pfiesteria* sampling location.

Figure A-8. View upstream to the NW of an industrial site from the location of the Clear Creek *Pfiesteria* sampling location.

Figure A-9. View upstream to the SW from the location of the Clear Creek *Pfiesteria* sampling location.

Figure A-10. View upstream to the SE from the location of the Clear Creek *Pfiesteria* sampling location.

Figure A-11. View downstream from the location of the Clear Creek *Pfiesteria* sampling location.

Figure A-12. View to the west from the location of the Clear Lake *Pfiesteria* sampling location.

Figure A-13. View to the east from the location of the Clear Lake *Pfiesteria* sampling location.

Dickinson Bayou

Dickinson Bayou is located in the northeastern portion of Galveston County in the San Jacinto-Brazos Coastal Basins. The Bayou originates near Alvin flowing east for 36 kilometers through Dickinson and eventually into Dickinson Bay. The topography of the Dickinson Bayou area consists of flat coastal plains with sandy loam and clay soils. Dickinson Bayou contains a tidal portion and a non-tidal portion. The non-tidal segment is a small coastal prairie stream. The tidal portion is narrow and heavily forested in the upper reach while the lower reach is wide and deep. The bottom of Dickinson Bayou consists of sandy substrate in the upper portion while the lower portion consists mostly of silty clays. The depth of Dickinson Bayou ranges from 0.8 to 3.5 m while the width ranges from 12.7 to 840 m. Flow of the non-tidal section of the bayou is comprised of wastewater return flow and runoff from the watershed above. Several types of agriculture exist within the Dickinson Bayou watershed including cattle, soybean, rice, and sorghum production. Oil and gas production facilities are also scattered throughout the watershed. Several permitted facilities discharge into Dickinson Bayou consisting mostly of municipal facilities. It appeared on the Texas 1998 303(d) list for organic enrichment, low dissolved oxygen and pathogens (TEP, 1998). Salinity in the tidal portion of the bay is relatively low ranging from 1-5 ppt in the upper water column. The tidal section of the bayou is used by local residents for recreational boating, fishing, water skiing, canoeing, and other activities. The tidal section is also used for shrimping and barge traffic.

The Dickinson Bayou 1 *Pfiesteria* sampling site was located on a small pier just upstream of the Route 3 bridge crossing over Dickinson Bayou (Figures A-14, A-15, A-16). This site has a history of depressed oxygen levels and fish kills.

The Dickinson Bayou 2 *Pfiesteria* sampling site was located on the Cemetary Road bridge crossing over Dickinson Bayou (Figures A-14, A-17, A-18). A fish kill was in progress at this site at the time the *Pfiesteria* sample was collected.

Figure A-14. Color infra-red Landsat image showing the location of the Dickinson Bayou 1 and 2 *Pfiesteria* sampling locations.

Figure A-15. View upstream from Dickinson Bayou 1 *Pfiesteria* sampling station.

Figure A-16. View downstream from Dickinson Bayou 1 *Pfiesteria* sampling station.

Figure A-17. View upstream from the Dickinson Bayou 2 *Pfiesteria* sampling station.

Figure A-18. View downstream from the Dickinson Bayou 2 *Pfiesteria* sampling station.

Moses Bayou and Moses Lake

Moses Bayou is located south of the city of Dickinson in the eastern portion of Galveston County in the San Jacinto-Brazos Coastal Basin. The Bayou originates in the central part of the county and flows east 3.2 kilometers into Moses Lake, an arm of Galveston Bay (TPWD, 1998). The bayou is tidal in nature and is channeled in its middle reaches. The bayou is relatively shallow outside of its channel and the substrate of the bayou consists mostly of silty clays. The surrounding area consists of flat to rolling coastal prairie surfaced by dark, commonly calcareous clay that supports mesquite, grasses, and some cacti (TSHA, 2002a). The lake, which is two miles wide and four miles long, has a narrow opening that allows it to drain into Galveston Bay at Miller Point. In 1974 an 3.4 meter-deep channel was dredged from Moses Bayou to Miller Point to accommodate a shrimp fleet that harbors there (TSHA, 2002b). Moses Lake is a mile from the Gillock South oilfield and has producing oil wells and storage tanks along the shoreline. Most of the lake is surrounded by marsh. The mean low-tide lake level is between one and three feet, however, during heavy rainstorms the lake used to crest at 1.5 meters. To reduce flooding from an increase in the lake level, an 2.4 meter levee on the south end of Moses Lake was installed by the city with ponding areas and Archimedes screw pumps behind it. The pumps control the lake level and lift storm waters from the city a maximum of 3.4 meters over levees into Moses Lake (TSHA, 2002b). The bayou and lake are bordered to the south by The Nature Conservancy of Texas' Texas City Prairie Preserve, which features rare coastal prairie habitat and is one of the last two or three remaining sites supporting a population of the federally endangered Attwater's Prairie chicken. The Bayou Golf Club golf course borders the upper reaches of the bayou to the south and domestic and industrial wastewater outfalls are located upstream of Moses Lake.

The Moses Lake *Pfiesteria* sampling was performed in the upper reaches of Moses Lake on the south side of the channel in 1.0 meter of water (Figure A-19).

The Moses Bayou *Pfiesteria* sampling was performed from the railroad trestle that crosses the bayou just upstream of the Route 146 bridge (Figures A-19, A-20, A-21)

Figure A-19. Color infra-red Landsat image showing the location of the Moses Lake and Moses Bayou *Pfiesteria* sampling locations.

Figure A-20. View upstream from the location of the Moses Bayou *Pfiesteria* sampling location.

Figure A-21. View downstream from the location of the Moses Bayou *Pfiesteria* sampling location.

Jamaica Beach

Jamaica Beach is a small town located on the West Bay side of Galveston Island in Galveston County. The town consists mostly of a canal subdivision on the east side of West Bay. West Bay is located on the landward side of Galveston Island and receives runoff from Chocolate Bay and Mustang Bayous and other local streams. San Luis Pass is the nearest cut from West Bay to the Gulf of Mexico at the west end with Bolivar Pass located at the east end of the bay. West Bay contains a high oyster population and also serves as a huge resource for recreational and commercial fisherman. The canal subdivision has a history of fish kills due to low dissolved oxygen in the water column. Low dissolved oxygen usually occurs during the summer due to high water temperature and low flow. Fish kills usually consist of small menhaden with little to no mortality to game fish such as red drum or spotted seatrout. No vegetation exists in the canals while the shoreline contains bulkhead along a majority of the shoreline. The area is not impacted from industry discharge but is highly impacted by reduced flow due to the maze-like nature of the canal subdivision.

The *Pfiesteria* samples were taken from a small pier adjacent to a boat ramp along the canals in approximately 1.0 meter of water with single residence homes located on each side of the canal (Figures A-22, A-23, A-24).

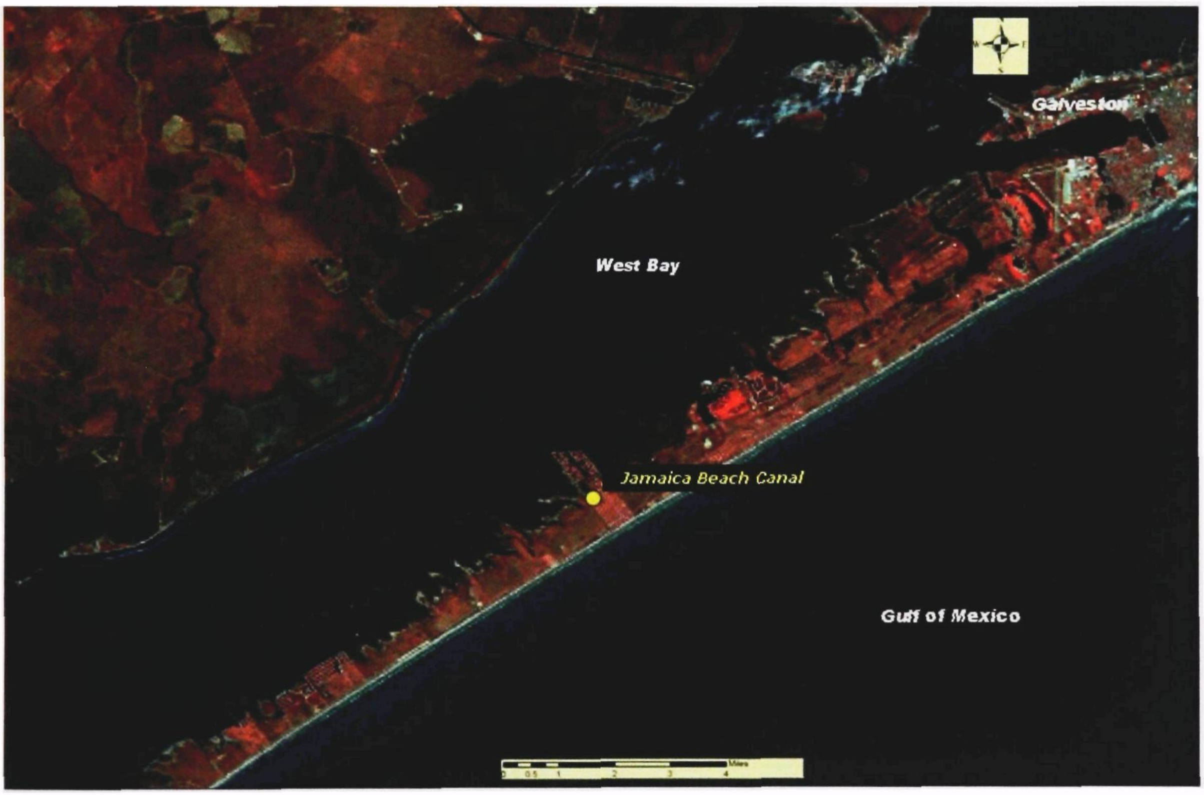

Figure A-22. Color infra-red Landsat image showing the location of the Jamaica Beach *Pfiesteria* sampling location.

Figure A-23. View from the location of the Jamaica Beach *Pfiesteria* sampling location.

Figure A-24. View from the location of the Jamaica Beach *Pfiesteria* sampling location.

Freeport North (Oyster Creek and Swan Lake)

Oyster Creek contains a tidal portion and a non-tidal portion. The tidal portion of Oyster Creek extends for approximately 33.5 kilometers from the confluence with the Intracoastal Waterway (ICWW) in Brazoria County to a point 100 meters upstream of FM 2004 in Brazoria County. The shoreline consists of emergent marsh consisting mostly of *Spartina alterniflora.* Several permitted discharges exist upstream of the site which consist of domestic and industrial facilities. The non-tidal portion of Oyster Creek has been impacted by dams, canals, and several residential developments, as evidenced by a history of fish kills due to the reduced flow.

Pfiesteria samples were taken in Swan Lake (Figure A-25) near the confluence of Oyster Creek and along Oyster Creek, several miles upstream from its confluence with the ICWW (Figures A-25, A-26, A-27).

Freeport South (ICWW and Jones Creek)

The Intracoastal Waterway (ICWW) is a dedged navigation channel that runs the length of the Texas coast. It is generally about 5 meters deep, usually much deeper than the neighboring bays and estuaries. The ICWW undergoes maintenance dredging in order to sustain barge traffic. Circulation is high due to the nearby Brazos River draining into the Gulf of Mexico. The area has been altered by maintenance dredging, locks, and boat traffic consisting of barges and recreational boats. The shoreline of the ICWW in this area is mostly marsh and prairie land.

Pfiesteria samples were taken at the edge of the ICWW adjacent to the confluence of Jones Creek (Figure A-25, A-28, A-29).

Jones Creek runs through the Peach Point Wildlife Management Area (WMA) and was once a tributary to the San Bernard until construction of the ICWW altered its path (Norris and Linam, 1999). Soils are primarily clays ranging from saline to non-saline. The creek is surrounded by bottomland hardwood forest in the north and coastal marsh and prairie land in the south. Elevation is generally 1.5 meters or less above mean sea level, with a few areas 3.0 meters or more above sea level.

Pfiesteria samples were collected from Jones Creek in the Peach Point WMA (Figure A-25).

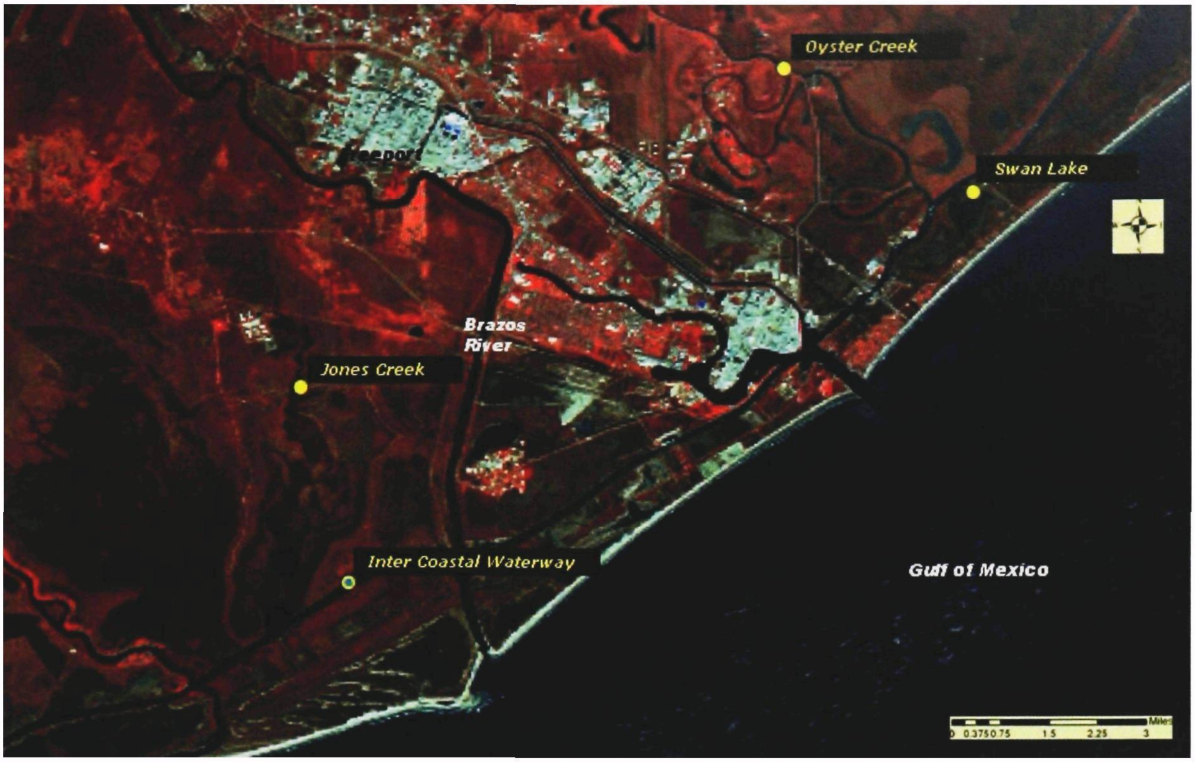

Figure A-25. Color infra-red Landsat image showing the location of the Oyster Creek, Swan Lake, Jones Creek and ICWW *Pfiesteria* sampling stations.

Figure A-26. View from the location of the Oyster Creek *Pfiesteria* sampling station.

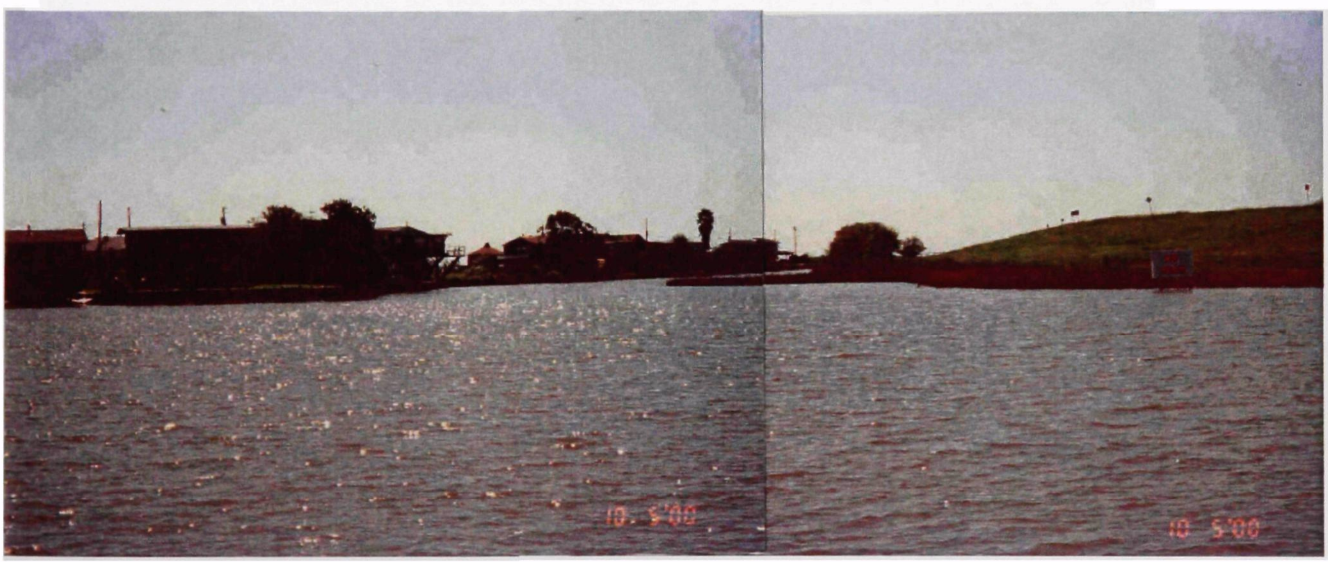

Figure A-27. View from the location of the Oyster Creek *Pfiesteria* sampling station.

Figure A-28. View to the WSW from the location of the ICWW *Pfiesteria* sampling station.

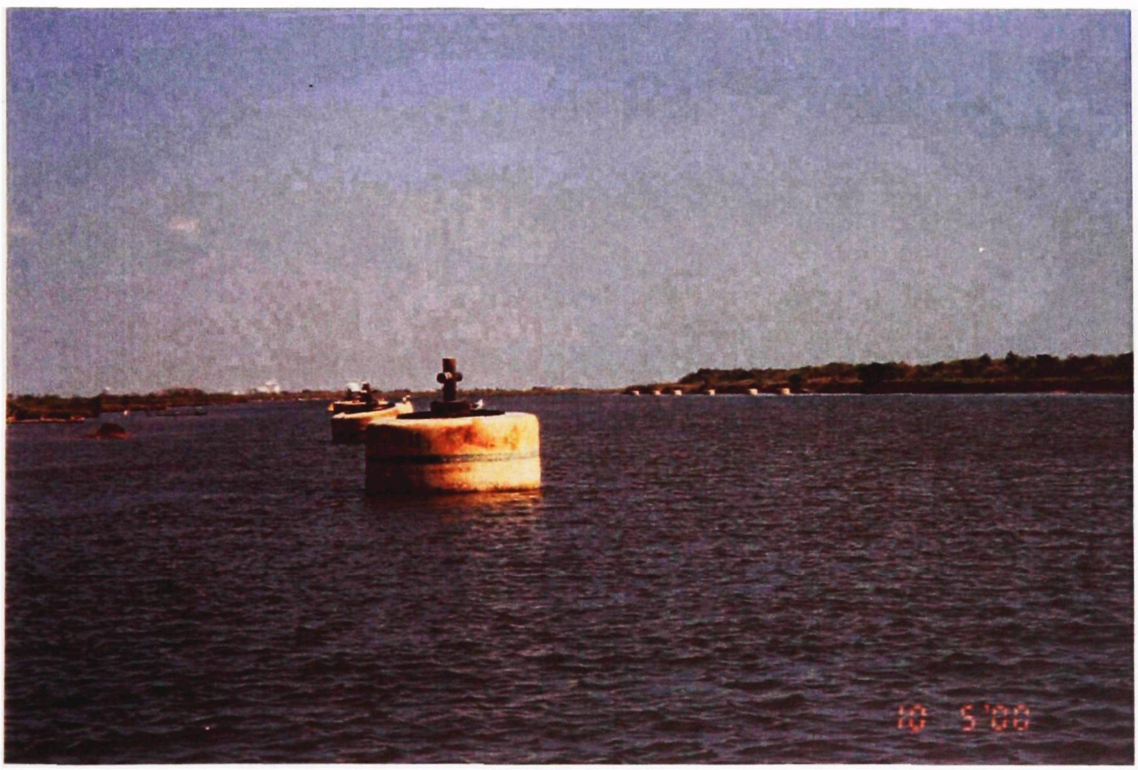

Figure A-29. View to the ENE from the location of the ICWW *Pfiesteria* sampling station.

Caney Creek

Caney Creek meanders through agricultural and rural land in Wharton and Matagorda Counties until its confluence with the ICWW and East Matagorda Bay. In Matagorda County, Caney Creek provides water for livestock, irrigation and recreation. The landscape in this region consists of broad, extensive, nearly level flood plains. Soils in the area of the coastal plain are poorly drained, nearly level, clayey saline soils. The natural vegetation consists of salt-tolerant prairie grasses and sedges. Currently all of this area is used as pasture, hayland or rangeland. The deep surface soils are underlain by clayey and loamy sediments. This area is not suited to cropland because of the high salinity and wetness. It is best suited to rangeland, pasture and wildlife habitat. The soil is poorly suited to most urban and recreational uses because of wetness, the high shrink-swell potential, excess sodium, clayey texture, corrosivity and hazard of flooding (Hyde, 2001).

The *Pfiesteria* sampling was conducted from a boat a short distance upstream from the confluence with East Matagorda Bay. The site is located near shore-side development (Figures A-30, A-31, A-32).

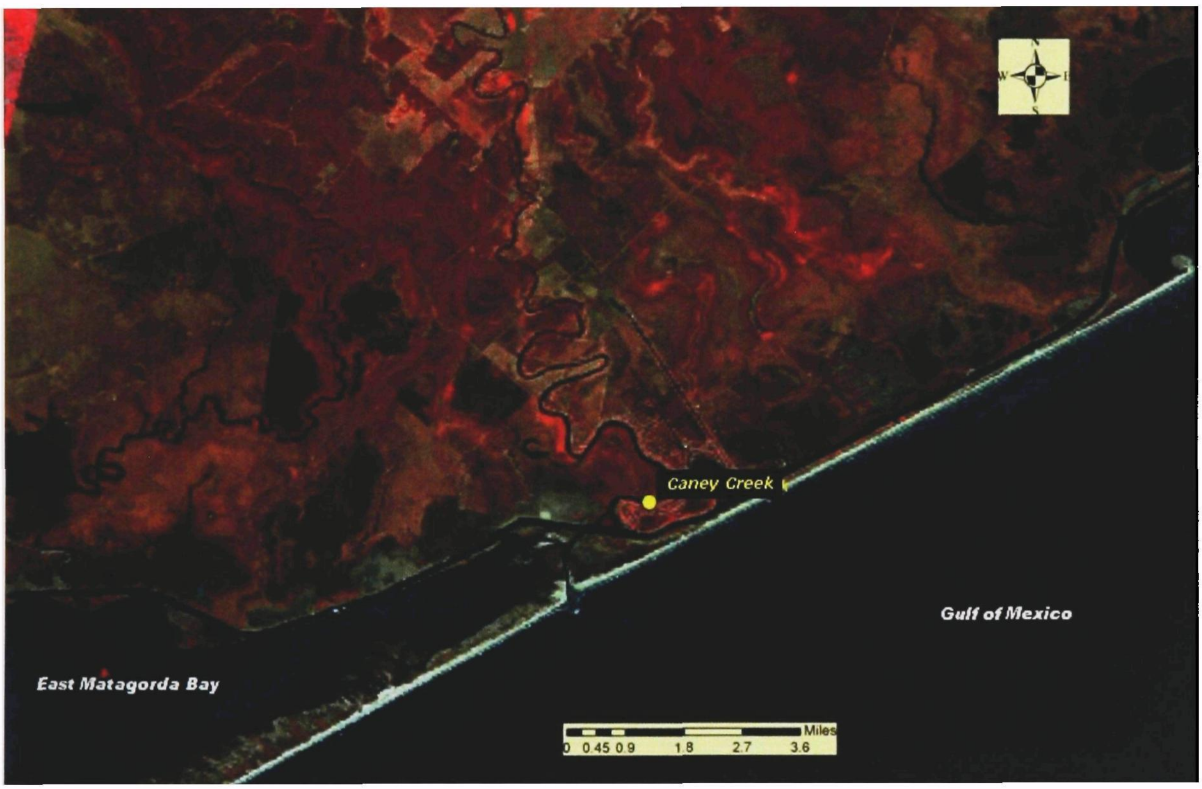

Figure A-30. Color infra-red Landsat image showing the location of the Caney Creek *Pfiesteria* sampling location.

Figure A-31. View from the location of the Caney Creek *Pfiesteria* sampling location.

Figure A-32. View from the location of the Caney Creek *Pfiesteria* sampling location.

Colorado River

The Colorado River begins in Dawson County near the Texas/New Mexico border and flows southeast approximately 956.6 kilometers to Matagorda Bay. Below the City of Austin, flow of the river is controlled exclusively by the series of Highland Lakes located upstream. The banks of the Colorado River gradually steepen and the flood plain deepens as the river moves downstream. The lower Colorado River is a slow, meandering river that is wide and deep with heavy vegetation and numerous sandbars along its banks (Belisle and Josselet, 1974). Freshwater inflows from the Colorado River help to support a productive estuarine community in the Matagorda Bay system.

Egret Island and the extended banks of the Colorado River that connect the mainland to Matagorda Peninsula and separate Matagorda Bay from East Matagorda Bay form an isthmus at the north end of the bay. Several major fish kills have occurred within this lower river segment in recent years and the old river channel has a history of low dissolved oxygen levels (LCRA, 2002). In August 1995, several million menhaden also died along this portion of the river.

The *Pfiesteria* sampling was performed from a boat just north of the location of the abovementioned fish kill. This is just upstream from the confluence with the GIWW in approximately 3 meters of water (Figure A-33).

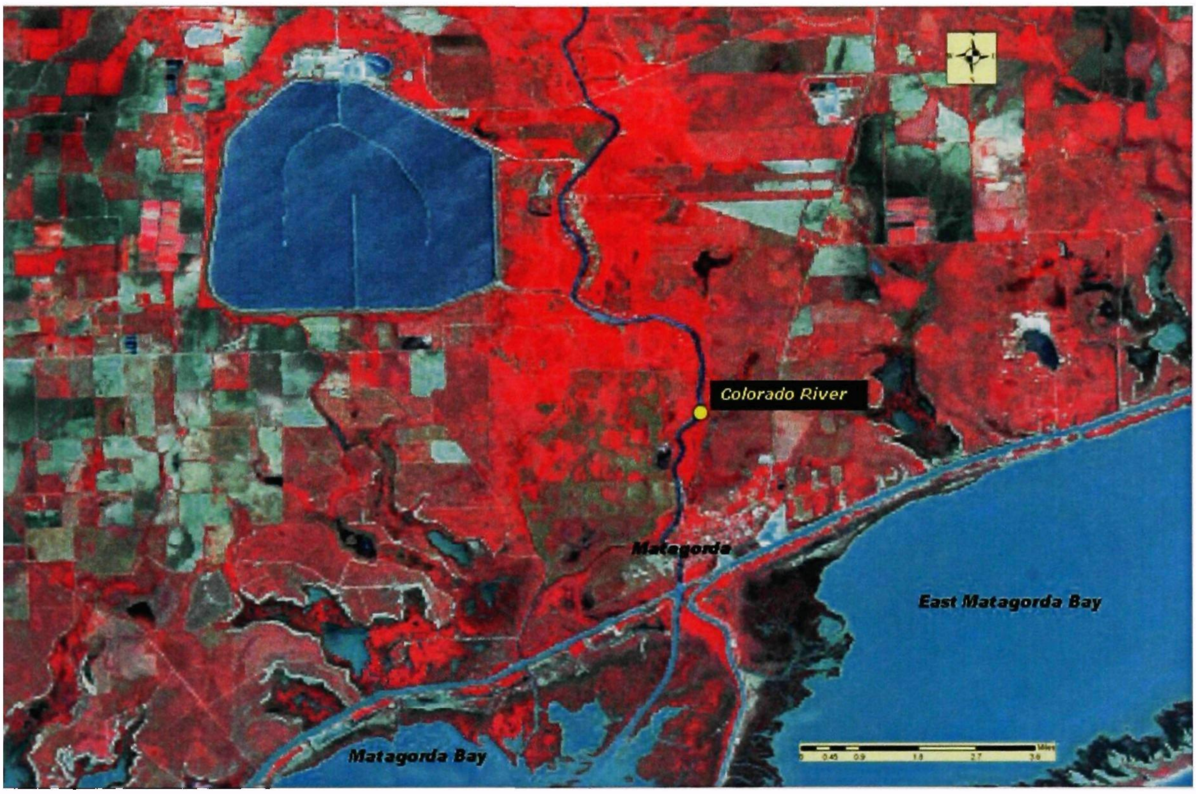

Figure A-33. Color infra-red Landsat image showing the location of the Colorado River *Pfiesteria* sampling station.

Lavaca Bay

Matagorda Bay is a major bay on the Texas coast with several smaller bays that open into it, including Tres Palacios Bay, Turtle Bay, Carancahua Bay, Keller Bay, Cox Bay, and Lavaca Bay (TSHS, 2002). The bay is also crossed by the Gulf Intracoastal Waterway (GIWW) and several ship channels to Palacios, Port O'Connor, and Port Lavaca, all of which have spoil banks alongside. The only entry to Matagorda Bay from the Gulf is through Cavallo Pass at the southern end of the Matagorda Peninsula, or the Matagorda Ship Channel.

Lavaca Bay is a micro-tidal estuary. Lavaca Bay was contaminated with mercury (Hg) from aluminum refining and chlor-alkali production during the late 1960's. Since 1988, a large portion of the bay has been closed to recreational and commercial shellfish and finfish harvesting because of elevated levels of Hg in tissues of a number of species collected in the area (Howard, 1999). Bay bottoms consist of muddy clays, shell hash and oyster reefs. The bay is currently listed on the Texas 303(d) list for mercury contamination, low dissolved oxygen and pathogens (Furnans et al., 2002)

Pfiesteria samples were collected along the north side of the causeway in 2000, just to the east of the ship channel that passes under the causeway. This has also been the location of a historic TWDB datasonde monitoring location (Figure A-34).

In 2001 *Pfiesteria* samples were collected from the Port Lavaca Fishing Pier, at approximately piling number 63. This portion of the pier no longer exists, having fallen victim to a fire in 2003 (Figures A-34, A-35, A-36).

Figure A-34. Color infra-red Landsat image showing the location of the Lavaca Bay *Pfiesteria* sampling stations.

Figure A-35. View from the Port Lavaca Fishing Pier *Pfiesteria* sampling station.

Figure A-36. View of the Port Lavaca Fishing Pier *Pfiesteria* sampling station.

Mesquite Bay

Mesquite Bay is an embayment of the Aransas Bay system. This bay is approximately 62 to 71 square kilometers in surface area (CBBEP-21, 1997). It is bounded on the west by several islands and the Intracoastal Waterway, Matagorda Island on the east, Carlos Bay on the south, and Ayres Bay on the north. There are no industrial, municipal or agricultural operations discharging directly to this body of water. The southeastern edge of the bay leads to the only single pass (Cedar Bayou Pass) along the Texas coast between Pass Cavallo, Calhoun County and the Corpus Christi Channel at Port Aransas, Nueces County. An oilfield and gas access channel was dredged over 20 years ago between Bludworth Island and Ayres Island and runs south-south east towards Matagorda Island.

Mesquite Bay is relatively shallow similar to one of eight minor bays in the area. It is less than 2.4 meters deep and varies from turbid to clear depending on wind weather. Seagrasses occur along the fringe shoreline that varies from 30 to 300 meters wide. Oysters reefs and shell hash occur in the bay. The oyster fishery is the second most important commercial fishery in the area next to the shrimp industry (U.S. Army Corps of Engineers, 1995).

The *Pfiesteria* samples were collected adjacent to a channel marker and piling about a 0.8 kilometers south-south east from the entrance to the bay from the Intracoastal Waterway (Figure A-37).

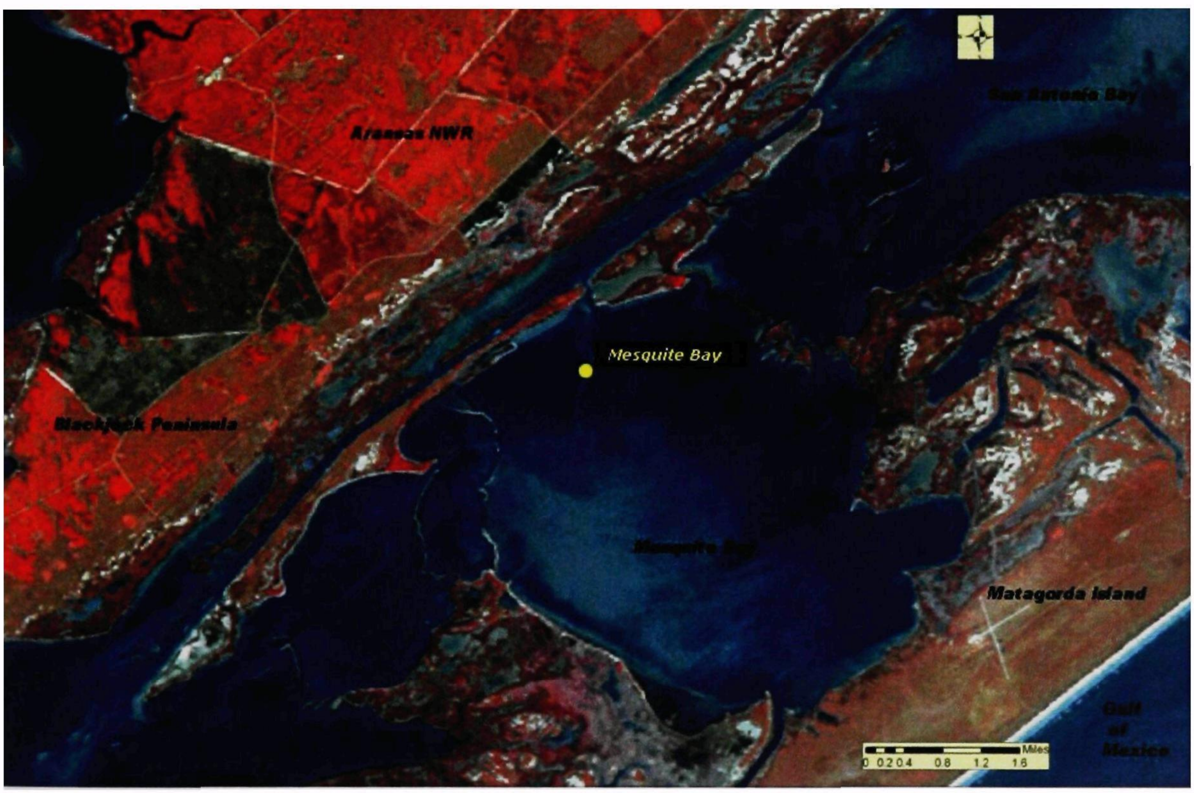

Figure A-37. Color infra-red Landsat image showing the location of the Mesquite Bay *Pfiesteria* sampling station.

Port Aransas Birding Center

The Port Aransas sewage treatment plant marsh is located on the southwest side of the town of Port Aransas, Texas. The plant discharges secondary treated sewage into a large saltmarsh area on the west side of Mustang Island. The discharge flows through a narrow channel into a broad, shallow area accessible by a boardwalk. The site is shallow (<0.5 m deep) and has extensive emergent plant growth. The bottom is generally soft silt and mud. The Port Aransas Birding Center is located here and extensive waterfowl populations are found here year round. This site was chosen because of the high organic loading found here, the soft mud bottom and shallow water.

The *Pfiesteria* samples were collected from the boardwalk that extends out into the marsh (Figures A-38, A-39).

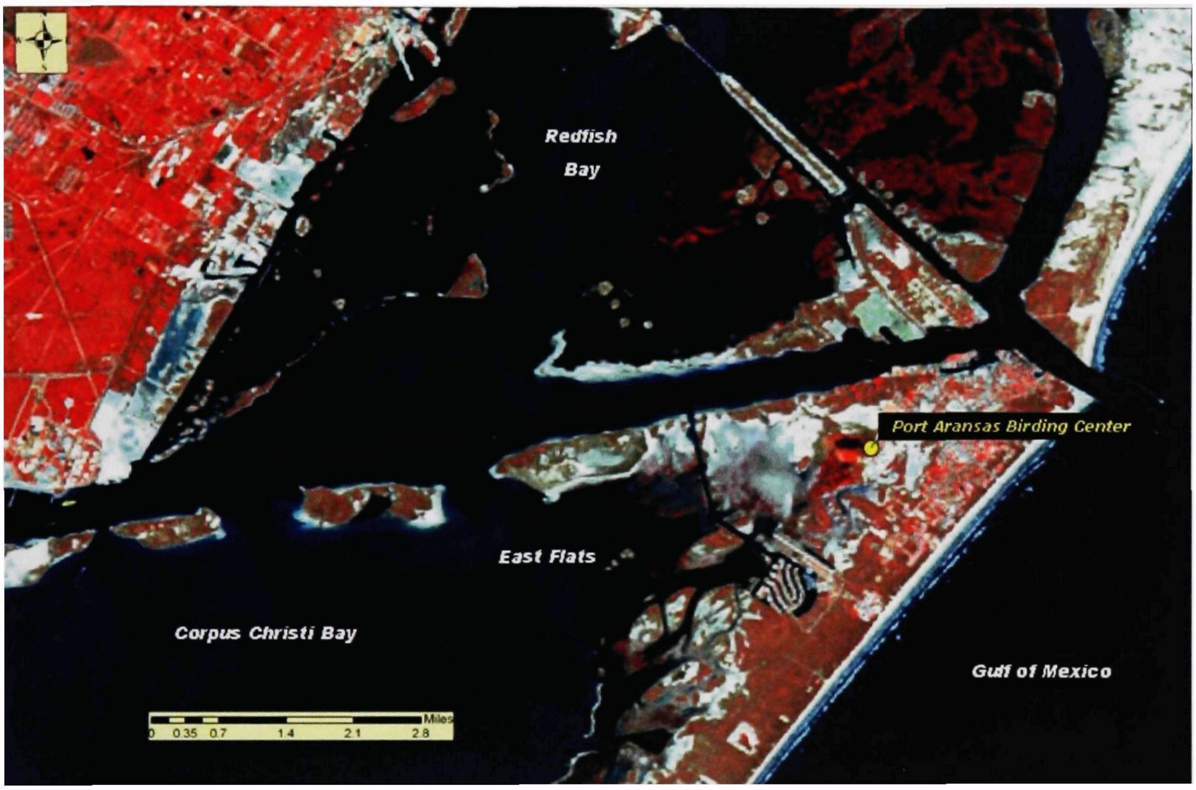

Figure A-38. Color infra-red Landsat image showing the location of the Port Aransas Birding Center *Pfiesteria* sampling station.

Figure A-39. View of the *Pfiesteria* sampling station at the Port Aransas Birding Center.

Nueces River

The study area is located in the lower portion of the Nueces River basin. This 97 kilometer corridor adjacent to the Gulf coast is the coastal prairie. Much of this land is under cultivation, including feed crops, sorghum, flax, cotton and vegetables. In addition, oil production and refining operations have led to significant industrial development. Soils in this area are clayey and loamy deltaic sediments, while relief is level to nearly level. Vegetation outside of agricultural areas is typically tall grasses, oak motts (US DOI 1983) and mesquite. There is a moderate amount of suburban development along the south bank of the Nuceces River adjacent to the study area. The north shore of the river is bordered by the marshes and pasture land of the Rincon Delta.

The *Pfiesteria* samples were collected from a small boat, a few hundred meters downstream of the Allison STP outfall, and just upstream of the Union Pacific railroad bridge over the Nueces River (Figures A-40, A-41, A-42).

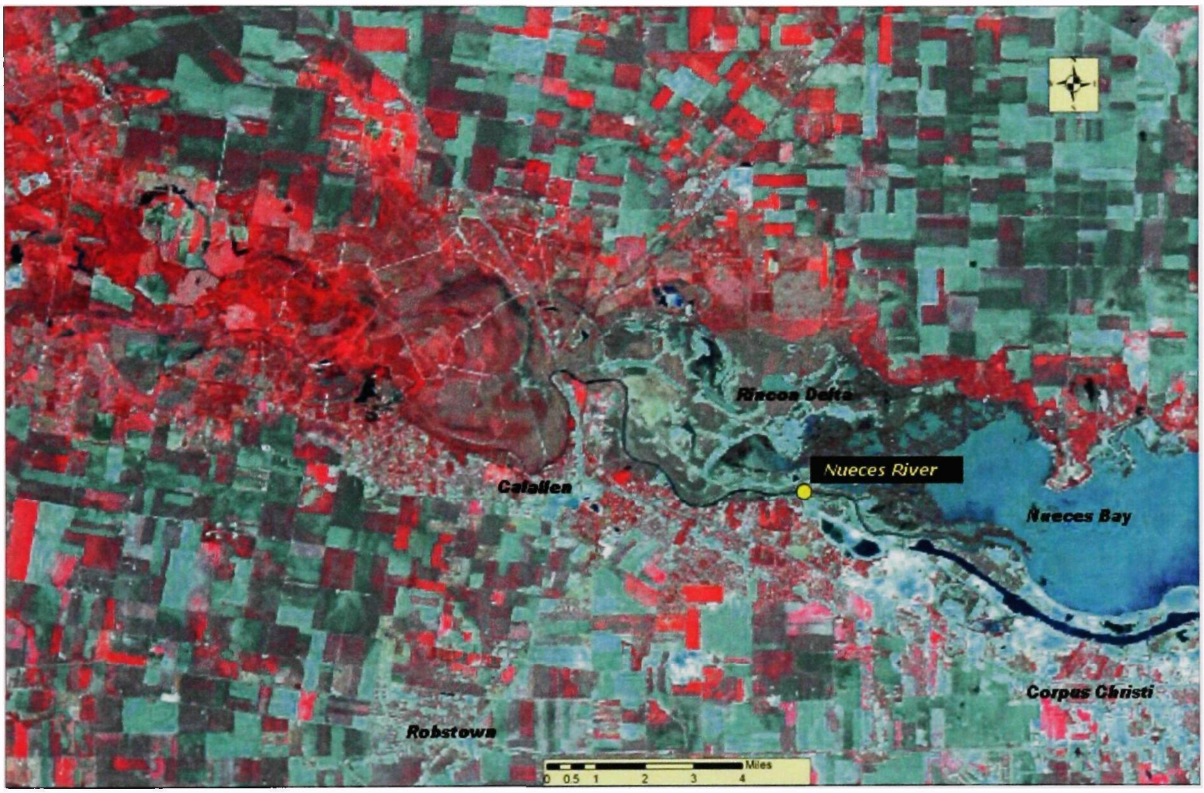

Figure A-40. Color infra-red Landsat image showing the location of the Nueces River *Pfiesteria* sampling location.

Figure A-41. View of the Allison STP just upstream from the location of the Nueces River *Pfiesteria* sampling location.

Figure A-42. View from upstream of the location of the Nueces River *Pfiesteria* sampling location.

Oso Bay

Cayo del Oso, or Oso Bay, is the estuary of Oso Creek. Oso Creek has a watershed of approximately 59,580 heactares and has only intermittent flow (Hildebrand and King, 1974, 1975, 1976). On its northern boundary, Oso Bay connects to Corpus Christi Bay. Because of its shallow depth and sediments composed primarily of silt clays or clay, it is easily stirred by the slightest wind resulting in very turbid waters, and hence the name of 'Mud Bridge' as known and recognized by the local population (Hildebrand et al. 1973).

While covering about 2,023 surface hectares, large portions of the Oso are very shallow, inundated only with several inches of water. Two major upstream sources of flow to the Oso from the sampling station include return flows from the Central Power and Light Power Plant cooling ponds (about 1.4 kilometers upstream), and the Greenwood Street Wastewater Treatment Plant (about 20.6 upstream). The bay is hydrologically driven by daily and seasonal tides, stream flow from Oso Creek, and warm water discharge from the Barney Davis Power Plant (CCBNEP, 1997). The bay may also be minimally influenced by the Oso Wastewater Treatment Plant which discharges near the Blind Oso, a wind tidal flat just west of Ward Island. The discharge from this plant is downstream and north west about 10.4 km.

Extensive intertidal wetlands along Oso Creek adjacent to Mud Bridge are important feeding and roosting sites for migratory and resident shorebirds. Warm waters discharging from the Barney Davis Power Plant Facility tend to attract fishermen who drive onto the exposed flats to reach prime fishing areas. Vehicular traffic across the intertidal flats has decreased vegetation cover and caused surface erosion. This has also led to occasional dumping of trash in the area (CCBNEP, 1997).

The Oso Bay 1 *Pfiesteria* samples were collected from the Ocean Drive bridge over the mouth of Oso Bay (Figures A-43, A-44, A-45).

The Oso Bay 2 *Pfiesteria* samples were collected from Mud Bridge, which is the Yorktown Rd, bridge over the upper reaches of Oso Bay (Figures (A-43, A-46, A-47).

The Oso Creek *Pfiesteria* sampling site was located at the Staples Road bridge (Figures A-43, A-48, A-49).

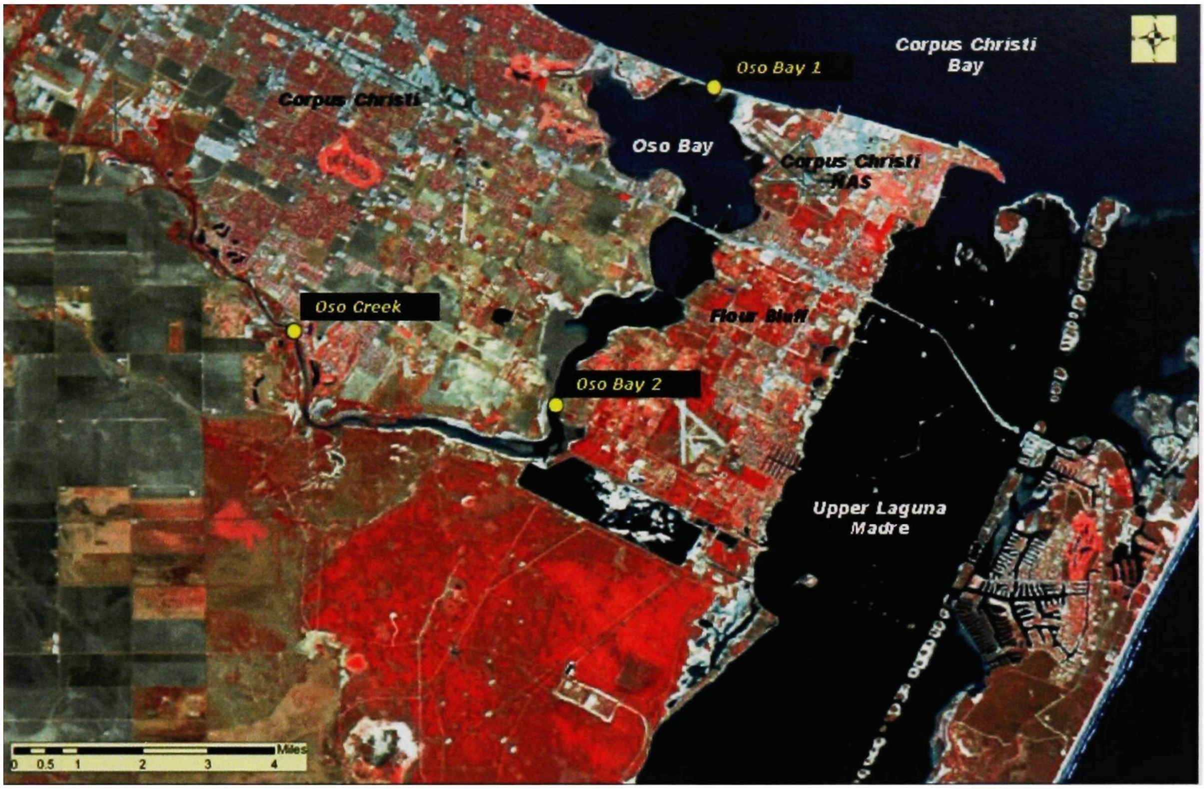

Figure A-43. Color infra-red Landsat image showing the location of the Oso Creek and Oso Bay 1 and 2 *Pfiesteria* sampling stations.

Figure A-44. View to the west from the location of the Oso Bay 1 *Pfiesteria* sampling station. TAMU-CC campus is in the mid to right background.

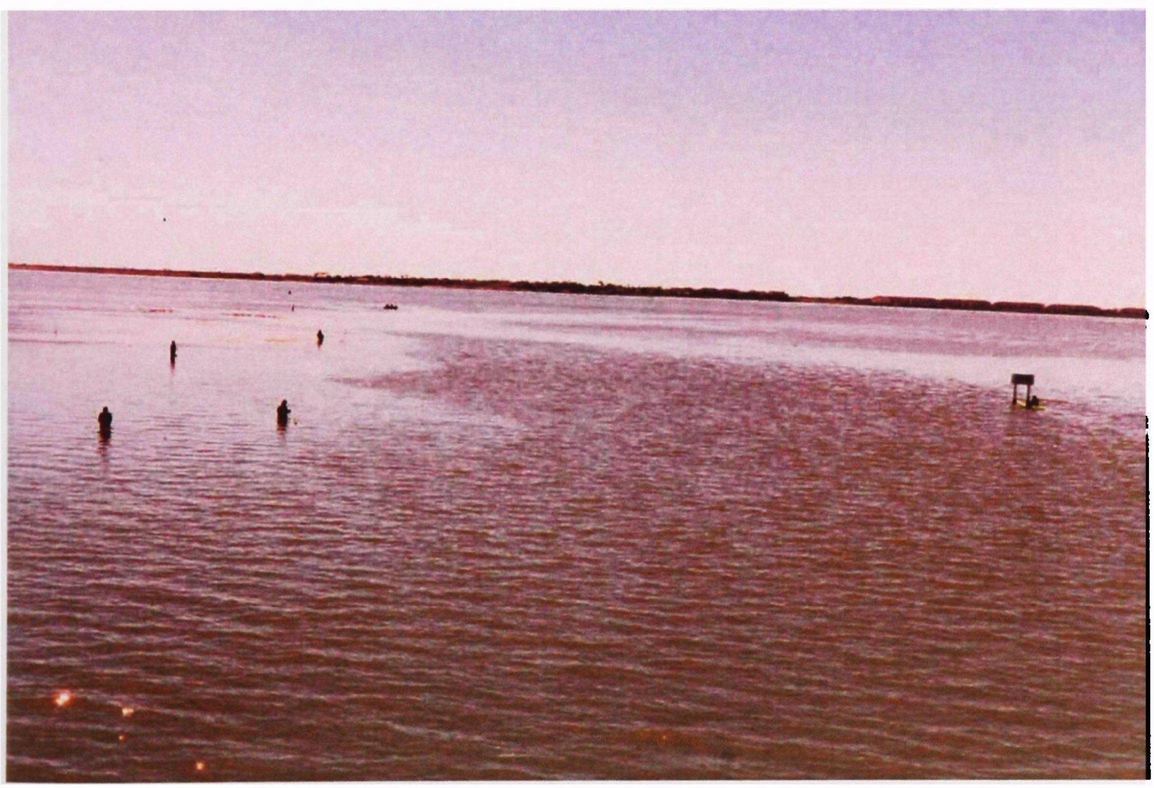

Figure A-45. View to the SSW from the location of the Oso Bay 1 *Pfiesteria* sampling station.

Figure A-46. View to the NW from the location of the Oso Bay 2 *Pfiesteria* sampling station.

Figure A-47. View to the SE from the location of the Oso Bay 2 *Pfiesteria* sampling station.

Figure A-48. View upstream to the NW from the location of the Oso Creek *Pfiesteria* sampling station.

Figure A-49. View downstream to the SE from the location of the Oso Creek *Pfiesteria* sampling station.

Baffin Bay (Bayview Campground and Kraatz Pier)

Baffin Bay covers approximately 22,015 to 24,605 hectares of surface area (Tunnel et al., 2002). In addition to the main bay, there are three smaller bays joining at the west end. The Cayo del Grullo arm extends northwest while Laguna Salada extends westward. The third arm is Alazan Bay, east of Cayo del Grullo, and extends north from the main body. It is nearest to the mouth of Baffin Bay before it connects to the Upper Laguna Madre.

The main freshwater inflows to this area include the following: Los Olmos Creek drains into the Laguna Salada. This area is primarily characterized by agriculture and ranching operations. The Cayo del Grullo arm receives flow from the San Fernando, Santa Gertrudis and Jaboncillos Creeks. Flows into one of these creeks are primarily a result of effluent discharges from Kingsville and Alice, and from Celanese Chemical plant near Bishop. These creeks are also surrounded by large agricultural or farming operations along their course to the bay. The main drainage to the third arm of Baffin Bay, Alazan Bay, is Petronila Creek and is also primarily influenced by agricultural and framing operations; the flow for this creek is intermittent. However, until oil field brine disposal was curtailed and stopped in the early 1990's, Petronila Creek was highly contaminated from numerous discharges from oil/salt water separators.

Except for the municipal discharges which enter Cayo del Grullo, freshwater inflows into Baffin Bay are lacking. Consequently, hypersaline conditions (reported as high as 80 ppt or higher in the past) are common in Baffin Bay (CCBNEP, 1996). Baffin Bay is also characterized by high turbidity and silty, clay bottoms. Seagrasses occur primarily along portions of the protected southern shoreline along the King Ranch and near the mouth of the Upper Laguna Madre.

The Bayview Campground *Pfiesteria* sampling site is located on a pier at the campground (Figures A-50, A-51, A-52).

The Kraatz Pier *Pfiesteria* sampling site is located at the end of a 15 meter pier on the eastern shoreline of Riveria Beach. This site sits at the juncture or split between two of three arms of Baffin Bay and the main bay (Figures A-53, A-54).

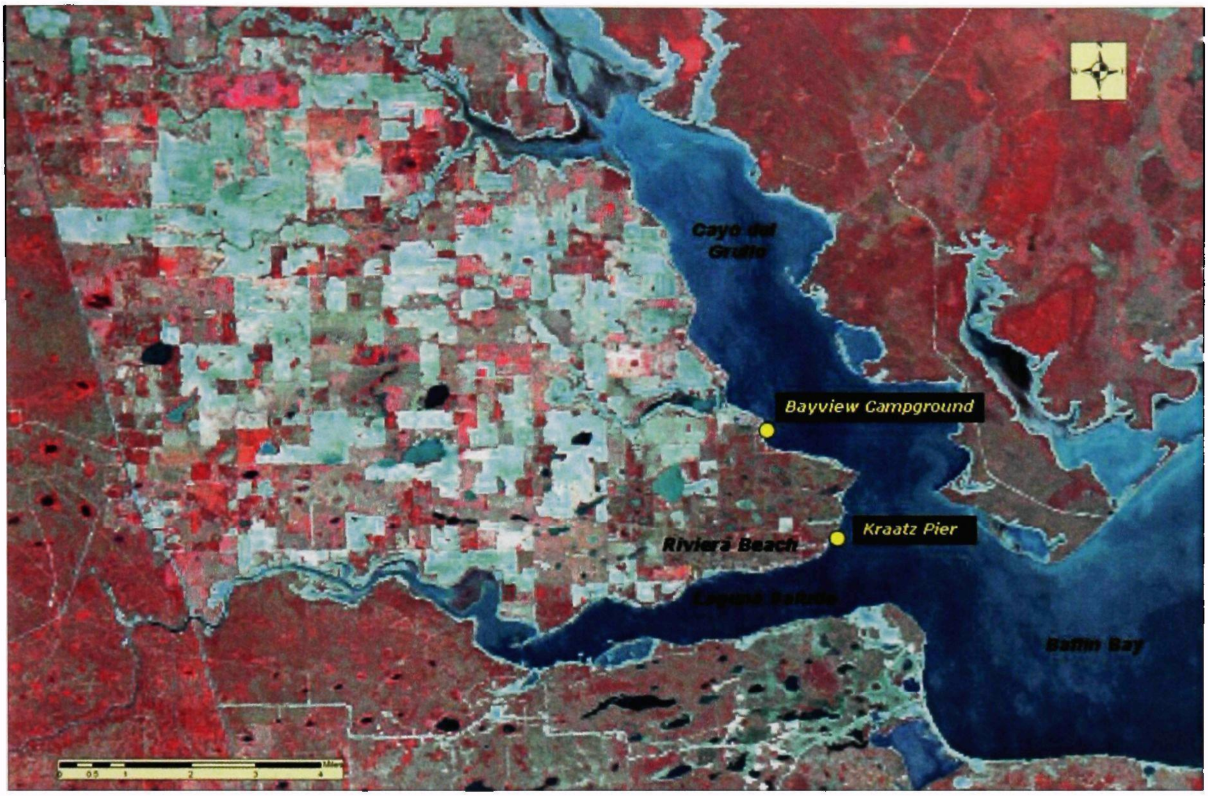

Figure A-50. Color infra-red Landsat image showing the location of the Bayview Campground and Kraatz Pier *Pfiesteria* sampling stations.

Figure A-51. View to the east of the location of the Bayview Campground *Pfiesteria* sampling station.

Figure A-52. View to the west from the location of the Bayview Campground *Pfiesteria* sampling station.

Figure A-53. View to the west from the location of the Kraatz Pier *Pfiesteria* sampling station.

Figure A-54. View to the west from the location of the Kraatz Pier *Pfiesteria* sampling station.

Arroyo Colorado

The Arroyo Colorado extends from Mission in Hidalgo County to the Laguna Madre in Cameron County. It serves as a floodway for overflow from the Rio Grande, inland waterway, and a recreation resource for boating and fishing. The tidal segment extends 42 kilometers from the confluence with the Laguna Madre in Cameron/Willacy County. The tidal reach is dredged to a depth of 5 meters to accommodate barge traffic to the Port of Harlingen. Perennial flow is maintained by domestic wastewater discharges (most municipalities along the above tidal portion reach discharge their treated effluent into the Arroyo Colorado), supplemented by irrigation return flow, a major activity along the course of the stream, and urban runoff on a seasonal basis. Frequent fish kills, and poor water quality and contaminant concerns have been documented on the Arroyo Colorado for at least the last 30 years. The entire Arroyo has been designated as an impaired water body and a Total Maximum Daily Loading (TMDL) water body by the TCEQ – the upper segment for depressed dissolved oxygen levels, and the tidal portion for chlordane, toxaphene and DDE levels in sediments. The Texas Department of Health issued a fish consumption closure for the upper tidal segment, and a fish consumption advisory for the tidal segment in the 1980's which continue today.

Discharges during the 1980's and the mid-1990's from aquaculture facilities in the Arroyo City area were the source of significant sediment and nutrient loading (TPWD internal reports). Frequent fish kills due to low dissolved oxygen levels are still reported in the Port of Harlingen portion. This may be attributed to a combination of several factors including the change of the topography of the stream bottom from sheet flows (-0.3 to-0.6 m) above tidal to the dredged channel and port (–6.1+ meter depth), low stream flows, poor circulation, and nutrient loading from point and non-point sources previously described.

The *Pfiesteria* samples were collected at the west-end of the fishing pier at the Adolph Tomae Jr. County Park. The pier is about 9.6 kilometers west from the intersection of the Arroyo Colorado with Gulf Intracoastal Waterway and Lower Laguna Madre (Figures A-55, A-56, A-57, A-58).

Figure A-55. Color infra-red Landsat image showing the location of the Adolph Tomae Jr. County Park *Pfiesteria* sampling location.

Figure A-56. View of the location of the Arroyo Colorado Pfiesteria sampling site at the Adolph Tomae Jr. County Park.

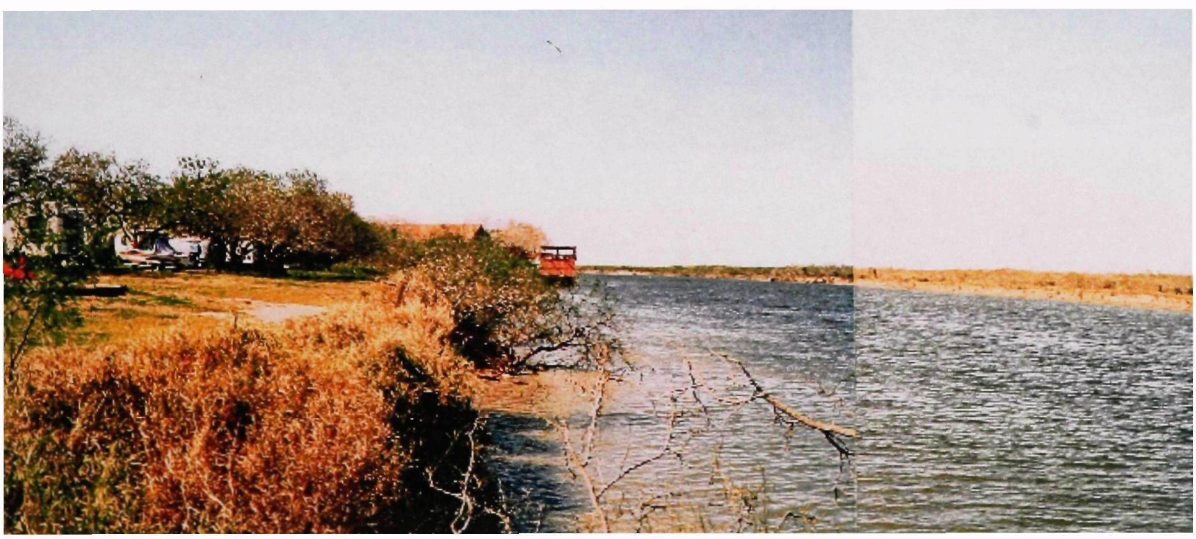

Figure A-57. View upstream from the location of the Arroyo Colorado Pfiesteria sampling site at the Adolph Tomae Jr. County Park.

Figure A-58. View downstream from the location of the Arroyo Colorado *Pfiesteria* sampling site at the Adolph Tomae Jr. County Park.

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Appendix B

Data Tables

Table B-1. Station data for *Pfiesteria* sampling sites in Texas in 2000. (Sample media codes: W=water, S=sediment).

Major System	Minor System	Location	Sample ID	Sample Medium	Date Collected	Time Collected	Latitude	Longitude	Comments
Sabine Lake	Sabine Lake	Sabine Pass	TX 17	W	4/25/2000	1450	29 45 50.1	93 53 51.6	
Sabine Lake	Sabine Lake	Sabine Pass	TX 18	W	4/25/2000	1450	29 45 50.1	93 53 51.6	
Sabine Lake	Sabine Lake	Sabine Pass	TX 44	S	4/25/2000	1450	29 45 50.1	93 53 51.6	
Sabine Lake	Sabine Lake	Sabine Pass	TX 26	W	6/1/2000	1138	29 45 50.1	93 53 51.6	
Sabine Lake	Sabine Lake	Sabine Pass	TX 61	W	6/23/2000	1202	29 45 47.8	93 53 48.2	
Sabine Lake	Sabine Lake	Sabine Pass	TX 67	W	7/12/2000	1333	29 45 46.7	93 53 47.6	
Sabine Lake	Sabine Lake	Sabine Pass	TX 74	W	8/2/2000	1335	29 45 46.7	93 53 47.9	
Sabine Lake	Sabine Lake	Sabine Pass	TX 80	W	9/15/2000	1358	29 45 46.7	93 53 47.9	
Galveston Bay	Cear Lake	Clear Lake	TX 20	W	4/26/2000	1405	29 33 50.5	95 03 51.9	
Galveston Bay	Cear Lake	Clear Creek	TX 30	W	5/11/2000	1337	29 31 10.8	95 06 08.6	
Galveston Bay	Cear Lake	Clear Creek	TX 27	W	6/21/2000	0900	29 31 09.7	95 06 08.7	
Galveston Bay	Cear Lake	Armand Bayou	TX 66	W	7/10/2000	1300	29 35 35.7	95 05 06.6	
Galveston Bay	Cear Lake	Armand Bayou	TX 75	W	8/7/2000	1343	29 35 43.7	95 05 24.5	
Galveston Bay	Cear Lake	Armand Bayou	TX 39	W	9/20/2000	1242	29 35 35.7	95 05 06.6	
Galveston Bay	Dickinson Bay	Dickinson Bayou 1	TX 11	W	4/19/2000	0845	29 27 26.3	95 02 57.4	
Galveston Bay	Dickinson Bay	Dickinson Bayou 1	TX 12	W	4/19/2000	0845	29 27 26.3	95 02 57.4	
Galveston Bay	Dickinson Bay	Dickinson Bayou 1	TX 41	S	4/19/2000	0845	29 27 26.3	95 02 57.4	
Galveston Bay	Dickinson Bay	Dickinson Bayou 1	TX 28	W	6/21/2000	0946	29 27 24.4	95 02 51.2	
Galveston Bay	Dickinson Bay	Dickinson Bayou 2	TX 45	S	7/26/2000	1603	29 25 48.9	95 06 52.8	fish kill in area
Galveston Bay	Dickinson Bay	Dickinson Bayou 2	TX 72	W	7/26/2000	1603	29 25 48.9	95 06 52.8	fish kill in area
Galveston Bay	Dickinson Bay	Dickinson Bayou 1	TX 76	W	8/7/2000	1557	29 27 24.6	95 02 51.2	
Galveston Bay	Dickinson Bay	Dickinson Bayou 1	TX 35	W	9/20/2000	1100	29 27 24.4	95 02 51.4	
Galveston Bay	Galveston Bay	Tabbs Bay	TX 19	W	4/26/2000	1110	29 42 52.3	94 58 52.5	
Galveston Bay	Galveston Bay	Tabbs Bay	TX 62	W	6/23/2000	1440	29 42 25.3	94 59 24.0	
Galveston Bay	Galveston Bay	Tabbs Bay	TX 78	W	8/10/2000	1411	29 41 55.5	94 58 55.5	
Galveston Bay	Moses Lake	Moses Bayou	TX 21	W	5/11/2000	1433	29 25 15.7	94 57 42.1	

Galveston Bay	Moses Lake	Moses Lake	TX 65	W	7/7/2000	1222	29 25 31.4	94 55 34.0	
Galveston Bay	Moses Lake	Moses Bayou	TX 37	W	9/20/2000	1145	29 25 15.4	94 57 42.0	
Galveston Bay	West Bay	Jamaica Beach Canal	TX 15	W	4/19/2000	1435	29 11 17.4	94 58 50.6	
Galveston Bay	West Bay	Jamaica Beach Canal	TX 16	W	4/19/2000	1435	29 11 17.0	94 58 51.0	
Galveston Bay	West Bay	Jamaica Beach Canal	TX 43	S	4/19/2000	1435	29 11 17.4	94 58 50.6	
Galveston Bay	West Bay	Jamaica Beach Canal	TX 22	W	5/15/2000	1240	29 11 20.0	94 58 49.6	
Galveston Bay	West Bay	Jamaica Beach Canal	TX 29	W	6/21/2000	1130	29 11 19.1	94 58 49.0	
Galveston Bay	West Bay	Jamaica Beach Canal	TX 73	W	7/27/2000	1210	29 11 19.1	94 58 49.3	
Galveston Bay	West Bay	Jamaica Beach Canal	TX 77	W	8/9/2000	1013	29 11 19.0	94 58 49.2	
Galveston Bay	West Bay	Jamaica Beach Canal	TX 105	W	10/4/2000	1525	29 11 19.4	94 58 49.1	
Brazos River	Freeport North	Oyster Creek	TX 24	W	5/30/2000	1239	29 00 16.9	95 18 46.7	
Brazos River	Freeport North	Swan Lake	TX 68	W	7/20/2000	1000	28 58 39.8	95 16 15.7	
Brazos River	Freeport North	Oyster Creek	TX 104	W	10/4/2000	1123	29 00 14.1	95 18 31.2	red tide in area
Brazos River	Freeport South	Intracoastal Waterway	TX 25	W	5/30/2000	1431	28 53 14.2	95 25 26.0	
Brazos River	Freeport South	Jones Creek	TX 69	W	7/20/2000	1140	28 56 07.2	95 25 14.6	
Brazos River	Freeport South	Intracoastal Waterway	TX 106	W	10/4/2000	1234	28 53 33.9	95 24 36.2	red tide in area
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 13	W	4/19/2000	1215	29 27 25.9	95 02 57.7	
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 14	W	4/19/2000	1215	29 27 26.9	95 02 57.7	
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 42	S	4/19/2000	1215	29 27 26.9	95 02 57.7	
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 64	W	6/28/2000	1105	28 46 06.7	95 38 25.3	
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 71	W	7/26/2000	1411	28 46 06.8	95 38 25.3	fish kill in area
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 79	W	8/15/2000	1114	28 46 06.8	95 38 25.3	
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 102	W	9/22/2000	1053	28 46 06.8	95 38 25.3	red tide in area
Matagorda Bay	Lavaca Bay	Lavaca Bay Causeway	TX 2	W	4/13/2000	1125	28 39 12.0	96 35 44.0	water color green-brown
Matagorda Bay	Lavaca Bay	Lavaca Bay Causeway	TX 32	W	5/17/2000	1430	28 39 12.0	96 35 44.0	
Matagorda Bay	Lavaca Bay	Lavaca Bay Causeway	TX 85	W	6/30/2000	1330	28 39 12.0	96 35 44.0	
Matagorda Bay	Lavaca Bay	Lavaca Bay Causeway	TX 91	W	7/25/2000	1330	28 39 12.0	96 35 44.0	
Matagorda Bay	Lavaca Bay	Lavaca Bay Causeway	TX 97	W	9/29/2000	1400	28 39 12.0	96 35 44.0	
Matagorda Bay	Matagorda Bay	Colorado River	TX 23	W	5/26/2000	1108	28 43 20.1	95 58 16.4	

Matagorda Bay	Matagorda Bay	Colorado River	TX 70	W	7/26/2000	1220	28 43 14.7	95 58 17.6	fish kill in area
Matagorda Bay	Matagorda Bay	Colorado River	TX 108	W	9/22/2000	1408	28 43 14.7	95 58 17.6	
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 8	W	4/18/2000	1100	27 49 38.0	97 04 42.9	
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 10	W	5/24/2000	1400	27 49 38.0	97 04 42.9	
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 9	W	6/21/2000	1000	27 49 38.0	97 04 42.9	
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 111	W	7/12/2000	0900	27 49 38.0	97 04 42.9	
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 112	W	8/14/2000	1100	27 49 38.0	97 04 42.9	
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 99	W	10/3/2000	1453	27 49 40.8	97 04 47.5	heavy algal bloom, water green
Aransas Bay	Mesquite Bay	Mesquite Bay	TX 33	W	5/17/2000	1130	28 09 46.0	96 51 35.0	
Aransas Bay	Mesquite Bay	Mesquite Bay	TX 93	W	7/24/2000	1233	28 10 04.2	96 51 29.6	
Aransas Bay	Mesquite Bay	Mesquite Bay	TX 100	W	10/4/2000	1030	28 10 01.1	96 51 30.2	
Corpus Christi Bay	Nueces Bay	Nueces River	TX 38	W	4/19/2000	950	27 51 36.0	97 33 23.0	
Corpus Christi Bay	Nueces Bay	Nueces River	TX 31	W	5/16/2000	1334	27 51 38.0	97 33 24.0	
Corpus Christi Bay	Nueces Bay	Nueces River	TX 87	W	6/14/2000	1527	27 51 22.7	97 33 37.7	
Corpus Christi Bay	Nueces Bay	Nueces River	TX 40	W	7/12/2000	1403	27 51 24.0	97 33 37.0	
Corpus Christi Bay	Nueces Bay	Nueces River	TX 34	W	8/10/2000	1323	27 51 38.0	97 33 24.0	
Corpus Christi Bay	Nueces Bay	Nueces River	TX 36	W	9/7/2000	1255	27 51 23.4	97 33 36.7	
Corpus Christi Bay	Oso Bay	Oso Bay 1	TX 3	W	4/13/2000	1700	27 43 05.8	97 19 52.9	incoming current from Corpus Christi Bay
Corpus Christi Bay	Oso Bay	Oso Bay 2	TX 82	W	5/30/2000	1617	27 38 25.1	97 20 34.1	CP&L releasing water
Corpus Christi Bay	Oso Bay	Oso Creek	TX 83	W	6/20/2000	1215	27 39 24.1	97 24 06.1	
Corpus Christi Bay	Oso Bay	Oso Bay 2	TX 86	W	7/12/2000	0945	27 38 26.3	97 20 36.5	
Corpus Christi Bay	Oso Bay	Oso Bay 2	TX 89	W	8/8/2000	1035	27 38 26.3	97 20 36.5	
Corpus Christi Bay	Oso Bay	Oso Bay 2	TX 95	W	9/15/2000	1000	27 38 26.3	97 20 36.9	CP&L releasing water
Upper Laguna Madre	Baffin Bay	Kraatz Pier	TX 4	W	4/27/2000	1505	27 17 19.2	97 39 39.0	water color tea green
Upper Laguna Madre	Baffin Bay	Kraatz Pier	TX 5	W	4/27/2000	1505	27 17 19.2	97 39 39.0	
Upper Laguna Madre	Baffin Bay	Bayview Campground	TX 7	W	5/31/2000	1235	27 18 49.4	97 40 30.2	
Upper Laguna Madre	Baffin Bay	Bayview Campground	TX 84	W	6/21/2000	1007	27 18 49.4	97 40 30.2	
Upper Laguna Madre	Baffin Bay	Bayview Campground	TX 90	W	7/28/2000	1505	27 18 49.6	97 40 30.1	
Upper Laguna Madre	Baffin Bay	Bayview Campground	TX 92	W	8/24/2000	1740	27 18 49.6	97 40 30.1	

Upper Laguna Madre	Baffin Bay	Bayview Campground	TX 92	W	8/24/2000	1740	27 18 49.6	97 40 30.1	
Upper Laguna Madre	Baffin Bay	Bayview Campground	TX 96	W	9/28/2000	1230	27 18 50.0	97 40 30.0	
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 1	W	4/6/2000	1730	26 20 46.3	97 24 42.7	
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 51	S	4/6/2000	1730	26 20 46.3	97 24 42.7	
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 52	S	6/13/2000	1205	26 20 46.3	97 24 42.7	
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 6	W	6/13/2000	1205	26 20 46.3	97 24 42.7	
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 53	S	8/9/2000	1600	26 20 46.3	97 24 42.7	
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 94	W	8/9/2000	1600	26 20 46.3	97 24 42.7	water color pea green

Table B-2. Station data for *Pfiesteria* sampling sites in Texas in 2001. (Sample media codes: W=water, S=sediment).

Major System	Minor System	Location	Sample ID	Sample Medium	Date Collected	Time Collected	Latitude	Longitude	Comments
Galveston Bay	Clear Lake	Clear Lake	TX 101	W	4/10/2001	0919	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 109	W	4/25/2001	1100	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 164	W	5/9/2001	1545	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 161	W	5/24/2001	0800	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 167	W	6/5/2001	0850	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 171	W	6/20/2001	0905	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 174	W	7/3/2001	1700	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 178	W	7/19/2001	0853	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 180	W	8/3/2001	0907	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 186	W	8/17/2001	1414	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 188	W	9/4/2001	1200	29 35 43.8	95 05 24.7	
Galveston Bay	Clear Lake	Clear Lake	TX 126	W	9/28/2001	1005	29 35 43.8	95 05 24.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 103	W	4/10/2001	1016	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 110	W	4/25/2001	1156	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 169	W	5/9/2001	1321	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 165	W	5/24/2001	0924	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 168	W	6/5/2001	0955	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 172	W	6/20/2001	1000	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 175	W	7/3/2001	1550	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 177	W	7/19/2001	1022	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 181	W	8/3/2001	1038	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 184	W	8/17/2001	1256	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 187	W	9/4/2001	1000	29 27 24.7	95 02 51.7	
Galveston Bay	Dickinson Bay	Dickinson Bayou	TX 190	W	9/18/2001	1531	29 27 24.7	95 02 51.7	
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 107	W	4/10/2001	1208	28 46 06.9	95 38 24.8	
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 162	W	4/25/2001	1517	28 46 06.9	95 38 24.8	
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 163	W	5/9/2001	1108	28 46 06.9	95 38 24.8	

Matagorda Bay	East Matagorda Bay	Caney Creek	TX 166	W	5/24/2001	1123	28 46 06.9	95 38 24.8
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 170	W	6/5/2001	1145	28 46 06.9	95 38 24.8
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 173	W	6/20/2001	1130	28 46 06.9	95 38 24.8
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 176	W	7/3/2001	1016	28 46 06.9	95 38 24.8
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 179	W	7/19/2001	1150	28 46 06.9	95 38 24.8
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 182	W	8/3/2001	1510	28 46 06.9	95 38 24.8
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 183	W	8/17/2001	1036	28 46 06.9	95 38 24.8
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 185	W	8/31/2001	1130	28 46 06.9	95 38 24.8
Matagorda Bay	East Matagorda Bay	Caney Creek	TX 189	W	9/18/2001	1126	28 46 06.9	95 38 24.8
Matagorda Bay	Lavaca Bay	Port Lavaca Fishing Pier	TX 133	W	4/19/2001	1400	28 38 30.5	96 36 28.5
Matagorda Bay	Lavaca Bay	Port Lavaca Fishing Pier	TX 345	W	6/20/2001	1215	28 38 30.5	96 36 28.5
Matagorda Bay	Lavaca Bay	Port Lavaca Fishing Pier	TX 335	W	6/28/2001	1320	28 38 30.5	96 36 28.5
Matagorda Bay	Lavaca Bay	Port Lavaca Fishing Pier	TX 121	W	7/11/2001	1248	28 38 30.5	96 36 28.5
Matagorda Bay	Lavaca Bay	Port Lavaca Fishing Pier	TX 122	W	8/6/2001	1640	28 38 30.5	96 36 28.5
Matagorda Bay	Lavaca Bay	Port Lavaca Fishing Pier	TX 358	W	8/15/2001	1215	28 38 30.5	96 36 28.5
Matagorda Bay	Lavaca Bay	Port Lavaca Fishing Pier	TX 337	W	9/19/2001	1330	28 38 30.5	96 36 28.5
Matagorda Bay	Lavaca Bay	Port Lavaca Fishing Pier	TX 127	W	9/27/2001	1225	28 38 30.5	96 36 28.5
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 141	W	4/10/2001	1415	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 142	W	4/25/2001	1445	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 301	W	5/8/2001	1115	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 302	W	5/24/2001	1120	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 303	W	6/12/2001	0900	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 304	W	6/26/2001	0900	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 305	W	7/10/2001	1000	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 306	W	7/31/2001	0900	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 307	W	8/14/2001	0900	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 308	W	8/30/2001	0930	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 309	W	9/15/2001	1000	27 49 38.0	97 04 42.9
Corpus Christi Bay	Corpus Christi Bay	Port Aransas Birding Center	TX 310	W	9/27/2001	1000	27 49 38.0	97 04 42.9
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 140	W	4/9/2001	1813	26 20 46.3	97 24 42.7

Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 139	W	4/23/2001	1217	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 134	W	5/9/2001	1325	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 137	W	5/24/2001	1420	26 20 46.0	87 24 43.0
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 356	W	6/7/2001	1947	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 755	S	6/7/2001	1947	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 136	W	6/19/2001	1310	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 338	W	7/10/2001	1223	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 338	S	7/10/2001	1223	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 132	W	7/24/2001	1403	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 343	W	8/13/2001	1815	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 780	S	8/13/2001	1815	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 131	W	8/29/2001	1354	26 20 46.3	97 24 42.7
Lower Laguna Madre	Arroyo Colorado	Adolph Tomae Jr. County Park	TX 336	W	9/12/2001	1434	26 20 46.3	97 24 42.7

Table B-3. Meteorological data for *Pfiesteria* sampling stations in Texas in 2000. Cloud cover code values: 1=0-9%, 2=10-25%, 3=26-50%, 4=51-75%, 5=76-90%, 6=91-100%. (nd=no data)

Location	Sample ID	Date Collected	Air temperature (degrees F)	Air temperature (degrees C)	Wind speed	Wind speed code (Beaufort)	Wind direction	Cloud cover	Cloud cover code	Sea state	Sea state code (Beaufort)	Comments
Sabine Pass Swing Bridge	TX 18	4/25/2000	85.0	29.4	<5 mph	2	nd	2%	1	calm	0	
Sabine Pass Swing Bridge	TX 26	6/1/2000	90.0	32.2	0-5 mph	1	S	30%	3	calm	0	
Sabine Pass Swing Bridge	TX 61	6/23/2000	90.0	32.2	10-15 mph	3	S	20%	2	calm	0	
Sabine Pass Swing Bridge	TX 67	7/12/2000	90.0	32.2	5-10 mph	2	S	20%	2	calm	0	
Sabine Pass Swing Bridge	TX 74	8/2/2000	95.0	35.0	10 mph	3	S	80%	5	calm	0	
Sabine Pass Swing Bridge	TX 80	9/15/2000	95.0	35.0	5 mph	2	N	90%	5	calm	0	
Tabbs Bay	TX 19	4/26/2000	80.0	26.7	5-10 mph	2	SE	20%	2	calm	0	
Tabbs Bay	TX 62	6/23/2000	96.0	35.6	15-20 mph	4	SE	20%	2	choppy	4	
Tabbs Bay	TX 78	8/10/2000	95.0	35.0	10 mph	3	S	10%	2	slightly choppy	3	
Clear Lake	TX 20	4/26/2000	85.0	29.4	10-15 mph	3	SE	20%	2	calm to choppy	2	
Clear Creek	TX 30	5/11/2000	88.0	31.1	15-20 mph	4	S	100%	6	calm	0	
Clear Creek	TX 27	6/21/2000	85.0	29.4	10 mph	3	SE	20%	2	slightly choppy	3	
Armand Bayou	TX 66	7/10/2000	90.0	32.2	10-15 mph	3	S	70%	4	slightly choppy	3	
Armand Bayou	TX 75	8/7/2000	95.0	35.0	5 mph	2	S	40%	3	calm	3	
Armand Bayou	TX 39	9/20/2000	90.0	32.2	20 mph	5	S	20%	2	rough	0	
Dickinson Bayou 1	TX 11	4/19/2000	78.0	25.6	10 mph	3	SE	90%	5	calm	0	
Dickinson Bayou 1	TX 28	6/21/2000	85.0	29.4	10 mph	3	SE	20%	2	slightly choppy	6	
Dickinson Bayou 2	TX 72	7/26/2000	95.0	35.0	10 mph	3	S	25%	2	calm	0	
Dickinson Bayou 1	TX 76	8/7/2000	95.0	35.0	5 mph	2	S	40%	3	calm	3	
Dickinson Bayou 2	TX 35	9/20/2000	90.0	32.2	0-5 mph	1	S	50%	3	calm	0	
Moses Bayou	TX 21	5/11/2000	88.0	31.1	15-20 mph	4	S	100%	6	slightly choppy	3	
Moses Lake	TX 65	7/7/2000	90.0	32.2	0-5 mph	1	SW	20%	2	calm	0	
Moses Bayou	TX 37	9/20/2000	90.0	32.2	5 mph	2	S	40%	3	calm	0	
Jamaica Beach Canal	TX 15	4/19/2000	84.0	28.9	10-20 mph	4	SE	nd	nd	calm	0	
Jamaica Beach Canal	TX 22	5/15/2000	88.0	31.1	10 mph	3	SE	30%	3	calm	0	

Jamaica Beach Canal	TX 29	6/21/2000	90.0	32.2	15 mph	4	SE	30%	3	calm	0	
Jamaica Beach Canal	TX 73	7/27/2000	90.0	32.2	10 mph	3	SE	15%	2	calm	0	
Jamaica Beach Canal	TX 77	8/9/2000	90.0	32.2	5 mph	2	S	0%	1	calm	0	
Jamaica Beach Canal	TX 105	10/4/2000	91.0	32.8	10 mph	3	S	5%	1	calm	0	
Oyster Creek	TX 24	5/30/2000	90.0	32.2	0-5 mph	1	SW	30%	3	calm	0	
Swan Lake	TX 68	7/20/2000	92.0	33.3	10-15 mph	3	SW	10%	2	calm	0	
Oyster Creek	TX 104	10/4/2000	90.0	32.2	10 mph	3	E	20%	2	calm	0	
Intracoastal Waterway	TX 25	5/30/2000	90.0	32.2	5-10 mph	2	SW	30%	3	calm	0	
Jones Creek	TX 69	7/20/2000	95.0	35.0	5-10 mph	2	SSW	20%	2	calm	0	
Intracoastal Waterway	TX 106	10/4/2000	90.0	32.2	10 mph	3	E	15%	2	slightly choppy	3	
Caney Creek	TX 13	4/19/2000	84.0	28.9	5-10 mph	2	SE	nd	nd	calm	0	
Caney Creek	TX 64	6/28/2000	90.0	32.2	15-20 mph	4	S	30%	3	slightly choppy	3	
Caney Creek	TX 71	7/26/2000	95.0	35.0	10 mph	3	S	25%	2	calm	0	
Caney Creek	TX 79	8/15/2000	85.0	29.4	10 mph	3	W	80%	5	slightly choppy	3	
Caney Creek	TX 102	9/22/2000	90.0	32.2	5 mpg	2	S	20%	2	calm	0	
Colorado River	TX 23	5/26/2000	92.0	33.3	10-15 mph	3	SE	10%	2	calm	0	
Colorado River	TX 70	7/26/2000	90.0	32.2	10 mph	3	S	25%	2	calm	0	
Colorado River	TX 108	9/22/2000	90.0	32.2	5 mph	2	S	40%	3	calm	0	
Lavaca Bay Causeway	TX 2	4/13/2000	78.0	25.6	5-10 kts	3	N	95%	6	slightly choppy	3	very turbid, silty water
Lavaca Bay Causeway	TX 32	5/17/2000	87.0	30.6	20-25 kts	6	SSW	50%	3	very choppy	6	
Lavaca Bay Causeway	TX 85	6/30/2000	92.0	33.3	10-15 kts	4	SE	40%	3	slightly choppy	3	
Lavaca Bay Causeway	TX 91	7/25/2000	95.0	35.0	10 kts	3	E	20%	2	light chop	2	
Lavaca Bay Causeway	TX 97	9/29/2000	85.0	29.4	5-10 kts	3	NE	0%	1	calm/slight chop	2	
Mesquite Bay	TX 33	5/17/2000	85.0	29.4	20-30 kts	6	SSE	mostly cloudy	5	very choppy/white caps	6	
Mesquite Bay	TX 93	7/24/2000	95.0	35.0	8-10 mph	3	E	partly cloudy	2	slightly choppy	3	temp recorded as 90's
Mesquite Bay	TX 100	10/4/2000	85.0	29.4	10 mph	3	SE	25%	2	calm	0	
Nueces River	TX 38	4/19/2000	79.0	26.1	15-20 kts	5	SE	mostly clear	1	nd	nd	temp recorded as 78-80
Nueces River	TX 31	5/16/2000	89.0	31.7	10-15 kts	4	SSE	partly cloudy	2	ripples	1	
Nueces River	TX 87	6/14/2000	92.0	33.3	20 mph	5	SE	mostly cloudy	5	calm	0	

Nueces River	TX 40	7/12/2000	90.0	32.2	15-20 kts	5	SE	clear	1	calm	0	
Nueces River	TX 34	8/10/2000	98.0	36.7	15 kts	4	NE	mostly clear	1	slightly choppy	3	recorded as mostly sunny
Nueces River	TX 36	9/7/2000	80.0	26.7	10-15 mph	3	ENE	100%	6	calm	0	
Port Aransas Birding Center	TX 8	4/18/2000	75.9	24.4	5.9 m/s	4	SE	nd	nd	nd	nd	wind direction 125 deg
Port Aransas Birding Center	TX 10	5/24/2000	80.2	26.8	7.7 m/s	4	SE	partly cloudy	2	calm	0	wind direction 153 deg
Port Aransas Birding Center	TX 9	6/21/2000	nd	nd	Nd	nd	nd	nd	nd	nd	nd	
Port Aransas Birding Center	TX 111	7/12/2000	nd	nd	Nd	nd	nd	nd	nd	nd	nd	
Port Aransas Birding Center	TX 112	8/14/2000	nd	nd	Nd	nd	nd	nd	nd	nd	nd	
Port Aransas Birding Center	TX 99	10/3/2000	90.0	32.2	15 mph	4	SE	clear	1	calm	0	
Oso Bay 1	TX 3	4/13/2000	78.0	25.6	10 mph	3	E	100%	6	slightly choppy	3	overcast cloud cover
Oso Bay 2	TX 82	5/30/2000	80.1	26.7	12-15 kts	4	ESE	0%	1	slightly choppy	3	
Oso Bay 2	TX 86	7/12/2000	87.8	31.0	15 mph	4	S	scattered	2	slightly choppy	3	
Oso Bay 2	TX 89	8/8/2000	89.0	31.7	2-5 mph	1	SE	cloudy	5	calm	0	
Oso Bay 2	TX 95	9/15/2000	87.5	30.8	10-15 mph	3	N	scattered	2	slightly choppy	3	temp recorded as 85-90
Oso Creek	TX 83	6/20/2000	90.0	32.2	5-10 mph	2	SSE	partly cloudy	2	calm	0	
Kraatz Pier	TX 4	4/27/2000	88.0	31.1	20-25 mph	5	E	<5% clouds	1	choppy/white caps	5	
Bayview Campground	TX 7	5/31/2000	81.1	27.3	12-15 kts	4	SSE	clear	1	slightly choppy	3	
Bayview Campground	TX 84	6/21/2000	88.0	31.1	10-15 mph	3	SSE	mostly clear	1	choppy	4	wind gusts to 20 mph
Bayview Campground	TX 90	7/28/2000	90.0	32.2	25 mph	6	S	clear	1	choppy	4	water very turbid
Bayview Campground	TX 92	8/24/2000	90.0	32.2	15-20 kts	5	ESE	50% clouds	3	choppy/white caps	5	water very turbid
Bayview Campground	TX 96	9/28/2000	85.0	29.4	5-10 mph	2	NE	scattered	2	slightly choppy	3	
Adolph Tomae Jr. County Park	TX 1	4/6/2000	80.0	26.7	15-20 mph	4	SE	partly	2	nd	nd	wind gusts 20-25 mph
Adolph Tomae Jr. County Park	TX 6	6/13/2000	79.5	26.4	5-10 mph	2	SE	mostly cloudy	5	calm	0	wind gusts to 15 mph
Adolph Tomae Jr. County Park	TX 94	8/9/2000	98.0	36.7	5-10 mph	2	SE	slightly cloudy	1	choppy	4	

Table B-4. Meteorological data for *Pfiesteria* sampling stations in Texas in 2001. Cloud cover code values: 1=0-9%, 2=10-25%, 3=26-50%, 4=51-75%, 5=76-90%, 6=91-100%. (nd=no data)

Location	Sample ID	Date collected	Air temperature (degrees F)	Air temperature (degrees C)	Wind speed	Wind speed code (Beaufort)	Wind direction	Cloud cover	Cloud cover code	Sea state	Sea state code (Beaufort)	Comments
Clear Lake	TX 101	4/10/2001	75.0	23.9	10 mph	3	S	80%	5	calm	0	
Clear Lake	TX 109	4/25/2001	75.0	23.9	5 mph	2	N	0-9%	1	calm	0	
Clear Lake	TX 164	5/9/2001	90.0	32.2	5 mph	2	SE	10-25%	2	calm	0	
Clear Lake	TX 161	5/24/2001	80.0	26.7	5 mph	2	S	0-9%	1	calm	0	
Clear Lake	TX 167	6/5/2001	80.0	26.7	0 mph	0	N/A	91-100%	6	calm	0	
Clear Lake	TX 171	6/20/2001	80.0	26.7	0 mph	0	N/A	0-9%	1	calm	0	
Clear Lake	TX 174	7/3/2001	85.0	29.4	0 mph	0	N/A	91-100%	6	calm	0	
Clear Lake	TX 178	7/19/2001	80.0	26.7	5 mph	2	S	0-9%	1	calm	0	
Clear Lake	TX 180	8/3/2001	85.0	29.4	5-10 mph	2	SE	10-25%	2	calm	0	
Clear Lake	TX 186	8/17/2001	88.0	31.1	5-10 mph	2	S	10-25%	2	calm	0	
Clear Lake	TX 188	9/4/2001	88.0	31.1	5-10 mph	2	S	76-90%	5	calm	0	
Clear Lake	TX 126	9/28/2001	80.0	26.7	0 mph	0	N/A	0-9%	1	calm	0	
Dickinson Bayou	TX 103	4/10/2001	78.0	25.6	10 mph	3	S	90%	5	slightly choppy	3	
Dickinson Bayou	TX 110	4/25/2001	75.0	23.9	5 mph	2	N	0-9%	1	calm	0	
Dickinson Bayou	TX 169	5/9/2001	85.0	29.4	5 mph	2	S	26-50%	3	calm	0	
Dickinson Bayou	TX 165	5/24/2001	80.0	26.7	5 mph	2	S	0-9%	1	calm	0	
Dickinson Bayou	TX 168	6/5/2001	80.0	26.7	5 mph	2	SE	91-100%	6	slightly choppy	3	
Dickinson Bayou	TX 172	6/20/2001	80.0	26.7	5 mph	2	S	26-50%	3	calm	0	
Dickinson Bayou	TX 175	7/3/2001	85.0	29.4	0 mph	0	N/A	91-100%	6	calm	0	
Dickinson Bayou	TX 177	7/19/2001	85.0	29.4	5 mph	2	S	26-50%	3	calm	0	
Dickinson Bayou	TX 181	8/3/2001	87.0	30.6	5 mph	2	SE	10-25%	2	calm	0	
Dickinson Bayou	TX 184	8/17/2001	86.0	30.0	5 mph	2	S	26-50%	3	calm	0	
Dickinson Bayou	TX 187	9/4/2001	88.0	31.1	5-10 mph	2	S	76-90%	5	calm	0	
Dickinson Bayou	TX 190	9/18/2001	87.0	30.6	5-10 mph	2	SW	26-50%	3	slightly choppy	3	
Caney Creek	TX 107	4/10/2001	84.0	28.9	5 mph	2	S	30%	3	slightly choppy	3	

Caney Creek	TX 162	4/25/2001	75.0	23.9	10 mph	3	N	0-9%	1	slightly choppy	3	
Caney Creek	TX 163	5/9/2001	80.0	26.7	5 mph	2	S	10-25%	2	calm	0	
Caney Creek	TX 166	5/24/2001	82.0	27.8	5 mph	2	S	26-50%	3	calm	0	
Caney Creek	TX 170	6/5/2001	80.0	26.7	10-15 mph	3	SE	91-100%	6	choppy	4	
Caney Creek	TX 173	6/20/2001	85.0	29.4	5 mph	2	S	26-50%	3	calm	0	
Caney Creek	TX 176	7/3/2001	80.0	26.7	5 mph	2	S	26-50%	3	calm	0	
Caney Creek	TX 179	7/19/2001	85.0	29.4	5 mph	2	S	26-50%	3	calm	0	
Caney Creek	TX 182	8/3/2001	87.0	30.6	10-15mph	3	S	10-25%	2	calm	0	
Caney Creek	TX 183	8/17/2001	86.0	30.0	5 mph	2	S	26-50%	3	calm	0	
Caney Creek	TX 185	8/31/2001	85.0	29.4	5 mph	2	S	91-100%	6	slightly choppy	3	
Caney Creek	TX 189	9/18/2001	87.0	30.6	3 mph	1	S	10-25%	2	calm	0	
Port Lavaca Fishing Pier	TX 133	4/19/2001	78.0	25.6	30 + kts	6	SE	91-100%	6	rough	6	
Port Lavaca Fishing Pier	TX 345	6/20/2001	95.0	35.0	15 kts	4	SE	0-9%	1	slightly choppy	3	
Port Lavaca Fishing Pier	TX 335	6/28/2001	90.0	32.2	5-10 kts	3	SE	26-50%	3	choppy	4	
Port Lavaca Fishing Pier	TX 121	7/11/2001	95.0	35.0	5-10 kts	3	SE	10-25%	2	light chop	2	
Port Lavaca Fishing Pier	TX 122	8/6/2001	92.0	33.3	15 kts	4	E	0-9%	1	choppy/some white caps	4	
Port Lavaca Fishing Pier	TX 358	8/15/2001	92.0	33.3	5 kts	2	SE	26-50%	3	calm	0	
Port Lavaca Fishing Pier	TX 337	9/19/2001	90.0	32.2	nd	Nd	SE	26-50%	3	nd	nd	
Port Lavaca Fishing Pier	TX 127	9/27/2001	nd	nd	1 mph	1	N	0-9%	1	calm	0	
Port Aransas Birding Center	TX 141	4/10/2001	75.2	24.0	15 mph	4	SE	partly cloudy	2	nd	nd	wind gusting to 30 mph
Port Aransas Birding Center	TX 142	4/25/2001	67.5	19.7	10-15 mph	3	NE	clear	1	nd	nd	
Port Aransas Birding Center	TX 301	5/8/2001	75.7	24.3	8 mph	3	NE	partly cloudy	2	nd	nd	
Port Aransas Birding Center	TX 302	5/24/2001	79.7	26.5	9-10 mph	3	SE	clear	1	nd	nd	
Port Aransas Birding Center	TX 303	6/12/2001	84.6	29.2	10 mph	3	SE	0-9%	1	nd	nd	
Port Aransas Birding Center	TX 304	6/26/2001	77.4	25.2	10-15 mph	3	SE	10-25%	2	nd	nd	
Port Aransas Birding Center	TX 305	7/10/2001	82.2	27.9	5-10 mph	2	SE	0-9%	1	nd	nd	
Port Aransas Birding Center	TX 306	7/31/2001	80.6	27.0	10-15 mph	3	SE	10-25%	2	nd	nd	
Port Aransas Birding Center	TX 307	8/14/2001	78.3	25.7	0-5 mph	1	SE	91-100%	6	calm	0	
Port Aransas Birding Center	TX 308	8/30/2001	77.0	25.0	5-8 mph	2	SE	91-100%	6	small ripples	1	

Port Aransas Birding Center	TX 309	9/15/2001	77.4	25.2	10-15 mph	3	SE	76-90%	5	nd	nd	
Port Aransas Birding Center	TX 310	9/27/2001	68.9	20.5	10 mph	3	nd	51-75%	4	nd	nd	
Adolph Tomae Jr. County Park	TX 140	4/9/2001	75.2	24.0	20 mph	5	E	5%	1	choppy	4	
Adolph Tomae Jr. County Park	TX 139	4/23/2001	nd	nd	10 mph	3	SE	91-100%	6	0.2 m chop	3	
Adolph Tomae Jr. County Park	TX 134	5/9/2001	84.7	29.3	10 mph	3	SE	51-75%	4	slightly choppy	3	
Adolph Tomae Jr. County Park	TX 137	5/24/2001	92.3	33.5	22 mph	5	SE	10-25%	2	0.12-0.37 m	5	.4-1.2 ft
Adolph Tomae Jr. County Park	TX 356	6/7/2001	79.9	26.6	15 mph	4	SE	91-100%	6	calm	0	
Adolph Tomae Jr. County Park	TX 136	6/19/2001	90.0	32.2	5-10 kts	3	SE	51-75%	4	light ripples	1	
Adolph Tomae Jr. County Park	TX 338	7/10/2001	nd	nd	3 mph	1	nd	10-25%	2	calm	0	
Adolph Tomae Jr. County Park	TX 132	7/24/2001	nd	nd	10 mph	3	SE	26-50%	3	0.15 m	3	.5 ft
Adolph Tomae Jr. County Park	TX 343	8/13/2001	90.0	32.2	5 mph	2	SE	91-100%	6	calm	0	
Adolph Tomae Jr. County Park	TX 131	8/29/2001	90.9	32.7	12 mph	3	E	76-90%	5	0.2 m	3	
Adolph Tomae Jr. County Park	TX 336	9/12/2001	90.0	32.2	10 mph	3	nd	76-90%	5	slightly choppy	3	

Table B-5. Physical-chemical data for *Pfiesteria* sampling stations in Texas in 2000. (nd=no data)

Minor System	Location	Sample ID	Date Collected	Time Collected	Depth (m)	Water Temperature (deg C)	DO (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	pH	Percent Saturation	Secchi Disk (cm)
Sabine Pass	Sabine Pass Swing Bridge	TX 17	4/25/2000	1450	0.61	23.24	6.11	25.60	23.4	nd	82.6	46
Sabine Pass	Sabine Pass Swing Bridge	TX 17	4/25/2000	1450	1.22	23.13	5.83	26.50	23.13	nd	80.6	46
Sabine Pass	Sabine Pass Swing Bridge	TX 17	4/25/2000	1450	1.83	22.84	5.74	27.60	23.11	nd	78.7	46
Sabine Pass	Sabine Pass Swing Bridge	TX 17	4/25/2000	1450	2.71	22.82	5.61	27.60	23.07	nd	77.1	46
Sabine Pass	Sabine Pass Swing Bridge	TX 18	4/25/2000	1450	0.61	23.24	6.11	25.60	23.4	nd	82.6	46
Sabine Pass	Sabine Pass Swing Bridge	TX 18	4/25/2000	1450	1.22	23.13	5.83	26.50	23.13	nd	80.6	46
Sabine Pass	Sabine Pass Swing Bridge	TX 18	4/25/2000	1450	1.83	22.84	5.74	27.60	23.11	nd	78.7	46
Sabine Pass	Sabine Pass Swing Bridge	TX 18	4/25/2000	1450	2.71	22.82	5.61	27.60	23.07	nd	77.1	46
Sabine Pass	Sabine Pass Swing Bridge	TX 26	6/1/2000	1138	0.25	29.42	4.69	21.80	34.4	7.83	71.9	100
Sabine Pass	Sabine Pass Swing Bridge	TX 26	6/1/2000	1138	1.5	29.31	4.68	22.10	35.2	7.83	71.9	100
Sabine Pass	Sabine Pass Swing Bridge	TX 61	6/23/2000	1202	0.25	29.84	6.28	13.10	21.9	7.71	91.7	80
Sabine Pass	Sabine Pass Swing Bridge	TX 61	6/23/2000	1202	1	29.61	6.02	13.60	22.7	7.79	89.1	80
Sabine Pass	Sabine Pass Swing Bridge	TX 61	6/23/2000	1202	2	29.28	5.47	17.80	28.6	7.83	80.9	80
Sabine Pass	Sabine Pass Swing Bridge	TX 61	6/23/2000	1202	3	29.22	5.38	17.80	30.2	7.83	80.2	80
Sabine Pass	Sabine Pass Swing Bridge	TX 67	7/12/2000	1333	0.25	32.1	7.12	20.30	32.9	7.95	112.1	60
Sabine Pass	Sabine Pass Swing Bridge	TX 67	7/12/2000	1333	1	32.02	6.83	21.30	34	7.92	108.9	60
Sabine Pass	Sabine Pass Swing Bridge	TX 67	7/12/2000	1333	2	31.59	6.23	23.10	36.7	7.86	96.1	60
Sabine Pass	Sabine Pass Swing Bridge	TX 74	8/2/2000	1335	0.25	30.98	6.97	20.20	32.3	8.06	105.2	75
Sabine Pass	Sabine Pass Swing Bridge	TX 74	8/2/2000	1335	1	30.11	6.29	22.40	36.5	8.03	96.3	75
Sabine Pass	Sabine Pass Swing Bridge	TX 74	8/2/2000	1335	1.3	29.89	5.8	24.30	37.8	8.03	87.9	75
Sabine Pass	Sabine Pass Swing Bridge	TX 80	9/15/2000	1358	1	28.6	7.04	16.90	27.6	7.81	103.8	60
Sabine Pass	Sabine Pass Swing Bridge	TX 80	9/15/2000	1358	2	28.52	6.11	17.10	27.8	7.8	93.3	60
Tabbs Bay	Tabbs Bay	TX 19	4/26/2000	1110	0.15	25.14	6.83	16.60	nd	nd	91.1	50
Tabbs Bay	Tabbs Bay	TX 19	4/26/2000	1110	0.52	25.03	6.98	16.60	nd	nd	92.7	50
Tabbs Bay	Tabbs Bay	TX 62	6/23/2000	1440	0.25	29.94	7.33	13.60	22.6	8.14	107.1	20

Tabbs Bay	Tabbs Bay	TX 62	6/23/2000	1440	1	29.93	7.31	13.60	22.6	8.15	106.6	20
Tabbs Bay	Tabbs Bay	TX 78	8/10/2000	1411	0.25	32.48	6.84	16.40	26.8	8.12	98.4	40
Tabbs Bay	Tabbs Bay	TX 78	8/10/2000	1411	0.7	31.48	5.94	16.60	27.2	8.03	88.9	40
Clear Lake	Clear Lake	TX 20	4/26/2000	1405	0.15	26.9	9.68	14.50	nd	nd	131.9	50
Clear Lake	Clear Lake	TX 20	4/26/2000	1405	0.3	26.83	9.77	14.70	nd	nd	133.2	50
Clear Lake	Clear Lake	TX 20	4/26/2000	1405	0.61	26.71	9.58	14.60	nd	nd	129.0	50
Clear Lake	Clear Lake	TX 20	4/26/2000	1405	0.91	26.54	9.03	14.90	nd	nd	120.0	50
Clear Lake	Clear Lake	TX 20	4/26/2000	1405	1.22	25.79	5.61	15.70	nd	nd	69.0	50
Clear Lake	Clear Creek	TX 30	5/11/2000	1337	0.25	28.8	8.83	5.51	9.709	8.34	117.2	25
Clear Lake	Clear Creek	TX 30	5/11/2000	1337	0.78	28.28	6.77	6.78	11.72	8.16	89.4	25
Clear Lake	Clear Creek	TX 27	6/21/2000	0900	0.25	29.26	6.22	5.94	11.67	8.36	82.7	30
Clear Lake	Clear Creek	TX 27	6/21/2000	0900	0.43	29.23	6.12	5.39	8.508	8.3	82.1	30
Clear Lake	Armand Bayou	TX 66	7/10/2000	1300	0.25	32.96	12.42	4.50	8.13	9.2	178.7	33
Clear Lake	Clear Lake	TX 75	8/7/2000	1343	0.25	32.31	11.88	2.90	5.24	9.54	170.6	20
Clear Lake	Armand Bayou	TX 75	8/7/2000	1343	1	31.09	7.33	2.80	5.18	9.32	98.6	20
Clear Lake	Armand Bayou	TX 39	9/20/2000	1242	0.25	29.11	11.44	4.00	7.13	9.18	153.5	40
Clear Lake	Armand Bayou	TX 39	9/20/2000	1242	1	29.03	10.48	4.10	7.24	9.18	139.5	40
Dickinson Bay	Dickinson Bayou 1	TX 11	4/19/2000	0845	0.25	25.42	5.33	3.37	6.16	nd	66.5	nd
Dickinson Bay	Dickinson Bayou 1	TX 11	4/19/2000	0845	1.89	21.48	0.38	17.16	27.92	nd	3.7	nd
Dickinson Bay	Dickinson Bayou 1	TX 12	4/19/2000	0845	0.25	25.42	5.33	3.37	6.16	nd	66.5	nd
Dickinson Bay	Dickinson Bayou 1	TX 12	4/19/2000	0845	1.89	21.48	0.38	17.16	27.92	nd	3.7	nd
Dickinson Bay	Dickinson Bayou 1	TX 28	6/21/2000	0946	0.25	30.4	5.71	5.72	10.11	7.58	81.0	60
Dickinson Bay	Dickinson Bayou 1	TX 28	6/21/2000	0946	0.6	30.34	4.82	6.08	10.72	7.51	66.1	60
Dickinson Bay	Dickinson Bayou 2	TX 72	7/26/2000	1603	0.25	29.44	2.93	2.00	3.68	7.28	37.7	80
Dickinson Bay	Dickinson Bayou 2	TX 72	7/26/2000	1603	1	29.16	0.32	6.60	11.2	6.93	4.0	80
Dickinson Bay	Dickinson Bayou 2	TX 72	7/26/2000	1603	1.3	29.22	0.22	7.60	13.16	6.76	2.8	80
Dickinson Bay	Dickinson Bayou 1	TX 76	8/7/2000	1557	0.25	32.81	11.04	11.90	20	8.77	161.9	40
Dickinson Bay	Dickinson Bayou 1	TX 76	8/7/2000	1557	0.4	32.78	9.78	11.90	20.1	8.75	147.7	40
Dickinson Bay	Dickinson Bayou 1	TX 35	9/20/2000	1100	0.25	28.84	8.47	6.10	10.65	8.37	114.9	77

Dickinson Bay	Dickinson Bayou 1	TX 35	9/20/2000	1100	0.5	28.72	7.22	6.30	10.89	8.34	106.2	77
Moses Lake	Moses Bayou	TX 21	5/11/2000	1433	0.25	28.44	7.69	20.19	32.35	8.02	111.4	20
Moses Lake	Moses Bayou	TX 21	5/11/2000	1433	0.91	28.14	7.32	20.35	32.71	7.93	106.9	20
Moses Lake	Moses Lake	TX 65	7/7/2000	1222	0.25	30.92	6.52	22.60	36	7.97	103.4	50
Moses Lake	Moses Lake	TX 65	7/7/2000	1222	1	30.1	5.97	22.60	35.7	7.94	93.1	50
Moses Lake	Moses Bayou	TX 37	9/20/2000	1145	0.25	28.15	5.77	17.60	28.4	7.92	82.3	40
Moses Lake	Moses Bayou	TX 37	9/20/2000	1145	1	27.69	5.12	18.70	30.4	7.93	72.4	40
West Bay	Jamaica Beach Canal	TX 15	4/19/2000	1435	0.25	26.08	7.38	30.62	47.06	nd	110.0	nd
West Bay	Jamaica Beach Canal	TX 15	4/19/2000	1435	0.6	25.15	6.61	30.69	47.04	nd	97.5	nd
West Bay	Jamaica Beach Canal	TX 15	4/19/2000	1435	1.19	25.07	6.47	30.51	46.88	nd	93.9	nd
West Bay	Jamaica Beach Canal	TX 16	4/19/2000	1435	0.25	26.08	7.38	30.62	47.06	nd	110.0	nd
West Bay	Jamaica Beach Canal	TX 16	4/19/2000	1435	0.6	25.15	6.61	30.69	47.04	nd	97.5	nd
West Bay	Jamaica Beach Canal	TX 16	4/19/2000	1435	1.19	25.07	6.47	30.51	46.88	nd	93.9	nd
West Bay	Jamaica Beach Canal	TX 22	5/15/2000	1240	0.25	26.58	7.12	30.61	46.14	8.21	106.1	30
West Bay	Jamaica Beach Canal	TX 22	5/15/2000	1240	1	25.82	6.62	30.30	45.61	8.1	91.4	30
West Bay	Jamaica Beach Canal	TX 22	5/15/2000	1240	1.6	25.79	6.52	30.10	45.6	8.1	90.6	30
West Bay	Jamaica Beach Canal	TX 29	6/21/2000	1130	0.25	28.92	5.67	32.40	49.47	7.81	89.6	60
West Bay	Jamaica Beach Canal	TX 29	6/21/2000	1130	1.06	28.49	4.8	32.06	48.96	7.77	74.6	60
West Bay	Jamaica Beach Canal	TX 73	7/27/2000	1210	0.25	29.93	2.78	36.50	54.9	7.79	46.6	40
West Bay	Jamaica Beach Canal	TX 73	7/27/2000	1210	1	29.31	1.61	36.50	55	7.77	25.2	40
West Bay	Jamaica Beach Canal	TX 73	7/27/2000	1210	1.2	29.17	1.38	36.50	54.9	7.73	24.4	40
West Bay	Jamaica Beach Canal	TX 77	8/9/2000	1013	0.5	29.63	2.48	35.20	53.3	7.89	40.6	40
West Bay	Jamaica Beach Canal	TX 77	8/9/2000	1013	0.9	29.13	1.84	35.30	53.3	7.81	32.5	40
West Bay	Jamaica Beach Canal	TX 105	10/4/2000	1525	0.25	28.31	7.32	34.70	52	8.05	116.1	60
West Bay	Jamaica Beach Canal	TX 105	10/4/2000	1525	1	27.63	6.8	34.50	51.8	8.05	108.9	60
Freeport North	Oyster Creek	TX 24	5/30/2000	1239	0.25	31.7	6.53	4.20	7.55	8.11	92.4	30
Freeport North	Oyster Creek	TX 24	5/30/2000	1239	1	31.1	6.07	4.40	7.75	8.11	82.1	30
Freeport North	Swan Lake	TX 68	7/20/2000	1000	0.25	30.43	5.25	nd	nd	7.91	91.3	30
Freeport North	Oyster Creek	TX 104	10/4/2000	1123	0.25	27.65	6.9	16.40	26.9	7.9	97.3	50

Freeport North	Oyster Creek	TX 104	10/4/2000	1123	0.5	27.71	6.94	16.40	27	7.93	98.9	50
Freeport South	Intracoastal Waterway	TX 25	5/30/2000	1431	0.1	33.49	5.53	11.90	20	7.77	84.4	10
Freeport South	Jones Creek	TX 69	7/20/2000	1140	0.1	30.44	7.83	21.00	22.1	8.14	121.0	50
Freeport South	Jones Creek	TX 69	7/20/2000	1140	0.2	30.07	6.35	nd	nd	8.15	114.4	50
Freeport South	Intracoastal Waterway	TX 106	10/4/2000	1234	0.25	27.84	7.74	31.80	48.6	7.98	119.8	60
Freeport South	Intracoastal Waterway	TX 106	10/4/2000	1234	1	27.88	8.64	31.90	48.7	8.04	130.6	60
Freeport South	Intracoastal Waterway	TX 106	10/4/2000	1234	2	27.26	5.63	32.20	49.1	7.98	87.2	60
Freeport South	Intracoastal Waterway	TX 106	10/4/2000	1234	3	27.05	5.34	32.30	48.9	7.93	82.0	60
East Matagorda Bay	Caney Creek	TX 13	4/19/2000	1215	0.1	26.9	6.43	4.83	8.74	nd	84.6	nd
East Matagorda Bay	Caney Creek	TX 13	4/19/2000	1215	0.25	26.03	6.06	7.47	11.47	nd	77.8	nd
East Matagorda Bay	Caney Creek	TX 14	4/19/2000	1215	0.1	26.9	6.43	4.83	8.74	nd	84.6	nd
East Matagorda Bay	Caney Creek	TX 14	4/19/2000	1215	0.25	26.03	6.06	7.47	11.47	nd	77.8	nd
East Matagorda Bay	Caney Creek	TX 64	6/28/2000	1105	0.25	29.43	5.45	10.70	18.3	8.19	76.4	66
East Matagorda Bay	Caney Creek	TX 64	6/28/2000	1105	0.66	29.37	5.21	10.80	18.3	8.18	72.2	66
East Matagorda Bay	Caney Creek	TX 71	7/26/2000	1411	0.25	31.5	5.55	21.30	34.1	8.08	90.2	50
East Matagorda Bay	Caney Creek	TX 71	7/26/2000	1411	0.5	31.51	7.43	21.30	33.9	8.11	113.1	50
East Matagorda Bay	Caney Creek	TX 79	8/15/2000	1114	0.25	29.59	3.47	32.70	49.8	7.95	54.6	30
East Matagorda Bay	Caney Creek	TX 79	8/15/2000	1114	0.5	29.59	3.14	32.80	50	7.94	54.1	30
East Matagorda Bay	Caney Creek	TX 102	9/22/2000	1053	0.25	28.06	5.09	30.50	46.6	8.12	77.6	80
East Matagorda Bay	Caney Creek	TX 102	9/22/2000	1053	0.8	28	4.77	30.50	46.5	8.1	73.8	80
Matagorda Bay	Colorado River	TX 23	5/26/2000	1108	0.25	30.06	6.94	0.70	1.427	8.28	92.0	30
Matagorda Bay	Colorado River	TX 23	5/26/2000	1108	1	29.94	6.83	0.70	1.417	8.28	91.8	30
Matagorda Bay	Colorado River	TX 70	7/26/2000	1220	0.25	31.3	10.78	3.40	6.2	8.78	150.6	40
Matagorda Bay	Colorado River	TX 70	7/26/2000	1220	1	31.09	11.57	3.50	6.34	8.78	157.4	40
Matagorda Bay	Colorado River	TX 70	7/26/2000	1220	2	31.09	1.7	16.20	26.7	7.49	24.2	40
Matagorda Bay	Colorado River	TX 70	7/26/2000	1220	3	31.07	1.62	27.00	41.9	7.67	19.0	40
Matagorda Bay	Colorado River	TX 108	9/22/2000	1408	0.25	29.93	9.8	5.50	9.8	8.37	134.1	55
Matagorda Bay	Colorado River	TX 108	9/22/2000	1408	1	29.35	9.59	6.00	10.57	8.34	131.1	55
Matagorda Bay	Colorado River	TX 108	9/22/2000	1408	2	28.72	4.15	18.80	29.9	7.8	60.5	55

Matagorda Bay	Colorado River	TX 108	9/22/2000	1408	3	28.6	3.71	28.40	43.7	7.79	56.6	55
Matagorda Bay	Colorado River	TX 108	9/22/2000	1408	4	28.44	3.85	32.70	49.5	7.83	59.5	55
Matagorda Bay	Colorado River	TX 108	9/22/2000	1408	5	28.17	2.8	33.40	51.4	8.37	44.8	55
Matagorda Bay	Colorado River	TX 108	9/22/2000	1408	7	27.96	2.07	34.00	51.1	7.74	33.1	55
Lavaca Bay	Lavaca Bay Causeway	TX 2	4/13/2000	1125	0.19	20.42	7.56	22.90	36.3	nd	95.7	87
Lavaca Bay	Lavaca Bay Causeway	TX 32	5/17/2000	1430	0.25	26.24	6.07	28.10	38.6	8.01	89.1	18
Lavaca Bay	Lavaca Bay Causeway	TX 32	5/17/2000	1430	1	26.26	5.74	25.90	40.7	7.99	85.8	18
Lavaca Bay	Lavaca Bay Causeway	TX 32	5/17/2000	1430	2	26.18	5.51	26.10	40.8	7.99	82.6	18
Lavaca Bay	Lavaca Bay Causeway	TX 85	6/30/2000	1330	0.25	29.92	4.59	17.50	28.4	7.98	nd	43
Lavaca Bay	Lavaca Bay Causeway	TX 85	6/30/2000	1330	1	29.9	4.47	17.40	28.3	7.97	nd	43
Lavaca Bay	Lavaca Bay Causeway	TX 91	7/25/2000	1330	0.25	30.55	6.58	20.30	32.6	8.28	102.7	82
Lavaca Bay	Lavaca Bay Causeway	TX 91	7/25/2000	1330	1	30.29	6.25	21.00	33.6	8.27	98.5	82
Lavaca Bay	Lavaca Bay Causeway	TX 91	7/25/2000	1330	1.89	30.29	4.19	22.10	35.2	8.14	58.5	82
Lavaca Bay	Lavaca Bay Causeway	TX 97	9/29/2000	1400	0.25	23.52	nd	27.20	40	8.34	nd	83
Mesquite Bay	Mesquite Bay	TX 33	5/17/2000	1130	0.25	25.82	6.24	28.50	44.1	8.01	93.4	nd
Mesquite Bay	Mesquite Bay	TX 93	7/24/2000	1233	0.4	30	2.9**	37.40	62.016	8.21	48.0**	51
Mesquite Bay	Mesquite Bay	TX 93	7/24/2000	1233	0.79	30.1	2.9**	37.40	62.012	8.2	47.2**	51
Mesquite Bay	Mesquite Bay	TX 100	10/4/2000	1030	0.5	27.78	6.11	37.47	59.931	7.8	96.5	55
Mesquite Bay	Mesquite Bay	TX 100	10/4/2000	1030	1	27.35	5.11	38.33	60.22	7.79	80.9	55
Nueces Bay	Nueces River	TX 38	4/19/2000	950	0.25	24.74	6.71	3.20	5.94	8.53	82.6	24
Nueces Bay	Nueces River	TX 38	4/19/2000	950	1	24.73	6.51	3.30	5.98	8.53	80.3	24
Nueces Bay	Nueces River	TX 38	4/19/2000	950	1.3	24.73	6.26	3.30	5.98	8.52	79.0	24
Nueces Bay	Nueces River	TX 31	5/16/2000	1334	0.25	28.12	10.59	4.60	8.37	8.81	140.5	37
Nueces Bay	Nueces River	TX 31	5/16/2000	1334	0.4	28.09	10.33	4.70	8.39	8.82	136.5	37
Nueces Bay	Nueces River	TX 87	6/14/2000	1527	0.25	28.76	8.69	1.70	3.29	8.79	115.0	35
Nueces Bay	Nueces River	TX 87	6/14/2000	1527	1	28.73	7.62	1.70	3.3	8.71	100.6	35
Nueces Bay	Nueces River	TX 40	7/12/2000	1403	0.25	30.72	7.97	0.40	0.875	8.66	108.4	32
Nueces Bay	Nueces River	TX 40	7/12/2000	1403	1	29.47	7.49	0.40	0.924	8.63	97.8	32
Nueces Bay	Nueces River	TX 40	7/12/2000	1403	1.5	29.14	7.11	0.50	0.947	8.57	94.1	32

Nueces Bay	Nueces River	TX 34	8/10/2000	1323	0.25	29.84	7.5	11.10	19.17	8.25	103.1	25
Nueces Bay	Nueces River	TX 34	8/10/2000	1323	1	29.7	6.8	11.70	19.6	8.24	97.6	25
Nueces Bay	Nueces River	TX 34	8/10/2000	1323	1.5	29.46	6.21	11.80	19.9	8.22	88.4	25
Nueces Bay	Nueces River	TX 36	9/7/2000	1255	0.25	29.2	8	22.80	35.8	8.5	122.9	36
Nueces Bay	Nueces River	TX 36	9/7/2000	1255	1	29.2	4	32.70	49.1	8.3	64.1	36
Nueces Bay	Nueces River	TX 36	9/7/2000	1255	2	29.1	3.6	35.90	54.2	8.2	59.2	36
Nueces Bay	Nueces River	TX 36	9/7/2000	1255	2.25	29.1	3.5	36.00	54.3	8.2	59.4	36
East Flats	Port Aransas Birding Center	TX 8	4/18/2000	1100	0.25	26	nd	0.00	nd	nd	nd	nd
East Flats	Port Aransas Birding Center	TX 10	5/24/2000	1400	0.25	33	nd	0.00	nd	nd	nd	nd
East Flats	Port Aransas Birding Center	TX 9	6/21/2000	1000	0.25	29.5	nd	0.00	nd	nd	nd	nd
East Flats	Port Aransas Birding Center	TX 111	7/12/2000	0900	0.25	28	nd	2.00	nd	nd	nd	nd
East Flats	Port Aransas Birding Center	TX 112	8/14/2000	1100	0.25	31	nd	1.00	nd	nd	nd	nd
East Flats	Port Aransas Birding Center	TX 99	10/3/2000	1453	0.15	33.8	13.86	0.92	21.46	9.35	196.9	15
Oso Bay	Oso Bay 1	TX 3	4/13/2000	1700	0.3	23.4	8.25	34.00	51.6	8.1	124.0	nd
Oso Bay	Oso Bay 1	TX 3	4/13/2000	1700	1.54	23.35	7.82	34.30	52	8.03	118.5	nd
Oso Bay	Oso Bay 1	TX 3	4/13/2000	1700	3.07	23.29	7.81	34.40	52.1	8.02	116.8	nd
Oso Bay	Oso Bay 2	TX 82	5/30/2000	1617	0.25	32.68	4.94	40.09	60.18	nd	85.7	58
Oso Bay	Oso Creek	TX 83	6/20/2000	1215	0.22	26.65	1.37	2.20	4.547	7.13	16.7	28
Oso Bay	Oso Creek	TX 83	6/20/2000	1215	0.27	29.47	3.21	2.08	4.301	nd	44.5	28
Oso Bay	Oso Bay 2	TX 86	7/12/2000	0945	0.3	30.4	1.8	45.50	74.04	8.04	32.1	85
Oso Bay	Oso Bay 2	TX 89	8/8/2000	1035	0.5	31.23	6.5	49.45	80.796	8.13	115.3	85
Oso Bay	Oso Bay 2	TX 89	8/8/2000	1035	1.01	31.19	6.57	49.44	80.769	7.96	115.8	85
Oso Bay	Oso Bay 2	TX 95	9/15/2000	1000	0.53	31.24	5.74	46.60	76.779	7.87	100.1	10
Oso Bay	Oso Bay 2	TX 95	9/15/2000	1000	1.4	31.1	5.5	46.70	76.74	8.15	95.5	10
Baffin Bay	Kraatz Pier	TX 4	4/27/2000	1505	0.3	28.86	8.07	36.20	54.1	8.39	135.6	18
Baffin Bay	Kraatz Pier	TX 5	4/27/2000	1505	0.3	28.86	8.07	36.20	54.1	8.39	135.6	18
Baffin Bay	Bayview Campground	TX 7	5/31/2000	1235	0.25	28.54	6.99	38.10	57.1	nd	113.4	37
Baffin Bay	Bayview Campground	TX 84	6/21/2000	1007	0.33	28.4	5.04	42.60	67.372	7.86	60.2	30
Baffin Bay	Bayview Campground	TX 84	6/21/2000	1007	0.94	28.34	2.82	42.00	65.844	7.63	35.4	30

Baffin Bay	Bayview Campground	TX 90	7/28/2000	1505	0.25	30.72	6.32	50.50	81.551	7.51	112.5	14
Baffin Bay	Bayview Campground	TX 90	7/28/2000	1505	0.88	30.74	6.23	50.46	81.522	8.03	110.1	14
Baffin Bay	Bayview Campground	TX 92	8/24/2000	1740	0.25	32.25	6.65	54.93	79.14	8.01	123.1	33
Baffin Bay	Bayview Campground	TX 92	8/24/2000	1740	0.5	32.2	6.81	54.72	78.88	8.07	126.2	33
Baffin Bay	Bayview Campground	TX 92	8/24/2000	1740	0.95	32.23	6.68	54.66	78.8	8.07	123.1	33
Baffin Bay	Bayview Campground	TX 96	9/28/2000	1230	0.6	22.93	9.71	60.59	82.284	8.22	160.4	40.5
Baffin Bay	Bayview Campground	TX 96	9/28/2000	1230	0.69	23.37	9.81	60.60	83.02	8.31	163.5	40.5
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 1	4/6/2000	1730	0.3	24.78	9.94	17.50	28.5	8.28	133.5	51
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 1	4/6/2000	1730	0.6	24.72	10.04	17.60	28.6	8.3	142.0	51
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 1	4/6/2000	1730	1.3	24.5	9.22	17.10	28.7	8.26	127.2	51
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 6	6/13/2000	1205	0.19	30.38	2.51	10.11	19.09	7.9	35.3	60
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 6	6/13/2000	1205	0.72	31.13	2.34	10.16	19.073	7.82	32.9	60
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 6	6/13/2000	1205	1.27	29.97	2.19	10.20	19.073	7.62	29.6	60
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 94	8/9/2000	1600	0.25	31.23	7.2	20.10	32.2	8.16	113.5	40
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 94	8/9/2000	1600	0.7	31.21	7.75	20.20	32.4	8.18	119.5	40

Table B.6. Physical-chemical data for *Pfiesteria* sampling stations in Texas in 2001. (nd=no data)

Minor System	Location	Sample ID	Date Collected	Time Collected	Depth (m)	Water Temperature (deg C)	DO (mg/L)	Salinity (ppt)	Conductivity (mS/cm)	pH	Percent Saturation	Secchi Disk (cm)
Clear Lake	Clear Lake	TX 101	4/10/2001	0919	0.5	24.43	8.07	0.40	0.889	nd	98.5	25
Clear Lake	Clear Lake	TX 101	4/10/2001	0919	1.2	24.44	8.24	0.40	0.887	nd	100.5	25
Clear Lake	Clear Lake	TX 109	4/25/2001	1100	0.5	22.29	6.22	0.60	1.086	8.2	72.4	20
Clear Lake	Clear Lake	TX 109	4/25/2001	1100	1	22.05	6.13	0.60	1.106	8.17	69.3	20
Clear Lake	Clear Lake	TX 164	5/9/2001	1545	0.5	28.27	13.34	1.10	2.05	9.11	174	20
Clear Lake	Clear Lake	TX 164	5/9/2001	1545	1	27.36	9.84	1.00	1.99	8.89	125	20
Clear Lake	Clear Lake	TX 161	5/24/2001	0800	0.5	25.06	5.86	1.00	1.83	8.62	71.3	15
Clear Lake	Clear Lake	TX 161	5/24/2001	0800	1	24.97	5.82	1.00	1.84	8.58	70.7	15
Clear Lake	Clear Lake	TX 167	6/5/2001	0850	0.5	27.82	5.59	1.30	2.46	8.83	72.3	20
Clear Lake	Clear Lake	TX 167	6/5/2001	0850	1	27.9	5.3	1.50	2.84	8.87	68.8	20
Clear Lake	Clear Lake	TX 167	6/5/2001	0850	1.5	27.88	5.14	1.50	2.67	8.86	67.1	20
Clear Lake	Clear Lake	TX 171	6/20/2001	0905	0.5	29.15	5.73	0.18	0.367	8.92	76.1	30
Clear Lake	Clear Lake	TX 171	6/20/2001	0905	0.8	29.15	5.6	0.18	0.373	8.93	72.8	30
Clear Lake	Clear Lake	TX 174	7/3/2001	1700	0.5	30.82	13.95	0.20	0.425	9.43	185	20
Clear Lake	Clear Lake	TX 174	7/3/2001	1700	0.8	30.39	10.5	0.20	0.429	9.23	142.8	20
Clear Lake	Clear Lake	TX 178	7/19/2001	0853	0.25	30.58	3.66	0.88	1.81	8.83	48.9	20
Clear Lake	Clear Lake	TX 178	7/19/2001	0853	0.9	30.61	3.43	0.97	1.9	8.82	46.2	20
Clear Lake	Clear Lake	TX 180	8/3/2001	0907	0.5	30.25	5.41	0.60	1.154	8.73	71.7	35
Clear Lake	Clear Lake	TX 180	8/3/2001	0907	0.8	30.19	5.44	0.60	1.28	8.71	72.3	35
Clear Lake	Clear Lake	TX 186	8/17/2001	1414	0.5	32.95	14.01	2.90	5.35	9.41	nd	35
Clear Lake	Clear Lake	TX 186	8/17/2001	1414	0.8	30.9	9.33	3.10	5.59	8.96	126.1	35
Clear Lake	Clear Lake	TX 188	9/4/2001	1200	0.5	28.43	2.53	0.10	0.193	7.19	32.5	35
Clear Lake	Clear Lake	TX 188	9/4/2001	1200	1	27.76	2.18	0.10	0.197	7.17	28	35
Clear Lake	Clear Lake	TX 126	9/28/2001	1005	0.5	21.91	7.53	0.50	0.96	8.43	85.8	25
Clear Lake	Clear Lake	TX 126	9/28/2001	1005	1	21.98	7.75	0.60	1.172	8.25	88.8	25
Dickinson Bay	Dickinson Bayou	TX 103	4/10/2001	1016	0.5	24.22	5.68	0.40	0.843	nd	68.8	25

Dickinson Bay	Dickinson Bayou	TX 110	4/25/2001	1156	0.5	23.16	3.56	1.00	1.79	7.57	41.4	20
Dickinson Bay	Dickinson Bayou	TX 169	5/9/2001	1321	0.5	26.8	7.94	1.00	1.93	8.62	98.6	30
Dickinson Bay	Dickinson Bayou	TX 169	5/9/2001	1321	0.8	26.65	8.24	1.10	1.72	8.61	99	30
Dickinson Bay	Dickinson Bayou	TX 165	5/24/2001	0924	0.5	26.5	6.22	3.60	8.58	8	79.4	35
Dickinson Bay	Dickinson Bayou	TX 168	6/5/2001	0955	0.5	28.84	6.23	6.10	10.79	8.02	84.2	50
Dickinson Bay	Dickinson Bayou	TX 168	6/5/2001	0955	1	28.82	6.17	6.10	10.78	8.01	83.2	50
Dickinson Bay	Dickinson Bayou	TX 172	6/20/2001	1000	0.5	30.98	6.42	0.19	0.4	7.81	86	40
Dickinson Bay	Dickinson Bayou	TX 175	7/3/2001	1550	0.5	30.72	6.02	0.30	0.567	8.08	80.8	30
Dickinson Bay	Dickinson Bayou	TX 175	7/3/2001	1550	1.5	30.09	4.38	0.30	0.6	7.84	56.4	30
Dickinson Bay	Dickinson Bayou	TX 177	7/19/2001	1022	0.25	31.64	6.08	3.10	5.71	7.88	85.1	45
Dickinson Bay	Dickinson Bayou	TX 181	8/3/2001	1038	0.5	30.9	5.14	6.40	11.26	7.84	71.5	50
Dickinson Bay	Dickinson Bayou	TX 181	8/3/2001	1038	1.5	30.76	4.72	6.50	11.33	7.81	66.7	50
Dickinson Bay	Dickinson Bayou	TX 184	8/17/2001	1256	0.5	32.36	9.68	10.60	17.7	8.15	142.8	55
Dickinson Bay	Dickinson Bayou	TX 184	8/17/2001	1256	1.5	30.5	4.15	11.20	19.7	7.73	61.2	55
Dickinson Bay	Dickinson Bayou	TX 187	9/4/2001	1000	0.5	28.44	4.11	0.10	0.197	7.19	52.7	35
Dickinson Bay	Dickinson Bayou	TX 187	9/4/2001	1000	2.5	28.29	3.89	0.10	0.19	7.25	50.7	35
Dickinson Bay	Dickinson Bayou	TX 190	9/18/2001	1531	0.5	31.27	7.47	0.70	1.29	8.16	101.4	35
Dickinson Bay	Dickinson Bayou	TX 190	9/18/2001	1531	1	30.6	7.95	0.80	1.57	7.95	76.4	35
East Matagorda Bay	Caney Creek	TX 107	4/10/2001	1208	0.4	23.04	6.01	12.90	21.8	nd	79.3	30
East Matagorda Bay	Caney Creek	TX 162	4/25/2001	1517	0.5	23.55	6.01	10.20	15.8	8.07	75.7	40
East Matagorda Bay	Caney Creek	TX 163	5/9/2001	1108	0.5	25.67	3.79	10.20	16.7	8.26	49.2	30
East Matagorda Bay	Caney Creek	TX 166	5/24/2001	1123	0.5	26.28	5.53	30.80	26.26	7.84	83.7	30
East Matagorda Bay	Caney Creek	TX 170	6/5/2001	1145	0.5	27.65	5.13	29.30	45	7.74	77.7	25
East Matagorda Bay	Caney Creek	TX 170	6/5/2001	1145	1	27.63	5.08	28.40	43.9	7.72	76.7	25
East Matagorda Bay	Caney Creek	TX 173	6/20/2001	1130	0.5	29.65	2.05	20.60	33.2	7.8	30.3	50
East Matagorda Bay	Caney Creek	TX 173	6/20/2001	1130	0.8	29.6	2.92	22.20	35.1	7.83	44.5	50
East Matagorda Bay	Caney Creek	TX 176	7/3/2001	1016	0.5	28.35	4.63	13.20	22.6	7.97	66.6	60
East Matagorda Bay	Caney Creek	TX 176	7/3/2001	1016	0.8	28.35	4.71	13.60	22.7	7.98	65.1	60
East Matagorda Bay	Caney Creek	TX 179	7/19/2001	1150	0.25	30.9	3.2	30.40	46.3	7.71	51.8	50
East Matagorda Bay	Caney Creek	TX 182	8/3/2001	1510	0.5	31.38	4.75	27.10	42.4	7.68	75.8	45

East Matagorda Bay	Caney Creek	TX 182	8/3/2001	1510	0.8	31.33	4.57	27.70	43	7.67	72.6	45
East Matagorda Bay	Caney Creek	TX 183	8/17/2001	1036	0.5	29.91	3.44	28.50	44.3	7.62	51.9	55
East Matagorda Bay	Caney Creek	TX 183	8/17/2001	1036	0.8	29.67	3.32	27.70	44	7.61	56.8	55
East Matagorda Bay	Caney Creek	TX 185	8/31/2001	1130	0.5	27.46	4.99	12.70	21.4	7.66	69.1	45
East Matagorda Bay	Caney Creek	TX 185	8/31/2001	1130	0.8	27.44	5.08	12.70	21.6	7.63	69.7	45
East Matagorda Bay	Caney Creek	TX 189	9/18/2001	1126	0.5	29.03	4.75	0.70	1.26	7.54	62	25
East Matagorda Bay	Caney Creek	TX 189	9/18/2001	1126	0.8	28.94	4.62	0.70	1.382	7.5	59.9	25
Lavaca Bay	Port Lavaca Fishing Pier	TX 133	4/19/2001	1400	0.25	21.96	nd	16.00	26.3	nd	nd	32
Lavaca Bay	Port Lavaca Fishing Pier	TX 345	6/20/2001	1215	0.25	30.62	7.34	20.30	32.5	8.19	111	41
Lavaca Bay	Port Lavaca Fishing Pier	TX 345	6/20/2001	1215	1	30.63	6.8	20.10	32.3	8.19	102.9	41
Lavaca Bay	Port Lavaca Fishing Pier	TX 345	6/20/2001	1215	1.3	30.63	6.88	20.10	32.2	8.2	104	41
Lavaca Bay	Port Lavaca Fishing Pier	TX 335	6/28/2001	1320	0.25	29.61	6.04	16.30	26.8	8.02	nd	16
Lavaca Bay	Port Lavaca Fishing Pier	TX 335	6/28/2001	1320	1.19	29.5	5.13	16.30	26.7	8.02	nd	16
Lavaca Bay	Port Lavaca Fishing Pier	TX 121	7/11/2001	1248	0.25	31.15	6.76	20.90	33.4	8.08	105.8	55
Lavaca Bay	Port Lavaca Fishing Pier	TX 121	7/11/2001	1248	1	31.14	6.73	20.90	33.5	8.08	105.8	55
Lavaca Bay	Port Lavaca Fishing Pier	TX 122	8/6/2001	1640	0.25	31.79	6.46	23.03	30.59	8.14	100.6	71
Lavaca Bay	Port Lavaca Fishing Pier	TX 122	8/6/2001	1640	1.5	31.79	6.46	23.03	36.42	8.14	100.7	71
Lavaca Bay	Port Lavaca Fishing Pier	TX 358	8/15/2001	1215	0.15	29.84	5.97	21.00	33.6	nd	89.3	53
Lavaca Bay	Port Lavaca Fishing Pier	TX 358	8/15/2001	1215	1	29.65	5.99	21.20	33.8	nd	89.6	53
Lavaca Bay	Port Lavaca Fishing Pier	TX 358	8/15/2001	1215	1.5	28.7	5.61	21.90	34.9	nd	82.9	53
Lavaca Bay	Port Lavaca Fishing Pier	TX 337	9/19/2001	1330	0.5	30.05	7.76	2.10	3.91	8.46	104.1	30
Lavaca Bay	Port Lavaca Fishing Pier	TX 337	9/19/2001	1330	3ft	30.05	7.76	2.10	4.03	8.47	99.9	30
Lavaca Bay	Port Lavaca Fishing Pier	TX 337	9/19/2001	1330	6ft	30.05	7.76	2.10	5.26	8.28	79.3	30
Lavaca Bay	Port Lavaca Fishing Pier	TX 127	9/27/2001	1225	0.5	22.86	8.6	4.40	7.93	8.12	104.7	30
Lavaca Bay	Port Lavaca Fishing Pier	TX 127	9/27/2001	1225	1	22.63	8.54	4.40	8	8.12	103.5	30
East Flats	Port Aransas Birding Center	TX 141	4/10/2001	1415	0.1	30.1	19.09	0.67	1.353	nd	252.6	nd
East Flats	Port Aransas Birding Center	TX 142	4/25/2001	1445	0.1	26.6	19.15	1.29	2.563	nd	236.2	nd
East Flats	Port Aransas Birding Center	TX 301	5/8/2001	1115	0.25	26.15	14.4	1.23	2.405	nd	179	nd
East Flats	Port Aransas Birding Center	TX 302	5/24/2001	1120	0.25	28.4	12.82	1.24	2.437	nd	165.2	nd
East Flats	Port Aransas Birding Center	TX 303	6/12/2001	0900	0.25	27.7	7.13	1.05	2.054	9.17	89.3	nd

East Flats	Port Aransas Birding Center	TX 304	6/26/2001	0900	0.25	26.85	5.24	1.35	2.717	8.92	65.4	nd
East Flats	Port Aransas Birding Center	TX 305	7/10/2001	1000	0.25	28.38	8.15	0.96	1.912	8.59	104.9	nd
East Flats	Port Aransas Birding Center	TX 306	7/31/2001	0900	0.25	27.52	5.08	0.96	1.827	10.37	61	nd
East Flats	Port Aransas Birding Center	TX 307	8/14/2001	0900	0.25	26.44	5.68	7.04	2.042	10.81	71.7	nd
East Flats	Port Aransas Birding Center	TX 308	8/30/2001	0930	0.25	25.67	10.38	0.83	1.638	8.78	127.7	nd
East Flats	Port Aransas Birding Center	TX 309	9/15/2001	1000	0.25	26.87	7.96	1.18	2.314	8.81	102.5	nd
East Flats	Port Aransas Birding Center	TX 310	9/27/2001	1000	0.25	22.7	8.31	1.15	2.24	nd	98.7	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 140	4/9/2001	1813	0.25	27.04	8.66	20.13	33.561	8.44	121	42
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 140	4/9/2001	1813	0.61	27.12	8.81	20.28	33.856	8.38	125	42
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 140	4/9/2001	1813	1.22	27	8.25	20.25	33.794	8.27	116	43
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 139	4/23/2001	1217	0.25	25.8	7	16.00	nd	nd	nd	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 139	4/23/2001	1217	1	25.5	6.8	18.00	nd	nd	nd	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 134	5/9/2001	1325	0.75	27.71	8.58	11.40	10.13	8.58	140.2	38
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 137	5/24/2001	1420	0.25	28.2	8.8	15.70	nd	nd	nd	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 137	5/24/2001	1420	1	28	8.8	15.80	nd	nd	nd	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 356	6/7/2001	1947	0.25	31.2	4.35	17.29	31.662	8.18	67.9	40
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 136	6/19/2001	1310	0.25	29.3	10.5	2.20	nd	nd	137.9	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 136	6/19/2001	1310	1	28.9	8.1	2.30	nd	nd	107.7	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 136	6/19/2001	1310	1.5	28.9	0.7	2.60	nd	nd	3.2	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 338	7/10/2001	1223	0.25	31.51	9.06	17.20	27.9	8.83	130	32
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 338	7/10/2001	1223	0.97	31	7.5	17.20	28	8.82	116.2	32
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 132	7/24/2001	1403	0.25	30.8	7.5	20.30	nd	nd	nd	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 132	7/24/2001	1403	1	30.7	7.4	20.40	nd	nd	nd	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 343	8/13/2001	1815	0.25	31.68	7.5	20.10	32.3	8.67	118	31
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 343	8/13/2001	1815	0.78	31.63	6.87	20.50	32.8	8.64	109.5	31
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 131	8/29/2001	1354	0.25	29	5.3	16.00	nd	nd	nd	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 131	8/29/2001	1354	1	28.9	4.8	16.20	nd	nd	nd	nd
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 336	9/12/2001	1434	0.25	30.55	13.93**	10.10	17.92	8.79	nd	40
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 336	9/12/2001	1434	0.91	30.51	13.2**	10.20	17.4	8.77	nd	40

Table B-7 Nutrient data for *Pfiesteria* sampling stations in Texas in 2000. (nd=no data)

Location	Sample ID	Date Collected	Chlorophyll a (ug/L) (mean)	Chlorophyll a (ug/L) (s.e.)	Silicate (ug/L) (mean)	Silicate (ug/L) (s.e.)	Phosphate (ug/L) (mean)	Phosphate (ug/L) (s.e.)	Nitrate+Nitrite (ug/L) (mean)	Nitrate+Nitrite (ug/L) (s.e.)	Ammonium (ug/L) (mean)	Ammonium (ug/L) (s.e.)	DIN (ug/L)	DON (ug/L)	TDN (ug/L)
Sabine Pass Swing Bridge	TX 17	4/25/2000	2.83	1.78	37.5	5.99	0.235	0.025	0.805	0.015	0.97	0.16	1.775	17.875	19.65
Sabine Pass Swing Bridge	TX 18	4/25/2000	2.83	1.78	37.5	5.99	0.235	0.025	0.805	0.015	0.97	0.16	1.775	17.875	19.65
Sabine Pass Swing Bridge	TX 26	6/1/2000	7	0.5	50.585	2.085	0.475	0.085	3.515	0.215	1.085	0.025	4.6	29.245	33.845
Sabine Pass Swing Bridge	TX 61	6/23/2000	7.95	0.6	41.13	0	5.03	0	8.98	0	0.22	0	9.2	18.015	27.215
Sabine Pass Swing Bridge	TX 67	7/12/2000	12.43	5.15	55.24	0.15	0.41	0.01	0.405	0.015	0.17	0.02	0.575	42.405	42.98
Sabine Pass Swing Bridge	TX 74	8/2/2000	4.19	2.65	53.54	0	7.11	0	0.93	0	0.28	0	1.21	20.22	21.43
Sabine Pass Swing Bridge	TX 80	9/15/2000	15.6	3.3	52.92	0	7.16	0	0.12	0	0	0	0.12	20.785	20.905
Tabbs Bay	TX 19	4/26/2000	3.81	0.95	64.55	2.98	5.66	0.34	39.08	0.79	11.92	0.18	51	49.71	100.71
Tabbs Bay	TX 62	6/23/2000	8.15	0.5	35.59	0	9.66	0	0.24	0	0.27	0	0.51	21.84	22.35
Tabbs Bay	TX 78	8/10/2000	8.03	3	71.87	0	14.28	0	24.82	0	0.19	0	25.01	21.09	46.1
Clear Lake	TX 20	4/26/2000	14.65	3.1	51.155	4.715	4.38	0.17	15.82	1.43	0.695	0.115	16.515	35.44	51.955
Clear Creek	TX 30	5/11/2000	44.93	0.25	40.68	0	10.49	0	29.98	0	0.27	0	30.25	37.865	68.115
Clear Creek	TX 27	6/21/2000	57.25	0.5	59.24	10.87	11.085	2.155	5.375	1.415	0.265	0.155	5.64	25.41	31.05
Armand Bayou	TX 66	7/10/2000	49	35	76.905	0.935	16.575	0.595	1.535	0.075	0.23	0.03	1.765	53.53	55.295
Armand Bayou	TX 75	8/7/2000	53.75	10	60.37	0	15.73	0	0.37	0	0.2	0	0.57	50.455	51.025
Armand Bayou	TX 39	9/20/2000	119	30	33.79	0	9.79	0	0.3	0	0.28	0	0.58	50	50.58
Dickinson Bayou 1	TX 11	4/19/2000	17.5	0	124.545	2.405	4.435	0.105	18.35	1.08	17.525	0.495	35.875	45.16	81.035
Dickinson Bayou 1	TX 12	4/19/2000	17.5	0	124.545	2.405	4.435	0.105	18.35	1.08	17.525	0.495	35.875	45.16	81.035
Dickinson Bayou 1	TX 28	6/21/2000	8.26	3.75	86.145	24.115	3.125	0.535	1.49	0.57	5.3	0.9	6.79	nd	nd
Dickinson Bayou 2	TX 72	7/26/2000	11.63	1.7	70.1	0	1.98	0	0.55	0	0.27	0	0.82	28.65	29.47
Dickinson Bayou 1	TX 76	8/7/2000	10.93	1.3	75.26	0	7.06	0	0.28	0	0.27	0	0.55	34.81	35.36
Dickinson Bayou 1	TX 35	9/20/2000	36.88	8.50	32.46	0	5.04	0	0.37	0	0.07	0	0.44	55.255	55.695
Moses Bayou	TX 21	5/11/2000	6.875	4.8	35.78	3.68	0.23	0.13	0.21	0	0.83	0.23	1.04	20.415	21.45
Moses Lake	TX 65	7/7/2000	13.43	5.35	66.08	0.56	2.385	0.035	0.085	0.005	0.05	0.04	0.135	25.205	25.34
Moses Bayou	TX 37	9/20/2000	35.5	11	57.41	0	7.06	0	0.35	0	0.09	0	0.44	47.115	47.555

Jamaica Beach Canal	TX 15	4/19/2000	7.78	3.5	43.17	0.69	0.06	0.06	0.125	0.005	0.3	0.07	0.425	25.71	26.135
Jamaica Beach Canal	TX 16	4/19/2000	7.78	3.5	43.17	0.69	0.06	0.06	0.125	0.005	0.3	0.07	0.425	25.71	26.135
Jamaica Beach Canal	TX 22	5/15/2000	17.8	0	67.65	1.27	0.575	0.025	0.105	0.025	0.39	0.02	0.495	24.55	25.045
Jamaica Beach Canal	TX 29	6/21/2000	24.6	5.7	63.14	0.03	0.375	0.015	0.065	0.015	0.215	0.195	0.28	21.875	22.155
Jamaica Beach Canal	TX 73	7/27/2000	45.13	9.75	68.495	0.295	0.495	0.005	0.065	0.015	0.285	0.025	0.35	26.335	26.685
Jamaica Beach Canal	TX 77	8/9/2000	19.71	0.55	72.63	0	13.86	0	0.13	0	0.11	0	0.24	37.22	37.46
Jamaica Beach Canal	TX 105	10/4/2000	15	2.1	48.93	0	12.31	0	0.18	0	0.23	0	0.41	26.05	26.46
Oyster Creek	TX 24	5/30/2000	13.13	4.35	128.02	12.35	3.02	0.27	21.72	3.17	9.805	1.025	31.525	21.215	52.74
Swan Lake	TX 68	7/20/2000	8.33	1.15	11.12	0	12.27	0	5.79	0	0.44	0	6.23	41.205	47.435
Oyster Creek	TX 104	10/4/2000	9.11	7.15	51.31	0	10.06	0	0.19	0	0.26	0	0.45	29.185	29.635
Intracoastal Waterway	TX 25	5/30/2000	5.53	0.15	135.44	2.89	8.965	0.105	27.16	0.06	3.735	0.125	30.895	49.745	80.64
Jones Creek	TX 69	7/20/2000	69.75	9.5	85.9	0	19.79	0	5.59	0	0.51	0	6.1	218.675	224.775
Intracoastal Waterway	TX 106	10/4/2000	54.75	14	22.55	0	11.21	0	17.57	0	0.27	0	17.84	26.455	44.295
Caney Creek	TX 13	4/19/2000	2.26	1.745	96.245	4.855	10.18	0.27	54.145	0.005	18.905	0.025	73.05	104.87	177.92
Caney Creek	TX 14	4/19/2000	2.26	1.745	96.245	4.855	10.18	0.27	54.145	0.005	18.905	0.025	73.05	104.87	177.92
Caney Creek	TX 64	6/28/2000	5.64	3.05	200	8.13	9.75	0.18	1.38	0.02	0.72	0.05	2.1	36.015	38.115
Caney Creek	TX 71	7/26/2000	8.61	4.95	42.16	0	14.08	0	0.56	0	0.2	0	0.76	31.02	31.78
Caney Creek	TX 79	8/15/2000	1.204	0.27	39.36	0	13.78	0	5.8	0	4.25	0	10.05	21.11	31.16
Caney Creek	TX 102	9/22/2000	10.06	8.25	16.47	0	18.74	0	2.17	0	0.21	0	2.38	26.615	28.995
Colorado River	TX 23	5/26/2000	12.65	0.9	173.29	3.9	6.36	0.19	32.39	0.4	4.91	0.01	37.3	32.125	69.425
Colorado River	TX 70	7/26/2000	106.25	50.5	139.01	0	3.56	0	0.73	0	0.32	0	1.05	17.29	18.34
Colorado River	TX 108	9/22/2000	23.64	9.45	59.35	0	10.32	0	38.4	0	0.26	0	38.66	19.57	58.23
Lavaca Bay Causeway	TX 2	4/13/2000	4.53	1.9	69.535	0.705	0.3	0.03	0.69	0.02	0.5	0.24	1.19	19.73	20.92
Lavaca Bay Causeway	TX 32	5/17/2000	9.55	1.9	85.905	0.745	0.595	0.005	1.365	0.015	1.73	0.03	3.095	nd	nd
Lavaca Bay Causeway	TX 85	6/30/2000	19.4	0.8	69.765	0.025	0.79	0	0.135	0.005	0.12	0.06	0.255	31.55	31.805
Lavaca Bay Causeway	TX 91	7/25/2000	12.33	3.55	130.85	8.95	0.995	0.145	nd	nd	0.295	0.185	0.295	27.95	28.245
Lavaca Bay Causeway	TX 97	9/29/2000	7.39	0.95	91.21	0	10.41	0	nd	0	0.25	0	0.12	50.145	50.265
Mesquite Bay	TX 33	5/17/2000	9.2	1.4	96.08	0	1.02	0	0.87	0	0.78	0	1.65	22.715	24.365
Mesquite Bay	TX 93	7/24/2000	7.63	0.15	82.3	0.31	0.865	0.015	0.08	0.04	0.015	0.065	0.095	19.96	20.055

Mesquite Bay	TX 100	10/4/2000	23.58	1.6	81.35	0	15.64	0	1.08	0	0	0	1.08	50.555	51.635
Nueces River	TX 38	4/19/2000	37.63	0.5	213.225	12.815	5.41	0.07	5.525	0.335	18.565	1.125	24.09	30.16	54.25
Nueces River	TX 31	5/16/2000	39.25	0.9	155.24	3.65	3.325	0.065	1.435	1.105	4.145	3.245	5.58	43.62	49.2
Nueces River	TX 87	6/14/2000	31.75	6	347.195	0.415	4.32	0.05	0.105	0.015	0.845	0.005	0.95	29.655	30.605
Nueces River	TX 40	7/12/2000	8.48	5.5	87.94	9.09	5.925	0.135	0.17	0	0.08	0.03	0.25	28.39	28.64
Nueces River	TX 34	8/10/2000	5.73	0	237.13	0	8.92	0	0.76	0	0.67	0	1.43	26.3	27.73
Nueces River	TX 36	9/7/2000	47.63	5.5	216.47	0	11.2	0	5.07	0	0.12	0	5.19	43.265	48.455
Port Aransas Birding Center	TX 8	4/18/2000	15.31	2.95	339.625	2.505	80.235	2.695	103.24	0.67	9.97	0.03	113.21	1191.155	1304.37
Port Aransas Birding Center	TX 10	5/24/2000	37.15	2.75	272.18	22.15	29.41	1.81	418.015	17.115	11.035	2.165	429.05	376.21	805.26
Port Aransas Birding Center	TX 9	6/21/2000	67.4	0.5	49.65	17.87	7.885	1.085	52.3	18.86	8.505	1.065	60.805	499.47	560.275
Port Aransas Birding Center	TX 111	7/12/2000	110.6	1.1	198.9	14.6	29.5	1.5	347.65	2.55	126.85	5.25	474.5	94.08	568.58
Port Aransas Birding Center	TX 112	8/14/2000	0	0	153.4	0	9.39	0	88.28	0	3.39	0	91.67	749.46	841.13
Port Aransas Birding Center	TX 99	10/3/2000	134.13	7.5	199.66	0	17.64	0	88.36	0	0.3	0	88.66	747.575	836.235
Oso Bay 1	TX 3	4/13/2000	6	0.7	74.57	6.2	0.235	0.005	1.31	0.13	4.025	0.265	5.335	33.15	38.485
Oso Bay 2	TX 82	5/30/2000	6.11	1.05	143.025	0.115	0.13	0.01	0.59	0.04	0.945	0.025	1.535	63.67	65.205
Oso Creek	TX 83	6/20/2000	25.93	8.3	260.275	1.695	8.635	0.055	0.2	0	0.71	0.01	0.91	48.495	49.405
Oso Bay 2	TX 86	7/12/2000	4.5	0.3	55.14	0.14	0.09	0.02	0.32	0.02	2.52	0.03	2.84	51.88	54.72
Oso Bay 2	TX 89	8/8/2000	3.05	0	75.12	0	13.03	0	0.66	0	0.81	0	1.47	53.645	55.115
Oso Bay 2	TX 95	9/15/2000	2.72	0.15	83.19	0	14.48	0	1	0	0.44	0	1.44	40.84	42.28
Kraatz Pier	TX 4	4/27/2000	26.75	6	189.75	7.56	1.67	0.06	1.86	0.07	0	0	1.86	nd	nd
Kraatz Pier	TX 5	4/27/2000	26.75	6	214.215	3.785	1.965	0.015	1.205	0.045	0.925	0.575	2.13	nd	nd
Bayview Campground	TX 7	5/31/2000	61.5	0	199.205	5.255	0.315	0.005	0.57	0.06	0.09	0.02	0.66	102.53	103.19
Bayview Campground	TX 84	6/21/2000	9.04	8.15	180.655	11.145	0.815	0.065	2.08	0.04	9.585	0.415	11.665	74.015	85.68
Bayview Campground	TX 90	7/28/2000	16.9	13.4	101.69	0.7	0.185	0.035	0.64	0.11	0.15	0.05	0.79	100.02	100.81
Bayview Campground	TX 92	8/24/2000	7.06	0	133.59	0	18.15	0	0.17	0	0.21	0	0.38	87.915	88.295
Bayview Campground	TX 96	9/28/2000	64.63	1.5	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Adolph Tomae Jr. County Park	TX 1	4/6/2000	11.89	17.05	227.275	16.155	7.06	0.16	53.295	2.835	0.06	0.06	53.355	35.945	89.3
Adolph Tomae Jr. County Park	TX 6	6/13/2000	19.25	7	304.42	2.91	73.685	0.535	326.75	20.65	24.99	0.31	351.74	nd	120.235
Adolph Tomae Jr. County Park	TX 94	8/9/2000	13.5	0	188.01	0	13.35	0	4.05	0	0.88	0	4.93	34.51	39.44

Table B-8. Nutrient data for *Pfiesteria* sampling stations in Texas in 2001. (nd=no data)

Location	Sample ID	Date Collected	Chlorophyll a (ug/L) (mean)	Chlorophyll a (ug/L) (stdev)	Silicate (ug/L) (mean)	Silicate (ug/L) (stdev)	Phosphate (ug/L) (mean)	Phosphate (ug/L) (stdev)	Nitrate+Nitrite (ug/L) (mean)	Nitrate+Nitrite (ug/L) (stdev)	Ammonium (ug/L) (mean)	Ammonium (ug/L) (stdev)	DIN (ug/L)	DON (ug/L)	TDN (ug/L)
Clear Lake	TX 101	4/10/2001	85.25	nd	82.37	74.837	6.78	0.612	14.21	4.179	0.38	0.194	14.59	26.24	40.84
Clear Lake	TX 109	4/25/2001	68.75	nd	229.08	0.861	8.58	0.040	11.17	0.249	0.27	0.019	11.44	43.94	55.39
Clear Lake	TX 164	5/9/2001	168.25	nd	180.40	0.098	15.72	0.645	10.90	0.659	0.21	0.037	11.11	53.44	64.55
Clear Lake	TX 161	5/24/2001	106.75	nd	298.60	109.670	12.67	0.920	5.79	1.007	3.77	0.194	9.56	61.99	71.56
Clear Lake	TX 167	6/5/2001	149.50	nd	69.21	4.699	18.11	3.141	19.44	0.592	12.02	0.129	31.47	35.52	66.99
Clear Lake	TX 171	6/20/2001	78.75	nd	72.08	3.271	7.41	0.039	20.63	0.570	0.69	0.205	21.32	25.33	46.65
Clear Lake	TX 174	7/3/2001	161.00	nd	28.19	0.293	10.32	1.027	40.55	0.310	0.00	nd	40.55	32.47	73.02
Clear Lake	TX 178	7/19/2001	14.05	nd	42.11	1.956	11.01	2.001	5.72	0.143	12.57	0.906	18.29	11.34	29.63
Clear Lake	TX 180	8/3/2001	65.50	nd	17.63	nd	4.76	nd	11.81	nd	9.53	nd	21.34	24.90	46.24
Clear Lake	TX 186	8/17/2001	150.75	nd	30.28	12.756	8.43	0.163	1.25	0.540	1.10	0.175	2.34	21.65	24.00
Clear Lake	TX 188	9/4/2001	1.85	nd	41.92	11.291	4.97	0.083	6.15	0.642	9.39	0.503	15.54	45.64	61.18
Clear Lake	TX 126	9/28/2001	81.75	nd	30.77	1.193	6.20	0.204	38.62	0.295	0.77	0.186	39.39	16.40	55.79
Dickinson Bayou	TX 103	4/10/2001	15.58	nd	94.65	87.937	5.39	1.293	14.30	1.711	13.04	1.852	27.34	71.85	99.20
Dickinson Bayou	TX 110	4/25/2001	12.86	nd	384.40	90.767	2.71	0.381	12.43	0.130	12.00	0.316	24.43	42.43	66.86
Dickinson Bayou	TX 169	5/9/2001	80.75	nd	250.81	31.097	2.74	0.189	3.38	0.198	2.70	0.093	6.07	38.50	44.58
Dickinson Bayou	TX 165	5/24/2001	39.75	nd	169.05	20.374	3.18	0.083	1.56	0.038	0.07	0.019	1.63	42.20	43.83
Dickinson Bayou	TX 168	6/5/2001	53.75	nd	34.26	0.740	7.46	0.165	15.76	0.177	11.68	0.013	27.44	19.00	46.44
Dickinson Bayou	TX 172	6/20/2001	83.50	nd	92.69	14.526	3.18	0.047	8.85	0.292	0.73	0.062	9.58	24.90	34.48
Dickinson Bayou	TX 175	7/3/2001	60.75	nd	90.53	4.073	1.19	0.024	4.12	0.023	0.99	0.067	5.11	18.82	23.93
Dickinson Bayou	TX 177	7/19/2001	7.78	nd	26.67	2.099	1.74	0.007	0.70	0.166	1.08	0.305	1.77	24.23	26.00
Dickinson Bayou	TX 181	8/3/2001	37.25	nd	46.68	3.228	3.72	0.980	3.20	0.011	4.73	0.022	7.92	59.08	67.00
Dickinson Bayou	TX 184	8/17/2001	52.13	nd	17.34	5.015	2.94	0.259	12.94	0.331	0.27	nd	13.21	13.75	26.96
Dickinson Bayou	TX 187	9/4/2001	1.36	nd	31.90	12.827	4.91	0.229	2.12	1.057	2.33	0.091	4.46	16.36	20.82
Dickinson Bayou	TX 190	9/18/2001	30.50	nd	100.07	2.876	2.61	0.052	0.92	0.140	0.87	0.075	1.80	29.68	31.48
Caney Creek	TX 107	4/10/2001	5.12	nd	133.60	12.499	1.45	0.009	23.16	0.194	5.13	0.006	28.29	27.69	55.99
Caney Creek	TX 162	4/25/2001	9.28	nd	268.57	58.521	1.04	0.011	4.77	0.026	1.95	0.061	6.71	30.36	37.08

Caney Creek	TX 163	5/9/2001	18.44	nd	274.27	57.754	0.18	0.033	0.11	0.035	0.03	0.025	0.14	44.15	44.29
Caney Creek	TX 166	5/24/2001	6.39	nd	80.87	0.093	0.64	0.052	0.83	0.079	1.43	0.079	2.26	23.04	25.30
Caney Creek	TX 170	6/5/2001	7.08	nd	18.70	0.183	0.91	0.025	3.08	0.135	6.83	0.063	9.91	9.03	18.95
Caney Creek	TX 173	6/20/2001	8.41	nd	36.66	2.078	4.40	0.157	2.73	0.132	7.40	0.097	10.13	20.77	30.90
Caney Creek	TX 176	7/3/2001	11.13	nd	22.68	1.175	1.19	0.221	1.30	0.352	2.21	0.141	3.51	21.14	24.66
Caney Creek	TX 179	7/19/2001	4.63	nd	9.79	0.439	0.74	0.028	1.83	0.004	3.49	0.866	5.32	14.08	19.40
Caney Creek	TX 182	8/3/2001	7.34	nd	29.05	1.087	2.47	0.039	3.43	0.916	6.29	0.312	9.72	35.20	44.93
Caney Creek	TX 183	8/17/2001	8.36	nd	45.89	0.470	3.39	0.118	1.57	0.086	2.11	0.769	3.68	18.56	22.24
Caney Creek	TX 185	8/31/2001	28.81	nd	19.62	3.502	6.52	0.294	2.22	0.403	7.35	0.510	9.57	8.82	18.40
Caney Creek	TX 189	9/18/2001	42.63	nd	62.39	5.529	21.63	0.008	5.19	0.081	6.97	0.035	12.16	28.72	40.88
Port Lavaca Fishing Pier	TX 133	4/19/2001	11.48	nd	154.19	9.274	0.51	0.078	0.83	0.119	0.13	0.033	0.96	24.85	25.81
Port Lavaca Fishing Pier	TX 345	6/20/2001	nd	nd	40.33	0.677	2.01	1.682	1.19	1.253	0.23	nd	1.43	944.39	945.82
Port Lavaca Fishing Pier	TX 335	6/28/2001	nd	nd	22.94	3.942	0.72	0.101	1.10	0.490	0.36	nd	1.47	44.38	45.85
Port Lavaca Fishing Pier	TX 121	7/11/2001	6.99	nd	26.12	3.764	0.39	0.063	0.23	0.059	0.60	0.105	0.83	26.55	27.38
Port Lavaca Fishing Pier	TX 122	8/6/2001	25.20	nd	48.35	0.342	0.95	0.071	0.96	0.145	0.88	0.244	1.84	23.81	25.65
Port Lavaca Fishing Pier	TX 358	8/15/2001	12.68	nd	38.59	1.448	3.38	1.296	0.96	0.037	7.54	3.049	8.50	55.74	64.25
Port Lavaca Fishing Pier	TX 337	9/19/2001	17.63	nd	48.24	45.514	4.13	0.085	12.78	0.117	1.15	0.409	13.93	23.73	37.66
Port Lavaca Fishing Pier	TX 127	9/27/2001	23.00	nd	15.32	4.687	3.64	0.049	9.52	0.563	0.23	nd	9.74	12.45	22.19
Port Aransas Birding Center	TX 141	4/10/2001	306.75	nd	404.07	73.421	14.97	0.428	95.69	0.301	0.33	0.062	96.02	609.20	705.22
Port Aransas Birding Center	TX 142	4/25/2001	149.50	nd	217.62	18.219	3.50	0.084	93.52	0.331	0.33	0.038	93.85	363.72	457.57
Port Aransas Birding Center	TX 301	5/8/2001	158.00	nd	250.29	13.805	5.29	0.497	87.58	0.772	5.27	0.107	92.86	337.32	430.18
Port Aransas Birding Center	TX 302	5/24/2001	85.30	nd	88.24	nd	42.22	nd	72.58	nd	15.88	nd	88.46	1044.29	1132.75
Port Aransas Birding Center	TX 303	6/12/2001	105.30	nd	728.84	4.440	28.34	2.468	94.09	1.027	52.69	1.080	146.78	704.77	851.56
Port Aransas Birding Center	TX 304	6/26/2001	90.40	nd	71.81	1.693	42.03	1.649	73.81	0.400	88.09	7.293	161.90	173.27	335.17
Port Aransas Birding Center	TX 305	7/10/2001	146.30	nd	85.11	0.456	45.56	2.111	74.24	0.525	117.32	4.811	191.56	141.21	332.77
Port Aransas Birding Center	TX 306	7/31/2001	126.70	nd	91.84	0.048	53.56	2.185	78.53	0.338	31.16	0.858	109.70	686.11	795.81
Port Aransas Birding Center	TX 307	8/14/2001	40.40	nd	76.91	0.555	43.70	0.375	78.06	0.433	41.55	0.103	119.61	725.67	845.28
Port Aransas Birding Center	TX 308	8/30/2001	65.90	nd	74.50	0.831	39.13	2.008	73.98	0.221	28.86	0.692	102.84	869.52	972.36
Port Aransas Birding Center	TX 309	9/15/2001	91.40	nd	81.36	1.239	48.42	5.073	72.37	0.157	62.44	2.535	134.80	805.02	939.83
Port Aransas Birding Center	TX 310	9/27/2001	48.40	nd	98.37	1.957	62.18	1.363	71.37	3.267	67.88	0.750	139.25	1119.27	1258.53

Adolph Tomae Jr. County Park	TX 140	4/9/2001	11.74	nd	325.82	34.395	7.94	0.375	66.38	0.691	0.01	0.010	66.39	63.36	129.76
Adolph Tomae Jr. County Park	TX 139	4/23/2001	18.56	nd	434.45	52.416	9.90	0.246	55.03	0.589	0.07	0.069	55.10	55.04	110.14
Adolph Tomae Jr. County Park	TX 134	5/9/2001	20.90	nd	44.94	nd	3.1	nd	44.07	nd	2.85	nd	46.92	52.28	99.19
Adolph Tomae Jr. County Park	TX 137	5/24/2001	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Adolph Tomae Jr. County Park	TX 356	6/7/2001	53.81	nd	41.45	0.073	4.42	0.354	18.30	0.028	2.18	0.411	20.47	1014.57	1035.04
Adolph Tomae Jr. County Park	TX 136	6/19/2001	nd	nd	73.08	nd	4.13	nd	2.37	nd	1.51	nd	3.88	37.30	41.18
Adolph Tomae Jr. County Park	TX 338	7/10/2001	nd	nd	38.71	15.212	3.28	2.321	29.16	40.004	9.34	8.710	38.50	349.62	388.12
Adolph Tomae Jr. County Park	TX 132	7/24/2001	34.81	nd	52.61	4.156	3.90	0.571	0.20	0.007	0.44	nd	0.65	55.29	55.94
Adolph Tomae Jr. County Park	TX 343	8/13/2001	31.50	nd	73.09	nd	4.13	nd	2.35	nd	1.08	nd	3.43	37.75	41.18
Adolph Tomae Jr. County Park	TX 131	8/29/2001	24.50	nd	68.63	14.449	7.35	1.360	8.75	0.935	11.08	0.975	19.83	24.48	44.31
Adolph Tomae Jr. County Park	TX 336	9/12/2001	96.38	nd	96.55	8.670	6.86	0.642	7.96	0.730	0.00	0.000	7.96	35.62	43.58

Table B-9. Results of PCR analysis for *Pfiesteria* samples in Texas in 2000. (P=positive, "—"=negative, X=no amplifiable DNA, na=no analysis done, nd=no data)

Minor System	Location	Sample ID	Sample Medium	Date Collected	Date Received	*P. piscicida*	*P. shumwayae*	Cryptoptero-diniopsis	*P. piscicida*	*P. shumwayae*
							Method 1		*Method 2*	
Sabine Lake	Sabine Pass Swing Bridge	TX 17	W	4/24/2000	4/27/2000	--	--	--	--	--
Sabine Lake	Sabine Pass Swing Bridge	TX 18	W	4/24/2000	4/27/2000	--	--	--	--	--
Sabine Lake	Sabine Pass Swing Bridge	TX 44	S	4/25/2000	4/27/2000	--	--	--	--	--
Sabine Lake	Sabine Pass Swing Bridge	TX 26	W	5/31/2000	6/8/2000	--	--	--	--	--
Sabine Lake	Sabine Pass Swing Bridge	TX 61	W	6/22/2000	6/29/2000	--	--	--	P	--
Sabine Lake	Sabine Pass Swing Bridge	TX 67	W	7/11/2000	7/17/2000	--	--	--	nd	--
Sabine Lake	Sabine Pass Swing Bridge	TX 74	W	8/1/2000	9/7/2000	--	--	--	--	--
Sabine Lake	Sabine Pass Swing Bridge	TX 80	W	9/14/2000	10/9/2000	--	--	--	--	--
Tabbs Bay	Tabbs Bay	TX 19	W	4/25/2000	4/27/2000	--	--	--	--	--
Tabbs Bay	Tabbs Bay	TX 62	W	6/22/2000	6/29/2000	--	--	--	--	--
Tabbs Bay	Tabbs Bay	TX 78	W	8/9/2000	9/7/2000	--	--	--	--	--
Clear Lake	Clear Lake	TX 20	W	4/25/2000	4/27/2000	--	--	--	P	--
Clear Lake	Clear Creek	TX 30	W	5/10/2000	5/12/2000	--	--	--	--	--
Clear Lake	Clear Creek	TX 27	W	6/20/2000	6/27/2000	--	--	--	--	--
Clear Lake	Armand Bayou	TX 66	W	7/9/2000	7/17/2000	--	--	--	--	--
Clear Lake	Armand Bayou	TX 75	W	8/6/2000	9/7/2000	P	--	--	na	na
Clear Lake	Armand Bayou	TX 39	W	9/19/2000	10/9/2000	P	--	P	P	--
Dickinson Bay	Dickinson Bayou 1	TX 11	W	4/18/2000	4/20/2000	--	--	--	--	--
Dickinson Bay	Dickinson Bayou 1	TX 12	W	4/18/2000	4/20/2000	--	--	--	--	--
Dickinson Bay	Dickinson Bayou 1	TX 41	S	4/19/2000	4/20/2000	--	--	--	--	--
Dickinson Bay	Dickinson Bayou 1	TX 28	W	6/20/2000	6/27/2000	P	--	--	--	--
Dickinson Bay	Dickinson Bayou 2 *	TX 72	W	7/25/2000	7/27/2000	--	--	--	P	--
Dickinson Bay	Dickinson Bayou 2 *	TX 45	S	7/26/2000	7/27/2000	--	--	--	--	--
Dickinson Bay	Dickinson Bayou 1	TX 76	W	8/6/2000	9/7/2000	P	--	--	na	na

Dickinson Bay	Dickinson Bayou 1	TX 35	W	9/19/2000	10/9/2000	P	--	--	P	--
Moses Lake	Moses Bayou	TX 21	W	5/10/2000	5/12/2000	--	--	--	--	--
Moses Lake	Moses Lake	TX 65	W	7/6/2000	7/14/2000	--	--	--	--	--
Moses Lake	Moses Bayou	TX 37	W	9/19/2000	10/9/2000	--	--	--	--	--
West Bay	Jamaica Beach Canal	TX 15	W	4/18/2000	4/20/2000	--	--	--	--	--
West Bay	Jamaica Beach Canal	TX 16	W	4/18/2000	4/20/2000	--	--	--	--	--
West Bay	Jamaica Beach Canal	TX 43	S	4/19/2000	4/20/2000	--	--	--	--	--
West Bay	Jamaica Beach Canal	TX 22	W	5/14/2000	5/16/2000	--	--	--	--	--
West Bay	Jamaica Beach Canal	TX 29	W	6/20/2000	6/27/2000	--	--	--	--	--
West Bay	Jamaica Beach Canal	TX 73	W	7/26/2000	7/27/2000	X	X	X	--	--
West Bay	Jamaica Beach Canal	TX 77	W	8/8/2000	9/7/2000	--	--	--	P	--
West Bay	Jamaica Beach Canal	TX 105	W	10/3/2000	10/9/2000	--	--	--	--	--
Freeport North	Oyster Creek	TX 24	W	5/29/2000	6/5/2000	X	X	X	--	--
Freeport North	Swan Lake	TX 68	W	7/19/2000	7/25/2000	--	--	--	nd	--
Freeport North	Oyster Creek	TX 104	W	10/3/2000	10/9/2000	--	--	--	--	--
Freeport South	Intracoastal Waterway	TX 25	W	5/29/2000	6/5/2000	X	X	X	--	--
Freeport South	Jones Creek	TX 69	W	7/19/2000	7/25/2000	X	X	X	--	--
Freeport South	Intracoastal Waterway	TX 106	W	10/3/2000	10/9/2000	--	--	--	--	--
East Matagorda Bay	Caney Creek	TX 13	W	4/19/2000	4/20/2000	--	--	--	--	--
East Matagorda Bay	Caney Creek	TX 14	W	4/19/2000	4/20/2000	X	X	X	--	--
East Matagorda Bay	Caney Creek	TX 42	S	4/19/2000	4/20/2000	--	--	--	--	--
East Matagorda Bay	Caney Creek	TX 64	W	6/27/2000	7/5/2000	--	--	--	--	--
East Matagorda Bay	Caney Creek *	TX 71	W	7/25/2000	7/27/2000	--	--	--	--	--
East Matagorda Bay	Caney Creek	TX 79	W	8/14/2000	9/7/2000	--	--	--	--	--
East Matagorda Bay	Caney Creek	TX 102	W	9/21/2000	10/9/2000	--	--	--	--	--
Matagorda Bay	Colorado River	TX 23	W	5/25/2000	6/5/2000	X	X	X	F	--
Matagorda Bay	Colorado River *	TX 70	W	7/25/2000	7/27/2000	--	--	--	nd	--
Matagorda Bay	Colorado River	TX 108	W	9/21/2000	Nd	X	X	X	--	--
Lavaca Bay	Lavaca Bay Causeway	TX 2	W	4/12/2000	4/17/2000	--	--	--	--	--

Lavaca Bay	Lavaca Bay Causeway	TX 32	W	5/16/2000	5/23/2000	X	X	X	na	na
Lavaca Bay	Lavaca Bay Causeway	TX 85	W	6/29/2000	7/7/2000	--	--	--	nd	P
Lavaca Bay	Lavaca Bay Causeway	TX 91	W	7/24/2000	7/27/2000	--	--	--	--	--
Lavaca Bay	Lavaca Bay Causeway	TX 97	W	9/28/2000	10/6/2000	--	--	--	--	--
Mesquite Bay	Mesquite Bay	TX 33	W	5/16/2000	5/23/2000	X	X	X	--	--
Mesquite Bay	Mesquite Bay	TX 93	W	7/23/2000	7/27/2000	--	--	--	--	--
Mesquite Bay	Mesquite Bay	TX 100	W	10/3/2000	10/6/2000	--	--	--	--	--
Nueces Bay	Nueces River	TX 38	W	4/18/2000	4/25/2000	--	--	--	--	--
Nueces Bay	Nueces River	TX 31	W	5/15/2000	5/23/2000	--	--	--	--	--
Nueces Bay	Nueces River	TX 87	W	6/13/2000	6/22/2000	--	--	--	--	--
Nueces Bay	Nueces River	TX 40	W	7/11/2000	7/17/2000	--	--	--	--	--
Nueces Bay	Nueces River	TX 34	W	8/8/2000	10/17/2000	--	--	--	--	--
Nueces Bay	Nueces River	TX 36	W	9/6/2000	10/17/2000	--	--	--	--	--
East Flats	Port Aransas Birding Center	TX 8	W	4/17/2000	4/24/2000	--	--	--	--	--
East Flats	Port Aransas Birding Center	TX 10	W	5/23/2000	6/1/2000	--	F	--	--	--
East Flats	Port Aransas Birding Center	TX 9	W	6/20/2000	6/27/2000	--	--	--	--	--
East Flats	Port Aransas Birding Center	TX 111	W	7/11/2000	7/17/2000	--	--	--	--	--
East Flats	Port Aransas Birding Center	TX 112	W	8/14/2000	8/17/2000	--	--	--	--	--
East Flats	Port Aransas Birding Center	TX 99	W	10/2/2000	10/6/2000	--	--	--	--	--
Oso Bay	Oso Bay 1	TX 3	W	4/12/2000	4/17/2000	--	--	--	--	--
Oso Bay	Oso Bay 2	TX 82	W	5/29/2000	6/1/2000	--	P	--	na	na
Oso Bay	Oso Creek	TX 83	W	6/19/2000	6/22/2000	--	--	--	--	--
Oso Bay	Oso Bay 2	TX 86	W	7/11/2000	7/27/2000	--	--	--	--	--
Oso Bay	Oso Bay 2	TX 89	W	8/7/2000	8/18/2000	--	--	--	--	--
Oso Bay	Oso Bay 2	TX 95	W	9/14/2000	9/15/2000	--	--	nd	--	--
Baffin Bay	Kraatz Pier	TX 4	W	4/26/2000	4/28/2000	--	--	--	--	--
Baffin Bay	Bayview Campground	TX 5	W	4/26/2000	4/28/2000	--	--	--	--	--
Baffin Bay	Bayview Campground	TX 7	W	5/12/2000	6/1/2000	--	--	--	--	F
Baffin Bay	Bayview Campground	TX 84	W	6/20/2000	6/22/2000	--	--	--	--	--

Baffin Bay	Bayview Campground	TX 90	W	7/28/2000	8/2/2000	X	X	X	na	na
Baffin Bay	Bayview Campground	TX 92	W	8/23/2000	8/31/2000	X	X	X	--	--
Baffin Bay	Bayview Campground	TX 96	W	9/27/2000	10/6/2000	--	--	--	--	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 1	W	4/5/2000	4/7/2000	--	P	--	nd	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 51	S	4/6/2000	4/7/2000	--	P	--	--	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 6	W	6/12/2000	6/22/2000	--	--	--	--	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 52	S	6/13/2000	6/22/2000	--	P	--	P	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 94	W	8/8/2000	8/18/2000	--	--	--	P	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 53	S	8/9/2000	8/18/2000	X	X	X	--	--

* Fish kill was occurring or had recently occurred at or near this station at the time sampling was conducted for *Pfiesteria*.

Table B-10. Results of PCR analysis for *Pfiesteria* samples in Texas in 2001. (P=positive, "—"=negative, X=no amplifiable DNA, na=no analysis done, nd=no data)

Minor System	Location	Sample ID	Sample Medium	Date Collected	Date Received	*P. piscicida*	*P. shumwayae*	*P. piscicida*	*P. shumwayae*
						Method 1		*Method 2*	
Clear Lake	Clear Lake	TX 101	W	4/10/2001	4/24/2001	--	--	--	P
Clear Lake	Clear Lake	TX 109	W	4/25/2001	6/11/2001	--	--	--	P
Clear Lake	Clear Lake	TX 164	W	5/9/2001	6/11/2001	--	--	--	P
Clear Lake	Clear Lake	TX 161	W	5/24/2001	6/11/2001	--	--	P	P
Clear Lake	Clear Lake	TX 167	W	6/5/2001	6/11/2001	X	X	--	P
Clear Lake	Clear Lake	TX 171	W	6/20/2001	7/20/2001	--	--	--	F
Clear Lake	Clear Lake	TX 174	W	7/3/2001	7/20/2001	--	--	--	--
Clear Lake	Clear Lake	TX 178	W	7/19/2001	8/20/2001	--	--	--	P
Clear Lake	Clear Lake	TX 180	W	8/3/2001	8/20/2001	--	--	--	--
Clear Lake	Clear Lake	TX 186	W	8/17/2001	nd	--	--	P	P
Clear Lake	Clear Lake	TX 188	W	9/4/2001	nd	--	--	--	P
Clear Lake	Clear Lake	TX 126	W	9/28/2001	10/10/01	X	X	--	P
Dickinson Bay	Dickinson Bayou	TX 103	W	4/10/2001	4/24/2001	--	--	--	--
Dickinson Bay	Dickinson Bayou	TX 110	W	4/25/2001	6/11/2001	--	--	--	--
Dickinson Bay	Dickinson Bayou	TX 169	W	5/9/2001	6/11/2001	--	--	--	--
Dickinson Bay	Dickinson Bayou	TX 165	W	5/24/2001	6/11/2001	--	--	--	--
Dickinson Bay	Dickinson Bayou	TX 168	W	6/5/2001	6/11/2001	--	--	P	P
Dickinson Bay	Dickinson Bayou	TX 172	W	6/20/2001	7/20/2001	--	--	P	--
Dickinson Bay	Dickinson Bayou	TX 175	W	7/3/2001	7/20/2001	--	--	--	--
Dickinson Bay	Dickinson Bayou	TX 177	W	7/19/2001	8/20/2001	--	--	P	P
Dickinson Bay	Dickinson Bayou	TX181	W	8/3/2001	8/20/2001	--	--	P	--
Dickinson Bay	Dickinson Bayou	TX 184	W	8/17/2001	nd	--	--	P	P
Dickinson Bay	Dickinson Bayou	TX 187	W	9/4/2001	nd	--	--	--	--
Dickinson Bay	Dickinson Bayou	TX 190	W	9/18/2001	nd	--	--	--	--
East Matagorda Bay	Caney Creek	TX 107	W	4/10/2001	4/24/2001	--	--	P	P

East Matagorda Bay	Caney Creek	TX 162	W	4/25/2001	6/11/2001	--	--	--	--
East Matagorda Bay	Caney Creek	TX 163	W	5/9/2001	6/11/2001	X	X	--	P
East Matagorda Bay	Caney Creek	TX 166	W	5/24/2001	6/11/2001	X	X	--	--
East Matagorda Bay	Caney Creek	TX 170	W	6/5/2001	6/11/2001	--	--	--	--
East Matagorda Bay	Caney Creek	TX 173	W	6/20/2001	7/20/2001	--	--	--	--
East Matagorda Bay	Caney Creek	TX 176	W	7/3/2001	7/20/2001	--	P	--	--
East Matagorda Bay	Caney Creek	TX 179	W	7/19/2001	8/20/2001	--	P	--	--
East Matagorda Bay	Caney Creek	TX 182	W	8/3/2001	8/20/2001	--	--	P	P
East Matagorda Bay	Caney Creek	TX 183	W	8/17/2001	nd	--	--	F	--
East Matagorda Bay	Caney Creek	TX 185	W	8/31/2001	nd	--	--	P	--
East Matagorda Bay	Caney Creek	TX 189	W	9/18/2001	nd	--	--	--	--
Lavaca Bay	Port Lavaca Fishing Pier	TX 133	W	4/19/2001	7/12/2001	--	--	--	--
Lavaca Bay	Port Lavaca Fishing Pier	TX 345	W	6/20/2001	7/31/2001	--	P	--	--
Lavaca Bay	Port Lavaca Fishing Pier	TX 335	W	6/28/2001	7/12/2001	--	--	P	--
Lavaca Bay	Port Lavaca Fishing Pier	TX 121	W	7/11/2001	7/31/2001	--	F	--	--
Lavaca Bay	Port Lavaca Fishing Pier	TX 122	W	8/6/2001	9/5/2001	--	--	--	--
Lavaca Bay	Port Lavaca Fishing Pier	TX 358	W	8/15/2001	823/01	--	--	--	P
Lavaca Bay	Port Lavaca Fishing Pier	TX 127	W	9/27/2001	10/1/2001	X	X	--	--
East Flats	Port Aransas Birding Center	TX 141	W	4/10/2001	5/1/2001	--	--	--	P
East Flats	Port Aransas Birding Center	TX 142	W	4/25/2001	5/1/2001	--	--	--	--
East Flats	Port Aransas Birding Center	TX 301	W	5/8/2001	5/28/2001	--	--	P	P
East Flats	Port Aransas Birding Center	TX 302	W	5/24/2001	5/28/2001	--	--	--	P
East Flats	Port Aransas Birding Center	TX 303	W	6/12/2001	6/20/2001	P	--	F	--
East Flats	Port Aransas Birding Center	TX 304	W	6/26/2001	7/5/2001	P	--	P	F
East Flats	Port Aransas Birding Center	TX 305	W	7/10/2001	7/20/2001	--	--	--	--
East Flats	Port Aransas Birding Center	TX 306	W	7/31/2001	8/8/2001	--	--	P	P
East Flats	Port Aransas Birding Center	TX 307	W	8/14/2001	8/27/2001	--	--	--	--
East Flats	Port Aransas Birding Center	TX 308	W	8/30/2001	9/6/2001	--	--	--	--
East Flats	Port Aransas Birding Center	TX 309	W	9/15/2001	9/27/2001	--	--	P	--

East Flats	Port Aransas Birding Center	TX 310	W	9/27/2001	10/16/2001	--	--	P	P
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 140	W	4/9/2001	4/11/2001	--	P	P	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 139	W	4/23/2001	4/30/2001	--	--	--	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 134	W	5/9/2001	5/14/2001	--	--	--	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 137	W	5/24/2001	nd	--	--	--	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 356	W	6/7/2001	6/11/2001	P	--	P	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 755	S	6/7/2001	6/11/2001	--	--	P	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 136	W	6/19/2001	7/1/2001	P	--	P	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 338	S	7/10/2001	7/12/2001	--	P	--	P
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 338	W	7/10/2001	7/12/2001	--	--	P	P
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 132	W	7/24/2001	8/10/2001	--	P	--	P
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 343	W	8/13/2001	8/20/2001	--	--	P	P
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 780	S	8/13/2001	8/17/2001	--	--	P	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 131	W	8/29/2001	9/18/2001	--	--	--	--
Arroyo Colorado	Adolph Tomae Jr. County Park	TX 336	W	9/12/2001	9/26/2001	P	--	P	P

Appendix C

Quality Assurance Project Plan

Quality Assurance Project Plan (QAPP)

for

Monitoring *Pfiesteria* in Texas Estuaries

EPA, Region 6

Approved by:

______________________________ Date: ___________
James D. Simons
Project Manager
Texas Parks and Wildlife Department

______________________________ Date: ___________
David Buzan
Quality Assurance Project Officer
Texas Parks and Wildlife Department

______________________________ Date: ___________
Larry D. McKinney
Senior Director for Aquatic Resources
Texas Parks and Wildlife Department

______________________________ Date: ___________
Barbara Schrodt
Project Officer
U.S. Environmental Protection Agency

______________________________ Date: ___________
Joan Brown
Chief of Assistance Programs
U.S. Environmental Protection Agency

Section A.2. Table of Contents

Section A.3. Distribution list

The following individuals will be provided copies of the approved Quality Assurance Project Plan (QAPP), and all approved future modifications of this QAPP.

Texas Parks and Wildlife Department (TPWD)

Larry D. McKinney, Senior Director for Aquatic Resources and
Resource Protection Division
Bob Spain, Assistant Director, Resource Protection Division
David Buzan, Branch Chief, Coastal Conservation Branch
James Simons, Project Manager
Woody Woodrow, Program Leader, Coastal Conservation, Clear Lake
Smiley Nava, Program Leader, Coastal Conservation, Corpus Christi
All field crew personnel

University of Texas Marine Science Institute

Tracy Villareal, Principal Investigator

University of North Carolina at Greensboro

Parke Rublee

U.S. Environmental Protection Agency (USEPA) Region 6

Barbara Schrodt
Phillip Crocker

Section A.4. Project organization

The following individuals will be responsible for implementation and completion of the project:

Executive Director, Texas Parks and Wildlife Department: Andrew Sansom (responsible for overall operation of Texas Parks and Wildlife Department)

Senior Director for Aquatic Resources and Resource Protection Division: Larry D. McKinney (responsible for performance of Division personnel who will implement the project)

Quality Assurance Project Officer and Branch Chief, Coastal Conservation: David Buzan (responsible for performance of Branch personnel who will implement the project and for assuring that the QAPP is followed and data of known quality are collected)

Project Manager: James Simons (responsible for overseeing all phases of project implementation, including compilation and revision of the QAPP)

Field Sampling Coordination Personnel: Winston Denton, Smiley Nava, Janet Nelson

Field Sampling Personnel: Chad Norris, Mike Weeks, Andy Tirpak, Sam Copeland, Jim Tolan

Contract Support: Tracy Villareal, University of Texas Marine Science Institute
Parke Rublee, University of North Carolina at Greensboro

EPA Project Officer: Barbara Schrodt

EPA Work Assignment Manager: Phillip Crocker

Section A.5. Problem definition and background

Concern has grown nationwide about the possible presence and impacts of toxic algae on coastal ecosystems and human health. During the past two years, awareness has increased about the group of toxic dinoflagellates referred to as *Pfiesteria* and *Pfiesteria*-like organisms (PLO). These recently discovered organisms have been found to cause massive fish kills, outbreaks of fish disease and some neurological effects in humans in coastal ecosystems.

Texas has experienced massive toxic blooms of *Gymnodinium breve* which have killed over 40 million fish along the Texas coast in the past 13 years. Toxic blooms of the dinoflagellate, *Alexandrium monilata*, have also occurred along the Texas coast. Texas has never had a documented incident caused by *Pfiesteria* or *Pfiesteria*-like organisms.

Recent toxic red tides led to the creation of a Texas Harmful Algal Bloom (HAB) coordinating committee in 1998 which is developing a HAB response contingency plan. One outcome of this effort is the creation of a coast-wide, cooperative monitoring program for the presence of *G. breve*. TPWD is collecting water samples from the Gulf and bays and experts at the University of Texas Marine Science Institute (UTMSI) are analyzing samples.

Section A.6. Project description

The proposed *Pfiesteria* monitoring project will determine if *Pfiesteria*-like organisms are present in Texas estuaries, and if present, what physical and chemical conditions they are found under. To accomplish the proposed project, TPWD staff will collect samples from appropriate sites. UTMSI will analyze the samples for nutrient and chlorophyll concentrations and ship sub-samples to the University of North Carolina at Greensboro. The University of North Carolina at Greensboro will conduct gene probe assays of the sub-samples for *Pfiesteria piscicida* and two *Pfiesteria*-like species. If the gene probe assays produce positive results, confirmation tests for toxicity of the sample will be conducted at Dr. JoAnn Burkholder's laboratory at North Carolina State University.

If *Pfiesteria* or PLO are found the field data will be analyzed for relationships in regards to the occurrence of *Pfiesteria*. Nutrient and chlorophyll data will be averaged and standard deviations calculated. The data will be plotted as a time series at each station for comparison to the presence/absence data for the two *Pfiesteria* taxa and the PLO results. Results of the monitoring project will be submitted for publication in an appropriate scientific journal.

Section A. 6.1. Site Selection

Site selection was based on the result of an evaluation of *Pfiesteria* habitat preferences and environmental requirements. This meant that targeted areas of interest are bays and estuaries that have a history of nutrient enrichment of high chlorophyll concentrations and algal blooms. A stated objective of the program is to determine the Texas estuaries most at risk during the initial year's efforts. Based on the results of this analysis, a list of target sites was created for sampling during April through September by the project working group. This group consisted of the Project Manager, the contracted Principal Investigator, and Field Coordinators from Clear Lake, Corpus Christi and Austin, each of whom have extensive experience and knowledge of the bays and estuaries of Texas. Prior to the 2001 sampling season all field crew team leaders and the Project Manager will meet to review, and revise if necessary, field data collection procedures.

Section A.6.2. Number of sites

A total of 17 stations (See Table 1 below) will be sampled, with 12 to be collected in April, June and August and 14 to be collected in May, July and September. There are nine stations that will be collected each month and 8 to be collected every other month. This design gives us broader coverage, yet enables us to take logistical considerations into account.

Table 1. List of the *Pfiesteria* sampling station locations and the month in which they will be sampled for sampling year 2000.

Location	April	May	June	July	Aug	Sept
Sabine Lake	X	X	X	X	X	X
Tabb's Bay	X		X		X	
Clear Lake	X	X	X	X	X	X
Dickinson Bay	X		X		X	
Moses Lake		X		X		X
Galveston Bay - canals	X	X	X	X	X	X
ICWW - Freeport (north)		X		X		X
ICWW Freeport (south)		X		X		X
Caney Creek	X	X	X	X	X	X
Matagorda Bay		X		X		X
Lavaca Bay	X	X	X	X	X	X
Mesquite Bay		X		X		X
Port Aransas	X	X	X	X	X	X
Nueces River	X	X	X	X	X	X
Oso Bay	X	X	X	X	X	X
Baffin Bay	X	X	X	X	X	X
Arroyo Colorado	X		X		X	
Total number of stations	12	14	12	14	12	14

Section A. 6.3. Sampling period.

Samples will be collected from April to September in 2000 and 2001

Section A.6.4. Sampling procedures and parameters

Upon arrival at the sampling site, location will be verified by global positioning system. Water quality parameters to be collected include:

1. Water temperature
2. Salinity
3. Dissolved Oxygen
4. Secchi disk

Meteorological conditions to be monitored will include:

1. Air temperature

2. Wind speed
3. Wind direction
4. Cloud cover
5. Sea state

Water samples will be collected and returned to the UTMSI laboratory for the following analyses:

1. Chlorophyll a
2. Dissolved inorganic nutrients (Nitrate+nitrite, phosphate, silicate and ammonium)
3. Dissolved organic nutrients (phosphorus and nitrogen)

A surface water sample will be collected, filtered throught a GFF, and the filter will be placed in a vial containing buffer provided by Dr. Parke Rublee. The vial will be mailed to Dr. Parke Rublee at the University of North Carolina at Greensboro (UNCG) for the following:

1. *Pfiesteria* and *Pfiesteria* like species genetic probe analysis

Sediment samples will be collected at as yet undetermined locations. The location of sediment collections will in part be determined by the results of the water sample analyses and in part on observations of the field sites visited for water sampling. The sediment sampling will be more selective due to the necessity of shipping these samples overnight to UNCG and the associated costs.

Sample collection protocols are listed in Section B.2.

Section A.6.5 Equipment and personnel

Equipment required for each sampling is included in the standard procedures outlined in Sec. B.2. Each team will consist of a minimum of 2 persons.

Section A.6.6. Required assessment tools

Annual program review will be conducted by the *Pfiesteria* working group. Suggestions for corrective action will be forwarded to the Project Manager.

Section A.6.7. Schedule, milestones and reports

A schedule for the project is presented below. Quarterly progress reports (December 1, March 1, June 1, September 1) will provide information regarding status of the individual work efforts. Significant changes to the work plan or schedule will be proposed in the progress reports.

See attached schedule for proposed scheduled starting and ending dates.

	1999				2000							
Tasks	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug
A	X	X	X	X	X	X	X					
B								X	X	X	X	X
C												

	2000				2001							
Tasks	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug
A		X	X	X	X	X	X					
B	X							X	X	X	X	X
C		X	X	X	X	X	X					

	2001				2002							
Tasks	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug
A												
B	X											
C		X	X	X	X	X	X					

Section A.7. Data quality objectives

The project will be directed towards Texas estuaries along the entire coast. The project intent is to characterize the presence of *Pfiesteria* or *Pfiesteria*-like organisms in these waters. Concurrent water quality parameters will permit comparison of this distribution against known factors documented from along the Atlantic seaboard.

This is a survey only and has no evaluation levels. The presence/absence of *Pfiesteria* may, or may not, be related to ambient nutrient/chlorophyll conditions. No action criteria or remedial action will be established based solely on this data.

Because the samples are collected in the field under variable conditions, it is accepted that at least 10% variation will be routine. This is considered acceptable since the variation expected between positive and negative *Pfiesteria* sites is expected to be orders of magnitude different. The effective quantification levels will be 0.2 uM for each nutrient and 0.1 ug chlorophyll per L due to the handling and shipping time between collection and processing. As noted above, this is a small fraction of the expected levels (10's uM nutrient and chlorophyll) between positive and negative *Pfiesteria* sites.

Section A.7.1. Data analysis and interpretation

Data will be analysed for presence or absence of *Pfiesteria* or *Pfiesteria*-like organisms. If *Pfiesteria* or *Pfiesteria*-like organisms are present, additional efforts (separate program) may be undertaken to determine if toxic or non-toxic strains are present. Water quality parameters will permit evaluation of the distribution (if present) in relation to nutrient loading as has been documented along the Atlantic seaboard.

Section A.7.2. Precision, accuracy, completeness, and comparability

Data representativeness is the extent to which data represent the physiochemical and biological conditions at the individual site, but also the degree to which the sampled population represents the larger universe of similar sites. The former concern will be addressed through the use of standard procedures consistently applied at each site by sampling teams. The latter concern the primary focus of the survey concept since we are examining a variety of estuaries with different hydrodynamic and physicochemical regimes.

Comparability centers on the ability to compare one data set to another and will be ensured by the use of standard procedures consistently applied across all estuaries with standard units and data recording techniques. All laboratory analyses will employ approved methods and meet quality assurance goals for the samples.

Precision and accuracy will be measured relative to procedures listed in section B.5.

Data completeness represents a proportion between the expected or potential quantity of data from a project and that which is actually available following collection and analysis. The ideal goal would be 100%, but data loss may occur through incidents outside the investigator's control. Consequently, the goal for this study is 90 % data completeness.

Section A.8. Special training requirements and certification

There are no special training requirements for this project. All field personnel will be provided with a detailed sampling and sample handling protocol prior to beginning of the field collecting season. Field data collection sheets will also be provided to all field crews for standardized collection of field data. If there are any questions concerning field collections they will be directed to the Project Manager for resolution. Prior to the 2001 sampling season all field crew team leaders and the Project Manager will meet to review, and revise if necessary, field data collection procedures.

Section A.9. Documents and records

Field data sheets will be filled out completely and accurately at each site. Field crew leaders will check the sheet prior to leaving the site. Upon returning to the office, the crew leader will fax or mail the data sheets to the Project Manager, and enclose a copy with the nutrient/chlorophyll samples sent to UTMSI and a copy with the *Pfiesteria* samples sent to UNCG.

Nutrient and chlorophyll data will be entered into a spreadsheet following completion of analysis. Turnaround time of laboratory data will vary depending upon workload. In addition, samples will be held until there are enough samples to justify running a batch of samples.

Hard copies and diskettes containing field and nutrient data will be stored in at least duplicate form at separate TPWD facilities. Nutrient, chlorophyll and field data will also be stored at UTMSI. The final report will be maintained by the Coastal Conservation Branch of TPWD.

Section B.1. Sampling process design (Experimental Design)

The entire coast of Texas is targeted to be sampled, at least in the initial stages of the project. Each bay and estuary of the coast was considered, and in general, areas that are know to have high nutrient or chlorophyll concentrations were selected. In addition, several locations, in more pristine areas were selected to serve as controls. There were 17 sampling locations selected, with 9 of these to be sampled each month, and the other 8 on an every other month basis. The 17 were selected to provide a wide coverage, the alternation of 8 of the stations was a logistical consideration. Ten of the stations are located on the upper coast and seven on the lower coast.
Several of the stations are also located near our regularly visited datasonde stations for logistical reasons, and because there is a good recent historical record of water quality conditions at these stations.

Section B.2. Sampling methods

Water samples will be collected just below the surface using a water sampling device such as a Van Dorn bottle, or a five gallon bucket dipped below the surface to prevent collecting surface material. Sediment samples, when collected, will be taken by disturbing the sediment-water interface, and then collecting water that includes sediment that has been re-suspended. In cases where sediment samples are collected, water samples will also be collected. Water samples collected for nutrients will be frozen on dry ice immediately after collection. Filters for chlorophyll a analysis will also be placed on dry ice. The vials for the *Pfiesteria* analysis are to be kept at ambient temperature conditions, but will be kept out of the sunlight or places that could reach extremely high temperatures.

Section B.2.1. Site verification

Sample sites will be located on standard nautical charts. Upon arrival at the site, the field team will record the latitude and longitude on the sample data sheet.

Section B.2.2. Water Quality Samples

Water quality samples will be collected using new, clean polyethylene bottles. Field blanks will be collected at least at 5% of the sites and will consist of de-ionized water transported into the field and then transferred to the sample bottles.

Chlorophyll samples will be filtered onto glass fiber filters and placed on dry ice (<4.0 ° C). Nutrient samples will be filtered to remove biological activity (0.45 μm polycarbonate filters) and placed on dry ice (<4.0° C). Both samples will be frozen until delivered or shipped to Dr. Tracy Villareal at UTMSI. Holding time for all frozen samples will be less than 1 week.
Pfiesteria and *Pfiesteria*-like genes assays will be collected on filters, placed in buffer, and returned to the lab. These samples will be mailed directly to Dr. Parke Rublee at UNCG.

Section B.2.3. On-site water quality measurements

Sampling teams will use a standard Hydrolab electrode sensor for temperature, salinity and oxygen measurements. Calibration will be as per the manufacturer's recommendation.

Section B.3. Sample tracking/Sample custody

Sample tracking and custody procedures center on being able to account for sample integrity from the collection time to the analysis. Proper sample custody is a joint effort of the sampling crew, sample transporter, and laboratory staff. A chain of custody record will be established that will document the following:
Site location
Time/date of collection
Collection team
Preservation
Signatures of collection team

Sample integrity must also be protected by preventing sample contamination. Samples in tape-sealed ice chests are assumed to be secure, whether transportation is by staff vehicle, common carrier, or commercial package delivery. Biological samples for gene assay will be shipped to UNC for analysis as per their protocols.

Section B.4. Analytical procedures

Nutrient analysis will be conducted at UTMSI using a LaChat QC 8000 ion analyzer with computer controlled sample selection and peak processing. Chemistries are as specified by the manufacturer and have ranges as follows: nitrate+nitrate (0.03-5.0 μM; Quikchem method 31-107-04-1-A), silicate (0.03-5.0 μM; Quikchem method 31-114-27-1-B), ammonium (0.1-10 μM; Quikchem method 31-107-06-5-A) and phosphate (0.03-2.0 μM; Quikchem method 31-115-01-3-A). Chlorophyll will be extracted overnight and read fluorometrically on a Turner Model 10-AU using a non-acidification technique (Welschmeyer, 1994; EPA method 445.0). Assays will be performed in duplicate. Dissolved organic nitrogen and dissolved organic phosphorus will be conducted by simultaneous persulfate digestion (Raimbault et al. 1999) and then assayed for nitrate+nitrite and phosphate by the above listed protocols.

The *Pfiesteria* and *Pfiesteria*-like genes assays will be conducted by Dr. Parke Rublee at the UNCG. DNA is purified using chloroform purification (Schaefer 1997). If samples have high suspended sediment loads, an additional clean up step can be used (DNeasy Plant Kit, Qiagen). Purified DNA is dissolved in sterile ddH_2O and stored at -20°C. 50 μl PCR reactions are run following standard protocols (Innis, *et al.* 1995). Both positive (template from confirmed *Pfiesteria piscicida*, species "B" or *Cryptoperidiniopsis brodyi* culture) and negative controls (no template) are carried through each PCR run. PCR products are visualized by electrophoresis and ethidium bromide staining. For each sample, at least two primer sets specific for *Pfiesteria piscicida*, and single primer sets for each of the other two organisms are run. If no test reactions were positive, a control reaction is run using generic eukaryotic primers to confirm that amplifiable DNA had been extracted from the sample.

Section B.5. Quality control checks and requirements

All water quality analyses are calibrated against known standards prior to each run. Seawater nutrient analysis is corrected for refractive index variations. Salinity effects are documented and corrected for where significant. Internal standards are run at the beginning and end of the run, and additional spiked seawater standards are run at 10 sample intervals. The chlorophyll fluorometer is calibrated against pure chlorophyll a, and secondary standards are run prior to every day's operation to insure against instrument drift. Correlation coefficients for analyses must exceed 0.999.

Section B.6. Instrument/equipment testing, inspection, and maintenance requirements

To minimize downtime of measurement systems, all field sampling and laboratory equipment must be maintained in a working condition. Equipment which has a manufacturer's recommended schedule of maintenance will receive preventative maintenance according to that schedule. Other equipment used only occasionally will be inspected for availability of spare parts, cleanliness, battery strength etc. at least monthly and always prior to being taken into the field. After use in the field, all equipment will be rechecked for needed maintenance.

A separate log book will be maintained for each type of equipment, whether laboratory or field. Preventative or corrective maintenance will be recorded. The history of maintenance performed will be available for inspection during a systems audit.

Section B.7. Calibration procedures and frequency

Calibration procedures for laboratory analysis are listed in section B.5. Field instruments will be calibrated prior to data measurement. Calibration procedures for Hydrolab multi-parameter instruments which will be employed in this project to measure dissolved oxygen, temperature and salinity are described in TNRCC (1994).

Section B.8. Inspection/acceptance requirements for supplies and consumables

All equipment used in the project is listed under different assessment categories (Section B.2.). Equipment used in the field collection of biological and water quality data will be procured directly by the project manager. These purchases are subject to competitive bids if the cost is greater than $1,000. Nationally-known suppliers of equipment whose products are recognized by the scientific and technical community as meeting standard capabilities are used.

Upon receipt of equipment, the project staff will inspect it to determine if it meets the minimum specifications and also for defects of breakage. Any equipment not capable of meeting minimum requirements will be returned to the supplier.

Section B.9. Data acquisition requirements (non-direct measurements)

Water quality, biological and physicochemical data from the other sources may be used to assist in interpreting data collected in this project. Available data are generally collected by agencies working under a separate QAPP. These data would normally be obtained in electronic format and would be inspected before using for interpretive purposes. Other biological and physicochemical data may be obtained through peer-reviewed publications in the scientific literature or from sources using accepted methods of data collection that include appropriate quality control.

Section B.10. Data management

Biological and physicochemical data will be entered on a personal computer. Raw field data will initially be entered in Excel format and later transferred, if necessary, to the appropriate statistical package. Nutrient and chlorophyll data will be recorded on FileMake. All data will be backed up on disks stored at different locations. Coordination is underway with TNRCC to facilitate transfer of the data into STORET.

Section C.1. Assessments and response actions

The commitment to use approved equipment and approved methods when obtaining environmental samples and when producing field or laboratory measurements must have periodic verification that the equipment and methods are being employed properly. The verification is accomplished through performance and systems audits, conducted by a person not directly involved in the project. This person will be familiar with the field sampling requirements for the project or laboratory quality assurance.

Before any project begins, availability of proper equipment for field personnel should be verified. This includes sampling equipment, safety equipment, and field measurement equipment. The project manager is also responsible to determine that personnel involved in field activities have been trained to properly use the equipment. This constitutes a systems audit for field sampling.

Laboratories contracted to perform analytical measurements will be monitored annually to evaluate that equipment is operational, that adequate personnel are available, and the procedures are followed for data quality verification. Any inadequacies noted in these laboratory systems audits will be noted in a response letter.

The application of procedures and equipment should be verified periodically. This verification constitutes a performance audit. Field personnel will be observed during the actual field sampling to verify that equipment and procedures are properly applied. The observer should be independent of direct project involvement.

Performance audits for laboratories providing analytical services will include successful participation in various quality assurance studies. Theses studies employ the receipt by the laboratory of a sample of unknown composition, which is analyzed and the results reported.

Section C.2. Reports to management

The Project Manager will be responsible for submitting written reports to the USEPA Project Officer on a quarterly basis. The QAPP Project Officer will report the status of implementation of procedures in this project plan and thereby the status of data quality. The complete project report will include a detailed quality assurance section that will address the accuracy, precision, and completeness of the measurement data used in drawing conclusions. A final report in the form of a journal article will be provided to EPA six months after completion of the project.

Section D.1. Data review, validation, and verification requirements

Each type of data will be randomly checked by the Project Manager and project staff. TPWD managers and staff will also provide oversight through the peer review process and editing of the final report. Data review will be conducted throughout the data analysis process including data entry, transfer, reporting, and storage. Data validation and verification checks will include examination of outliers, total numbers, and unusual values.

Section D.2. Data reduction, validation, and reporting procedures

Despite safeguards in collecting and analysis, data loss and errors can occur through manipulation and reporting of the results. Sample collectors are responsible for assuring that all pertinent information is recorded on sample sheets, that it is error-free, and that proper reporting units are utilized. All chain of custody tags will be rechecked before samples are shipped to verify that field data are complete and that reporting units are correct.

All results will be perused for conformance to precision and accuracy requirements. Results which do not meet acceptance criteria will be rejected. Outliers will be checked against laboratory sheets, historical data, and field notes to establish questionable values.

Transcription of data into electronic formats creates a high possibility of error. At a minimum, each phase of data generation and handling should have routine independent checks made on 10 percent of the data. No reduction of data or conversion to different reporting units is anticipated from this project. All validated results will be presented in tabular form in any final report.

Section D.3. Reconciliation with data quality objectives

Whenever procedures and guidelines established in the project to meet the specified levels of data quality are not successful, corrective action is required. Corrective action may be initiated by the performance and system auditors if variances from proper protocol are noted. The Project Manager is responsible for seeing that required corrections are made.

Variances that require corrective action may include equipment failure, excursions from precision and accuracy control limits, samples arriving at the laboratory in incomplete documentation or compromised integrity, samples lost in transit, samples ruined in laboratory accidents, reporting data in wrong units, and calculating data using improper formulas or statistics.

Most corrective action will consist of some combination of the following: repair or replacement of faulty equipment, re-analysis of samples and standards, checking reagents for proper strength, or re-sampling. A formal correction action program which would cover all the possible problems would be difficult, if not impossible, to establish. Unique problems which cannot be corrected by the procedures listed above will require corrective actions to be defined as the need arises.

Section D.4. Literature cited

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Raimbault, P., Diaz, F., Pouvesle, W. & Boudjellal, B. 1999. Simultaneous determination of particulate organic carbon, nitrogen and phosphorus collected on filters, using a semi-automatic wet-oxidation method. *Mar. Ecol. Prog. Ser.* 180:289-295.

Schaefer, E.F. 1997. A DNA assay to detect the toxic dinoflagellate *Pfiesteria piscicida*, and the application of a PCR based probe. MS Thesis, Biology Dept., Univ. North Carolina at Greensboro. 86p.

TNRCC 1994. Water quality monitoring procedures manual. Surface water quality monitoring team. Texas Natural Resource Conservation Commission. Austin, Texas.

Welschmeyer, N. A. 1994. Fluorometric analysis of chlorophyll a in the presence of chlorophyll b and pheopigments. *Limnol. Oceanogr.* 39:1985-1992.

Appendix D

Abstracts Accepted By Professional Conferences

Accepted by the Galveston Bay Estuary Program Symposium, January 2001.

Pfiesteria Monitoring in Texas Estuaries

James D. Simons, PhD

Texas Parks and Wildlife Department, Austin, TX.

Pfiesteria piscicida was first identified in 1988 by researchers at North Carolina State University. These organisms and *Pfiesteria* like organisms (PLO) are presently classified as dinoflagellates and they display very complex life cycles and habits, which are not totally understood at present. *Pfiesteria* has been implicated as the causative agent in several major fish kills in estuaries of North Carolina and the southeastern United States. It appears that nutrient rich waters tend to be most susceptible to harboring the *Pfiesteria* fish kills. In addition, *Pfiesteria* has been purported to cause neurological problems in fisherman and researchers alike. In light of the potential harm these organisms can cause, Texas Parks and Wildlife Department obtained a grant from EPA for a two-year monitoring program to look for *Pfiesteria* in the bays and estuaries of Texas. In the first year of the program 9 stations were monitored monthly and 8 stations were monitored on a bi-monthly basis from April through September 2000. In addition to the *Pfiesteria* samples, water samples were collected for nutrient and chlorophyll analyses. *Pfiesteria* was found at four sites along the Texas coast, those areas being Dickinson Bayou, Port Aransas, Oso Bay and Arroyo Colorado. Two species of *Pfiesteria* were identified, with *P. piscicida* found at Dickinson Bayou and *P. shumwayae* found at the other three stations.

Accepted by the Estuarine Research Federation Biennial Symposium, November 2001.

Pfiesteria DISTRIBUTION ALONG THE TEXAS COAST

Tracy Villareal *, James D. Simons, and Parke Rublee,

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A two-year monitoring program examined the Texas coast for the presence/absence of *Pfiesteria piscicida* and *P. shumwayae.* The sampling included a variety of bays and estuaries with differing degrees of nutrient input, sewage treatment outfalls, and heavily urbanized channels. Nine stations were monitored monthly and eight stations were monitored on a bi-monthly basis from April through September 2000. In 2001, a selected set of stations was monitored at two week intervals. Water samples were collected for nutrient and chlorophyll analyses. Two polymerase chain reaction assays were used in in the study. A conventional PCR assay for detection of a large amplified fragment was less sensitive than a second assay using a fluorogenic probe and quantitative PCR. Despite evidence of DNA degradation after prolonged storage at -20° C, the follow-up Q-PCR technique yielded substantially more positives. Using this method, we found both *Pfiesteria* species occurred at some time during 2001 at every station sampled. Water collected after a fish kill in Dickinson Bayou tested positive for *Pfiesteria*, but there is no supporting data to indicate that this was the cause of the fish kill. The two species occurred at a wide range of chlorophyll and nutrient concentrations. They appear to be a common and widely distributed members of the Texas coastal dinoflagellate community.

Accepted by Harmful Algal Bloom Conference, October 2002.

Pfiesteria Distribution in Texas Bays and Estuaries

James Simons[1], Tracy Villareal[2], Parke Rublee[3], Smiley Nava[4] and Michael Weeks[4]

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Texas Parks and Wildlife Department has developed a two-year monitoring program to look for *Pfiesteria* and *Pfiesteria* like organisms in the bays and estuaries of Texas. Nine stations were monitored monthly and eight stations were monitored on a bi-monthly basis from April through September 2000. A gene probe PCR assay was used to detect the presence of *Pfiesteria.* In addition to the samples for *Pfiesteria* analysis, water samples were collected for nutrient and chlorophyll analyses.

Pfiesteria piscicida was found at Dickinson Bayou and Clear Lake and *P. shumwayae* was found at Port Aransas, Oso Bay and Arroyo Colorado. *Cryptoperidiniopsis,* a *Pfiesteria* like organism, was found at Dickinson Bayou and Jamaica Beach.

Preliminary inspection of the chlorophyll and nutrient data showed elevated levels of chlorophyll, TDN and DON at some of the *Pfiesteria* sites, but several sites with higher values did not test positive for *Pfiesteria. Pfiesteria* was also found at sites with either <10 μg L-1 Chl a and/or total DIN <1 μM. Water collected after a fish kill in Caney Creek, Dickinson Bayou and Matagorda Bay did not test positive for *Pfiesteria.*

Of interest is the apparent split in species distribution, with *P. piscicida* being found only in the Galveston Bay area, and *P. shumwayae* being found in southern stations from Port Aransas to Arroyo Colorado. More sampling is planned for year two to further investigate this pattern.

Appendix E

Papers Published

Villareal, T.A., J.D. Simons, and P. Rublee. (2004). *Pfiesteria* distribution along the Texas (USA) coast. Proceedings of the Xth International Conference on Harmful Marine Algae. In: Steidinger, K. A.., Landsberg, J. H., Tomas, C. R. and G.A. Vargo (Eds.). 2004. Harmful Algae 2002. Florida Fish and Wildlife Conservation Commission, Florida Institute of Oceanography, and Intergovernmental Oceanographic Commission of UNESCO. 371-373.

Pfiesteria distribution along the Texas (USA) coast.

Tracy Villareal [1], James D. Simons[2], and Parke Rublee[3],

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Abstract

A two-year monitoring program examined the Texas coast for the presence/absence of *Pfiesteria piscicida* and *P. shumwayae*. The sampling included a variety of bays and estuaries with differing degrees of nutrient input, sewage treatment outfalls, and heavily urbanized channels. Nine stations were monitored monthly and eight stations were monitored on a bi-monthly basis from April through September 2000. In 2001, a selected set of stations was monitored at two week intervals. Water samples were collected for nutrient and chlorophyll analyses. Two polymerase chain reaction assays were used in in the study. A conventional PCR assay for detection of a large amplified fragment was less sensitive than a second assay using a fluorogenic probe and quantitative PCR. Despite evidence of DNA degradation after prolonged storage at -20° C, the follow-up Q-PCR technique yielded substantially more positives. Using this method, we found both *Pfiesteria* species occurred at some time during 2001 at every station sampled. Water collected after a fish kill in Dickinson Bayou, Texas tested positive for *Pfiesteria*, but there is no supporting data to indicate that this was the cause of the fish kill. The two species occurred at a wide range of chlorophyll and nutrient concentrations. They appear to be a common and widely distributed members of the Texas coastal dinoflagellate community.

Introduction

The heterotrophic dinoflagellate *Pfiesteria* has been implicated in both fish kills and human health issues along the eastern U.S. coast (Burkholder et al. 2001). In response, significant resources have been devoted to understanding the nature of its toxicity, response to environmental variables and importance in estuarine environments . The *Pfiesteria*-like complex appears to be broadly distributed (Rublee et al. 2001), but difficulty in identifying the two described *Pfiesteria* species along with the extensive discussions surrounding this group has slowed advance in this area. The Texas coast appears to be a likely habitat for *Pfiesteria* but there have been no attempts to determine if the species is present on this coast. The shallow, estuarine systems typical of the Texas coast are similar to its habitat along the eastern U.S. coast and the records of this species from the eastern Gulf of Mexico suggest it is likely to be present. Along the eastern U.S. seaboard, *Pfiesteria* is considered to be a major cause of fish mortality (Glasgow et al. 2001). Fish kills are common along the Texas coast, and while there is no evidence to suggest *Pfiesteria* has been a causative agent, information on its distribution and occurrence in these waters is an important part of the state's overall resource management program. We report here the results of two years of sampling using two different gene assays for both *Pfiesteria piscicida* and *P. shumwayae*.

Methods

Presence/absence of P. *piscicida* and *P. shumwayae* was determined using gene assays. 100 ml of water were filtered and returned to UNC, Greensboro for processing. Initially, samples were analyzed by a conventional PCR approach (M1) using probes for *P. piscicida* from Rublee, et al. (1999) and for *P. shumwayae* by Oldach, et al. (2000). Samples were later re-assayed by real-time PCR (M2) using primers and Taqman probes (Bowers et al. 2000) on a Cepheid Smart Cycler. Although the real-time PCR assay is more sensitive, storage of samples at -20C and additional freezing and thawing of samples prior to this second assay may have resulted in some degradation of DNA between assays. At each station, additional samples were collected for chlorophyll (Welschmeyer 1994) and automated nutrient analysis (Lachat Quikchem 8000) for nitrate+nitrite, silicate, phosphate, ammonium and dissolved organic nitrogen. The M2 assay was not available until 6 months after all samples were run using M1. Station selection in Year 1 was based on the need to do a broad coast wide survey that would sample both impacted and pristine areas. In Year 2, more intensive sampling (two week intervals) focused on a sub set of sites that represented extremes found in Year 1. Statistical analysis used Statview 5.01. Sample sites for both years are noted in Fig. 1.

Results

Both *Pfiesteria* spp. were present along the coast in both years (Table 1, Fig. 2, 3). *Pfiesteria* was present across the range of environmental conditions found (Fig. 4) Substantially more positive records were found using the M2 assay. There were more records in 2001 than 2000, probably due to sample degradation upon reanalysis. In 2001, nutrients, chlorophyll and hydrographic parameters showed no consistent difference in relation to presence or absence except for Si. Silcate concentrations were significantly higher at stations that showed positive for *P. piscicida* (57.3 vs. 36.3 µM, p= <0.0001). The data from 2000 was not analyzed in this way due to the likelihood of sample degradation over time.

Sampling Sites for Pfiesteria Monitoring in Texas – 2000-2001

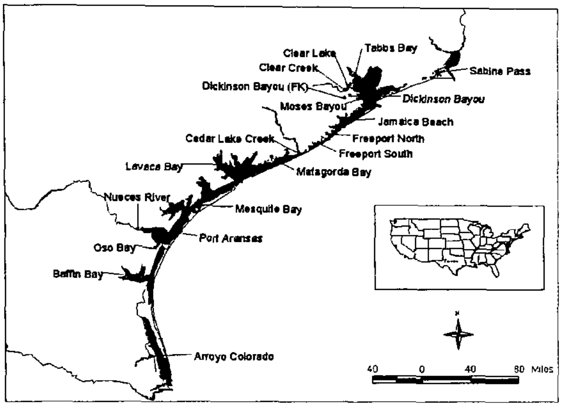

Figure 1. Sampling sites in this study

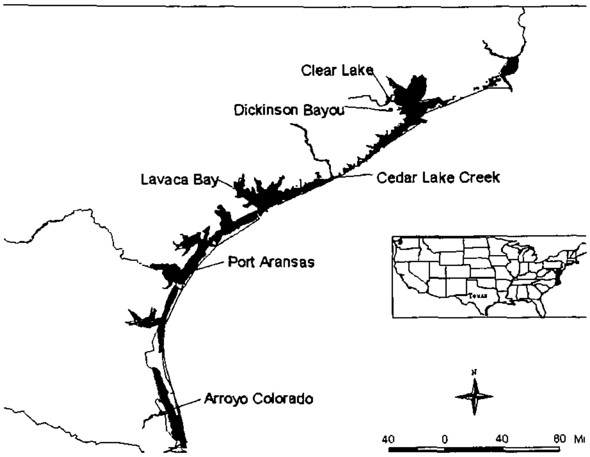

Fig. 2. *Pfiesteria* presence In 2000

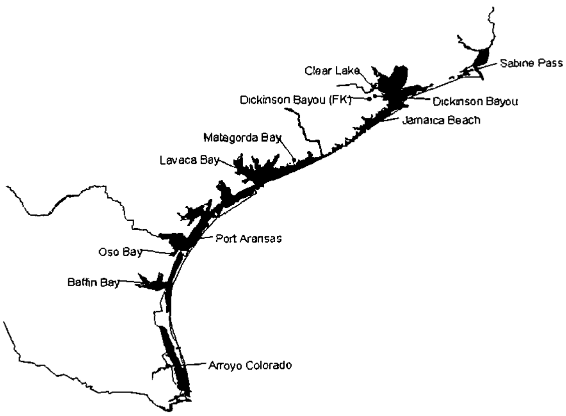

Figure 3. *Pfiesteria* presence in 2001

Table 1. Total number of occurrences using the two gene probes. Joint records by M1 and M2 are recorded as a single occurrence; hence the sum of the columns may not equal the total.

		P. piscicida		
Year	n=	M1	M2	Total
2000	90	5	9	12
2001	68	5	26	22

		P. shumwayae		
Year	n=	M1	M2	Total
2000	90	5	2	7
2001	68	7	28	33

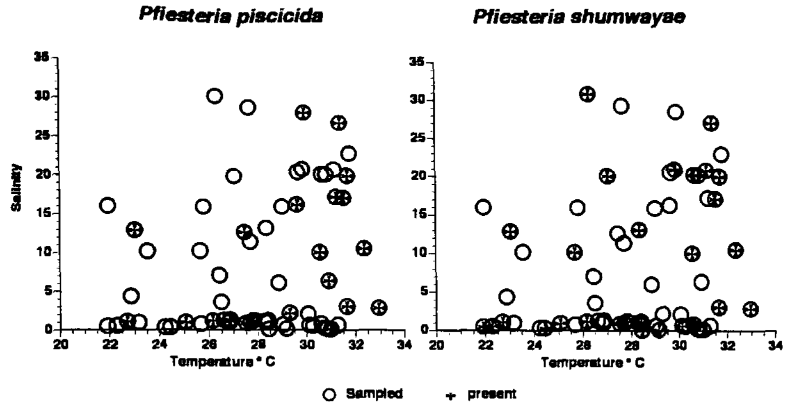

Fig. 4. Temperature and salinity conditions at *Pfiesteria* sites. Open circles indicate conditions at all sites sampled, crosses indicate sites where one or both species were found.

Discussion

Pfiesteria spp. appear to be a broadly distributed member of the coastal dinoflagellate community along the Texas coast. Both species of *Pfiesteria* were present along the entire Texas coast. The temperature-salinity conditions where the species could be found spanned essentially the entire range found along the coast during the May - Sept. sampling period. We found no evidence of preferred conditions although we recognize that presence/absence is not a useful indicator for biological response. It is relevant to note that the distribution of either species was not statistically linked to any inorganic nutrient, DON or chlorophyll concentration except for silicate. The curious link to silicate concentration for *P. piscicida* cannot be explained at this time by a direct relation to *Pfiesteria* physiology. It may be a proxy for other environmental or biological factors such as residence time, benthic processes, or preferred prey items; however, the data cannot resolve this issue.

The genetic test used cannot distinguish toxic from non-toxic forms of the species. Although one sample from a fish kill tested positive for *Pfiesteria*, there is no ancillary evidence to suggest *Pfiesteria* was responsible. Thus at this time, we cannot state whether we have Tox-1, Tox –2, non-inducible strains or any combination of the above.

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