Amanda C. Marsh. EFFECTS ON A SALT MARSH ECOSYSTEM FOLLOWING A BROWN MARSH EVENT. (Under the direction of Dr. Robert Christian) Department of Biology, January 2007.

In summer 2004, an area of salt marsh within the Virginia Coast Reserve Long-Term Ecological Research site (USA) had little new growth of the dominant *Spartina alterniflora*. This circumstance had not been noticed during more than 15 years of study of this marsh. Similar but larger brown marsh events have been observed in Georgia, Louisiana, and other states along the Atlantic and Gulf coasts of the United States. Such events may affect marsh ecosystems in numerous ways that warrant characterization. Permanent transects were set up through healthy (H), intermediate (I), and dieback (D) conditions of *S. alterniflora* to track development of the marsh in 2004 and possible subsequent recovery or long-term effects. Subsequent evaluations of effects in 2005 and 2006 come from measurements of ground cover, bacterial and *Melampus bidentatus* densities, distribution of algal taxa and chlorophyll a concentrations in surface sediments, HPLC analysis of pigments in surface sediments, pore water sulfide concentrations, and elevation. The disturbance affects the variables dependent on scale with the greatest and most long-term effects at larger scales. Chlorophyll a concentrations were not different among the conditions and any differences in the bacterial densities may not be ecologically significant. Snail densities and sulfide concentrations did show differences. Hypotheses concerning expectations of response to dieback are rejected as stated originally but the differences among conditions could often be explained and understood. There were increases in healthy ground cover from 2005-2006, which indicated recovery is occurring more quickly in the smaller patches than the larger patches, but elevation and flooding may have changed preventing a full recovery.

EFFECTS ON A SALT MARSH ECOSYSTEM FOLLOWING A BROWN MARSH EVENT

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Brown marsh, marsh balding, salt marsh dieback, and sudden wetland dieback are all terms that are used to describe what appears to be an increasing disturbance phenomenon. Marsh dieback is characterized by the sudden loss of *Spartina alterniflora* and perhaps other plant species. From the Gulf Coast of the United States to New England some areas of salt marsh have experienced this type of loss of vegetation. The cause of dieback is not well understood. It appears that at least some of the events may be caused by a combination of factors associated with prolonged drought. Pathogens and herbivory have also been posited as causes of dieback. There have been a series of experiments in Louisiana (Mendelssohn and McKee, 1988; Webb and Mendelssohn, 1996; McKee et al., 2004; Silliman et al., 2005) and Georgia (Silliman et al., 2005; Ogburn and Alber, 2006) that addressed possible causes of the dieback. Results were interpreted that a combination of sublethal (but stressful) conditions contributed to the dieback (Mendelssohn and McKee, 1988; Webb and Mendelssohn, 1996; McKee et al., 2004). These conditions included increases in salinity, sulfide concentrations, submergence, and soil reduction. In Georgia (Ogburn and Alber, 2006) it was shown that the cause of the dieback was no longer present in the soils 2 years after the occurrence. Experiments on marshes in three states (LA, GA, and SC) showed that the snail *Littoraria irrorata* has a role in the expansion of the dieback (Silliman et al., 2005). *Fusarium* spp. (a crop fungus) has been proposed as a possible pathogen contributing to dieback (Schneider and Useman, 2005), but at this time, it has not be determined if its presence in dead shoots is causative or secondary and opportunistic.

Many of the dieback sites have experienced at least some level of recovery. An area of dieback in South Carolina studied by de Souza and Yoch (1997) showed over 90% recovery in 2 years. The dieback that occurred in Louisiana in 2000 (>100,000 ha affected) has shown a variable degree of recovery. Anywhere from 0-58% live cover had regrown at the separate sites 15 months after the disturbance (McKee et al., 2004). By 2004, 3 years after the initial dieback in Georgia, some areas had recolonized by way of rhizome extension. Transplants could be a possible strategy for restoration (Ogburn and Alber, 2006). The sites in New England are variable in regard to recovery. Some sites are showing regrowth (Hundred Acre Cove in Rhode Island) while others have shown no recolonization (Rachel Carson National Wildlife Refuge in Maine) (http://wetland.neers.org). It appears that at many sites, the factors that caused the dieback are no longer present; and given enough time, even more recovery will occur.

Brown marsh events result in vegetation loss that occurs over a larger area in a shorter time period than the normal vegetation loss in marshes. I investigated the effects of a dieback that occurred in a salt marsh within the Virginia Coast Reserve Long Term Ecological Research site (VCR-LTER), USA. At Upper Phillips Creek Marsh, the dieback was observed in the summer of 2004 and has persisted through 2006. My study focused on biotic factors such as ground cover and plant, bacterial, benthic algal, and snail abundance. The abiotic factors sulfide concentrations in pore water, pH, salinity, temperature, and elevation were measured. The study considered these in the context of three marsh conditions: healthy, intermediate, and dieback. These conditions were defined by amount of plant ground cover. Hypotheses investigated the differences among the conditions in sulfide and chlorophyll concentrations and snail and bacterial densities. My study design was arranged at varying scales. At the largest scale, the perimeter of the dieback was marked and measured a year later to determine if the dieback was expanding or contracting. Eight transects were established to measure ground cover from a 1-m to 30-m scale. Many environmental variables were measured along the transects. Also bacterial and snail densities and chlorophyll a concentrations were measured. The variables that were measured can allow us to determine the degree the disturbance affected the marsh and the recovery that occurred. The recovery can indicate that disturbance may not have resulted in a state change but was transitioning back to low marsh.

LITERATURE REVIEW

Disturbance

Sousa (1984) defines a disturbance as ‘a discrete, punctuated killing, displacement, or damaging of one or more individuals (or colonies) that directly or indirectly creates an opportunity for new individuals (or colonies) to become established.’ This differs from the older viewpoint that disturbances are uncommon or irregular events that move a community away from a near equilibrium state. The role a disturbance plays within a community is that of creating temporal and spatial heterogeneity in the structure. Disturbance also acts as an agent of natural selection in the evolution of life histories. Biological and physical processes can both be causes of disturbance. Biological disturbance can include things such as predation and grazing. Physical factors include fires, floods, droughts, and wind (Sousa, 1984).

To understand the impact of a disturbance, one should consider its characteristics. These are the size of the disturbance, the intensity and severity of the disturbance, the frequency, the predictability, and the turnover rate or rotation period. Local physical and biological factors are the controlling factors of the extent of a disturbance as opposed to large-scale climatic variation (Sousa, 1984; Shumway and Bertness, 1994; Brewer et al., 1998). The resistance and recovery to disturbance varies from site to site, and these differences must be examined to understand the effects the disturbance has on a community (Shumway and Bertness, 1994; Collins et al., 1995; Brewer et al., 1998). One way in which disturbances affect a community is by reducing the numbers of the dominant species and thereby increasing the numbers of subordinate species (Shumway and Bertness, 1994; Brewer et al., 1998). With this in mind, at intermediate levels of disturbance, species diversity is at its peak. With no disturbance, only the dominant species survive and at high levels of disturbance only the fugitive species will exist (Abugov, 1982).

According to Sousa (1984), there are three things that affect the rate at which a community can reestablish once a disturbance has occurred. The first factor is the morphological and reproductive traits of the species that are present on the site at the time of the disturbance. The next factor is the reproductive traits of the species that have occupied the site since the time of the disturbance. The last factor affecting the rate of reestablishment is the characteristics of the disturbed patch including, but not limited to, size and shape, intensity and severity, and time it was created (Sousa, 1984). These three factors relate to my research where information is available on species present both before and since the disturbance, and also on the size and intensity of the disturbed area.

Brown marsh events

Background

Vegetation loss and regeneration often occurs in salt marshes. Patches of vegetation may be lost to grazing by muskrat and geese, wrack deposition, ice damage, and submergence. The process of submergence can lead to permanent vegetation loss and usually takes years to destroy a marsh (Mitsch and Gosselink, 2000). One such instance is the Blackwater Wildlife Refuge where 49.6 ha of loss occurs annually (since 1938) mostly by interior marsh ponding caused by rising water levels. Revegetation does not appear to be a widespread mechanism for regeneration (Kearney et al., 1988). This is different from brown marsh events which occur much more rapidly. The phenomenon referred to as brown marsh, marsh balding, salt marsh dieback (Flory and Alber, 2002),

Table 1. Summary of major dieback studies. Gray boxes indicate that the causation or recovery was not addressed for that study.

Study	U.S. state/Year	Plants most affected	Causation	Recovery
Mendelssohn and McKee, 1988	LA / 1982	*Spartina alterniflora*	Soil waterlogging	
Webb et al, 1996 (field manipulation on healthy marsh)	LA / 1993	*Sagittaria lancifolia*	Submergence and saltwater intrusion	
de Souza and Yoch, 1997	SC / 1992	*S. alterniflora*		Recolonized by >90%
McKee et al, 2004	LA / 2000	*S. alterniflora* and *Spartina patens*	Combination of effects caused by drought (soil acidification)	0-58% live cover at separate sites
Silliman et al, 2005	LA, GA, SC / 2002-2003	*S. alterniflora*	1) Protracted and intense drought 2)Consumer fronts by concentrated snails	Most sites yet to fully recover
Ogburn and Alber, 2006	GA / 2001	*S. alterniflora* and *Juncus roemerianus*	Unknown but cause is no longer present	Recovery in some sites in 2004 by way of rhizome extension
NEERS Website	CT, RI, MA, MN, NH / 2002	*S. alterniflora*	Drought/fungal pathogen	Several sites in New England have recovered
My study	VA / 2004	*S. alterniflora*		Recovery along transects and within main dieback area

and sudden wetland dieback (http://wetland.neers.org) is summarized in Table 1. Due to the recent nature of the dieback phenomenon, a lot of the information available is not published in refereed sources (Online databases : brownmarsh.net (Louisiana), http://wetland.neers.org (New England), marsci.uga.edu/coastalcouncil/ (Georgia)). The earliest case found in the literature of marsh dieback is Goodman's (1959) exploration of loss of *Spartina townsendii* in Britain. Patches totaling over 600 ha. were killed or badly degraded. Goodman concluded that the diebacks were associated with soils that were soft, wet, finely particled, and had impeded drainage. It wasn't until decades later in the United States that the phenomenon gained attention. Flory and Alber (2002) have reviewed and summarized information on dieback events that occurred from the late 1980s up until 2002. An early dieback, relative to recent interest in the topic, is one that occurred in Charleston Harbor in South Carolina in 1986. This event occurred the summer following the temporary diversion of the Cooper River and a drought, a combination of events that doubled the salinity of the harbor. An event occurred again in South Carolina in 2002. Other early incidences of marsh dieback date to 1990 in the Florida panhandle. The events in the panhandle occurred through 1995 and were generally about a hectare in size. Sulfide concentrations and salinity did not exceed lethal limits. A fungus of the genus *Fusarium* was found in the dead plants but pathogenicity could not be demonstrated. No anthropogenic cause could be determined. A small event occurred in New York's Jamaica Bay in 1998. Other small events have occurred in Texas starting in 1999 and ranged in size from 2-5 acres (0.8-2ha). The largest event to date occurred in Louisiana in 2000 when over 100,000 ha died. In this case *S. alterniflora* and *Spartina patens* were affected. There has been some recovery of these sites (McKee et al., 2004). Two years later an event that occurred in Georgia caused the dieback of *S. alterniflora* and *Juncus roemerianus*. Aerial surveys conducted in 2002 revealed that over 800ha had been affected. The most common type of dieback in Georgia was creekbank dieback where 1-3m wide strips died back along small and large tidal creeks. Beginning in 2004, recovery was observed in some sites by way of rhizome extension from healthy plants (Ogburn and Alber, 2006).

According to the NEERS website (http://wetland.neers.org), 2002 was the first time New England marshes experienced these diebacks. Connecticut was the first to experience such a dieback, and the vegetation loss could not be explained by ice, wrack, or herbivory. Like the dieback in Georgia, most of the dieback areas were categorized as occurring along the creekbank, but some patches occurred in the high marsh. Since the initial discovery in Connecticut, diebacks have occurred in Rhode Island, Massachusetts, Maine and now possibly New Hampshire (http://wetland.neers.org). At Hundred Acre Cove in Barrington, RI there is a significant amount of recovery in a dieback area mostly by short form *S. alterniflora* and *Salicornia* spp. A dieback area in Rachel Carson National Wildlife Refuge in Maine has not shown as much of a recovery despite a wet summer in 2006. American burnweed, *Erechtites hieracifolia*, has been coming back and is growing alongside *S. alterniflora* at the site (Susan Adamowicz, personal communication).

Causation

There are many possibilities for dieback causation. Researchers agree that the most likely cause is a combination of factors related to periods of drought (McKee, Mendelssohn, and Materne 2004; Mendelssohn, 2005). The pannes in New England can increase in size due to increases in salinity, resulting from high temperatures and evaporation rates (Roman, James-Pirri, and Helshe, 2001).

An experiment conducted in Louisiana by Mendelssohn and McKee (1988) involved transplanting swards of grass from a streamside *S. alterniflora* marsh into the more waterlogged inland/dieback transition zone and inland/dieback *S. alterniflora* swards into the streamside site. Twelve swards were transplanted for each condition: streamside to waterlogged inland, waterlogged inland to streamside, streamside to streamside, and waterlogged inland to waterlogged inland. The last two conditions acted as controls. Samples were taken throughout a 13-month time period. The transplants experienced changes in their soil chemistry. For example, the streamside to inland swards showed a decrease in Eh (soil redox potential) to levels typical of the inland sward levels. The inland to streamside swards had the reciprocal effect with the Eh levels reaching those typical of streamside plants. Other changes in soil chemistry included those that occurred in sulfides and ammonium. The experiments concluded that differences in salinity and pH were not significant enough to cause the dieback. The study also concluded that inland soils caused accumulation of sulfides in streamside soils previously low in sulfide. The sulfides not only have a direct toxic effect but also affect the amount of ammonium taken up by the plants. The researchers could not determine which of the following factors caused the majority of the dieback: soil reduction, sulfide concentration, or root anaerobic metabolism. They believe a combination of all the conditions increased the amount of the vegetation dieback (Mendelssohn and McKee, 1988).

Webb and Mendelssohn (1996) conducted an experiment to determine how marsh vegetation reacted to increased submergence, increased salinity, and the combination of these factors. Sods were exhumed from a 'donor marsh' and moved to a different area depending on the treatment. The four treatments were increased submergence, increased salinity, increased salinity and submergence, and a control. The plants were harvested at the end of the growing season and soil cores were taken. The researchers concluded that the increase in salinity did not cause the vegetation dieback, but that plant submergence affected the dieback especially in association with increased salinity (Webb and Mendelssohn, 1996). These conclusions agreed with the study conducted by Mendelssohn and McKee in 1988.

In May 2000, a brown marsh event was observed in the Mississippi River Deltaic Plain (MRDP). By October 2000 areas of the marsh had been converted to mud flats (McKee et al., 2004). The conversion of the wetlands has been occurring in the area due to a combination of the natural processes associated with the deltaic cycle and anthropogenic activities (Turner, 1990; McKee et al., 2004). This dieback occurred rapidly unlike the gradual dieback that had been occurring historically (McKee et al., 2004). In this study, researchers wanted to assess areas of the acute dieback, find possible causes of the dieback, and determine if restoration efforts were possible. Examination of the dead shoots indicated that they had died suddenly after reaching their full height. *S. alterniflora* and *S. patens* (to a lesser extent) were the only types of vegetation that were affected by the event. Species that occurred in the same vicinity but were unaffected were *Avicennia germinans*, *Batis maritima*, *Distichlis spicata*, and *Juncus roemerianus*. Snails had grazed heavily on the dead shoots, but it was concluded that they in fact were not the cause of the dieback. The dieback coincided with the most severe drought that had occurred in 100 years. The marsh may have received less tidal flooding thereby decreasing water availability. The decrease in water availability could have increased salt concentrations in the pore water. The fact that more salt tolerant species survived supports this hypothesis. However, the salinity of the surface and pore water prior to and during the survey did not exceed the tolerance level of *S. alterniflora*. Sulfide concentrations in the dead and transition zones exceeded levels known to decrease *S. alterniflora* growth; however, it is not known if those levels were as high prior to sampling (McKee et al., 2004).

Following the dieback in Georgia, Ogburn and Alber (2006) conducted a field transplant study from May to October of 2003. The study was designed to test if healthy plants could survive in the dieback areas. The study sites consisted of four paired experimental plots. For each dieback plot used, there was a corresponding healthy area of equal elevation and soil saturation to act as the source of transplants. A reciprocal transplant experiment was designed much like the one Mendelssohn et al. had in 1988. At 3 of the sites *S. alterniflora* was transplanted and at one site *J. roemerianus* was transplanted. At the completion of the experiment, there were live stems persisting in all of the transplanted pots, but there were differences among the sites in regard to the increases in stem height and stem number during the experiment. Elemental analyses and porewater analysis on salinity and pH showed no differences between dieback and healthy areas except for a decrease in pH at the *J. roemerianus* site in July. The *J. roemerianus* site also showed significant differences in redox potential among the dieback and healthy areas. Ammonium concentrations were oftentimes significantly greater in the dieback areas than the healthy ones at one of the *S. alterniflora* sites and at the *J. roemerianus* site. The results suggest that the cause of the dieback was no longer present and that transplanting may be an option in restoration of this dieback area.

Often when data on salinity and sulfide concentrations are measured in the dieback areas, the concentrations are non-lethal. However, a combination of close to lethal concentrations of several factors such as salinity and sulfide would very likely produce lethality in plants such as *S. alterniflora* (Mendelssohn, 2005). Other drought-related factors include water deficiency in plants and high soil acidity (McKee, Mendelssohn, and Materne, 2004; Mendelssohn, 2005).

Pathogens and herbivory have also been examined as possible factors in causing marsh diebacks. The pathogens in question are several species of *Fusarium* that have been isolated from dead vegetation. *Fusarium* is a fungal genus often associated with causing disease in natural plants and in crops (Schneider and Useman, 2005). In summer of 2005, at the 14th Biennial Coastal Zone Conference it was proposed that plant pathogens (*Fusarium* sp.) might play a role in the brown marsh phenomena. Schneider and Useman (2005) propose the plants stressed by drought and unusually high temperatures were susceptible to a relatively weak pathogen. *Fusarium spp.* has been found on *S. alterniflora* on the Cape Cod National Seashore (http://wetland.neers.org). According to Brewer et al. (1998), a pre-existing stress can increase the effects of a disturbance within a community. However, all of the isolations have been done post brown marsh event, so the fungus may be opportunistic and not a causative agent (Flory and Alber, 2002).

Herbivory has been examined for the possible role snails have in dieback causation (Silliman and Zieman, 2001; Silliman et al., 2005). Silliman et al. (2005) performed a study on diebacks in the southeastern and Gulf regions of the United States. The researchers found that snails contribute to the expansion of marsh dieback in the Southern U.S. The snails were concentrated in areas of the marsh adjacent to the dieback more than in healthy areas of the marsh inferring their movement outward from the mudflat caused by their grazing. However, not all dieback sites have evidence of high snail densities or snail predation on living plant tissue (Flory and Alber, 2002).

Vegetation dieback in Louisiana occurs mostly in the interior of the marshes and results in vegetated marsh being converted to shallow ponds that eventually convert to larger lakes and wetland loss (Webb and Mendelssohn, 1996; Mendelssohn and McKee, 1988). Reasons for this vegetation dieback have been cited as marsh subsidence, flooding (McKee and Mendelssohn, 1989), and saltwater intrusion, although this last factor has not been studied often in oligohaline marshes. While these individual factors may affect the dieback of vegetation in salt marshes, their combined effects may have even greater consequences (Webb and Mendelssohn, 1996). Increases in soil waterlogging can create reduced soils that have high, potentially toxic, sulfide concentrations (Gambrell and Patrick, 1978; Webb and Mendelssohn, 1996). These increased sulfide levels have been shown to reduce the growth of some freshwater marsh plant species (Koch and Mendelssohn, 1989). Waterlogging can also create root oxygen deficiencies. (Mendelssohn, McKee, and Patrick, 1981). Singly or interactively these can reduce nitrogen uptake by plants and assimilation (Morris and Dacey, 1984; Howes, Dacey, and Goehringer, 1986; Mendelssohn and McKee, 1988).

Once the event is noticed it becomes much more difficult to determine the reasons for its occurence. A combination of factors and not any one alone seems to be the most likely cause of the ‘brown marsh’ events that have been occurring along the East Coast and Gulf Coast.

Ecosystem state change

Christian et al. (2000) define ecosystems as “self-sustaining units of landscapes that perpetuate structure and functioning over time through the acquisition of energy and matter within a range of environmental conditions and disturbance regimes.” The species present in salt marshes are often used to define them as opposed to geomorphic setting (Christian et al., 2000).

An ecosystem state change occurs when one ecosystem class changes to another. These changes often occur following a disturbance or an alteration in external controlling forces (Hayden et al., 1991; Brinson et al., 1995). According to Hayden et al. (1991), these perturbations can cause changes in both successional sequences and system states. Olff et al. (1997) state that changes in marsh ecosystems occur from a combination of factors including changes in geomorphology, flooding regime, water sediment loads and salinity, soil characteristics, vegetation type and herbivory. In coastal wetlands, rising sea level has long been recognized as being a primary force of these system-state changes. As sea level rises, the high marsh is replaced by mineral low marsh. However, it is hypothesized that the states are self-resistant to change (Brinson et al., 1995). At the Upper Phillips Creek Marsh of the Virginia Coast Reserve, Blum and Christian (2004) found that the rates of sedimentation and accumulation of organic matter allow the marsh to sustain itself despite sea-level rise. Stresses and disturbances must occur to facilitate transitions from one state to another. For example an important factor in system-state change within the marshes is the occurrence of major storms, including hurricanes. Hurricanes are independent of the rate of sea-level rise, but when the two are combined they can increase the rate at which coastal changes occur (Brinson et al., 1995).

According to Brinson et al. (1995), there are four patterns of terrestrial-estuarine interactions. These interactions result in state changes. The patterns are: migrating overland and prograding towards the estuary, migrating at the overland and eroding away from the estuary, stalling at the terrestrial margin and prograding toward the estuary, and stalling at the terrestrial margin and eroding away from the estuary. All of the types occur at the Virginia Coast Reserve (Brinson et al., 1995) although eroding marshes dominate due to low sediment supplies (Oertel et al. 1992; Brinson et al., 1995).

The Louisiana coast has one of the highest rates of deterioration in the world (Mendelssohn and McKee, 1988). According to a press release issued in May 2003 by the USGS, 90% of wetland loss within the United States occurs in the state of Louisiana. If no restoration occurs, by the year 2050 one-third of Louisiana's coast will have disappeared into the Gulf of Mexico. USGS data indicate that from between 1990 and 2000 wetland loss was occurring at a rate of 24 square miles per year. This is a decrease from previous years. From 1956 to 1978 wetland loss in LA averaged 39 square miles per year (USGS press release, 2003). It is caused by subsidence of the deltaic plain, decreased sediment influx, increased oceanic influences, and vegetation dieback. Rising sea levels submerge coastal wetlands and accelerate wetland loss (McKee et al., 2004). The process of submergence can have the same results as a brown marsh event on the vegetation in a marsh and eventually on the conversion of low marsh to mud flat.

However, by definition, the ‘brown marsh’ phenomenon is the loss of vegetation over a relatively short amount of time, which excludes slow processes such as submergence (http://wetland.neers.org). This is interesting in the case of the brown marsh disturbance at Upper Phillips Creek, which has created some patches of mud flats in the low marsh. Will these patches be converted back to low marsh since the marsh is keeping up with sea level rise?

STUDY DESIGN AND HYPOTHESES

Sampling started in the summer of 2004 and continued through summer 2006. Marsh conditions were categorized according to visual observations of the plant growth along transects so that by their definition “healthy” areas have higher plant densities than “intermediate” or “dieback” areas. Most samplings included data across conditions for an entire year (2005-2006), and therefore information was also gathered on seasonality within conditions. The design of this study was as follows:

I. Measurements and study design were arranged at various scales. Measurements were taken at a landscape level where the whole dieback area was considered. Flagging was set up around the perimeter of the main area of dieback to monitor any changes over the course of the year. Eight transects were used to measure ground cover at the 1-m to 30-m scale. Sediment cores that represented the top 1 to 2 centimeters of marsh surface were sampled to measure chlorophyll and bacterial biomass. By making measurements at different scales, I obtained a broad understanding of the effects the dieback has had on the marsh, from the microbial ecology through the physical landscape.

II. I set up my sampling design according to three conditions in the marsh: healthy, intermediate, and dieback. I considered what the intermediate condition was doing over meters to tens of meters. Is the intermediate condition a transient condition moving from healthy to dead or dead to healthy? Or is the intermediate condition an end point that is partially dead but not necessarily moving one way or the other? Since Fall 2005 I monitored 8 transects that are categorized according to the conditions. The percentage of ground covered by plants, mud, algal, or purple sulfur bacterial mats was recorded. The progression or recession of plants during my study period indicated whether the intermediate area was expanding or decreasing in size.

III. After the variables to sample were selected, there were expectations of how some of these are affected by the dieback:

Hypothesis 1: A higher biomass of algal mats, as measured by chlorophyll a, will be present in the dieback areas, the intermediate condition will act as a transition from high to low biomass, and the healthy areas will have the lowest biomass. According to Keusenkothen and Christian (2004), light levels were higher in deer trails at Upper Phillips Creek than in areas off the trails. Like the deer trails at Upper Phillips Creek, the dieback areas of the marsh have patches of exposed surface where light levels would be higher than the healthy areas. Taylor (1995) found that nutrient levels were higher in areas that were covered in wrack than in vegetated areas. Fewer plants resulted in decreased uptake of nutrients. A combination of higher light and nutrient levels in the exposed areas creates conditions ideal for increased algal growth.

Hypothesis 2: There will be a higher density and biomass of bacteria in the dieback area, the intermediate condition will act as a transition from high to low density/biomass, and the healthy areas will have the lowest density and biomass of bacteria. This is the expectation because of the decomposition of the plant matter at these sites as well as the increased mats of purple sulfur bacteria that visibly cover the surface of the marsh during the winter months. The photosynthetic purple sulfur bacteria take advantage of the increased light in the dieback areas, and the heterotrophic bacteria are fostered by the algae mat’s primary production.

Hypothesis 3: The intermediate areas will have the highest density/biomass of the snail *Melampus bidentatus* compared to the other conditions. The dieback areas will have the lowest density/biomass of *M. bidentatus*. The healthy areas near the dieback will have same density/biomass as healthy areas in other areas of the marsh. This trend was observed by Silliman et al. (2005) in several salt marsh diebacks in the southern United States with the snails *Littoraria irrorata*.

Hypothesis 4: Sulfide levels will be higher in dieback areas than in the healthy areas. This trend is expected due to decomposition of plants within the dieback areas resulting in elevated levels of sulfide.

The methods I used answered 'how?' questions about the changes in the marsh structure since the beginning of the brown marsh event. 'Why?' questions were addressed on a lesser level with tests that measured sulfide concentrations and salinity. Once the data were analyzed I was able to answer questions pertaining to what is happening to the marsh at various scales and conditions. In a broader sense studying one dieback contributes information to what appears to be an increasingly common phenomenon.

MATERIALS AND METHODS

Upper Phillips Creek marsh (32˚ 27'N, 75˚ 50'W) (Tirrell, 1995) is dominated by *S. alterniflora* in the mineral low marsh and *S. patens*, *D. spicata*, and *J. roemerianus* in the organic high marsh. *J. roemerianus* stands within the marsh are distinct and often monospecific (Tolley and Christian 1999). The low marsh is flooded twice daily by Upper Phillips Creek (Tolley and Christian, 1999). It is part of the Virginia Coast Reserve/Long-Term Ecological Research program (VCR-LTER). In the summer of 2004 researchers observed that an area of the low marsh's vegetation had not grown back. Four 30-meter transects (T1-T4) were established within the marsh to include three conditions of marsh: healthy, intermediate, and dieback (Figure 1). In 2005, four more transects (T5-T8) were established under the same criterion that each transect include all conditions (Figure 1). The positions along the transects were then visually categorized as healthy, intermediate, or dieback. Areas were categorized as 'dieback' if the amount of live/dead plants was 25% or less. It was considered 'intermediate' from 26% to 85% live/dead plant cover, and a plot was considered 'healthy' at any plant ground cover over 85%. These transects were used throughout the experiment to measure ground cover and also for the sampling of cores.

Sulfide, Salinities, Temperature, pH:

Sulfide concentrations: A total of 6 equilibrators, modified from Huang and Morris (2003), were placed haphazardly in healthy and dieback areas of the marsh. Three equilibrators were placed in each of the two conditions. Each equilibrator held 4 scintillation vials. The equilibrator was vertically placed to a known depth (scintillation vial depths: ~2.75, ~6.5, ~10, and ~13.5cm) within the sediment and left for 4-6 weeks at which time the water in the vials will have reached equilibrium with the surrounding pore water. The equilibrated pore water was collected and analyzed for hydrogen sulfide concentrations. At the time of collection, 5ml of 10mM zinc acetate was drawn into a 10 ml Luer-Lok™ syringe equipped with an 18 G1.5 needle and a 3-way air-tight valve. Five ml of pore water were then drawn from the scintillation vials into the syringe. The zinc acetate precipitated the sulfide immediately. The samples were kept at room temperature in the dark and processed as soon as possible. I modified a method developed by Cline (1969) to estimate sulfide concentrations in pore water between the different sites (Appendix C).

Salinity/Temperature/pH: A portable refractometer was used to measure the salinities of the pore water collected from the equilibrators. The salinity and pH (Oakton pHTestr 3™) of the surface water and temperature (ºC) at 1-cm depth were also measured within 1-m^2 quadrats within each of the 3 conditions along all eight transects. The same 10-cm x 10-cm square of the quadrat was used for these measurements at all sites.

Elevations

Elevations of the 3 conditions along the transects: In August 2006, elevations were measured on the 8 transects. Three replicates were taken per condition per transect totaling 72 measurements for conditions. Also measured were the 0-meter and 30-m endpoints for each transect totaling 16 additional measurements. The 'Hayden' benchmark (1.0306m known elevation) was used in the calculations.

Size of Dieback

Size and change in the perimeter of the main dieback area. Approximately 30 flags were placed around the perimeter of the large brown marsh area before the vegetation died back in September 2005. The following summer, the distance from edge of present growth to the flags was measured to determine if the plants had receded further or filled in.

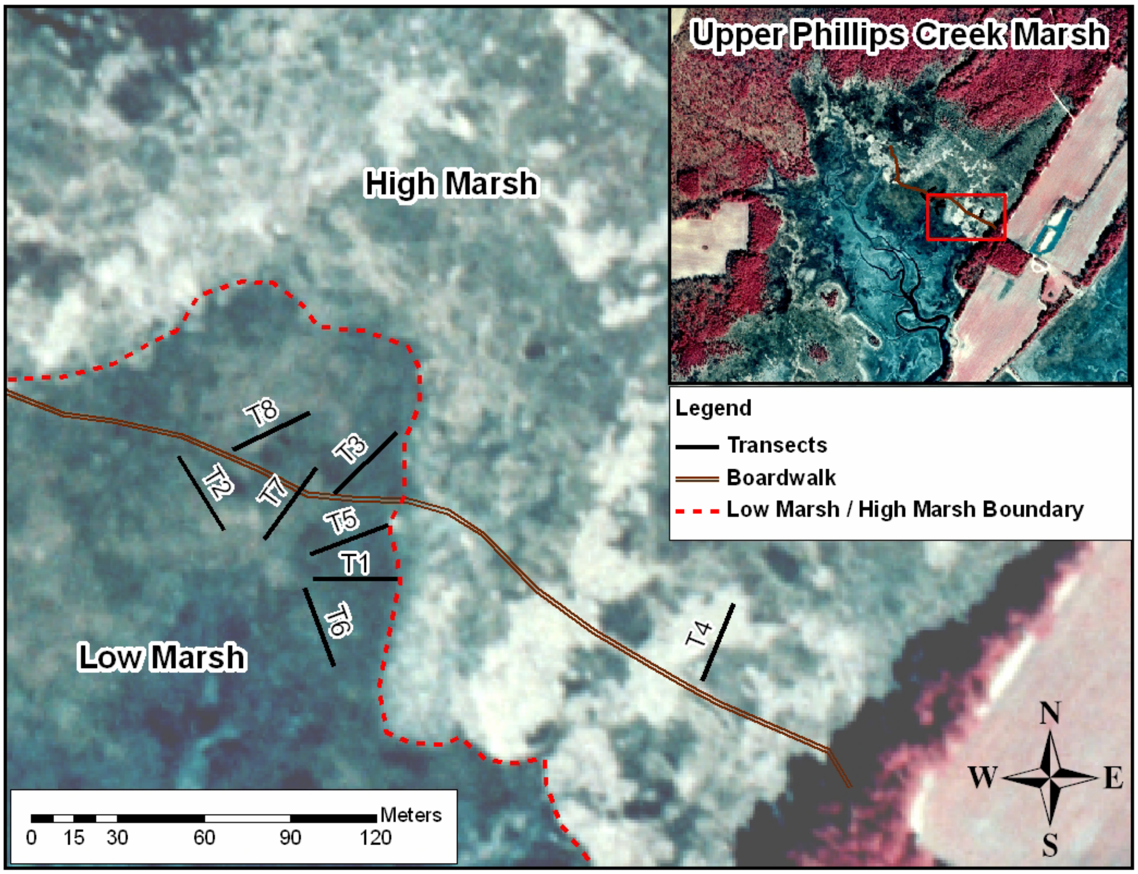

Figure 1. Map of transects. USGS DOQQ NE Nassawadox, VA. March 1994. (http://seamless.usgs.gov/) : Generated by David Kunz.

Plants

Condition of vegetation/Ground cover: Initially, in 2004, each meter along the four original transects (T1-T4) was categorized by visual observation as dieback, intermediate, or healthy condition. The following 2 summers, the transects (T1-T8) were again categorized to determine any changes in plant cover. Furthermore, I chose specific 1-m^2 patches within these transects to monitor throughout the year (every 4-6 weeks). Once the transects were categorized according to vegetation condition, a random numbers table was used to decide which locations would be monitored as permanent 1-m^2 plots. Two plots were monitored per each of three conditions for a total of 6 per transect and a total of 48 samples for all transects. A 1-m^2 quadrat was divided into 10-cm X 10-cm squares. For each of the following categories I counted the number of squares per 1-m^2: live and dead plants, mud, filamentous algal mats, and purple sulfur bacterial mats. These numbers were converted to percentage values for the quadrat as a whole.

End-of-year biomass: In the fall of 2004, 2005, and 2006 end-of-year biomass clippings were taken from these transects. The clippings were taken near the transects in areas that corresponded to the 3 conditions. Samples were taken by haphazardly tossing a 0.0625-m^2 quadrat into an area designated as one of the conditions. Two samples were taken per condition per transect for a total of 48 clippings per year and were frozen until analysis. Analysis consisted of sorting the plants by species and by live or dead status. A plant was considered living if there were any green leaves present. The culms were counted and placed into paper bags. There was a separate category for detritus recovered from the ground. These bags were placed into a drying oven at ~80°C for 3-4 days. Once dry, they were weighed and a fraction of each sample was archived.

Snails

Snail density: Snails (*Melampus bidentatus*) were sampled by counting the number that was present per 0.0625-m^2 quadrat. A quadrat was haphazardly tossed into each condition near a transect. Two counts were taken per condition per transect for a total of 48 observations per sampling. During 2006, another condition was added called 'healthy_away' that measured the number of snails in healthy areas that did not surround the dieback.

Bacteria

Bacterial counts: The top 2 cm^3 of sediment was collected in a modified BD™ 10mL syringe corer and placed in a scintillation vial with 18ml of 2% formalin. Samples were taken by haphazardly tossing the syringe into areas designated as the 3 conditions. One sample was taken per condition per transect for a total of 24 cores each sampling. The samples were kept refrigerated until processed. Following the method of Schallenberg et al. (1989) (Appendix A), I stained the samples with 4'-6-Diamidino-2-phenylindole (DAPI) to estimate the density of bacteria per cm^3 of sediment.

Algae

Amount of chlorophyll a and bacteriochlorophyll in sediment cores: A 3.7-cm diameter beveled plumbing pipe was used as a corer to collect the top 1 cm of sediment along the transects. The samples were taken by haphazardly tossing the corer into an area identified as one of the three conditions. One sample was taken per condition per transect for a total of 24 cores per sampling. Samples were kept frozen and in the dark until processed. A method modified from the *Standard Methods for the Examination of Waste and Wastewater, 20th Edition* (Clesceri et al., 1998) (Appendix B) was used to determine concentrations of chlorophyll a in sediment cores collected from the eight transects across the three conditions. High Performance Liquid Chromatography (HPLC) was performed on samples from February 2006 when purple sulfur bacterial mats were highly distinct and visible. The samples were analyzed in June 2006 by Karen Rossignol at UNC's Institute of Marine Sciences in Morehead City. She used methods modified from Van

Heukelem et al. (1992). The detector was a Shimadzu SPD-M10AV photodiode array and data acquisition and analysis was performed with Shimadzu software. The samples were extracted in an acetone:methanol (50:50) mixture. Concentrations of bacteriochlorophyll were evaluated.

Identification of algae using microscopic techniques: Algal mats were collected in early April 2006 to identify major green algae genera. *Seaweeds of the Southeastern United States* and *Freshwater Algae of the United States* (Schneider and Searles, 1991) along with a light microscope and the assistance of a phycologist were used to identify algae.

Statistics

The statistical tests were run using SPSS 13.0. For the dependent variables bacteria, chlorophyll a, snail (*Melampus bidentatus*), sulfide concentrations, salinity (porewater and surface), temperature and pH data a univariate general linear model using transect, condition, and month as the fixed factors was used for analysis. A custom model was used to test for interactions between condition and month. For the end-of-year biomass and mass/stem data, transect, condition, and year were the fixed factors and the custom model was used to test for interactions between condition and year. Tests were considered statistically significant if $p \leq 0.05$. Descriptive statistics (mean and standard deviation) and a Tukey's post-hoc test were performed for all variables. Box and whisker plots were generated to display visually differences among conditions, months, and/or the condition/month interaction.

RESULTS

The abiotic variables are presented prior to the biotic variables to establish the conditions for the living organisms. Mean values for the months and conditions can be found in Appendix L.

Sulfide

Statistically significant differences among condition ($p<0.001$) and month ($p<0.001$) existed for the sulfide concentrations. Also there was a significant month*condition ($p=0.002$) interaction found for the hydrogen sulfide (H_2S) concentrations. For all the months, the average sulfide concentration was 5.4±2.7mM (mean and standard deviation) in the dieback condition and 4.3±3.0mM for the healthy condition. Although the conditions were significantly different when averaged over all sampling times, there were also differences among the months. A Tukey's post-hoc test revealed that the only month with significant differences between healthy and dieback was April. For this month, the dieback condition averaged 5.4± 2.0mM, and the healthy condition averaged 0.1± 0.2mM (Figure 2). However, for summer there was a strong trend for sulfide concentrations to be higher in the dieback condition than in the healthy condition.

Salinity

Pore water salinity

Salinity was also measured from the pore water collected from the equilibrators. There was a significant difference among conditions ($p<0.001$) and months ($p<0.001$). However, there was no significant condition*month interaction ($p=0.435$). For all months, average pore water salinity in the dieback areas (36±13ppt) was higher than in the healthy areas (31±10ppt) across all months (Figure 3a). By months, the average

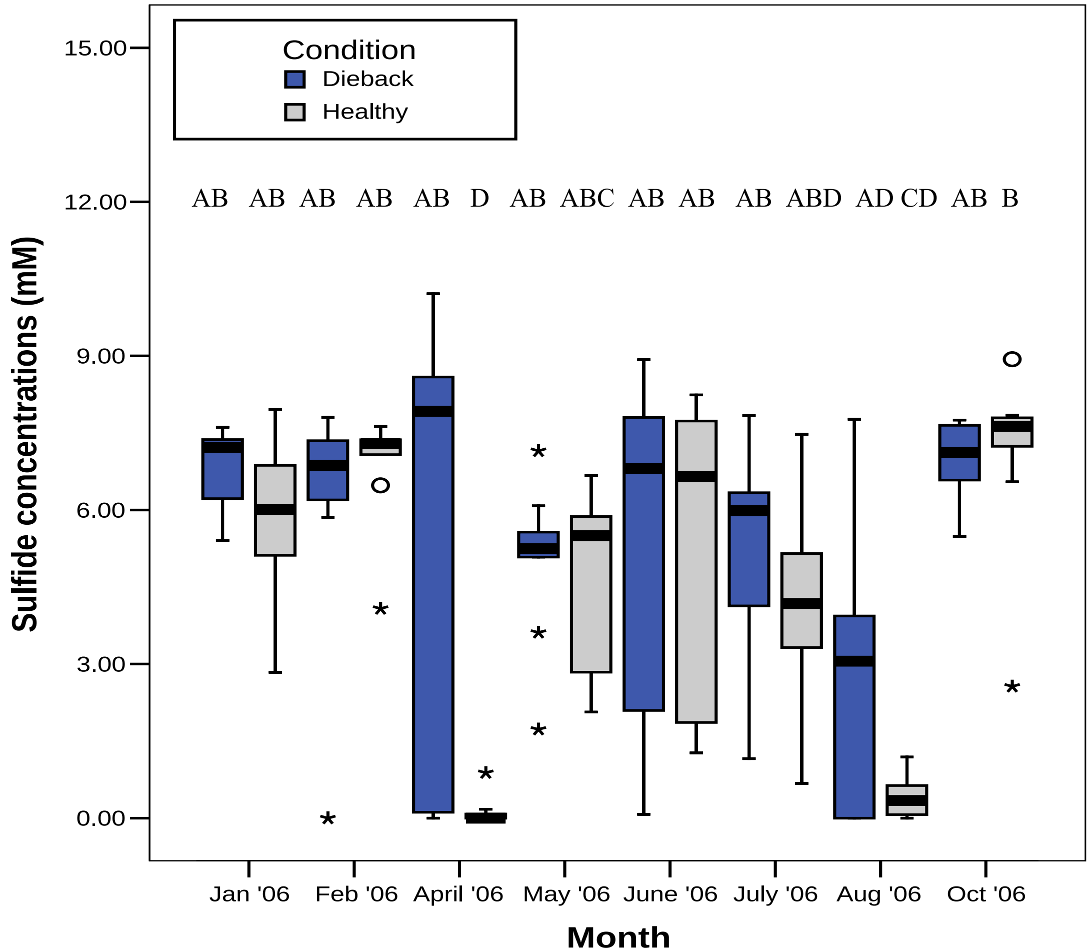

Figure 2. Sulfide concentrations (mM) by condition and month. Letters indicate significant differences. The results are presented in box and whisker plots. The dark line within the box is the median, the upper end of the box is the upper quartile (75^{th} percentile). The lower end of the box is the lower quartile (25^{th} percentile). The whiskers indicate the lowest and highest observed values not considered outliers. Outliers are indicated by open circles (mild) and asterisks (extreme). All box and whisker plots in this section are interpreted the same.

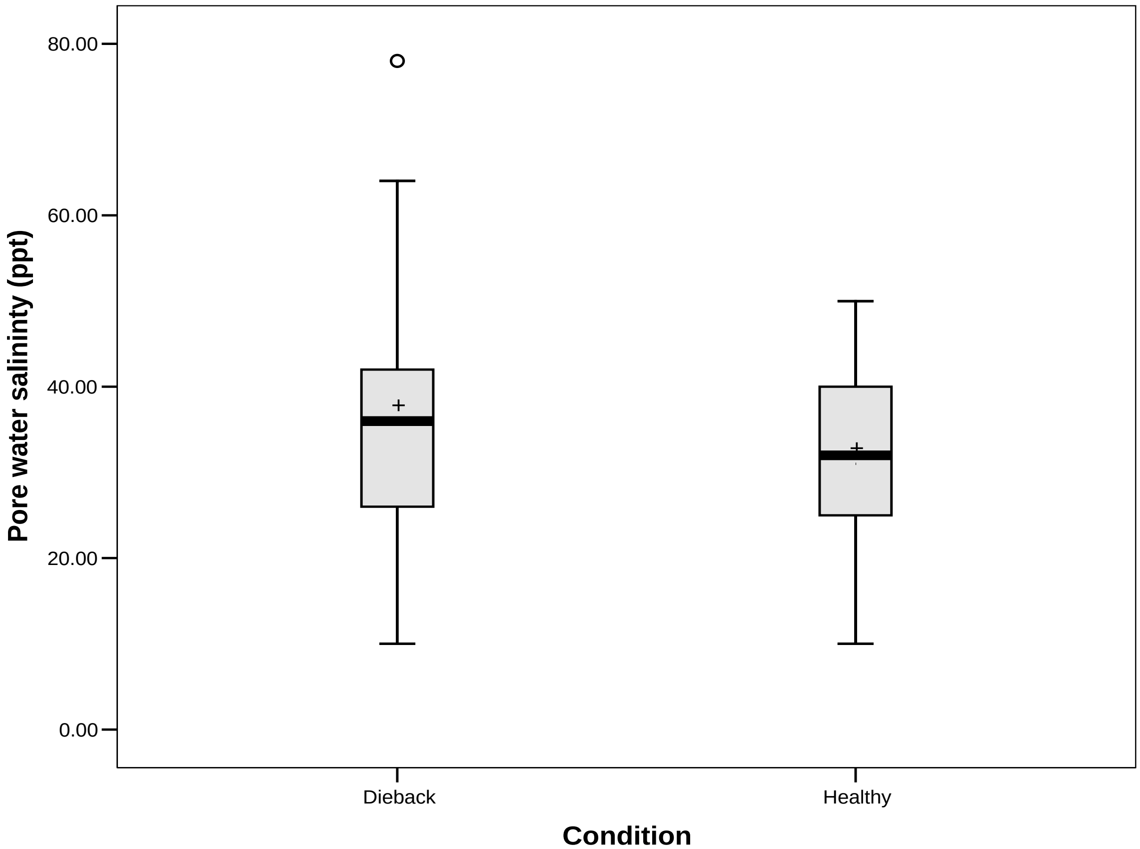

Figure 3a. Pore water salinities (ppt) by condition. '+' = mean for each condition

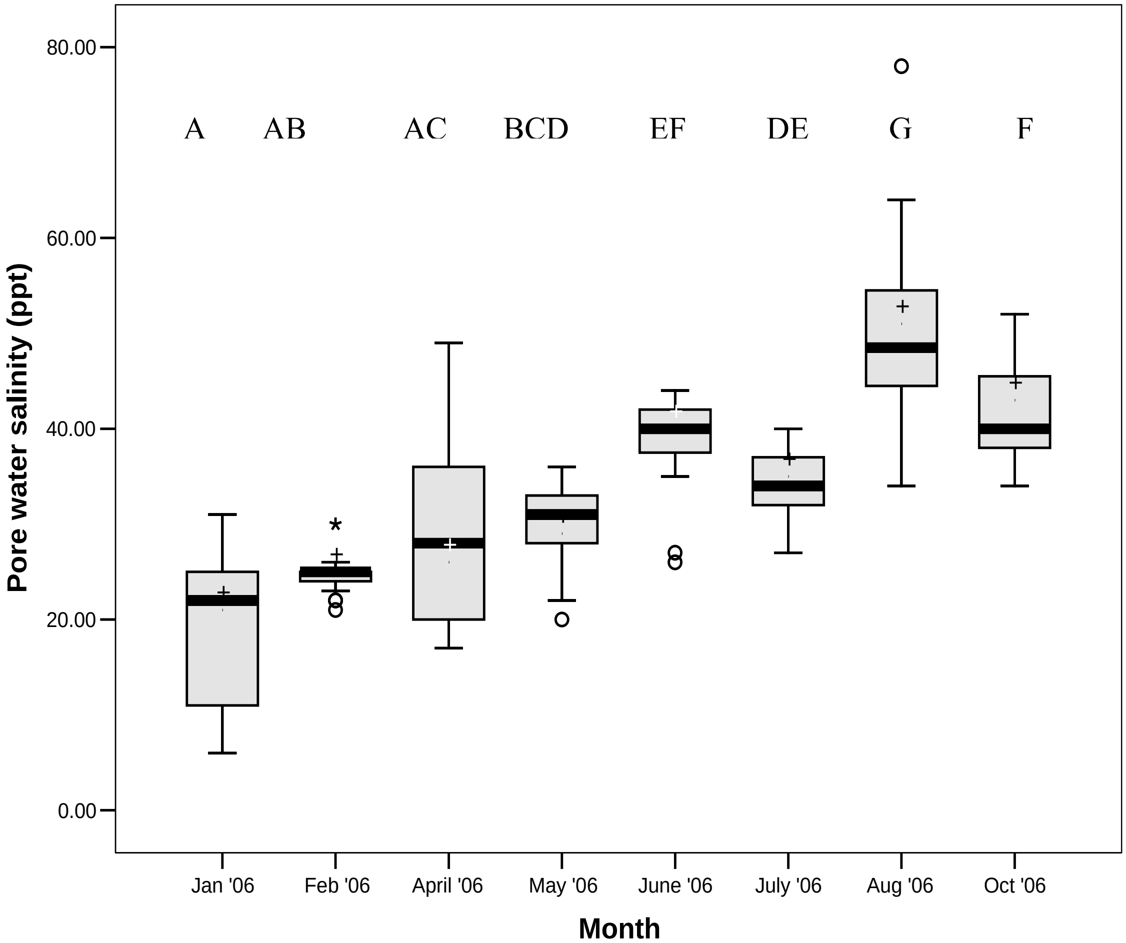

Figure 3b. Pore water salinities by month (ppt). '+' = mean for each month. Letters indicate significant differences.

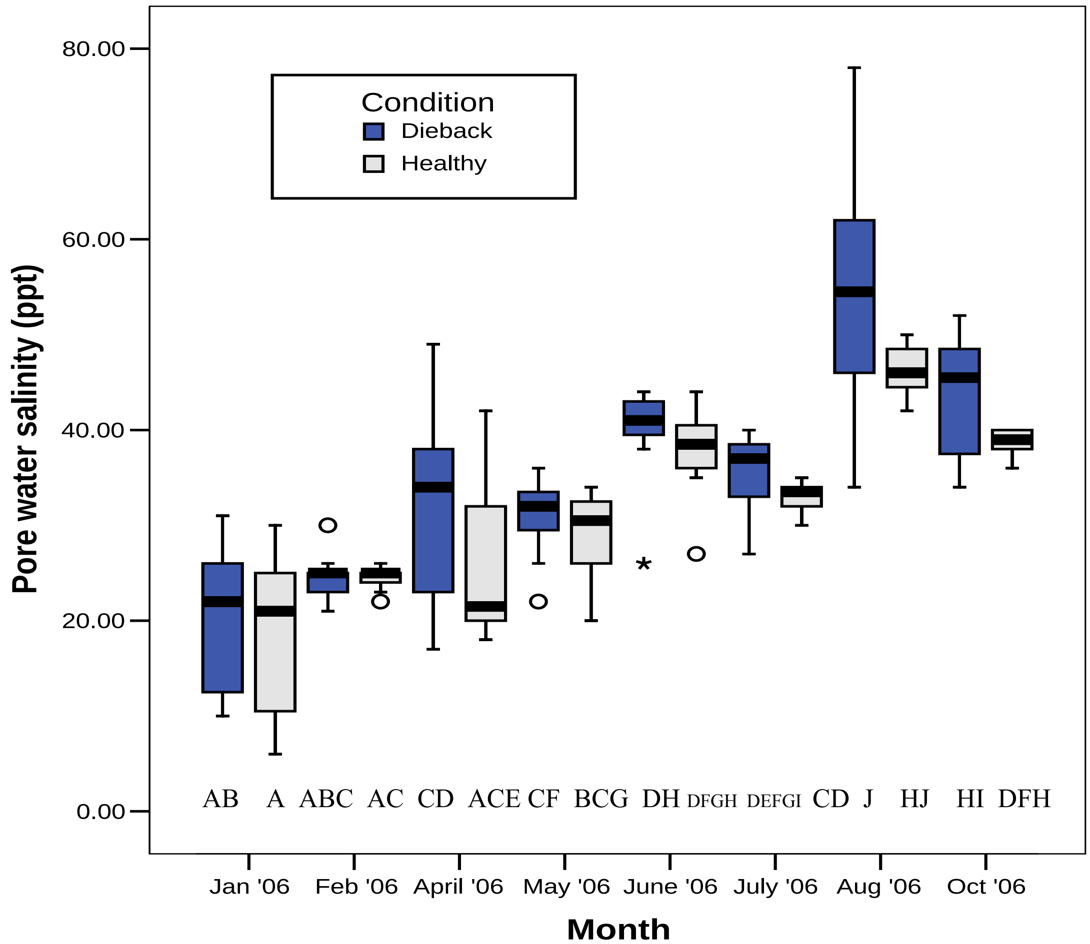

Figure 3c. Pore water salinities (ppt) by month and condition. Letters indicate significant differences.

salinities were lowest in the winter and increased in the summer (Figure 3b). Mean salinities in the dieback condition reached 55ppt in the month of August 2006. Figure 3c shows that despite the variation in salinities by months, dieback had higher salinities than the healthy condition.

Surface water salinity

The surface water salinities measured along the transects at the permanent plots showed no differences among the 3 conditions ($p=0.331$) but significant differences were observed among months ($p<0.001$). There was no significant condition*month interaction ($p=0.359$). For all the months combined, the averages for surface salinity were 27±11ppt for both the dieback and intermediate condition and 26±11ppt for the healthy condition (Figure 4a). By months, salinities were lower during the first few months of the year than in the spring and summer (Figure 4b).

Soil surface temperature

For soil surface temperatures, there were significant differences among the conditions ($p<0.001$) and among months ($p<0.001$). There was also a significant interaction among condition*month ($p=0.022$). Over all months, the average surface temperature was 18.6±11.0ºC in the dieback condition, 17.6±11.0ºC in the intermediate condition, and 18.3±11.0ºC in the healthy condition. In the months of July and August 2006 temperatures were high. The highest mean temperatures occurred across condition at over 30ºC during these two months. A Tukey's post hoc test revealed that the only month that there were significant differences among the conditions was May 2006 (Figure 5). In that month, the dieback condition had an average temperature of 25.6±1.5ºC. The intermediate had an average temperature of 22.9±1.8ºC, and the healthy

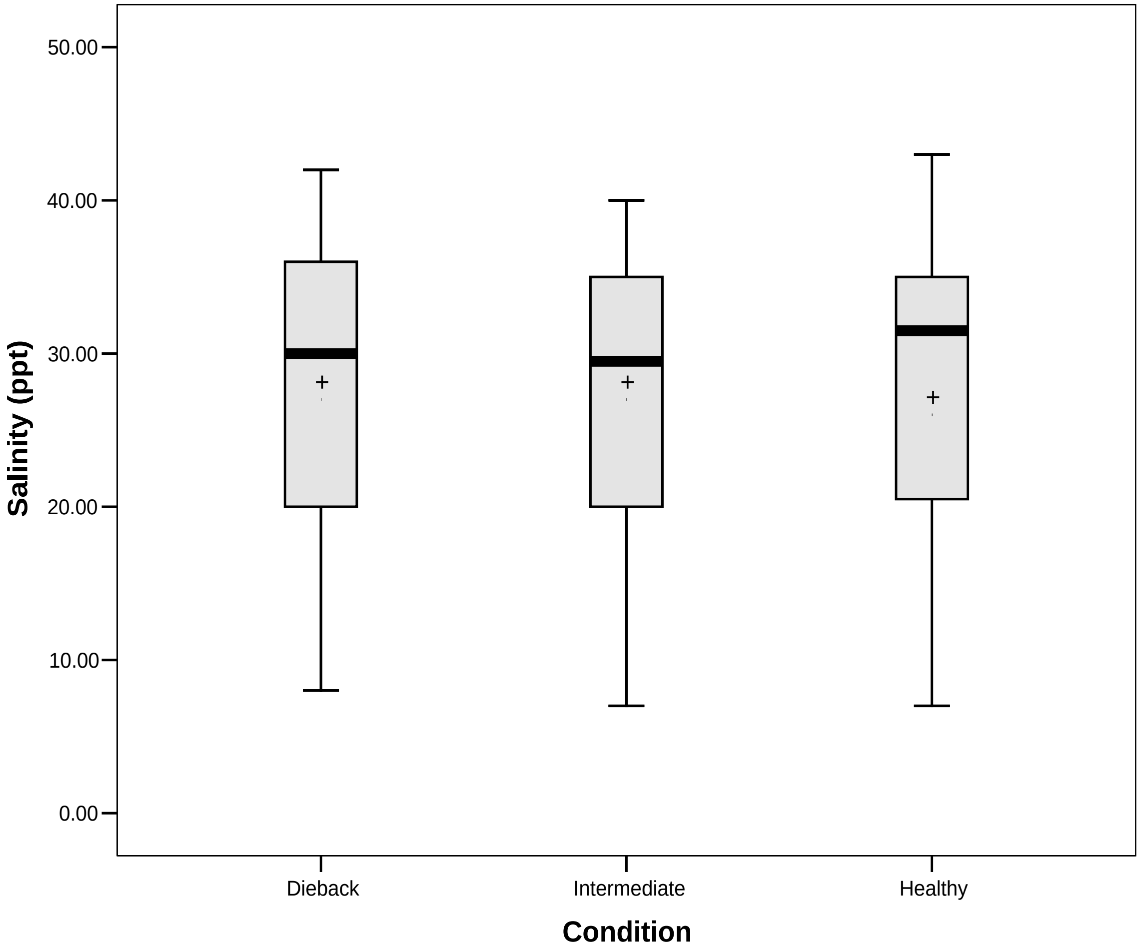

Figure 4a. Surface salinity (ppt) by condition. '+' = mean for each condition

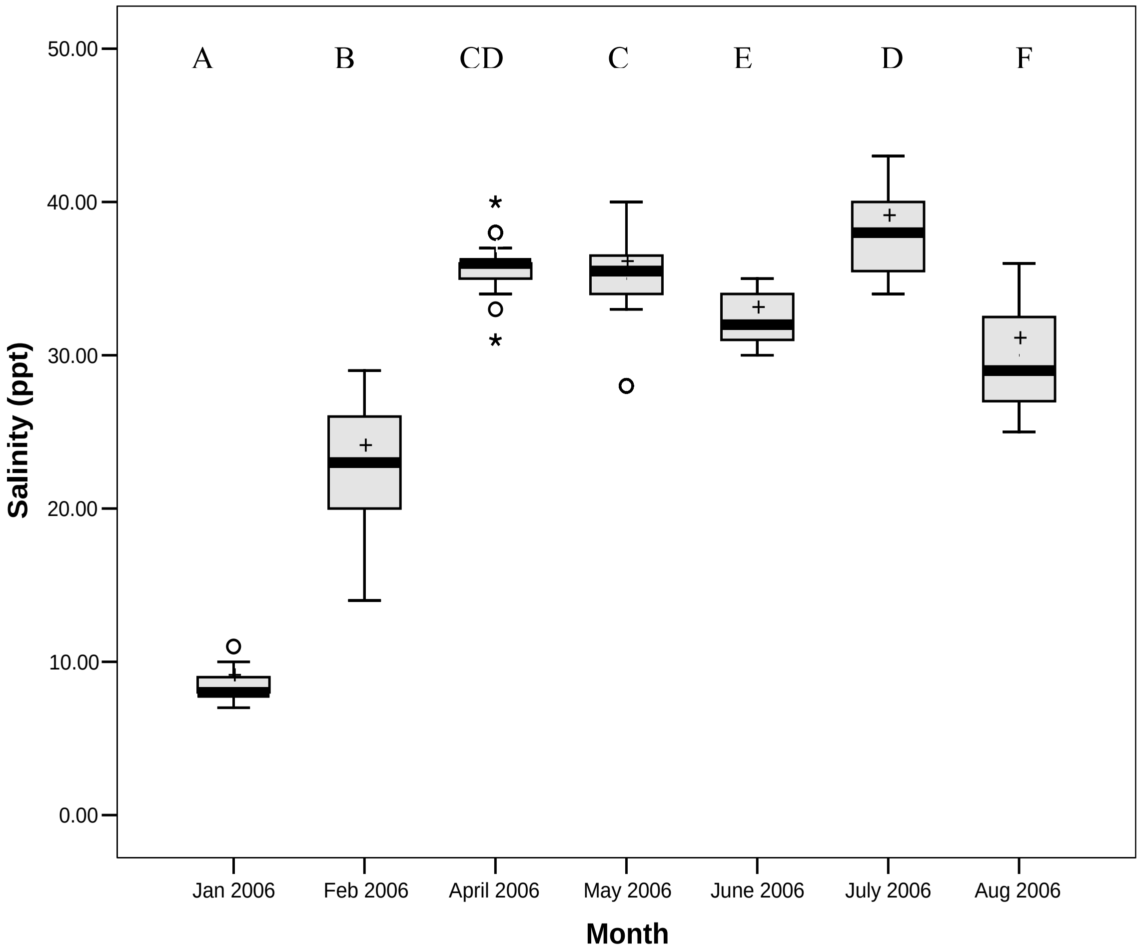

Figure 4b. Surface salinity (ppt) by month. '+' = mean for each month; letters indicate significant differences

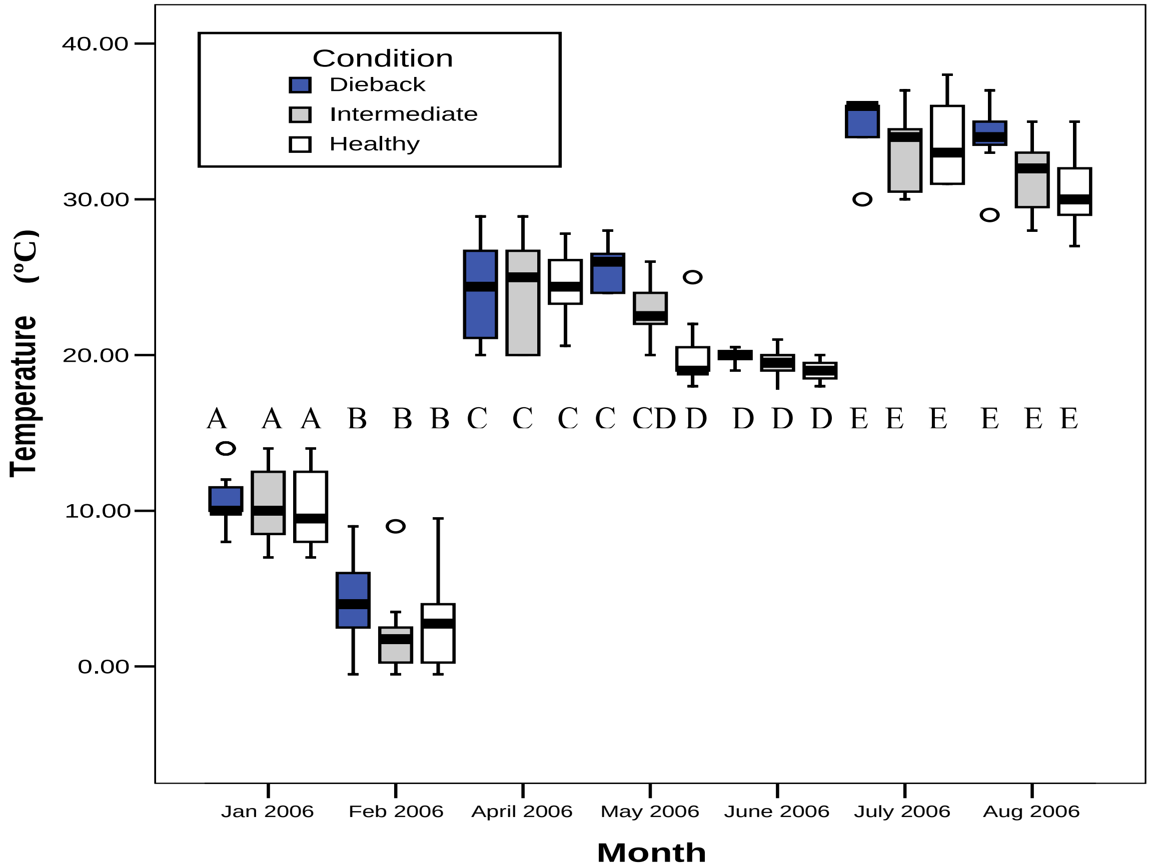

Figure 5. Temperatures (ºC) by condition and month. Letters indicate significant differences

had an average temperature of 20.0±2.3ºC. Although not statistically significant, the mean temperatures in the dieback was highest among the 3 conditions on six of the seven samplings.

pH of surface water

There were significant differences among conditions ($p<0.001$) and among months ($p<0.001$). Also the condition*month interaction was significant ($p<0.001$). The average pH across months was 7.7±1.1 for dieback condition, 7.4±1.0 for the intermediate condition, and 6.9±0.7 for the healthy condition. In April, May, and June 2006, dieback has the highest average pH (8.1- 8.9) and healthy areas have the lowest average pH values (6.9 and 7.5). In July (5.9-6.2) and August (6.6-6.9) pH values among conditions were more similar and generally lower (Figure 6).

Elevation

There were significant differences among the conditions ($p<0.001$) and also among transects ($p<0.001$) for elevations. There was no significant condition*transect ($p=0.210$) interaction. Averaging all transects, the lowest average elevation was found in the dieback condition (0.966±0.044m), and the highest in the healthy condition (0.996±0.053m). The average of the intermediate condition fell between the two other conditions (0.980±0.043m) (Figure 7a). A Tukey's post hoc test showed that Transect 4, located in a higher area of the marsh, had significantly higher elevations than the other transects with an average across conditions of 1.10±0.029m. The other 7 transects had averages across conditions ranging from 0.958±0.007m to 0.970±0.019m with an overall average among these transects of 0.964±0.014m elevation (Figure 7b).

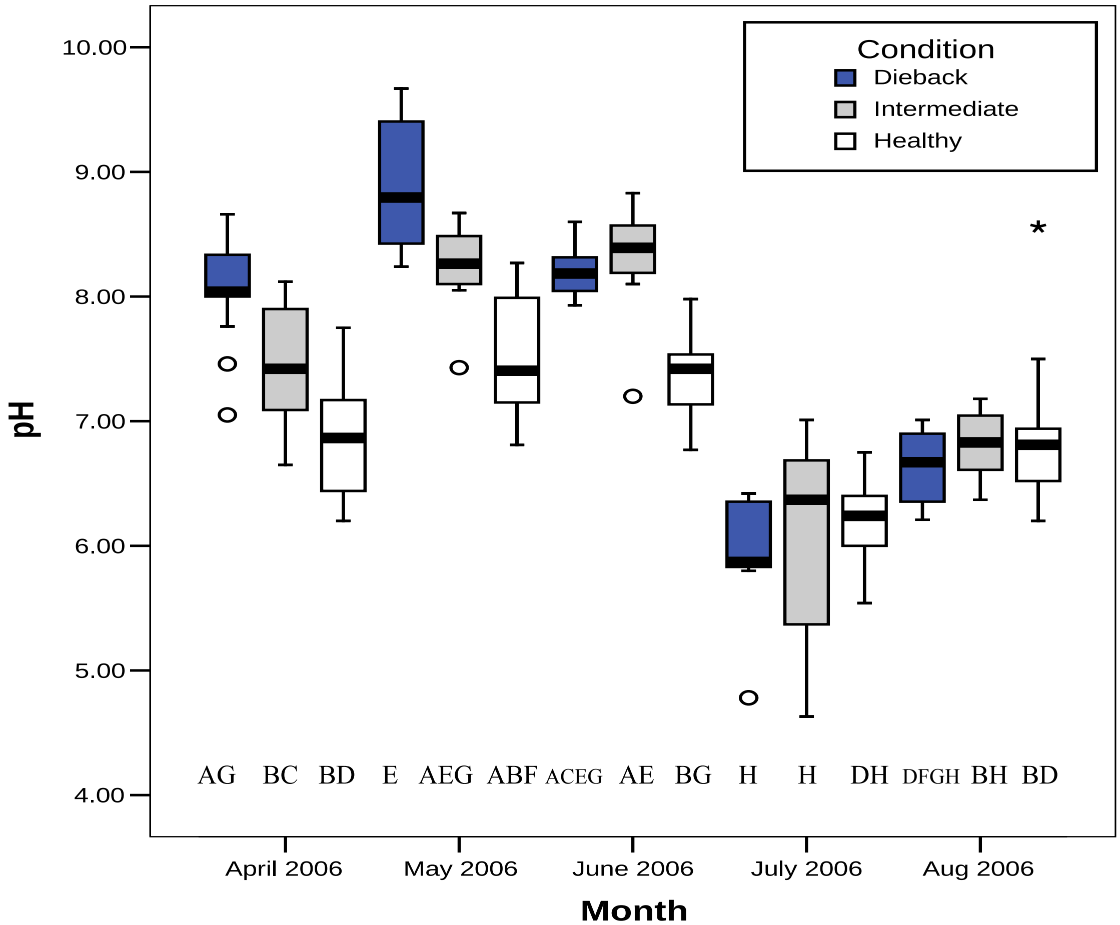

Figure 6. pH by condition and month. Letters indicate significant differences.

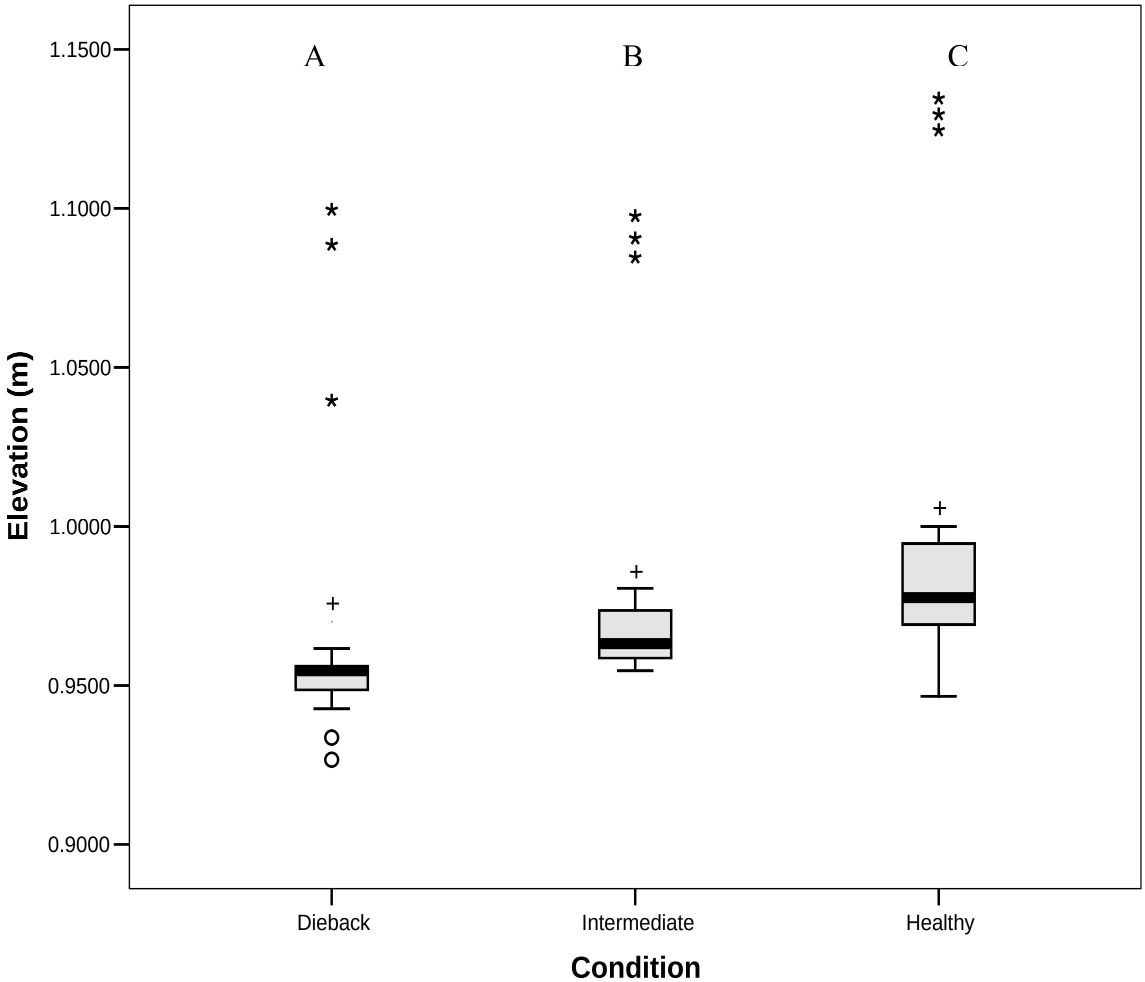

Figure 7a. Elevation (meter) by condition. '+' = means for each condition. Letters indicate significant differences.

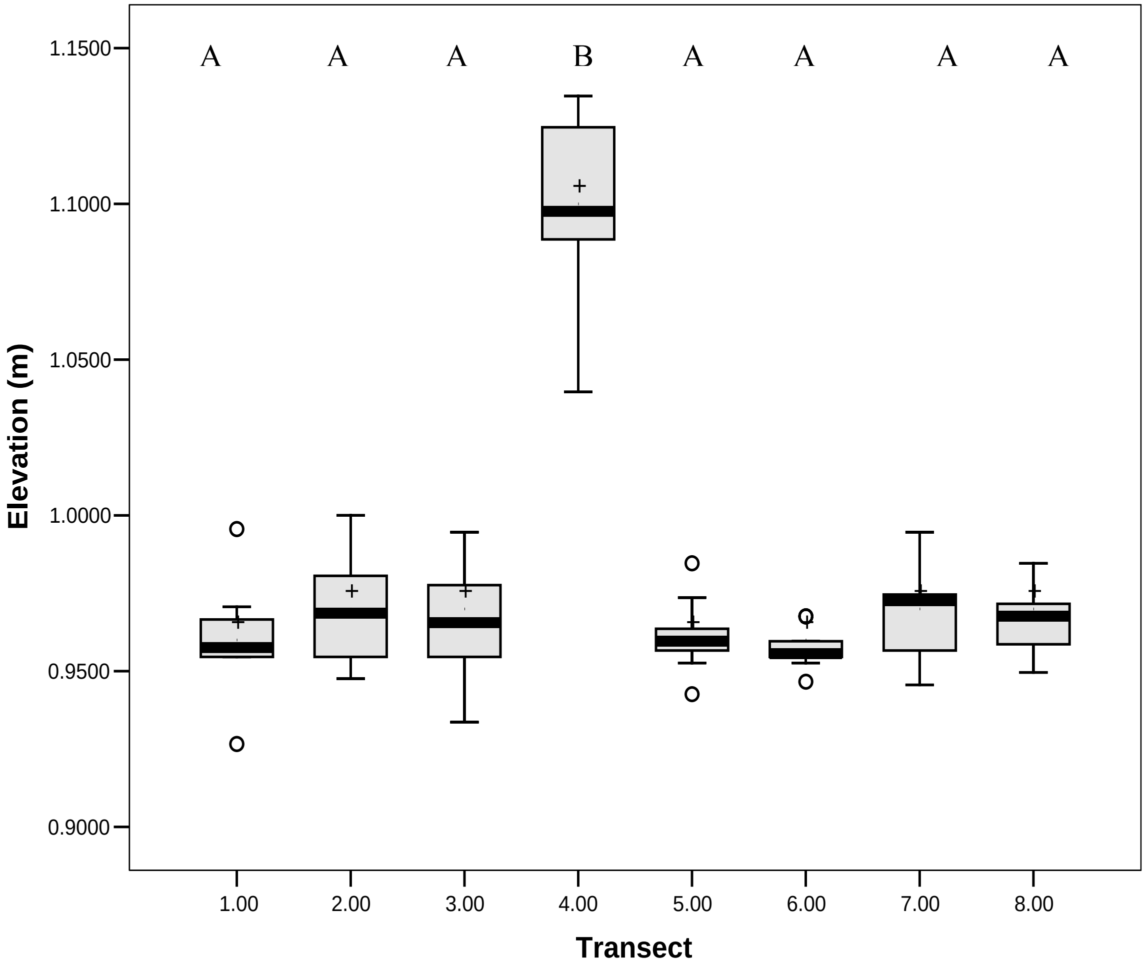

Figure 7b. Elevation (meter) by transect. '+' = mean for each transect; letters indicate significant differences

Size of Dieback

Twenty-nine flags were placed on the boundary of the main area of dieback in summer 2005. Using the perimeter flagging, the main dieback area was measured to be $721m^2$. In 2006 the distance from the flagging to the growth of healthy plants was measured. Two flags were located equal to the interface between the healthy and dead area and 27 were located within the vegetation. This indicated that the main dieback area was filling in and regrowing likely through rhizome extension. The average distance for all 29 flags that the marsh had filled in was 11.4±8.2cm (Table 2.). These measurements indicated that the main area of dieback filled in $21m^2$, or a 3% decrease.

Ground Cover

Transect cover

From 2004 until 2005, when the original four transects were categorized, there was very little regrowth along the transects. The only changes were in transects 1 and 2 and were so small they may be due to observer error. Transect 1 and 2 showed no increases in percent healthy but both had small increases in the percent categorized as intermediate and conversely decreases in the percent categorized as dieback. Transect 3 and 4 had no changes in the percentages of categorization.

However, by 2006 when the transects were recategorized, there was considerable regrowth of *S. alterniflora* into dieback areas. All 8 transects showed regrowth (Figure 8). There was a 27% increase in healthy areas from 2005 to 2006 with decreases in other categories (Table 3). For 2006, an additional category 'standing dead' was added that accounted for shoots that browned in late summer. These 'standing dead' areas had originally been considered healthy. Transects 1, 2, and 6 had areas where this had occurred (Table 3).

Meter plots

The percent cover of 1-m plots was measured throughout the year for all 8 transects and averaged (Figure 9). Table 4 shows the percent values by months and conditions for ground cover category. Four categories were used: purple sulfur bacterial mats, filamentous algal mats, mud, and live and dead plants (L/D). In the dieback condition, at the 1 meter plot scale, algal mats dominated the ground cover from July 2005 through October 2005. In December 2005, the algal mats had almost disappeared and the dieback was dominated by mud. In January and February 2006, purple sulfur bacteria dominated the ground cover in the meter plots peaking in January. In April 2006, the layer of purple sulfur bacteria had almost disappeared, and the dieback was dominated by an exposed mud surface. In June 2006, the dieback area experienced an increase in *S. alterniflora* cover that continued throughout the summer. In June the exposed mud was predominate in the dieback. The algal mats showed an increase from June to July and remained high in August. In June 2006, the purple sulfur bacteria were still present, but by July they were no longer present. They had not returned in August.

In the intermediate condition plots, as followed the definition (26-84% ground cover by plants) established for the conditions, *S. alterniflora* had the greatest percent cover for all months. From June through August 2006 plant cover steadily increased as it had in the dieback condition. Algal mats had the highest coverage (besides plants) from July to October 2005. Purple sulfur bacteria peaked in January and February 2006 in the intermediate condition.

Table 2. Distances vegetation (*Spartina alterniflora*) had changed relative to flag perimeter. Positive numbers indicate centimeters vegetation has filled dieback.

Flag number	cm filled-in
1	2
2	8
3	10
4	6
5	6
6	15
7	23
8	22
9	19
10	14
11	33
12	12
13	20
14	10
15	16
16	20
17	6
18	3
19	15
20	3
21	15
22	5
23	14
24	20
25	0
26	1
27	0
28	3
29	11
Mean =	11.448276
SD =	8.1922708

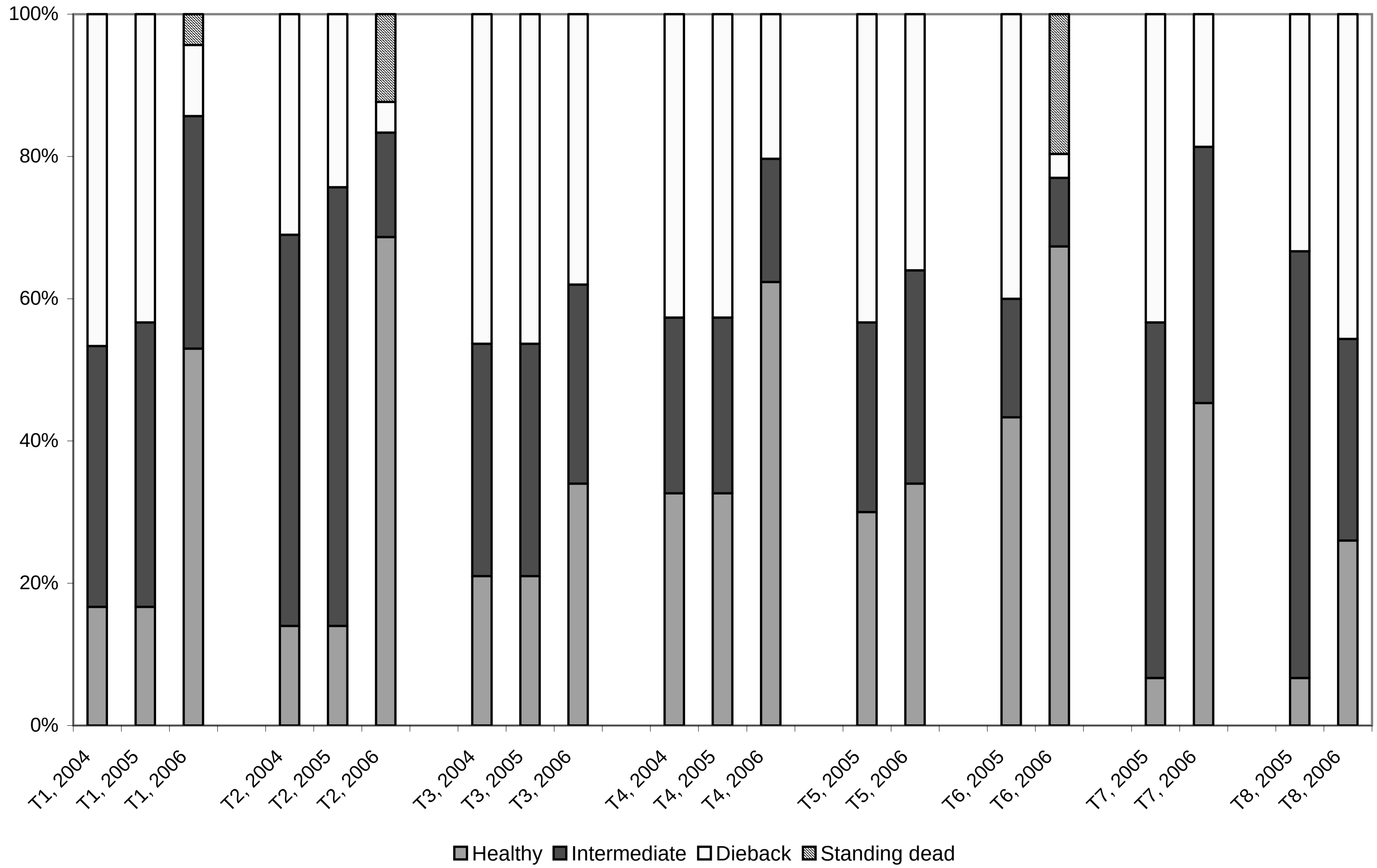

Figure 8. Categorization of transects from 2004-2006. In 2006, an additional category (standing dead) was added to account for several browned areas that occurred during that summer in 3 transects.

Table 3. Percent change in condition from 2005-2006. Positive percentages indicate increases within a transect categorized as a condition. Negative numbers indicate decreases within a transect categorized as a condition. The category of 'Standing Dead' was added in 2006 when some transects experienced a browning late in the summer.

Transect	Healthy	Intermediate	Dieback	Standing Dead
1	36%	-7%	-33%	4%
2	55%	-47%	-20%	12%
3	13%	-5%	-8%	0%
4	29%	-8%	-23%	0%
5	4%	3%	-7%	0%
6	24%	-7%	-37%	20%
7	38%	-14%	-24%	0%
8	19%	-32%	13%	0%
Average	27±16%	-15±17%	-17±16%	5±8

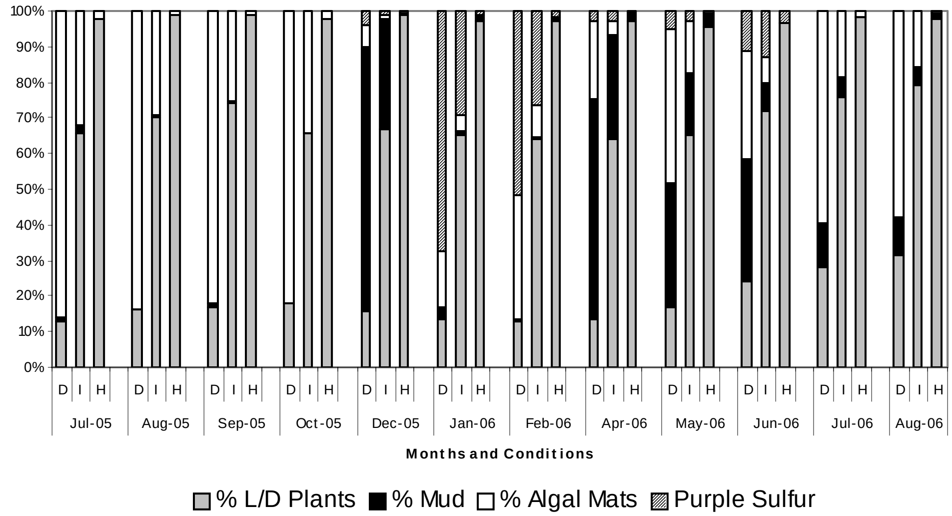

Figure 9. Percent cover by months. The figure represents the percentages by month of meter plots falling into 4 separate cover categories. Along the x-axis, 'D'=Dieback, 'I'=Intermediate, and 'H'=Healthy. The category '%L/D Plants' represents live and dead plants.

Month	Condition	% L/D Plants	% Mud	% Algal Mats	%Purple Sulfur
Jul-05	D	13±12	1±3	86±11	0
	I	66±13	2±5	32±11	0
	H	98±2	0	2±2	0
Aug-05	D	16±13	0	84±13	0
	I	70±14	0±2	29±13	0
	H	99±2	0	1±2	0
Sep-05	D	17±14	1±3	82±14	0
	I	74±11	1±3	25±11	0
	H	99±2	0	1±2	0
Oct-05	D	18±11	0	82±11	0
	I	66±15	0	35±15	0
	H	98±3	0	2±3	0
Dec-05	D	16±14	74±22	6±8	4±10
	I	67±16	31±16	1±2	1±2
	H	99±2	1±2	0±1	0
Jan-06	D	13±11	4±13	16±16	67±25
	I	65±17	1±3	5±4	29±18
	H	97±3	2±2	0±1	1±3
Feb-06	D	13±11	0±1	35±32	52±32
	I	64±18	1±3	9±8	26±18
	H	97±4	1±1	0±1	2±3
Apr-06	D	13±13	62±26	22±22	3±3
	I	63±16	29±16	4±5	3±3
	H	97±4	3±3	0	0
May-06	D	17±17	35±39	43±34	5±7
	I	65±21	17±18	15±10	3±5
	H	95±4	4±4	0±1	0±1
Jun-06	D	24±26	35±35	30±30	11±10
	I	72±24	8±15	7±7	13±14
	H	96±3	0	0±2	3±3
Jul-06	D	28±30	12±7	60±25	0
	I	76±22	6±9	19±16	0
	H	99±2	0	2±2	0
Aug-06	D	32±14	10±12	58±17	0
	I	77±21	5±4	15±19	0
	H	98±2	2±2	0±1	0

Table 4. Percent ground cover by month and condition. Mean± Standard deviation; 'D' = dieback, 'I' = intermediate, 'H' = healthy

The healthy plots were by definition dominated by *S. alterniflora* cover. Algal mats made up the remaining percent cover from July 2005 through October 2005. Purple sulfur bacteria appeared in January 2006. They persisted through June 2006. Algal mats peaked in the healthy condition in May 2006.

End-of-year biomass

Dry live mass

From 2004-2006, there were a significant difference in the dry mass of live *S. alterniflora* among the conditions ($p<0.001$), among years ($p=0.001$). Also between condition*year there was an interaction ($p<0.001$). This interaction may be due to sampling not being done at the exact same time each year. Averaging the 3 years, the live mass as dry mass was lowest in the dieback (26±37g/m^2), and highest in the healthy (599±251g/m^2). The intermediate condition had an average live mass between the two (229±124g/m^2) (Figure 10a). Across all conditions, for the three years, the total live mass was highest in 2005 (331±339g/m^2) and lowest in 2006 (227±203g/m^2). In 2004 the average mass was 260±301g/m^2. A Tukey's post hoc test revealed that 2005 and 2006 were significantly different from one another, but 2004 was not significantly different than 2005 or 2006 (Figure 10b). As expected, when the 3 years are separated by condition, all had lowest mass in the dieback: 14±22g/ m^2 (2004), 26±37g/ m^2 (2005), and 35±43g/ m^2 (2006); followed by the intermediate condition: 320±207g/ m^2 (2004), 223±64g/ m^2 (2005), and 189±97g/ m^2 (2006). The healthy condition had the highest live biomass for all three years: 590±311g/ m^2 (2004), 745±242g/ m^2 (2005), and 457±144g/ m^2 (2006) (Figure 10c).

Mass per stem

In terms of dry mass per live stem (2005-2006), there was a significant difference among conditions ($p<0.001$). There was no difference among years ($p=0.876$) or the condition*year interaction ($p=0.616$). The average mass of a live stem was lowest in the dieback condition (0.133±0.132g), followed by the intermediate condition (0.231±0.124g), and the healthy condition had the highest average mass per live stem at 0.343±0.177g (Figure 11a).

For the dead stems, there was a significant difference among conditions ($p=0.017$), but there was no significant difference among years ($p=0.124$) or the interaction condition*year ($p=0.242$). The average mass per dead stem in the dieback condition was 0.088±0.053g, in the intermediate condition 0.100±0.038g, and in the healthy condition was 0.116±0.053g. A Tukey's post hoc test revealed that while the dieback condition and the healthy condition had differences in the mass per dead stem, the intermediate was not different from the dieback or the healthy condition (Figure 11b).

Melampus bidentatus

There were significant differences in *M. bidentatus* density among the conditions ($p<0.001$), among months ($p<0.001$). Also there was a condition*month interaction ($p<0.001$). This may be due to the seasonal differences in the number of snails. For all months, dieback areas had the lowest average density of snails (32±135/m^2), followed by intermediate areas (134±196/m^2), and healthy areas had the highest average number of snails (449±404/m^2)(Figure 12a). In May 2006, the new category 'healthy away' was created to account for snails in healthy areas outside of the main area of dieback. The

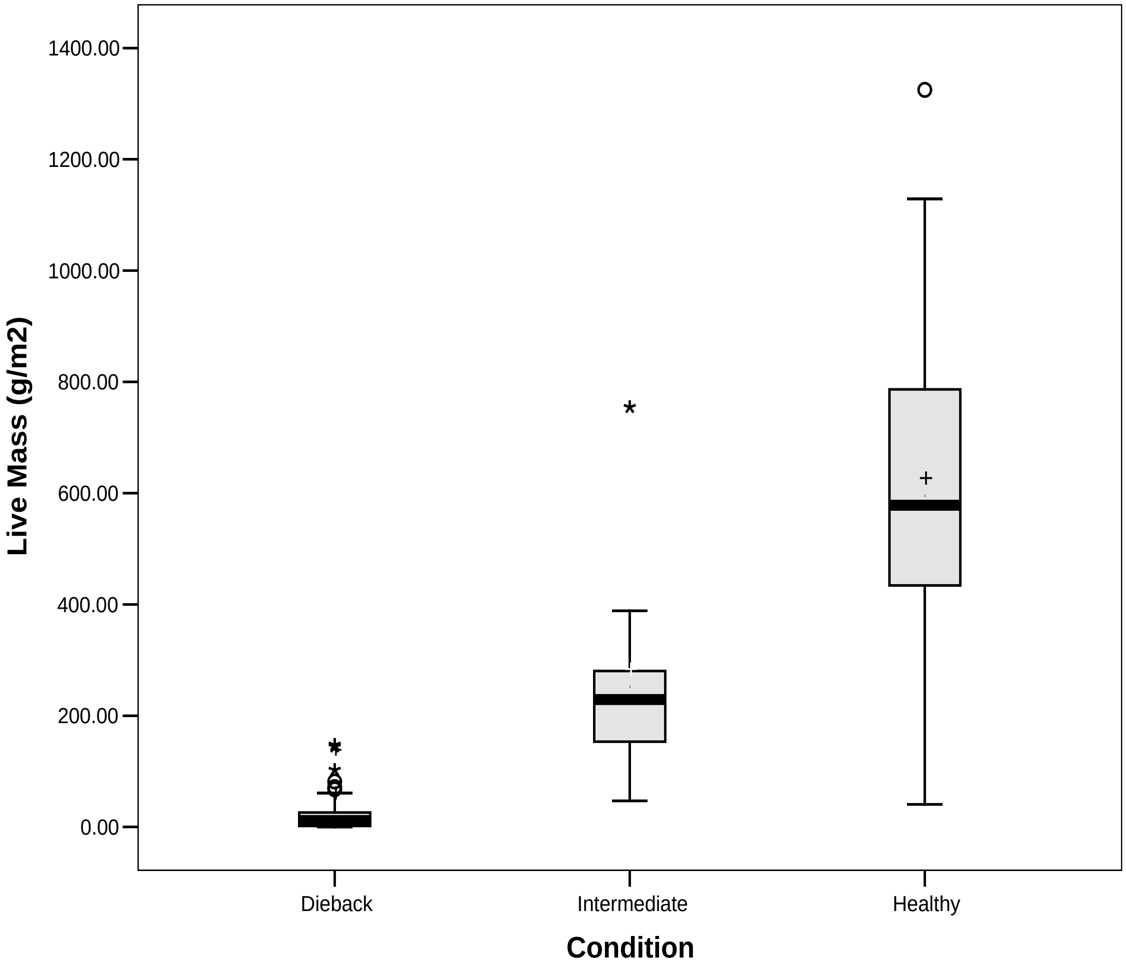

Figure 10a. End of year live biomass (g/m^2) across conditions averaging three summers (2004-2006). '+' = mean for each condition.

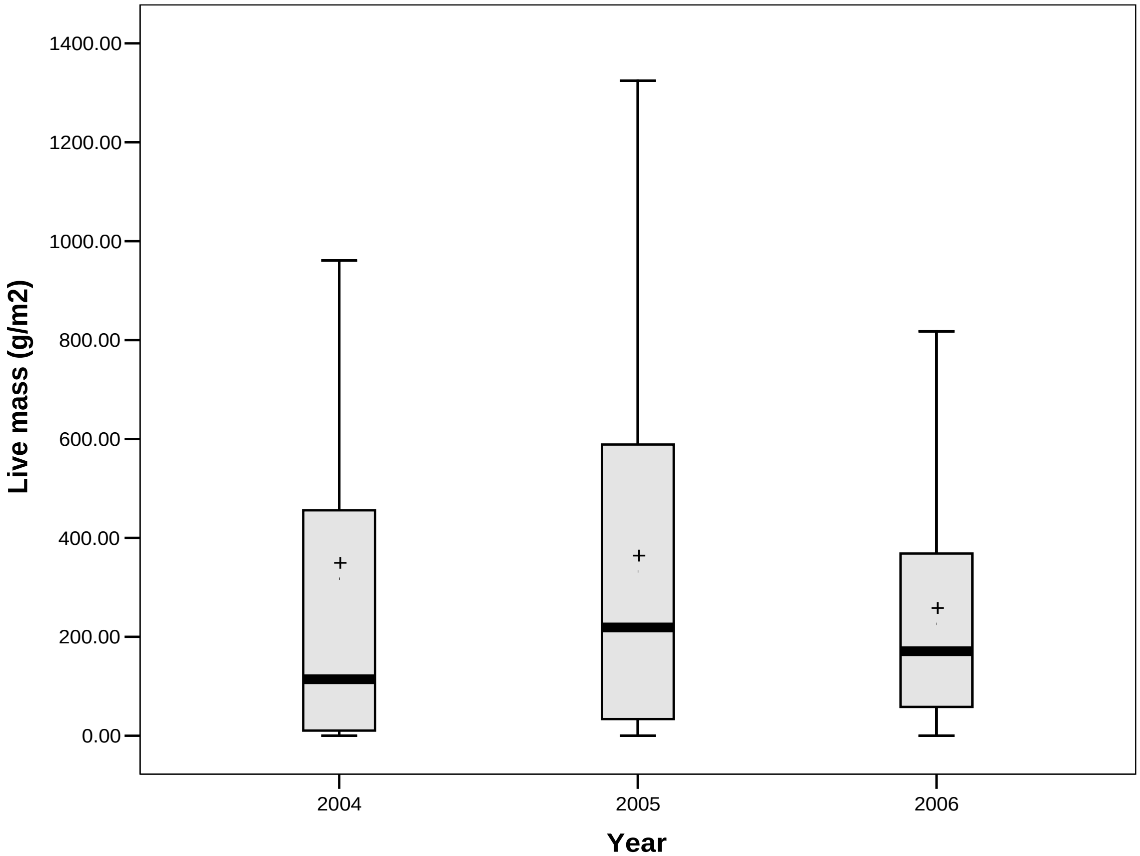

Figure 10b. End of year live biomass (g/m^2) by year. ‘+’ = mean for each year

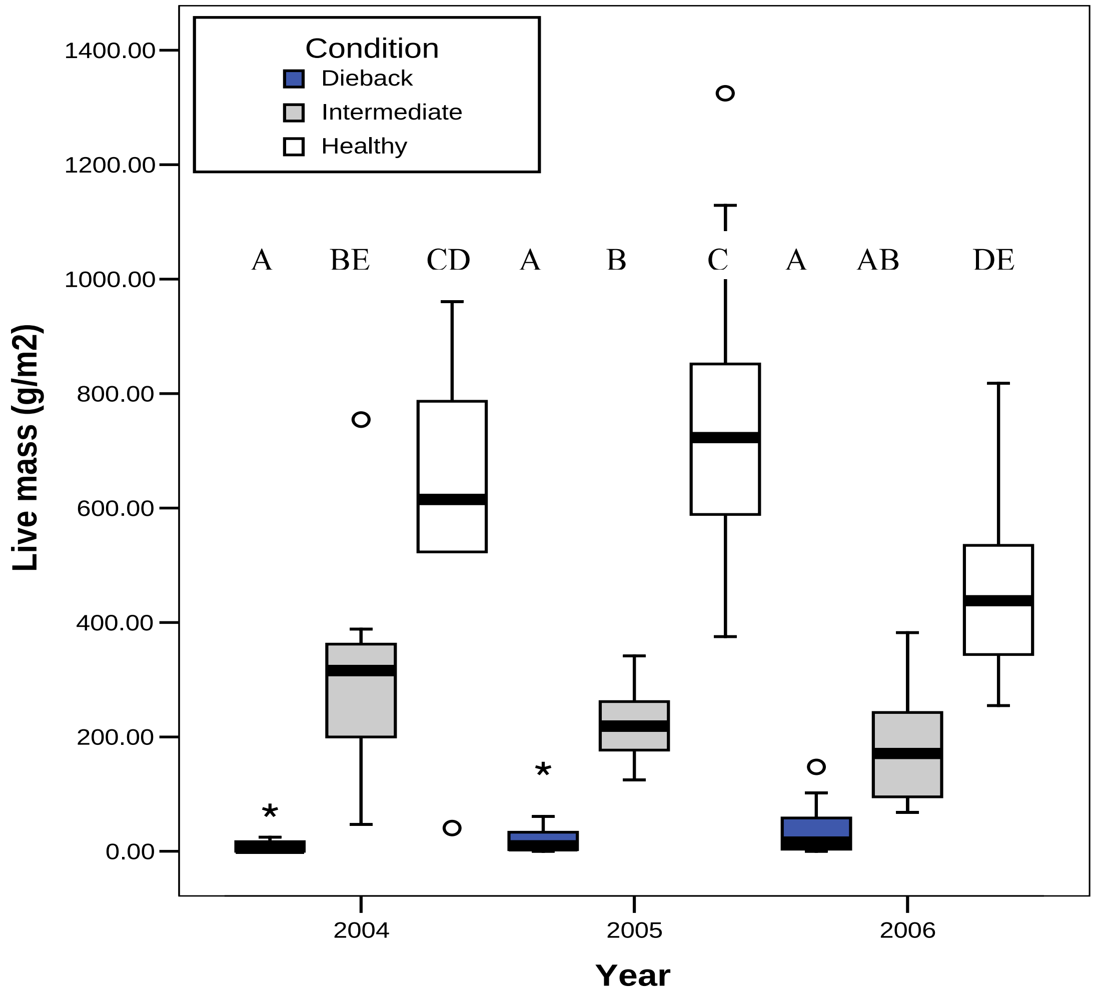

Figure 10c. End of year biomass (g/m^2) by year and condition. Letters indicate significant differences.

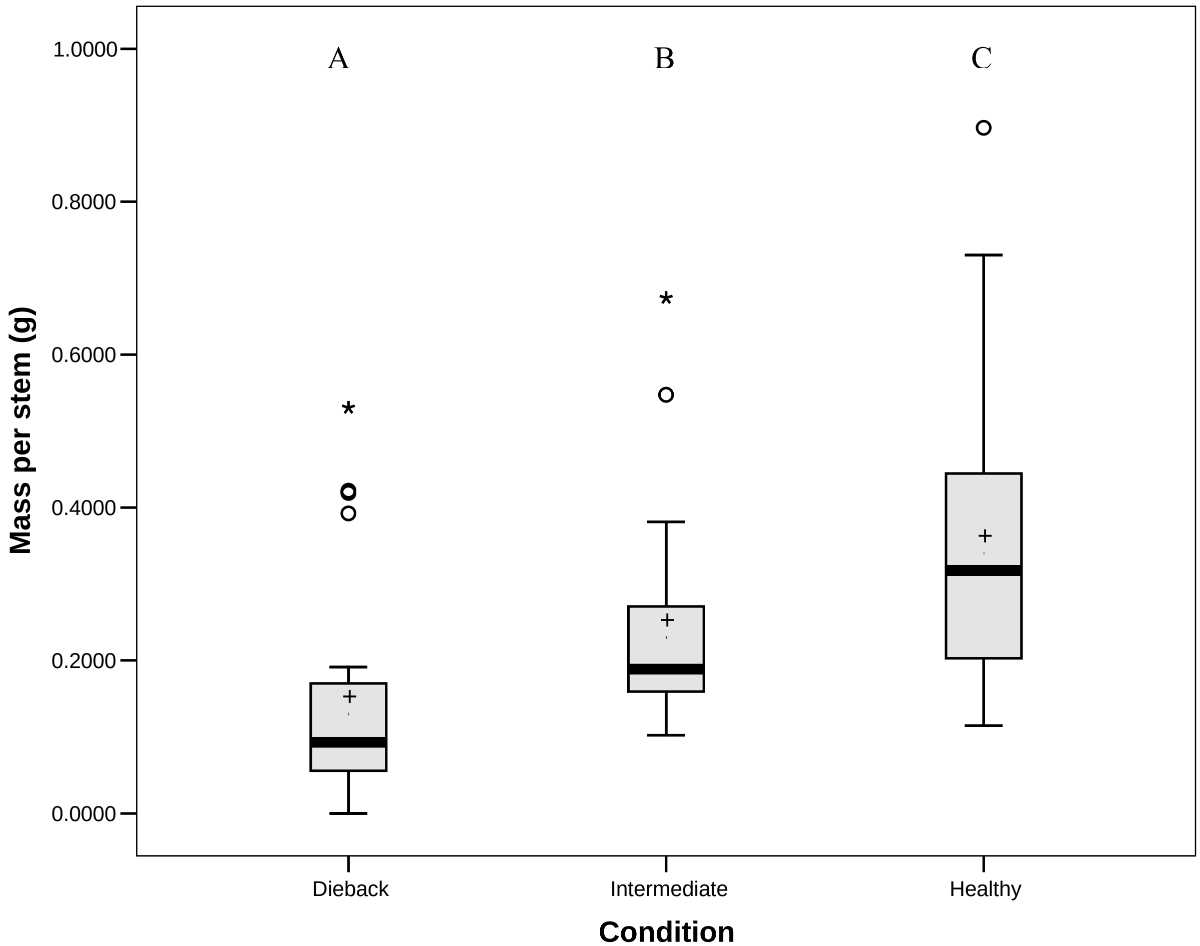

Figure 11a. Mass per live stem (g) by condition. '+' = means for condition; letters indicate significant differences

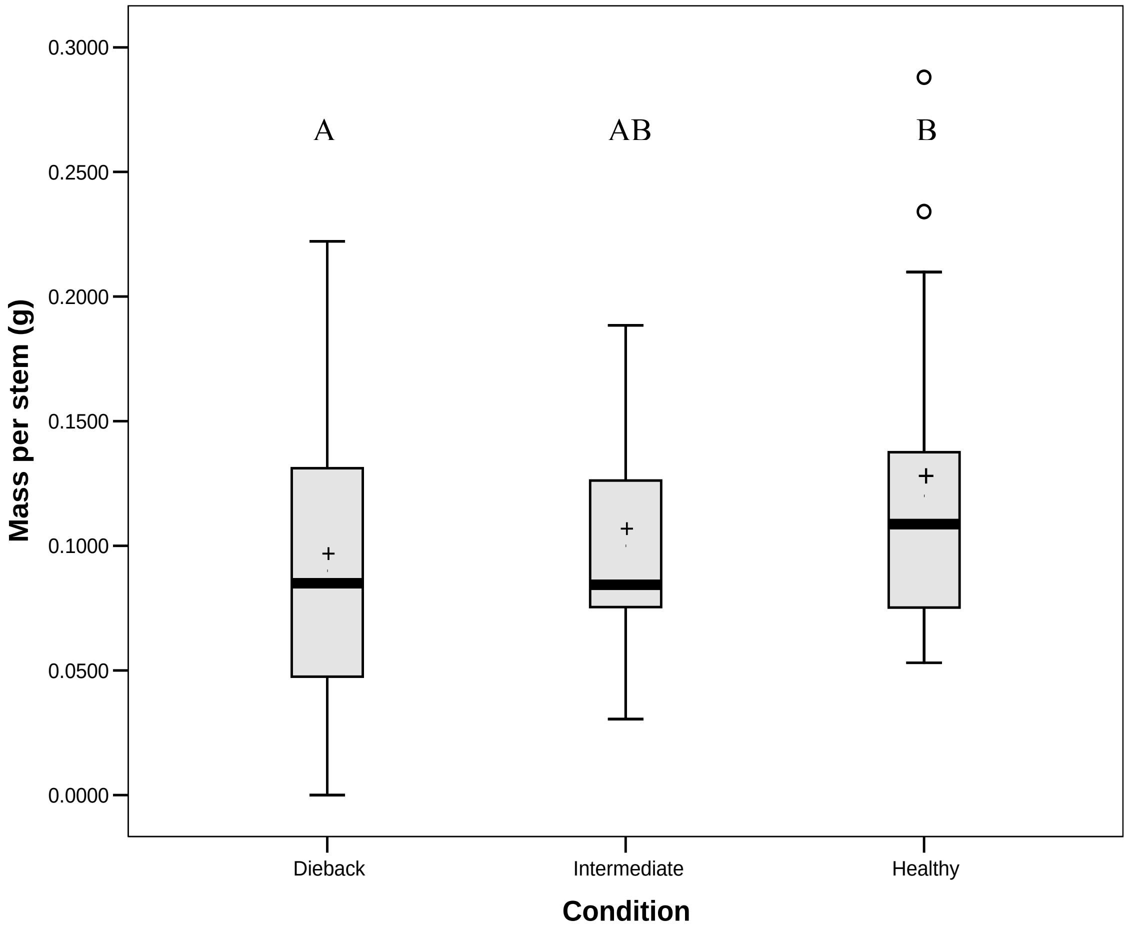

Figure 11b. Mass per dead stem by condition for 2005-2006. ‘D’ = dieback, ‘I’ = intermediate, and ‘H’ = healthy; ‘+’ = mean for each condition

'healthy away' counts were made in areas ~50m from the dieback in the low marsh. For all months that this new condition was counted, May 2006 through August 2006, there were significant differences among the conditions ($p<0.001$), among months ($p<0.001$), and also a condition*month interaction ($p<0.001$). From May to August 2006, the average number of snails for conditions were: $11\pm32/m^2$ in dieback, $171\pm204/m^2$ intermediate, $720\pm423/m^2$ in healthy, and $583\pm343/m^2$ in 'healthy away' (Figure 12b).

Bacterial density

The average densities of bacteria/cm^3, showed significant differences among conditions ($p=0.011$) and months ($p<0.001$). There was no significant condition*month interaction ($p=0.112$). The healthy condition had the highest average with $3.54\pm0.67X10^9$ bacteria/cm^3, followed by the dieback condition with $3.38\pm0.73X10^9$ bacteria/cm^3, and the intermediate condition had the lowest density of bacteria over all months with $3.29\pm0.59X10^9$ bacteria/cm^3. Tukey's post-hoc test revealed that the dieback condition is not different than the other two conditions, but that the intermediate and healthy conditions are different than one another (Figure 13).

Algae

Chlorophyll a

The sediment cores were analyzed for chlorophyll a concentrations. No significant differences among the conditions ($p=0.481$). The concentration of chlorophyll a averaged $7.8\pm3.3mg/m^2$ in the dieback condition, $7.8\pm3.0mg/m^2$ in the intermediate condition, and $8.1\pm3.2mg/m^2$ for the healthy condition over all months (Figure 14a). However, there was a significant difference in concentrations of chlorophyll a among months ($p = 0.000$) indicating a possible seasonal component. September 2005 showed a decline in the overall amount of chlorophyll a, averaging $3.7\pm1.7mg/m^2$ but October 2005

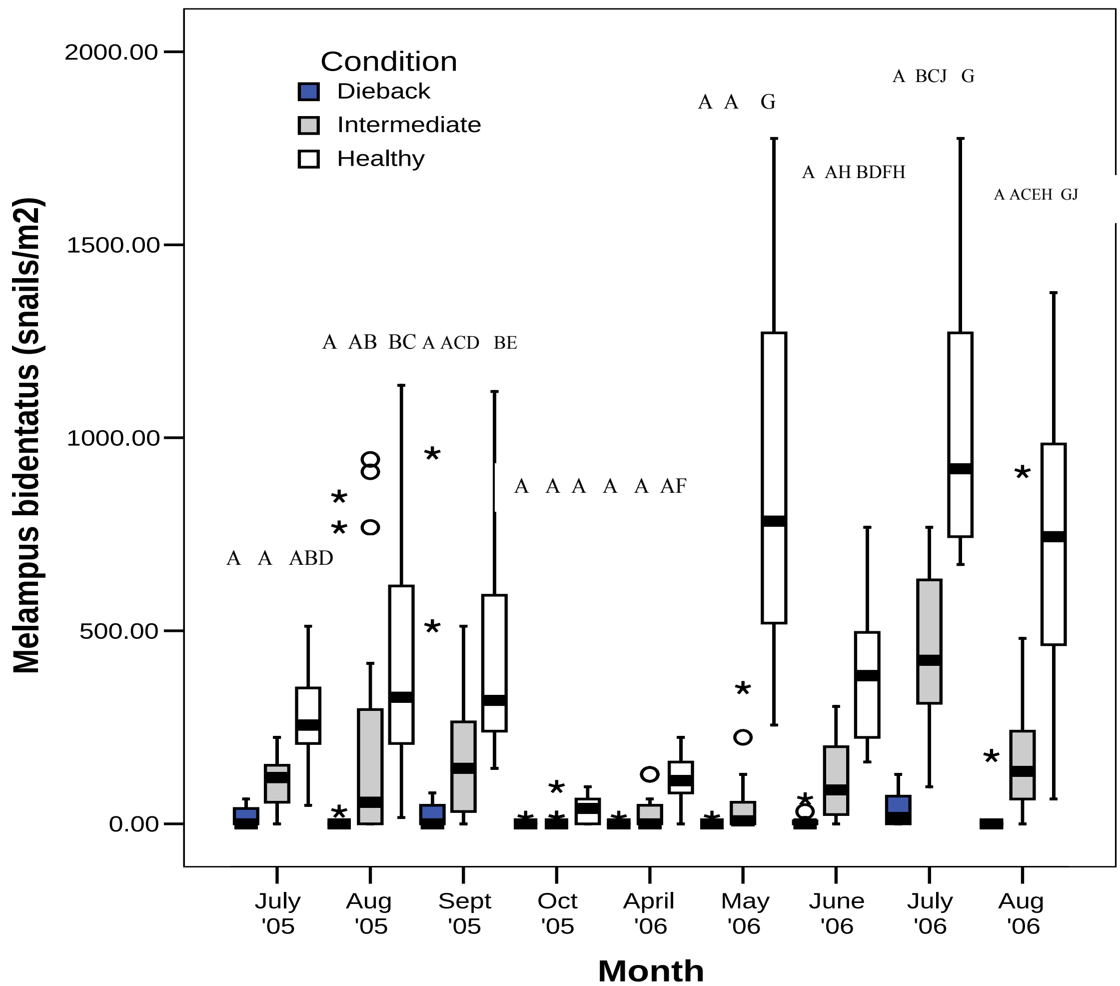

Figure 12a. *Melampus bidentatus* densities by month and condition. Letters indicate significant differences

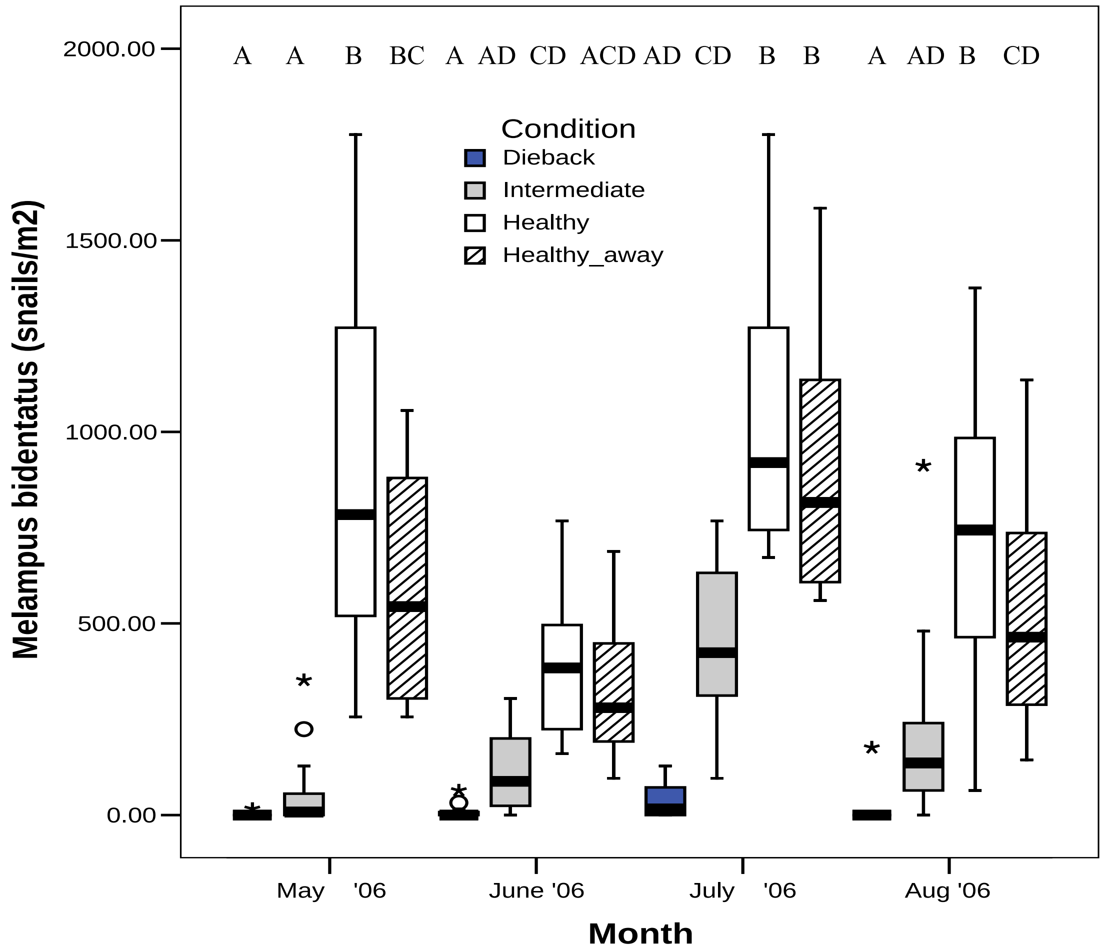

Figure 12b. *Melampus bidentatus* densities for months that contained the category 'healthy away.' Letters indicate significant differences.

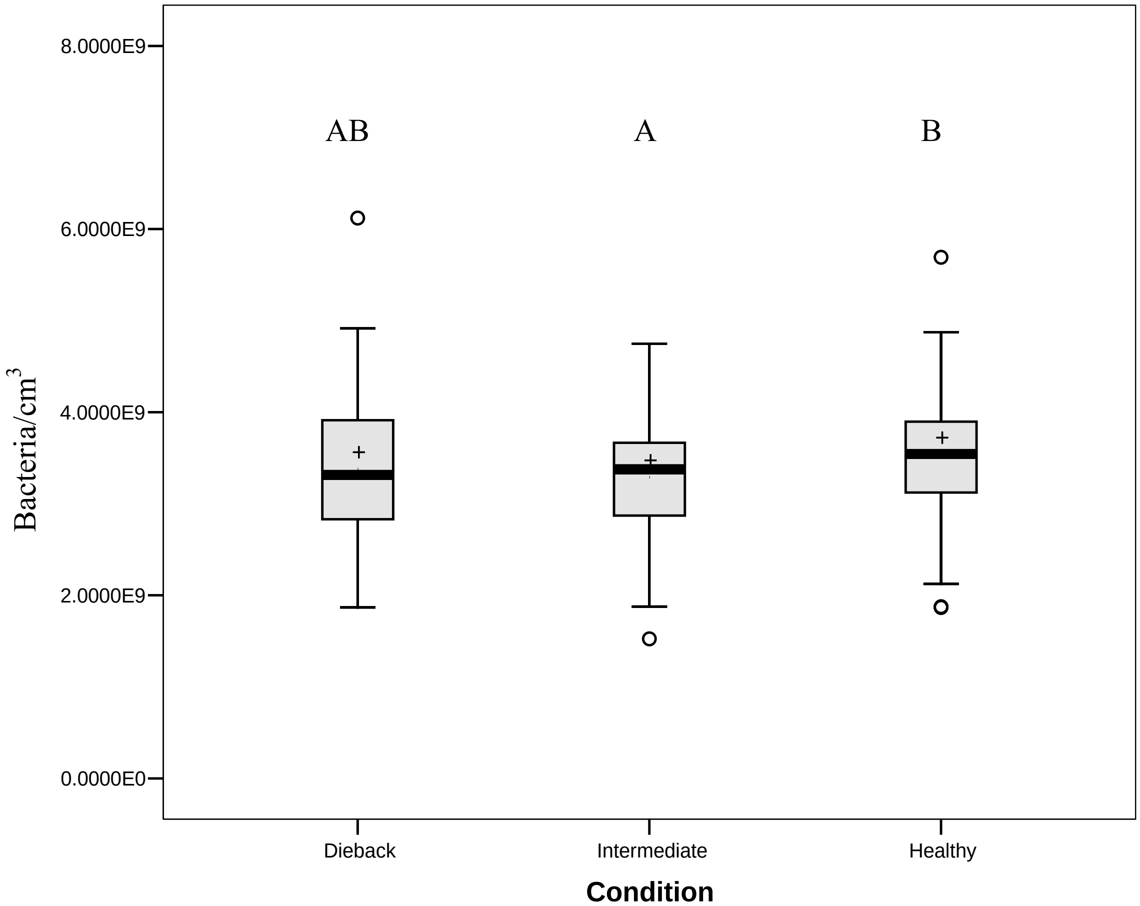

Figure 13. Bacteria per cm^3 by condition. '+' = mean for each condition; letters indicate significant differences

had a noticeable increase, averaging 8.2±3.6mg/m^2. December 2005 and January 2006 both showed decreased amounts of chlorophyll a, averaging 5.1±1.1mg/m^2 and 5.6±1.2mg/m^2 respectively. In February 2006 through the end of summer August 2006, chlorophyll concentrations remained above 8.0mg/m^2 averaging 9.8±2.3mg/m^2 (Figure 14b).

Identification of Algae

In May 2006, samples of the algal mats were taken from Upper Phillips Creek marsh and major algal genera identified. An algal mat close to Transect 7, which crossed through the main dieback area, had mats mostly composed of the filamentous green algae *Cladophora* spp. and *Enteromorpha* spp. Transect 4, located higher in the marsh closer to the high marsh, had algal mats dominated by *Rhizoclonium* spp. also filamentous green algae.

Bacteriochlorophyll

HPLC analysis was performed on a set of sediment samples from February 2006 when filamentous algal mats and purple sulfur bacterial mats were highly visible. There were no significant differences found in the concentrations of bacteriochlorophyll in the sediment samples among the conditions ($p=0.655$); however, concentrations were extremely variable. In the 24 samples (8 for each condition), only 6 contained any measurable bacteriochlorophyll (2 in the dieback, 2 in the intermediate, and 2 in the healthy condition). The concentrations averaged 0.78±1.77mg/m^2 in the dieback condition, 0.45±1.03mg/m^2 in the intermediate condition, and 0.19±0.36mg/m^2 in the healthy condition (Figure 15).

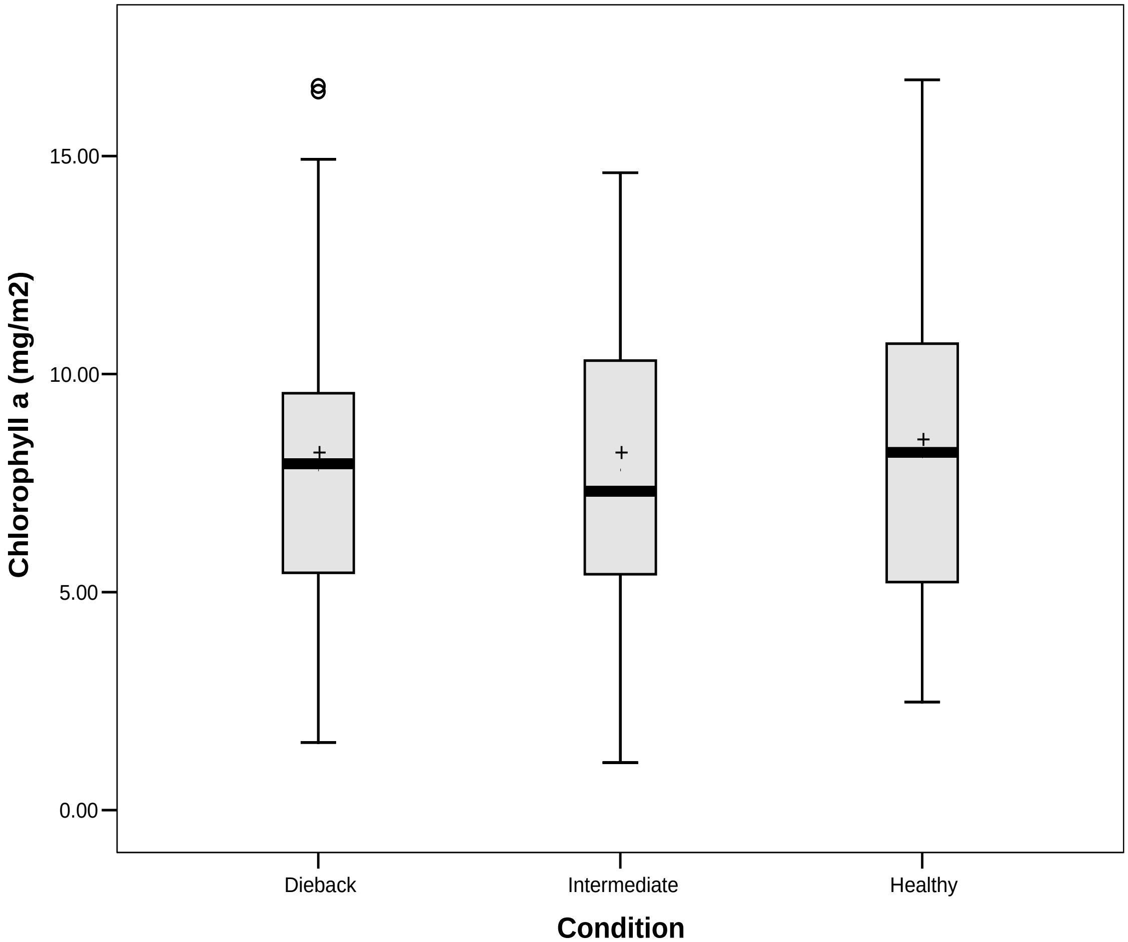

Figure 14a. Chlorophyll concentrations (mg/m^2) by condition. '+' = mean for each condition.

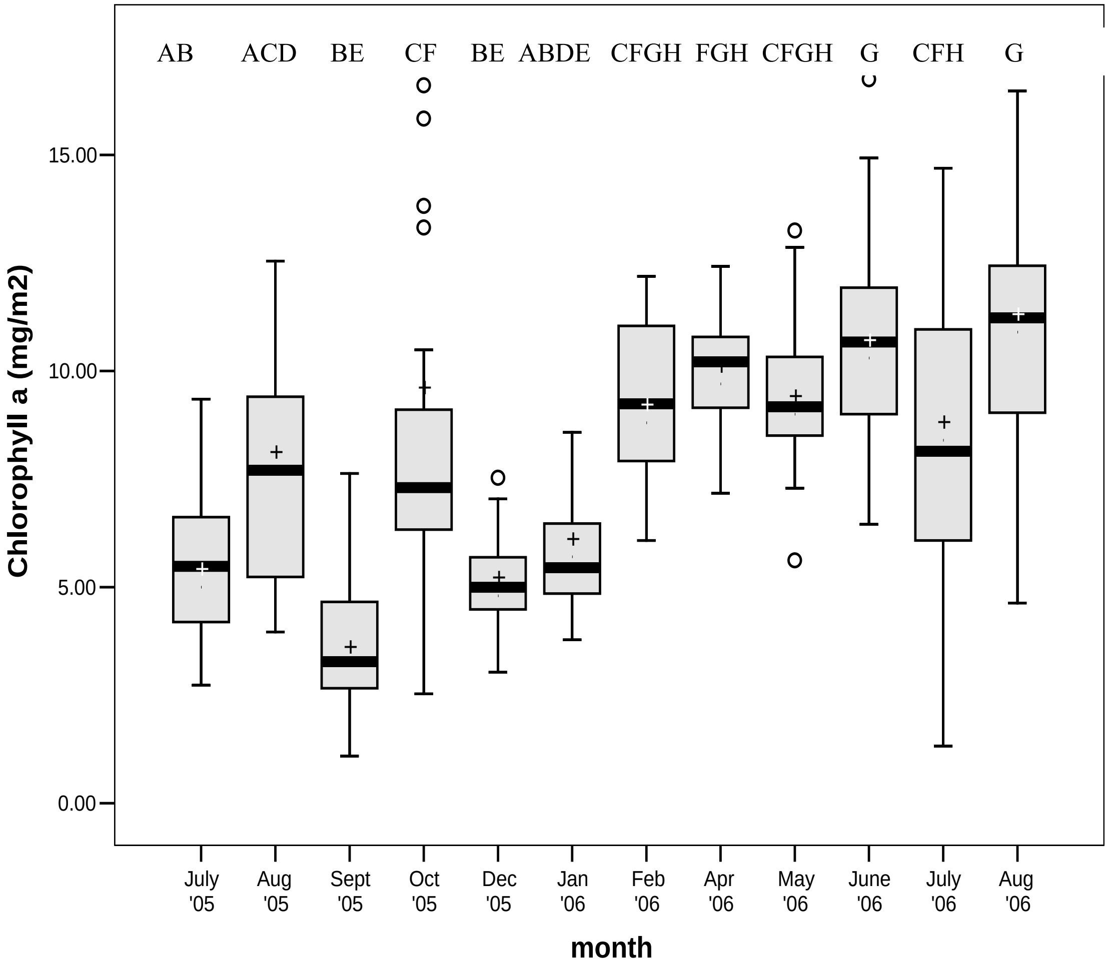

Figure 14b. Concentrations of chlorophyll a (mg/m^2) by month. '+' = mean for each month; letters represent significant differences

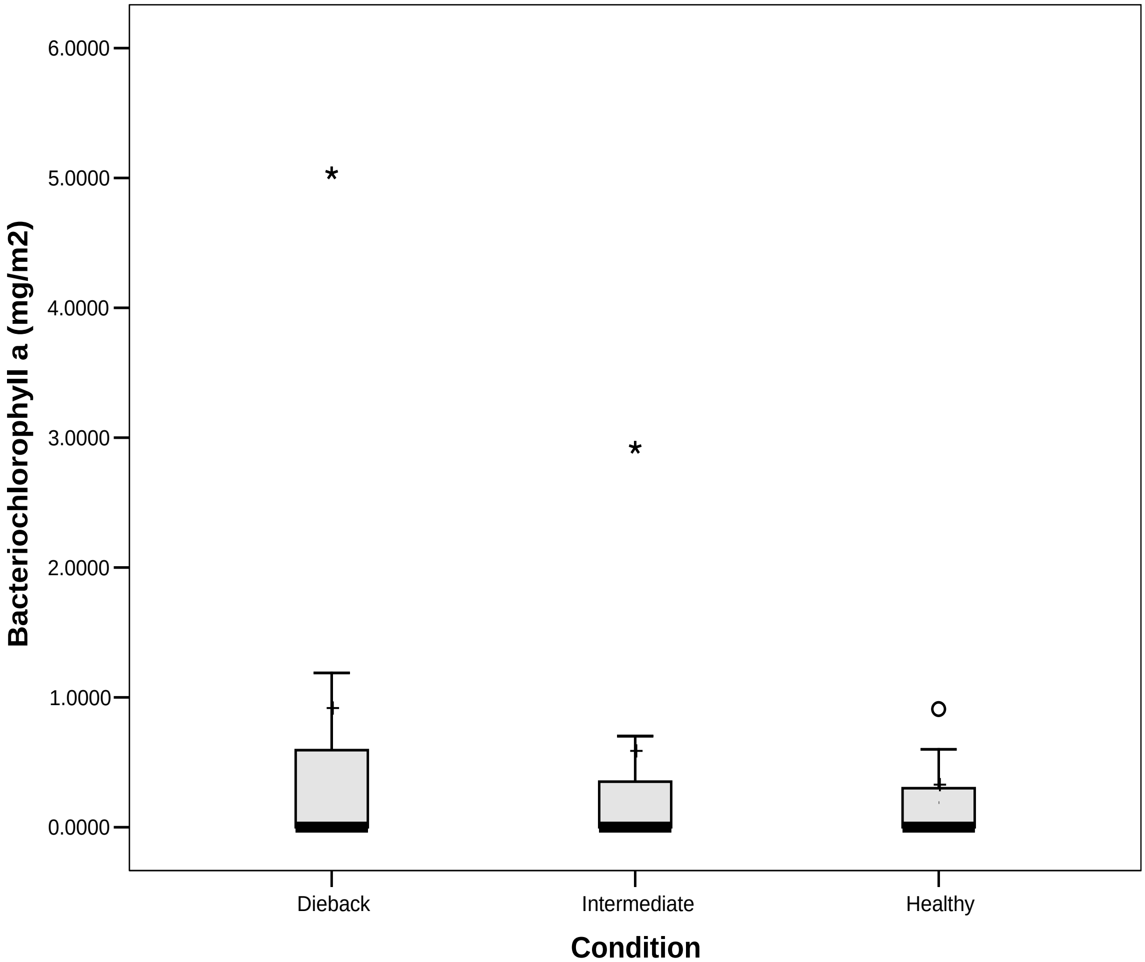

Figure 15. Concentrations of bacteriochlorophyll a (mg/m^2). Cores were taken in February 2006 and analyzed via HPLC. '+' = mean of each condition

DISCUSSION

This study demonstrated that there are several effects in the ecosystem structure associated with a sudden dieback event in Upper Phillips Creek Marsh. Many of these differences have been seen in other marsh dieback studies. Other dieback studies so far have focused on variables that are associated with drought conditions. These include increased sulfide concentrations, salinity, and soil reduction. Herbivory and pathogens have also been studied. My study measured salinities of pore water and surface water, hydrogen sulfide concentrations, surface water temperature, pH of surface water, elevation, bacterial densities, densities of *M. bidentatus*, chlorophyll a and bacteriochlorophyll concentrations, and ground cover. While my findings cannot lead to identifying a definite cause for the dieback, they can inform us of the effects that such a change can have on a marsh and the nature of recovery. These differences occur at various scales to varying degrees. The sampling regime was designed to test variables based on differences in condition, time, and scale. Samplings were made over the course of a year capturing any seasonal differences. The variables covered the cm^2 scale to the landscape scale. The variables were measured for the three conditions of dieback, intermediate, and healthy.

Hypotheses

All four of the original hypotheses concerning the effects of the dieback were rejected. However, one of the hypotheses could be accepted at certain times under some circumstances. It had been hypothesized that chlorophyll a would be present at higher concentrations in the dieback condition, lower concentrations in the intermediate condition, and the lowest concentrations in the healthy condition. It was reasoned this would be the case due to higher light levels (Keusenkothen and Christian, 2004) and increased nutrient concentrations (Taylor, 1995) in the dieback areas. These conditions would foster algal growth and therefore increase its biomass. However, it was seen that there were not differences in the chlorophyll a concentrations among the conditions. Therefore this hypothesis was rejected. Although Keusenkothen and Christian (2004) found that the light intensity on-trail is lower than off-trail, the lower light must not be so low that it limits algal growth. Therefore enough light permeates the *S. alterniflora* canopy.

Three filamentous green algae taxa dominated the algal mats found during the course of the study: *Cladophora* spp. , *Enteromorpha* spp., and *Rhizoclonium* spp. These genera of green algae are commonly opportunistic (Taylor et al., 2001; Salovius and Bonsdorff, 2004). It is therefore not surprising to find these genera within the bare patches previously inhabited by *S. alterniflora* prior to the dieback. However, their visible appearance did not result in higher chlorophyll a concentrations.

Another potential variable could be grazing on the algal mats. According to Williams and Ruckelshaus (1993), algal biomass is often regulated by the top-down effects of herbivory. Since there was standing water in the main area of dieback at all times during the study, fish were often seen in the dieback area. Some of these fish may have grazed the filamentous algae of the mats. *M. bidentatus* are known to feed mainly on detritus but have been shown to consume green algae as well (Rietsma et al., 1988) However, during the course of the study, these snails were seen mainly in the healthy condition and not within the dieback. Insects could be another possible grazer. Grazing could mean biomass did not increase although production may have.

Microphytobenthos can inhabit the top centimeters in intertidal sediment. In a study by Kelly et al. (2001), they found that some methods of coring do not detect significant differences in chlorophyll a between diverse sample sites. They found that in order to accurately determine biomass, the separation of 'photosynthetically active biomass' at the top of the sediment and 'photosynthetically inactive biomass' below surface about 1mm had to be made. The use of chlorophyll a concentrations to estimate biomass has been shown to sometimes result in overestimations due to the inclusion of plant litter in the samples. Non-living detritus may still contain large levels of chlorophyll (Ryther and Yentsch, 1957; Tsujimura et al., 2000). My sediment samples did contain some detrital material. Contrary to this could also be the underestimation of algal mat biomass using chlorophyll a concentrations as an indicator. Algal mats can contain dead material including dead cells that do not contain much chlorophyll. During the study, some of these algal mats were observed under a microscope to determine dominant genera. It was noticed during this time that some of the filamentous algal material had browned and was no longer green. Thus the algal biomass could be higher than inferred from chlorophyll a concentrations. It is possible that phaeopigements are a better measure of algal history.

My results agreed with what Keusenkothen and Christian (2004) had seen in the low marsh. Concentrations of chlorophyll a on deer trails was not significantly different than the chlorophyll a concentrations off deer trails. The correspondence is that deer trails were like the dieback areas; they are exposed areas where light was higher. My concentrations of chlorophyll a were several times higher than what Keusenkothen and Christian (2004) had found in their study (median values: 2.81mg/m^2 on trail and

3.30mg/m^2 off trail). My mean concentrations were: 7.8±3.3mg/m^2 in the dieback condition and 8.1±3.2mg/m^2 in the healthy condition.

Bacterial densities were hypothesized to be highest in the dieback condition and lowest in the healthy condition with the intermediate falling between the two. This was expected due to plant decomposition in the dieback area as well as the visible appearance of purple sulfur bacterial mats in the winter months. However, the healthy condition actually had the highest densities of bacteria, followed by the dieback, and finally the intermediate having the lowest densities. Therefore this hypothesis was rejected. Any differences that were seen may not have been ecologically significant. However, it has been shown that dissolved organic matter can be released from live belowground macrophyte tissue (Mitsch and Gosselink, 2000). Therefore the higher bacterial densities in the healthy area may indeed signify microbial communites use of this dissolved organic matter. The difference between the highest densities of bacteria in the healthy condition and the lowest densities in the dieback was less than 10%.

In a fully formed microbial mat in many salt marshes, purple sulfur bacteria are found beneath layers of diatoms and cyanobacteria. The layering is caused by successive absorption of selected wavelength bands (Zaar et al., 2003). Purple sulfur bacteria use H_2S as their reducing agent producing elemental sulfur. This can be further oxidized to form sulfate (Mitsch and Gooselink, 2000). Despite visible purple sulfur bacterial mats in the wintertime, bacterial density did not peak in the dieback condition during that time. The HPLC analyses revealed no differences among conditions in terms of bacteriochlorophyll concentrations. However, there was only one sampling taken in February 2006 of a small size (24 samples). Only 25% of the samples had any bacteriochlorophyll at all (two from each condition). To make determinations regarding differences it would be best to have a larger sampling.

In Christian et al. (1978), it was postulated that the microbial community in salt marsh soils displays a resistance to perturbations in plant production and nutrient status. They determined two possible reasons for this. The microbial community could be nutrient limited. If the microbes rely primarily on decomposing plant matter, then the response to an elimination of *S. alterniflora* production would be greatly buffered. Secondly, the response may be because the microbial community is spatially limited. The spatial limitation could refer to physical space or to the buildup of chemical end products that inhibit growth. Tirrell (1995) found contrasting results in her study where bacterial numbers were greatest in plots with live roots compared to devegetated plots. It was determined it might be due to the presence of the rhizosphere surrounding the live *S. alterniflora* roots. The rhizosphere provides sources of energy, carbon, and nitrogen for the bacteria through its excretion products and sloughed-off tissue.

It was hypothesized that snail densities (*Melampus bidentatus*) would be highest in the intermediate area and lowest in the dieback as this trend was observed by Silliman et al. (2005) in several marshes in the Southeast. The results showed that the highest densities were found in the healthy area surrounding the dieback, followed by healthy areas away from the dieback, then the intermediate conditions, and finally the dieback condition had the lowest density of snails. This means this hypothesis was rejected. However, one facet of the hypothesis was correct. The dieback condition did have the lowest density of snails.

The species of snails measured in this study (*M. bidentatus*) was different than the snails that have been previously studied as possibly causing increases in the effects of the dieback (*L. irrorata*). These two species feed on different things (Loomis and Hayes, 1987; Rietsma et al., 1988; Graca et al., 2000; Silliman et al., 2005). This may be why *L. irrorata* is often seen on the outer edges of the dieback (usually classified as 'intermediate' in my study) as they consume their way outward from the dieback condition (Silliman et al., 2005). *M. bidentatus* is seen in higher densities in denser *S. alterniflora* which are considered healthy areas. During my study, they were found attached to the lower part of the shoots close to the marsh surface. In Silliman et al.'s (2005) study, researchers focused on *L. irrorata*, a species that consumes and damages *S. alterniflora* shoots when grazing their fungal food. *M. bidentatus* is a species that feeds more on detritus than living plant material (Loomis and Hayes, 1987; Graca et al., 2000). The concentration of snails seen in healthy areas surrounding the dieback may not be related to consumption. It may be a movement outward from the dieback in response to habitat loss and a preference for the denser *S. alterniflora* in the healthy condition.

Sulfide concentrations were hypothesized to be higher in the dieback condition than would be in the healthy condition. This was seen with statistical significance but with significant interaction with time at Upper Phillips Creek. The dieback areas had significantly higher concentrations of sulfide than the healthy areas during the month of April. For all other months there were not significant differences among the conditions. However, in the months of July and August sulfide concentrations were higher in the dieback condition than in the healthy condition although not significantly so (5.4±2.0mM to 4.0±2.1mM in July and 2.7±2.7mM to 0.4±0.4mM in August). This was possibly due to the return of *S. alterniflora* and a reduction in hydrogen sulfide as sulfur is taken up by the plants and sulfide is oxidized by the rhizosphere (Raven and Scrimogeour, 1997). It is unknown whether *S. alterniflora* actively facilitates oxidation (Lee et al., 1999). In other studies it was seen that dieback had higher concentrations of sulfide than healthy areas (Webb and Mendelssohn, 1996; McKee et al., 2004). In the Webb and Mendelssohn (1996) study, concentrations were <0.1mM/L in the healthy donor marsh and ranged from 0.2mM/L to 0.8mM/L in the recipient dead marsh with lower elevations. In McKee et al. (2004), healthy areas had concentrations from 0mM to 0.19±0.06mM, and dieback areas had concentrations ranging from 0.15±0.02mM to 1.15mM. Sulfide concentrations higher than 1mM have been shown to reduce biomass of *S. alterniflora* (Koch and Mendelssohn, 1989). Concentrations at Upper Phillips Creek during the study period were several times higher than this concentration. However, none of the measurements in those studies or mine were taken prior to dieback so it unknown if those higher concentrations were causative or just a result of the disturbance. At an earlier study at Upper Phillips Creek, sulfide concentrations were much lower than was found in my study (55-114μ mol/L) (Thomas, 2004).

Disturbance, State Change, and Scale

Sousa (1984) defined a disturbance as ‘a discrete, punctuated killing, displacement, or damaging of one or more individuals (or colonies) that directly or indirectly creates an opportunity for new individuals (or colonies) to become established.’ This definition describes the dieback at Upper Phillips Creek. The dieback occurred rapidly in 2004 when *S. alterniflora* did not regrow. The bare area created an opportunity for other primary producers to become established. The ground cover of the bare areas was dominated at different times by filamentous algae (summer) and purple sulfur bacteria (winter).

Small disturbances often occur in salt marshes and affect *S. alterniflora* growth. These include wrack deposition (Tolley and Christian, 1999), ice damage (Ewanchuk and Bertness, 2004), submergence (Mendelssohn and McKee, 1988; Webb and Mendelssohn, 1996), and grazing by muskrat and geese (http://wetland.neers.org). The dieback at Upper Phillips Creek created a disturbance that affected the end-of-year biomass among the conditions and also the mass per stem. End-of-year biomass was found to be highest in the healthy areas and lowest in the dieback areas. This is not surprising since the healthy areas were denser in *S. alterniflora* cover (>85% cover by definition) than the dieback or intermediate. Site choices using haphazard throws into the dieback could randomly allow for bare spots to be sampled. Therefore the end-of-year biomass was merely confirmation that the conditions defined as dieback, intermediate, and healthy were appropriate. The mass per live stem was also found to be highest in the healthy condition than the dieback condition with the intermediate condition found between the two. In terms of the mass per dead stem, the intermediate condition had the same mass as the healthy and the dieback conditions, but the dieback and healthy conditions were significantly different than one another. The dieback condition had the lowest mass per dead stem and the healthy had the highest mass per dead stem. In both cases this may indicate a hardier stem within the healthy condition than the intermediate or dieback.

The dieback also created the possibility for changes in some abiotic factors in the marsh. The presence or absence of vegetation can cause differences in the soil salinities. While evaporation is reduced by vegetation cover, transpiration is increased. Whether the rates of evaporation or transpiration are higher depends on environmental setting and vegetation type (Mitsch and Gosselink, 2000). Pore water salinities were significantly higher in the dieback than in the healthy conditions. In August 2006, the pore water salinities were the higher than the other sampling months over the course of the study (55ppt in dieback and 46ppt in the healthy). None of the salinities exceeded lethal levels of *S. alterniflora* which range from 63ppt to 93ppt depending on genotype (Hester et al., 2001). In another dieback study, pore water salinity was higher in the dieback (32ppt) than in the healthy areas (29ppt) (McKee et al., 2004). However, in Ogburn and Alber (2006), levels were similar among the dieback and healthy conditions in the *S. alterniflora* sites (~25ppt) but were higher in the healthy condition (31-34ppt) than the dieback condition (18-24ppt) at the *J. roemerianus* site.

The surface salinities showed no significant difference among the conditions. This was not surprising because at Upper Phillips Creek there are generally several centimeters of standing water in the low marsh. Therefore the surface rarely dried out in the area where 7 of the 8 transects were located, and salt is unlikely to accumulate due to evaporation. Transect 4 is the only sample site located in the transition and high marsh and the only one that had periods of drying out. However, this transect did not have a higher salinity than the others.

Dieback had the highest mean pH values for surface waters overall. This was different than the other dieback studies which showed pH values to be similar among the conditions (Mendelssohn and McKee, 1988; McKee et al., 2004; Ogburn and Alber, 2006). However, these studies measured pore water pH and it ranged from 6.2 to 7.5. Soils that have been previously drained and then flooded have a tendency to move to a neutral pH ranging from 6.7 – 7.2 (Mitsch and Gosselink, 2000). In the McKee study (2004) there was evidence of soil acidification because dieback areas acidified upon oxidation whereas the control areas did not. At Upper Phillips Creek, the dieback areas' surface waters were more alkaline. This could be because of the filamentous green algal mats that were often present on the surface of the open dieback areas. High algal productivity can drive the pH higher by pulling CO_2 out of the water and shifting the carbonate equilibrium (Mitsch and Gosselink, 2000). The 2 months where pH was highest in the dieback (April and May 2006) were the first two months where algal mats began to dominate the dieback ground cover.

With no vegetation there is no canopy to provide shade. However, there was only one month where there were differences among the conditions in terms of surface water temperature. Dieback in May 2006 had the highest average temperature (25.6±1.5ºC) and healthy had the lowest average temperature (20.0±2.3ºC). The intermediate condition had a mean temperature between the other two (22.9±1.8ºC). For this month (May 2006), temperatures did not exceed numbers that would limit growth.

At this point it is not obvious that this disturbance has resulted in a state change from low marsh to tidal mud flat as the dieback area appears to be recovering. According to Brinson et al. (1995), the alteration between mineral low marsh to intertidal mud flat can be cyclic instead of unidirectional. Although some recovery had occurred indicating possible change back to low marsh, elevation differences could prevent a full recovery. Elevation was highest in the healthy areas, followed by those categorized as intermediate, and finally lowest in dieback areas. Lower elevations allow water to pool and increase periods of plant submergence. Increased submergence can lead to a loss in vegetation due to waterlogging (Mendelssohn and McKee, 1988). However, in this case, elevations were measured 2 years after the dieback event. It is unknown if the dieback areas had lower elevations at the time of the occurrence or if the differences in elevation are a result of plant decomposition and subsequent erosion or aerenchyma collapse. In a study by DeLaune et al. (1994), it was shown that peat collapse rather than erosion caused the conversion of marsh to open water in an area of marsh that died. They believe that peat collapse following plant death may originate from an increase in the decomposition rate of root tissue and loss of root turgor. *S. alterniflora* has a dense root network containing aerenchyma. These gas filled aerenchyma occupy a significant amount of root volume. If the loss of turgor in thousands of these roots occurred, it could perhaps be one mechanism of peat collapse (DeLaune et al., 1994). However, whether the elevation were lower prior to or since the dieback, increased flooding in the lowered elevations in the dieback area could affect the revegetation of this area.

The study was designed to examine the effects of the dieback at a variety of scales. The sediment cores measured differences at the centimeter-squared scale in terms of chlorophyll concentrations and bacterial densities. The variables of salinity, pH, and temperature were made in permanent 1-meter plots. The 30-meter transects allowed for changes in vegetation cover to be measured. Changes at this largest scale were accounted for by measuring differences that occurred within the perimeter flagging set-up in 2005. The dieback seems to have affected the marsh at primarily the larger scales only. At the centimeter-squared scale, chlorophyll concentrations were not significantly different, although community shifts did occur. Although the bacterial densities were significantly different, as stated earlier, the differences may not be ecologically significant. At the meter plot scale, there were differences seen in many of the variables among conditions. At the 30-meter transect scale and within the perimeter flagging, there were obvious differences among the conditions in terms of vegetation cover. Although none of the prior dieback studies have discussed the effects of the disturbance in relation to scale differences, Sousa (1984) addressed it. He said reproductive traits of the organisms involved prior to and after the disturbance can affect the rate at which the community can recover from the disturbance. The bacteria were seen to have either responded less or recovered more quickly than the vegetation at the site. In terms of Sousa's argument this would make sense because if the bacterial densities were affected, their rapid turnover rate compared to *S. alterniflora* would allow them to recover more quickly.

Recovery and the Intermediate Condition

Many of the previous dieback studies have revealed some degree of recovery through the reestablishment of *S. alterniflora* in previously disturbed areas: over 90% in the deSouza and Yoch (1997) study, 0-58% in the McKee et al. (2004) study, rhizome extension in the Ogburn and Alber (2006) study, and regrowth at many New England sites (http://wetland.neers.org, 2006). The Upper Phillips Creek Marsh dieback has also shown some recovery. During the first year, no significant regrowth was seen. By the second summer, the reestablishment of *S. alterniflora* had occurred within the flagging perimeter (3% decrease in main dieback area), on the 30-meter transect scale (increases in the healthy condition within all 8 transects) and also within the established 1-meter plots within the transects (increases in average percent cover starting in June 2006). The rate of expansion of *S. alterniflora* from 2005 to 2006 using the perimeter flagging was similar to what was seen by Hartman (1988) in a wrack disturbed patch in New England (12cm/yr compared to 11.4±8.2cm/yr in my study).

Although direct comparisons cannot be made, visually, at the transect level, more recovery occurred than within the main dieback area. This observation agrees with Sousa (1984). He said that the size and shape of a disturbed patch affects repopulation because physical and biological environments vary with patch size such as light intensity and surface temperature. Small patches have a greater perimeter-to-area ratio than large patches. If the organism that is recolonizing the patch is adjacent to the patch edges and will revegetate patch by lateral encroachment, then small patches will recolonize small clearings faster than large clearings. Allison (1995) made the same observation in his study on small-scale disturbances in a California salt marsh. Vegetative spread is slower in larger-scale disturbances than in the smaller-scale. It appeared that rhizome extension and not seed dispersal was the primary manner in which recovery occurred. If seed dispersal had occurred the patch size would be less relevant as recovery would have been comparable between the large and small patches.

Recovery along the perimeter of the main dieback area may have been less than at the transect level not only due to the spread of *S. alterniflora* by lateral encroachment, but also by algal mat cover during peak growing months. A study by van Hulzen et al. (2006), found that algal mats growing from May to November had a severe negative impact on *Spartina anglica* growth. They found that non-lethal mat cover during a season decreased plant vigor during the next season by decreasing belowground carbon storage. Light reduction, and the effects of lowered elevations that are already stressing the plants due to soil anaerobiosis, also cause negative effects. In my study the algal mats dominated from July 2005 to October 2005 and again from July 2006 to August 2006 when the study ended. It would have been interesting to have designed an experiment to remove algal mats from a section of the main dieback area and see if recovery occurred more quickly.

One of the objectives of this study was to consider the intermediate condition. I wanted to determine if this condition was transient to either the dieback or healthy conditions or whether the intermediate was an endpoint to a stable unchanging middle ground. Based on the ground cover of plants during the first year, 2004-2005, it was unclear because no real regrowth occurred. However, from 2005 to 2006, it seems evident that the intermediate is transient moving toward a healthy condition. During that time, there had been some recovery to the healthy condition. It appears the dieback condition has been transitioning to the intermediate and healthy conditions and the intermediate condition transitions to the healthy condition. This indicates the intermediate is not transitioning into dieback. Increases in plant cover occurred in the landscape scale (flag perimeter), at the 30-meter transect scale, and within the 1-meter plot scale. Visually, at the landscape scale, most of the recovery appeared to have occurred in the area surrounding the main dieback, which was categorized as intermediate condition. At the 30-meter and 1-meter plot scale, the recovery shifted areas previously described as dieback to intermediate and areas described as intermediate areas to healthy. Given enough time and positive abiotic conditions, it seems possible that this intermediate condition will continue to fill-in and recovery will occur at Upper Phillips Creek Marsh.

CONCLUSIONS

After two years the dieback event at Upper Phillips Creek Marsh showed signs of recovery through the regrowth of *S. alterniflora*. During the course of the study there were differences among the conditions for sulfide concentrations, pore water salinities, pH, elevation, snail densities, and ground cover. However, sulfide concentrations were only different during one month and snail densities were not different among the conditions according to the terms of the hypotheses. Chlorophyll concentrations and bacterial densities did not differ among the conditions as had been hypothesized. Therefore the only hypothesis that could be accepted for one month of the study is that sulfide concentrations are higher in the dieback condition than the healthy condition.

There was some recovery at the site that indicates the cause of the dieback is no longer present and that, given enough time, a full recovery may occur. The intermediate condition appears to be transitioning toward a healthy condition. The dieback disturbance affected the variables to different degrees depending on the scale. The measurements made at the cm^2-scale showed minimal differences while some of the measurements made at the 1-m^2 scale and 30-m scale did show significant differences. This indicates that while the dieback affects the vegetation and some of the environmental variables, some of the smaller scale variables are resistant to disturbance.

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APPENDIX A. BACTERIA PROTOCOL

Field Sample Collection:

1. 18ml of 2% bacteria-free formalin is placed in an autoclaved scintillation vial.
2. One sample is taken per condition per transect for a total of 24 samples per sampling. Sediment cores are taken from each site with a syringe corer. $2cm^3$ sediment cores were taken and placed into the vials. Samples were refrigerated until processed.

Lab Methods: All glassware should be autoclaved prior to work.

Stock Solutions: All solutions need to be bacteria free. Filter solutions using 0.2µm pore size filter and tower filter rig.

- 2% formalin: Use 50mL of 40% formaldehyde solution per 1000mL water.

- DAPI (0.1mg/ml concentration): Dissolve 0.001gm of DAPI in 10ml DIH_2O.

- Tetrasodium Pyrophosphate (TSP) (0.1M): MW= 265.9g.

  265.9g/1L = 1M, 26.59g/1L = 0.1M, 2.659g/100ml = 0.1M.

1. Make stock solution of dilute field sample with 0.1M:
   Combine 0.25ml of field sample with 9.25ml TSP into autoclaved scintillation vial.
2. Sonicate (Fisher Scientific Sonicator FS30) diluted sample for 10 minutes.
3. Stain diluted sample. Use stock DAPI to obtain a final DAPI concentration of 5µg/ml in 10ml diluted sample. Add 0.5ml of stock DAPI to diluted sample to give final volume of 10ml of stained diluted sample with DAPI concentration of 5µg/ml.
4. Incubate stained diluted sample in refrigerator for 20 minutes (wrap in foil to inhibit light).
5. Rinse the tower with 2% bacteria-free formalin prior to and after filtering. Filter 1ml of stained diluted sample onto black filter (0.2µm pore size) using small tower filter rig. Place a larger pore-sized filter below the black filter (0.8µm pore size) to aid in evenly dispersing the bacteria.
6. Place a drop of oil on a slide and place a coverslip over it. Once the filtering is complete, remove the coverslip, place the black filter on the slide, add another drop of oil on top of filter and replace coverslip on top.
7. Count the bacteria in 10 fields using a Nikon Optiphot model XF-EF (AND FILTERS). Heterotrophic bacteria will fluoresce blue.
   Rules for counting:
   - Bacteria should be no larger than 1/16 the width of a grid square.
   - Count bacteria on only 2 edges.

8. Calculations: [(mean per field) * 51,000 (number of fields) * dilution factor (total volume/sample volume) * dilution factor (0.25ml field sample in 10ml diluted sample)] / [(ml of sample filtered) * dilution]

   Example of calculation:
   [55 * 51,000 * 10.5 (21ml total volume/2ml field sample) * 40 (10ml total volume diluted sample/ 0.25ml field sample)] / [1ml sample filtered * 1 (dilution factor)] = 1.18 * 10^9 bacteria/ml

APPENDIX B. CHLOROPHYLL A PROTOCOL

Field Sample Collection:

1. Samples are collected with a 3.7cm diameter beveled plumbing pipe. A stopper with a dowel glued to one end is used to create suction and then to gently expel core from pipe thereby causing minimal compression.
2. The cores are placed in a separate plastic tube covered in aluminum foil so that subsamples could be taken back in the lab.
3. Cores are placed in the freezer as soon as possible after collection.

Lab Methods: All lab methods should be performed in darkness.

1. The cores are cut to a depth of 0.5cm. This core is divided in half.
2. The halves are placed in two labeled Falcon tubes.

Materials:

- 15mL Falcon tubes
- 10ml solution per sample of 45% acetone, 45% methanol, and 10% distilled
- Thermolyne Maxi Mix II Vortex
- Sorvall General Purpose RC-3 automatic refrigerated centrifuge
- Turner Designs TD-700 fluorometer

Day prior to reading:

1. 10ml acetone solution (45% acetone, 45% methanol, and 10%DI water) is added to the 15mLFalcon tubes.
2. Vortex samples and place in cold room for 12-20hrs.

Day of sample processing.

1. **Using the fluorometer.**
    - The lenses to be used are 2-64 (black) and 5-60 (blue).
    - Plug in machine.
    - Turn power on.
    - Press lamp start switch. (Blue light should come on.)
    - Mode should be on end point. Let lamp warm for 15 minutes.
2. Spin centrifuge tubes at 1500rpm for 30 minutes at 4°C.
3. While samples are spinning make standards.
4. Make a standard curve. Add appropriate amount of 45/45/10 acetone/methanol/water mixture to 6 fluorometer tubes (There will be 5 standards and 1 blank). Add appropriate amounts of the chlorophyll stock (in freezer). Stock concentration is 12.5mg/L.

Standard	µl added	45/45/10 ml added	µg/l (in 4ml = 0.004L)
1	9	3.991	28
2	17.60	3.982	55
3	88	3.912	275
4	176	3.824	550
5	264	3.736	825

5. Blank the fluorometer with 45/45/10 solution. Wipe each standard tube with a Kimwipe and place each standard in the fluorometer to be read.
6. Read all the standards.
7. Place 2 drops 0.4N hydrochloric acid into the standards, vortex, and reread. Do not allow this to sit long before they are read.
8. For samples: Place 4mL of the extracted volume into the fluorometer tubes and read. Read 5 samples at a time (manageable number). Then add 2 drops of acid, vortex, and reread.
9. Discard samples in appropriate waste container and rinse tubes with deionized water before reusing.
10. Continue until all samples have been read without acid and then with acid.

APPENDIX C. SULFIDE PROTOCOL

Field sample collection:

1. An in-situ pore-water sampler (equilibrator) modified from Otte and Morris (1994) is randomly placed into areas of the marsh categorized as either dieback or healthy.
2. The equilibrator is vertical placed to a known depth within the sediment and left for 4-6 weeks at which time the water in the vials will have reached equilibrium with the surrounding pore-water (Otte and Morris, 1994).
3. At the time of collection, 5ml of 10mM zinc acetate is drawn into a 10ml luer-lok™ syringe equipped with an 18G1.5 needle and a 3-way air-tight valve. 5ml of liquid is then drawn from the scintillation vials into the syringe. The zinc acetate fixes the sulfide immediately. The samples are kept at room temperature in the dark and processed as soon as possible.

Lab methods:

Reagents: MW=g/L = 1M

1. Zinc acetate:

- preservative (precipitates sulfides as their zinc salts and makes them less sensitive to oxidation)
- stable for several weeks (~1month)
- Desired concentration = [Zinc acetate] = 10mM
- MW = 219.49g/mol

219.49g/mol * (1mol/1000mM) = 0.21949g/mM * 10mM = 2.1949g in 1L in DI water
2.1949g/4 = **0.5487g in 250ml DI water**

2. Diamine reagent: (N,N-dimethyl-p-phenylenediamine sulfate + ferric chloride (FeCl3 *6H2O) in 6N HCL (50% HCL))

- stable for several months in dark bottle, refrigerate (~2month)
- 0.4ml of diamine reagent needed per 5ml sample
- to make the most concentrated diamine reagent (Cline, 1969): **0. 2g** N,N-dimethyl-p-phenylenediamine sulfate + **0. 3g** ferric chloride to **5ml cool 6N hydrochloric acid** that is added slowly to help dissolve dry ingredients
- When determining how much to make, remember to account for standards.

3. Standards (Sodium Sulfide)

- Refrigerated
- MW = 240.18g/mol
  240.18g/mol * (1mol/1,000,000mM) = 0.0002402 g/µM,
  0.0002402 g/µM * (1mol/1000mM) = 0.2402g/mM * (1L/1000ml) = 0.0002402g/ml * 100ml = 0.02402g in 100ml deaerated DI water for a 1mM stock solution

So for 250ml of deaerated DI water add 0.060g of sodium sulfide for a 1mM stock solution.

The Standard Curve: Standards must be made up and fixed with zinc acetate under anoxic conditions.

1. Prior to turning on nitrogen, setup scintillation vials for the standards. Label the vials and place the appropriate amount of water into each one. (See chart below.) Place the vials into the glove bag with the caps off.

2. A glove bag is setup with a nitrogen tank attached. A tube from the nitrogen tank is fitted through the small hole in the back of the bag. There are three knobs on the tank; the smallest one and largest ones are turned counter-clockwise to open while the medium knob is turned clockwise to open.

3. Once the nitrogen is on, allow 20-25 minutes for the bag to become anoxic. The tube can be placed directly in the 250mL water to be used for making sodium sulfide.

4. After 25minutes, add 0.06g sodium sulfide to 250mL deaerated water.

5. Swirl the flask until the sodium sulfide is dissolved into the water. Add 250mL of zinc acetate to fix. Once the sodium sulfide is fixed with zinc acetate, the nitrogen can be turned off and the remaining steps completed outside of the glove bag.

6. Add the appropriate amounts of stock to each of the scintillation vials. (See chart below.)

Standards	(Stock[]/working[])	Final column/coln.II
0uM/L	0	0mL in 20mL H20
100uM/L	10	2mL in 18mL H20
200uM/L	5	4mL in 16mL H20
300uM/L	3.33	6mL in 14mL H20
400uM/L	2.5	8mL in 12mL H20
500uM/L	2	10mL in 10mL H20
600uM/L	1.67	12mL in 8mL H20
700uM/L	1.43	14mL in 6mL H20
800uM/L	1.25	16mL in 4mL H20
900uM/L	1.11	18mL in 2mL H20
1000uM/L	1	20mL in 0mL H20

7. Five-ml of each standard is placed into a scintillation vial. 0.4ml of the concentrated diamine reagent is added to the scintillation vial and the solution is allowed to sit for 20 minutes.

8. During this 20 minutes, setup the spectrophotometer. Turn the spectrophotometer on and look for the H2S program where the absorbance is setup for 670nm. Turn the bulb on and allow it to warm up for 20 minutes.

9. The concentrated diamine is too dark to be read on the spectrophotometer so the standards are diluted 8X (1:7). Add 7mL water to each of a set of scintillation vials. Add 1mL of the dyed standards to the vials. Mix well.

10. Blank the machine with a cuvette of water dyed with diamine ([0uM/L] – See chart above.). Once the cuvette is filled, click on the BLANK button at the bottom left of the screen. Then hit READ SAMPLES to record the blank. For the other samples, just click on READ SAMPLES at the top left of the screen. Aspirate the fluid out of the cuvette so that it does not have to be removed after each sample. Rinse with DIH_2O between readings. Reread the blank after the standards are read.
11. Once the standard curve is complete, setup the samples from the syringes. 5mL of each sample is placed into a scintillation vial. 0.4mL of the diamine reagent is added. Allow the samples to sit for 20 minutes.
12. These samples will need to be diluted 51X(1:50). Add 5mL of water to each of a set of scintillation vials. Add 0.1mL of the dyed field sample to the water. Mix well.
13. Prior to reading these samples a new blank is made. Take the original 0uM/L dyed standard and dilute it the same way as the samples (5mL water to 0.1mL dyed solution). BLANK the machine using this sample and also hit READ SAMPLES to record it.
14. Now read each sample. Aspirate the fluid out of the cuvette so that it does not have to be removed after each sample. Rinse the cuvette with DIH_20 between samples. Reread the dyed blank at the end.
15. Print results before hitting the QUIT button. The spectrophotometer will not save them for you.

APPENDIX D. Sulfide and pore water salinity data. Values of –1 indicate missing data.

Condition	Layer	Month	Sulfide (uM)	PoreH20 sal.(ppt)
Dieback	1	Jan '06	3064.16	21
Dieback	2	Jan '06	7372.8	25
Dieback	3	Jan '06	7608.28	27
Dieback	4	Jan '06	7409.03	25
Dieback	1	Jan '06	1761.75	22
Dieback	2	Jan '06	7225.56	22
Dieback	3	Jan '06	7033.32	29
Dieback	4	Jan '06	7217.38	31
Dieback	1	Jan '06	5189.85	11
Dieback	2	Jan '06	6220.56	10
Dieback	3	Jan '06	5408.96	11
Dieback	4	Jan '06	6201.28	14
Dieback	1	Feb '06	-1	-1
Dieback	2	Feb '06	-1	-1
Dieback	3	Feb '06	6868.78	25
Dieback	4	Feb '06	5859.37	30
Dieback	1	Feb '06	2463.32	21
Dieback	2	Feb '06	7632.28	24
Dieback	3	Feb '06	7802.79	22
Dieback	4	Feb '06	6970.98	25
Dieback	1	Feb '06	4583.32	23
Dieback	2	Feb '06	7349.95	26
Dieback	3	Feb '06	6500.94	25
Dieback	4	Feb '06	6195.34	25
Dieback	1	April '06	217.75	34
Dieback	2	April '06	3370.51	36
Dieback	3	April '06	114.04	28
Dieback	4	April '06	9705.11	17
Dieback	1	April '06	64.47	35
Dieback	2	April '06	8247.53	40
Dieback	3	April '06	7921.03	26
Dieback	4	April '06	-1	20
Dieback	1	April '06	-1	48
Dieback	2	April '06	-1	49
Dieback	3	April '06	8588.28	-1
Dieback	4	April '06	10209.96	20
Dieback	1	May '06	3863.24	31
Dieback	2	May '06	5439	32
Dieback	3	May '06	5247.55	29
Dieback	4	May '06	5082.12	26
Dieback	1	May '06	2194.2	32
Dieback	2	May '06	1727.36	30
Dieback	3	May '06	5569.58	34
Dieback	4	May '06	7150.25	33

Dieback	1	May '06	1957.1	35
Dieback	2	May '06	5088.5	36
Dieback	3	May '06	6081.09	-1
Dieback	4	May '06	3612.39	22
Dieback	1	June '06	3380.67	38
Dieback	2	June '06	8925.7	41
Dieback	3	June '06	7941.33	41
Dieback	4	June '06	7801.6	40
Dieback	1	June '06	6232.48	39
Dieback	2	June '06	2888.14	44
Dieback	3	June '06	1771.73	42
Dieback	4	June '06	7634.63	44
Dieback	1	June '06	3615.41	26
Dieback	2	June '06	71.26	44
Dieback	3	June '06	6807.45	42
Dieback	4	June '06	2095.89	40
Dieback	1	July '06	0	37
Dieback	2	July '06	7836.07	37
Dieback	3	July '06	6336.33	40
Dieback	4	July '06	6251.7	34
Dieback	1	July '06	138.43	30
Dieback	2	July '06	1157.87	32
Dieback	3	July '06	5985.49	35
Dieback	4	July '06	4131	38
Dieback	1	July '06	2459.21	27
Dieback	2	July '06	7185.4	37
Dieback	3	July '06	5351.64	39
Dieback	4	July '06	4063.19	40
Dieback	1	Aug '06	4855.26	50
Dieback	2	Aug '06	3056.19	55
Dieback	3	Aug '06	3936.67	78
Dieback	4	Aug '06	7765.78	40
Dieback	1	Aug '06	4875.19	56
Dieback	2	Aug '06	3899.16	42
Dieback	3	Aug '06	-1	64
Dieback	4	Aug '06	4959.6	34
Dieback	1	Aug '06	360.22	50
Dieback	2	Aug '06	884.29	54
Dieback	3	Aug '06	0	64
Dieback	4	Aug '06	0	60
Dieback	1	Oct '06	3347.45	35
Dieback	2	Oct '06	5785.67	41
Dieback	3	Oct '06	7430.03	49
Dieback	4	Oct '06	7119.39	47
Dieback	1	Oct '06	6169.45	35
Dieback	2	Oct '06	7749.94	44
Dieback	3	Oct '06	7681.42	48
Dieback	4	Oct '06	7648.97	50

Dieback	1	Oct '06	3881.67	34
Dieback	2	Oct '06	6678.94	40
Dieback	3	Oct '06	6581.58	48
Dieback	4	Oct '06	5484.82	52
Healthy	1	Jan '06	318.52	6
Healthy	2	Jan '06	2838.62	10
Healthy	3	Jan '06	6867.38	10
Healthy	4	Jan '06	7154.27	11
Healthy	1	Jan '06	4692.02	24
Healthy	2	Jan '06	7955.94	25
Healthy	3	Jan '06	6862.71	23
Healthy	4	Jan '06	4082.6	30
Healthy	1	Jan '06	4138.11	19
Healthy	2	Jan '06	5116.23	19
Healthy	3	Jan '06	5857.12	25
Healthy	4	Jan '06	6010.21	29
Healthy	1	Feb '06	1677.05	24
Healthy	2	Feb '06	6478.68	26
Healthy	3	Feb '06	7178.94	25
Healthy	4	Feb '06	7392.96	25
Healthy	1	Feb '06	1865.27	24
Healthy	2	Feb '06	7076.73	25
Healthy	3	Feb '06	7345.9	22
Healthy	4	Feb '06	7365.64	24
Healthy	1	Feb '06	1863.75	25
Healthy	2	Feb '06	4077.86	25
Healthy	3	Feb '06	7624.69	23
Healthy	4	Feb '06	7293.28	25
Healthy	1	April '06	0	32
Healthy	2	April '06	0	20
Healthy	3	April '06	-1	-1
Healthy	4	April '06	-1	20
Healthy	1	April '06	0	42
Healthy	2	April '06	0	22
Healthy	3	April '06	881.58	32
Healthy	4	April '06	173.87	18
Healthy	1	April '06	-1	40
Healthy	2	April '06	-1	-1
Healthy	3	April '06	-1	21
Healthy	4	April '06	77	21
Healthy	1	May '06	1761.72	34
Healthy	2	May '06	2839.72	32
Healthy	3	May '06	5871.48	29
Healthy	4	May '06	6672.12	20
Healthy	1	May '06	229.16	32
Healthy	2	May '06	2769.04	27
Healthy	3	May '06	5500.36	25
Healthy	4	May '06	3699.28	25

Healthy	1	May '06	0	34
Healthy	2	May '06	2065.1	33
Healthy	3	May '06	5811.1	31
Healthy	4	May '06	6321.63	30
Healthy	1	June '06	5583.45	39
Healthy	2	June '06	7731.04	36
Healthy	3	June '06	1863.25	35
Healthy	4	June '06	7869.37	44
Healthy	1	June '06	2407.48	40
Healthy	2	June '06	1578.9	42
Healthy	3	June '06	6646.77	38
Healthy	4	June '06	1268.71	41
Healthy	1	June '06	2811.29	36
Healthy	2	June '06	8239.64	40
Healthy	3	June '06	3822.9	37
Healthy	4	June '06	6958.36	27
Healthy	1	July '06	0	34
Healthy	2	July '06	677.01	35
Healthy	3	July '06	1278.36	32
Healthy	4	July '06	5151.56	30
Healthy	1	July '06	163.65	35
Healthy	2	July '06	3322.29	34
Healthy	3	July '06	7473.46	33
Healthy	4	July '06	4218.43	32
Healthy	1	July '06	165.33	32
Healthy	2	July '06	5421.13	34
Healthy	3	July '06	4124.27	34
Healthy	4	July '06	4180.88	32
Healthy	1	Aug '06	0	45
Healthy	2	Aug '06	0	50
Healthy	3	Aug '06	34.29	49
Healthy	4	Aug '06	476.29	46
Healthy	1	Aug '06	35.47	44
Healthy	2	Aug '06	632.22	46
Healthy	3	Aug '06	1189.12	50
Healthy	4	Aug '06	732.47	46
Healthy	1	Aug '06	14.95	48
Healthy	2	Aug '06	65.36	46
Healthy	3	Aug '06	339.71	43
Healthy	4	Aug '06	196.67	42
Healthy	1	Oct '06	5333.36	36
Healthy	2	Oct '06	7726.24	38
Healthy	3	Oct '06	7395	38
Healthy	4	Oct '06	7793.73	40
Healthy	1	Oct '06	1408.42	36
Healthy	2	Oct '06	7626.3	39
Healthy	3	Oct '06	7843.7	40
Healthy	4	Oct '06	2563.39	40

Healthy	1	Oct '06	6961.76	38
Healthy	2	Oct '06	6547.58	40
Healthy	3	Oct '06	8933.24	40
Healthy	4	Oct '06	7240.45	39

APPENDIX E. Temperature, Surface water salinity, and pH data. Values of –1 indicate missing data.

Transect	Condition	Month	Temp (°C)	Surface sal (ppt)	pH
1	Dieback	Jan-06	9	10	-1
1	Dieback	Jan-06	9	10	-1
2	Dieback	Jan-06	10	14	-1
2	Dieback	Jan-06	10	14	-1
3	Dieback	Jan-06	8	8	-1
3	Dieback	Jan-06	8	8	-1
4	Dieback	Jan-06	8	9	-1
4	Dieback	Jan-06	8	10	-1
5	Dieback	Jan-06	10	10	-1
5	Dieback	Jan-06	9	10	-1
6	Dieback	Jan-06	8	10	-1
6	Dieback	Jan-06	9	10	-1
7	Dieback	Jan-06	10	11	-1
7	Dieback	Jan-06	10	11	-1
8	Dieback	Jan-06	10	12	-1
8	Dieback	Jan-06	10	12	-1
1	Dieback	Feb-06	25	9	-1
1	Dieback	Feb-06	23	6	-1
2	Dieback	Feb-06	25	3.5	-1
2	Dieback	Feb-06	22	6	-1
3	Dieback	Feb-06	20	2	-1
3	Dieback	Feb-06	20	4	-1
4	Dieback	Feb-06	20	2.5	-1
4	Dieback	Feb-06	20	2.5	-1
5	Dieback	Feb-06	29	-0.5	-1
5	Dieback	Feb-06	25	5.5	-1
6	Dieback	Feb-06	29	-0.5	-1
6	Dieback	Feb-06	25	3.5	-1
6	Dieback	Feb-06	14	9	-1
7	Dieback	Feb-06	14	9	-1
7	Dieback	Feb-06	25	5	-1
8	Dieback	Feb-06	25	5.5	-1
8	Dieback	Feb-06	20	-0.5	-1
1	Dieback	Apr-06	36	20	8.41
1	Dieback	Apr-06	36	27.8	8.04
2	Dieback	Apr-06	34	22.8	7.05
2	Dieback	Apr-06	36	20	7.46
3	Dieback	Apr-06	35	28.9	8.24
3	Dieback	Apr-06	36	24.4	8.47
4	Dieback	Apr-06	-1	-1	-1
4	Dieback	Apr-06	-1	-1	-1
5	Dieback	Apr-06	36	28.9	8.59
5	Dieback	Apr-06	36	28.9	8.66
6	Dieback	Apr-06	35	21.1	8.26

6	Dieback	Apr-06	35	21.1	7.99
6	Dieback	Apr-06	36	25.6	8.02
7	Dieback	Apr-06	37	20	7.76
7	Dieback	Apr-06	37	24.4	8.01
8	Dieback	Apr-06	40	25.6	8.03
8	Dieback	Apr-06	38	24.4	8.25
1	Dieback	May-06	37	24	9.23
2	Dieback	May-06	36	24	8.24
3	Dieback	May-06	40	27	9.58
4	Dieback	May-06	28	24	8.73
5	Dieback	May-06	37	26	9.67
6	Dieback	May-06	37	26	8.86
7	Dieback	May-06	36	28	8.31
8	Dieback	May-06	37	26	8.54
1	Dieback	Jun-06	31	19	8.6
2	Dieback	Jun-06	34	20	8.26
3	Dieback	Jun-06	32	20	8.15
4	Dieback	Jun-06	32	19.5	7.94
5	Dieback	Jun-06	32	20.5	7.93
6	Dieback	Jun-06	30	20	8.37
7	Dieback	Jun-06	32	20.5	8.16
8	Dieback	Jun-06	30	20	8.21
1	Dieback	Jul-06	38	34	5.86
2	Dieback	Jul-06	40	34	5.87
3	Dieback	Jul-06	34	36	6.42
4	Dieback	Jul-06	36	36	6.39
5	Dieback	Jul-06	37	36	6.32
6	Dieback	Jul-06	35	30	4.78
7	Dieback	Jul-06	42	36	5.8
1	Dieback	Aug-06	27	34	7.01
2	Dieback	Aug-06	34	34	7.01
3	Dieback	Aug-06	28	37	6.33
4	Dieback	Aug-06	27	33	6.21
5	Dieback	Aug-06	27	35	6.67
6	Dieback	Aug-06	36	29	6.79
7	Dieback	Aug-06	33	35	6.38
1	Intermediate	Jan-06	8	10	-1
1	Intermediate	Jan-06	9	10	-1
2	Intermediate	Jan-06	8	14	-1
2	Intermediate	Jan-06	10	14	-1
3	Intermediate	Jan-06	8	7	-1
3	Intermediate	Jan-06	8	8	-1
4	Intermediate	Jan-06	8	9	-1
4	Intermediate	Jan-06	8	9	-1
5	Intermediate	Jan-06	7	8	-1
5	Intermediate	Jan-06	9	8	-1
6	Intermediate	Jan-06	9	10	-1
6	Intermediate	Jan-06	8	10	-1

7	Intermediate	Jan-06	9	13	-1
7	Intermediate	Jan-06	9	13	-1
8	Intermediate	Jan-06	10	12	-1
8	Intermediate	Jan-06	11	12	-1
1	Intermediate	Feb-06	28	-0.5	-1
1	Intermediate	Feb-06	20	2	-1
2	Intermediate	Feb-06	20	2	-1
2	Intermediate	Feb-06	29	0	-1
3	Intermediate	Feb-06	24	3	-1
3	Intermediate	Feb-06	28	1	-1
4	Intermediate	Feb-06	28	0	-1
4	Intermediate	Feb-06	24	1.5	-1
5	Intermediate	Feb-06	20	2	-1
5	Intermediate	Feb-06	20	1.5	-1
6	Intermediate	Feb-06	28	0.5	-1
6	Intermediate	Feb-06	28	-0.5	-1
7	Intermediate	Feb-06	24	3.5	-1
7	Intermediate	Feb-06	25	9	-1
8	Intermediate	Feb-06	20	2.5	-1
8	Intermediate	Feb-06	20	2.5	-1
1	Intermediate	Apr-06	34	20	7.1
1	Intermediate	Apr-06	36	20	7.77
2	Intermediate	Apr-06	34	26.1	6.87
2	Intermediate	Apr-06	36	23.9	6.65
3	Intermediate	Apr-06	37	21.1	7.91
3	Intermediate	Apr-06	38	20	7.36
4	Intermediate	Apr-06	-1	-1	-1
4	Intermediate	Apr-06	-1	-1	-1
5	Intermediate	Apr-06	35	20	7.9
5	Intermediate	Apr-06	36	24.4	7.35
6	Intermediate	Apr-06	35	28.9	8.12
6	Intermediate	Apr-06	35	26.1	8.09
7	Intermediate	Apr-06	36	27.8	7.48
7	Intermediate	Apr-06	35	26.7	6.78
8	Intermediate	Apr-06	38	25.6	7.69
8	Intermediate	Apr-06	37	26.7	7.09
1	Intermediate	May-06	33	22	8.15
2	Intermediate	May-06	36	20	8.67
3	Intermediate	May-06	34	24	8.35
4	Intermediate	May-06	28	24	7.43
5	Intermediate	May-06	36	22	8.36
6	Intermediate	May-06	34	22	8.05
7	Intermediate	May-06	38	23	8.18
8	Intermediate	May-06	35	26	8.61
1	Intermediate	Jun-06	32	17.5	8.47
2	Intermediate	Jun-06	35	19	8.67
3	Intermediate	Jun-06	34	21	8.28
4	Intermediate	Jun-06	32	19	7.2

5	Intermediate	Jun-06	34	19	8.46
6	Intermediate	Jun-06	30	20	8.83
7	Intermediate	Jun-06	30	20	8.1
8	Intermediate	Jun-06	33	20	8.32
1	Intermediate	Jul-06	40	30	6.37
2	Intermediate	Jul-06	40	30	4.63
3	Intermediate	Jul-06	35	37	6.56
4	Intermediate	Jul-06	35	34	7.01
5	Intermediate	Jul-06	40	34	6.81
6	Intermediate	Jul-06	38	35	5.86
8	Intermediate	Jul-06	39	31	4.88
1	Intermediate	Aug-06	27	29	6.83
2	Intermediate	Aug-06	33	33	7.18
3	Intermediate	Aug-06	29	33	6.52
4	Intermediate	Aug-06	26	33	6.7
5	Intermediate	Aug-06	27	28	6.37
5	Intermediate	Aug-06	-1	30	-1
6	Intermediate	Aug-06	25	35	7.17
8	Intermediate	Aug-06	32	31	6.92
1	Healthy	Jan-06	7	8	-1
1	Healthy	Jan-06	7	8	-1
2	Healthy	Jan-06	8	14	-1
2	Healthy	Jan-06	8	14	-1
3	Healthy	Jan-06	7	7	-1
3	Healthy	Jan-06	7	7	-1
4	Healthy	Jan-06	7	9	-1
4	Healthy	Jan-06	7	9	-1
5	Healthy	Jan-06	7	8	-1
5	Healthy	Jan-06	8	8	-1
6	Healthy	Jan-06	8	10	-1
6	Healthy	Jan-06	8	10	-1
7	Healthy	Jan-06	8	13	-1
7	Healthy	Jan-06	8	14	-1
8	Healthy	Jan-06	8	12	-1
8	Healthy	Jan-06	9	12	-1
1	Healthy	Feb-06	22	3	-1
1	Healthy	Feb-06	16	9	-1
2	Healthy	Feb-06	17	2.5	-1
2	Healthy	Feb-06	26	2.5	-1
3	Healthy	Feb-06	22	3.5	-1
3	Healthy	Feb-06	22	-0.5	-1
4	Healthy	Feb-06	26	0.5	-1
4	Healthy	Feb-06	17	4	-1
5	Healthy	Feb-06	19	9.5	-1
5	Healthy	Feb-06	26	5.5	-1
6	Healthy	Feb-06	22	-0.5	-1
6	Healthy	Feb-06	22	4	-1
7	Healthy	Feb-06	27	2.5	-1

7	Healthy	Feb-06	22	3	-1
8	Healthy	Feb-06	23	-0.5	-1
8	Healthy	Feb-06	27	0	-1
1	Healthy	Apr-06	36	24.4	7.17
1	Healthy	Apr-06	35	27.8	6.95
2	Healthy	Apr-06	35	23.9	6.71
2	Healthy	Apr-06	37	20.6	7.75
3	Healthy	Apr-06	36	27.8	7.56
3	Healthy	Apr-06	34	26.1	7.04
4	Healthy	Apr-06	-1	-1	-1
4	Healthy	Apr-06	-1	-1	-1
5	Healthy	Apr-06	36	23.3	7.04
5	Healthy	Apr-06	36	22.2	7.33
6	Healthy	Apr-06	33	24.4	6.71
6	Healthy	Apr-06	31	26.7	6.78
7	Healthy	Apr-06	35	23.3	6.44
7	Healthy	Apr-06	35	25.6	6.33
8	Healthy	Apr-06	36	25.6	6.24
8	Healthy	Apr-06	36	22.2	6.2
1	Healthy	May-06	35	19	7.42
2	Healthy	May-06	34	19	8.27
3	Healthy	May-06	35	19	7.38
4	Healthy	May-06	28	19	6.81
5	Healthy	May-06	36	19	8.12
6	Healthy	May-06	35	18	6.92
7	Healthy	May-06	36	22	7.86
8	Healthy	May-06	33	25	7.39
1	Healthy	Jun-06	31	18.5	7.15
2	Healthy	Jun-06	34	19	7.42
3	Healthy	Jun-06	35	19.5	7.98
4	Healthy	Jun-06	-1	-1	-1
5	Healthy	Jun-06	33	19.5	7.52
6	Healthy	Jun-06	32	18.5	6.77
7	Healthy	Jun-06	35	18	7.12
8	Healthy	Jun-06	30	20	7.55
1	Healthy	Jul-06	36	31	6.31
2	Healthy	Jul-06	38	31	6.4
3	Healthy	Jul-06	34	36	6.05
4	Healthy	Jul-06	36	31	6.5
5	Healthy	Jul-06	40	33	6.75
6	Healthy	Jul-06	34	33	6
6	Healthy	Jul-06	36	38	6.17
7	Healthy	Jul-06	38	32	5.54
7	Healthy	Jul-06	38	36	5.7
8	Healthy	Jul-06	43	36	6.31
1	Healthy	Aug-06	25	29	6.32
2	Healthy	Aug-06	34	33	7.5
3	Healthy	Aug-06	32	30	6.2

4	Healthy	Aug-06	25	30	6.76
5	Healthy	Aug-06	28	27	6.52
6	Healthy	Aug-06	-1	-1	-1
6	Healthy	Aug-06	32	29	6.81
7	Healthy	Aug-06	31	32	6.82
7	Healthy	Aug-06	32	35	8.56
8	Healthy	Aug-06	35	31	6.94

APPENDIX F. Elevation data.

Transect	Replicate	Condition	Elevation (m)
1	a	Dieback	0.9546
1	b	Dieback	0.9556
1	c	Dieback	0.9266
2	a	Dieback	0.9476
2	b	Dieback	0.9476
2	c	Dieback	0.9546
3	a	Dieback	0.9546
3	b	Dieback	0.9336
3	c	Dieback	0.9536
4	a	Dieback	1.0886
4	b	Dieback	1.0996
4	c	Dieback	1.0396
5	a	Dieback	0.9566
5	b	Dieback	0.9526
5	c	Dieback	0.9426
6	a	Dieback	0.9546
6	b	Dieback	0.9556
6	c	Dieback	0.9526
7	a	Dieback	0.9616
7	b	Dieback	0.9516
7	c	Dieback	0.9456
8	a	Dieback	0.9586
8	b	Dieback	0.9496
8	c	Dieback	0.9556
1	a	Intermediate	0.9546
1	b	Intermediate	0.9586
1	c	Intermediate	0.9576
2	a	Intermediate	0.9806
2	b	Intermediate	0.9686
2	c	Intermediate	0.9626
3	a	Intermediate	0.9776
3	b	Intermediate	0.9626
3	c	Intermediate	0.9716
4	a	Intermediate	1.0846
4	b	Intermediate	1.0976
4	c	Intermediate	1.0906
5	a	Intermediate	0.9626
5	b	Intermediate	0.9596
5	c	Intermediate	0.9636
6	a	Intermediate	0.9556
6	b	Intermediate	0.9586
6	c	Intermediate	0.9596
7	a	Intermediate	0.9566
7	b	Intermediate	0.9746

7	c	Intermediate	0.9726
8	a	Intermediate	0.9586
8	b	Intermediate	0.9676
8	c	Intermediate	0.9696
1	a	Healthy	0.9706
1	b	Healthy	0.9956
1	c	Healthy	0.9666
2	a	Healthy	0.9936
2	b	Healthy	0.9736
2	c	Healthy	1
3	a	Healthy	0.9656
3	b	Healthy	0.9806
3	c	Healthy	0.9946
4	a	Healthy	1.1296
4	b	Healthy	1.1346
4	c	Healthy	1.1246
5	a	Healthy	0.9736
5	b	Healthy	0.9846
5	c	Healthy	0.9586
6	a	Healthy	0.9676
6	b	Healthy	0.9466
6	c	Healthy	0.9676
7	a	Healthy	0.9746
7	b	Healthy	0.9946
7	c	Healthy	0.9826
8	a	Healthy	0.9716
8	b	Healthy	0.9846
8	c	Healthy	0.9746

APPENDIX G. End-of-year biomass data. Values of –1 indicate missing data.

Year	Condition	Transect	Replicate	Live stem (g)	Dead stem(g)	Dry live (g/m2)
2004	Dieback	1	1	-1	-1	1.76
2004	Dieback	1	2	-1	-1	8.48
2004	Dieback	2	1	-1	-1	24.64
2004	Dieback	2	2	-1	-1	16.96
2004	Dieback	3	1	-1	-1	0
2004	Dieback	3	2	-1	-1	0
2004	Dieback	3	3	-1	-1	71.36
2004	Dieback	4	1	-1	-1	0
2004	Dieback	4	2	-1	-1	0
2004	Dieback	4	3	-1	-1	12
2004	Intermediate	1	1	-1	-1	754.56
2004	Intermediate	1	2	-1	-1	242.24
2004	Intermediate	2	1	-1	-1	312.48
2004	Intermediate	2	2	-1	-1	336
2004	Intermediate	2	3	-1	-1	157.6
2004	Intermediate	2	4	-1	-1	47.04
2004	Intermediate	3	1	-1	-1	319.36
2004	Intermediate	4	2	-1	-1	388.48
2004	Healthy	1	1	-1	-1	523.2
2004	Healthy	1	2	-1	-1	615.68
2004	Healthy	3	1	-1	-1	614.24
2004	Healthy	3	2	-1	-1	40.64
2004	Healthy	4	1	-1	-1	960.8
2004	Healthy	4	2	-1	-1	786.56
2005	Dieback	1	2	0.5305882	-1	144.32
2005	Dieback	1	1	0.18	0.046	2.88
2005	Dieback	2	1	0.1078571	0.088	24.16
2005	Dieback	2	2	0.039	0.1128571	6.24
2005	Dieback	3	1	0.0538462	0.0666667	11.2
2005	Dieback	3	2	0.0625	0.0675	8
2005	Dieback	4	2	0.09	0.1525	1.44
2005	Dieback	4	1	0.0766667	0.1592857	14.72
2005	Dieback	5	2	0	0.0911111	0
2005	Dieback	5	1	0.1225806	0.0989474	60.8
2005	Dieback	6	2	0.18	0.1423077	2.88
2005	Dieback	6	1	0.08	0.0442857	40.96
2005	Dieback	7	2	0.1809524	0.094	60.8
2005	Dieback	7	1	0	0.0266667	0
2005	Dieback	8	2	0.1472727	0.085	25.92
2005	Dieback	8	1	0.055	0.058	7.04
2005	Intermediate	1	1	0.2139175	0.0824242	332
2005	Intermediate	1	2	0.2229825	0.09	203.36
2005	Intermediate	2	1	0.1736842	0.07775	211.2
2005	Intermediate	2	2	0.1328736	0.0693182	184.96

2005	Intermediate	3	1	0.1444444	0.1131818	124.8
2005	Intermediate	3	2	0.6742857	0.0304918	226.56
2005	Intermediate	4	2	0.2097826	0.1435	154.4
2005	Intermediate	4	1	0.1340984	0.1333333	130.88
2005	Intermediate	5	2	0.2661667	0.1884615	255.52
2005	Intermediate	5	1	0.2407843	0.119	196.48
2005	Intermediate	6	1	0.274918	0.0775	268.32
2005	Intermediate	6	2	0.3812821	0.105	237.92
2005	Intermediate	7	1	0.194	0.0821429	341.44
2005	Intermediate	7	2	0.1777	0.0782857	284.32
2005	Intermediate	8	2	0.11	0.061746	168.96
2005	Intermediate	8	1	0.1559596	0.0618182	247.04
2005	Healthy	1	2	0.4860748	0.1147761	832.16
2005	Healthy	1	1	0.5557047	0.1162338	1324.8
2005	Healthy	2	1	0.1148289	0.0530952	483.2
2005	Healthy	2	2	0.1609565	0.0756934	592.32
2005	Healthy	3	1	0.3208108	0.0808571	759.68
2005	Healthy	3	2	0.1708811	0.0882	620.64
2005	Healthy	4	2	0.7302326	0.12	502.4
2005	Healthy	4	1	0.3775373	0.1516667	809.44
2005	Healthy	5	2	0.217868	0.0748276	686.72
2005	Healthy	5	1	0.3501493	0.12925	375.36
2005	Healthy	6	2	0.5306579	0.1167742	645.28
2005	Healthy	6	1	0.5236538	0.109434	871.36
2005	Healthy	7	1	0.3964045	0.108	1128.96
2005	Healthy	7	2	0.3075275	0.0817544	895.52
2005	Healthy	8	2	0.3147205	0.1007059	810.72
2005	Healthy	8	1	0.2300629	0.0977083	585.28
2006	Dieback	1	a	0.4190909	0.1483333	147.52
2006	Dieback	1	b	0.422	0.1333333	67.52
2006	Dieback	2	a	0.1153846	0.0625	24
2006	Dieback	2	b	0.0809091	0.0368421	14.24
2006	Dieback	3	a	0.079375	0.062	20.32
2006	Dieback	3	b	0.096	0.049	15.36
2006	Dieback	4	a	0.13125	0.1528571	16.8
2006	Dieback	4	b	0.16	0.2221429	5.12
2006	Dieback	5	a	0	0	0
2006	Dieback	5	b	0	0.01	0
2006	Dieback	6	b	0.3923077	0.1588889	81.6
2006	Dieback	6	a	0	0.0933333	0
2006	Dieback	7	a	0.0777778	0.044	11.2
2006	Dieback	7	b	0.0566667	0.03	2.72
2006	Dieback	8	b	0.19125	0.1288889	48.96
2006	Dieback	8	a	0.1185185	0.0513158	102.4
2006	Intermediate	1	b	0.3003571	0.1073684	134.56
2006	Intermediate	1	a	0.3064516	0.1336364	152
2006	Intermediate	2	b	0.2114159	0.0576344	382.24
2006	Intermediate	2	a	0.1764706	0.081	96

2006	Intermediate	3	b	0.3304444	0.1525	237.92
2006	Intermediate	3	a	0.1022807	0.1011111	93.28
2006	Intermediate	4	a	0.1440625	0.144	73.76
2006	Intermediate	4	b	0.1196694	0.1834783	231.68
2006	Intermediate	5	b	0.1782143	0.0733824	159.68
2006	Intermediate	5	a	0.1903226	0.08625	94.4
2006	Intermediate	6	a	0.3678049	0.1112903	241.28
2006	Intermediate	6	b	0.5475	0.1517949	350.4
2006	Intermediate	7	a	0.1625532	0.0571429	244.48
2006	Intermediate	7	b	0.1868852	0.0718841	182.4
2006	Intermediate	8	b	0.1676699	0.0796491	276.32
2006	Intermediate	8	a	0.1847826	0.0816667	68
2006	Healthy	1	a	0.2649533	0.101573	453.6
2006	Healthy	1	b	0.3434177	0.1381308	434.08
2006	Healthy	2	b	0.2654795	0.0574419	310.08
2006	Healthy	2	a	0.1545631	0.0582759	254.72
2006	Healthy	3	a	0.2496296	0.1369474	539.2
2006	Healthy	3	b	0.2630952	0.1406061	530.4
2006	Healthy	4	b	0.4645455	0.288	327.04
2006	Healthy	4	a	0.3247273	0.1222727	571.52
2006	Healthy	5	a	0.8966667	0.2340816	817.76
2006	Healthy	5	b	0.4568966	0.2098529	424
2006	Healthy	6	a	0.4321127	0.1517797	490.88
2006	Healthy	6	b	0.4121212	0.177931	652.8
2006	Healthy	7	a	0.16272	0.0617949	325.44
2006	Healthy	7	b	0.1878333	0.073299	360.64
2006	Healthy	8	a	0.1605233	0.0743333	441.76
2006	Healthy	8	b	0.1415663	0.0657143	376

APPENDIX H. *Melampus bidentatus* Density data. Values of –1 indicate missing data.

Transect	Condition	Month	Snails/m2
1	Dieback	July '05	32
1	Dieback	July '05	64
1	Dieback	Aug '05	0
1	Dieback	Aug '05	0
1	Dieback	Sept '05	0
1	Dieback	Sept '05	48
1	Dieback	Oct '05	0
1	Dieback	Oct '05	0
1	Dieback	April '06	0
1	Dieback	April '06	0
1	Dieback	May '06	0
1	Dieback	May '06	0
1	Dieback	June '06	0
1	Dieback	June '06	32
1	Dieback	July '06	-1
1	Dieback	July '06	96
1	Dieback	Aug '06	0
1	Dieback	Aug '06	0
2	Dieback	July '05	32
2	Dieback	July '05	64
2	Dieback	Aug '05	768
2	Dieback	Aug '05	848
2	Dieback	Sept '05	512
2	Dieback	Sept '05	960
2	Dieback	Oct '05	0
2	Dieback	Oct '05	0
2	Dieback	April '06	0
2	Dieback	April '06	0
2	Dieback	May '06	0
2	Dieback	May '06	0
2	Dieback	June '06	0
2	Dieback	June '06	0
2	Dieback	July '06	-1
2	Dieback	July '06	0
2	Dieback	Aug '06	0
2	Dieback	Aug '06	0
3	Dieback	July '05	0
3	Dieback	July '05	48
3	Dieback	Aug '05	0
3	Dieback	Aug '05	0
3	Dieback	Sept '05	0
3	Dieback	Sept '05	0
3	Dieback	Oct '05	0
3	Dieback	Oct '05	0

3	Dieback	April '06	0
3	Dieback	April '06	0
3	Dieback	May '06	0
3	Dieback	May '06	0
3	Dieback	June '06	0
3	Dieback	June '06	0
3	Dieback	July '06	-1
3	Dieback	July '06	48
3	Dieback	Aug '06	0
3	Dieback	Aug '06	0
4	Dieback	July '05	0
4	Dieback	July '05	0
4	Dieback	Aug '05	0
4	Dieback	Aug '05	0
4	Dieback	Sept '05	16
4	Dieback	Sept '05	80
4	Dieback	Oct '05	0
4	Dieback	Oct '05	0
4	Dieback	April '06	0
4	Dieback	April '06	0
4	Dieback	May '06	0
4	Dieback	May '06	0
4	Dieback	June '06	0
4	Dieback	June '06	16
4	Dieback	July '06	-1
4	Dieback	July '06	0
4	Dieback	Aug '06	0
4	Dieback	Aug '06	0
5	Dieback	July '05	0
5	Dieback	July '05	0
5	Dieback	Aug '05	0
5	Dieback	Aug '05	0
5	Dieback	Sept '05	0
5	Dieback	Sept '05	0
5	Dieback	Oct '05	0
5	Dieback	Oct '05	0
5	Dieback	April '06	0
5	Dieback	April '06	0
5	Dieback	May '06	0
5	Dieback	May '06	0
5	Dieback	June '06	0
5	Dieback	June '06	16
5	Dieback	July '06	-1
5	Dieback	July '06	32
5	Dieback	Aug '06	0
5	Dieback	Aug '06	0
6	Dieback	July '05	0
6	Dieback	July '05	48

6	Dieback	Aug '05	0
6	Dieback	Aug '05	0
6	Dieback	Sept '05	0
6	Dieback	Sept '05	48
6	Dieback	Oct '05	0
6	Dieback	Oct '05	0
6	Dieback	April '06	0
6	Dieback	April '06	16
6	Dieback	May '06	0
6	Dieback	May '06	16
6	Dieback	June '06	0
6	Dieback	June '06	0
6	Dieback	July '06	-1
6	Dieback	July '06	128
6	Dieback	Aug '06	0
6	Dieback	Aug '06	176
7	Dieback	July '05	0
7	Dieback	July '05	32
7	Dieback	Aug '05	0
7	Dieback	Aug '05	32
7	Dieback	Sept '05	0
7	Dieback	Sept '05	0
7	Dieback	Oct '05	0
7	Dieback	Oct '05	0
7	Dieback	April '06	0
7	Dieback	April '06	0
7	Dieback	May '06	0
7	Dieback	May '06	0
7	Dieback	June '06	0
7	Dieback	June '06	64
7	Dieback	July '06	-1
7	Dieback	July '06	0
7	Dieback	Aug '06	0
7	Dieback	Aug '06	0
8	Dieback	July '05	0
8	Dieback	July '05	0
8	Dieback	Aug '05	0
8	Dieback	Aug '05	0
8	Dieback	Sept '05	0
8	Dieback	Sept '05	0
8	Dieback	Oct '05	0
8	Dieback	Oct '05	16
8	Dieback	April '06	0
8	Dieback	April '06	0
8	Dieback	May '06	0
8	Dieback	May '06	0
8	Dieback	June '06	0
8	Dieback	June '06	0

8	Dieback	July '06	-1
8	Dieback	July '06	0
8	Dieback	Aug '06	0
8	Dieback	Aug '06	0
1	Intermediate	July '05	144
1	Intermediate	July '05	224
1	Intermediate	Aug '05	0
1	Intermediate	Aug '05	0
1	Intermediate	Sept '05	0
1	Intermediate	Sept '05	160
1	Intermediate	Oct '05	0
1	Intermediate	Oct '05	0
1	Intermediate	April '06	0
1	Intermediate	April '06	128
1	Intermediate	May '06	0
1	Intermediate	May '06	0
1	Intermediate	June '06	80
1	Intermediate	June '06	192
1	Intermediate	July '06	-1
1	Intermediate	July '06	96
1	Intermediate	Aug '06	96
1	Intermediate	Aug '06	256
2	Intermediate	July '05	128
2	Intermediate	July '05	192
2	Intermediate	Aug '05	768
2	Intermediate	Aug '05	944
2	Intermediate	Sept '05	240
2	Intermediate	Sept '05	512
2	Intermediate	Oct '05	16
2	Intermediate	Oct '05	16
2	Intermediate	April '06	0
2	Intermediate	April '06	48
2	Intermediate	May '06	0
2	Intermediate	May '06	48
2	Intermediate	June '06	224
2	Intermediate	June '06	304
2	Intermediate	July '06	-1
2	Intermediate	July '06	368
2	Intermediate	Aug '06	80
2	Intermediate	Aug '06	912
3	Intermediate	July '05	112
3	Intermediate	July '05	144
3	Intermediate	Aug '05	0
3	Intermediate	Aug '05	0
3	Intermediate	Sept '05	176
3	Intermediate	Sept '05	240
3	Intermediate	Oct '05	0
3	Intermediate	Oct '05	0

3	Intermediate	April '06	0
3	Intermediate	April '06	0
3	Intermediate	May '06	48
3	Intermediate	May '06	352
3	Intermediate	June '06	16
3	Intermediate	June '06	256
3	Intermediate	July '06	-1
3	Intermediate	July '06	320
3	Intermediate	Aug '06	48
3	Intermediate	Aug '06	128
4	Intermediate	July '05	0
4	Intermediate	July '05	64
4	Intermediate	Aug '05	64
4	Intermediate	Aug '05	112
4	Intermediate	Sept '05	0
4	Intermediate	Sept '05	64
4	Intermediate	Oct '05	0
4	Intermediate	Oct '05	0
4	Intermediate	April '06	0
4	Intermediate	April '06	0
4	Intermediate	May '06	0
4	Intermediate	May '06	0
4	Intermediate	June '06	0
4	Intermediate	June '06	0
4	Intermediate	July '06	-1
4	Intermediate	July '06	672
4	Intermediate	Aug '06	176
4	Intermediate	Aug '06	192
5	Intermediate	July '05	112
5	Intermediate	July '05	160
5	Intermediate	Aug '05	80
5	Intermediate	Aug '05	176
5	Intermediate	Sept '05	0
5	Intermediate	Sept '05	112
5	Intermediate	Oct '05	0
5	Intermediate	Oct '05	0
5	Intermediate	April '06	0
5	Intermediate	April '06	128
5	Intermediate	May '06	64
5	Intermediate	May '06	128
5	Intermediate	June '06	48
5	Intermediate	June '06	160
5	Intermediate	July '06	-1
5	Intermediate	July '06	304
5	Intermediate	Aug '06	144
5	Intermediate	Aug '06	224
6	Intermediate	July '05	48
6	Intermediate	July '05	96

6	Intermediate	Aug '05	0
6	Intermediate	Aug '05	0
6	Intermediate	Sept '05	128
6	Intermediate	Sept '05	288
6	Intermediate	Oct '05	0
6	Intermediate	Oct '05	0
6	Intermediate	April '06	0
6	Intermediate	April '06	48
6	Intermediate	May '06	0
6	Intermediate	May '06	0
6	Intermediate	June '06	32
6	Intermediate	June '06	80
6	Intermediate	July '06	-1
6	Intermediate	July '06	480
6	Intermediate	Aug '06	288
6	Intermediate	Aug '06	480
7	Intermediate	July '05	144
7	Intermediate	July '05	208
7	Intermediate	Aug '05	416
7	Intermediate	Aug '05	912
7	Intermediate	Sept '05	0
7	Intermediate	Sept '05	128
7	Intermediate	Oct '05	0
7	Intermediate	Oct '05	96
7	Intermediate	April '06	0
7	Intermediate	April '06	64
7	Intermediate	May '06	0
7	Intermediate	May '06	32
7	Intermediate	June '06	96
7	Intermediate	June '06	192
7	Intermediate	July '06	-1
7	Intermediate	July '06	592
7	Intermediate	Aug '06	0
7	Intermediate	Aug '06	64
8	Intermediate	July '05	0
8	Intermediate	July '05	16
8	Intermediate	Aug '05	16
8	Intermediate	Aug '05	48
8	Intermediate	Sept '05	304
8	Intermediate	Sept '05	400
8	Intermediate	Oct '05	0
8	Intermediate	Oct '05	0
8	Intermediate	April '06	0
8	Intermediate	April '06	16
8	Intermediate	May '06	16
8	Intermediate	May '06	224
8	Intermediate	June '06	16
8	Intermediate	June '06	208

8	Intermediate	July '06	-1
8	Intermediate	July '06	768
8	Intermediate	Aug '06	0
8	Intermediate	Aug '06	64
1	Healthy	July '05	288
1	Healthy	July '05	416
1	Healthy	Aug '05	240
1	Healthy	Aug '05	304
1	Healthy	Sept '05	224
1	Healthy	Sept '05	448
1	Healthy	Oct '05	16
1	Healthy	Oct '05	64
1	Healthy	April '06	0
1	Healthy	April '06	64
1	Healthy	May '06	256
1	Healthy	May '06	544
1	Healthy	June '06	240
1	Healthy	June '06	528
1	Healthy	July '06	-1
1	Healthy	July '06	736
1	Healthy	Aug '06	720
1	Healthy	Aug '06	768
2	Healthy	July '05	352
2	Healthy	July '05	512
2	Healthy	Aug '05	976
2	Healthy	Aug '05	1136
2	Healthy	Sept '05	800
2	Healthy	Sept '05	1120
2	Healthy	Oct '05	48
2	Healthy	Oct '05	80
2	Healthy	April '06	96
2	Healthy	April '06	128
2	Healthy	May '06	1312
2	Healthy	May '06	1568
2	Healthy	June '06	448
2	Healthy	June '06	464
2	Healthy	July '06	-1
2	Healthy	July '06	1056
2	Healthy	Aug '06	1136
2	Healthy	Aug '06	1376
3	Healthy	July '05	256
3	Healthy	July '05	256
3	Healthy	Aug '05	288
3	Healthy	Aug '05	480
3	Healthy	Sept '05	672
3	Healthy	Sept '05	880
3	Healthy	Oct '05	0
3	Healthy	Oct '05	0

3	Healthy	April '06	128
3	Healthy	April '06	176
3	Healthy	May '06	688
3	Healthy	May '06	976
3	Healthy	June '06	208
3	Healthy	June '06	768
3	Healthy	July '06	-1
3	Healthy	July '06	1264
3	Healthy	Aug '06	64
3	Healthy	Aug '06	448
4	Healthy	July '05	48
4	Healthy	July '05	64
4	Healthy	Aug '05	96
4	Healthy	Aug '05	176
4	Healthy	Sept '05	176
4	Healthy	Sept '05	256
4	Healthy	Oct '05	0
4	Healthy	Oct '05	0
4	Healthy	April '06	96
4	Healthy	April '06	160
4	Healthy	May '06	288
4	Healthy	May '06	640
4	Healthy	June '06	320
4	Healthy	June '06	512
4	Healthy	July '06	-1
4	Healthy	July '06	784
4	Healthy	Aug '06	896
4	Healthy	Aug '06	992
5	Healthy	July '05	256
5	Healthy	July '05	352
5	Healthy	Aug '05	240
5	Healthy	Aug '05	352
5	Healthy	Sept '05	240
5	Healthy	Sept '05	304
5	Healthy	Oct '05	0
5	Healthy	Oct '05	0
5	Healthy	April '06	64
5	Healthy	April '06	128
5	Healthy	May '06	880
5	Healthy	May '06	1472
5	Healthy	June '06	208
5	Healthy	June '06	352
5	Healthy	July '06	-1
5	Healthy	July '06	752
5	Healthy	Aug '06	480
5	Healthy	Aug '06	608
6	Healthy	July '05	256
6	Healthy	July '05	368

6	Healthy	Aug '05	512
6	Healthy	Aug '05	736
6	Healthy	Sept '05	256
6	Healthy	Sept '05	480
6	Healthy	Oct '05	64
6	Healthy	Oct '05	96
6	Healthy	April '06	96
6	Healthy	April '06	224
6	Healthy	May '06	496
6	Healthy	May '06	928
6	Healthy	June '06	288
6	Healthy	June '06	480
6	Healthy	July '06	-1
6	Healthy	July '06	1776
6	Healthy	Aug '06	304
6	Healthy	Aug '06	352
7	Healthy	July '05	176
7	Healthy	July '05	224
7	Healthy	Aug '05	512
7	Healthy	Aug '05	720
7	Healthy	Sept '05	144
7	Healthy	Sept '05	240
7	Healthy	Oct '05	32
7	Healthy	Oct '05	64
7	Healthy	April '06	64
7	Healthy	April '06	160
7	Healthy	May '06	352
7	Healthy	May '06	608
7	Healthy	June '06	160
7	Healthy	June '06	416
7	Healthy	July '06	-1
7	Healthy	July '06	1280
7	Healthy	Aug '06	656
7	Healthy	Aug '06	928
8	Healthy	July '05	192
8	Healthy	July '05	240
8	Healthy	Aug '05	16
8	Healthy	Aug '05	80
8	Healthy	Sept '05	336
8	Healthy	Sept '05	512
8	Healthy	Oct '05	64
8	Healthy	Oct '05	96
8	Healthy	April '06	96
8	Healthy	April '06	176
8	Healthy	May '06	1232
8	Healthy	May '06	1776
8	Healthy	June '06	160
8	Healthy	June '06	528

8	Healthy	July '06	-1
8	Healthy	July '06	672
8	Healthy	Aug '06	976
8	Healthy	Aug '06	1216
9	Healthy_away	May '06	256
9	Healthy_away	May '06	288
9	Healthy_away	May '06	304
9	Healthy_away	May '06	368
9	Healthy_away	May '06	512
9	Healthy_away	May '06	576
9	Healthy_away	May '06	736
9	Healthy_away	May '06	880
9	Healthy_away	May '06	928
9	Healthy_away	May '06	1056
9	Healthy_away	June '06	96
9	Healthy_away	June '06	176
9	Healthy_away	June '06	192
9	Healthy_away	June '06	224
9	Healthy_away	June '06	256
9	Healthy_away	June '06	304
9	Healthy_away	June '06	448
9	Healthy_away	June '06	448
9	Healthy_away	June '06	560
9	Healthy_away	June '06	688
9	Healthy_away	July '06	560
9	Healthy_away	July '06	576
9	Healthy_away	July '06	608
9	Healthy_away	July '06	640
9	Healthy_away	July '06	656
9	Healthy_away	July '06	976
9	Healthy_away	July '06	1008
9	Healthy_away	July '06	1136
9	Healthy_away	July '06	1152
9	Healthy_away	July '06	1584
9	Healthy_away	Aug '06	144
9	Healthy_away	Aug '06	176
9	Healthy_away	Aug '06	288
9	Healthy_away	Aug '06	352
9	Healthy_away	Aug '06	384
9	Healthy_away	Aug '06	544
9	Healthy_away	Aug '06	576
9	Healthy_away	Aug '06	736
9	Healthy_away	Aug '06	800
9	Healthy_away	Aug '06	1136

APPENDIX I. Bacterial density data.

Transect	Condition	Month	Bacteria/mL(X10^9)
1	Dieback	July '05	2.399
2	Dieback	July '05	3.282
3	Dieback	July '05	2.99
4	Dieback	July '05	2.99
5	Dieback	July '05	3.102
6	Dieback	July '05	3.093
7	Dieback	July '05	2.116
8	Dieback	July '05	3.204
1	Dieback	Aug '05	3.102
2	Dieback	Aug '05	2.87
3	Dieback	Aug '05	2.305
4	Dieback	Aug '05	2.57
5	Dieback	Aug '05	3.273
6	Dieback	Aug '05	2.853
7	Dieback	Aug '05	2.776
8	Dieback	Aug '05	2.365
1	Dieback	Sept '05	2.509
2	Dieback	Sept '05	2.581
3	Dieback	Sept '05	2.621
4	Dieback	Sept '05	3.917
5	Dieback	Sept '05	3.692
6	Dieback	Sept '05	3.805
7	Dieback	Sept '05	2.407
8	Dieback	Sept '05	3.468
1	Dieback	Oct '05	4.029
2	Dieback	Oct '05	3.315
3	Dieback	Oct '05	3.611
4	Dieback	Oct '05	2.938
5	Dieback	Oct '05	3.896
6	Dieback	Oct '05	3.427
7	Dieback	Oct '05	3.968
8	Dieback	Oct '05	2.53
1	Dieback	Dec '05	2.862
2	Dieback	Dec '05	4.001
3	Dieback	Dec '05	2.399
4	Dieback	Dec '05	1.868
5	Dieback	Dec '05	3.127
6	Dieback	Dec '05	3.127
7	Dieback	Dec '05	2.142
8	Dieback	Dec '05	2.716
1	Dieback	Jan '06	4.07
2	Dieback	Jan '06	3.59
3	Dieback	Jan '06	4.916
4	Dieback	Jan '06	-1

5	Dieback	Jan	'06	4.774
6	Dieback	Jan	'06	4.508
7	Dieback	Jan	'06	3.733
8	Dieback	Jan	'06	2.999
1	Dieback	Feb	'06	3.652
2	Dieback	Feb	'06	3.284
3	Dieback	Feb	'06	3.917
4	Dieback	Feb	'06	2.744
5	Dieback	Feb	'06	3.346
6	Dieback	Feb	'06	2.581
7	Dieback	Feb	'06	3.927
8	Dieback	Feb	'06	4.478
1	Dieback	April	'06	3.397
2	Dieback	April	'06	3.162
3	Dieback	April	'06	3.162
4	Dieback	April	'06	3.927
5	Dieback	April	'06	4.294
6	Dieback	April	'06	4.478
7	Dieback	April	'06	4.06
8	Dieback	April	'06	3.397
1	Dieback	May	'06	3.172
2	Dieback	May	'06	2.601
3	Dieback	May	'06	3.335
4	Dieback	May	'06	3.672
5	Dieback	May	'06	2.846
6	Dieback	May	'06	2.764
7	Dieback	May	'06	2.683
8	Dieback	May	'06	3.295
1	Dieback	June	'06	3.172
2	Dieback	June	'06	2.815
3	Dieback	June	'06	2.642
4	Dieback	June	'06	2.978
5	Dieback	June	'06	2.693
6	Dieback	June	'06	6.12
7	Dieback	June	'06	4.661
8	Dieback	June	'06	4.468
1	Dieback	July	'06	3.682
2	Dieback	July	'06	4.396
3	Dieback	July	'06	4.141
4	Dieback	July	'06	3.896
5	Dieback	July	'06	2.621
6	Dieback	July	'06	4.019
7	Dieback	July	'06	3.407
8	Dieback	July	'06	3.774
1	Dieback	Aug	'06	3.978
2	Dieback	Aug	'06	3.907
3	Dieback	Aug	'06	3.315
4	Dieback	Aug	'06	3.794

5	Dieback	Aug '06	3.499
6	Dieback	Aug '06	4.06
7	Dieback	Aug '06	3.743
8	Dieback	Aug '06	4.111
1	Intermediate	July '05	2.356
2	Intermediate	July '05	1.525
3	Intermediate	July '05	1.928
4	Intermediate	July '05	2.33
5	Intermediate	July '05	2.168
6	Intermediate	July '05	4.747
7	Intermediate	July '05	2.656
8	Intermediate	July '05	2.528
1	Intermediate	Aug '05	4.67
2	Intermediate	Aug '05	2.536
3	Intermediate	Aug '05	2.69
4	Intermediate	Aug '05	2.853
5	Intermediate	Aug '05	2.81
6	Intermediate	Aug '05	3.633
7	Intermediate	Aug '05	2.853
8	Intermediate	Aug '05	2.75
1	Intermediate	Sept '05	2.611
2	Intermediate	Sept '05	3.111
3	Intermediate	Sept '05	2.958
4	Intermediate	Sept '05	2.672
5	Intermediate	Sept '05	3.509
6	Intermediate	Sept '05	3.203
7	Intermediate	Sept '05	3.723
8	Intermediate	Sept '05	2.774
1	Intermediate	Oct '05	3.835
2	Intermediate	Oct '05	3.886
3	Intermediate	Oct '05	-1
4	Intermediate	Oct '05	3.376
5	Intermediate	Oct '05	4.141
6	Intermediate	Oct '05	4.304
7	Intermediate	Oct '05	3.621
8	Intermediate	Oct '05	2.611
1	Intermediate	Dec '05	3.89
2	Intermediate	Dec '05	2.913
3	Intermediate	Dec '05	1.876
4	Intermediate	Dec '05	3.05
5	Intermediate	Dec '05	3.444
6	Intermediate	Dec '05	3.581
7	Intermediate	Dec '05	2.613
8	Intermediate	Dec '05	3.187
1	Intermediate	Jan '06	3.927
2	Intermediate	Jan '06	3.509
3	Intermediate	Jan '06	3.478
4	Intermediate	Jan '06	3.539

5	Intermediate	Jan	'06	2.968
6	Intermediate	Jan	'06	3.723
7	Intermediate	Jan	'06	3.029
8	Intermediate	Jan	'06	3.376
1	Intermediate	Feb	'06	4.457
2	Intermediate	Feb	'06	3.162
3	Intermediate	Feb	'06	3.468
4	Intermediate	Feb	'06	2.366
5	Intermediate	Feb	'06	3.295
6	Intermediate	Feb	'06	2.836
7	Intermediate	Feb	'06	2.856
8	Intermediate	Feb	'06	3.182
1	Intermediate	April	'06	3.356
2	Intermediate	April	'06	3.427
3	Intermediate	April	'06	3.743
4	Intermediate	April	'06	3.958
5	Intermediate	April	'06	3.019
6	Intermediate	April	'06	2.978
7	Intermediate	April	'06	3.203
8	Intermediate	April	'06	3.723
1	Intermediate	May	'06	3.478
2	Intermediate	May	'06	2.642
3	Intermediate	May	'06	3.182
4	Intermediate	May	'06	3.998
5	Intermediate	May	'06	2.948
6	Intermediate	May	'06	4.039
7	Intermediate	May	'06	3.274
8	Intermediate	May	'06	3.315
1	Intermediate	June	'06	3.662
2	Intermediate	June	'06	3.611
3	Intermediate	June	'06	3.346
4	Intermediate	June	'06	3.407
5	Intermediate	June	'06	3.488
6	Intermediate	June	'06	3.458
7	Intermediate	June	'06	3.662
8	Intermediate	June	'06	3.713
1	Intermediate	July	'06	3.703
2	Intermediate	July	'06	2.887
3	Intermediate	July	'06	3.509
4	Intermediate	July	'06	3.121
5	Intermediate	July	'06	3.672
6	Intermediate	July	'06	3.57
7	Intermediate	July	'06	3.458
8	Intermediate	July	'06	2.55
1	Intermediate	Aug	'06	3.784
2	Intermediate	Aug	'06	4.039
3	Intermediate	Aug	'06	4.192
4	Intermediate	Aug	'06	3.601

5	Intermediate	Aug '06	3.478
6	Intermediate	Aug '06	3.784
7	Intermediate	Aug '06	3.407
8	Intermediate	Aug '06	3.998
1	Healthy	July '05	4.875
2	Healthy	July '05	2.682
3	Healthy	July '05	4.524
4	Healthy	July '05	2.125
5	Healthy	July '05	1.876
6	Healthy	July '05	4.001
7	Healthy	July '05	3.993
8	Healthy	July '05	4.438
1	Healthy	Aug '05	2.219
2	Healthy	Aug '05	3.059
3	Healthy	Aug '05	3.941
4	Healthy	Aug '05	3.076
5	Healthy	Aug '05	3.084
6	Healthy	Aug '05	2.425
7	Healthy	Aug '05	2.588
8	Healthy	Aug '05	1.868
1	Healthy	Sept '05	3.692
2	Healthy	Sept '05	2.907
3	Healthy	Sept '05	2.54
4	Healthy	Sept '05	3.386
5	Healthy	Sept '05	3.019
6	Healthy	Sept '05	3.427
7	Healthy	Sept '05	2.978
8	Healthy	Sept '05	2.999
1	Healthy	Oct '05	3.539
2	Healthy	Oct '05	4.468
3	Healthy	Oct '05	4.58
4	Healthy	Oct '05	3.805
5	Healthy	Oct '05	3.917
6	Healthy	Oct '05	4.172
7	Healthy	Oct '05	3.06
8	Healthy	Oct '05	2.785
1	Healthy	Dec '05	3.333
2	Healthy	Dec '05	3.838
3	Healthy	Dec '05	2.468
4	Healthy	Dec '05	3.247
5	Healthy	Dec '05	3.324
6	Healthy	Dec '05	2.905
7	Healthy	Dec '05	2.382
8	Healthy	Dec '05	3.547
1	Healthy	Jan '06	4.498
2	Healthy	Jan '06	4.539
3	Healthy	Jan '06	3.835
4	Healthy	Jan '06	4.131

5	Healthy	Jan	'06	4.621
6	Healthy	Jan	'06	3.601
7	Healthy	Jan	'06	3.529
8	Healthy	Jan	'06	5.692
1	Healthy	Feb	'06	3.611
2	Healthy	Feb	'06	3.162
3	Healthy	Feb	'06	3.703
4	Healthy	Feb	'06	3.305
5	Healthy	Feb	'06	3.366
6	Healthy	Feb	'06	3.274
7	Healthy	Feb	'06	3.754
8	Healthy	Feb	'06	3.754
1	Healthy	April	'06	2.999
2	Healthy	April	'06	3.478
3	Healthy	April	'06	3.448
4	Healthy	April	'06	3.672
5	Healthy	April	'06	3.305
6	Healthy	April	'06	3.386
7	Healthy	April	'06	3.397
8	Healthy	April	'06	2.897
1	Healthy	May	'06	2.836
2	Healthy	May	'06	3.499
3	Healthy	May	'06	3.611
4	Healthy	May	'06	3.478
5	Healthy	May	'06	4.202
6	Healthy	May	'06	3.427
7	Healthy	May	'06	3.743
8	Healthy	May	'06	3.835
1	Healthy	June	'06	3.794
2	Healthy	June	'06	3.815
3	Healthy	June	'06	3.896
4	Healthy	June	'06	3.896
5	Healthy	June	'06	2.927
6	Healthy	June	'06	4.284
7	Healthy	June	'06	4.682
8	Healthy	June	'06	4.58
1	Healthy	July	'06	3.478
2	Healthy	July	'06	3.743
3	Healthy	July	'06	3.315
4	Healthy	July	'06	3.784
5	Healthy	July	'06	3.335
6	Healthy	July	'06	3.397
7	Healthy	July	'06	3.172
8	Healthy	July	'06	3.896
1	Healthy	Aug	'06	3.764
2	Healthy	Aug	'06	3.754
3	Healthy	Aug	'06	3.927
4	Healthy	Aug	'06	4.284

5	Healthy	Aug	'06	3.55
6	Healthy	Aug	'06	4.121
7	Healthy	Aug	'06	3.672
8	Healthy	Aug	'06	4.182

APPENDIX J. Chlorophyll a data.

Transect	Condition	Month	Chla (mg/m2)
1	Dieback	Jul '05	8.7
1	Dieback	Aug '05	7.87
1	Dieback	Sept '05	6.42
1	Dieback	Oct '05	4.76
1	Dieback	Dec '05	5.55
1	Dieback	Jan '05	8.58
1	Dieback	Feb '06	7.01
1	Dieback	Apr '06	8.66
1	Dieback	May '06	5.62
1	Dieback	June '06	14.93
1	Dieback	July '06	7.31
1	Dieback	Aug '06	5.95
2	Dieback	Jul '05	-1
2	Dieback	Aug '05	9.55
2	Dieback	Sept '05	2.14
2	Dieback	Oct '05	6.09
2	Dieback	Dec '05	5.02
2	Dieback	Jan '05	4.65
2	Dieback	Feb '06	9.85
2	Dieback	Apr '06	9.1
2	Dieback	May '06	7.29
2	Dieback	June '06	11.27
2	Dieback	July '06	12.09
2	Dieback	Aug '06	9.37
3	Dieback	Jul '05	6.62
3	Dieback	Aug '05	11.06
3	Dieback	Sept '05	1.55
3	Dieback	Oct '05	9.48
3	Dieback	Dec '05	6.04
3	Dieback	Jan '05	5.44
3	Dieback	Feb '06	12.04
3	Dieback	Apr '06	12.42
3	Dieback	May '06	8.02
3	Dieback	June '06	9.13
3	Dieback	July '06	11.89
3	Dieback	Aug '06	9.45
4	Dieback	Jul '05	2.93
4	Dieback	Aug '05	9.35
4	Dieback	Sept '05	2.68
4	Dieback	Oct '05	6.97
4	Dieback	Dec '05	4.16
4	Dieback	Jan '05	4.85
4	Dieback	Feb '06	9.33
4	Dieback	Apr '06	8.74

4	Dieback	May '06	13.25
4	Dieback	June '06	9.56
4	Dieback	July '06	3.65
4	Dieback	Aug '06	8.94
5	Dieback	Jul '05	4.19
5	Dieback	Aug '05	8.04
5	Dieback	Sept '05	3.33
5	Dieback	Oct '05	8.34
5	Dieback	Dec '05	7.04
5	Dieback	Jan '05	6.81
5	Dieback	Feb '06	6.08
5	Dieback	Apr '06	7.17
5	Dieback	May '06	9.41
5	Dieback	June '06	8.4
5	Dieback	July '06	6.88
5	Dieback	Aug '06	11.82
6	Dieback	Jul '05	2.73
6	Dieback	Aug '05	7.54
6	Dieback	Sept '05	3.63
6	Dieback	Oct '05	16.61
6	Dieback	Dec '05	3.41
6	Dieback	Jan '05	5.76
6	Dieback	Feb '06	9.54
6	Dieback	Apr '06	9.95
6	Dieback	May '06	10.34
6	Dieback	June '06	8.4
6	Dieback	July '06	5.36
6	Dieback	Aug '06	13.72
7	Dieback	Jul '05	-1
7	Dieback	Aug '05	3.96
7	Dieback	Sept '05	2.79
7	Dieback	Oct '05	13.82
7	Dieback	Dec '05	3.03
7	Dieback	Jan '05	5.59
7	Dieback	Feb '06	10.1
7	Dieback	Apr '06	10.88
7	Dieback	May '06	9.36
7	Dieback	June '06	12.48
7	Dieback	July '06	10.77
7	Dieback	Aug '06	11.35
8	Dieback	Jul '05	5.6
8	Dieback	Aug '05	4.52
8	Dieback	Sept '05	2.71
8	Dieback	Oct '05	7.81
8	Dieback	Dec '05	4.44
8	Dieback	Jan '05	3.78
8	Dieback	Feb '06	6.81
8	Dieback	Apr '06	10.54

8	Dieback	May	'06	8.38
8	Dieback	June	'06	8.94
8	Dieback	July	'06	9.91
8	Dieback	Aug	'06	16.48
1	Intermediate	Jul	'05	-1
1	Intermediate	Aug	'05	8.72
1	Intermediate	Sept	'05	7.63
1	Intermediate	Oct	'05	6.81
1	Intermediate	Dec	'05	4.53
1	Intermediate	Jan	'05	5.14
1	Intermediate	Feb	'06	10.85
1	Intermediate	Apr	'06	10.26
1	Intermediate	May	'06	9.1
1	Intermediate	June	'06	11.97
1	Intermediate	July	'06	1.32
1	Intermediate	Aug	'06	12.59
2	Intermediate	Jul	'05	7.21
2	Intermediate	Aug	'05	5.06
2	Intermediate	Sept	'05	3.54
2	Intermediate	Oct	'05	2.53
2	Intermediate	Dec	'05	5.14
2	Intermediate	Jan	'05	5.98
2	Intermediate	Feb	'06	9.1
2	Intermediate	Apr	'06	10.54
2	Intermediate	May	'06	10.31
2	Intermediate	June	'06	9.91
2	Intermediate	July	'06	6.8
2	Intermediate	Aug	'06	7.85
3	Intermediate	Jul	'05	5.8
3	Intermediate	Aug	'05	7.19
3	Intermediate	Sept	'05	4.89
3	Intermediate	Oct	'05	6.57
3	Intermediate	Dec	'05	5.04
3	Intermediate	Jan	'05	5.46
3	Intermediate	Feb	'06	10.77
3	Intermediate	Apr	'06	12.27
3	Intermediate	May	'06	11.52
3	Intermediate	June	'06	12.91
3	Intermediate	July	'06	12.67
3	Intermediate	Aug	'06	11
4	Intermediate	Jul	'05	5.36
4	Intermediate	Aug	'05	12.54
4	Intermediate	Sept	'05	1.09
4	Intermediate	Oct	'05	7.42
4	Intermediate	Dec	'05	4.84
4	Intermediate	Jan	'05	4.85
4	Intermediate	Feb	'06	9.15
4	Intermediate	Apr	'06	7.97

4	Intermediate	May '06	8.43
4	Intermediate	June '06	7.11
4	Intermediate	July '06	7.93
4	Intermediate	Aug '06	14.62
5	Intermediate	Jul '05	5.72
5	Intermediate	Aug '05	9.46
5	Intermediate	Sept '05	5.87
5	Intermediate	Oct '05	5.82
5	Intermediate	Dec '05	6.12
5	Intermediate	Jan '05	6.34
5	Intermediate	Feb '06	11.29
5	Intermediate	Apr '06	10.9
5	Intermediate	May '06	8.89
5	Intermediate	June '06	6.45
5	Intermediate	July '06	6.84
5	Intermediate	Aug '06	14.5
6	Intermediate	Jul '05	-1
6	Intermediate	Aug '05	6.74
6	Intermediate	Sept '05	1.66
6	Intermediate	Oct '05	6.74
6	Intermediate	Dec '05	5.27
6	Intermediate	Jan '05	7.08
6	Intermediate	Feb '06	8.84
6	Intermediate	Apr '06	9.61
6	Intermediate	May '06	8.74
6	Intermediate	June '06	11.08
6	Intermediate	July '06	4.51
6	Intermediate	Aug '06	4.63
7	Intermediate	Jul '05	4.84
7	Intermediate	Aug '05	5.41
7	Intermediate	Sept '05	3.78
7	Intermediate	Oct '05	13.32
7	Intermediate	Dec '05	5.83
7	Intermediate	Jan '05	3.99
7	Intermediate	Feb '06	7.86
7	Intermediate	Apr '06	10.52
7	Intermediate	May '06	9.92
7	Intermediate	June '06	10.53
7	Intermediate	July '06	7.04
7	Intermediate	Aug '06	9.52
8	Intermediate	Jul '05	5.69
8	Intermediate	Aug '05	4.55
8	Intermediate	Sept '05	3.08
8	Intermediate	Oct '05	7.81
8	Intermediate	Dec '05	4.57
8	Intermediate	Jan '05	6.6
8	Intermediate	Feb '06	11.96
8	Intermediate	Apr '06	10.96

8	Intermediate	May '06	8.66
8	Intermediate	June '06	10.88
8	Intermediate	July '06	9.41
8	Intermediate	Aug '06	11.23
1	Healthy	Jul '05	-1
1	Healthy	Aug '05	8.19
1	Healthy	Sept '05	6.14
1	Healthy	Oct '05	8.73
1	Healthy	Dec '05	4.97
1	Healthy	Jan '05	5.08
1	Healthy	Feb '06	7.14
1	Healthy	Apr '06	10.7
1	Healthy	May '06	8.61
1	Healthy	June '06	10.42
1	Healthy	July '06	10.92
1	Healthy	Aug '06	11.74
2	Healthy	Jul '05	5.22
2	Healthy	Aug '05	4.44
2	Healthy	Sept '05	3.23
2	Healthy	Oct '05	5.16
2	Healthy	Dec '05	4.67
2	Healthy	Jan '05	4.03
2	Healthy	Feb '06	8.22
2	Healthy	Apr '06	8.02
2	Healthy	May '06	11.01
2	Healthy	June '06	10.81
2	Healthy	July '06	8.36
2	Healthy	Aug '06	8.05
3	Healthy	Jul '05	9.06
3	Healthy	Aug '05	4.88
3	Healthy	Sept '05	5.62
3	Healthy	Oct '05	10.49
3	Healthy	Dec '05	4.23
3	Healthy	Jan '05	5.44
3	Healthy	Feb '06	12.01
3	Healthy	Apr '06	11.78
3	Healthy	May '06	7.89
3	Healthy	June '06	14.11
3	Healthy	July '06	11.86
3	Healthy	Aug '06	12.09
4	Healthy	Jul '05	3.28
4	Healthy	Aug '05	12.1
4	Healthy	Sept '05	2.48
4	Healthy	Oct '05	15.84
4	Healthy	Dec '05	4.7
4	Healthy	Jan '05	6.6
4	Healthy	Feb '06	6.65
4	Healthy	Apr '06	10.08

4	Healthy	May '06	12.86
4	Healthy	June '06	8.51
4	Healthy	July '06	14.69
4	Healthy	Aug '06	9.13
5	Healthy	Jul '05	-1
5	Healthy	Aug '05	6.98
5	Healthy	Sept '05	2.71
5	Healthy	Oct '05	7.19
5	Healthy	Dec '05	6.87
5	Healthy	Jan '05	6.76
5	Healthy	Feb '06	11.24
5	Healthy	Apr '06	10.16
5	Healthy	May '06	11.68
5	Healthy	June '06	16.75
5	Healthy	July '06	8.36
5	Healthy	Aug '06	13.14
6	Healthy	Jul '05	3.49
6	Healthy	Aug '05	5.56
6	Healthy	Sept '05	2.64
6	Healthy	Oct '05	3.67
6	Healthy	Dec '05	4.33
6	Healthy	Jan '05	5.85
6	Healthy	Feb '06	7.97
6	Healthy	Apr '06	9.2
6	Healthy	May '06	9.74
6	Healthy	June '06	11.58
6	Healthy	July '06	11
6	Healthy	Aug '06	12.28
7	Healthy	Jul '05	9.35
7	Healthy	Aug '05	9.82
7	Healthy	Sept '05	4.43
7	Healthy	Oct '05	7.88
7	Healthy	Dec '05	7.53
7	Healthy	Jan '05	5.31
7	Healthy	Feb '06	12.19
7	Healthy	Apr '06	9.2
7	Healthy	May '06	9.25
7	Healthy	June '06	11.89
7	Healthy	July '06	3.81
7	Healthy	Aug '06	8.36
8	Healthy	Jul '05	5.25
8	Healthy	Aug '05	7.98
8	Healthy	Sept '05	3.92
8	Healthy	Oct '05	6.85
8	Healthy	Dec '05	5.23
8	Healthy	Jan '05	3.88
8	Healthy	Feb '06	8.48
8	Healthy	Apr '06	10.57

8	Healthy	May '06	8.58
8	Healthy	June '06	9.06
8	Healthy	July '06	4.7
8	Healthy	Aug '06	11.23

APPENDIX K. Bacteriochlorophyll data.

Transect	Condtion	BacChla(mg/m2)
1	Dieback	0
2	Dieback	1.188
3	Dieback	0
4	Dieback	0
5	Dieback	0
6	Dieback	0
7	Dieback	0
8	Dieback	5.0362
1	Intermediate	0.7015
2	Intermediate	0
3	Intermediate	2.9239
4	Intermediate	0
5	Intermediate	0
6	Intermediate	0
7	Intermediate	0
8	Intermediate	0
1	Healthy	0.9094
2	Healthy	0.5999
3	Healthy	0
4	Healthy	0
5	Healthy	0
6	Healthy	0
7	Healthy	0
8	Healthy	0

APPENDIX L. MEAN VALUES OF DATA

mM Sulfide

Condition	Month	Mean	Std. Deviation	N
Dieback	Jan '06	5.9761	1.86299	12
	Feb '06	5.1854	2.83356	12
	April '06	4.0363	4.46073	12
	May '06	4.4177	1.74189	12
	June '06	4.9305	2.95001	12
	July '06	4.2414	2.72773	12
	Aug '06	2.8826	2.58466	12
	Oct '06	6.2966	1.46205	12
	Total	4.7458	2.81933	96
Healthy	Jan '06	5.1578	2.13355	12
	Feb '06	5.6034	2.47546	12
	April '06	.0940	.25360	12
	May '06	3.6284	2.37088	12
	June '06	4.7318	2.70646	12
	July '06	3.0147	2.48976	12
	Aug '06	.3097	.37984	12
	Oct '06	6.4478	2.26608	12
	Total	3.6234	3.00581	96
Total	Jan '06	5.5669	2.00291	24
	Feb '06	5.3944	2.61080	24
	April '06	2.0651	3.68805	24
	May '06	4.0230	2.07412	24
	June '06	4.8311	2.77049	24
	July '06	3.6280	2.62977	24
	Aug '06	1.5962	2.23404	24
	Oct '06	6.3722	1.86660	24
	Total	4.1846	2.96039	192

Pore water salinity

Condition	Month	Mean	Std. Deviation	N
Dieback	Jan '06	21.5556	7.90745	9
	Feb '06	25.2500	2.25198	8
	April '06	29.5000	11.23769	8
	May '06	30.2500	4.55914	8
	June '06	42.0000	1.65831	9
	July '06	36.8889	2.75882	9
	Aug '06	54.5556	13.92041	9
	Oct '06	46.5556	4.06544	9
	Total	36.1449	12.81460	69
Healthy	Jan '06	20.2222	8.07431	9
	Feb '06	24.4444	1.23603	9
	April '06	22.0000	4.58258	7
	May '06	28.0000	4.15331	9
	June '06	37.7778	4.99444	9
	July '06	32.8889	1.53659	9
	Aug '06	46.4444	2.83333	9
	Oct '06	39.3333	.86603	9
	Total	31.6571	9.59602	70
Total	Jan '06	20.8889	7.78300	18
	Feb '06	24.8235	1.77607	17
	April '06	26.0000	9.33503	15
	May '06	29.0588	4.36564	17
	June '06	39.8889	4.21327	18
	July '06	34.8889	2.98799	18
	Aug '06	50.5000	10.60105	18
	Oct '06	42.9444	4.68379	18
	Total	33.8849	11.49044	139

Surface Water Salinity

Condition	Month	Mean	Std. Deviation	N
Dieback	Jan 2006	9.1250	.88506	16
	Feb 2006	22.4118	4.31652	17
	April 2006	36.2000	1.42428	15
	May 2006	36.0000	3.46410	8
	June 2006	31.6250	1.30247	8
	July 2006	37.4286	2.82000	7
	Aug 2006	30.2857	3.90360	7
	Total	26.7308	10.78921	78
Intermediate	Jan 2006	8.6875	1.01448	16
	Feb 2006	24.1250	3.66742	16
	April 2006	35.8571	1.29241	14
	May 2006	34.2500	2.96407	8
	June 2006	32.5000	1.85164	8
	July 2006	38.1429	2.26779	7
	Aug 2006	28.4286	3.04725	7
	Total	26.6711	10.67382	76
Healthy	Jan 2006	7.6250	.61914	16
	Feb 2006	22.2500	3.58701	16
	April 2006	35.0714	1.54244	14
	May 2006	34.0000	2.61861	8
	June 2006	32.8571	1.95180	7
	July 2006	37.3000	2.75076	10
	Aug 2006	30.4444	3.64387	9
	Total	26.4750	10.98443	80
Total	Jan 2006	8.4792	1.05164	48
	Feb 2006	22.9184	3.89357	49
	April 2006	35.7209	1.46914	43
	May 2006	34.7500	3.03959	24
	June 2006	32.3043	1.71715	23
	July 2006	37.5833	2.55235	24
	Aug 2006	29.7826	3.51563	23
	Total	26.6239	10.77330	234

Temperature

Condition	Month	Mean	Std. Deviation	N
Dieback	Jan 2006	10.5625	1.75000	16
	Feb 2006	4.2059	3.13777	17
	April 2006	24.2600	3.35214	15
	May 2006	25.6250	1.50594	8
	June 2006	19.9375	.49552	8
	July 2006	34.5714	2.22539	7
	Aug 2006	33.8571	2.47848	7
	Total	18.5628	10.99316	78
Intermediate	Jan 2006	10.4375	2.27944	16
	Feb 2006	1.8750	2.26201	16
	April 2006	24.0929	3.24475	14
	May 2006	22.8750	1.80772	8
	June 2006	19.4375	1.05009	8
	July 2006	33.0000	2.70801	7
	Aug 2006	31.5000	2.39046	8
	Total	17.6078	11.01972	77
Healthy	Jan 2006	10.1875	2.58763	16
	Feb 2006	3.0000	3.04959	16
	April 2006	24.5643	2.15892	14
	May 2006	20.0000	2.32993	8
	June 2006	19.0000	.70711	7
	July 2006	33.7000	2.58414	10
	Aug 2006	30.6667	2.39792	9
	Total	18.2613	11.00626	80
Total	Jan 2006	10.3958	2.19030	48
	Feb 2006	3.0510	2.95318	49
	April 2006	24.3047	2.91294	43
	May 2006	22.8333	2.97331	24
	June 2006	19.4783	.84582	23
	July 2006	33.7500	2.48911	24
	Aug 2006	31.8750	2.67537	24
	Total	18.1472	10.96639	235

Surface Water pH

Condition	Month	Mean	Std. Deviation	N
Dieback	April 2006	8.0827	.42365	15
	May 2006	8.8950	.54874	8
	June 2006	8.2025	.21946	8
	July 2006	5.9200	.57023	7
	Aug 2006	6.6286	.32784	7
	Total	7.6858	1.10165	45
Intermediate	April 2006	7.4400	.49049	14
	May 2006	8.2250	.38737	8
	June 2006	8.2913	.49605	8
	July 2006	6.0171	.93769	7
	Aug 2006	6.8129	.30788	7
	Total	7.4114	.95674	44
Healthy	April 2006	6.8750	.48019	14
	May 2006	7.5213	.52762	8
	June 2006	7.3586	.38719	7
	July 2006	6.1730	.36491	10
	Aug 2006	6.9367	.71676	9
	Total	6.9185	.66849	48
Total	April 2006	7.4802	.67670	43
	May 2006	8.2138	.74183	24
	June 2006	7.9765	.55731	23
	July 2006	6.0538	.61509	24
	Aug 2006	6.8052	.50892	23
	Total	7.3288	.96968	137

Elevation

Condition	Transect	Mean	Std. Deviation	N
Dieback	1.00	.945600	.0164621	3
	2.00	.949933	.0040415	3
	3.00	.947267	.0118462	3
	4.00	1.075933	.0319427	3
	5.00	.950600	.0072111	3
	6.00	.954267	.0015275	3
	7.00	.952933	.0080829	3
	8.00	.954600	.0045826	3
	Total	.966392	.0440020	24
Intermediate	1.00	.956933	.0020817	3
	2.00	.970600	.0091652	3
	3.00	.970600	.0075498	3
	4.00	1.090933	.0065064	3
	5.00	.961933	.0020817	3
	6.00	.957933	.0020817	3
	7.00	.967933	.0098658	3
	8.00	.965267	.0058595	3
	Total	.980267	.0433526	24
Healthy	1.00	.977600	.0157162	3
	2.00	.989067	.0137715	3
	3.00	.980267	.0145029	3
	4.00	1.129600	.0050000	3
	5.00	.972267	.0130512	3
	6.00	.960600	.0121244	3
	7.00	.983933	.0100664	3
	8.00	.976933	.0068069	3
	Total	.996283	.0530374	24
Total	1.00	.960044	.0181115	9
	2.00	.969867	.0189721	9
	3.00	.966044	.0178263	9
	4.00	1.098822	.0291023	9
	5.00	.961600	.0120312	9
	6.00	.957600	.0067823	9
	7.00	.968267	.0156924	9
	8.00	.965600	.0109087	9
	Total	.980981	.0479433	72

Dry Live Marss (g/m2)

Year	Condition	Mean	Std. Deviation	N
2004	Dieback	13.5200	22.05580	10
	Intermediate	319.7200	207.28578	8
	Healthy	590.1867	311.00931	6
	Total	259.7533	300.64984	24
2005	Dieback	25.7100	37.49847	16
	Intermediate	223.0100	64.30384	16
	Healthy	745.2400	242.23335	16
	Total	331.3200	338.53893	48
2006	Dieback	34.8600	43.42648	16
	Intermediate	188.6500	96.93920	16
	Healthy	456.8700	143.59595	16
	Total	226.7933	203.07217	48
Total	Dieback	26.2933	37.14483	42
	Intermediate	228.6080	123.64274	40
	Healthy	599.3389	251.42517	38
	Total	275.1960	285.10880	120

Mass per live stem

Year	Condition	Mean	Std. Deviation	N
2005	Dieback	.1191	.12437	16
	Intermediate	.2317	.13600	16
	Healthy	.3618	.16887	16
	Total	.2375	.17314	48
2006	Dieback	.1463	.14220	16
	Intermediate	.2298	.11441	16
	Healthy	.3238	.18879	16
	Total	.2333	.16546	48
Total	Dieback	.1327	.13214	32
	Intermediate	.2307	.12363	32
	Healthy	.3428	.17725	32
	Total	.2354	.16846	96

Mass per dead stem

Year	Condition	Mean	Std. Deviation	N
2005	Dieback	.0889	.03981	15
	Intermediate	.0946	.03814	16
	Healthy	.1012	.02461	16
	Total	.0950	.03435	47
2006	Dieback	.0865	.06352	16
	Intermediate	.1046	.03808	16
	Healthy	.1308	.06906	16
	Total	.1073	.06008	48
Total	Dieback	.0876	.05252	31
	Intermediate	.0996	.03783	32
	Healthy	.1160	.05316	32
	Total	.1012	.04920	95

Snails per m2

Condition	month	Mean	Std. Deviation	N
Dieback	July '05	20.0000	25.12900	16
	Aug '05	103.0000	275.70612	16
	Sept '05	104.0000	261.01750	16
	Oct '05	1.0000	4.00000	16
	April '06	1.0000	4.00000	16
	May '06	1.0000	4.00000	16
	June '06	8.0000	17.52712	16
	July '06	38.0000	49.82254	8
	Aug '06	11.0000	44.00000	16
	Total	31.5294	134.76833	136
Intermediate	July '05	112.0000	70.59367	16
	Aug '05	221.0000	342.62516	16
	Sept '05	172.0000	151.73310	16
	Oct '05	8.0000	24.08872	16
	April '06	27.0000	44.76904	16
	May '06	57.0000	99.48668	16
	June '06	119.0000	100.00000	16
	July '06	450.0000	220.94860	8
	Aug '06	197.0000	226.70509	16
	Total	133.8824	195.89926	136
Healthy	July '05	266.0000	119.28677	16
	Aug '05	429.0000	323.98683	16
	Sept '05	443.0000	286.02098	16
	Oct '05	39.0000	36.93598	16
	April '06	116.0000	55.57937	16
	May '06	876.0000	475.80388	16
	June '06	380.0000	167.96190	16
	July '06	1040.0000	382.85544	8
	Aug '06	745.0000	359.86220	16
	Total	448.7059	404.28809	136
Healthy_away	May '06	590.4000	293.81294	10
	June '06	339.2000	189.43471	10
	July '06	889.6000	339.34420	10
	Aug '06	513.6000	310.56765	10
	Total	583.2000	342.96948	40
Total	July '05	132.6667	129.81514	48
	Aug '05	251.0000	337.30496	48
	Sept '05	239.6667	277.66790	48
	Oct '05	16.0000	30.06942	48
	April '06	48.0000	64.08505	48
	May '06	359.4483	470.97209	58
	June '06	198.3448	201.20484	58
	July '06	621.1765	476.74811	34
	Aug '06	351.4483	388.15258	58
	Total	238.5000	342.25942	448

Bacterial density per cm3 (meanX10^9)

Condition	month	Mean	Std. Deviation	N
Dieback	July '05	2.8970	.41372	8
	Aug '05	2.7643	.33809	8
	Sept '05	3.1250	.65178	8
	Oct '05	3.4643	.52835	8
	Dec '05	2.7803	.66831	8
	Jan '06	4.0843	.69435	7
	Feb '06	3.4911	.63490	8
	April '06	3.7346	.51991	8
	May '06	3.0460	.37845	8
	June '06	3.6936	1.25846	8
	July '06	3.7420	.54259	8
	Aug '06	3.8009	.27686	8
	Total	3.3779	.72509	95
Intermediate	July '05	2.5298	.96397	8
	Aug '05	3.0994	.71352	8
	Sept '05	3.0701	.39781	8
	Oct '05	3.6820	.56377	7
	Dec '05	3.0693	.62640	8
	Jan '06	3.4436	.32270	8
	Feb '06	3.2028	.61050	8
	April '06	3.4259	.35711	8
	May '06	3.3595	.47934	8
	June '06	3.5434	.13596	8
	July '06	3.3088	.41522	8
	Aug '06	3.7854	.27942	8
	Total	3.2892	.59460	95
Healthy	July '05	3.5643	1.16357	8
	Aug '05	2.7825	.64532	8
	Sept '05	3.1185	.36232	8
	Oct '05	3.7908	.63830	8
	Dec '05	3.1305	.50935	8
	Jan '06	4.3058	.70352	8
	Feb '06	3.4911	.24001	8
	April '06	3.3228	.25570	8
	May '06	3.5789	.39158	8
	June '06	3.9843	.55160	8
	July '06	3.5150	.26045	8
	Aug '06	3.9068	.26471	8
	Total	3.5409	.66565	96
Total	July '05	2.9970	.96866	24
	Aug '05	2.8820	.58411	24
	Sept '05	3.1045	.46694	24
	Oct '05	3.6441	.57024	23
	Dec '05	2.9933	.59887	24
	Jan '06	3.9385	.68335	23

	Feb '06	3.3950	.52243	24
	April '06	3.4944	.41585	24
	May '06	3.3281	.45835	24
	June '06	3.7404	.78433	24
	July '06	3.5219	.44203	24
	Aug '06	3.8310	.26730	24
	Total	3.4032	.66981	286

Chla (mg/m2)

Condition	month	Mean	Std. Deviation	N
Dieback	July '05	5.1283	2.30952	6
	Aug '05	7.7363	2.44056	8
	Sept '05	3.1563	1.46773	8
	Oct '05	9.2350	4.02406	8
	Dec '05	4.8363	1.35012	8
	Jan '06	5.6825	1.46963	8
	Feb '06	8.8450	2.02361	8
	April '06	9.6825	1.61778	8
	May '06	8.9588	2.26260	8
	June '06	10.3888	2.33156	8
	July '06	8.4825	3.13827	8
	Aug '06	10.8850	3.22764	8
	Total	7.8072	3.29010	94
Intermediate	July '05	5.7700	.78948	6
	Aug '05	7.4588	2.68370	8
	Sept '05	3.9425	2.15438	8
	Oct '05	7.1275	2.98345	8
	Dec '05	5.1675	.56623	8
	Jan '06	5.6800	1.01538	8
	Feb '06	9.9775	1.42802	8
	April '06	10.3788	1.23285	8
	May '06	9.4463	1.05897	8
	June '06	10.1050	2.25024	8
	July '06	7.0650	3.32346	8
	Aug '06	10.7425	3.38262	8
	Total	7.7803	3.02675	94
Healthy	July '05	5.9417	2.66215	6
	Aug '05	7.4938	2.60523	8
	Sept '05	3.8963	1.40032	8
	Oct '05	8.2263	3.71477	8
	Dec '05	5.3163	1.21844	8
	Jan '06	5.3688	1.05449	8
	Feb '06	9.2375	2.22725	8
	April '06	9.9638	1.14675	8
	May '06	9.9525	1.73348	8
	June '06	11.6413	2.69682	8
	July '06	9.2125	3.66696	8
	Aug '06	10.7525	1.95249	8
	Total	8.1291	3.23658	94
Total	July '05	5.6133	1.99155	18
	Aug '05	7.5629	2.46705	24
	Sept '05	3.6650	1.67345	24
	Oct '05	8.1963	3.55107	24
	Dec '05	5.1067	1.07060	24
	Jan '06	5.5771	1.15420	24

	Feb '06	9.3533	1.89915	24
	April '06	10.0083	1.32087	24
	May '06	9.4525	1.72791	24
	June '06	10.7117	2.42361	24
	July '06	8.2533	3.35872	24
	Aug '06	10.7933	2.79600	24
	Total	7.9056	3.17911	282

Bacteriochlorophyll (mg/m2)

Condition	Transect	Mean	Std. Deviation	N
Dieback	1	.000000	.	1
	2	1.188020	.	1
	3	.000000	.	1
	4	.000000	.	1
	5	.000000	.	1
	6	.000000	.	1
	7	.000000	.	1
	8	5.036190	.	1
	Total	.778026	1.7700687	8
Intermediate	1	.701520	.	1
	2	.000000	.	1
	3	2.923900	.	1
	4	.000000	.	1
	5	.000000	.	1
	6	.000000	.	1
	7	.000000	.	1
	8	.000000	.	1
	Total	.453178	1.0280608	8
Healthy	1	.909400	.	1
	2	.599870	.	1
	3	.000000	.	1
	4	.000000	.	1
	5	.000000	.	1
	6	.000000	.	1
	7	.000000	.	1
	8	.000000	.	1
	Total	.188659	.3589897	8
Total	1	.536973	.4765069	3
	2	.595963	.5940196	3
	3	.974633	1.6881145	3
	4	.000000	.0000000	3
	5	.000000	.0000000	3
	6	.000000	.0000000	3
	7	.000000	.0000000	3
	8	1.678730	2.9076457	3
	Total	.473288	1.1726364	24