ABSTRACT

Title of Document: EFFECTS OF THE THERMAL EFFLUENT FROM C.P. CRANE GENERATING STATION ON SUBMERSED AQUATIC MACROPHYTE COMMUNITIES IN THE SALTPETER-DUNDEE CREEK SYSTEM

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While water quality is often cited as the main factor that controls the distribution of submersed aquatic macrophytes (SAM) in the Chesapeake Bay, additional factors associated with physical and/or biological disturbances also affect the distribution. At local scales, such as in Saltpeter Creek, a tributary to the Gunpowder River, the thermal effluent from C.P. Crane Power Plant may be an important environmental gradient. I mapped the temperature signature of the effluent in Saltpeter Creek and intensively sampled the plant community structure to investigate the ecological similarity of SAM communities within and across different thermal regimes. I also conducted growth chamber experiments to study how different species and populations sampled from different temperature regimes respond to a controlled temperature gradient. Analyses show that although significant differences in water temperature exist across the study site, differences in temperature do not appear to significantly drive the plant community composition of the system.

EFFECTS OF THE THERMAL EFFLUENT FROM C.P. CRANE GENERATING STATION ON SUBMERSED AQUATIC MACROPHYTE COMMUNITIES IN THE SALTPETER-DUNDEE CREEK SYSTEM

By

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Chapter 1: Background Information

INTRODUCTION

Power plants that generate electricity through the use of coal or nuclear reactions change the temperature regime of aquatic systems by discharging thermal effluent into aquatic systems (Carter, 1968; Hamilton, et al., 1970; Parker, 1979; Coleman, 1996; Ma, et al. 1998; Martinez-Arroyo, 2000; Choi, 2002; Contador, 2005). Temperature effects of power plants on aquatic ecosystems may be viewed positively or negatively depending on who studies the system; a conservationist refers to thermal pollution; utility representatives refer to thermal enrichment; and the biologist refers to thermal addition (Sorge, 1969). These differing viewpoints reflect that thermal discharge on ecosystems can be detrimental or beneficial, or may still be uncertain (Gibbons and Sharitz, 1981). One such uncertainty is how aquatic organisms are affected by thermal effluent when the period of maximum use of electricity and cooling water overlaps with the warmest period of the year when surface waters are at or near their maximum temperatures and organisms in these waters may be near their upper temperature tolerance (Cairns, 1972). My thesis research examined the effects of thermal effluent on the structure of submersed aquatic macrophyte communities in a tidal fresh/oligohaline tributary of northern Chesapeake Bay.

With over 50 percent of the world's human population living in the coastal zone, the natural resources of coastal zones are considered to be under extreme pressure (Douven, 1999; Boesch, 2002; Charlier and Bologa 2003). The Chesapeake Bay watershed is now populated by sixteen million people (Chesapeake Bay Program, 2006). One million people are projected to settle in Maryland alone within the next 20 years

(Mark Goldstein, Maryland Department of Planning, Planning Data Services, pers. comm.). All of these people use electricity in their everyday life. The production of electricity usually requires a water source for use in power plant cooling systems. Owing to the proximity to both population centers and water, the tributaries of the Chesapeake Bay provide convenient locations for power plants. The production of electricity either from nuclear or fossil-fuel plants may have many different environmental impacts, but one constant by-product is excess heat of the water discharge (Gibbons and Sharitz, 1974). With thermally altered aquatic systems becoming more commonplace the consequences of elevated temperature on aquatic ecosystems are becoming better defined, however uncertainties still exist (Gibbons and Sharitz, 1981; Pilon and Santamaria, 2002).

Thirty-four power plants have been established in the Maryland portion of the Chesapeake Bay watershed alone. Power plants that use the Bay’s water in their cooling system discharge this water back into the estuary (Nauman and Cory, 1969; Gatz et al., 1973; Mountford et al, 1977; Sanders, 1982; Jordon and Sutton, 1984; Schreiner et al., 2002). However, estuarine systems are highly productive and home to many species of submersed aquatic vegetation (Jordan and Sutton, 1984; Stevenson, 1988) that are sensitive to changes in land-use and inputs of sediments, nutrients, toxins, and heat (Cunningham et al., 1984; Moore et al., 1996; Santamaria and van Vierssen, 1997; Boesch, 2002). Although efforts are underway to protect coastal ecosystems, global environmental changes are taking place (Tilman and Lehman, 2001) and dramatic changes in biodiversity are expected (Sala et al., 2000). Caused by changes in land use, biotic exchange and global climate, the most dramatic changes in biodiversity are expected to be witnessed in freshwater aquatic ecosystems, with the rate of decline for freshwater ecosystems being far greater than for even the most affected terrestrial ecosystem (Sala et al., 2000). Furthermore, Worm et al. (2006) have estimated up to a 90% reduction in marine fisheries before the end of this century.

Submersed aquatic macrophyte beds (SAM) are among the most biologically diverse, productive, and valuable habitats in coastal and estuarine ecosystems (Livingston et al., 1998; Orth et al., 2003). SAM can be considered a keystone community in tidal and non-tidal systems (Parrish and Litle, 2001) in that SAM provides food web support for a variety of heterotrophic organisms; affects ecosystem processes, such as nutrient cycling and productivity; and can enhance its own habitat through, for example, attenuation of water currents and wave energy (Koch, 2001). Thus, the loss of highly productive and diverse freshwater SAM communities, or certain species within those communities, can lead to a loss of ecosystem services that are valuable to humans (Chapin et al., 1998; Tilman, 1999; Giller et al., 2004). If species or entire communities are lost, the potential for aesthetic, recreational, and commercial losses exists (Wilson and Carpenter, 1999). In addition to economic losses, ecosystem reliability, productivity, and stability could be depressed (Kemp et al., 1983; Naeem et al., 2000; Petchey and Gaston, 2002; Naeem, 2002).

My thesis study focused on how the thermal effluent from a coal-fired power plant affects the species composition and diversity of the submersed aquatic macrophyte community in the Dundee-Saltpeter Creek system, a tidal fresh/oligohaline tributary of Chesapeake Bay. Results of the study may be used to educate power plant developers and managers, natural resources managers, and citizens about the effects of thermal effluent on important estuarine plant communities. The study may also be used to explore the potential effects of global warming on species abundance patterns.

THERMAL EFFLUENTS AND GLOBAL CLIMATE CHANGE

An estimated one-sixth of all the freshwater in the United States was used for power plant cooling systems by the year 2000 (de Sylva, 1969; Hutson et al., 2000). Although many studies have been conducted on thermal effluent effects on lakes and reservoirs (Lewis, 1974; Grace and Tilly, 1976; Haag and Gorham, 1977; Nicholas et al., 1980; Schneider, 1981; Coleman 1996; Ma et al. 1998; Martinez-Arroyo 2000), marine and estuarine water resources are now used without proportional research to document the effects of the thermal effluent on these ecosystems (Naylor, 1965; Schneider, 1981; Martinez-Arroyo, 2000). Although the effects of thermal effluents may be more pronounced in the cool climates (Taylor and Helwig, 1995), the effects of thermal effluent may also be observed as the thermal tolerance of the plants is reached in hotter climates.

In estuarine areas, changes in temperature can cause changes in salinity, dissolved oxygen, pH, CO_2, the uptake and effect of toxins on aquatic life (de Sylva, 1969), and the magnitude and extent of river ice (Dingman et al., 1968). Temperature fluctuations over the short- or long-term may also have a pronounced effect on the estuarine fauna in the discharge area. The most extreme effect of thermal effluent on estuarine flora and fauna is local extinction through heat death caused by protein denaturing and aggregation (Levitt, 1969). More subtle effects can include changes in plant metabolism, growth, reproduction and breeding; exclusion from heat-stressed areas; increased levels of parasites/toxins; and changes in length/weight relationships of plants (Naylor, 1965; Levitt, 1969; Texas Instruments, 1980; Taylor and Helwig, 1995). The stress of thermal effluent on aquatic systems is not likely to diminish in the face of an expanding population in the coastal zone and with projected changes in global climate.

Global climate change studies increasingly suggest that one of the main environmental changes that has taken place on a global scale is the rise in oceanic temperature (Levitus et al., 2000). In the Maryland region, the expected air temperature increase is 1.7-2.4 ^{o}C over the next century with seasonal variations (EPA, 1998). Local water temperatures are also predicted to rise (Albritton and Filho, 2001) and, owing to the development of coastal areas, more water will be used in power plant cooling systems, creating thermal discharge. The compounding elevation of temperatures could push waters past the thermal tolerance of several SAM species, especially those species adapted to cooler water temperatures.

Global warming is predicted to result in more hot days and heat waves over land areas and cause the frequency of extreme precipitation events to increase (Albritton and Filho, 2001). These long-term changes are likely to result in changes in water temperature with potential consequences on aquatic plant community composition. An increased frequency of hot days and heat waves can heighten the human energy demand and, thus, intensify environmental stressors that aquatic systems, whose water is used in power plant cooling systems, are faced with. Heating and cooling systems may need to be run for longer periods of time, requiring power suppliers to maximize power plant production and/or build new plants. Maximization of power plant production and construction of new power plants can increase the intensity and number of heated effluents, increasing the ecological effects of power plants (Barnett, 1972; Parker et al., 1973; Sharitz et al., 1974). Thermal effluents can result in a wide variety of changes in aquatic plant communities, including changes in species composition, standing crop, net production (Grace and Tilly, 1976; Haag and Gorham, 1977) and a loss of diversity (Brown, 1971). Although the biotic effects of thermal effluents may be minimal in areas with already high ambient temperatures or where other factors such as nutrient availability is strongly limiting (Haag and Gorham, 1977), thermal effluents may indeed be a dominant environmental driver in small creek systems

RESPONSE OF SUBMERSED AQUATIC MACROPHYTES TO ENVIRONMENTAL CHANGE

Submersed aquatic vegetation is sensitive to changes in water quality conditions; light and nutrient concentrations are considered primary factors, but other stressors include water temperature, salinity, tidal range and wave activity (Short and Short, 1984; Batiuk et al., 2000; Koch, 2001). Changes in the amplitude or magnitude of any of these stressors could trigger declines in SAM abundance if species cannot acclimate to the changes. Unlike SAM beds in higher salinity areas, freshwater SAM beds are usually comprised of more than one species (Stevenson, 1988; Orth, 2003). If hypotheses explaining the responses of biodiversity to environmental stressors are applied to aquatic systems (Yachi and Loreau, 1999), multi-species SAM beds may have a higher resistance to the stressors (Duarte, 2000) than monotypic SAM beds. Temporary and acute changes in local environmental conditions may favor one species over another for a short time. However, long-term environmental changes, such as the operation of a power plant or global warming, may lead to permanent changes in species richness, abundance and distribution.

Many of the resident and migratory animal species that frequent freshwater habitats in Chesapeake Bay rely on SAM beds for food, protection, and provision of oxygen. The Upper Bay and its diverse SAM beds play an important role in faunal life cycles, such as during spawning or juvenile development (Posey et al., 1993; Thorpe et al., 1997). The most notable example of this is the Canvasback duck (*Aythya valisineria*), which declined after Tropical Storm Agnes in June 1972, coinciding with the decline of tuber forming Wild celery (*Vallisneria americana* Michx.) and Sago pondweed (*Stuckenia pectinata* (L) Boemer). Not only did the number of Canvasback ducks decline, they were forced to change their main food source to anthropogenic corn (Kemp et al., 1984; Haramis et al., 2001). Additional studies show that SAM beds provide protection and prey for both finfish and shellfish (Kemp et al., 1984; Rozas and Odum, 1988; Stevenson, 1988; Diaz et al., 2001; Tetra Tech, 2000; Heck et al., 2001; Sime, 2005). Thus, understanding environmental factors that influence the abundance, diversity, and distribution of submersed aquatic macrophyte beds is important for enhancing the protection of this important estuarine habitat. My thesis research focuses specifically on the effect of temperature on submersed aquatic macrophyte communities, taking into account other covarying environmental factors (dissolved inorganic phosphorus, light attenuation, total suspended solids, chlorophyll-a, etc.) that might also affect SAM communities.

TEMPERATURE AND SUBMERSED AQUATIC MACROPHYTES

Temperature is known to be a major factor determining the distribution and productivity of plants in both terrestrial and aquatic ecosystems (Setchell, 1924; Haag and Gorham, 1977; Seemann et al., 1984). In terrestrial systems, for example, a decline in CO_2 uptake by *Camissonia brevipes* was observed under high temperatures in Death Valley, CA (Seemann et al., 1984). Setchell (1924) noted differences in various plant species' anthesis on Mt. Tamalpais near San Francisco, CA, as a response to changes in temperature. In aquatic systems, Haag and Gorham (1977) observed increased productivity and earlier flowering of *Elodea canadensis* Michx. in thermal effluents. While most evidence and research shows that light has the greatest influence on the distribution of aquatic macrophytes (Goldsborough and Kemp, 1988; Koch, 2001), evidence also exists that temperature influences the growth and distribution of SAM (Rooney and Kalff, 2000). Temperature effects on SAM distribution has been researched since the early 1920's (Setchell, 1922). Temperature affects plant morphology (Setchell, 1924) and controls reproductive events such as flowering and the germination of seeds (Santamaria and van Vierssen, 1997). While inland aquatic systems may be well buffered against extreme temperature fluctuations, terrestrial systems show great variations in temperature (Santamaria and van Vierssen, 1997). True seagrass systems have a narrow optimal temperature range (Santamaria and van Vierssen, 1997). For non-marine aquatic systems the temperature response is expected to be intermediate between terrestrial and marine systems (Santamaria and van Vierssen, 1997). Conducting studies on power plant thermal discharge areas and comparing observed patterns and processes to areas that are not influenced by thermal discharge allows the separation of temperature effects from other environmental factors that influence the distribution of SAM.

Differences in other environmental factors, such as fetch and turbidity, among thermally impacted and un-impacted sites need to be accounted for to ensure that other factors are not confounding or masking a temperature effect (Rooney and Kalff, 2000). My thesis research uses this observational approach and combines it with an experiment investigating survival and growth responses of common species observed in my study area.

Temperatures can vary along diel cycles, as well as seasonal cycles, but broad-scale changes in temperature have also been observed in the mid-Atlantic region (EPA, 1998; Levitus et al., 2000). On a global scale, warming will affect SAM both directly and indirectly (Neckles et al., 1997). Direct effects can include changes in the respiration rate of plants, nutrient uptake and other enzymatic processes which are temperature dependent (Short and Neckles, 1999). At high temperatures, photosynthesis cannot keep up with respiration and the plant dies with consequences on population dynamics and species extinction. Plant communities and physiological functions may also be indirectly altered by climate change. Changes in severe weather events or carbon dioxide levels can cause changes in community structure or individual plant responses (Short and Neckles, 1999). The sensitivity of submersed macrophyte communities to higher temperatures and an earlier onset of the growing season suggest that littoral plant communities, and associated epiphyte, zooplankton, zoobenthic, and fish communities, are particularly susceptible to long-term climate changes (Rooney and Kalff, 2000). For species growing in locations with temperatures above the optimum for growth or near the upper limit of thermal tolerance, an increase in average annual temperature should decrease productivity and distribution (Short and Neckles, 1999). Although each species of SAM may respond to global warming in an individualistic manner, entire macrophyte communities may be lost from an ecosystem, and the most vulnerable ecosystem are likely to be those where eutrophication and other stressors already exist (McKee et al., 2002).

Heat injury in plants can manifest itself in several forms. Submersed aquatic macrophytes will generally not suffer from desiccation if water temperatures increase. However, their metabolic processes may be affected by an increase in water temperature (Sutcliffe, 1977), decreasing growth rates and leading to eventual death when high temperatures combined with low light levels trigger rapid respiration. When respiration is more rapid than photosynthesis, food reserves in the plant are exhausted leading to starvation and eventual death of the plant (Sutcliffe, 1977). Higher respiration rates can also lead to a shortage of oxygen in the plant tissues and the accumulation of toxic products from anaerobic respiration (Sutcliffe, 1977). Heat injury in plants can also be caused by protein denaturation (Levitt, 1969) after continued high temperatures. This process at high temperatures can be reversible if the denaturation is not followed by protein aggregation.

WATER TEMPERATURE DURING THE STUDY PERIOD (2005)

The National Oceanographic and Atmospheric Administration (NOAA) reported that Maryland experienced higher than normal air temperatures during 2005, and high water temperatures in parts of Chesapeake Bay (Figure 1) were attributed to causing declines in submersed aquatic macrophytes (Blankenship, 2006; NOAA, 2006). The higher air temperatures within the region in 2005, the year of my study, could have confounded my results and therefore requires careful examination and consideration. The NOAA reports also indicate that Maryland air temperatures during 2005 were similar to previous years and did not exceed temperatures reached in 1998 (NOAA, 2006); similar to findings regarding water temperatures from the Dundee Creek study area (Figure 2). As part of Aberdeen Proving Ground’s water quality monitoring program, water temperatures have been recorded, *in situ*, for nearly a decade (Figure 2). At the mouth of Dundee Creek, water temperatures are recorded with hand-held water quality monitors (YSI-85), 5 cm below the waters surface. These measurements were not always collected at the same intensity during this time period, but measurements were made during the

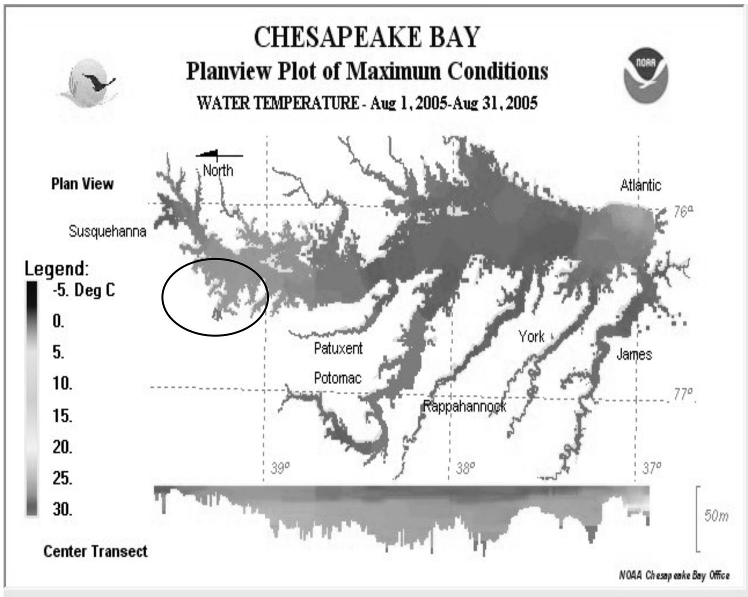

Figure 1. A map of interpolated water temperatures created by NOAA (Chesapeake Bay and Tidal Tributary Interpolator, VOL3D, version 4.6, August, 2006), for the Chesapeake Bay for August 2005. Data are collected at over 50 stations throughout the Bay and its’ tributaries and interpolated vertically and laterally to provide a snapshot of water quality in the Bay. The circled area is the general area in which Dundee Creek is located. Higher water temperatures appear in the lower Chesapeake Bay, while relatively lower water temperatures were observed in the study area. This trend was observed for most of the SAM growing season.

SAM growing season (April – October) at the same locations. The water temperature data from Dundee Creek show 2005 was one of three years in the past decade where maximum water temperature exceeded 30 °C during the summer (Figure 2).

Water temperature data presented by NOAA (Figure 1) show an interesting trend throughout the Chesapeake Bay; water temperatures at the study site often do not correspond with temperatures recorded in areas of the Lower Bay (Figure 1). When water temperatures are depressed in the Lower Bay, they appear to be higher in the Upper Bay (Bahner, 2006), while the opposite appears when water temperatures are higher in the Lower Bay (the latter situation is illustrated in Figure 1). While elevated water

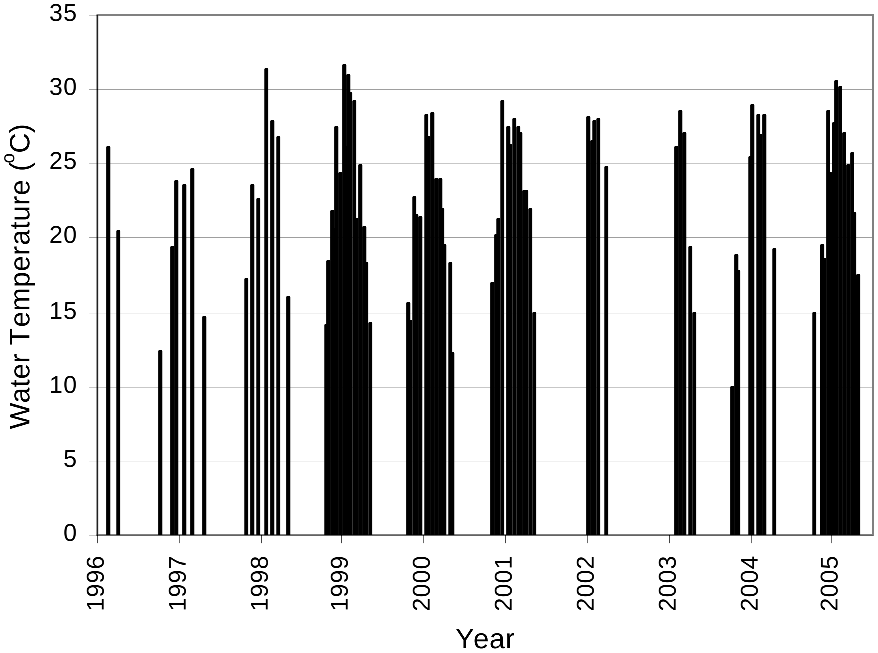

Figure 2. Surface (top 5 cm of water column) water temperatures as part of Aberdeen Proving Ground's submersed aquatic vegetation program over the last ten years during the SAM growing season (April –October). This data was collected at the mouth of Dundee Creek (station DM1), which is located outside the influence of the thermal effluent.

temperatures may have had a detrimental effect on submersed aquatic vegetation in the Lower Bay in 2005 (NOAA, 2006; Blankenship, 2006), conditions in the study area were near average in 2005. In the study area, which receives freshwater inputs from small restricted creeks, water temperatures are probably driven more by localized inputs rather than regional climatic changes; thus, the record high temperatures in 2005 experienced by most of the region probably did not have a confounding effect on my results. Ideally, a multi-year study would have been conducted to place the study within the context of short-term inter-annual temperature fluctuations and long-term directional temperature trends. Thus, my results need to be interpreted with caution when examining submersed aquatic vegetation responses to changes in water temperature. Given that the thermal effluent has been a constant presence in my study system since 1961, however, a difference in submersed aquatic macrophyte communities between thermally affected and unaffected areas should be detected if submersed aquatic macrophytes respond to the temperature ranges experienced in my study system.

CHARACTERISTICS OF STUDY AREA AND HISTORICAL SAM CONDITIONS

Built between 1961 and 1963, C.P. Crane Power Plant is located between Seneca and Saltpeter Creeks, both of which are tributaries to Upper Chesapeake Bay. The surface area of the Saltpeter-Dundee Creek system is 5.5×10^6 m^2 and the total mean low water volume is 6.5×10^6 m^3 (Jacobs, 1983). The drainage area for the Saltpeter-Dundee Creek system is 62 km^2 and the estimated annual runoff is 0.86 m^3 s^{-1}. Since this is a shallow water system with an average water depth of 1.2 m at mean low water, water column stratification can occur, but wind events can frequently mix the water column

(Jacobs, 1983). The mean tidal range in the area is 0.36 m and the tidal prism is approximately 2,014,000 m^3 (Jacobs, 1983). The thermal discharge comprises about 20% of the intertidal volume of the creek system and over 50% of the water entering upper Saltpeter Creek on the flood tides. The study area is subject to ice scouring during the winter and ambient water temperatures (Figure 1) can reach over 30 °C during the summer (Jacobs, 1983).

The power plant houses two units capable of producing 400 megawatts and is usually only run at full capacity during the day. The plant draws water from Seneca Creek at approximately 21 $m^3\ s^{-1}$, and in 2001 C.P. Crane withdrew approximately 345 million gallons of creek water per day to use in its once-through cooling system (Jacobs, 1983). The discharge flows through an open canal approximately 735 m long and into an impoundment approximately 61 x $10^3\ m^2$. The water then flows over a submerged weir and into Saltpeter Creek. Owing to cycles in C.P. Crane's electricity production, discharge temperature and velocity can vary between 3 ^oC and 8 ^oC above ambient and between 55 cm s^{-1} and 95 cm s^{-1}, respectively (Jacobs, 1983). The temperature plume of the C.P. Crane Generating Station is evident in water quality data collected by the Maryland Department of Natural Resources (MDDNR) DATAFLOW system, which is a system of shipboard water quality probes that rapidly measures parameters from a flow-through stream of water collected near the water body's surface, (Madden and Day, 1992) and through the Aberdeen Proving Grounds (APG) water quality monitoring program (Figure 3).

Biological effects of a coal fired power plant cooling system include entrainment, impingement, and discharge effects. Discharge effects can be further broken down into temperature exposure effects, modification effects, and scouring effects (Jacobs, 1983). This study investigated the exposure effects of submersed aquatic vegetation to the heated effluent. Some vegetated sites within Saltpeter and Dundee Creeks are continuously affected by the discharge, while others are affected only on flood tides (Jacobs, 1983). Other sites within the system are physically buffered from the effluent and provide good control sites, provided other physical and chemical parameters are similar.

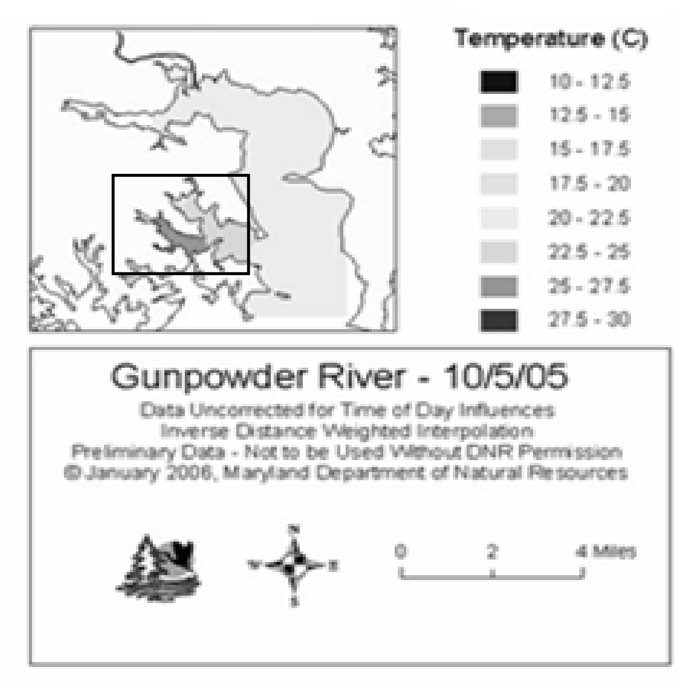

Figure 3. Water temperature map created by Maryland Department of Natural Resources of the Gunpowder River, including Saltpeter and Dundee Creeks (highlighted by the rectangle). The thermal effluent from C.P. Crane Generating Station is visible as darker shades of gray. Permission obtained from Tidewater Ecosystem Assessment Division of MDDNR

Prior to the establishment of the power plant, the submersed aquatic macrophyte community in the Saltpeter-Dundee Creek system consisted of several of the native Chesapeake Bay species including *Vallisneria americana Michx.*, *Potamogeton perfoliatus* (L.) (Redhead Grass), *Potamogeton crispus* (L.) (Curly Pondweed), *Ceratophyllym demersum* (L.) (Coontail) and *Elodea canadensis Michx.* and these species are still present in the system. *Myriophyllum spicatum* (L.) (Eurasian Watermilfoil) was first noticed in this system in 1902 (Reed, 1977), but the species is currently not a dominant species. The diverse SAM community within the creek system creates a situation in which peak productivity is extended during the growing season owing to differences in life cycles. The diversity of the SAM communities also creates stratification of plants within the water column with *V. americana* occupying the lower two thirds of the water column and other plants such as *E. canadensis* forming a canopy (Nichols et al., 1980).

After the power plant began production, localized effects on the vegetation within the discharge impoundment were observed but were attributed to construction activities (Nichols et al., 1980). More recently, the area has undergone large natural fluctuations in submersed aquatic macrophyte abundance owing to changes in precipitation patterns in the area. The Upper Chesapeake Bay is severely affected by drought years that increase water temperatures and salinity. For example, during the drought years of 2000-2002, the vegetation in Dundee Creek decreased significantly (Orth et al., 2003; Julie Bortz, pers. comm.). During 2003 and 2004, higher precipitation allowed a rebound of SAM in Upper Chesapeake Bay, while the lower portions of Chesapeake Bay were affected by an increase in pollutant inputs (Chesapeake Bay Program, 2005). I hypothesize that the largest environmental influence on the SAM in Dundee and Saltpeter Creeks to be the thermal effluent from C.P. Crane power plant.

The following chapters present the research I conducted on the effects of elevated water temperatures on species richness and abundances of submersed aquatic macrophytes in the Dundee and Saltpeter Creeks estuarine ecosystem. I also present the results from a controlled growth chamber experiment, where three common submersed aquatic macrophyte species of the study site were placed in three growth chambers set at different temperatures. Furthermore, this controlled experiment compared the response of a single species, *V. americana*, collected from three separate locations, to three different temperatures. The final chapter places empirical results into the larger context of global climate change and submersed aquatic vegetation management. Specifically, the alternative hypotheses I set out to test with my complementary field observations and growth chamber experiment were:

H_1 - The submersed aquatic macrophyte species observed growing at the study site tolerate the higher temperatures of the thermal effluent. If so, I predicted that the thermal effluent of the C.P. Crane power plant would have no effect on submersed aquatic macrophyte species richness and cover, which is my null statistical hypothesis.

H_2 – Some of the submersed aquatic macrophyte species observed at the study site are not tolerant of the higher temperatures of the thermal effluent. If so, I expected species richness and cover to be lower in areas affected by the thermal effluent.

H_3 – The higher temperatures of the thermal effluent are more favorable to submersed aquatic macrophyte growth and survival. If so, I predicted that species richness and cover would be higher in areas affected by the thermal effluent compared to unaffected areas with similar environmental conditions.

Chapter 2: Effects of the thermal effluent from C.P. Crane Generating Station on submersed aquatic macrophyte communities in the Saltpeter-Dundee Creek system

Introduction

Temperature is one of the most important environmental factors controlling the growth, reproduction and death of plants (Anderson, 1969; Barko and Smart, 1981; Bulthuis, 1987; Pip, 1989; Hartleb et al., 1993). Owing to the ease of measuring temperature, a vast body of information exists about its effects on living organisms (Brock, 1970). As early as 1922, Setchell reported that aquatic macrophytes occupy certain habitats based on the temperature profile of the water column. Setchell also suggested that macrophytes can invade neighboring aquatic habitats if the temperature conditions change to support hospitable conditions. Thus, while factors such as light and nutrient availability are known to affect growth rates of submersed aquatic macrophytes (Barko and Filbin, 1983; Goldsborough and Kemp, 1988; Olesen and Madsen, 2000), water temperature may also structure submersed aquatic macrophyte communities (Anderson, 1969; Barko and Smart, 1981; Bulthuis, 1987; Pip, 1989; Hartleb et al., 1993).

Most natural temperature variation is driven by climatic fluctuations. However, with increasing global industrialization, aquatic environments are being exposed to unnatural temperature elevations (Schneider, 1981). Of water withdrawn for industrial uses, an estimated 70% is used for cooling purposes (Schneider, 1981). Around power plants, water temperatures can fluctuate annually, seasonally, diurnally, vertically and laterally through tidal cycles in response to the amount of electricity bring produced

(Nauman and Cory, 1969). The main effect fossil fuel power plants have on aquatic life is the removal of large quantities of water for condenser cooling and the return of this water to the system at an elevated temperature (Adams, 1969), sometimes 8 ºC above ambient water temperature (Nichols, 1981). The elevated water temperatures from the thermal effluent from the coal fired C.P. Crane Generating Station, MD, is the focus of this research. The effluent impacts a relatively small area of Northern Chesapeake Bay, but has been an impact since the 1960's when it went into operation.

As part of the Maryland Department of Natural Resources' (MDDNR) Power Plant Siting Program (PPSP), several studies have been conducted to evaluate the effect of the thermal effluent from Crane Power Plant on the surrounding ecosystem (Nichols et al., 1980; Texas Instruments, 1980; Jacobs, 1983; Jordon and Sutton, 1984). One of these studies (Nichols et al., 1980) focused on the effects of thermal effluent on the submersed aquatic macrophyte community and its associated fauna. Seven sites were selected near the power plant intake in Seneca Creek, upstream and downstream of the thermal discharge in Saltpeter Creek, in the upper and lower portions of Dundee Creek and in a portion of the lower Gunpowder River (Figure 4). Nichols et al. (1980) concluded there were no significant differences in submersed aquatic macrophyte biomass between sites, although differences in density (i.e., many small plants at the control site vs. few large plants at the thermally affected site) were observed (Nichols et al., 1980). The study concluded that biodiversity and biomass of submersed aquatic macrophyte beds were not affected in areas that received the thermal discharge. Although the study observed no effects of the thermal effluent, the study area has undergone natural and anthropogenic changes since 1980. The human population increased approximately 57-persons km^{-2}

while houses km^{-2} have increased from 23 to 30 (Chesapeake Bay Program, 2000). The Gunpowder River and its' tributaries have undergone fluctuations in water quality and precipitation, which has been associated with changes in the submersed aquatic macrophyte communities (Orth et al., 2003).

The initial series of PPSP studies did not incorporate two important areas. The

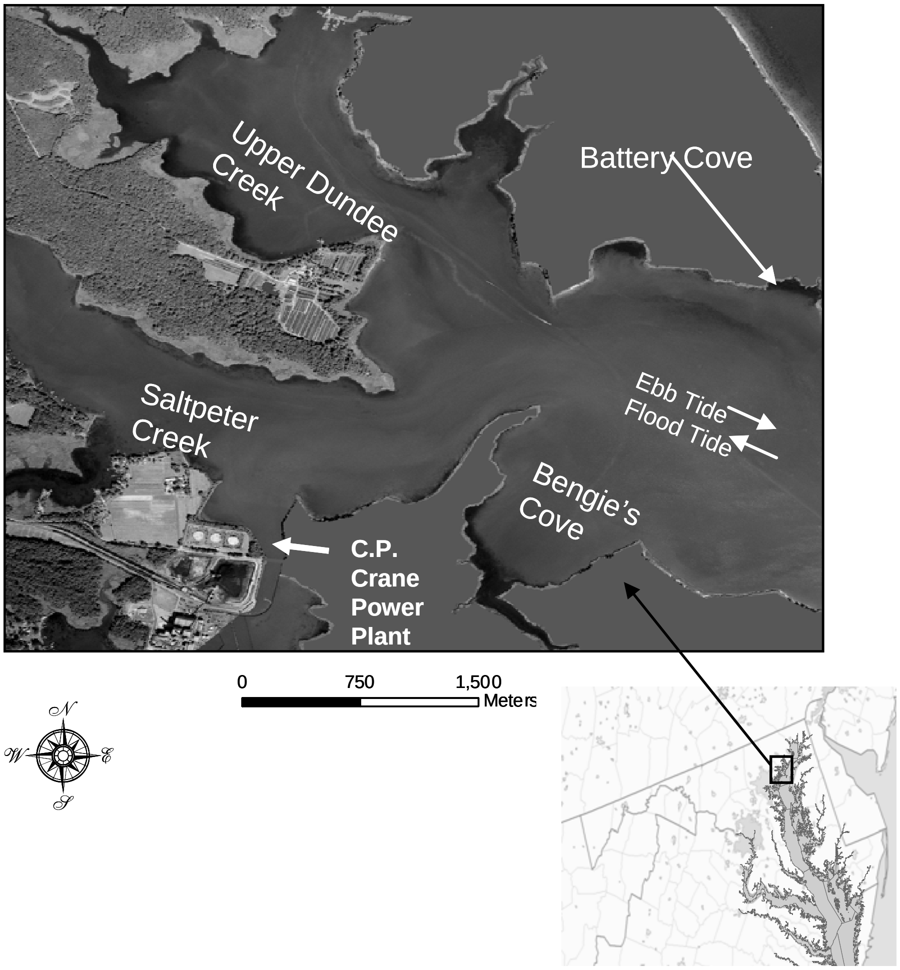

Figure 4. Aerial photograph of the Saltpeter-Dundee Creek study area. (Air Photographics, Inc. 2005)

first area is upper Saltpeter Creek (Figure 4), which supports large submersed aquatic macrophyte beds, and is influenced by the thermal plume on flood tides. The second, Bengies Cove (Figure 4), supports a large and diverse macrophyte bed within the area of the heated effluent, but the bed may be physically buffered from the plume. Bengies Cove, located east of the discharge canal, is protected by Bengies Point. Bengies Point forces the discharge from Saltpeter Creek towards Battery Point and away from Bengies Cove. This effect on the hydrology of the estuary may allow Bengies Cove to be an accurate representation of the area's submersed aquatic macrophyte if the thermal effluent did not exist. Differences of a few degrees of temperature can alter the growth of submersed aquatic macrophytes (Barko and Smart, 1981). Thus, by studying these two additional reference areas, one that may be physically buffered from the effluent and one that is only affected on flooding tides, temperature-related diversity differences could be determined, accounting for other environmental factors that influence submersed aquatic macrophyte growth and may be different among sites.

The objective of my study was to evaluate whether water temperature has a discernable impact on the community structure of submersed aquatic macrophytes in the Saltpeter-Dundee Creek system. I predicted that species diversity and macrophyte cover would be lower in thermally-affected areas if several of the submersed macrophyte species common at ambient temperatures are not tolerant of higher water temperatures. On the other hand, I predicted that species diversity and macrophyte cover would be higher in thermally-affected areas if the higher temperatures are more favorable to submersed aquatic macrophyte growth. This prediction may be realized if some species observed in the study system are at their northern range limit or if water temperature increases the availability of resources that are otherwise limiting under ambient conditions. Alternatively, no effect of thermal effluent on submersed aquatic macrophytes would be detected if species are tolerant of and are not favored by the higher temperatures. These hypotheses were tested by interpolating water temperature across 131 sampling locations 12 times during the 2005 growing season (April – October). This spatially intensive sampling was complemented by intensive temporal sampling that continuously recorded water temperatures at 5 sites affected and unaffected by the thermal effluent. I sampled the submersed aquatic macrophytes at 13 sites throughout the creek system six times during the 2005 growing season to relate submersed aquatic macrophyte community structure with the study site's temperature regime. To account for the effects of environmental factors on submersed aquatic macrophytes that could confound or mask a temperature effect, I measured dissolved inorganic nitrogen, dissolved inorganic phosphorus, total suspended solids, chlorophyll-a, secchi disk depth and salinity at 5 sites. Complementary to the field observations, I conducted a growth chamber experiment to test a) how different submersed aquatic macrophyte species respond to water temperature and b) whether populations of one abundant species, *V. americana*, growing in areas affected by thermal effluent would be more tolerant of higher water temperature than populations growing elsewhere within the system or in a northern climate. Combined, my field observations and lab experiments were designed to provide useful information on how the thermal effluent of power plants, and possibly global climate change, can affect submersed aquatic macrophyte communities in oligohaline portions of estuaries.

Methods

Temperature Sampling

I used two approaches to map the thermal plume and compare temperature differences throughout the Saltpeter-Dundee Creek system. One approach was temporally intensive and used underwater continuously-logging temperature probes to record changes in temperature through time in areas that were and were not affected by the thermal plume. Five Onset HOBO® Water Temp Pro data loggers were attached to ½″ PVC pipe (Figure 5) and anchored at or near sites DM2, DN1, DN2, DN3, and SP1 (Figure 6) at a water depth of approximately 0.75 meters from the sediment surface at low tide. SP1 was chosen to represent Saltpeter Creek (always heated), DN1 to represent Bengies Cove (never heated), and DN2 to represent Battery Cove (tidally heated). DN1 and DN2 were both located in lower Dundee Creek. DN3 was located in upper Dundee Creek (never heated) and DM2 represented the confluence of upper Dundee and Saltpeter Creeks (tidally heated) (Figure 6). The sites were marked using an additional piece of ½″ PVC with a piece of floating white polyline attached. The probes recorded temperatures every fifteen minutes and were downloaded in the field on a monthly basis, between 10 June and 26 October 2005. The control site at Aberdeen Proving Ground (APG) was located 3.5 nautical miles upriver from Dundee Creek in the Gunpowder River near Canal Creek and was maintained by Maryland Department of Natural Resources. The water temperature data for APG, which was collected using a YSI 6600 every 15 minutes throughout the year, was downloaded from a publicly accessible internet site (www.eyesonthebay.net) at the end of the 2005 growing season.

The second approach to sample temperature at the study site was spatially intensive to create one interpolated map of the thermal plume for each month of the growing season (May to October) for each tidal cycle, resulting in 6 flood tide and 6 ebb tide maps of watet temperature. Sampling was conducted from 17 May to 13 October 2005 at a GIS-created 200-meter interval point grid covering Dundee and Saltpeter Creeks (Figure 7). The grid for temperature sampling resulted in 131 points. Three additional points could occasionally not be reached owing to shallow depth restrictions. At each point, surface, bottom, and mid-depth water temperatures were recorded, along with total water depth and salinity. Owing to the number of points, each sampling event covered a four-day period with two days dedicated to each tidal cycle beginning at the

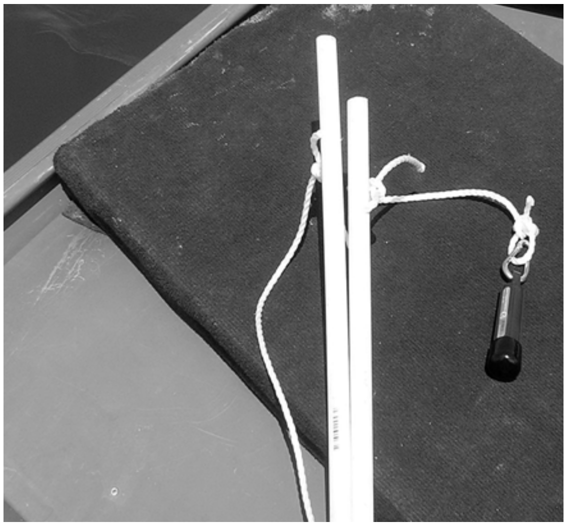

Figure 5. The deployment setup of the underwater HOBO® temperature probe. The PVC pole on the left was used as a marker and the pole on the right was used as an anchoring pole with the probe attached. The positive buoyancy of the probe kept it near mid-depth throughout each tidal cycle. This setup was modified to test for stratification by attaching additional probes near the middle and at the bottom of the PVC pole. The top probe remained at the surface with fishing floats and at the bottom probe was weighted down with fishing weights.

predicted start of each tidal cycle and continuing through the entire cycle or until all sites were sampled. Times for sampling during each tidal cycle were selected from MDDNR tide charts for Battery Point in the Gunpowder River and were chosen to occur throughout the morning and early afternoon to control for diurnal variations in temperature. All sampling sites were located to the nearest 10 meters using a handheld Garmin® etrex Venture global positioning system (GPS), using the World Geodetic System of 1984 (WGS 84) datum.

Measuring tidal levels concurrently with water temperature provides estimates of the time and duration that the higher temperatures of the thermal effluent affects each site and also the maximum depth experienced at each site. One wave gauge (Macrowave, Coastal Leasing), housing a pressure transducer was deployed for two weeks in Saltpeter Creek (SP1; Figure 6) to measure wave height, wave period and water level. Water level was recorded at a 5Hz frequency for 13 minutes at the top of the hour. The data was offloaded and Fast-Fourier transformed to obtain wave height, wave frequency, and water depth.

Stratification of the water column could affect interpretations of temperature effects on submersed aquatic macrophytes because species occupy different areas of the water column and may therefore not experience changes in water temperatures the same way if the water column is stratified. For example, *V. americana* is a rosette-forming species that elongates its leaves in the lower part of the water column where its meristems are located. *Elodea canadensis*, on the other hand, is a canopy-former and has its meristems located close to the water surface. The temperature probes were therefore deployed for one month in 2006 to determine whether the water column was stratified.

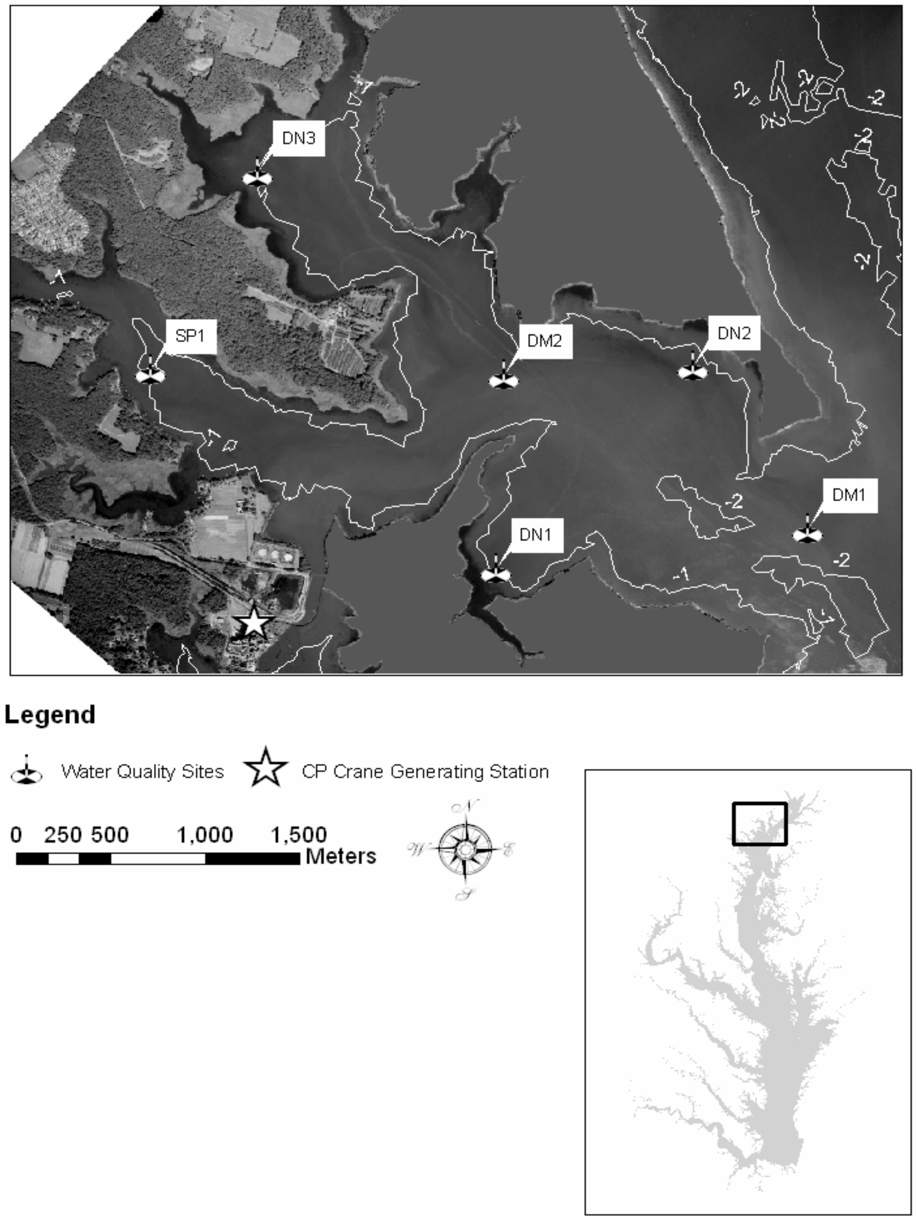

Figure 6. Aerial photograph of Dundee and Saltpeter Creeks in the Upper Chesapeake Bay including bathymetric data in meters (at low water) and locations of 6 water quality monitoring stations. Only water temperature data was used from station DM1 for comparisons to previous years. A seventh site at Aberdeen Proving Ground was used as a control and was located near Canal Creek. C.P. Crane Generating Station is identified by a star. Areas are grayed out due to security reasons of the Department of Defense.

Two sites were selected in Saltpeter Creek, one upstream of the discharge impoundment and one downstream of the impoundment. Two temperature probes were attached to one pole which held one probe at the surface with small fishing floats and one probe at the sediment surface with 4oz. fishing weights. The probes were originally deployed on 31 August 2006 near Bengies Point. After two weeks the probes were relocated to upstream of the impoundment and downloaded after 2 weeks deployment on 29 September 2006.

Wind data was obtained from the United States Army Testing Center collected from a weather station (Model # RMY 05103) near the Gunpowder River for the same dates and times as the temperature grid sampling. Wind direction and speed, and duration may affect the spatial extent of the thermal plume. I therefore created ebb and flood tide wind roses (Lakes Environmental Software, 2005) for the dates and times I measured water temperatures to visually inspect the impact of wind on the thermal plume. One constraint of this analysis is that I sampled temperature during calm days such that my analysis was biased towards finding little effect of wind on the thermal plume. Complementary to the visual inspection, I calculated the thermal plume area for ebb and flood tides for each monthly sampling and correlated area with average wind speed.

Vegetation sampling

After the first round of temperature sampling was completed in May 2005, thirteen sites were selected throughout the study site (Figure 8) based on their location in the thermal effluent. Two sites were always heated, 6 sites were tidally heated and 4 sites were outside the influence of the thermal effluent. At each site, macrophyte sampling was conducted with a mask and snorkel to keep disturbance of submersed aquatic macrophytes to a minimum. Once anchored at the sampling site, a 0.25 m^2 PVC grid was blindly tossed 10 times within a 25 m^2 radius from the boat. The cover class model presented by the global seagrass monitoring network (SeagrassNet) was used to guide the

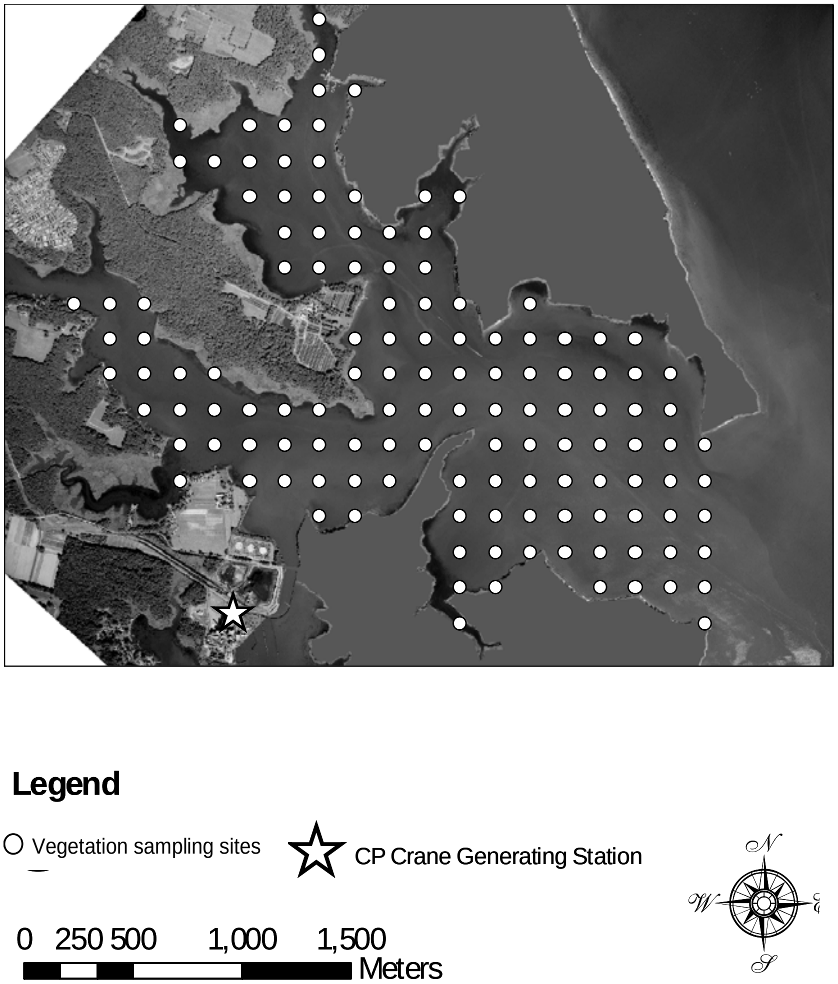

Figure 7. Sampling points for the temperature grid survey. Sample points are 200 m apart. Areas are grayed out due to security restrictions. C.P. Crane Generating Station is identified by a star.

estimates of total percent cover and percent cover of each species (Short et al., 2004). Total depth and secchi depth were also recorded at each site. Intensive macrophyte sampling with mask and snorkel was not conducted at the 131 grid sites used for temperature sampling owing to time constraints. Water temperature sampling was constrained to late morning and early afternoon; intensive macrophyte sampling would not have allowed enough time to complete temperature measurements. Furthermore, with the number of points sampled during the temperature grid sampling, intensive macrophyte sampling was not a viable option while controlling for time of day, and hence diurnal fluctuations in temperature, during the temperature survey.

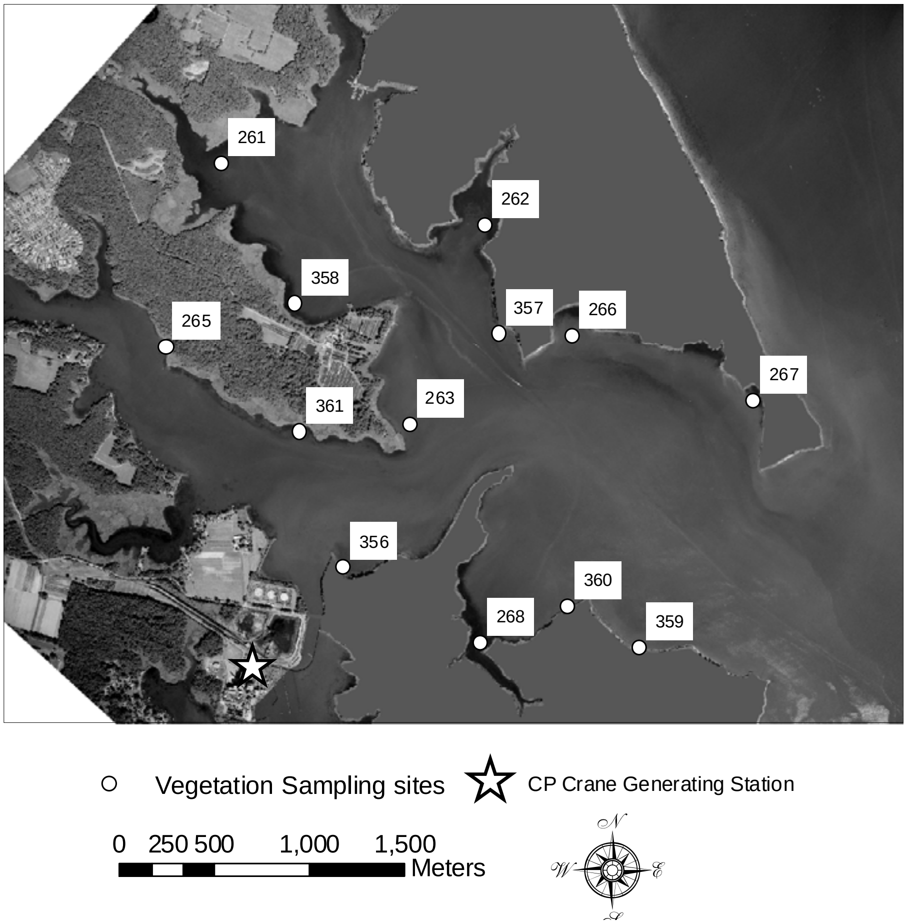

Figure 8. Vegetation sampling sites in Saltpeter-Dundee Creek. Areas grayed out are due to security reasons. C.P. Crane Generating Station is identified with a star.

Water Quality

Water quality parameters were measured to control for factors that influence survival and distribution of submersed aquatic macrophytes so that temperature effects could be isolated. Throughout the 2005 growing season (April – October), five sites in Dundee and Saltpeter Creeks (Figure 6) were monitored for a suite of water quality parameters on a biweekly schedule. Sampling was conducted between 1000 and 1400 hours. The five sites selected for water quality monitoring are a subset of the sites used for Aberdeen Proving Grounds' water quality program which have been monitored since 1996.

In situ measurements of salinity, temperature (ºC), conductivity (µs), and dissolved oxygen (mg l^{-1}) were collected at the water surface and just above the sediment surface with a Yellow Springs Instrument (YSI) 85 multi-parameter water quality instrument, which was calibrated by YSI Inc, in March 2005. The instrument was not calibrated post sampling. At each of the water quality sites and the 13 sites surveyed for macrophytes, total depth and secchi disk depth were also measured. Secchi disk depth was measured by lowering the disk from the sunny side of the boat until the disk visually disappeared. The disk was then raised until it was visible and the depth was measured and used to estimate the light attenuation coefficient (Kd = 1.45/Secchi depth; Walker, 1980). Total depth was measured with a 0.01 m graduated 2-m PVC pole; if the depth was greater than 2 meters, a weighted line was dropped overboard, marked and measured. A grab sample of water was also collected just below the water surface and transported back to the laboratory on ice in a cooler. The grab samples were processed according to established water sample preparation and filtering protocols, including use of pre-weighed 47-mm GF/F filters for total suspended solids and chlorophyll-a (Koch et al., 2004). Samples were frozen and transported monthly to the University of Maryland Center for Environmental Science's Chesapeake Biological Laboratory where they were analyzed for total suspended solids (TSS), chlorophyll a (Chl-a), nitrite, nitrite plus nitrate, ammonium, phosphate (DIP), and total volatile solids (Keefe et al., 2004).

Growth Chamber Methods

Three species of submersed aquatic macrophytes that are common at the study site (*V. americana*, *E. canadensis* and *C. demersum*), were acquired from a nursery (Kester's Wild Game and Seed) in Wisconsin. Forty-five specimens of each species were placed in 2366 cm^3 plastic containers (height = 13.5 cm, diameter = 16 cm) filled 4 cm high with previously dried and sterilized sediment collected from Otter Point Creek in the Bush River, MD. The containers were filled with reverse osmosis water to 1 cm below the top of the containers. Each set of containers was then randomly divided among three growth chambers so that each growth chamber contained five containers of each species. The growth chambers were set at 28, 32, and 36 ºC and ran on a 12 hour light: 12 hour dark cycle. The temperatures were selected to represent cool ambient conditions (28 ^{o}C), conditions experienced in the thermal plume (32 ^{o}C), and extreme temperatures that are potentially lethal (36 ^{o}C). This design corresponded to 4 ^{o}C temperature differences that the National Phytotron at Duke University has used in the past. The design intentionally spanned temperatures from cool to extreme to set the study up to find a temperature effect. Temperatures were not decreased at night because the thermal effluent is a constant presence, even at night. A combination of fluorescent and incandescent light bulbs produced a constant light intensity of 200 μmol m^{-2} s^{-1}, which is above light compensation that occurs at 20-25 μmol m^{-2} s^{-1} but below light-saturated photosynthesis that occurs at 450 µmol m^{-2} s^{-1} as determined using laboratory oxygen-production data (Blanch et al., 1998) Harley and Findlay (1994) showed that light-saturation occurred between 100 and 280 µmol m^{-2} s^{-1} and light compensation between 2.5 and 82 µmol m^{-2} s^{-1}. Thus, our light levels were reasonable for growing *V. americana* in the controlled growth chamber environment. Thus, our light levels were reasonable for growing *V. americana* in the controlled growth chamber environment. Water pH in the field is typically between 6 and 9 (Figure B2) suggesting free CO_2 limitation; thus, pH in the experimental containers was allowed to rise. Given that all three species are able to use bicarbonate as an alternative carbon source (Maberly and Madsen, 1988; Stevenson, 1988), free CO_2 limitation should not have affected the outcome of the experiments and more realistically represented natural conditions. On a weekly basis for 8 weeks the specimens were measured for maximum length, number of ramets and number of branches (*E. canadensis* and *C. demersum*) or leaves (*V. americana*) per ramet. These parameters were chosen because they are easily obtained with minimal disturbance while representing vertical and lateral growth of plants. After measurements were collected, the containers were refilled with tap water filtered through a carbon filter. Nutrient concentrations of the water were: Ammonium-N = 0.117 mg/L; Nitrate + Nitrite – N = 0.1620 mg/L; Total Phosphorus = 0.0752 mg/L. No organic N was detected. After containers were refilled, they were placed back into each temperature treatment using randomly generated numbers. In addition to the Wisconsin plants, samples of *V. americana* were collected from areas of Dundee/Saltpeter Creek that experienced different magnitudes of the thermal effluent. Five sites were selected from areas of elevated water temperature and five sites were from areas of colder water. At University of Maryland Center for Environmental Science's Appalachian Laboratory, three specimens from each of the 10 sites were individually placed into three separate 2366 cm^3 containers that were filled with steam-treated (6 h at 99 ^oC after establishing a vacuum) sediment from Otter Point Creek and with reverse osmosis water. Each set of three containers per site was then randomly divided among the three growth chambers so that each growth chamber contained 5 containers from heated areas and 5 containers with plants from unheated sties. The plants were measured on a weekly basis for 8 weeks for the maximum length, number of ramets and number of leaves per ramet. Containers were refilled with the same carbon-filtered tap water as above and placed back into each growth chamber using the same described protocol that randomized placement.

Statistical and Geographic Information System Analysis

To test for differences in water temperatures among the five temperature probe locations, 1000 readings were randomly selected from data collected with the temperatures probes and was analyzed using the non-parametric Kruskal-Wallis test with the Nemenyi comparison for ranked sums. These tests parallel the analysis of variance (ANOVA) procedure and Tukey comparisons of means (Zar, 1996). The thermal plume was mapped using data collected from the temperature grid sampling. The maps were created using the ordinary kriging method in the Geostatistical Analyst extension of ArcMap, (ESRI, 2001). Boundaries cannot be used in this method; however use of the Gaussian semivariogram with a circular neighborhood containing between 2 and 4 neighbors kept the interpolation across land features to a minimum. Interpolations were displayed using the standard deviation classification scheme in ArcMap, which shows how much a feature's attribute value varies from the mean. This classification scheme was selected to standardize class breaks as seasonal water temperatures varied.

Time series analysis was conducted by selecting hourly temperature probe data from the full data series for three time periods; 22 June 2005 to 11 July 2005, 12 September 2005 to 2 October 2005 and 15 October 2005 to 26 October 2005. The three time periods were selected because daily maximums, minimums, averages and standard deviations that were calculated from the hourly readings were likely to change as the growing season progressed. The above time periods were also selected to capture data from all of the temperature probe sites. One probe (DM2) was lost during the sampling period and at the control site (APG) the temperature probe failed to record data for a short time period.

Temperature stratification data using temperature probes suspended at the top and bottom of the water column were analyzed using the student's t-test. Data was also graphically inspected. The spatial extent of the thermal plume was calculated in ArcGIS. Correlations of the thermal plume with wind direction and wind speed were quantified using Pearson product moment correlations.

In addition to comparing water temperatures at sites within Saltpeter and Dundee Creeks, I compared 1000 random water temperature readings within the creek system to the APG control site to determine if differences existed between water temperatures in the study area and a control area. Although random selection of water temperatures may miss differences in time of day or tidal cycle, they were selected to test for water temperature differences in the study area.

Ecological similarity of submersed aquatic macrophyte communities was calculated between sites and months. Several separate software packages were used, including SAS (SAS Institute Inc., 2004), Arcmap (ESRI, 2005), PC-ORD (McCune and Grace, 2002) and EstimateS (Colwell, 2005). To relate macrophytes to water quality, water quality measurements, including salinity, had to be interpolated across the study site and extracted to the macrophyte sampling sites using ArcMap. This approach does have it's limitations as water quality can vary at smaller resolutions than was measured, especially if groundwater seepages occur within the study area. However, due to the small extent of the study system and the similarity of shoreline development, I assumed that interpolation would approximate water quality at unsampled locations reasonably well. Unlike the temperature grid, the inverse distance weighted (IDW) interpolation method was used. Because only a few sites were sampled, interpolation across the land features would have created inaccurate predictions, since two sites may be close to each other "as the crow flies" but far apart "as the fish swims" (Little et al., 1997). Using boundaries in the IDW method forces the nearest neighbor to be "as the fish swims". This method assumes that the variable being mapped decreases in influence as the distance from the sampled location increases. The resulting community and environmental matrices were used in PC-ORD to conduct a Bray-Curtis ordination and non-metric multidimensional scaling to relate environmental variables to species presence/absence. Ordination was used to reduce the redundancy of multiple univariate tests and to emphasize trends or gradients in the data, as well as produce graphical results that reveal species-environment relationships. In both cases, the Bray-Curtis distance measure was used and Pearson and Kendall correlations were calculated. PC-ORD was also used to conduct hierarchal classification of the data, again using the Bray-Curtis distance measure to complement and validate the ordination. Site-by-site Bray-Curtis similarity comparisons of plant communities were calculated using the EstimateS software. Likewise, the Shannon diversity index was calculated using EstimateS. Repeated measures ANOVA was used to test for macrophyte cover differences among heated and non-heated sites and between months of the growing season. Coupled with ordination, this test was used to test for differences in abundance and location of thermally tolerant species. In addition, Pearson product-moment correlation coefficients were calculated to test for correlations between water temperature and cover of specific species and total cover of all species. This was done on a monthly basis, where average macrophyte cover at the 13 macrophyte sampling sites was correlated with average monthly water temperature.

Water quality and submersed aquatic macrophyte habitat data collected at the five water quality sites were analyzed using ANOVA with Tukey HSD comparisons on log transformed data. Pearson product-moment correlation coefficients were calculated to determine if water levels from the wave gauge and water temperatures in Saltpeter Creek were correlated. A significant correlation would show how the thermal effluent impacts the sites as heated and unheated water is pushed in and out of areas during the tidal cycle. Correlations were also calculated for salinity and water temperature at the five water quality stations. Water quality was analyzed to control for factors besides temperature that can influence submersed aquatic macrophyte distribution and to isolate the temperature effect on plant communities.

Growth chamber data were statistically analyzed using the general linear model (GLM) procedure, as *V. americana* was the only species to be collected from high and low temperature areas of the study area and from the Wisconsin nursery. The GLM procedure in conjunction with the Ryan-Einot-Gabriel-Welsch Multiple Range Test was used to discern if temperature, time and source effects were significant and if any of the interactions between these effects were significant. The maximum lengths of *V. americana, E. canadensis* and *C. demersum* were analyzed graphically and statistically to determine how each species fared at the respective temperatures. Alpha level was determined at 0.05.

Results

Temperature

Spatially extensive temperature sampling at 131 sites and geostatistical interpolation (Figures 9-14) show that the thermal effluent from C.P. Crane raises the water temperature in Saltpeter Creek 4-5 ºC over the water temperatures in Dundee Creek throughout the growing season. The thermal plume extends into Dundee Creek on the ebb tide and is pushed into Saltpeter Creek on the flood tides. The water temperatures recorded from May through October show the expected seasonal rise and fall throughout the growing season (Figure B1). Water temperatures differed among the five sites outfitted with temperature loggers (Figure 15) and validated the observed water temperature gradients within Dundee/Saltpeter Creek. Sites DM2 and SP1 experienced the highest water temperatures with readings greater then 33 ºC recorded for as long as 24 h in July 2005. Water temperatures greater than 30 ^{o}C were recorded for 51 days in June, July, August and September 2005. Sites DN3 and DN1 supported the lowest recorded

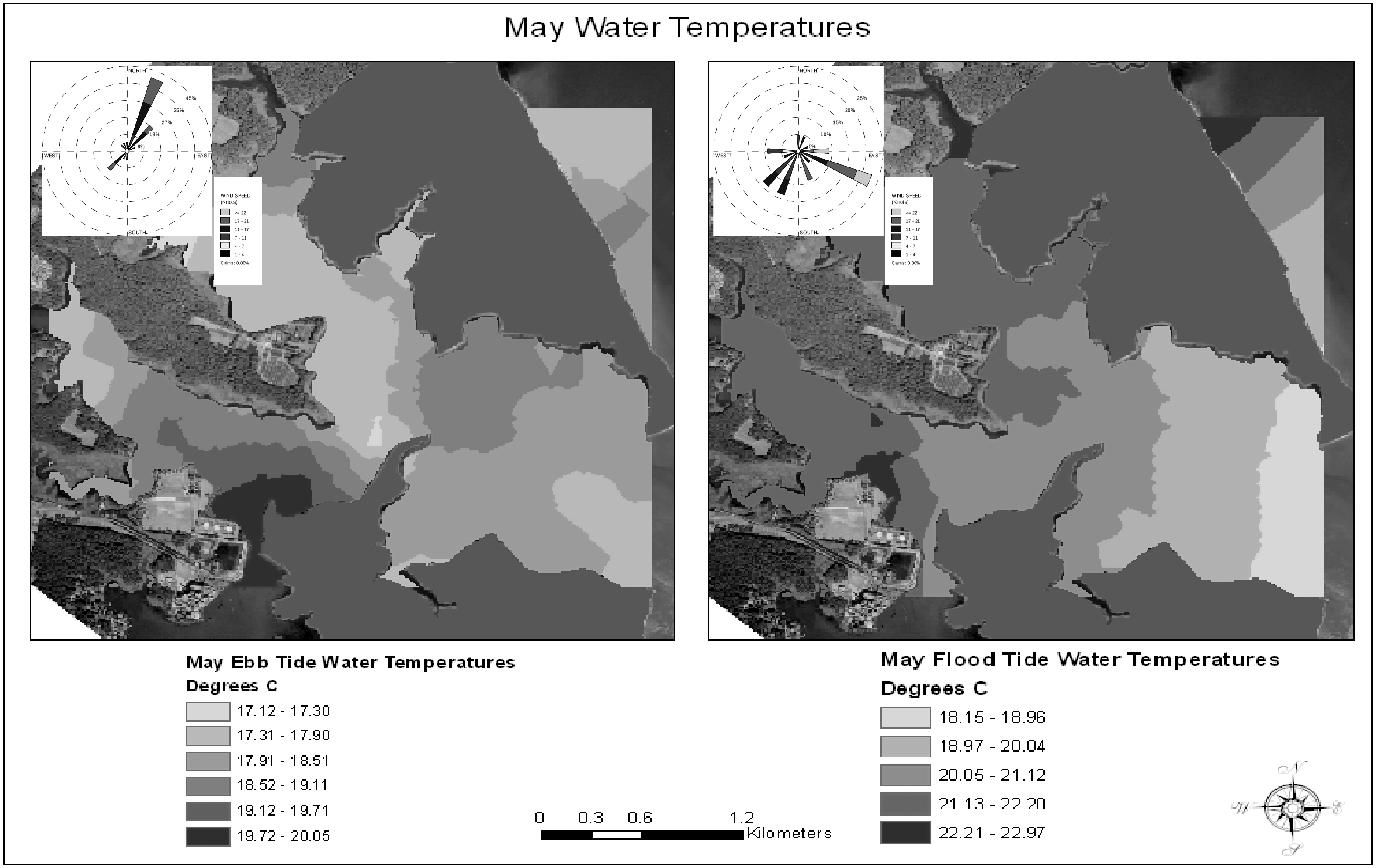

Figure 9. Krigged interpolation of water temperatures in Dundee and Saltpeter Creeks during May 2005. The left panel shows water temperatures during the ebb tide, while the right panel is the flood tide. The classification of the data is based on the standard deviations computed in ArcGIS. C.P. Crane Generating Station is located in the lower left corner of the map. Wind roses displaying wind direction and speed are also displayed for the selected sampling dates.

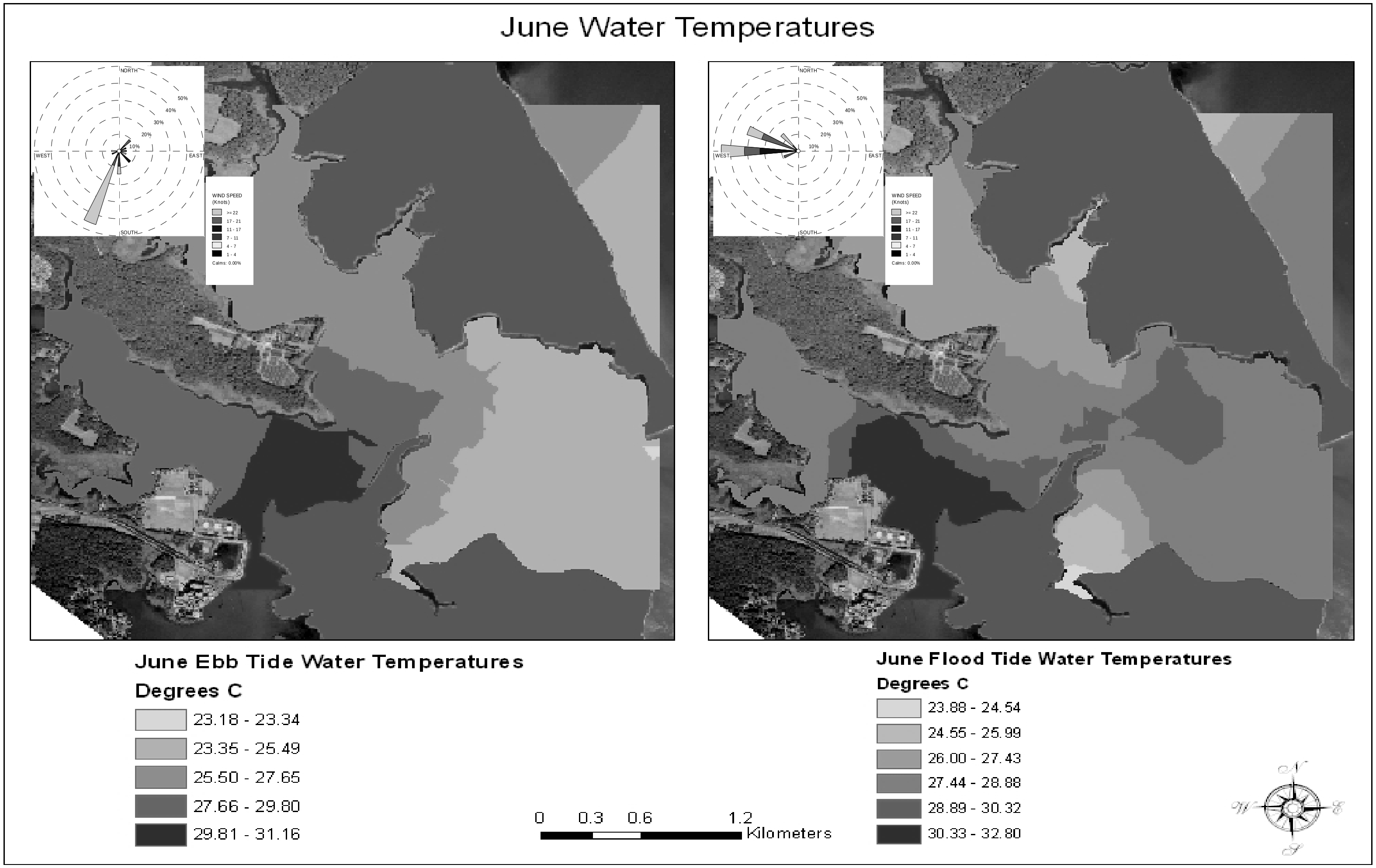

Figure 10. Krigged interpolation of water temperatures in Dundee and Saltpeter Creeks during June 2005. The left panel shows water temperatures during the ebb tide, while the right panel is the flood tide. The classification of the data is based on the standard deviations computed in ArcGIS. C.P. Crane Generating Station is located in the lower left corner of the map. Wind roses displaying wind direction and speed are also displayed for the selected sampling dates.

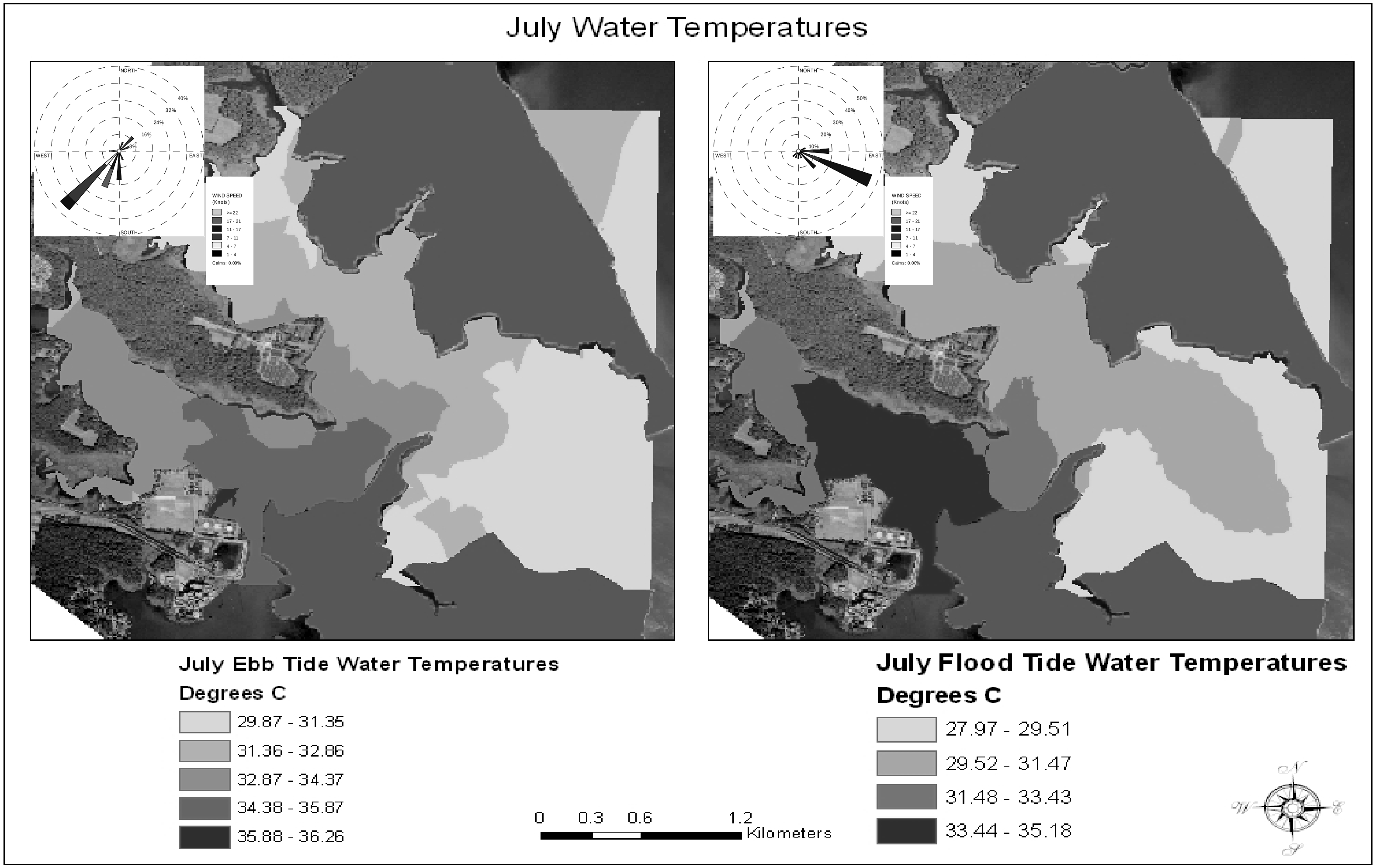

Figure 11. Krigged interpolation of water temperatures in Dundee and Saltpeter Creeks during July 2005. The left panel shows water temperatures during the ebb tide, while the right panel is the flood tide. The classification of the data is based on the standard deviations computed in ArcGIS. C.P. Crane Generating Station is located in the lower left corner of the map. Wind roses displaying wind direction and speed are also displayed for the selected sampling dates.

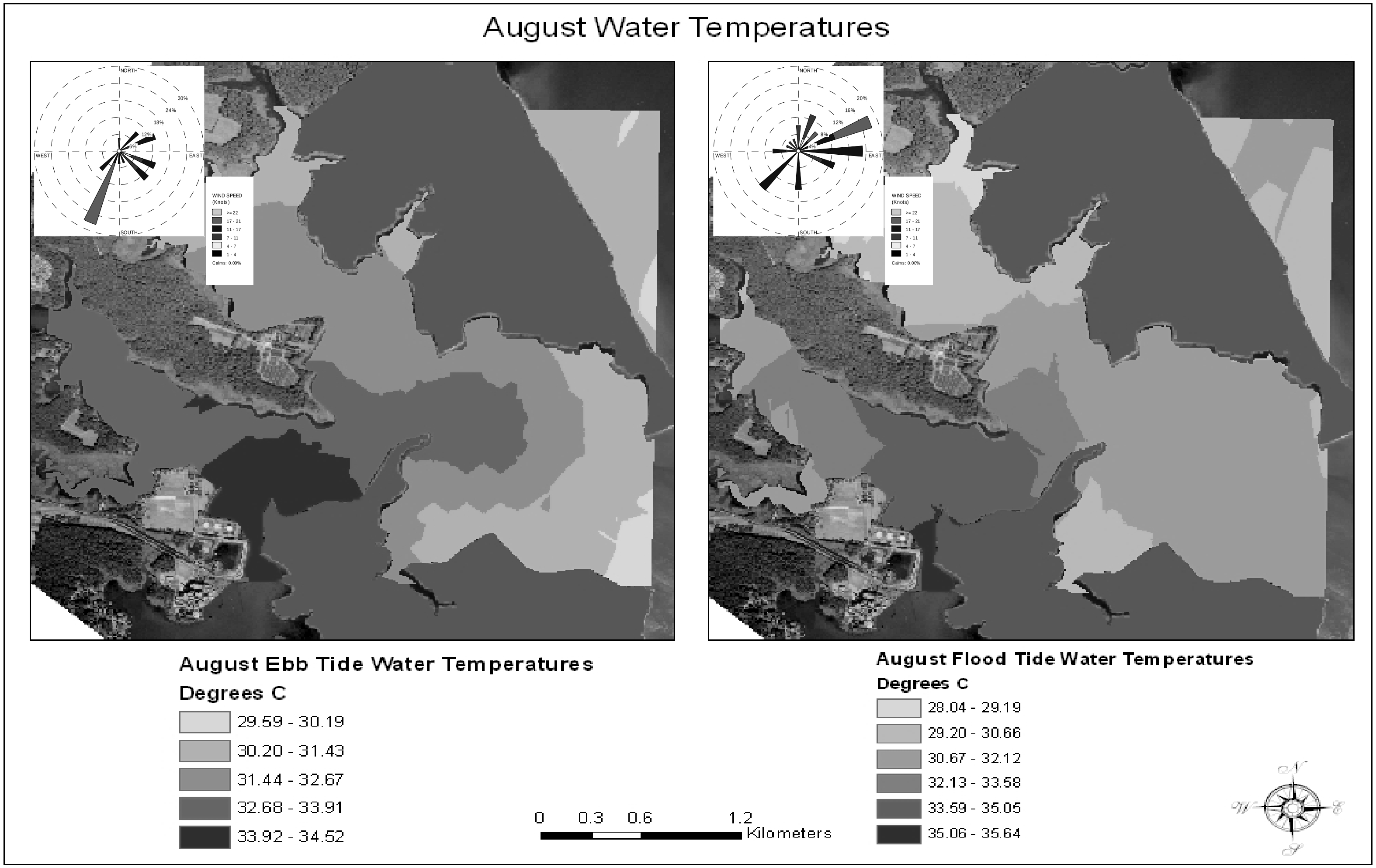

Figure 12. Krigged interpolation of water temperatures in Dundee and Saltpeter Creeks during August 2005. The left panel shows water temperatures during the ebb tide, while the right panel is the flood tide. The classification of the data is based on the standard deviations computed in ArcGIS. C.P. Crane Generating Station is located in the lower left corner of the map. Wind roses displaying wind direction and speed are also displayed for the selected sampling dates.

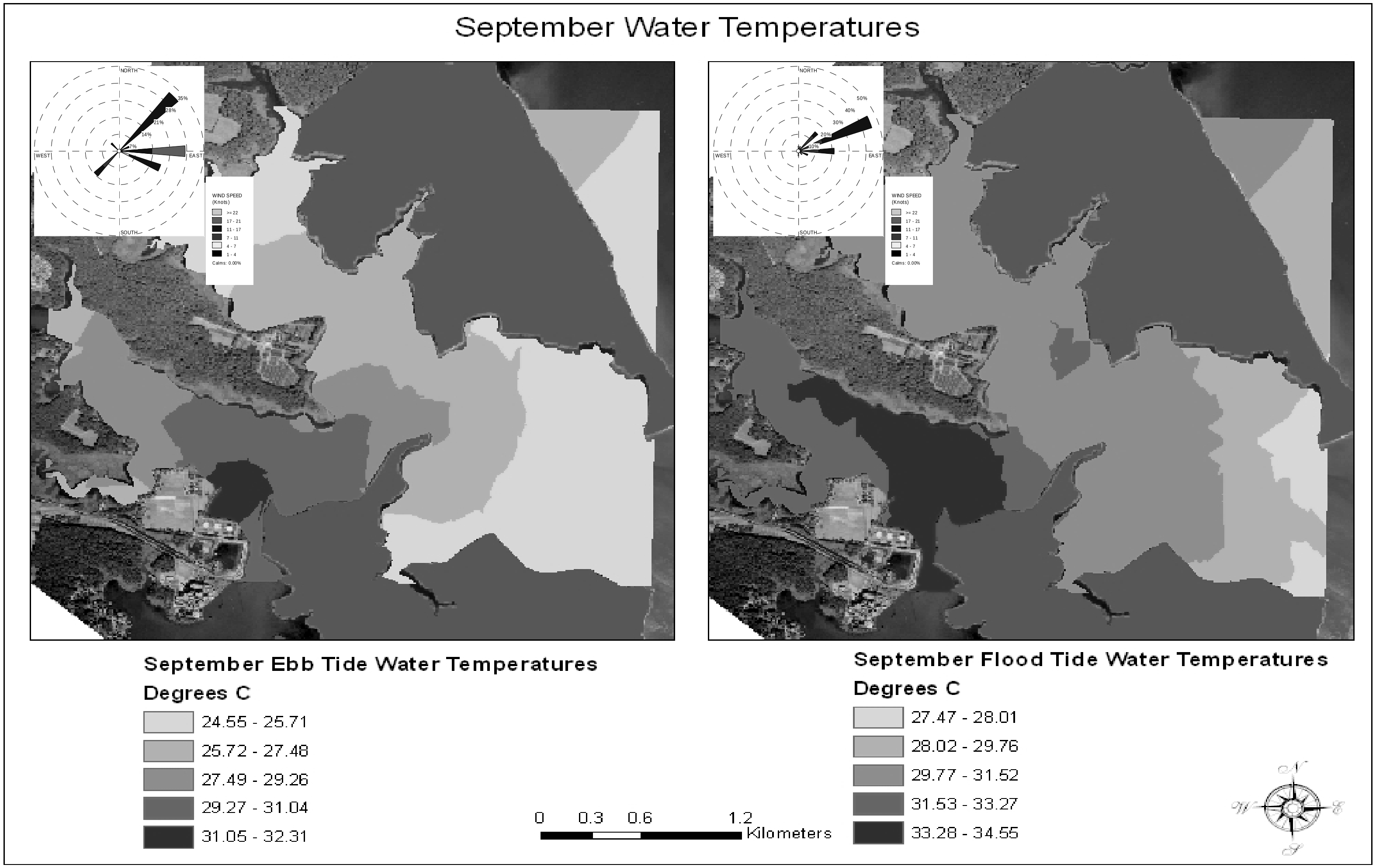

Figure 13. Krigged interpolation of water temperatures in Dundee and Saltpeter Creeks during September 2005. The left panel shows water temperatures during the ebb tide, while the right panel is the flood tide. The classification of the data is based on the standard deviations computed in ArcGIS. C.P. Crane Generating Station is located in the lower left corner of the map. Wind roses displaying wind direction and speed are also displayed for the selected sampling dates.

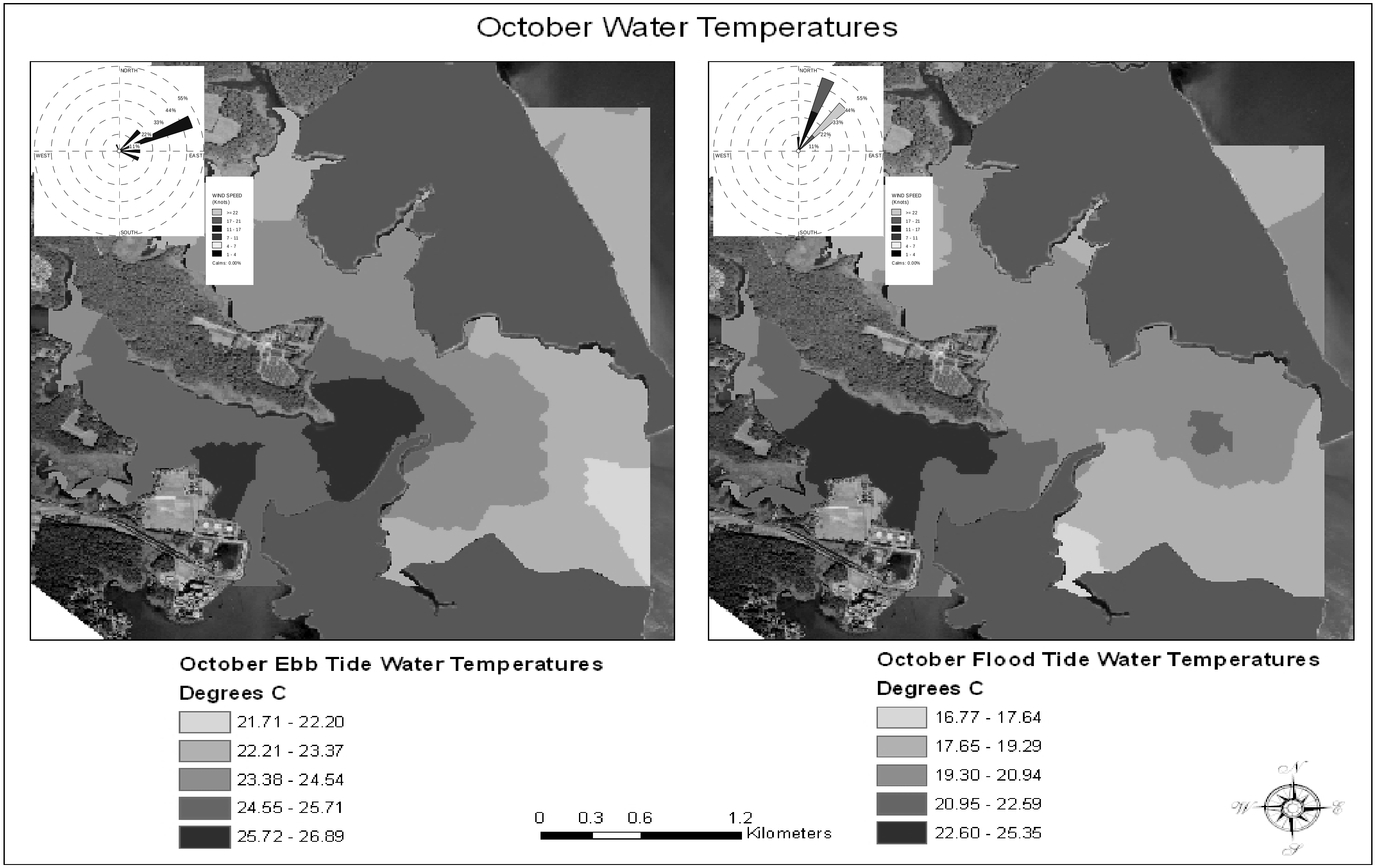

Figure 14. Krigged interpolation of water temperatures in Dundee and Saltpeter Creeks during October 2005. The left panel shows water temperatures during the ebb tide, while the right panel is the flood tide. The classification of the data is based on the standard deviations computed in ArcGIS. C.P. Crane Generating Station is located in the lower left corner of the map. Wind roses displaying wind direction and speed are also displayed for the selected sampling dates.

water temperatures (Figure 15). Time series analysis also confirms higher water temperatures in Saltpeter Creek. From 22 June 2005 through 11 July 2005 (Figure 16), the highest daily average and maximum water temperatures were measured in Saltpeter Creek at SP1 and DM2. The highest daily minimum water temperature was observed at SP1 in Saltpeter Creek. Most of the sites displayed similar standard deviations in water temperature. Temperature at DM2 was generally more variable than the rest of the sites in the study area. The other two time periods showed similar trends (Figures 17 and 18).

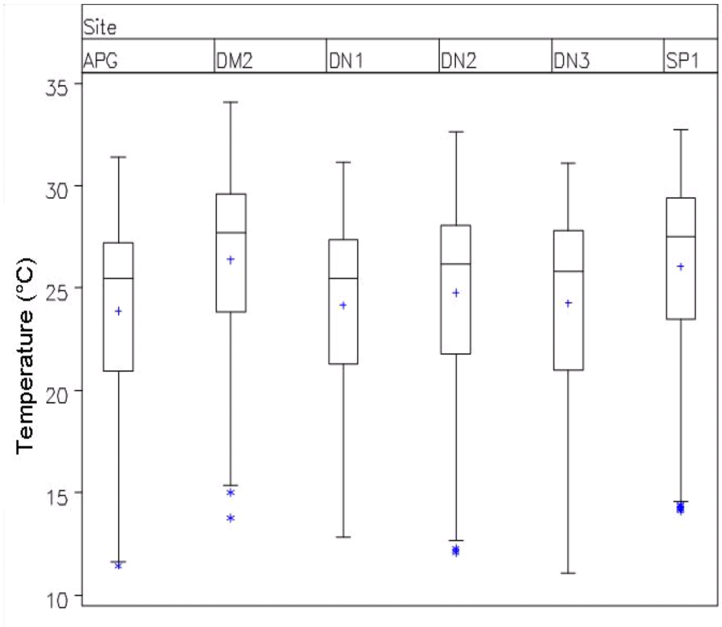

Figure 15. Average water temperature at the five temperature probe sites and MDDNR's continuous monitoring site at Aberdeen Proving Ground (APG). DM2 = Dundee Creek mid-channel 2; DN1 = Dundee Creek nearshore 1; DN2 = Dundee Creek nearshore 2; DN3 = Dundee Creek nearshore 3; SP1 = Saltpeter Creek 1. Water temperatures at SP1 and DM2, the sites located within the thermal effluence of the CP Crane power plant, were higher ($P<0.05$) than the sites located outside the effluent.

Comparison with the MDDNR continuous monitoring site showed that temperatures at DN1, DN2, and DN3 are similar to ambient conditions outside of Saltpeter-Dundee, while sites SP1 and DM2 represent sites affected by the thermal plume (ANOVA; $F_{5, 5980} = 58.06$, $P < 0.001$; Table A1). Due to the continuous operation of the power plant, the temperature signature of the effluent is affected by the diurnal tidal cycle, carrying the heated water to different parts of the creek in a regular pattern. Indeed, water temperature at DM2 was negatively correlated with water depth (Figure 19, Table 1), and positively correlated at SP1 (Figure 19, Table 1). A weak negative correlation with water depth was observed at DN2 whereas a weak positive correlation was detected at DN1 (Figure 19, Table 1). Temperature and depth were not correlated at DN3 (Figure 19, Table 1). In several instances, the highest water temperatures were recorded near midnight and in the early morning. Visual analysis of the temperature probe data (Figures 16, 17, 18) and the correlation analysis of water temperature and depth (Figure 19, Table 1) show that DM2 is influenced by the thermal plume for at least the ebb tide

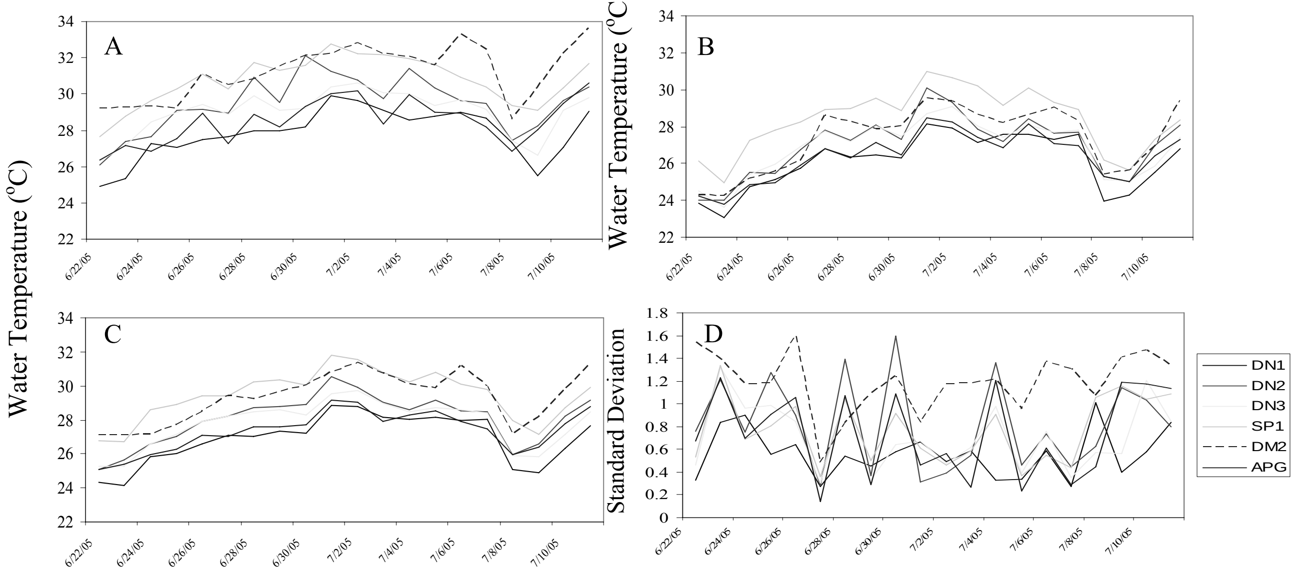

Figure 16. Time series of maximum (A), minimum (B), average (C), and standard deviation (D) daily water temperature at continuous monitoring sites from 22 June 2005 through 11 July 2005.

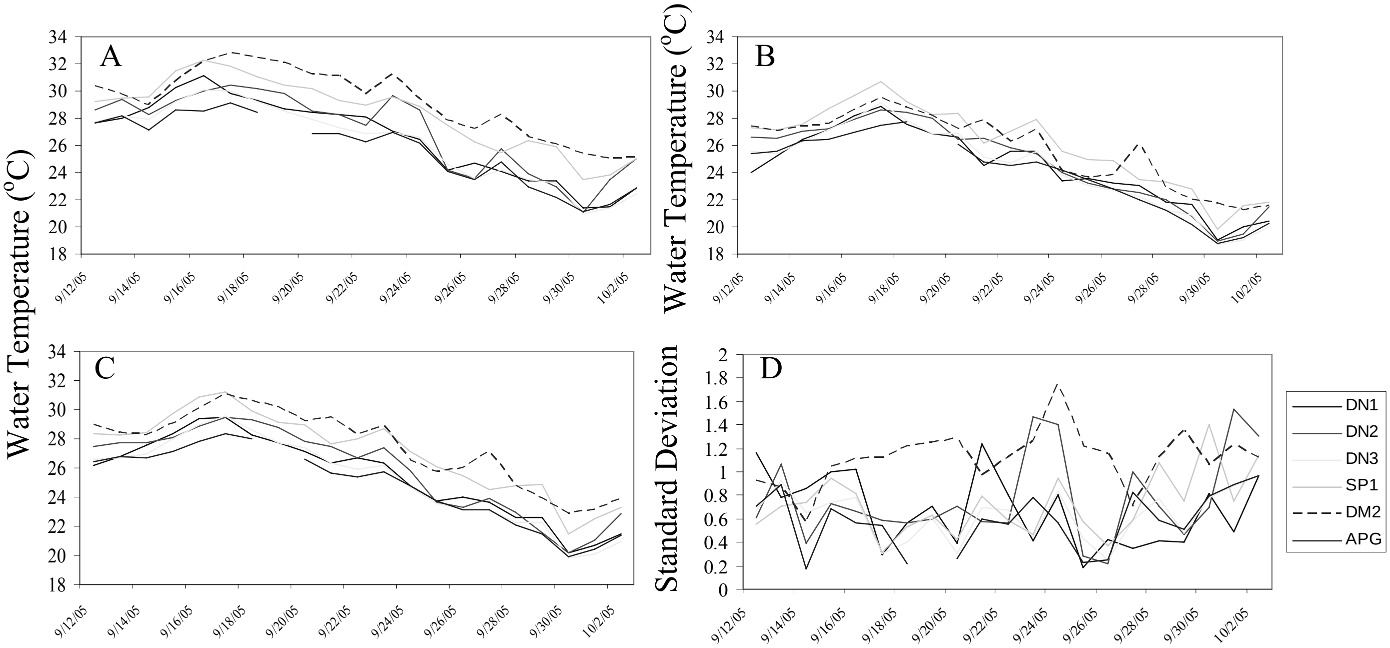

Figure 17. Time series of maximum (A), minimum (B), average (C), and standard deviation (D) daily water temperature at continuous monitoring sites from 12 September 2005 through 2 October 2005.

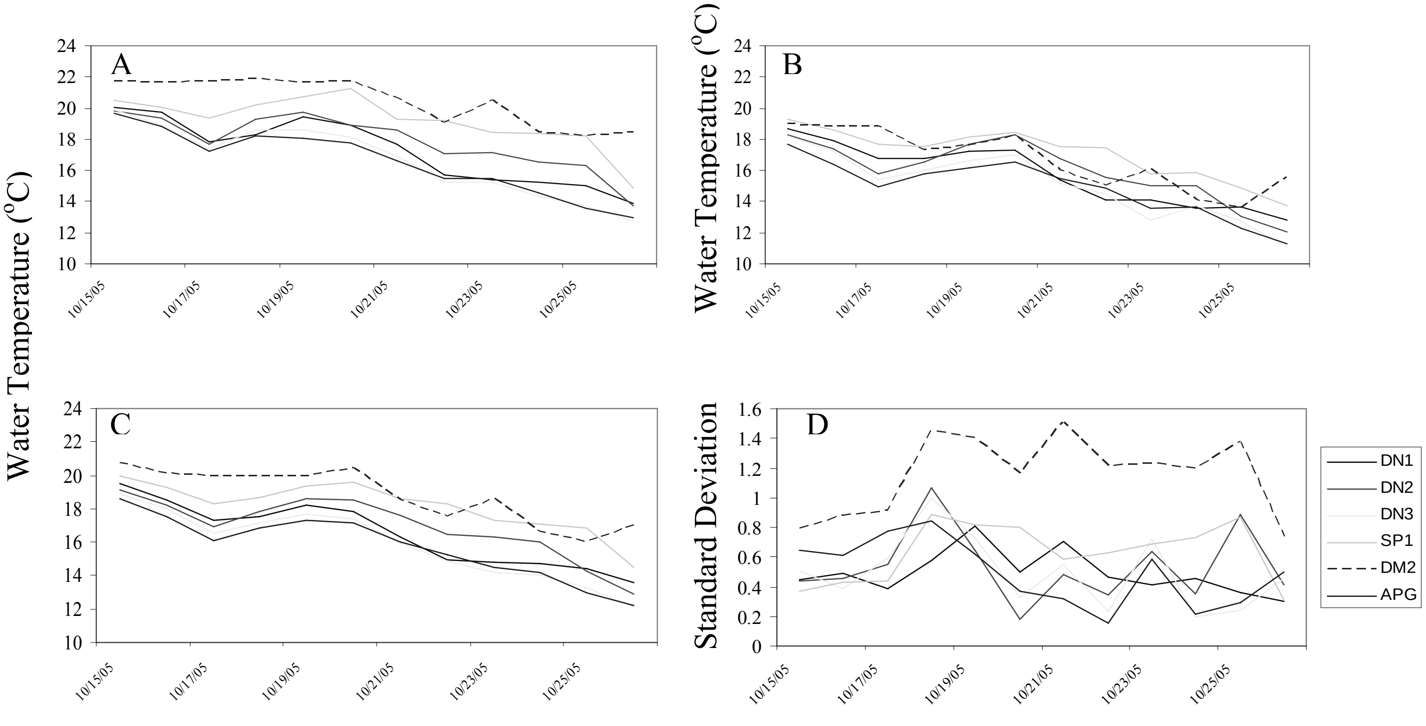

Figure 18. Time series of maximum (A), minimum (B), average (C), and standard deviation (D) daily water temperature at continuous monitoring sites from 15 October 2005 through 26 October 2005.

cycle, or approximately 6-7 hours, which occurs approximately twice a day (Figure 20). Surface and bottom water temperatures differed in upper Saltpeter Creek (ANOVA; F = 3.95, P = 0.04) and also at the mouth of Saltpeter Creek near Bengies Point (ANOVA; F = 21.58, P <0.001) indicating water column stratification does occur. However, visual analysis of water temperature at the different depths (Figures 21 and 22) show that stratification of the water column can be broken down, creating a well-mixed environment either during the day or at night. The area of the thermal plume in Saltpeter and Dundee Creeks was not corelated with wind speed (r = -0.07, p = 0.58, n = 7

Table 1. Pearson product moment correlations of depth and water temperatures at the five sites in Saltpeter and Dundee Creeks.

Site	Model		
	r	P	N
DN1	0.123	0.048	248
DN2	-0.188	0.003	248
DN3	0.018	0.777	248
SP1	0.165	0.009	248
DM2	-0.636	<0.001	248

Vegetation

Several of the 13 surveyed sites in Bengies Cove and upper Dundee Creek supported large diverse submersed aquatic macrophyte beds. Species present included *M. spicatum*, *V. americana*, *N. guadalupensis* (Spreng.) Magnus, *E. canadensis*, *P. perfoliatus*, *P. pusillus* (L.), *P. crispus* and *C. demersum*. Number and cover of species varied greatly over the study area (Figure 23). *Vallisneria americana* was the most prevalent species in the areas directly affected by the thermal effluent, while *C.*

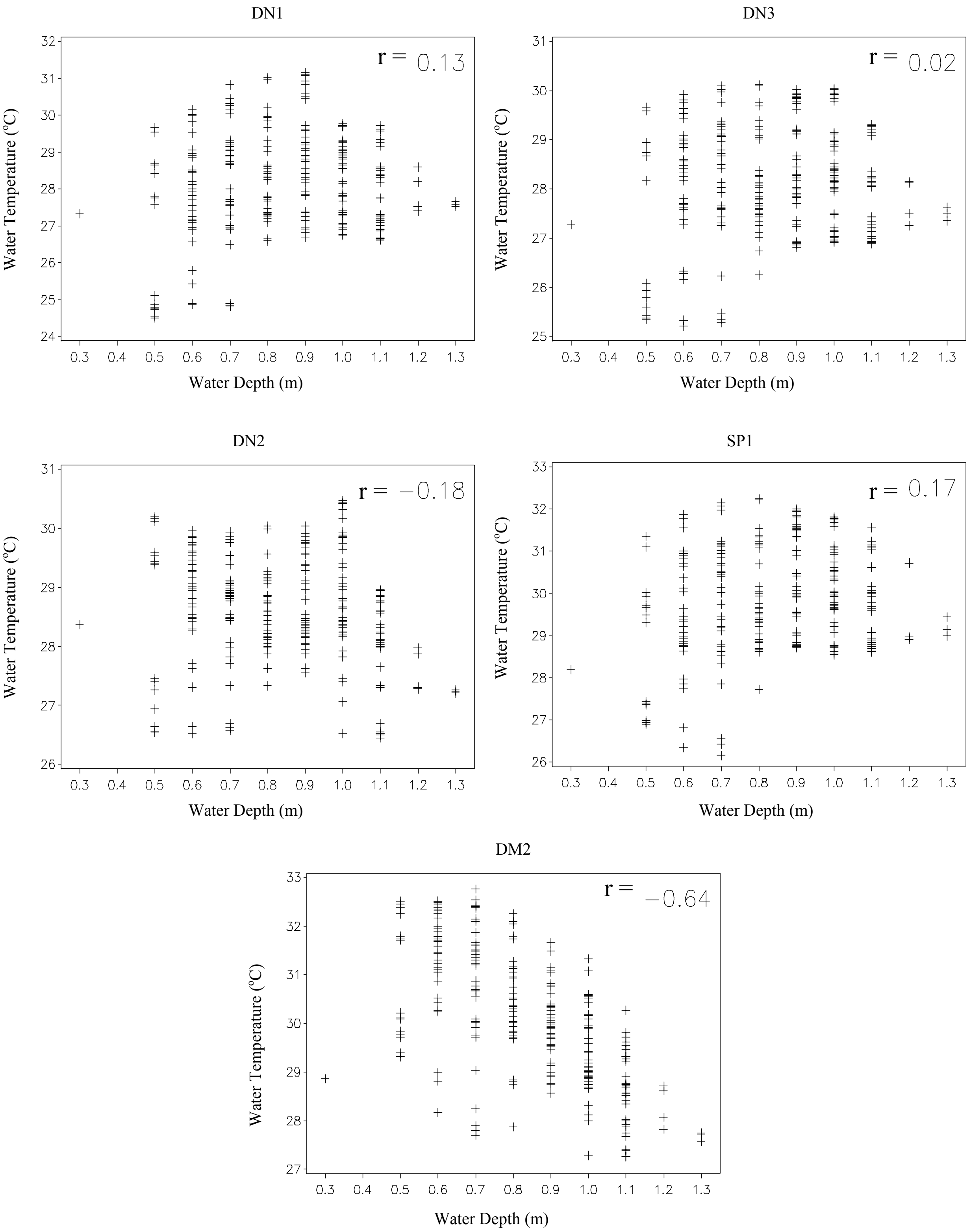

Figure 19. Water temperature and water depth scatter plots for the five continuous monitoring sites in the study area. DN1 and SPI were positively correlated and negatively at DM2 and DN2 (Table 1).

demersum was one of the most dominant species at the most diverse sites outside the thermal plume (Figure 23). The thirteen macrophyte sampling sites differed in total percent plant cover (Repeated Measures ANOVA; $F_{12,\ 57.4} = 159.31$, $P < 0.001$). Macrophyte cover also differed across time (Repeated Measures ANOVA $F_{4,\ 135} = 33.88$, $P < 0.001$; Table A2). In general, sites outside the thermal plume supported higher cover and higher species richness than sites within the plume; however, this observation could not be corroborated statistically as variability in macrophyte cover and richness was high

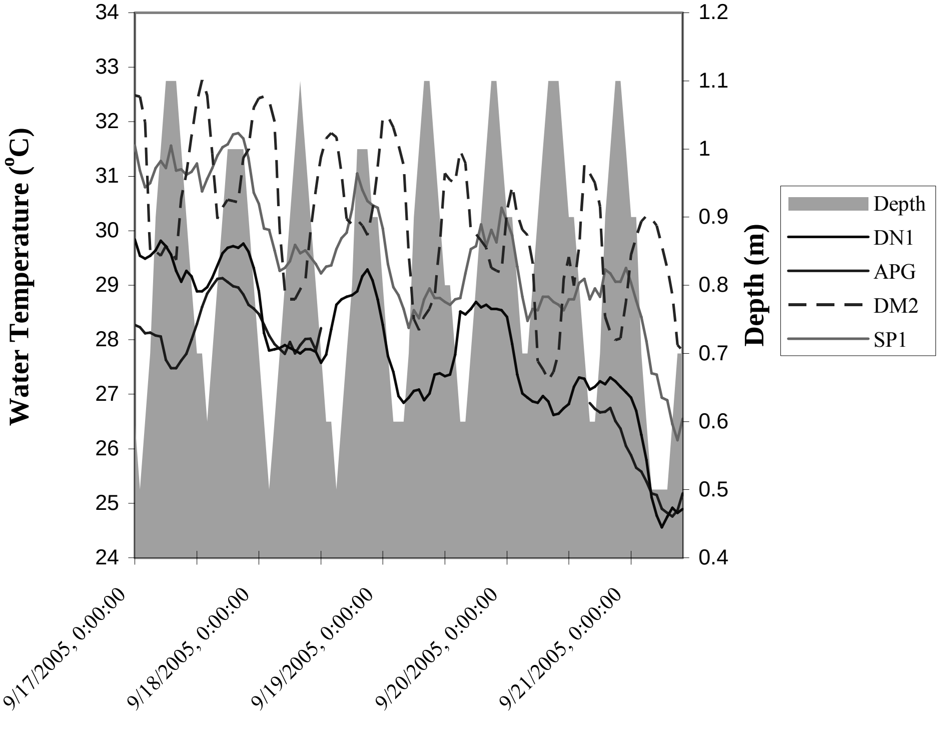

Figure 20. The water temperatures at DM2 were correlated with the ebb tide. The outgoing tide carried the thermal effluent out of Saltpeter Creek, where the highest water temperatures were recorded at DM2 during low tide.

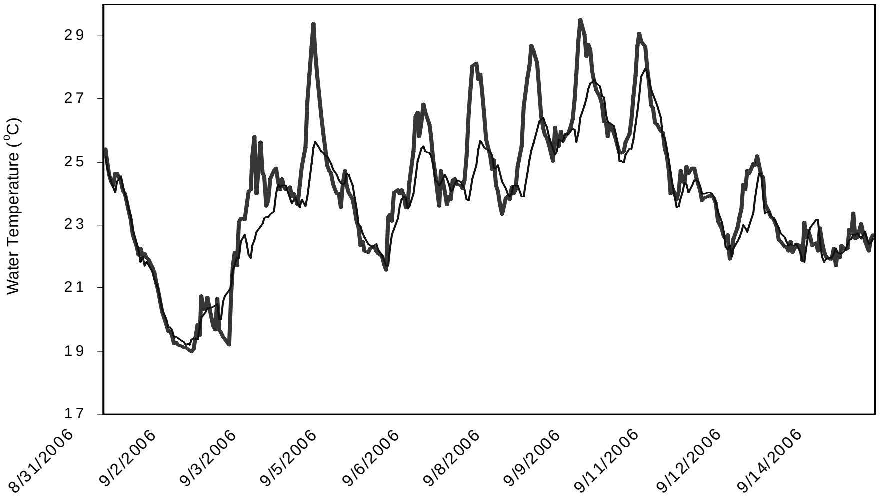

Figure 21. Surface (solid line) and bottom (dashed line) water temperatures (º C) at Bengies Point, downstream of the discharge impoundment.

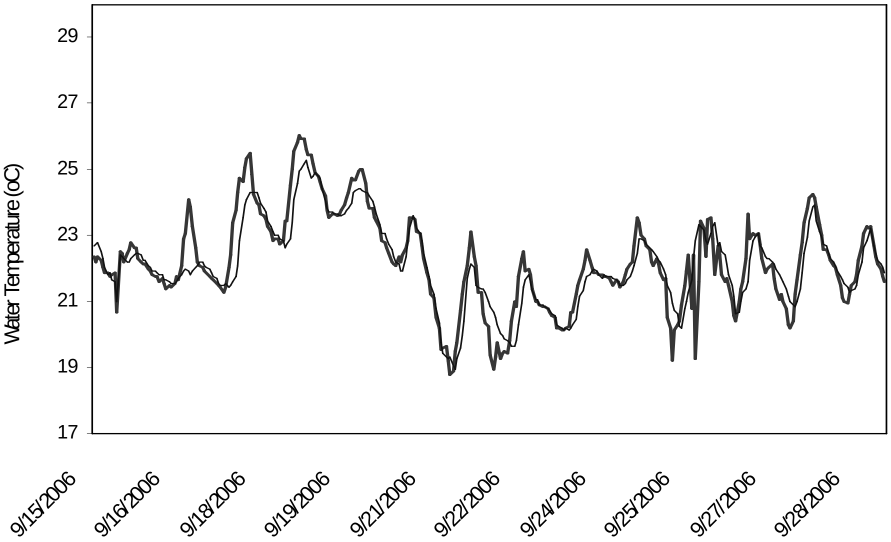

Figure 22. Surface (solid line) and bottom (dashed line) water temperatures (º C) in upper Saltpeter Creek, upstream of the discharge impoundment.

and one site within the thermal plume (361) supported high cover and species richness similar to some sites outside the plume.

Species-specific cover data was also analyzed to test for differences between sites and months. *Vallisneria americana, E. canadensis and N. guadalupensis* cover differed between sites whereas *M. spicatum* and *P. perfoliatus* did not. Only *P. perfoliatus* differed in cover across months and *C. demersum* was the only species to differ in cover across months and sites.

Classification and ordination analysis by its nature reduces highly dimensional data into a low-dimensional summary. Several complementary methods (Hierarchal classification, Bray-Curtis, Non-metric multidimensional scaling) were used and the results were compared to evaluate similarity of submersed aquatic macrophyte

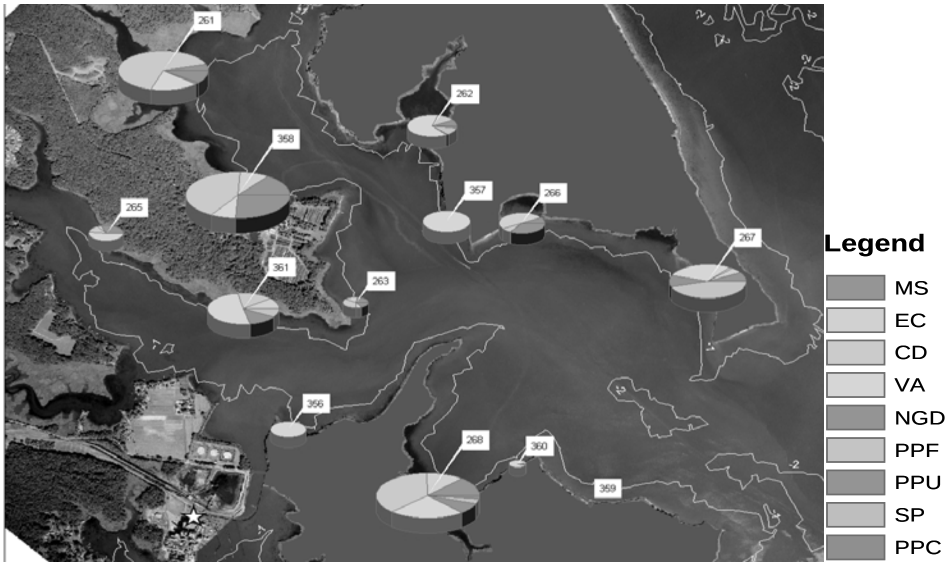

Figure 23. Pie charts showing average macrophyte cover (over the sampling events) per species at the macrophyte sampling sites, where larger pies represent greater total macrophyte cover averaged over the sampling events.

communities within Dundee Creek. Site 359 was dropped from this analysis because macrophytes were absent and null entries cannot be used in the analyses . In all three multivariate analyses, sites 261, 268 and 358 (Figure 24) were found to support similar community structures. These three sites supported a total of seven species throughout the growing season, peaking at 100% total cover in August. This grouping was dominated by the ubiquitous species, *C. demersum*. Additional species recorded at the 3 sites were *M. spicatum*, *V. americana*, *E. canadensis*, *N. guadalupensis*, *P. perfoliatus*, *P. pusillus* and one instance of *S. pectinata*.

The second group emerging from ordination analysis was made up of five sites, 262, 267, 356, 357, and 361 (Figure 24). The dominant species in this grouping was *V. americana*. Other species observed at these sites included *M. spicatum*, *E. canadensis*, *N. guadalupensis*, *C. demersum*, *P. perfoliatus* and a few instances of *P. pusillus*. These sites did not support any populations of *S. pectinata*. Compared to the most diverse sites of the first grouping, little *M. spicatum* was observed at these five sites. Less *C. demersum* was observed in the second grouping compared to the first. At site 356, in Saltpeter Creek, there was a switch from *C. demersum* and *N. guadalupensis* dominance to *V. americana* dominance in the summer months of August into September.

The third grouping contained sites 263, 265 and 360 (Figure 24). These sites all supported low total macrophyte cover, with no site exceeding 25%. Site 263 did not support a clear dominant species. *Vallisneria americana* dominated sites 265 and 360, with small amounts of *M. spicatum*, *E. canadensis*, *N. guadalupensis*, *C. demersum and P. perfoliatus*. At site 265, species dominance switched from *M. spicatum*, *E. canadensis* and *C. demersum* to *V. americana* from August into September.

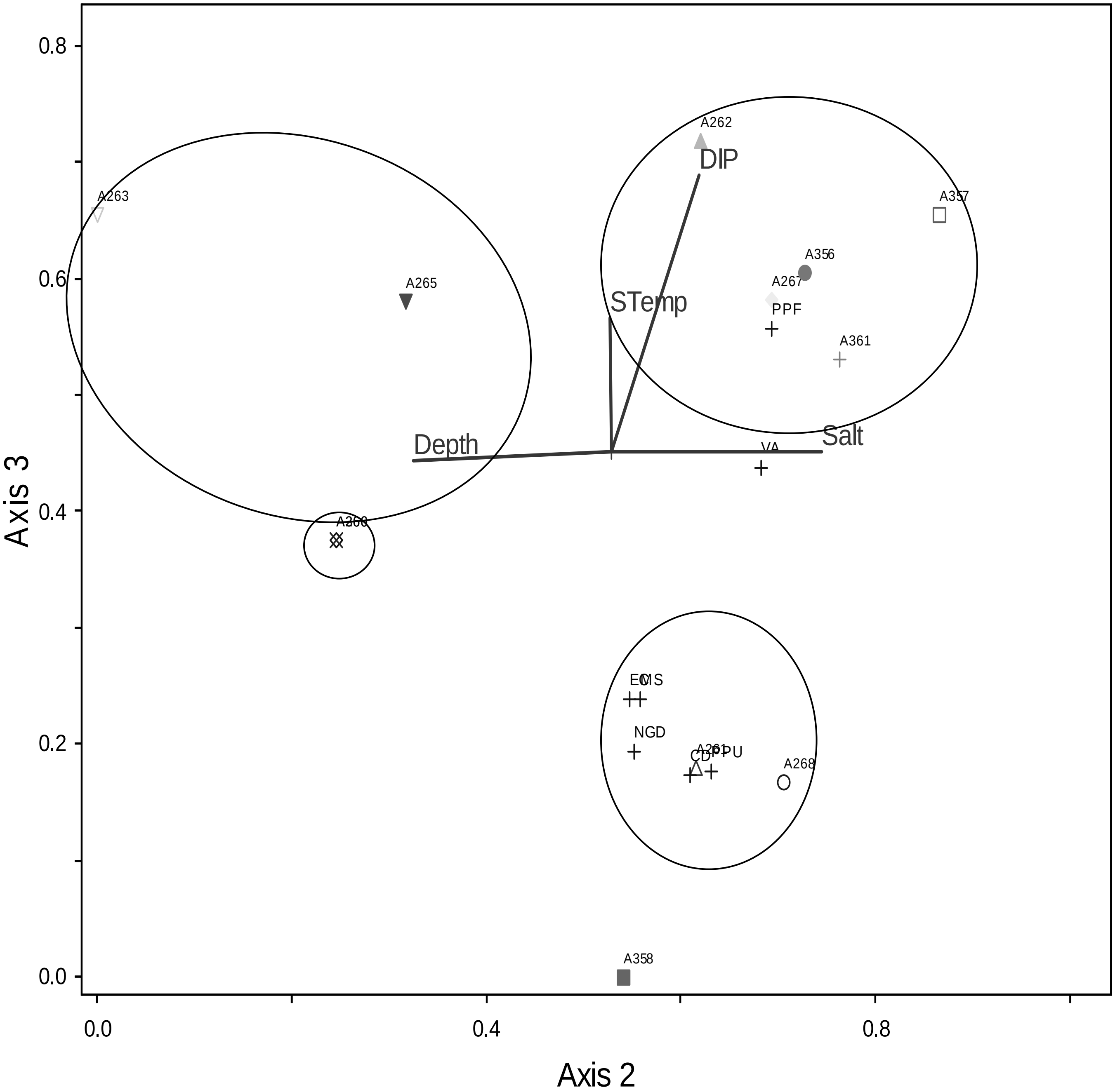

Figure 24. Ordination graph from the Bray Curtis analysis. Similar groups are circled and axes are vectors extending in the positive direction. Axes are non-dimensional ordination axes and additional combinations of axes are not shown. Sites contain a nonnumeric character "A" for software analysis purposes. Macrophyte species are abbreviated as follows: EC = *E. canadensis*; NGD = *N. guadalupensis*: VA = *V. americana*; MS = *M. spicatum*; PPF = *P. perfoliatus*; PPU = *P. pusillus*; CD = *C. demersum.* Vector labels are as follows: Salt = salinity; DIP = dissolved inorganic phosphorus; S Temp = surface water temperature; Depth = water depth.

Site 266 was classified into its own group. This site was dominated by *E. canadensis* and *N. guadalupensis* throughout the growing season and did not support a high abundance of *V. americana*. The total cover of all of the species at this site dropped off considerably after July

Supporting the results observed in the ordination analyses, Shannon Diversity (Magurran, 1981) was the highest for the sites in the first ordination group (Figure 25). Only site 268, in Bengies Cove, was significantly different from sites 356 and 357. Shannon Diversity indices of the remaining macrophyte sampling sites were comparable and independent of location.

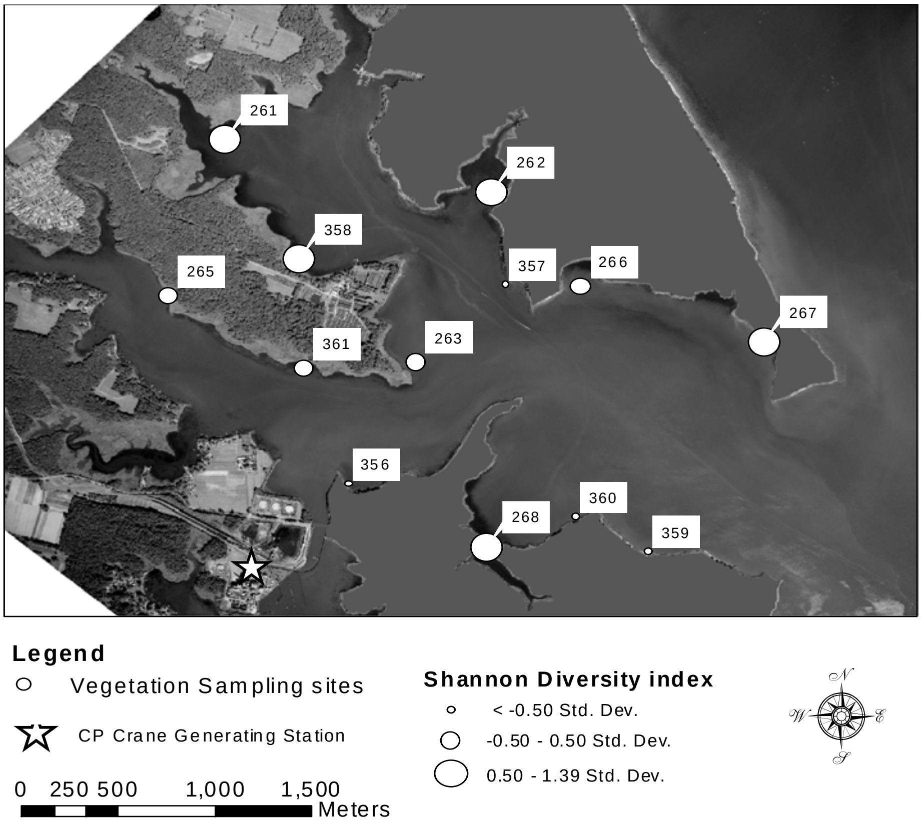

Figure 25. Vegetation sampling sites displaying the Shannon diversity index using the standard deviation classification created in ArcGIS. Areas are grayed out due to security restrictions. C.P. Crane Generating Station is identified with a star.

Relating macrophytes and temperature

Pearson product-moment correlation was used to relate cover of specific species to water temperature at the 13 sites on a monthly basis. Water temperature and cover of submersed aquatic macrophytes for any of the sampling months were not correlated. Similarly, total macrophyte cover was not correlated with water temperature in any of the months in which sampling occurred. Fluctuations in water temperature may have been important, but no correlations were found between standard deviation in water temperature and total macrophyte cover at the sampling sites (Figure 26; r = -0.23, P = 0.05).

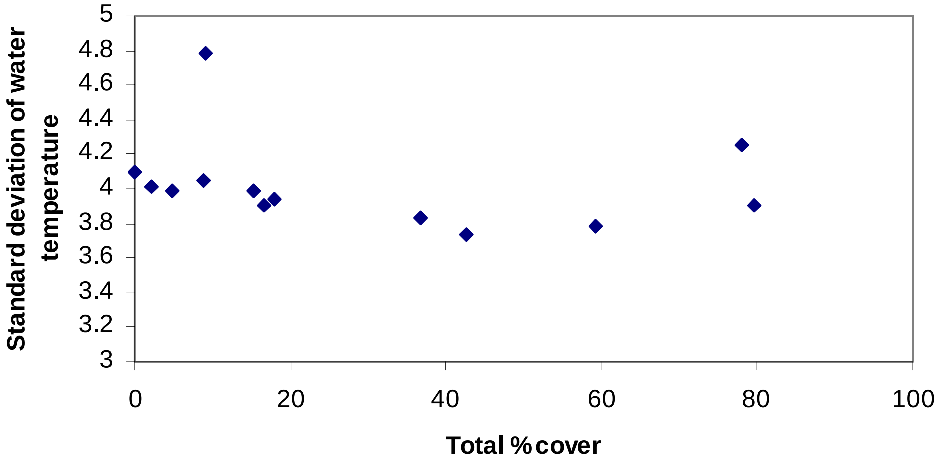

Figure 26. Scatter plot of total percent macrophyte cover and standard deviation of water temperature at the 13 macrophyte sampling sites.

Other covarying factors

Habitat Parameters

Dundee Creek is a relatively small system, with little water quality variation throughout the creek (Table 2), allowing a reliable representation of the water quality in the creek system using the 5 water quality stations. Of a suite of water quality

Table 2. Submersed aquatic macrophyte habitat parameters recorded in the study area throughout the 2005 season. KD = light attenuation coefficient; Chl-a = Chlorophyll-a; TSS = Total suspended solids; DIP = Dissolved Inorganic Phosphorus; DIN = Dissolved inorganic nitrogen. Detection limits are TSS = 0.5 mg/L, DIN = 0.002 mg/L, DIP = 0.0011

		SP1	**DM2**	**DN3**	**DN2**	**DN1**
KD (m^{-1})	Mean	2.06	1.92	2.08	1.88	2.56
	Median	2.07	1.73	1.79	1.69	2.26
	SD	0.62	0.62	0.75	0.73	1.48
Chl-a (µg/l)	Mean	16.32	12.26	13.46	10.05	14.64
	Median	10.6	11.51	10.69	9.4	14.62
	SD	11.74	5.3	10.32	5.33	7.34
TSS (mg/l)	Mean	10.23	9.77	9.12	8.1	13.92
	Median	9.5	8.75	8	6.5	12.5
	SD	5.2	6.21	3.85	3.94	11.75
DIP (mg/l)	Mean	0.005	0.003	0.003	0.003	0.003
	Median	0.002	0.002	0.002	0.002	0.002
	SD	0.006	0.001	0.002	0.002	0.002
DIN (mg/l)	Mean	0.19	0.182	0.106	0.185	0.128
	Median	0.091	0.104	0.015	0.052	0.016
	SD	0.079	0.173	0.048	0.068	0.061

parameters, only four, light attenuation coefficient (Kd), dissolved inorganic phosphorus (DIP), chlorophyll-a (Chl-a), and total suspended solids (TSS), were defined as habitat requirements for tidal fresh and oligohaline portions of the Chesapeake Bay (Batiuk et al., 2000). The requirements were defined as: Kd $<2m^{-1}$; TSS $<15mgl^{-1}$; Chl-a $<15\mu ml^{-1}$ and DIP $<0.02mgl^{-1}$ (Batiuk et al., 2000). All four requirements were either met or only slightly exceeded at all five sites within the study area (Table 2). Dissolved inorganic nitrogen is also presented in Table 2, although it is not considered a habitat requirement in the tidal fresh/oligohaline regions because it is so high (i.e., the system is P limited). The mean light attenuation coefficient was slightly higher than the habitat requirement at sites DN1 and SP1 and DN3, while DIP was slightly higher at all sites except DN3. Analysis of Variance shows that the 4 habitat variables did not differ among the five water quality sites (Table 3).

Table 3. Summary of water quality habitat requirement ANOVA tables (A3-A6).

Habitat requirement variable	F	df	p
Light attenuation coefficient	1.26	4,60	0.30
Chlorophyll-a	0.80	4,60	0.53
Dissolved inorganic phosphorus	0.83	4,60	0.51
Total suspended solids	0.89	4,60	0.47

Although no differences were found among the water quality sites for habitat parameters, salinity differed between the 13 sites surveyed for macrophyte (RMANOVA $F_{12, 328} = 154.44$, $p < 0.001$, Table A7) and months (RMANOVA $F_{4, 433} = 9455.86$, $p < 0.001$, Table A7). Site 361 supported the highest mean salinity of 5.86 and site 268 the lowest mean salinity of 4.44 (Figure 27). Salinity was highest in October and lowest in

April. Salinity and water temperature were negatively correlated (Pearson product moment: r = -0.51, p = <0.001).

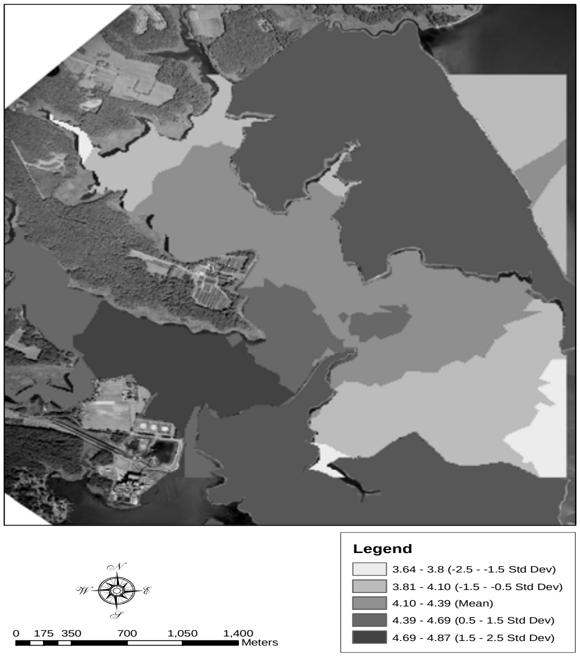

Figure 27. Average salinity in Dundee and Saltpeter Creeks during the 2005 SAM growing season. Grayed out areas are part of Aberdeen Proving Ground and grayed out due to security restrictions. C.P. Crane Generating Station is located in the lower left corner of the map.

Ecological similarity and ordination

Similarity analysis

The quantitative Sorenson similarity index, or Bray-Curtis index, was calculated for each pair of the 13 macrophyte sampling sites to determine the variation in species composition along the environmental gradients in Dundee Creek. The results contain a wide range of coefficients. The two most similar sites were 268 and 358, with a Bray-Curtis coefficient of $C_n = 0.726$. The two most frequently observed sites with high Bray-Curtis coefficients were 262 and 361. Site 262 supported four species and was located in the second lowest temperature standard deviation, while site 361 supported five species and was located in the second highest temperature standard deviation. On the other extreme, sites 359 and 266 were most commonly found to be completely dissimilar (C_n= 0) from other macrophyte sampling sites in the creek system.

Bray-Curtis Ordination

Using Bray-Curtis ordination, four groupings of the 12 (Site 359 was dropped because it did not support any species) sites emerge across three ordination axes. The three axes explain 83.9% of the total variance. The locations of the sites on the Bray-Curtis ordination graph (Figure 24) are similar to the results of the classification analysis. The most dominant environmental variables related to community structure were depth (r^2 = 0.55 on Axis 1), salinity (r^2 = 0.43 on Axis 2), DIP (r^2 = 0.47 on Axis 3) and water temperature (r^2 = 0.229 on Axis 3). The species with the highest correlation on any axis was *V. americana* (r^2 = 0.749 on Axis 2). Several species were correlated with Axis 3, including *C. demersum* (r^2 = 0.72), which is also the axis with some correlation with surface temperature. In combination with the classification results, the ordination results show that sites within the thermal plume are similar to sites outside of the thermal plume, as evidenced by site 361 being classified with sites 262 and 267.

Growth Chamber Results

None of the species obtained from the Wisconsin nursery performed well in the 36 °C chamber with *V. americana* dying after only 4 weeks. *Elodea canadensis* and *C. demersum* survived the length of experiment but showed signs of stress by the end of the experiment that would have eventually lead to death (Figure 28). *Vallisneria americana* produced the longest leaves in the 32 °C chamber and the shortest leaves in the 36 °C chamber (ANOVA; F = 131.49, P < 0.001; Figure 28A). *Ceratophyllum demersum* fared the best at the highest temperature of 36 °C (Figure 28B), but maximum length of leaves

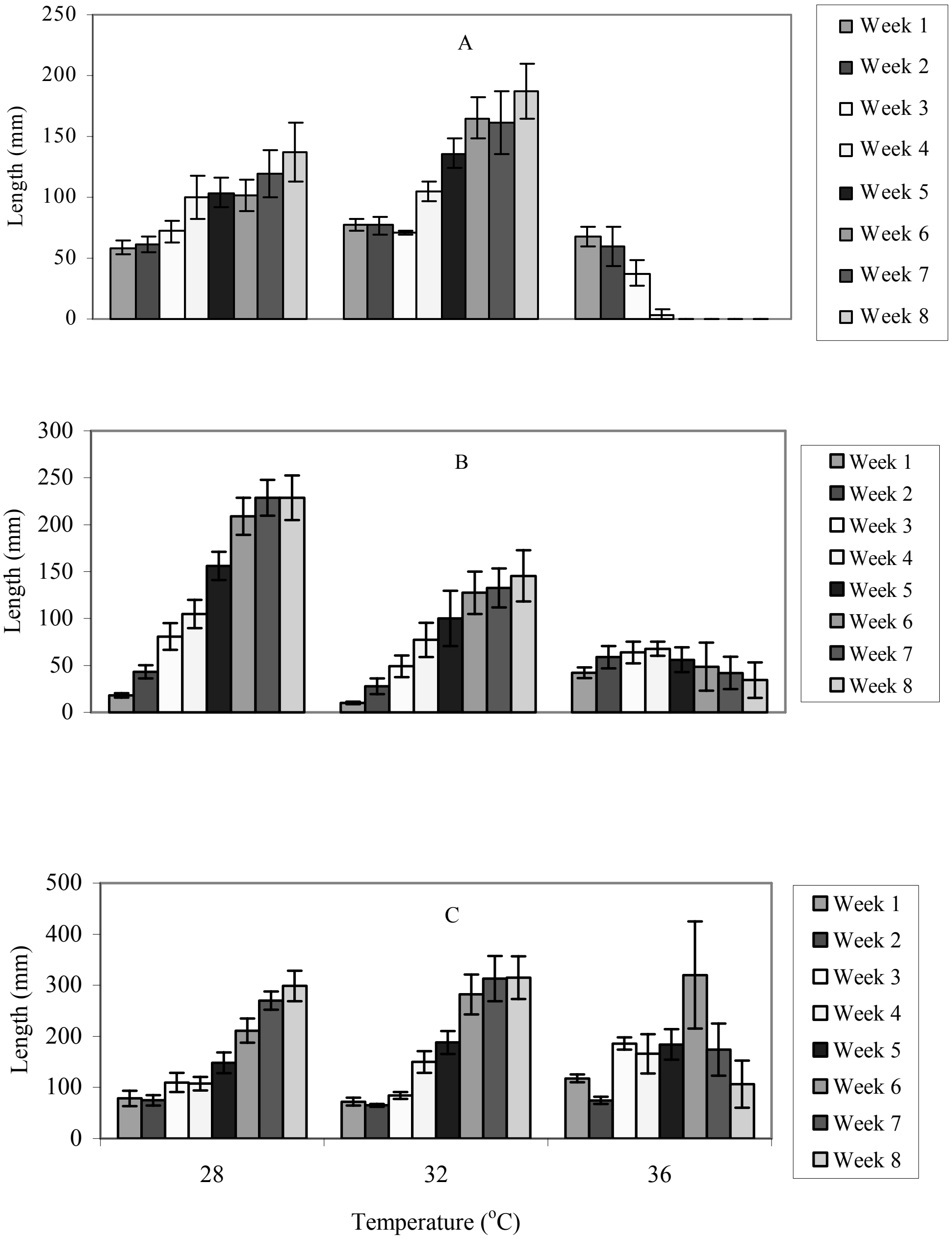

Figure 28. Maximum length (±SE) of *V. americana* (A), *E. canadensis* (B) and *C. demersum* (C) from the Wisconsin nursery.

did not differ between temperature treatments (ANOVA; F = 2.43, P = 0.09). *Elodea*

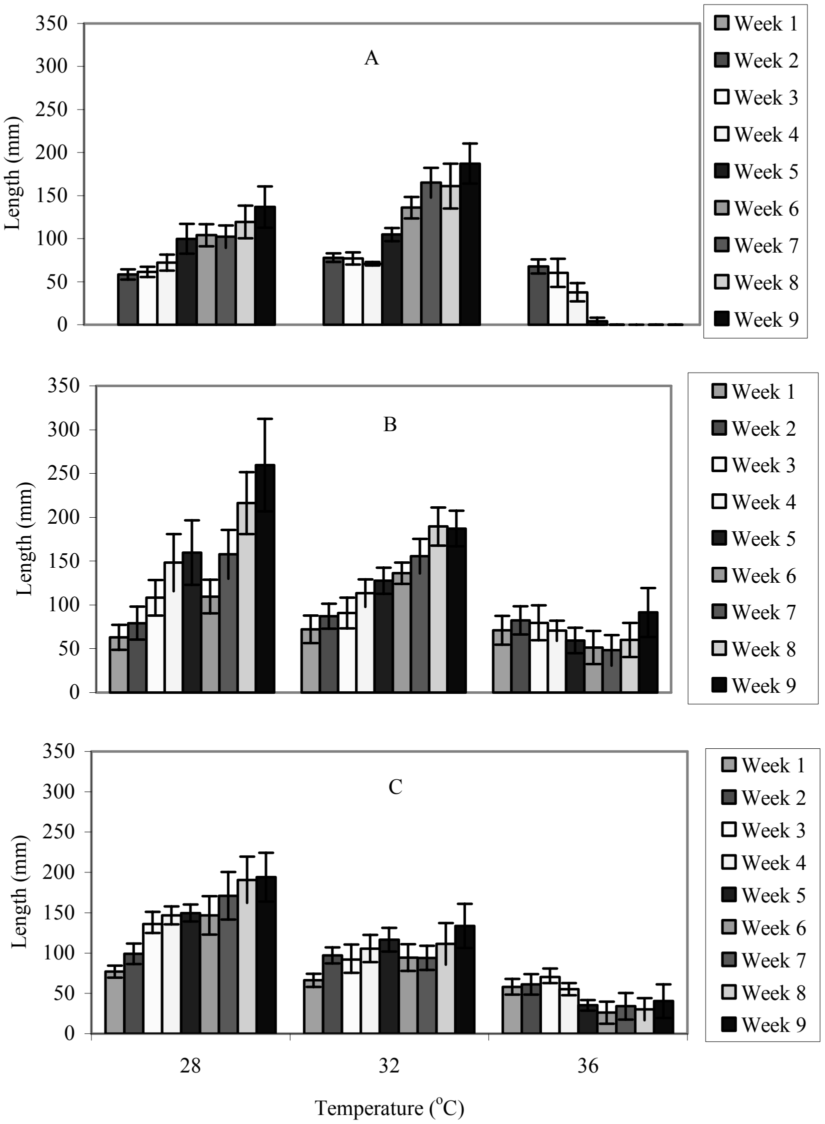

Figure 29. Maximum length (± SE) of *V. americana* obtained from Wisconsin (A), low temperature areas from the study area site (B) and high temperature areas of the study area site (C).

canadensis survived the eight week experiment in the 36 °C chamber, but the maximum length peaked in week 4 and declined through the end of the experiment (Figure 28C). Maximum length was reached in the 28 °C chamber and was shorter in the other two treatments (ANOVA; F = 46.87, P <0.001). Each of these species showed the same general trends in the 28 °C and 32 °C chambers of increasing maximum leaf length through the 8 week period (Figure 28). The number of ramets also showed a significant temperature effect (ANOVA; F = 29.38, P <0.001) where the number of ramets in the 36 °C (1.3 ramets) chamber was lower than the two lower temperature chambers (3.6 ramets). Similarly, the maximum number of leaves for one plant showed a significant temperature effect (ANOVA; F = 90.20, P <0.001). The maximum number of leaves for one plant in the 36 °C (4.2 leaves) chamber was lower than in the 28 °C (8.6 leaves) and 32 °C (8.6 leaves) chambers.

The source of plant material also had an effect on how plants performed in the three temperature treatments. *Vallisneria americana* plants from the low temperature areas of the study area produced the longest leaves and the plants from Wisconsin produced the shortest leaves (ANOVA; F = 27.73, P <0.001). The number of ramets also showed a source effect (F = 12.79, P <0.001), but in this case the number of ramets of plants collected in low temperature areas (3.7 ramets) were higher than plants from Wisconsin and plants from the high temperature areas (2.2 ramets; Figure, 29). Temperature effects on leaf production was also affected by source of plant material (ANOVA; F = 11.33, P <0.001); the plants from Wisconsin supported fewer leaves than the plants from the study area (Figure 29). Finally, the sum of all leaves among all plants in a container differed among temperature (F = 26.91, P <0.001) and source treatments (F = 11.69, P <0.001). The sum of all leaves was lower in the 36 °C chamber, while the plants from the low temperature areas produced more leaves than the Wisconsin plants or plants from the thermally impacted area.

Discussion

As expected, significant differences in water temperature were observed within the study site that were generated by the thermal effluent of the C.P. Crane power generating station; however, owing to the high variability in submersed aquatic macrophyte species presence and cover at the 13 sample sites and the necessary small sample size within the thermal plume to avoid autocorrelation issues, the temperature differences did not result in statistically detectable differences in submersed aquatic macrophyte communities. Thus, the null hypothesis could not be falsified. Nevertheless, water temperature does appear to play a role in structuring the macrophyte communities at the study site; diversity and cover were generally higher outside the thermally impacted area than inside (Figure 23) and temperature was an important environmental gradient in ordinations (Figure 24). In addition, *Elodea canadensis* performed best in the 28°C temperature treatment of the growth chamber experiment (Figure 28) and appeared stressed at the higher temperatures that represent temperatures commonly experienced in the thermal plume (32 °C) or above the thermal tolerance of many species (36 °C). Thus, at least one species at the study site may be sensitive to the temperatures commonly experienced within the thermal plume.

Results from the continuous temperature probes support the hypothesis that temperature differences existed within the creek (Figure15). The two sites nearest the discharge impoundment experienced the highest water temperatures, exceeding 30 °C during the summer for approximately 12 hours per day. Temperature not only varied among sites but also changed with the tidal cycle. At the mouth of Saltpeter Creek, at Bengies Point, the water temperatures were found to correlate with the ebb tide owing to circulation patterns and the location of the discharge impoundment (Table 1). Peak water temperatures at DM2 were reached twice a day and at times may have occurred during the middle of the night. Unlike the other sites in the creek system, the dual peaks in water temperature persisted for the entire tidal cycle. The disruption of the coinciding light:dark - temperature cycle could cause physiological stress to the plants in this area (Hennessey et al., 1991 and Liu et al., 1998). Disruption of the diel light:dark - temperature cycle may have an influence on temperature dependent processes such as nutrient uptake, and translocation (Bulthuis, 1987). Water temperature is also known to affect photosynthesis (Anderson, 1969; Bulthuis, 1987; Santamaria and van Vierrsen, 1997) and respiration (Bulthuis, 1987). The temperature probe in upper Saltpeter Creek did not show any correlation with water levels (Table 1). This was surprising, as a correlation with the flood tide was expected. The lack of correlation could be due to the build-up of heated water over several tidal cycles, similar to observations made at Chalk Point Station, MD (Schreiner et al., 2002).

Temperature effects on submersed aquatic macrophyte communities were more subtle than expected, which may have several explanations. Perhaps the most obvious explanation is that the 4-5 ºC increase in temperature within the thermal effluent was not large enough to noticeably impact plant growth and survival of most local species. The "average" rainfall year (McPherson, 2006) created conditions in which published stressful or lethal temperatures for most submersed aquatic macrophyte species (Table 4) were not reached. Along with average precipitation, ambient water temperatures during 2005 were not significantly different from the previous nine years in the study area (Figure 30), even though water temperatures were higher in the Lower Chesapeake Bay (Blankenship, 2006). The "average" rainfall and average water temperatures mitigated the increase in salinity caused by the effluent. Conditions in which temperature and salinity tolerances for submersed aquatic macrophytes are exceeded may only be achieved during years of low river flow and high air temperatures coinciding with drought conditions.

Despite temperatures within the thermal effluent falling within the thermal tolerances of submersed aquatic macrophytes, changes in the balance between photosynthesis and respiration of some species can be expected (Ryan, 1991) even for the relatively small temperature difference experienced within the thermal plume compared to ambient conditions. Indeed, the temperature tolerance of *E. canadensis* appears to be reached at relatively low temperatures and should have been reached at the study site. Furthermore, I expected the *V. americana* plants collected from the thermal plume to perform better than plants collected from sites outside the thermal plume. That the

Table 4. Species specific temperature ranges and information concerning important growth aspects for several species present in Dundee and Saltpeter Creeks.

Species	Temp °C	Important growth information	Reference
V. americana	33-36	Grew Best	Korschgen and Green, 1988
P. perfoliatus	35/45	Tolerant/Lethal	Anderson, 1969
M. spicatum	30-35/Broad range	Net Photosynthesis	Nichols and Shaw, 1986; Barko and Smart, 1981
E. canadensis	27-35	Optimum growth	Santamaria and van Vierssen, 1997; Olesen and Madsen, 2000
C. demersun	Caribbean	World Wide Dist.	Lowden, 1978
P. crispus	30	Net Photosynthesis	Nichols and Shaw, 1986
P. pectinatus	23-30	Optimum Temp for early growth	Spencer, 1986

opposite was observed (Figure 29) suggests that the plants from the thermal plume were not acclimated to the higher temperatures, but were stressed enough to be affected by the experimental conditions. Still, plants collected from the study site do appear to be acclimated to the higher temperatures of the mid-Atlantic region compared to the plants from Wisconsin that generally experience cooler temperatures during the summer; *V. americana* from Wisconsin died within 4 weeks of the experiment whereas the *V. americana* from the study site did not.

Another explanation for the subtle temperature effects is that the water column at the study site stratified during the summer such that temperatures at the bottom were often 2 ^{o}C and in one instance 4 ^{o}C cooler than at the water surface (Figure 21) except when wind events and strong tidal currents could break down the stratification. Thus, some species with meristems close to the bottom of the water column experience cooler temperatures than other species that form canopies at the water surface. This could explain why *V. americana*, a rosette-forming species, was abundant within the thermal effluent.

Finally, temperature effects on plant metabolism may be compounded when combined with other environmental changes such as salinity and nutrient inputs (Ryan 1991). Water quality is known to vary significantly within systems larger than Dundee Creek; however, water quality at the study site did not vary significantly (Table 3). The water quality data also shows that the habitat requirements for Kd ($<2m^{-1}$), TSS ($<15mgl^{-1}$), Chl-a ($<15\mu ml^{-1}$), and DIP ($<0.02mgl^{-1}$) (Batiuk et al., 2000) were either met, or only slightly exceeded. These favorable conditions allowed the submersed aquatic macrophytes within the study site to grow and provided consistent conditions under which the influence of the thermal effluent could be investigated. In addition to the habitat requirements, salinity can also be a driving force in the distribution of submersed aquatic macrophytes (Batiuk et al., 2000). Differences were found in salinity between the 13 sites in Dundee Creek, but the highest mean salinity was only 5.86 at site 361. Salinity was also identified as an important gradient in the ordination analysis (Figure 24). Jordon and Sutton (1984) suggested that without the salinity gradient, the benthic communities in the thermally affected areas would probably resemble the freshwater areas in the nearby Bush River. However, unlike benthic invertebrates, the salinity gradient should not be an influencing factor of the distribution of submersed aquatic macrophytes in Saltpeter and Dundee Creeks because the range of salinity did not exceed the tolerance of the tidal fresh/oligohaline submersed aquatic macrophyte species observed at the study site (Stevenson, 1988; Twilley and Barko, 1990, and Doering et al., 2001).

In conclusion, although results of the field surveys show that the thermal effluent of the studied power plant creates a thermal gradient within the study system, sample sites were ecologically similar within and outside the thermal plume. Although no statistical correlations were found between water temperature and macrophyte cover in the field, *E. canadensis* preformed best at the coolest temperature (28 °C) in the growth chamber experiment. This suggests that *E. canadensis* can not survive as well as other species in areas of elevated water temperature. Acclimation of populations to warmer temperature is conceivable considering *V. americana* from Maryland was able to survive 36 °C temperature but the Wisconsin plants could not. Thus, introduction of a new thermal effluent to a coastal ecosystem may cause short term changes in macrophyte community structure, but once plants acclimate, the communities may return to historic conditions, assuming other influencing variables remain the same and plants can recolonize via seeds or vegetative propagules from nearby populations. If such populations are absent, restoration efforts should use local sources of plant materials that are acclimated to higher water temperatures rather than plants from places such as Wisconsin that are less tolerant of warmer water. In combination with passive or active restoration of submersed aquatic macrophytes, techniques should be developed to reduce the temperature of the effluent so that the initial shock and overall effect of the thermal effluent is reduced.

Chapter 3: Broader Theoretical Context

One by-product common to fossil fuel and nuclear power plants is excess heat (Gibbons and Sharitz, 1974). Thermally-altered aquatic environments are commonplace throughout the world (Parker et al., 1973), affecting organisms directly and sub-lethally and impacting the environmental conditions (de Sylva, 1969). These local thermal effects of power plants may be heightened as global climate change is causing whole regions to become hotter, including the Chesapeake Bay. On an annual mean basis, North American annual mean surface air temperatures are predicted to increase by 2 to 4 ^{o}C, with eastern North America, including Maryland, increasing by 3.6 ^{o}C over the next century (IPCC, 2007). Global climate models also predict increases in precipitation and extreme hot days in the summer (IPCC, 2007). Influences of temperature on biological processes are not a new topic and have been studied for many years. Studies show that increases in water temperature can cause changes in community composition, life cycles of organisms and productivity (Brock, 1970; Barnett; 1972; Jordon and Sutton, 1984). The scale of the temperature fluctuations are difficult to capture in a single study as they can fluctuate hourly, daily, seasonally, yearly and even on century scales. The potential effects of global warming on terrestrial plant communities have received considerable attention, but little attention has been given to how aquatic plant communities may respond to fluctuations in water temperatures (Short and Neckles, 1999).

My research addressed how water temperature affects submersed aquatic macrophyte community composition by sampling macrophyte coverage and diversity based on the thermal regime in an area that has been thermally altered for almost 45 years. The results of the study showed that the submersed aquatic macrophyte communities within the thermal plume were statistically similar to the communities that occurred outside of the plume. However, statistical similarity of the macrophyte communities may overshadow actual biological differences between sites within the thermal plume and unaffected sites. For example, the most diverse sites were found outside the heated areas while a lack of diversity was found at one site within the themal plume. To reduce auto correlation effects, only three sites within the plume were sampled compared to 10 sites outside the plume. This design increased the chance of sampling highly diverse sites outside the plume (261, 268, 358) but also sites that could not support any plant life (359), essentially increasing the variability of the data to swamp any real biological effects of the thermal discharge. Even so, *E. canadensis,* coverage was negatively correlated with water temperature in the field (Table A8) and showed depressed growth in the 32 ^{o}C and 36 ^{o}C growth chamber. The growth chamber results coupled with the field correlations suggest that *E. canadensis* may indeed be sensitive to a thermal alteration of the environment, refuting the hypothesis that all species at the study site are tolerant of higher temperatures. Water temperatures were significantly different throughout the creek, but water temperature was not the only dominant variable in the system with salinity and dissolved inorganic phosphorus also being as, if not more, important (Figure 24). Thus, although the results of this study do not show a statistically significant thermal effect from C.P. Crane Generating Station on the SAM communities, effects of higher temperatures on specific species coupled with other environmental changes, such as increase salinity, increased nutrients, and decreased light availability to submersed leaves, can be observed now and may become more prevalent in the future as global temperature rise and the demand for electricity increases.

Currently ambient water temperatures in the Dundee-Saltpeter Creek system are below the lethal limits of the native submersed aquatic macrophytes. Even had surface water temperatures been closer to the lethal limit in 2005, stratification of the water column (Figures 21, 22) may have served as a buffer against higher temperatures for some species with meristems close to the bottom of the water column (e.g. *V. americana*). A major influence on water temperatures in this system is the amount of precipitation. During drought years the ambient water temperatures increase, causing the thermally elevated areas to reach or exceed the tolerances of several species. In years with drought conditions (2001, 2002) a large loss of vegetation was observed at the study site, but this loss of vegetation may also be attributed to increased salinity. Years with greater than average precipitation (2003, 2004) reduced ambient water temperatures, allowing the macrophytes to re-colonize the creeks (Orth et al., 2005). Global warming models predict increases in precipitation as well in many areas, but droughts are expected in horse latitudes (EPA, 1998). Although increased precipitation may keep water temperatures below the lethal limits for submersed aquatic macrophytes, it could cause increases in sediment and nutrient pollution, both of which can decrease the amount of sunlight penetrating the water column as well as increased epiphytic growth on leaves.

An additional change that is predicted to take place with global warming is sea level rise. Sea level rise has several consequences, but one of the most important changes to the tidal fresh and oligohaline regions will be saltwater intrusion. Tidal fresh/oligohaline species of submersed aquatic macrophytes can already withstand small fluctuations in salinity, as reported in my study, but large saltwater intrusions into the Upper Chesapeake Bay will start to displace vegetation. Setchell (1922) showed that submersed aquatic macrophytes can invade neighboring zones if the temperature is raised or lowered to ideal conditions and the same is expected for changes in salinity (Short and Neckles, 1999 and Doering et al, 2001). Gradual changes in salinity may allow species such as *Ruppia maritima* to invade more of the Upper Bay, but *Zostera marina* is unlikely to move northward if temperatures increase.

Increases in temperature and saltwater intrusion could lead to a loss of biodiversity in the tidal fresh/oligohaline regions of the Chesapeake Bay. Loss of biodiversity could lead to a loss of ecosystem productivity (Lehman and Tilman, 2000), function (Solan et al., 2004) and resistance to stress (Yachi and Loreau, 1999). Communities composed of several species may be able to survive the effects of multiple stressors better than communities consisting of only one species. This was evidenced in 2005 when a large die-off of *Z. marina* was observed in the Lower Chesapeake Bay believed to be have been caused by a single stressor, high water temperatures. However Stevenson and Confer (1978) found almost every species in the Mid-Upper Bay declined after Hurricane Agnes hit in 1972. Diverse tidal fresh/oligohaline submersed aquatic macrophyte communities in the Upper Chesapeake Bay have been able to persist in areas with constant higher than ambient water temperatures such as Dundee and Saltpeter Creeks. Although the submersed aquatic macrophytes in Dundee and Saltpeter Creeks have been able to persist, the cumulative effects of the additional stressors that will accompany global warming may cause the health and biodiversity of these important ecosystems to decline.

This study shows that significant differences in water temperature exist in Dundee and Saltpeter Creeks. The thermal effluent is a constant presence in the system but does not cause diversity differences between submersed aquatic macrophyte communities in different areas of the thermal regime. The once-through cooling system of the power plant also alters the salinity gradient, but the salinities do not exceed the tolerance of the tidal fresh/oligohaline submersed aquatic macrophytes found in this system. An additional important conclusion was the correlation between maximum water temperature and tidal cycle at the mouth of Saltpeter Creek, which could inspire further research. I concluded that the thermal effluent does not cause significant diversity differences between submersed aquatic macrophyte communities in Dundee and Saltpeter Creeks.

Dundee and Saltpeter Creeks provide and excellent location for further research due to their undeveloped nature. Further research should consider the presence of the thermal effluent and its correlation with the tidal cycle and the power plant's creation of a salinity gradient. Two important questions that arose during the course of this research are 1. does the disruption of the natural light:dark cycle and the diel temperature fluctuation affect photosynthesis/respiration processes and 2. have physiological modifications allowed the macrophytes to tolerate the higher temperatures at the study site (Pilon and Santamaria, 2002). Other considerations should include seasonal climate patterns and how these can influence the effect of the thermal effluent. Although conducting research in a thermal effluent may provide insight into how ecosystems may respond to global warming, there are many synergistic effects of global warming that are still poorly understood for aquatic systems.

Appendix A

Table A1. Results of the ANOVA comparing Maryland DNR's continous monitoring site at APG and the five temperature probes in Saltpeter and Dundee Creeks.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	5534	1107	1.625	< 0.001
Error	5980	114009	19.06		
Total	5985	119542			

Table A2. Repeated measures ANOVA using Month as the grouping variable.

Month	Effect	Num DF	Dem DF	F value	Pr > F
June	Site	6	63	39.03	< 0.001
July	Site	12	117	68.75	< 0.001
August	Site	12	117	33.49	< 0.001
September	Site	12	117	29.21	< 0.001
October	Site	12	117	15.22	< 0.001

Table A3. ANOVA comparing log transformed light attenuation coefficient across water quality sampling sites.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.54	0.134	1.259	0.296
Error	60	6.39	0.011		
Total	64	6.92			

Table A4. ANOVA comparing log transformed chlorophyll a concentration across macrophyte sampling sites.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.21	0.302	0.804	0.528
Error	60	22.56	0.386		
Total	64	23.77			

Table A5. ANOVA comparing log transformed dissolved inorganic phosphorus concentration across water quality sampling sites.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.33	0.333	0.829	0.512
Error	60	24.10	0.402		
Total	64	25.43			

Table A6. ANOVA comparing log transformed total suspended solids concentration across water quality sampling sites.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.20	0.300	0.892	0.475
Error	60	19.52	0.337		
Total	64	20.72			

Table A7. Repeated measures analysis of variance for salinity extracted from the GIS interpolations at the 13 macrophyte sampling sites for the 5 sampling months.

Effect	Num. DF	Den. DF	F value	Pr > F
Month	4	433	9455	<0.001
Site	12	328	154	<0.001

Table A8. Pearson product moment correlations of submersed aquatic macrophytes and water temperature. CD = *C. demersum*; EC = *E. canadensis*; MS = *M. spicatum*; NGD = *N. guadalupensis*; PPF = *P. perfoliatus*; PPU = *P. pusillus*; VA = *V. americana*

	CD	EC	MS	NGD	PPF	PPU	VA
r =	-0.05726	-0.27686	0.02292	0.18495	-0.30618	0.05307	0.03998
p =	0.4665	0.0244	0.8029	0.0921	0.0547	0.7693	0.5368
	N = 164	N = 66	N = 121	N = 84	N = 40	N = 33	N = 241

Appendix B

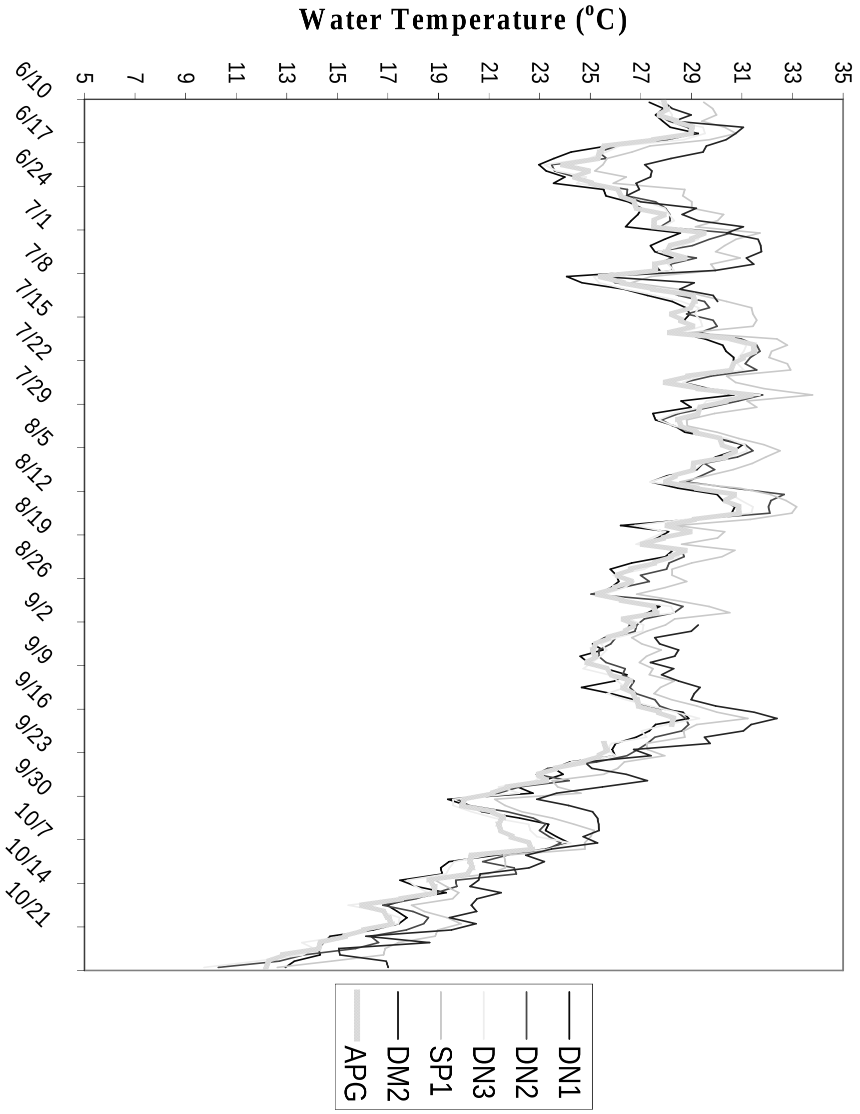

Figure B1. Water temperatures recorded at 15 minute intervals from 10 June 2005 though 27 October 2005 at the five sites within the study area and the control site at Aberdeen Proving Ground (APG).

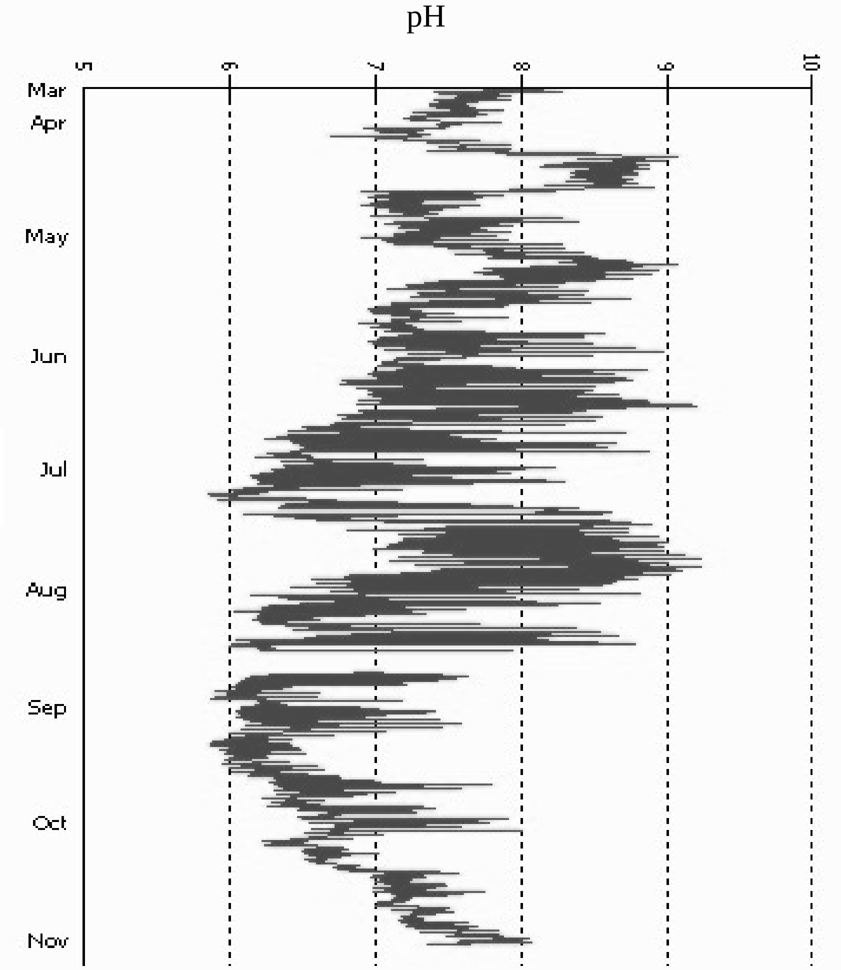

Figure B2. pH data collected by Maryland DNR at the continuous monitoring site at Aberdeen Proving Ground for the 2005 season.

Appendix C

Table C1. Raw data from macrophyte sampling events

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
June	261	30-Jun-05	1028	0.8						5					5
June	261	30-Jun-05	1028	0.8					3	3					5
June	261	30-Jun-05	1028	0.8	8				8	8					25
June	261	30-Jun-05	1028	0.8					3	3					5
June	261	30-Jun-05	1028	0.8						5					5
June	261	30-Jun-05	1028	0.8						5					5
June	261	30-Jun-05	1028	0.8					3						0
June	261	30-Jun-05	1028	0.8	3										5
June	261	30-Jun-05	1028	0.8					3	5					5
June	261	30-Jun-05	1028	0.8						3					5
June	262	30-Jun-05	1103	0.75	5	15				5					25
June	262	30-Jun-05	1103	0.75		3				3					5
June	262	30-Jun-05	1103	0.75		4				1					5
June	262	30-Jun-05	1103	0.75											0
June	262	30-Jun-05	1103	0.75	3					3					5
June	262	30-Jun-05	1103	0.75	15					5		5			25
June	262	30-Jun-05	1103	0.75	13	13									25
June	262	30-Jun-05	1103	0.75		5									5
June	262	30-Jun-05	1103	0.75	13	13									25
June	262	30-Jun-05	1103	0.75								5			5
June	263	30-Jun-05	1127	1.13					15	5					25
June	263	30-Jun-05	1127	1.13						5					5
June	263	30-Jun-05	1127	1.13	5					20					25
June	263	30-Jun-05	1127	1.13	1			15		14					30
June	263	30-Jun-05	1127	1.13	15					15					25
June	263	30-Jun-05	1127	1.13	8			8		8					25
June	263	30-Jun-05	1127	1.13	8			8		8					25
June	263	30-Jun-05	1127	1.13	3					3					5
June	263	30-Jun-05	1127	1.13				5							5
June	263	30-Jun-05	1127	1.13	13			13							25
June	265	30-Jun-05	1219	1.05	35					5					40
June	265	30-Jun-05	1219	1.05											0
June	265	30-Jun-05	1219	1.05											0
June	265	30-Jun-05	1219	1.05						5					5
June	265	30-Jun-05	1219	1.05	3					3					5
June	265	30-Jun-05	1219	1.05											0
June	265	30-Jun-05	1219	1.05	13					13					25
June	265	30-Jun-05	1219	1.05	13					13					25
June	265	30-Jun-05	1219	1.05						5					5
June	265	30-Jun-05	1219	1.05	30										30
June	266	30-Jun-05	1245	1.23				40							40
June	266	30-Jun-05	1245	1.23				15	15						30
June	266	30-Jun-05	1245	1.23				55							55
June	266	30-Jun-05	1245	1.23	15				15						30
June	266	30-Jun-05	1245	1.23	15			15	15	10					55
June	266	30-Jun-05	1245	1.23	10			20	10						40
June	266	30-Jun-05	1245	1.23	9	1		10	10						30
June	266	30-Jun-05	1245	1.23					20	10					40
June	266	30-Jun-05	1245	1.23				15	15						30
June	266	30-Jun-05	1245	1.23				10	10	10					30
June	267	30-Jun-05	1320	1											0

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
June	267	30-Jun-05	1320	1	10				20	20	5				55
June	267	30-Jun-05	1320	1							55				55
June	267	30-Jun-05	1320	1							65				65
June	267	30-Jun-05	1320	1	25				20	10					55
June	267	30-Jun-05	1320	1							100				100
June	267	30-Jun-05	1320	1	10						90				100
June	267	30-Jun-05	1320	1	5						95				100
June	267	30-Jun-05	1320	1											0
June	267	30-Jun-05	1320	1	20						80				100
June	268	30-Jun-05	1345	0.95		50				50					100
June	268	30-Jun-05	1345	0.95				50		50					100
June	268	30-Jun-05	1345	0.95	25	25				50					100
June	268	30-Jun-05	1345	0.95		50				50					100
June	268	30-Jun-05	1345	0.95		60		40							100
June	268	30-Jun-05	1345	0.95	10	50		20		20					100
June	268	30-Jun-05	1345	0.95				80		20					100
June	268	30-Jun-05	1345	0.95		33			33	33					100
June	268	30-Jun-05	1345	0.95	15	35				50					100
June	268	30-Jun-05	1345	0.95		25		25	25	25					100
July	261	27-Jul-05	1012	1.1		10				90		10			100
July	261	27-Jul-05	1012	1.1						80		5			90
July	261	27-Jul-05	1012	1.1		5				80		10			90
July	261	27-Jul-05	1012	1.1						90					100
July	261	27-Jul-05	1012	1.1		20				40		10			60
July	261	27-Jul-05	1012	1.1		10				80		10			100
July	261	27-Jul-05	1012	1.1		50				40		5			100
July	261	27-Jul-05	1012	1.1		5				80		5			90
July	261	27-Jul-05	1012	1.1		5				80		10			90
July	261	27-Jul-05	1012	1.1		10				80		10			100
July	262	27-Jul-05	1045	1.03		20		5		5					40
July	262	27-Jul-05	1045	1.03											0
July	262	27-Jul-05	1045	1.03		5			5						10
July	262	27-Jul-05	1045	1.03		3				3					5
July	262	27-Jul-05	1045	1.03		10				10		10			30
July	262	27-Jul-05	1045	1.03		3		3							5
July	262	27-Jul-05	1045	1.03		30			5	5					40
July	262	27-Jul-05	1045	1.03						5	35				40
July	262	27-Jul-05	1045	1.03		3			3						5
July	262	27-Jul-05	1045	1.03		5					45				50
July	263	27-Jul-05	1118	1.3		3			3						5
July	263	27-Jul-05	1118	1.3		5									5
July	263	27-Jul-05	1118	1.3		3			3						5
July	263	27-Jul-05	1118	1.3					5						5
July	263	27-Jul-05	1118	1.3					5						5
July	263	27-Jul-05	1118	1.3											0
July	263	27-Jul-05	1118	1.3											0
July	263	27-Jul-05	1118	1.3					5						5
July	263	27-Jul-05	1118	1.3		3		3							5
July	263	27-Jul-05	1118	1.3		9			1						10
July	265	27-Jul-05	1233	1.08	10	10									20
July	265	27-Jul-05	1233	1.08	3					3					5

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
July	265	27-Jul-05	1233	1.08				3		3					5
July	265	27-Jul-05	1233	1.08	3			3							5
July	265	27-Jul-05	1233	1.08	5										5
July	265	27-Jul-05	1233	1.08		9		1							10
July	265	27-Jul-05	1233	1.08		3		3							5
July	265	27-Jul-05	1233	1.08	1			1		3					5
July	265	27-Jul-05	1233	1.08	3			3							5
July	265	27-Jul-05	1233	1.08	5										5
July	266	27-Jul-05	1306	1.46				14	14	2					30
July	266	27-Jul-05	1306	1.46	1			14	15						30
July	266	27-Jul-05	1306	1.46				10	10						20
July	266	27-Jul-05	1306	1.46				20	20						40
July	266	27-Jul-05	1306	1.46				35		5					40
July	266	27-Jul-05	1306	1.46	3			15	3	10					30
July	266	27-Jul-05	1306	1.46				5	5						10
July	266	27-Jul-05	1306	1.46	3	3		30	40						75
July	266	27-Jul-05	1306	1.46				30	30						60
July	266	27-Jul-05	1306	1.46		3		11	11	3					50
July	267	27-Jul-05	1347	1.1		5					85				90
July	267	27-Jul-05	1347	1.1		20					60				80
July	267	27-Jul-05	1347	1.1		60			5		35				100
July	267	27-Jul-05	1347	1.1		15					15				30
July	267	27-Jul-05	1347	1.1		20			40						60
July	267	27-Jul-05	1347	1.1	8	8				T	8	8			30
July	267	27-Jul-05	1347	1.1		10		70			20				100
July	267	27-Jul-05	1347	1.1	10	20		25			40	T			95
July	267	27-Jul-05	1347	1.1	5	65					10				80
July	267	27-Jul-05	1347	1.1		35				5	60				100
July	268	27-Jul-05	1432	1.08		10		30		30	10	20			100
July	268	27-Jul-05	1432	1.08	10	10		30		40		10			100
July	268	27-Jul-05	1432	1.08		75		20		5					100
July	268	27-Jul-05	1432	1.08	10	10			5	70					100
July	268	27-Jul-05	1432	1.08	5	10		80				5			100
July	268	27-Jul-05	1432	1.08	5	20		30		40		5			100
July	268	27-Jul-05	1432	1.08		15		60		15		10			100
July	268	27-Jul-05	1432	1.08	20	50				20		10			100
July	268	27-Jul-05	1432	1.08		20		35	35		10				100
July	268	27-Jul-05	1432	1.08		5		43	42		10				100
July	356	28-Jul-05	1007	0.35											0
July	356	28-Jul-05	1007	0.35											0
July	356	28-Jul-05	1007	0.35											0
July	356	28-Jul-05	1007	0.35		T									T
July	356	28-Jul-05	1007	0.35		30									30
July	356	28-Jul-05	1007	0.35		30									30
July	356	28-Jul-05	1007	0.35											0
July	356	28-Jul-05	1007	0.35						T					T
July	356	28-Jul-05	1007	0.35											0
July	356	28-Jul-05	1007	0.35											0
July	357	28-Jul-05	1052	0.57		10									10
July	357	28-Jul-05	1052	0.57		10									10
July	357	28-Jul-05	1052	0.57		20									20

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
July	357	28-Jul-05	1052	0.57		50									50
July	357	28-Jul-05	1052	0.57		8				2					10
July	357	28-Jul-05	1052	0.57		8			1	1					10
July	357	28-Jul-05	1052	0.57											0
July	357	28-Jul-05	1052	0.57		30									30
July	357	28-Jul-05	1052	0.57		10									10
July	357	28-Jul-05	1052	0.57		5									5
July	358	28-Jul-05	1201	0.77	10	10			80						100
July	358	28-Jul-05	1201	0.77	10	10			35	35					90
July	358	28-Jul-05	1201	0.77	40			10							50
July	358	28-Jul-05	1201	0.77	10	10			70						90
July	358	28-Jul-05	1201	0.77	20	10			60	10					100
July	358	28-Jul-05	1201	0.77	20	20			60						100
July	358	28-Jul-05	1201	0.77		10		45	45						100
July	358	28-Jul-05	1201	0.77	10	10		35	35						90
July	358	28-Jul-05	1201	0.77	10	10			80						100
July	358	28-Jul-05	1201	0.77	10			25	25	40					100
July	359	28-Jul-05	1255	0.66		2									2
July	359	28-Jul-05	1255	0.66		2									2
July	359	28-Jul-05	1255	0.66		T									T
July	359	28-Jul-05	1255	0.66											0
July	359	28-Jul-05	1255	0.66											0
July	359	28-Jul-05	1255	0.66											0
July	359	28-Jul-05	1255	0.66											0
July	359	28-Jul-05	1255	0.66											0
July	359	28-Jul-05	1255	0.66											0
July	359	28-Jul-05	1255	0.66											0
July	360	28-Jul-05	1230	0.67		10									10
July	360	28-Jul-05	1230	0.67											0
July	360	28-Jul-05	1230	0.67		4		1	1		4				10
July	360	28-Jul-05	1230	0.67											0
July	360	28-Jul-05	1230	0.67		3									3
July	360	28-Jul-05	1230	0.67		20									20
July	360	28-Jul-05	1230	0.67		T									T
July	360	28-Jul-05	1230	0.67											0
July	360	28-Jul-05	1230	0.67		5									5
July	360	28-Jul-05	1230	0.67		10									10
July	361	28-Jul-05	1335	0.72	10					30					40
July	361	28-Jul-05	1335	0.72					20	20					40
July	361	28-Jul-05	1335	0.72				30							30
July	361	28-Jul-05	1335	0.72				10	10		50				80
July	361	28-Jul-05	1335	0.72				20							20
July	361	28-Jul-05	1335	0.72		60			10						70
July	361	28-Jul-05	1335	0.72	2	18		50							70
July	361	28-Jul-05	1335	0.72		10			10		5				25
July	361	28-Jul-05	1335	0.72				15	15		30				60
July	361	28-Jul-05	1335	0.72	T				40		10				50
August	261	26-Aug-05	1100	0.88		10				80		10			100
August	261	26-Aug-05	1100	0.88		10				80		10			100
August	261	26-Aug-05	1100	0.88		5				90		5			100
August	261	26-Aug-05	1100	0.88		45				45		10			100

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
August	261	26-Aug-05	1100	0.88		34				33		33			100
August	261	26-Aug-05	1100	0.88	45	5				45		5			100
August	261	26-Aug-05	1100	0.88		5				90		5			100
August	261	26-Aug-05	1100	0.88		50				50					100
August	261	26-Aug-05	1100	0.88		45				45		10			100
August	261	26-Aug-05	1100	0.88		10				60		30			100
August	262	30-Aug-05	1010	1.02		10									10
August	262	30-Aug-05	1010	1.02		5				5					10
August	262	30-Aug-05	1010	1.02		3				3					5
August	262	30-Aug-05	1010	1.02		30									30
August	262	30-Aug-05	1010	1.02		T				T					T
August	262	30-Aug-05	1010	1.02											0
August	262	30-Aug-05	1010	1.02		T									T
August	262	30-Aug-05	1010	1.02		50									50
August	262	30-Aug-05	1010	1.02		30				10					40
August	262	30-Aug-05	1010	1.02	T	5									5
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	263	30-Aug-05	1020	1.4											0
August	265	26-Aug-05	1156	0.63	T										T
August	265	26-Aug-05	1156	0.63	2	2				2					6
August	265	26-Aug-05	1156	0.63	T	70									70
August	265	26-Aug-05	1156	0.63	T										T
August	265	26-Aug-05	1156	0.63	T										T
August	265	26-Aug-05	1156	0.63		20									20
August	265	26-Aug-05	1156	0.63		T									T
August	265	26-Aug-05	1156	0.63	T	20									20
August	265	26-Aug-05	1156	0.63		40									90
August	265	26-Aug-05	1156	0.63		10									10
August	266	30-Aug-05	1034	1.35											0
August	266	30-Aug-05	1034	1.35				T	T						T
August	266	30-Aug-05	1034	1.35		T		T	T						T
August	266	30-Aug-05	1034	1.35		T									T
August	266	30-Aug-05	1034	1.35											0
August	266	30-Aug-05	1034	1.35											0
August	266	30-Aug-05	1034	1.35				T	T						T
August	266	30-Aug-05	1034	1.35				T	T						T
August	266	30-Aug-05	1034	1.35											0
August	266	30-Aug-05	1034	1.35											0
August	267	30-Aug-05	1048	1.15		90									90
August	267	30-Aug-05	1048	1.15		40					10				50
August	267	30-Aug-05	1048	1.15	T	20			10						30
August	267	30-Aug-05	1048	1.15		T			T		20				20
August	267	30-Aug-05	1048	1.15	10	T					10				20

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
August	267	30-Aug-05	1048	1.15		55					20				75
August	267	30-Aug-05	1048	1.15		50			20		10				80
August	267	30-Aug-05	1048	1.15		50					50				100
August	267	30-Aug-05	1048	1.15	10	50			40						100
August	267	30-Aug-05	1048	1.15	3						3				5
August	268	30-Aug-05	1122	1.03	10	60			5	25					100
August	268	30-Aug-05	1122	1.03	10	10				70					90
August	268	30-Aug-05	1122	1.03	30	30				30					90
August	268	30-Aug-05	1122	1.03	30	50			5	15					100
August	268	30-Aug-05	1122	1.03	5	50			10	5	5				75
August	268	30-Aug-05	1122	1.03		45			5	40					90
August	268	30-Aug-05	1122	1.03						50	50				100
August	268	30-Aug-05	1122	1.03		20			20	60					100
August	268	30-Aug-05	1122	1.03	10	20		10	40	20					100
August	268	30-Aug-05	1122	1.03					25	50	25				100
August	356	26-Aug-05	1241	0.8		90									90
August	356	26-Aug-05	1241	0.8											0
August	356	26-Aug-05	1241	0.8		T									T
August	356	26-Aug-05	1241	0.8		5									5
August	356	26-Aug-05	1241	0.8		30									30
August	356	26-Aug-05	1241	0.8		5									5
August	356	26-Aug-05	1241	0.8		10									10
August	356	26-Aug-05	1241	0.8											0
August	356	26-Aug-05	1241	0.8											0
August	356	26-Aug-05	1241	0.8		30									30
August	357	26-Aug-05	1318	0.89		10									10
August	357	26-Aug-05	1318	0.89		10									10
August	357	26-Aug-05	1318	0.89		10									10
August	357	26-Aug-05	1318	0.89		10									10
August	357	26-Aug-05	1318	0.89		80									80
August	357	26-Aug-05	1318	0.89		100									100
August	357	26-Aug-05	1318	0.89		40									40
August	357	26-Aug-05	1318	0.89		10									10
August	357	26-Aug-05	1318	0.89		5									5
August	357	26-Aug-05	1318	0.89		5									5
August	358	30-Aug-05	1152	1.02		50				50					100
August	358	30-Aug-05	1152	1.02	5	5		70		20					100
August	358	30-Aug-05	1152	1.02	5	5			65	25					100
August	358	30-Aug-05	1152	1.02	10	5		35	40	10					100
August	358	30-Aug-05	1152	1.02	15	5		20	5	55					100
August	358	30-Aug-05	1152	1.02	5			40	45	10					100
August	358	30-Aug-05	1152	1.02	10	5			75	10					100
August	358	30-Aug-05	1152	1.02	15	15			20	45		5			100
August	358	30-Aug-05	1152	1.02	10	10		20	50	10					100
August	358	30-Aug-05	1152	1.02	35	5			25	35					100
August	359	30-Aug-05	1105	0.98											0
August	359	30-Aug-05	1105	0.98											0
August	359	30-Aug-05	1105	0.98											0
August	359	30-Aug-05	1105	0.98											0
August	359	30-Aug-05	1105	0.98											0
August	359	30-Aug-05	1105	0.98											0

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
August	359	30-Aug-05	1105	0.98											0
August	359	30-Aug-05	1105	0.98											0
August	359	30-Aug-05	1105	0.98											0
August	359	30-Aug-05	1105	0.98											0
August	360	30-Aug-05	1115	1											0
August	360	30-Aug-05	1115	1											0
August	360	30-Aug-05	1115	1											0
August	360	30-Aug-05	1115	1											0
August	360	30-Aug-05	1115	1		5									5
August	360	30-Aug-05	1115	1		5									5
August	360	30-Aug-05	1115	1		5									5
August	360	30-Aug-05	1115	1		5									5
August	360	30-Aug-05	1115	1		T									T
August	360	30-Aug-05	1115	1											0
August	361	26-Aug-05	1220	1.05		80									80
August	361	26-Aug-05	1220	1.05		90									90
August	361	26-Aug-05	1220	1.05		10				70					80
August	361	26-Aug-05	1220	1.05		10			40	40					90
August	361	26-Aug-05	1220	1.05					45	45					90
August	361	26-Aug-05	1220	1.05		90				10					100
August	361	26-Aug-05	1220	1.05		60				40					100
August	361	26-Aug-05	1220	1.05		10				T					10
August	361	26-Aug-05	1220	1.05						10					10
August	361	26-Aug-05	1220	1.05					10	10					20
September	261	28-Sep-05	1015	0.67		20			10	60					90
September	261	28-Sep-05	1015	0.67		40				60					100
September	261	28-Sep-05	1015	0.67		30				40		10			80
September	261	28-Sep-05	1015	0.67		40				60					100
September	261	28-Sep-05	1015	0.67		10				50		20			80
September	261	28-Sep-05	1015	0.67		30				30					60
September	261	28-Sep-05	1015	0.67		20			5	25					50
September	261	28-Sep-05	1015	0.67		40				20					60
September	261	28-Sep-05	1015	0.67		5				55					60
September	261	28-Sep-05	1015	0.67		5				55					60
September	262	28-Sep-05	1050	0.82		5									5
September	262	28-Sep-05	1050	0.82	5	5									10
September	262	28-Sep-05	1050	0.82	1	9									0
September	262	28-Sep-05	1050	0.82											10
September	262	28-Sep-05	1050	0.82											0
September	262	28-Sep-05	1050	0.82		5									5
September	262	28-Sep-05	1050	0.82		5									5
September	262	28-Sep-05	1050	0.82		10									10
September	262	28-Sep-05	1050	0.82		75									75
September	262	28-Sep-05	1050	0.82											0
September	263	28-Sep-05	1118	1.17											0
September	263	28-Sep-05	1118	1.17											0
September	263	28-Sep-05	1118	1.17											0
September	263	28-Sep-05	1118	1.17											0
September	263	28-Sep-05	1118	1.17		T									T
September	263	28-Sep-05	1118	1.17											0
September	263	28-Sep-05	1118	1.17		T									T

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
September	263	28-Sep-05	1118	1.17		T									T
September	263	28-Sep-05	1118	1.17											0
September	263	28-Sep-05	1118	1.17											0
September	265	28-Sep-05	1150	1.08											0
September	265	28-Sep-05	1150	1.08											0
September	265	28-Sep-05	1150	1.08											0
September	265	28-Sep-05	1150	1.08											0
September	265	28-Sep-05	1150	1.08											0
September	265	28-Sep-05	1150	1.08		T									T
September	265	28-Sep-05	1150	1.08		T									T
September	265	28-Sep-05	1150	1.08	T										T
September	265	28-Sep-05	1150	1.08											0
September	265	28-Sep-05	1150	1.08		20									20
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	266	28-Sep-05	1222	1.2											0
September	267	28-Sep-05	1234	0.97	8	2									10
September	267	28-Sep-05	1234	0.97		5									5
September	267	28-Sep-05	1234	0.97	T	15			5						20
September	267	28-Sep-05	1234	0.97		5					5				10
September	267	28-Sep-05	1234	0.97		30									30
September	267	28-Sep-05	1234	0.97	10						30				30
September	267	28-Sep-05	1234	0.97		20			10		10				40
September	267	28-Sep-05	1234	0.97	T						T				T
September	267	28-Sep-05	1234	0.97		5			T						5
September	267	28-Sep-05	1234	0.97		10									10
September	268	28-Sep-05	1310	0.96	20					80					100
September	268	28-Sep-05	1310	0.96	10	10				80					100
September	268	28-Sep-05	1310	0.96	10	50		20		20					100
September	268	28-Sep-05	1310	0.96	33	33				34					100
September	268	28-Sep-05	1310	0.96	10	20				70					100
September	268	28-Sep-05	1310	0.96	30					50					80
September	268	28-Sep-05	1310	0.96	40	40				20					100
September	268	28-Sep-05	1310	0.96		80				20					100
September	268	28-Sep-05	1310	0.96	15	40				15					70
September	268	28-Sep-05	1310	0.96	20	20				20					60
September	356	28-Sep-05	1130	0.74		5									5
September	356	28-Sep-05	1130	0.74		10									10
September	356	28-Sep-05	1130	0.74		10									10
September	356	28-Sep-05	1130	0.74		20									20
September	356	28-Sep-05	1130	0.74		0									0
September	356	28-Sep-05	1130	0.74		20									20
September	356	28-Sep-05	1130	0.74		60									60
September	356	28-Sep-05	1130	0.74		0									0

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
September	356	28-Sep-05	1130	0.74		0									0
September	356	28-Sep-05	1130	0.74		5									5
September	357	28-Sep-05	1108	0.71		5									5
September	357	28-Sep-05	1108	0.71		5									5
September	357	28-Sep-05	1108	0.71		T									T
September	357	28-Sep-05	1108	0.71		10									10
September	357	28-Sep-05	1108	0.71		10									10
September	357	28-Sep-05	1108	0.71		T									T
September	357	28-Sep-05	1108	0.71		10									10
September	357	28-Sep-05	1108	0.71		90									90
September	357	28-Sep-05	1108	0.71		100									100
September	357	28-Sep-05	1108	0.71		0									0
September	358	28-Sep-05	1040	0.98	10					30					40
September	358	28-Sep-05	1040	0.98	10	60				20					90
September	358	28-Sep-05	1040	0.98	10					80					90
September	358	28-Sep-05	1040	0.98	10					70					80
September	358	28-Sep-05	1040	0.98	10	5		25		60					100
September	358	28-Sep-05	1040	0.98	10					80					90
September	358	28-Sep-05	1040	0.98	10					60					70
September	358	28-Sep-05	1040	0.98	10			40		40					90
September	358	28-Sep-05	1040	0.98	10					60					70
September	358	28-Sep-05	1040	0.98	5				15	60					80
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	359	28-Sep-05	1257	0.93											0
September	360	28-Sep-05	1300	0.88											0
September	360	28-Sep-05	1300	0.88											0
September	360	28-Sep-05	1300	0.88											0
September	360	28-Sep-05	1300	0.88											0
September	360	28-Sep-05	1300	0.88											0
September	360	28-Sep-05	1300	0.88											0
September	360	28-Sep-05	1300	0.88											0
September	360	28-Sep-05	1300	0.88		T									T
September	360	28-Sep-05	1300	0.88		T									T
September	360	28-Sep-05	1300	0.88		5									5
September	361	28-Sep-05	1208	0.78											0
September	361	28-Sep-05	1208	0.78						T					T
September	361	28-Sep-05	1208	0.78		5				5					10
September	361	28-Sep-05	1208	0.78		T									T
September	361	28-Sep-05	1208	0.78		100									100
September	361	28-Sep-05	1208	0.78						5					5
September	361	28-Sep-05	1208	0.78		80									80
September	361	28-Sep-05	1208	0.78		60									60
September	361	28-Sep-05	1208	0.78		60									60

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
September	361	28-Sep-05	1208	0.78											0
October	261	26-Oct-05	1151	0.79								5			5
October	261	26-Oct-05	1151	0.79	5										5
October	261	26-Oct-05	1151	0.79	30										30
October	261	26-Oct-05	1151	0.79		10									10
October	261	26-Oct-05	1151	0.79		25									25
October	261	26-Oct-05	1151	0.79	10										10
October	261	26-Oct-05	1151	0.79						40	20				60
October	261	26-Oct-05	1151	0.79											0
October	261	26-Oct-05	1151	0.79	5					40		15			60
October	261	26-Oct-05	1151	0.79		30									30
October	262	26-Oct-05	1230	0.75		5									5
October	262	26-Oct-05	1230	0.75		10									10
October	262	26-Oct-05	1230	0.75		10									10
October	262	26-Oct-05	1230	0.75		50									50
October	262	26-Oct-05	1230	0.75											15
October	262	26-Oct-05	1230	0.75	10	50									60
October	262	26-Oct-05	1230	0.75		40				10					50
October	262	26-Oct-05	1230	0.75		10				5					15
October	262	26-Oct-05	1230	0.75		30				30					60
October	262	26-Oct-05	1230	0.75		5									5
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	263	26-Oct-05	1355	1.25											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	265	26-Oct-05	1448	1.05											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0
October	266	26-Oct-05	1254	1.16											0

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
October	267	26-Oct-05	1306	0.9											0
October	267	26-Oct-05	1306	0.9											0
October	267	26-Oct-05	1306	0.9											0
October	267	26-Oct-05	1306	0.9											0
October	267	26-Oct-05	1306	0.9											0
October	267	26-Oct-05	1306	0.9											0
October	267	26-Oct-05	1306	0.9		T									T
October	267	26-Oct-05	1306	0.9	5										5
October	267	26-Oct-05	1306	0.9		T									T
October	267	26-Oct-05	1306	0.9	5										5
October	268	26-Oct-05	1334	0.9	T										T
October	268	26-Oct-05	1334	0.9	T										T
October	268	26-Oct-05	1334	0.9	5	T									5
October	268	26-Oct-05	1334	0.9	10										10
October	268	26-Oct-05	1334	0.9	10	T									10
October	268	26-Oct-05	1334	0.9	T										T
October	268	26-Oct-05	1334	0.9	5										5
October	268	26-Oct-05	1334	0.9									T		T
October	268	26-Oct-05	1334	0.9	5										5
October	268	26-Oct-05	1334	0.9	T										T
October	356	26-Oct-05	1400	0.6											0
October	356	26-Oct-05	1400	0.6											0
October	356	26-Oct-05	1400	0.6		T									T
October	356	26-Oct-05	1400	0.6											0
October	356	26-Oct-05	1400	0.6											0
October	356	26-Oct-05	1400	0.6		T									T
October	356	26-Oct-05	1400	0.6											0
October	356	26-Oct-05	1400	0.6											0
October	356	26-Oct-05	1400	0.6		T									T

Month	Site	Date	Time	Depth	MS	VA	HD	EC	NGD	CD	PPF	PPU	SP	PPC	TC
October	356	26-Oct-05	1400	0.6											0
October	357	26-Oct-05	1242	0.65		T									T
October	357	26-Oct-05	1242	0.65											0
October	357	26-Oct-05	1242	0.65		T									T
October	357	26-Oct-05	1242	0.65											0
October	357	26-Oct-05	1242	0.65											0
October	357	26-Oct-05	1242	0.65											0
October	357	26-Oct-05	1242	0.65											0
October	357	26-Oct-05	1242	0.65											0
October	357	26-Oct-05	1242	0.65		T									T
October	357	26-Oct-05	1242	0.65											0
October	358	26-Oct-05	1214	1.04						100					100
October	358	26-Oct-05	1214	1.04						60					60
October	358	26-Oct-05	1214	1.04		5				60					65
October	358	26-Oct-05	1214	1.04	10					60					70
October	358	26-Oct-05	1214	1.04	10					40					50
October	358	26-Oct-05	1214	1.04		10				10					20
October	358	26-Oct-05	1214	1.04	10					10					20
October	358	26-Oct-05	1214	1.04	5	35									40
October	358	26-Oct-05	1214	1.04	15					15					30
October	358	26-Oct-05	1214	1.04	3	3									5
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	359	26-Oct-05	1319	0.8											0
October	360	26-Oct-05	1326	0.85											0
October	360	26-Oct-05	1326	0.85											0
October	360	26-Oct-05	1326	0.85											0
October	360	26-Oct-05	1326	0.85											0
October	360	26-Oct-05	1326	0.85											0
October	360	26-Oct-05	1326	0.85											0
October	360	26-Oct-05	1326	0.85		T									T
October	360	26-Oct-05	1326	0.85											0
October	360	26-Oct-05	1326	0.85											0
October	360	26-Oct-05	1326	0.85											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0
October	361	26-Oct-05	1410	0.86											0

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