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Assessing the suitability of the eelgrass (Zostera marina L) deep edge as an indicator of water clarity in estuarine systems

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ASSESSING THE SUITABILITY OF THE EELGRASS (*ZOSTERA MARINA* L.) DEEP EDGE AS AN INDICATOR OF WATER CLARITY IN ESTUARINE SYSTEMS

BY

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ABSTRACT

ASSESSING THE SUITABILITY OF THE EELGRASS (*ZOSTERA MARINA* L.) DEEP EDGE AS AN INDICATOR OF WATER CLARITY IN ESTUARINE SYSTEMS

By

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University of New Hampshire, December 2006

The suitability of the seagrass deep edge as an indicator of water clarity was assessed by examining the sensitivity and specificity of this indicator to changes in light. Indicator specificity was assessed by examining the extent to which seasonal variation in environmental parameters affected the location of the deep edge at five eelgrass meadows in the Great Bay Estuary, New Hampshire. The mean location of the eelgrass deep edge was seasonally stable at three sites, confirming its suitability as an indicator. At two sites, the deep edge responded to long-term light reduction and changes in deep edge location of 1.3 meters were detectable between seasons. The recommended method of monitoring the deep edge is to measure deep edge location in reference to a permanent transect. The sensitivity of eelgrass growing along a depth gradient to a reduction in light was examined through a literature review and an experimental design.

CHAPTER I

INTRODUCTION

Background

Seagrass Ecology and Distribution

Seagrasses are a specialized group of flowering plants that have adapted to life in coastal marine systems (Short and Coles 2001). Seagrasses are represented by approximately 60 species from 13 distinct genera (Short *et al.* 2001a), and can be found along the coastlines of every continent except Antarctica (Green and Short 2003). The majority of seagrass species thrive in marine habitats, although certain species can be found in conditions ranging from freshwater to hypersaline (Green and Short 2003). Eelgrass (*Zostera marina* L.) is the dominant seagrass species in temperate waters of the northern Atlantic (Green and Short 2003). Eelgrass plants are rooted in bottom sediments and produce leaves ranging from a few centimeters to over a meter in length (Bak 1980; Short *et al.* 1989). Eelgrass is a mono-meristematic plant that produces new leaf material and new rhizome material from a common meristem (Short and Short 2000). Depth distribution of eelgrass ranges from intertidal to several meters deep (Krause-Jensen *et al.* 2003) but eelgrass abundance is greatest at shallow subtidal depths (Krause-Jensen *et al.*

2000). The shoot density of eelgrass meadows can exceed 2000 shoots m^{-2} (Bak 1980; Krause-Jensen *et al.* 2000).

Seagrass meadows are valuable natural resources that provide a wide range of important ecosystem functions. Seagrasses promote ecosystem health by absorbing nutrients and filtering sediments from the water column (Ward *et al.* 1984; Hemminga *et al.* 1999). The meadows protect coastlines by stabilizing sediments and baffling wave energy (Koch and Gust 1999; van Keulen and Borowitzka 2002). Seagrass meadows rank among the world's most productive communities (Duarte and Chiscano 1999). The plants provide food for manatees, dugongs, sea turtles and a variety of fish and waterfowl species (Peterken and Conacher 1997; Nacken and Reise 2000; Alcoverro and Mariani 2004), and seagrass detritus forms the basis of complex food webs (Thresher *et al.* 1992). Seagrass meadows offer unique habitat that harbors a greater diversity of species than unvegetated areas (Stoner *et al.* 1983; Heck *et al.* 1989; Jenkins *et al.* 1997). In the north Atlantic, eelgrass meadows provide important habitat for fish and invertebrate species (Heck *et al.* 1995). Eelgrass meadows also provide nursery grounds for many commercially valuable species including lobster, flounder and shellfish (Grizzle *et al.* 1996; Short *et al.* 2001b).

The extent to which seagrasses contribute to any marine ecosystem depends on the areal distribution of the meadows (Duarte 1991). Seagrass distribution is primarily controlled by physical factors (Short *et al.* 2001a), although in some cases distribution is limited by competition (Williams 1987; Robbins and Bell 2000) or grazing (Peterson *et* *al.* 2002). Temperature affects seagrass distribution through its influence on plant photosynthesis and respiration. Seagrass respiration increases faster with increasing temperature than seagrass photosynthetic rates (Marsh *et al.* 1986), and temperature stress can lead to plant death (Terrados and Ros 1995). Temperature limits the geographic range of seagrasses, with species generally confined to either temperate or tropical regions (Green and Short 2003). At the meadow scale, seagrass distribution can be limited by salinity (Quammen and Onuf 1993; Charpentier *et al.* 2005), substrate (Carruthers and Walker 1999), and high water velocity (Fonseca and Kenworthy 1987). Perhaps the most influential factor controlling seagrass distribution is light (Duarte 1991; Dennison *et al.* 1993; Kenworthy and Fonseca 1996; Greve and Krause-Jensen 2005a). Seagrasses require light for photosynthesis, and insufficient light can result in a negative plant carbon balance and plant death (Alcoverro *et al.* 1999). Seagrasses have a greater light requirement than most photoautotrophs (Dennison *et al.* 1993), yet the amount of light reaching the plants is often highly variable (Gallegos 1994; Banas *et al.* 2005). The deterioration of ambient light conditions has been considered the leading cause of seagrass decline worldwide (Duarte 2002).

Seagrass as an Ecological Indicator

Increasing coastal development worldwide has had a large impact on the habitat quality of coastal ecosystems (Short and Wyllie-Echeverria 1996; Duarte 2002). Concern over the management and protection of coastal resources has resulted in the increased use of indicators as a means of describing ecosystem status (Niemi and McDonald 2004). An ecological indicator is a measurable variable that identifies and qualifies a target characteristic of an ecosystem (Jackson *et al.* 2000; Pergent-Martini *et al.* 2005). Ecological indicators are commonly used to assess the health of an ecosystem or as early warning systems of deteriorating environmental conditions (Niemi and McDonald 2004). Often a single species representing key ecological functions is selected as an indicator (Pergent-Martini *et al.* 2005). The presence of the indicator species shows that the ecosystem is meeting the habitat requirements needed to support that species; the decline of the indicator species shows that a change in environmental conditions has occurred (Murtaugh 1996; Pergent-Martini *et al.* 2005).

Seagrasses have proven useful indicator species for assessing nearshore marine ecosystem health (Dennison *et al.* 1993; Boudouresque *et al.* 2000; Short *et al.* 2002; Pergent-Martini *et al.* 2005). Ecosystem impacts attributed to human activities include pollution, eutrophication, increased runoff and turbidity, and other factors that deteriorate water quality. These water quality problems can have negative impacts at many trophic levels within a community (Gacia *et al.* 1999; Smith *et al.* 1999). With the exception of heavy metal pollution and other toxins, a side effect of many water quality problems is a reduction in the amount of light in reaching seagrasses (Gallegos 1994). Seagrasses respond to light reduction by reducing shoot density (Short *et al.* 1995; Lee and Dunton 1997), and prolonged light reduction can lead to plant death and loss of meadow area (Dennison and Alberte 1982; Ruiz and Romero 2001). The seagrass response to light reduction is often indicative of water quality problems that affect the whole ecosystem

(Dennison *et al.* 1993). Therefore, seagrass has been considered an integrative indicator species for assessing ecosystem health (Dennison *et al.* 1993; Pergent-Martini *et al.* 2005).

Seagrasses have been successfully used to detect changes in water clarity (Onuf 1994; Bach *et al.* 1998) and heavy metal pollution (Pergent-Martini and Pergent 2000; Prange and Dennison 2000; Amado Filho *et al.* 2004). Eelgrass in particular has been a successful indicator species capable of detecting impacts from heavy metal pollution (Francois *et al.* 1989; Munksgaard *et al.* 2002), decreased water clarity (Orth and Moore 1983; Dennison *et al.* 1993), and coastal eutrophication (Short and Burdick 1996; Lee *et al.* 2004). In cases where seagrass has been used as an indicator for changes in light, a commonly monitored response has been change in seagrass abundance (Duarte 2002). Seagrass abundance is measured as percent cover, shoot density (Duarte and Kirkman 2001) or areal distribution of meadows (McKenzie *et al.* 2001). Declining seagrass abundance has been linked to reductions in light caused by algal blooms (Onuf 1996), epiphytes (Cambridge *et al.* 1986), and siltation (Bach *et al.* 1998). In the northeast United States, eelgrass abundance has been monitored to detect water quality problems affecting light. Declines in eelgrass abundance in Chesapeake Bay were attributed to increased turbidity in that system (Orth and Moore 1983; 1984). In Waquoit Bay, Massachusetts, eelgrass decline was attributed to coastal eutrophication (Short and Burdick 1996). Although water clarity in Waquoit Bay was not greatly affected, the eutrophication promoted the growth of macroalgae and epiphytes which reduced the amount of light reaching the eelgrass (Short and Burdick 1996; Hauxwell *et al.* 2001).

Seagrass Maximal Depth Limit

In most cases where seagrass abundance has been monitored as an indicator of light, it was used to show that environmental conditions had deteriorated (Orth and Moore 1983; Cambridge *et al.* 1986; Onuf 1996; Short and Burdick 1996). Whereas seagrass abundance is capable of quantifying the condition of an ecosystem, it is not always a useful indicator for the early detection of light reduction events. The seagrass maximal depth limit has been suggested as a more precise seagrass indicator that can be used as an early warning system of deteriorating light conditions (Dennison *et al.* 1993; Pergent-Martini *et al.* 2005). The maximal depth limit is the theoretical maximum depth at which seagrasses can persist under a given light regime (Dennison *et al.* 1993). Since the maximal depth limit is controlled by light (Duarte 1991), it is presumably a more sensitive indicator of changes in light than seagrass abundance alone.

The maximal depth limit varies depending on the light requirements of a given seagrass species and the extent of light attenuation in the water column (Duarte 1991; Dennison *et al.* 1993). The seagrass minimum light requirement is the minimum average amount of light required for seagrasses to persist (Dennison *et al.* 1993), and is usually expressed as a percentage of light at the water surface (% surface irradiance, or SI). Seagrasses receiving light levels below the minimum requirement enter a negative carbon balance, and the plants die of carbon starvation after prolonged periods of insufficient light (Alcoverro *et al.* 1999; Ruiz and Romero 2001). Minimum light requirements for seagrass species are generally measured as the % SI at the seagrass maximal depth limit

(Dennison *et al.* 1993). As such, seagrass minimum light requirements and maximal depth limits are dependent measures, but they can be used to predict each other if light attenuation is known (Dennison *et al.* 1993). The minimum light requirement for different seagrass species varies from 4 – 30% SI (Duarte 1991; Dennison *et al.* 1993), but averages around 11% SI for all species (Duarte 1991). The minimum light requirement of eelgrass averages around 20% SI (Dennison *et al.* 1993). Eelgrass in Woods Hole, Massachusetts was found to have a minimum light requirement of 19% SI (Dennison 1987).

Light attenuation influences seagrass maximal depth limits by affecting the depth at which the minimal light requirement is met (Dennison *et al.* 1993; Gallegos 1994; Gallegos and Kenworthy 1996). Light attenuation is the reduction in intensity of light as it passes through the water column due to the scattering and absorption of photons (Van Duin *et al.* 2001). It is described by the Beer-Lambert exponential decay function:

$$I_z = I_0 e^{-K_d z}$$

where I_z is the light measured at depth z, I_0 is the light level just beneath the water surface, and K_d is the light attenuation coefficient (Carruthers *et al.* 2001). Light attenuation is affected by water quality parameters that promote absorption and scattering, including total suspended solids (TSS), phytoplankton, humic substances, epiphytes, and pollution (Gallegos 1994). Light attenuation is indirectly affected by factors influencing those water quality parameters, such as coastal construction, dredging and runoff which can increase total suspended solids (Orth and Moore 1984; Onuf 1994) or eutrophication which can promote the growth of phytoplankton, macroalgae and epiphytes (Onuf 1996; Short and Burdick 1996).

An increase in light attenuation due to deteriorating water quality reduces the depth at which the seagrass minimum light requirement is met, and thus causes the seagrass maximal depth limit to become shallower (Dennison *et al.* 1993). When the maximal depth limit becomes shallower, seagrasses growing deeper than the new limit receive insufficient light for survival and eventually decline (Dennison and Alberte 1982). Whereas seagrasses growing at shallower areas of the meadow can acclimate in response to light reduction (Krause-Jensen *et al.* 2000; Olesen *et al.* 2002), the response of seagrasses growing at the maximal depth limit may be more severe since those plants are already receiving the minimum light required for survival. A change in the seagrass maximal depth limit may therefore provide an earlier indication of light reduction than changes in seagrass abundance at shallower depths.

The Seagrass Meadow Deep Edge

The seagrass maximal depth limit is a conceptually useful indicator, but it is a theoretical value that is not always directly measurable in the field. A measurable indicator variable that best represents the maximal depth limit is the seagrass meadow deep edge (Boudouresque *et al.* 2000). The meadow deep edge, defined here as the average deepest occurrence of seagrass at a given time, is predominantly controlled by light (Duarte 1991; Kenworthy and Fonseca 1996; Greve and Krause-Jensen 2005a) and mostly coincides with the maximal depth limit. In some systems the meadow deep edge is controlled by factors other than light, such as competition (Robbins and Bell 2000) or sediment type (Carruthers and Walker 1999). In these systems, the meadow deep edge is not useful as an indicator of light conditions. Also, when a system experiences an increase in light availability the seagrass maximal depth limit becomes deeper, but there can be a lag of up to several years before the meadow expands to the new depth limit (Greve and Krause-Jensen 2005a). When light reduction causes the maximal depth limit to become shallower, the seagrass meadow deep edge responds more quickly and eventually recedes to the new depth limit (Dennison *et al.* 1993). A shade experiment by Dennison and Alberte (1982) exposed eelgrass growing at the meadow deep edge to a 55% reduction in ambient light, and demonstrated that eelgrass declined within 30 days. Therefore, changes in the location or depth of the meadow deep edge are measurable values that can be used to detect a light reduction event.

Useful indicator variables are sensitive to and respond specifically to the target condition (Murtaugh 1996). The sensitivity of an indicator is the strength of the indicator's response to the target condition; the response of a sensitive indicator is easy to detect and measure (Murtaugh 1996). The specificity of an indicator is the ability of the indicator to positively detect the target condition with only minimal or predictable responses caused by outlying factors (Murtaugh 1996). In order to be useful as an indicator variable, the sensitivity and specificity of the seagrass deep edge response to changes in light needs to be established. Shading experiments have demonstrated that plants at the seagrass deep edge are sensitive to changes in light (Dennison and Alberte 1982, 1985). Seagrasses at the deep edge are presumed to be more sensitive to light reduction than shallower seagrasses because they are receiving the minimum light required for survival (Dennison *et al.* 1993). However, the response of the seagrass deep edge to light reduction has never been directly compared to the response of shallower portions of the meadow. The specificity of the seagrass deep edge to light has been partly supported by modeling efforts, which demonstrated that light explains the majority of the variability in deep edge location (Nielsen *et al.* 2002). However, the possible influence of seasonal variability in environmental factors on the location of the deep edge has not been examined. Large seasonal variability in the location of the deep edge would make it difficult to detect changes caused by light reduction from water quality problems, and would thereby confound the use of the seagrass deep edge as an indicator of water clarity.

Thesis Objectives

The objective of this thesis was to assess the suitability of the seagrass deep edge as an indicator of light conditions in estuarine systems. The work was conducted at the deep edges of eelgrass meadows in the Great Bay Estuary, New Hampshire, USA. Chapter 2 assessed the specificity of the location of the deep edge to light by examining the extent to which the location of the deep edge is affected by seasonal changes in environmental parameters. The locations of the meadow deep edges were assessed on a seasonal (quarterly) basis for a two year period, and observed changes in deep edge location were compared to the amount of light reaching the deep edge. In Chapter 3, the literature concerning the physiology of light limitation on seagrasses was reviewed, and evidence explaining why changes in the location of the deep edge may be useful as an early warning indicator of light reduction was presented. Then a design was created and given a preliminary test for an experiment to investigate whether eelgrass growing at the meadow deep edge responds faster to a reduction in light than shallower growing plants. The results of both Chapters 2 and 3 help determine the applicability of using change in the seagrass deep edge as an indicator of light conditions and changes in an estuary.

CHAPTER II

RESPONSE OF THE EELGRASS DEEP EDGE TO SEASONAL VS. LONG-TERM LIGHT REDUCTION

Introduction

Increasing coastal development worldwide has caused water quality problems for many coastal systems (Short and Wyllie-Echeverria 1996; Duarte 2002). Deteriorating water quality due to nutrient inputs, sediment inputs, or pollution, can have detrimental impacts at all trophic levels within a coastal community (Kennish 1998; McClelland and Valiela 1998; Smith *et al.* 1999). In order to manage and protect coastal resources, negative impacts to water quality need to be accurately detected and addressed. Because water quality is a complex concept that incorporates many environmental parameters, indicator variables that are more easily measured are often used as diagnostic tools (Murtaugh 1996). Deteriorating water quality is often associated with decreased water clarity or increased abundance of nuisance macroalgae, epiphytes and phytoplankton (Short and Burdick 1996). Increases in turbidity, water color, or abundance of nuisance algae ultimately reduce the amount of light reaching benthic communities. Seagrasses, which are responsive to changes in light, have proven useful indicators of water quality conditions in coastal marine systems (Pulich and White 1991; Dennison *et al.* 1993; Onuf 1996; Frederiksen *et al.* 2004).

Seagrasses are important components of marine ecosystems worldwide (den Hartog 1970; Green and Short 2003), and their value as an indicator species is magnified by their dominant role in the community. Seagrasses provide habitat for a wide variety of marine organisms and are known to harbor a higher diversity of species than unvegetated sites (Heck *et al.* 1989; Jenkins *et al.* 1997). As primary producers, seagrasses directly provide food for fish and waterfowl (Alcoverro and Mariani 2004; Moore *et al.* 2004), and seagrass detritus forms the basis of complex food webs (Thresher *et al.* 1992). Traditionally, seagrass abundance has been monitored as an indicator variable for assessing water quality. In several historic cases, large-scale declines in seagrass abundance have been attributed to deteriorating water quality conditions (Orth and Moore 1983; 1984; Short and Burdick 1996; Kendrick *et al.* 2002). Since changes in the abundance of seagrass can affect entire communities, seagrass abundance provides a good indicator of overall ecosystem health.

Several studies have implied that the seagrass deep edge, a variable related to seagrass abundance, may be a more useful indicator than abundance alone (Dennison *et al.* 1993; Gallegos and Kenworthy 1996; Tomasko *et al.* 2001; Greve and Krause-Jensen 2005a). The seagrass deep edge is defined here as the location or depth of the deepest occurrence of seagrass at a meadow. Whereas decreased seagrass abundance has been predominantly used to indicate systems in a state of decline, the seagrass deep edge has been suggested as a indicator for the early detection of changes in water quality before entire meadows are lost (Gallegos and Kenworthy 1996; Kenworthy and Fonseca 1996). In addition the deep edge may be useful for assessing habitat suitability for restoration efforts (Dennison *et al.* 1993; Steward *et al.* 2005). The seagrass deep edge is predominantly controlled by light (Duarte 1991; Greve and Krause-Jensen 2005a), and differences in the depth of the deep edge among closely situated meadows have been attributed to differences in light availability (Dawes and Tomasko 1987; Koch and Beer 1996). Seagrasses require light for photosynthesis and a minimum average amount of light is required for the plants to maintain a positive carbon balance and survive (Duarte 1991; Zimmerman *et al.* 1995). By comparing the seagrass deep edge to water column light attenuation, minimum light requirements have been calculated for many seagrass species (Duarte 1991; Dennison *et al.* 1993; Dunton 1994). The minimum light requirement of seagrasses, in combination with local water clarity conditions, dictates the maximal depth at which the plants can survive (Dennison 1987; Dennison *et al.* 1993). A reduction in water clarity changes the depth at which the minimum light requirement of seagrass is met. Over time, plants that receive insufficient light decline and the deep edge recedes to a shallower depth (Dennison and Alberte 1982, 1985). The strong relationship between the seagrass deep edge and light suggests that the deep edge might be a useful indicator for assessing water quality conditions.

Useful indicator variables are sensitive to the condition being examined, allowing change to be easily detected (Patil 1991; Murtaugh 1996). In addition, indicators respond specifically to the target condition and are not easily influenced by other factors (Murtaugh 1996). The sensitivity of the seagrass deep edge to light has been tested through *in situ* light manipulation experiments, which have shown that plants at the deep edge decline after being shaded, causing the deep edge to recede (Dennison and Alberte

1982, 1985). However, in order to be useful as an indicator variable, the depth of the meadow deep edge must be controlled specifically by light, with minimal influence from other environmental factors. Modeling studies have shown that in Danish coastal systems, the location of the deep edge of seagrass meadows is better explained by light than by other environmental factors (Nielsen *et al.* 2002; Greve and Krause-Jensen 2005a). Occasionally, the seagrass deep edge is controlled by factors other than light (Carruthers and Walker 1999; Robbins and Bell 2000), and at these sites the meadow deep edge would not be an applicable water clarity indicator. At sites where the deep edge is light limited, a large seasonal variability in the location of the deep edge would complicate the use of this variable as an indicator, as responses caused by long-term changes in light might be confounded by the seasonal responses. Many studies examining seagrass depth in relation to light have used data gathered within one season; few have examined whether the deep edge varies seasonally (Dennison and Alberte 1985; Olesen 1996; Boudouresque *et al.* 2000; Krause-Jensen *et al.* 2000; Greve and Krause-Jensen 2005a).

Monitoring the seagrass deep edge can be more difficult than monitoring shallower portions of the meadow, as deep edge fieldwork typically requires the use of SCUBA. In order for the seagrass deep edge to be a feasible indicator, a simple and accurate method for detecting changes in the deep edge needs to be developed. Two methods for monitoring the deep edge have been described in the literature. The first method directly measures the depth in the water column at which the seagrass deep edge occurs, using either pressure-depth gauges or vertical measurements from the water surface (Krause-Jensen *et al.* 2000; Krause-Jensen *et al.* 2003; Greve and Krause-Jensen 2005b, a). Measuring deep edge depth allows direct comparisons to be made between sites (Krause-Jensen *et al.* 2000; Krause-Jensen *et al.* 2003), but depth measurements need to account for variability caused by wind, currents, tidal stage, and other environmental factors. The second method involves measuring the location of the seagrass deep edge as the distance from a fixed reference transect (Boudouresque *et al.* 2000; Pergent-Martini *et al.* 2005). An initial effort is required to establish the reference transects, but measuring the location of the deep edge from a fixed point eliminates much of the unpredictable environmental variability from the measurements. A comparison of the depth and location methods for monitoring the deep edge will assess which measurement approach is preferable when using the deep edge as a water clarity indicator.

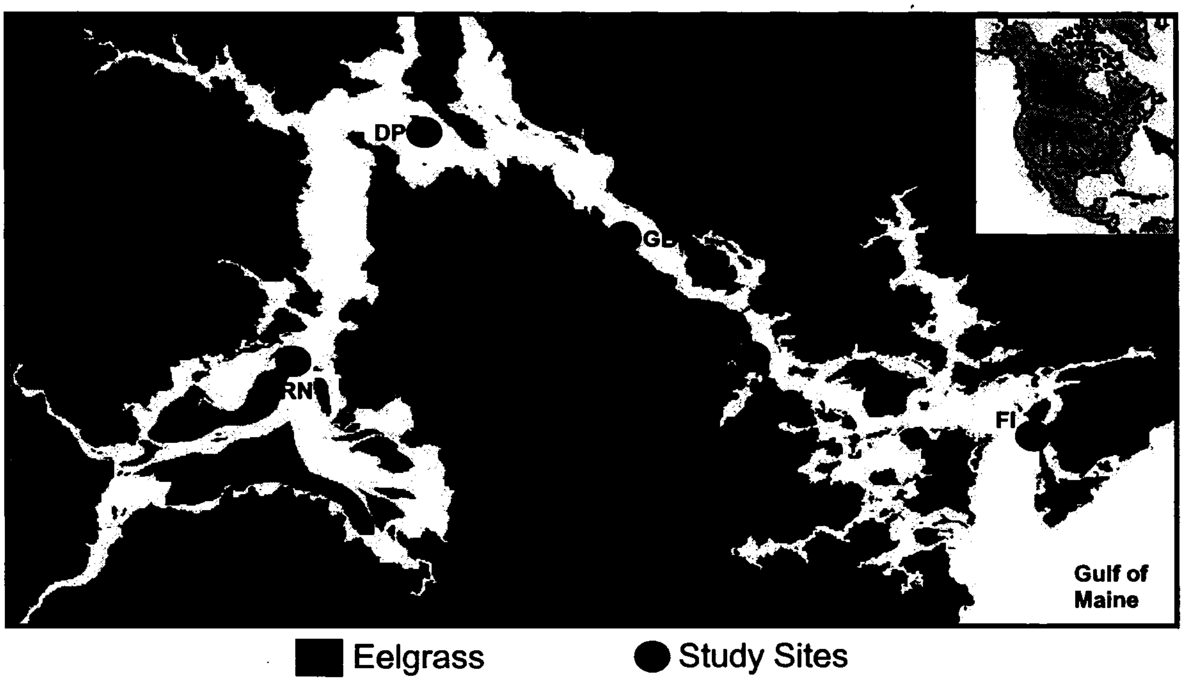
In the present study, I assess the specificity of the seagrass deep edge as an indicator of water clarity by examining how seasonal change in available light influenced the deep edge of five eelgrass (*Zostera marina* L.) meadows. Two variables describing the deep edge were examined in this study: the location of the meadow deep edge, measured as distance of the meadow edge from permanent reference transect markers, and the depth of the meadow deep edge, which was calculated based on an initial measurement of depth, the bottom slope, and the deep edge location. The objectives of this study were to determine if the location and calculated depth of the meadow deep edges change on a seasonal basis; to compare observed changes in the deep edge to the amount of light reaching the plants; and to compare the two measures of deep edge variability to see which is better, measuring deep edge location from fixed transect points on the bottom or measuring water depth.

Methods

Site Description

The study was conducted in the Great Bay Estuary, located on the border of New Hampshire and Maine, USA. The Great Bay Estuary is comprised of the Piscataqua River, Little Bay and Great Bay (Figure 1). Seven major rivers and several smaller creeks contribute freshwater inflow to the estuary from a 2400 km^2 watershed (Short 1992). The estuary experiences a diurnal tide averaging 2.5 m, and tidal lag is 3 hours from the mouth of the estuary to Great Bay (Short 1992). Great Bay is a shallow embayment with almost 50% of its surface area exposed at low tide (Short 1992). Water flow is constricted in the Piscataqua River, where current velocities are generally faster than in the bays (Short 1992). The Piscataqua River has a central channel which is maintained for commercial shipping. Water temperature has greater fluctuation and a higher range in Great Bay than in the Piscataqua River; Great Bay temperatures range from -2 °C to 27 °C (Short 1992). Salinities range from 5 during spring runoff events to 35 in late summer (Short 1992). The estuary follows a decreasing gradient of salinity and water clarity from the coast towards Great Bay (Short 1992; Chadwick *et al.* 1993).

Figure 1: Great Bay Estuary, on the border of New Hampshire and Maine, USA, and the five eelgrass meadows monitored for this study. Site names are Red Nun (RN), Dover Point (DP), Great Bay Fish (GBF), Outer Cutts Cove (OCC) and Fishing Island (FI).



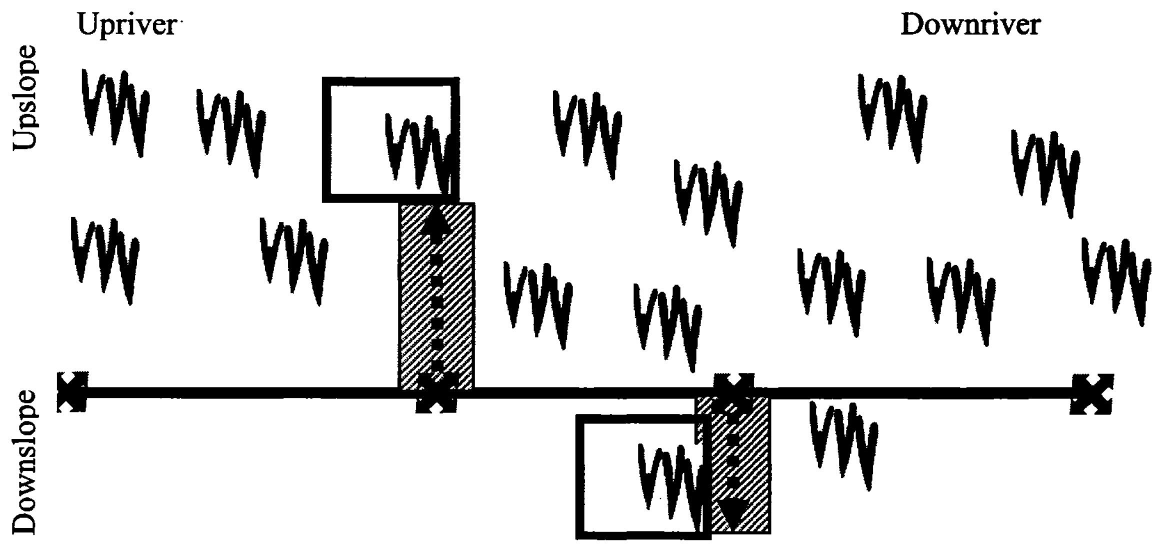
Five eelgrass meadows following the estuarine gradient were selected as study sites (Figure 1). The Fishing Island meadow (FI) is located near the mouth of the Piscataqua River and is routinely exposed to 1-2 m ocean swells. The Outer Cutts Cove meadow (OCC) in Portsmouth, New Hampshire, was partially dredged in 1998 for the construction of a pier; the remaining portion of the meadow where the present study was conducted was not directly impacted by dredging (Evans and Short 2005). The eelgrass meadow near the Great Bay Fishing pier (GBF) is a restored meadow created in 1993 – 1994 as part of a large-scale mitigation project (Davis and Short 1997). The Dover Point meadow (DP) is located in Little Bay near the mouth of the Oyster and Bellamy Rivers. The Red Nun meadow (RN) is found near the entrance of Great Bay proper, alongside a tidal channel. Eelgrass in the Great Bay Estuary has seasonal fluctuations in growth and biomass, with peak levels occurring in August and low levels occurring in February (Burdick *et al.* 1993; Gaeckle and Short 2002).

Eelgrass Monitoring

Permanent transects were established near the deep edge of each eelgrass meadow and were used as reference points for tracking changes in the location of the meadow edge. Transects were comprised of eight permanent markers spaced at haphazard intervals of 1 m or greater in a straight line roughly parallel to the meadow edge; distances between consecutive markers were recorded. The eelgrass meadows were monitored using SCUBA on a quarterly basis (March, June, September, December) over a two year period from June 2004 through March 2006. During each sampling period, the location of the deep edge of the continuous eelgrass meadow was measured in relation to the transect (Figure 2). For this study, the continuous meadow was defined as eelgrass shoots separated by no more than 1 m from neighboring shoots. The transect line was demarked by attaching a tape measure between the permanent markers at each sampling site. At each marker, the distance to the edge of the meadow was measured in a direction perpendicular to the transect. The location of the deep edge was recorded as the distance from each marker to the deepest eelgrass shoot that was part of the continuous eelgrass meadow along the perpendicular line of measurement (Figure 2). Shoots growing within 10 cm of either side of the perpendicular line of measurement were included for determining deep edge locations. Measurements were made either upslope or downslope from the permanent markers, depending on the location of the meadow during each sampling period. Occasionally, shoots or seedlings would occur greater than 1 m distance from neighboring shoots. These individuals were not considered part of the continuous eelgrass meadow, but their distance from the transect line was recorded as a separate measurement.

Eelgrass shoot density and canopy height were recorded from a 0.0625 m^2 quadrat placed at the deep edge location for each transect marker (Figure 2). Quadrats were positioned parallel to the transect line, oriented upslope and upriver such that they fell within the bounds of the continuous eelgrass meadow. The numbers of vegetative and reproductive eelgrass shoots were recorded. Canopy height, defined as the height above the plant meristem of 80% of leaves (Duarte and Kirkman 2001), was recorded for three non-reproductive shoots within the quadrat.

Figure 2: Conceptual diagram showing the methods used to sample eelgrass parameters at the deep edge and monitor the location of the meadow deep edge in reference to permanent transects. The reference transect is represented as a solid black line with X symbols representing the permanent markers, and the location measurement is represented by a dashed line. Measurements were made in an upslope or downslope direction, depending on the location of the deep edge at each marker. Shoots growing within 10 cm of the perpendicular line of measurement (shaded box) were included for location measurements at each permanent marker. Quadrats for sampling eelgrass parameters were placed at the deep edge in an upslope and upriver direction, such that they fell within the bounds of the eelgrass meadow. Figure is not to scale.



The water depth and landscape slope at each transect were measured once during the experiment. Depths were measured using a tape measure attached to a small mooring ball. At each transect marker, the tape was pulled taut against the buoyancy of the mooring ball to achieve a near vertical measurement. Measurements were conducted on a calm day (01 October 2005) at slack tide to reduce error from wind or currents. The time of measurement was recorded, and depth measurements were later calibrated in reference to mean low water. The slope at each transect marker was measured using a 1.22 m level. One end of the level was placed at the sediment surface next to a marker, perpendicular to the transect line. The opposite end of the level was raised until aligned, and the distance from the base of the level to the sediment surface was recorded. Measurements were taken in an upslope direction from each transect marker. Slopes were calculated as change in height per meter distance.

Change in the areal distribution of eelgrass near the transects was calculated based on the measurements of deep edge location. After the distance from each transect marker to the deep edge of the meadow was established during each sampling period, the area of unvegetated mudflat between the transect and the eelgrass meadow was determined using triangulation. In order to account for meadow expansion past the transect, the area of eelgrass meadow downslope of the transect was subtracted from the total area of unvegetated mudflat. Changes in the area of unvegetated mudflat between sampling periods reflected changes in eelgrass area; i.e., a loss of mudflat was equivalent to a gain in eelgrass habitat. The water column depth of the meadow deep edge was calculated using the measurements of transect marker depth, slope and distance to the deep edge. Depth of the eelgrass deep edge was calculated separately for each transect marker, and depth values were averaged for each site and sampling period.

The percent light reaching the deep edge of the meadows was also monitored during each sampling period. Light measurements were carried out using Onset Hobo™ light sensors, which measure instantaneous irradiance in lumens ft^{-2}. Sensors were placed in cylindrical waterproof casings with a desiccant pack. The sensors were set to record at half-hour intervals and were synchronized to record within 30 seconds of each other. For each meadow, sensors were deployed at one end of the transect line, at a height above the sediment surface equivalent to the height in the water column of the deep edge eelgrass canopy. Additional sensors were deployed above the water surface near the FI and RN sites. The light sensors recorded for one week periods before removal; fouling of the waterproof cases prevented longer deployment.

The light reaching the deep edge of each site was calculated as a percentage of incoming surface irradiance. Only measurements recorded between 1000 and 1400 hours were used for percent light calculations. Light measurements from the FI surface sensor were used in calculations for the lower estuary sites (FI, OCC, GBF) while the RN surface sensor was used in calculations for the upper estuary sites (DP, RN). Light values above 50% SI were considered erroneous measurements and were excluded from analysis. Hobo™ sensors are inaccurate at extremely low light levels, and values below 1% SI were also excluded. An overall average percent light value for each sampling period was calculated from the daily averages over the one week interval.

The average light attenuation coefficient (Kd) was calculated for each site and sampling period using the Beer-Lambert equation:

$$-K_d = \ln (I_z / I_0) / z$$

where I_z was light intensity measured by the underwater sensors; I_0 was light intensity measured by the surface sensors, and z was the depth of the underwater sensor, adjusted for tidal stage. Attenuation coefficients were calculated for each pair of hourly light measurements, and the average daily K_d was determined. An average K_d for each sampling period was calculated using daily K_d values over the one week time period that the light sensors were deployed.

The depth of the underwater light sensor in the water column varied between sampling periods depending on the depth of the eelgrass meadow deep edge. In order to account for differences in sensor placement over time, light values recorded by the underwater sensors were depth-corrected to a consistent depth in the water column. The baseline depth selected for each site was the initial depth of the June 2004 sensor. For each sampling period, the change in sensor depth compared to the June 2004 depth was determined. The change in depth and the K_d value for each sampling period were input into the Beer-Lambert equation to determine the amount of light reaching baseline depth in the water column. Finally, the depth-corrected light values were compared to the surface light values to calculate the percent surface light reaching the baseline depth.

The calculations of the depth of the meadow deep edge were analyzed using a repeated-measures ANOVA with transect markers as subjects, sites as a within-subject factor and sampling date as an among-subject factor (Zar 1999). The distance to the meadow deep edge was compared within each site over time using a one-way ANOVA. The distance to the deep edge could not be compared between sites because the initial distances from the transect markers to the meadow were not equal between sites. Instead, the changes in distance to the deep edge and change in depth of the deep edge from June 2004 to March 2006 were calculated for each transect marker. Change in deep edge location and depth were compared between sites using a one-way ANOVA. The light attenuation coefficients, eelgrass canopy height and eelgrass shoot density were compared between sites and sampling dates using a two-way ANOVA. Eelgrass shoot density at each site was examined over time using a one-way ANOVA. For all ANOVAs, data were examined for normality and homogeneous variance and when necessary data were log transformed prior to analysis. Post-hoc multiple comparisons were performed using a Tukey's HSD test. Probabilities less than or equal to 0.05 were considered significant. Analyses were performed using JMP for Windows® (Version 6.0, SAS Institute, Inc).

Results

During the first year of monitoring (June 2004 through June 2005), the location of the eelgrass meadow deep edge showed fluctuating gains and losses at all five monitoring sites (Figure 3). At individual transect markers, the location of the deep edge often varied by over a meter between sampling periods. However, the direction of change was not consistent along the entire meadow edge. The meadow advanced or receded at different points during each sampling period, resulting in little net change in average deep edge location along the length of the transect during year one (Figure 4). For all sites, the average deep edge location was not significantly different over time ($p > 0.05$) throughout the first year of monitoring (Figure 4).

During the second year of monitoring (June 2005 through March 2006), a significant change in the location of the deep edge was detected at the FI and GBF sites (Figure 4). The meadow receded in an upslope direction at both sites, beginning in September 2005 at FI and in December 2005 at GBF. Although the average location of the deep edge showed a receding trend at these sites, the magnitude and direction of change at some transect markers continued to show fluctuating gains and losses from season to season (Figure 3A, 3C). The meadow deep edge at FI and GBF receded substantially at a majority of transect markers during year two, although the meadow edge at some markers actually advanced during this time period (Figure 3A, 3C). At the remaining sites, OCC, DP and RN, the average location of the deep edge did not change significantly ($p > 0.05$) over the course of the monitoring effort (Figure 4), and the fluctuating gains and losses of the deep edge at individual transect markers was observed throughout the duration of the study (Figure 3B, 3D, 3E).

The changes in the location of the eelgrass meadow deep edges are reflected in the changes in meadow area. The permanent transects were arbitrarily placed at each eelgrass meadow, and at the OCC and DP sites, the transects were situated near the lateral border of the meadows. At the OCC and DP sites, the eelgrass meadow receded from the side during the course of monitoring for undetermined reasons (Figure 3B, 3D), and these sections of the transect were not included in area calculations. During the first year of monitoring (June 2004 through June 2005), all sites showed fluctuating gains and losses in meadow area along the transects, but the gains and losses did not have a consistent pattern between sites or sampling periods (Figure 5). The DP site had the highest variability in the fluctuations of meadow area during the first year. During the second year of monitoring (June 2005 to March 2006), a trend of declining eelgrass meadow area occurred at the FI and GBF sites (Figure 5). From September 2005 to March 2006, the loss of meadow area along the length of the transect exceeded 30 m^2 at both the FI and GBF sites. The loss of meadow area at FI and GBF during this time period was larger in magnitude than losses at OCC or RN (Figure 5). At DP, a reduction in meadow area exceeding 10 m^2 occurred in December 2005, however meadow area at DP expanded by a similar amount in March 2006 (Figure 5).

The repeated-measures ANOVA for deep edge depth detected a significant interaction between sampling period and site ($F_{28, 236} = 3.413$; $p < 0.001$), with multiple comparisons indicating that each site had a significantly distinct depth range ($p < 0.05$). The maximum depth of the eelgrass deep edge followed the estuarine gradient; eelgrass grew deepest at the FI site and was shallowest at the RN site (Figure 6). The exception to the pattern was the GBF and OCC sites; eelgrass at GBF grew deeper even though it is further up the estuary than OCC (Figure 1). Multiple comparisons of deep edge depth among sites are not shown, but the results indicate that each site had a significantly distinct depth range ($p < 0.05$), although some overlap occurred between the maximum and minimum depths recorded at consecutive sites along the estuarine gradient. At OCC, DP and RN, sites where the location of the meadow edge did not change (Figure 4), average deep edge depth was not significantly different between sampling periods ($p > 0.05$, Figure 6). At GBF, the average deep edge depth decreased from initial levels only in March 2006 ($p < 0.05$, Figure 6). At FI, the average deep edge depth decreased from initial levels in both December 2005 and March 2006 ($p < 0.05$, Figure 6).

A comparison of the two methods of monitoring the deep edge, measuring location from fixed transects and calculating depth, demonstrated that both methods were able to detect the significant changes in the eelgrass deep edge that occurred at the FI and GBF sites (Table 1). However, a statistically significant change in deep edge location at FI and GBF was detectable three to six months earlier than the change in deep edge depth at those sites (Table 1). Further differences in the ability of each method to detect significant changes are shown in analysis of change in deep edge location and depth between June 2004 and March 2006 (Table 2, Figure 7). A one-way ANOVA showed a significant effect of site for change in distance data ($F_{4, 34} = 5.906$; $p < 0.001$) and change

Figure 3A: Quarterly location of the eelgrass meadow deep edge at Fishing Island from June 2004 to March 2006. The location of the deep edge was recorded as distance from a permanent transect, with measurements taken at eight points. Positive distances indicate an upslope direction and negative distances indicate a downslope direction. The transect is represented as a horizontal line at zero distance on the y axis with vertical dashes representing the eight measurement points. Shaded figures represent the areal coverage of the eelgrass meadow during each sampling period

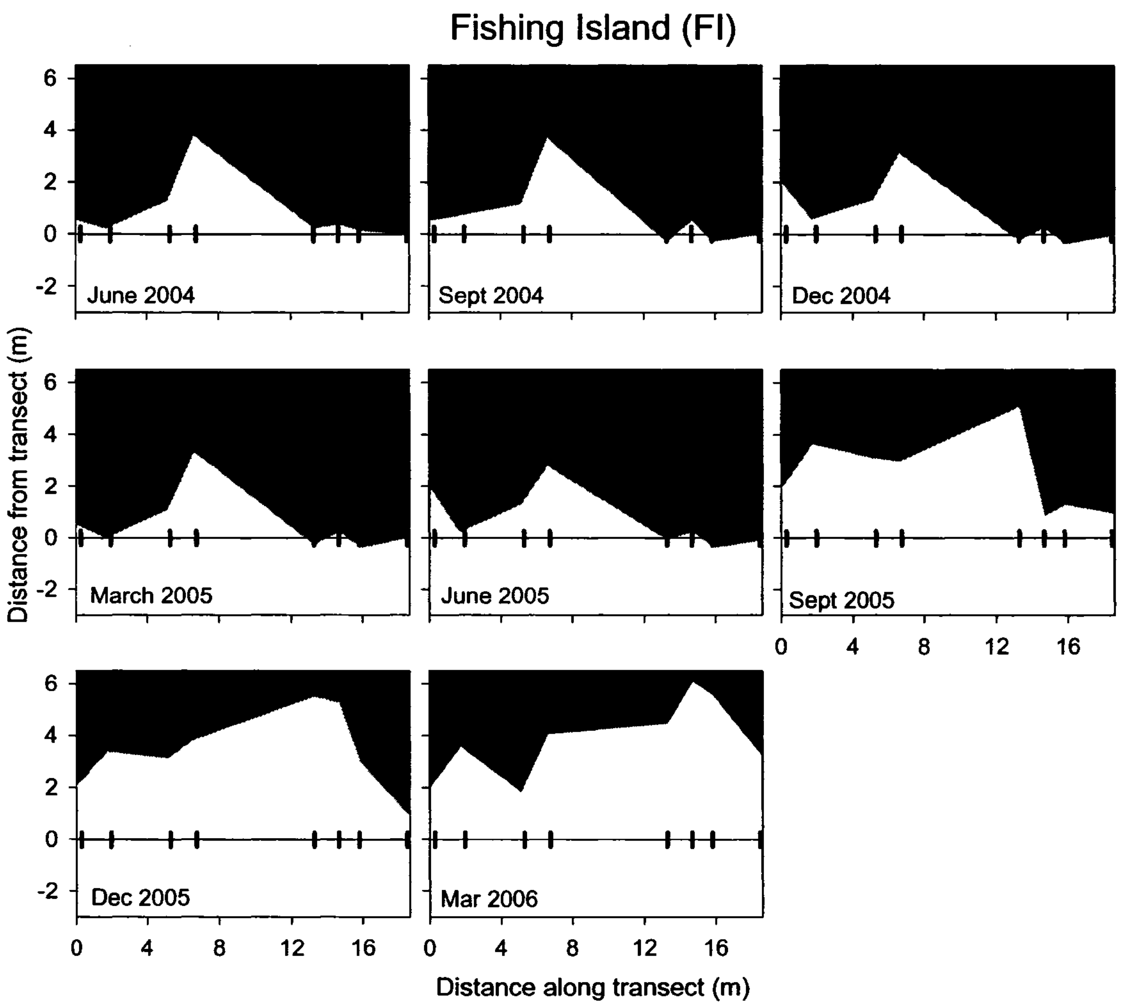


Figure 3B: Quarterly location of the eelgrass meadow deep edge at Outer Cutts Cove from June 2004 to March 2006. The location of the deep edge was recorded as distance from a permanent transect, with measurements taken at eight points. Positive distances indicate an upslope direction and negative distances indicate a downslope direction. The transect is represented as a horizontal line at zero distance on the y axis with vertical dashes representing the eight measurement points. Shaded figures represent the areal coverage of the eelgrass meadow during each sampling period.

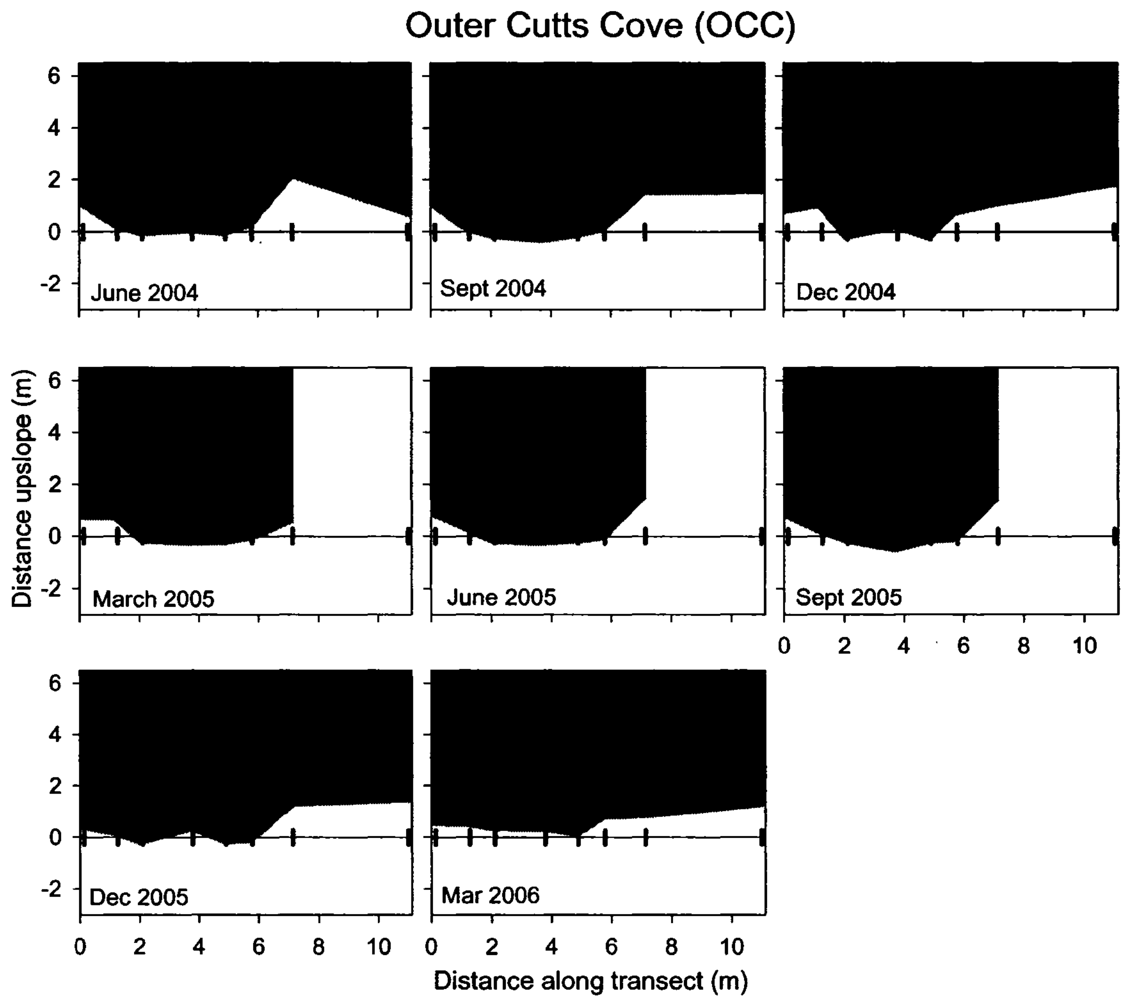


Figure 3C: Quarterly location of the eelgrass meadow deep edge at Great Bay Fish from June 2004 to March 2006. The location of the deep edge was recorded as distance from a permanent transect, with measurements taken at eight points. Positive distances indicate an upslope direction and negative distances indicate a downslope direction. The transect is represented as a horizontal line at zero distance on the y axis with vertical dashes representing the eight measurement points. Shaded figures represent the areal coverage of the eelgrass meadow during each sampling period.

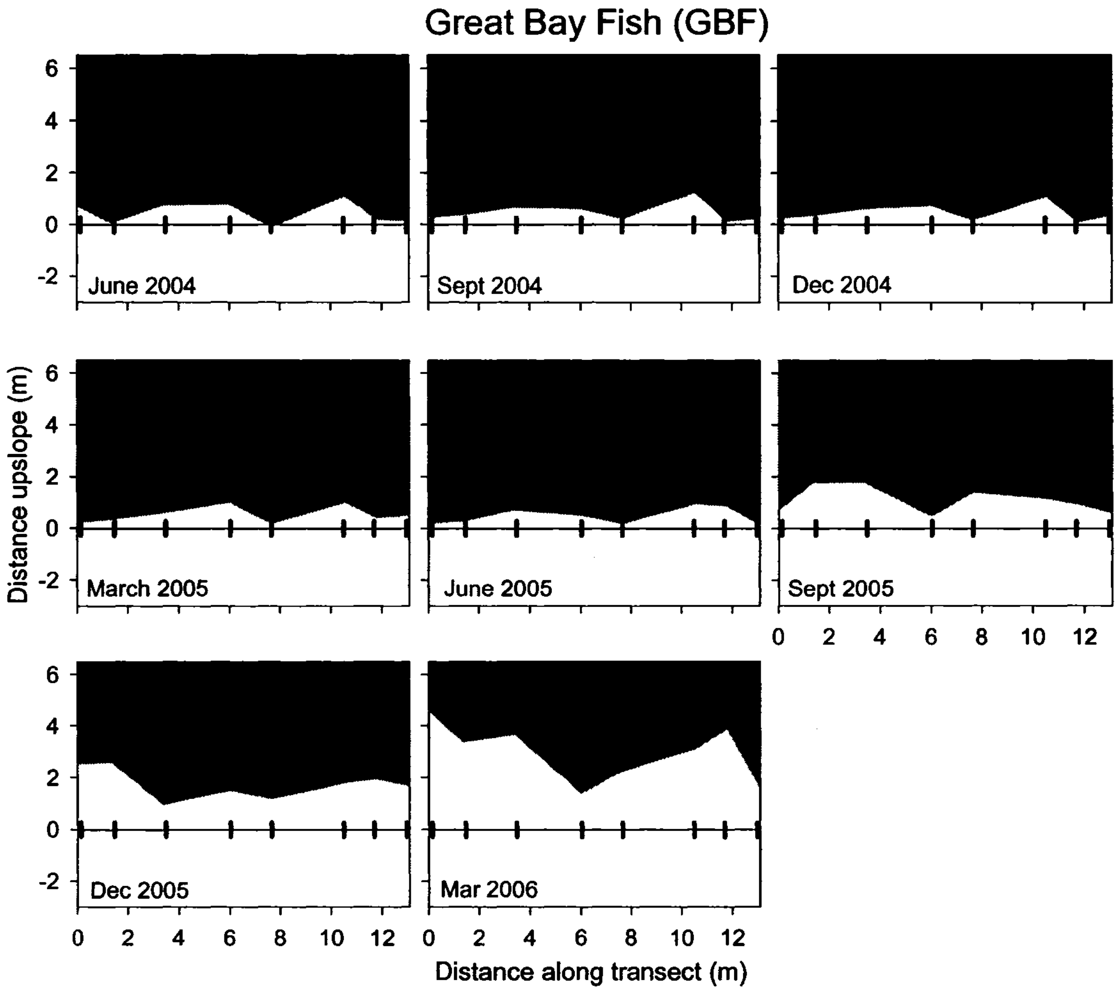


Figure 3D: Quarterly location of the eelgrass meadow deep edge at Dover Point from June 2004 to March 2006. The location of the deep edge was recorded as distance from a permanent transect, with measurements taken at eight points. Positive distances indicate an upslope direction and negative distances indicate a downslope direction. The transect is represented as a horizontal line at zero distance on the y axis with vertical dashes representing the eight measurement points. Shaded figures represent the areal coverage of the eelgrass meadow during each sampling period.

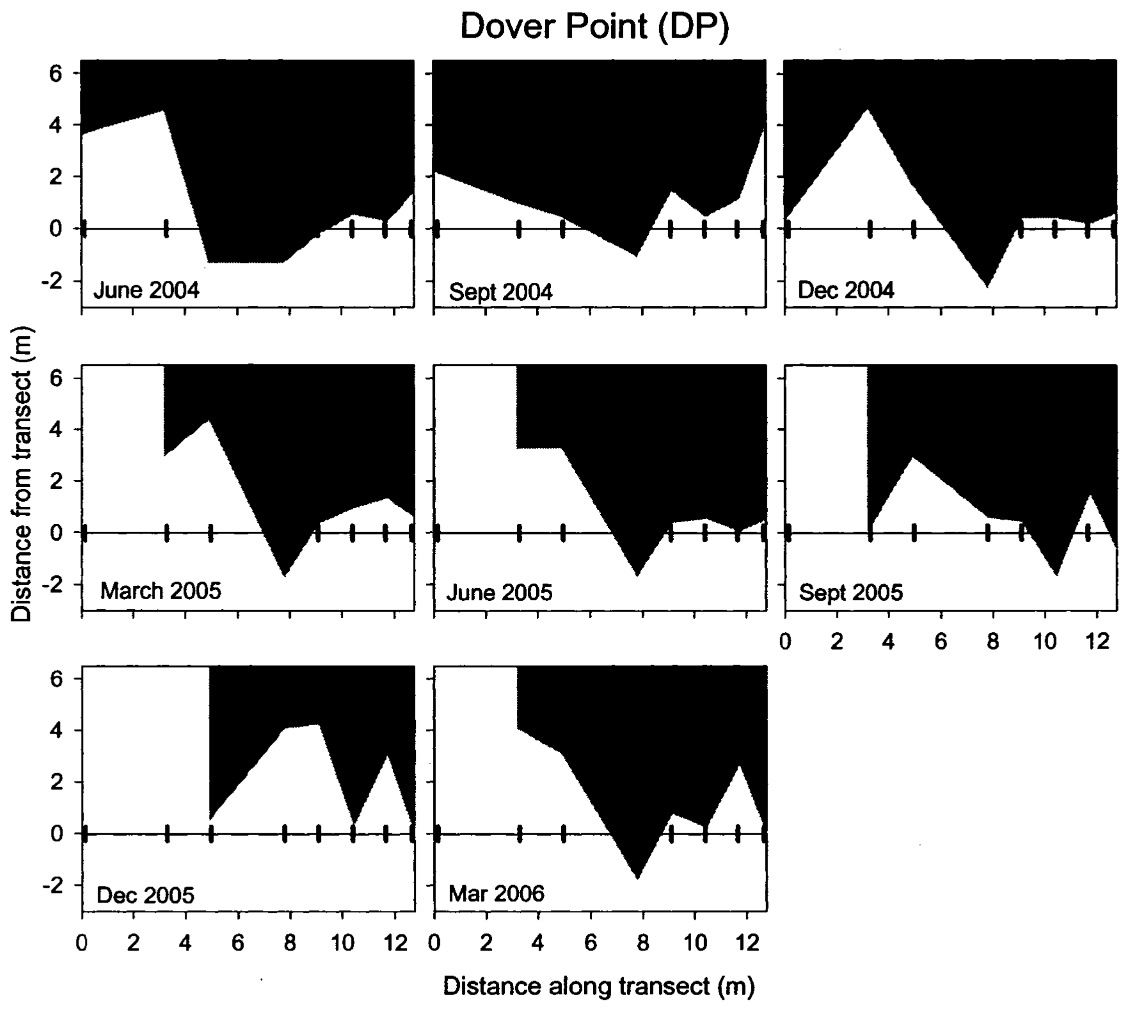


Figure 3E: Quarterly location of the eelgrass meadow deep edge at Red Nun from June 2004 to March 2006. The location of the deep edge was recorded as distance from a permanent transect, with measurements taken at eight points. Positive distances indicate an upslope direction and negative distances indicate a downslope direction. The transect is represented as a horizontal line at zero distance on the y axis with vertical dashes representing the eight measurement points. Shaded figures represent the areal coverage of the eelgrass meadow during each sampling period.

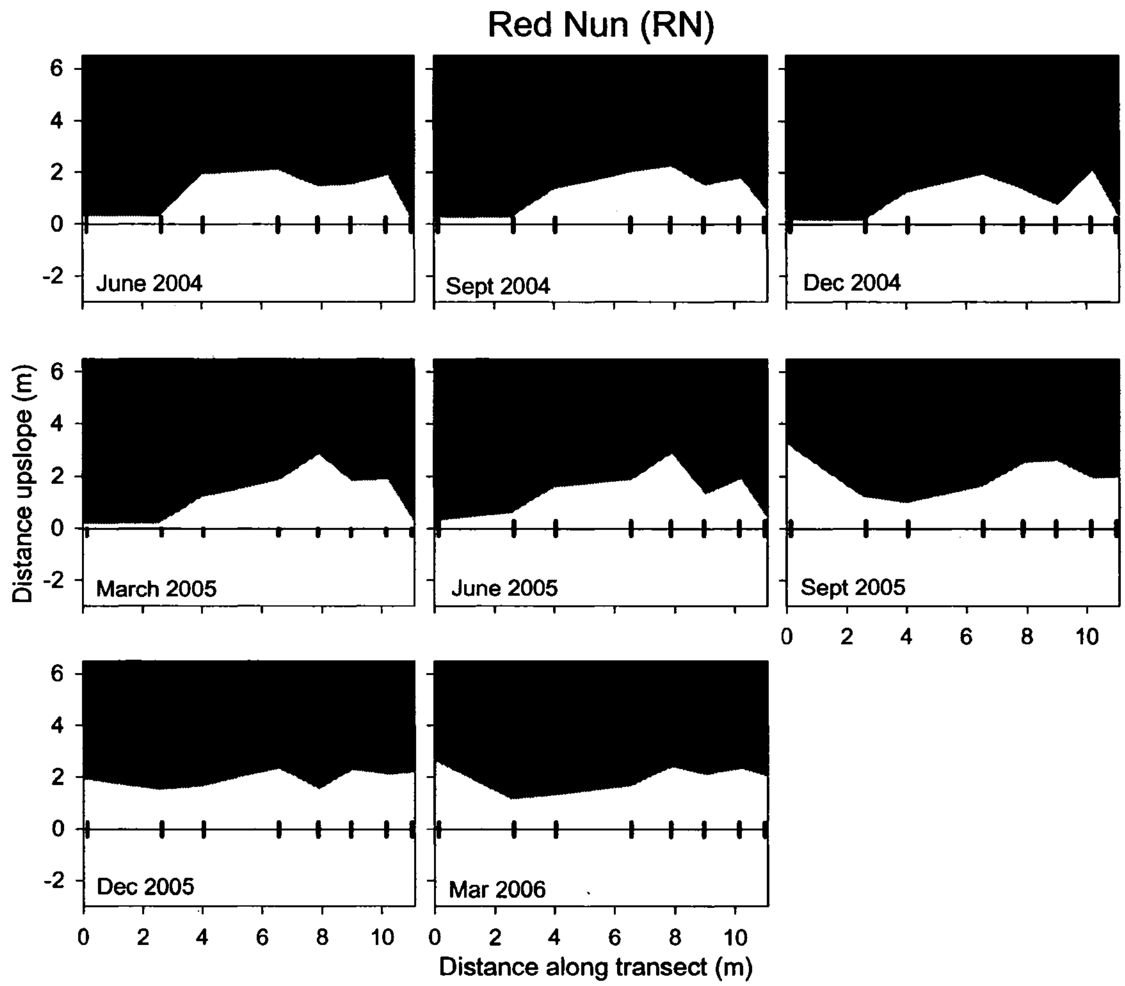
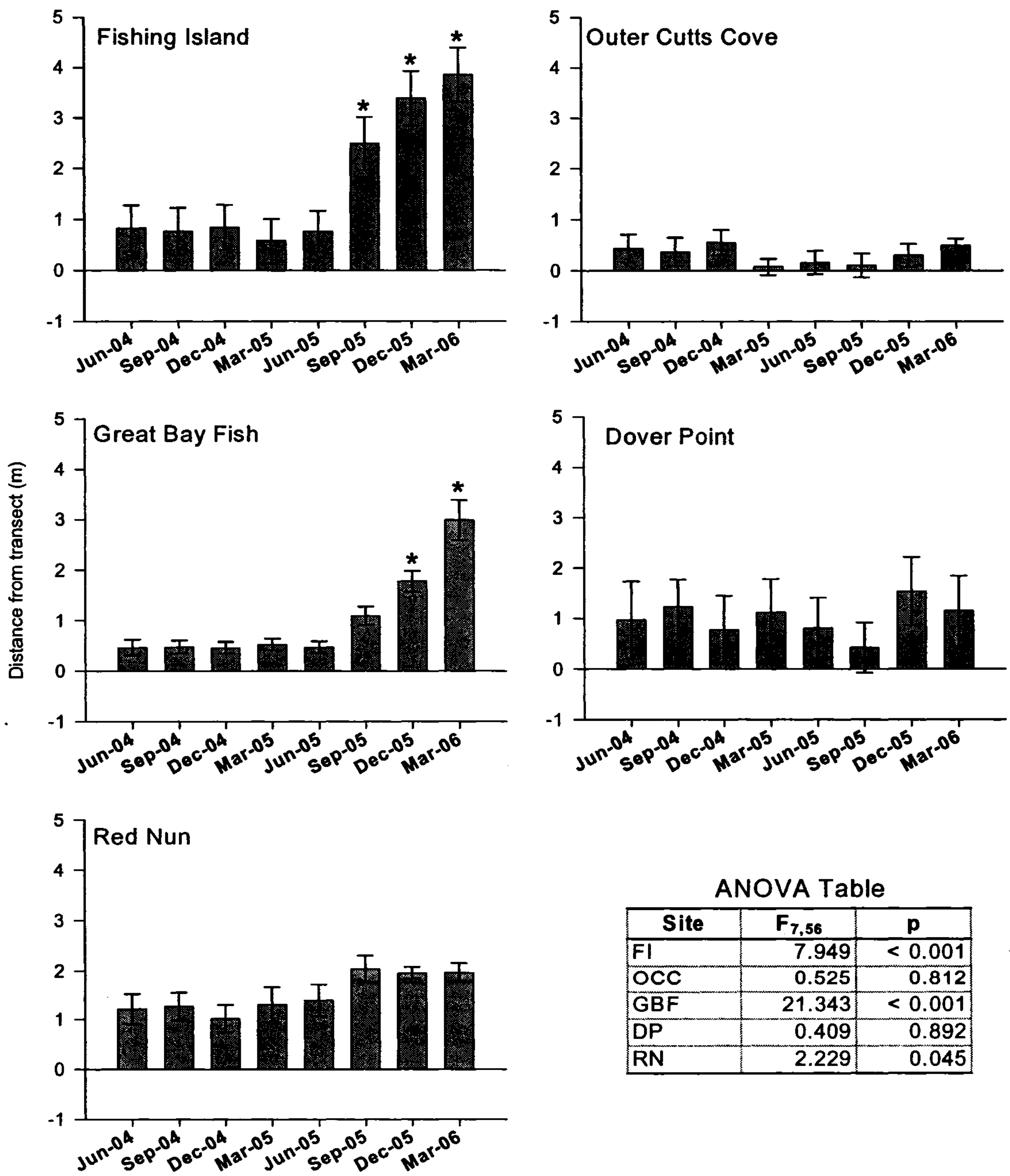


Figure 4: Mean location (± SE, n ranges from 6 to 8) of the eelgrass meadow deep edge at five monitoring sites, measured as distance from a permanent transect. Positive values are distance in an upslope direction and negative values are distance in a downslope direction. Within each site, asterisks (*) indicate a significant difference ($p < 0.05$) in deep edge location from the initial, June 2004 location. Results of one-way ANOVAs conducted for each site, comparing distance data among sampling periods.



ANOVA Table

Site	$F_{7,56}$	p
FI	7.949	< 0.001
OCC	0.525	0.812
GBF	21.343	< 0.001
DP	0.409	0.892
RN	2.229	0.045

Figure 5: Change in eelgrass meadow area between consecutive sampling periods. Sampling periods occurred every three months beginning in June 2004. Positive values (shaded bars) indicate a gain in eelgrass area, negative values (hatched bars) indicate a loss of eelgrass area. Area calculations are based on the location of the eelgrass meadow deep edge in reference to permanent markers. Eight location measurements per sampling period were used for the FI, GBF and RN calculations; 7 measurements for the OCC calculations; and 6 measurements for the DP calculations.

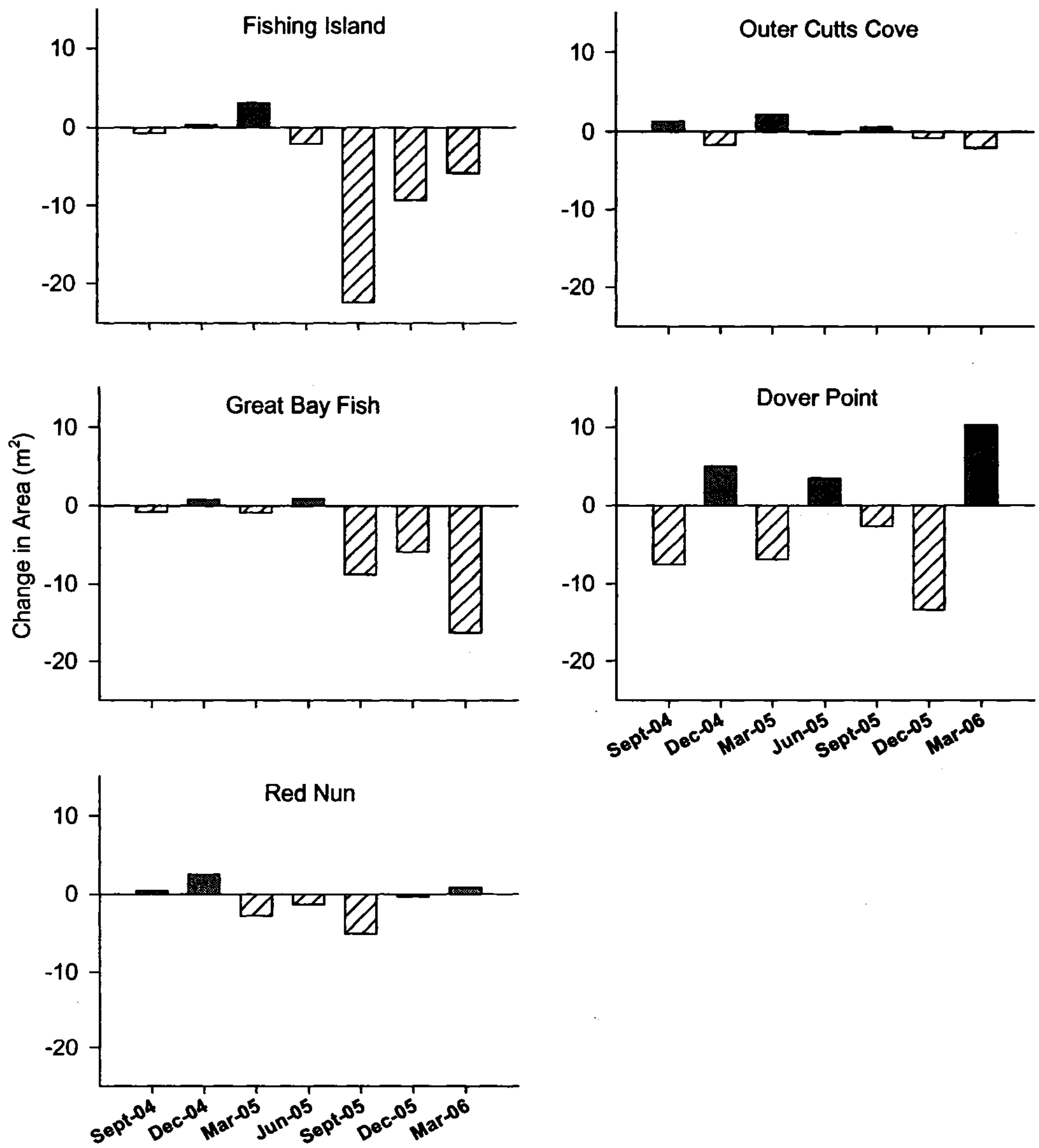
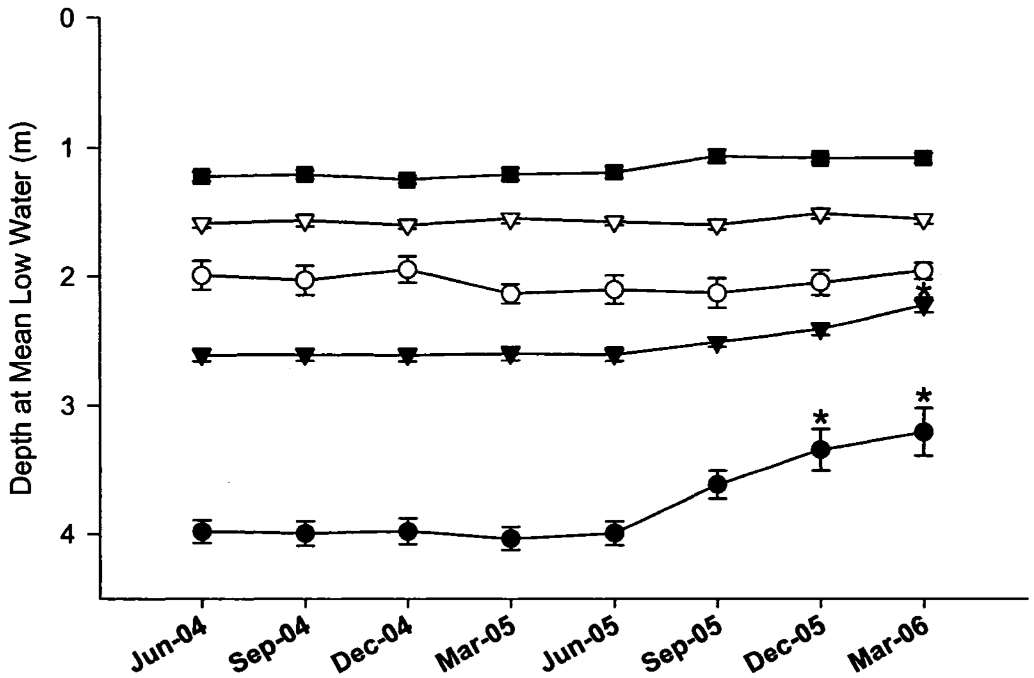


Figure 6: Mean depth at mean low water (± SE, n ranges from 6 to 8) of the eelgrass meadow deep edge at five monitoring sites. Within a site, asterisks indicate significant changes in depth compared to the initial June 2004 depth. Minimum and maximum recorded depths of the deep edge for each site are listed in the figure legend.



Symbol	Site	Minimum Depth (m)	Maximum Depth (m)
■	RN	0.8	1.4
▽	DP	1.3	1.8
▼	GBF	1.9	2.8
○	OCC	1.3	2.5
●	FI	2.1	4.3

in depth data ($F_{4, 34} = 6.431$; $p < 0.001$). FI had a greater increase in distance and depth than all sites except GBF ($p < 0.05$, Table 2), and the change in distance at GBF was detected to be greater than at OCC ($p < 0.05$, Table 2). Even though significant changes in distance were detectable at the GBF site, change in deep edge depth at GBF was not significantly different from other sites ($p > 0.05$, Table 2).

Slope varied significantly among sites (one-way ANOVA, $F_{4, 34} = 77.236$, $p < 0.001$). OCC had the steepest slope followed by FI (Table 2, Figure 7), and the meadow edges at those sites were consistently the most clearly defined. The slopes at GBF and RN were the next steepest and were not different from each other (Table 2). At DP, which had the gentlest slope, the meadow edge was patchy and often poorly defined.

The percent surface light reaching the eelgrass meadow deep edge ranged from 2 - 31% during the course of the study (Figure 8). GBF had the greatest fluctuations in light, with values ranging from 3 - 31%. RN had the most consistent light levels, which ranged from 10 – 20%. Percent light reaching the eelgrass depth limit was compared against an estimated 11% minimum light requirement for seagrasses (Duarte 1991). At OCC, DP and RN, sites where the location of the meadow deep edge did not change, the percent light reaching the deep edge eelgrass never fell below the 11% light requirement for more than two consecutive sampling periods. At FI and GBF, the percent light reaching deep edge eelgrass fell below the 11% threshold during the first three sampling periods. By September 2005, when the meadow edge at FI and GBF was beginning to recede, the percent light reaching deep edge eelgrass at these sites was above 11%. At

GBF the percent light remained above the threshold through March 2006, whereas at FI the percent light dropped below the threshold in December 2005 and recovered in March 2006 (Figure 8).

The light attenuation coefficient during each sampling period was consistently higher at the RN site than at the FI site (two-way ANOVA: $F_{28,240} = 27.75$, $p < 0.01$; Tukey's HSD $p < 0.05$), with intermediate values occurring at the OCC, GBF and DP sites (Figure 9). The greatest range in light attenuation coefficient values occurred at the DP site (0.43 – 1.87 m^{-1}), while FI had the lowest range (0.31 – 1.02 m^{-1}). The light attenuation coefficient values were used to depth-correct the percent light to a consistent level in the water column, representing the initial location of the eelgrass deep edge in June 2004 (Figure 10). At the OCC, DP and RN sites, the depth-corrected percent light never fell below the 11% threshold for more than two consecutive sampling periods (Figure 10). In contrast, at the FI and GBF sites the depth-corrected percent light was below the 11% threshold for the majority of sampling periods. During the September 2005 to March 2006 time period when the eelgrass deep edge was receding at the FI and GBF sites, the percent light reaching the eelgrass deep edge was above the 11% requirement (Figure 8). However, the depth-corrected light at these two sites was below the 11% threshold during most of the September 2005 to March 2006 time period (Figure 10).

There was a significant interaction between site and sampling date for eelgrass canopy height ($F_{28,270} = 2.120$, $p = 0.001$) and shoot density ($F_{28,270} = 1.864$, $p = 0.006$) at the meadow depth limit. Shoot density varied little among sites and ranged from 20 – 250 shoots m^{-2}. GBF had detectable decreases in shoot density in December 2005 and March 2006, while FI had detectable declines in March 2006 (Figure 11). At all monitoring sites, eelgrass at the deep edge grew in small clusters of shoots, with patches separated by up to a meter. Although not directly measured, patch survival was observed to be quite variable, with newly established patches appearing or old patches disappearing between consecutive sampling periods. Eelgrass canopy height showed seasonal fluctuations at all sites ($p < 0.05$, Figure 12). The greatest canopy height occurred in June or September while the low values occurred in March. Canopy height was not significantly different among sites ($p > 0.05$) with the exception that RN had higher values than the other sites in June 2004 and September 2004 ($p < 0.05$).

Table 1: Quarterly mean distance and depth of the eelgrass deep edge (± SE, n = 8) at the FI and GBF sites from June 2004 to March 2006. Distance was measured in reference to a permanent transect, and depth is in reference to mean low water. Asterisks indicate significant differences from the June 2004 sampling period.

	Fishing Island		Great Bay Fish	
	Distance (m)	**Depth (m)**	**Location (m)**	**Depth (m)**
Jun-04	0.82 ± 0.48	3.98 ± 0.10	0.47 ± 0.16	2.60 ± 0.05
Sep-04	0.76 ± 0.49	3.99 ± 0.10	0.48 ± 0.14	2.60 ± 0.05
Dec-04	0.84 ± 0.47	3.98 ± 0.11	0.46 ± 0.13	2.60 ± 0.05
Mar-05	0.57 ± 0.46	4.04 ± 0.10	0.53 ± 0.12	2.60 ± 0.05
Jun-05	0.76 ± 0.44	3.99 ± 0.10	0.47 ± 0.13	2.60 ± 0.05
Sep-05	2.45 ± 0.56 *	3.62 ± 0.12	1.09 ± 0.19	2.50 ± 0.04
Dec-05	3.39 ± 0.59 *	3.34 ± 0.18 *	1.78 ± 0.22 *	2.40 ± 0.05
Mar-06	3.85 ± 0.58 *	3.20 ± 0.20 *	2.99 ± 0.43 *	2.22 ± 0.06 *

Table 2: Change in the depth of the eelgrass meadow deep edge and change in the distance of the deep edge from reference transects from June 2004 to March 2006 (mean ± SE, n = 8). Values with the same letter are not significantly different between sites ($p > 0.05$).

Site	Slope (m)	Change in Depth (m)	Change in Distance (m)
FI	0.23 ± 0.02 [a]	0.78 ± 0.24 [a]	3.03 ± 0.74 [a]
OCC	0.39 ± 0.02 [b]	0.04 ± 0.08 [b]	0.06 ± 0.23 [b]
GBF	0.15 ± 0.02 [c]	0.39 ± 0.06 [ab]	2.52 ± 0.40 [ac]
DP	0.05 ± 0.02 [d]	0.04 ± 0.05 [b]	0.73 ± 0.77 [bc]
RN	0.15 ± 0.04 [c]	0.15 ± 0.07 [b]	0.76 ± 0.37 [bc]

Figure 7: Change in mean location and depth of the eelgrass meadow deep edge from June 2004 (hollow triangle) to March 2006 (solid triangle). Asterisks (*) indicate sites with significant ($p < 0.05$) change in both location and depth. Location of the deep edge was measured as distance from a permanent transect (solid circle). Graphs are cross-sectional depictions of the monitoring sites with shaded areas representing the substrate. Depth, distance and slope are to scale between sites.

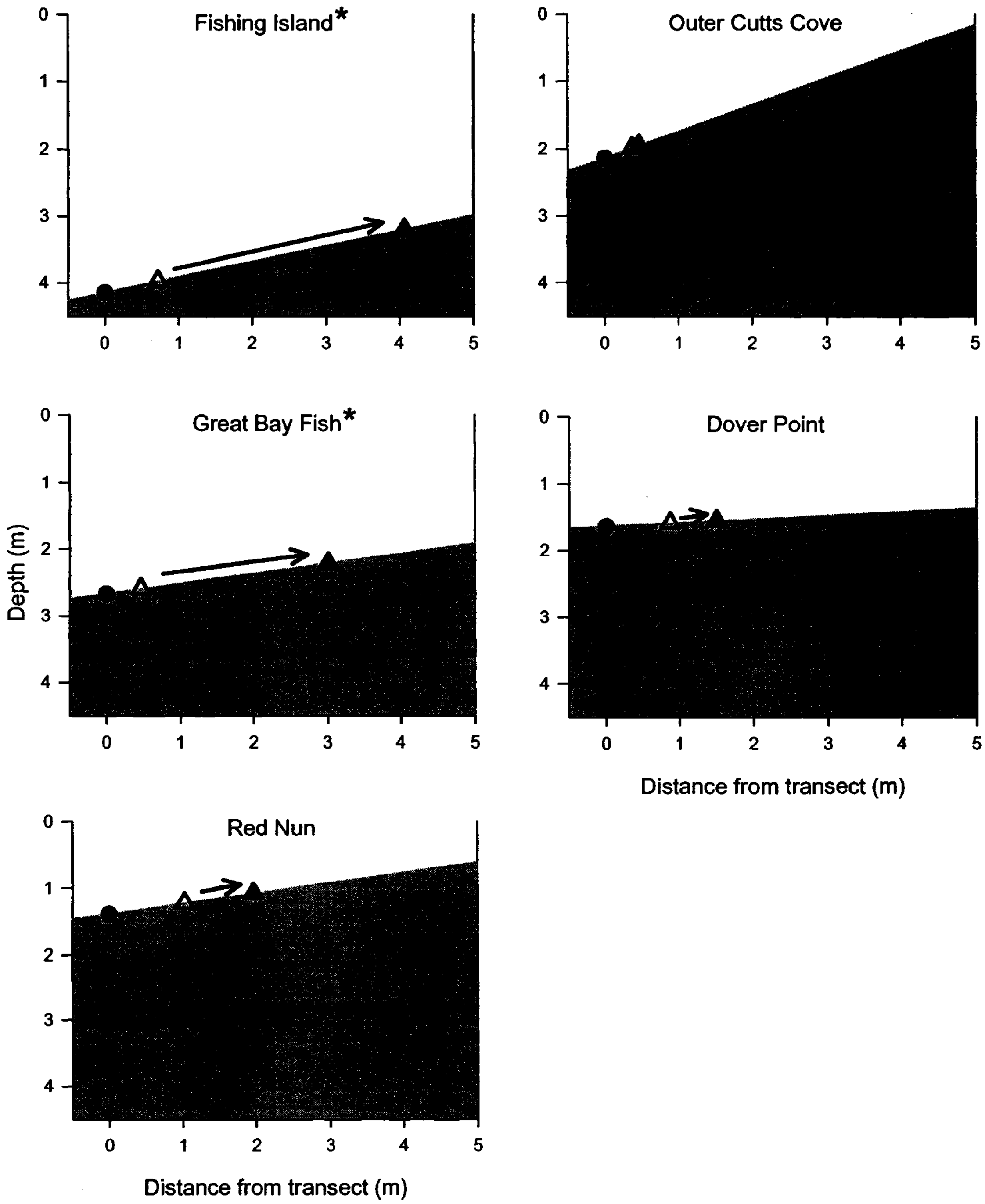


Figure 8: Percent surface light (± SE) reaching the eelgrass canopy at the meadow deep edge for each site and sampling period. Bars represent daily average irradiance over one week (n = 7) for each sampling period. The dashed line represents an estimated 11% minimum light requirement for seagrasses (Duarte 1991).

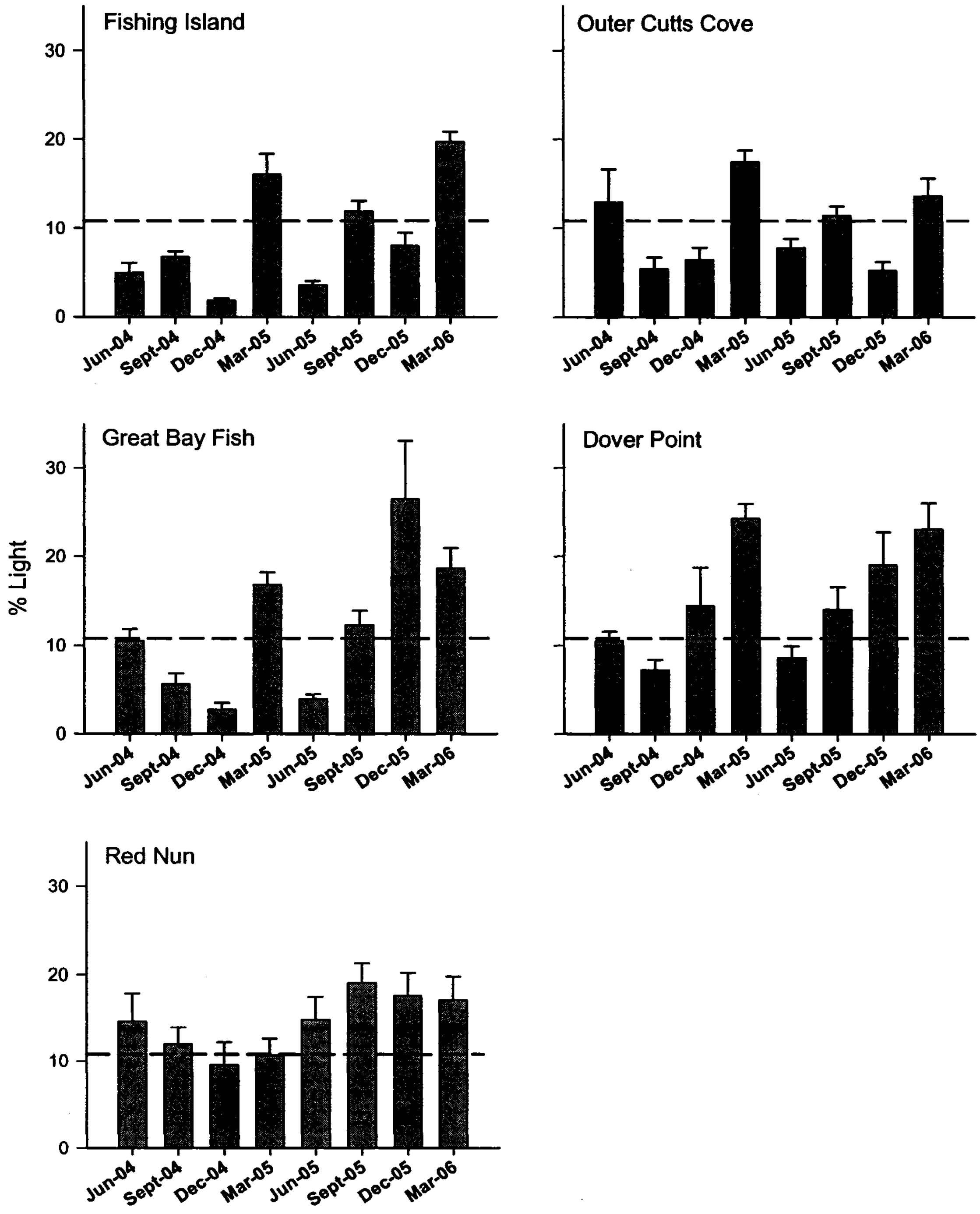


Figure 9: Quarterly mean light attenuation coefficients (± SE, n = 7) at the deep edge of eelgrass meadows from June 2004 to March 2006.

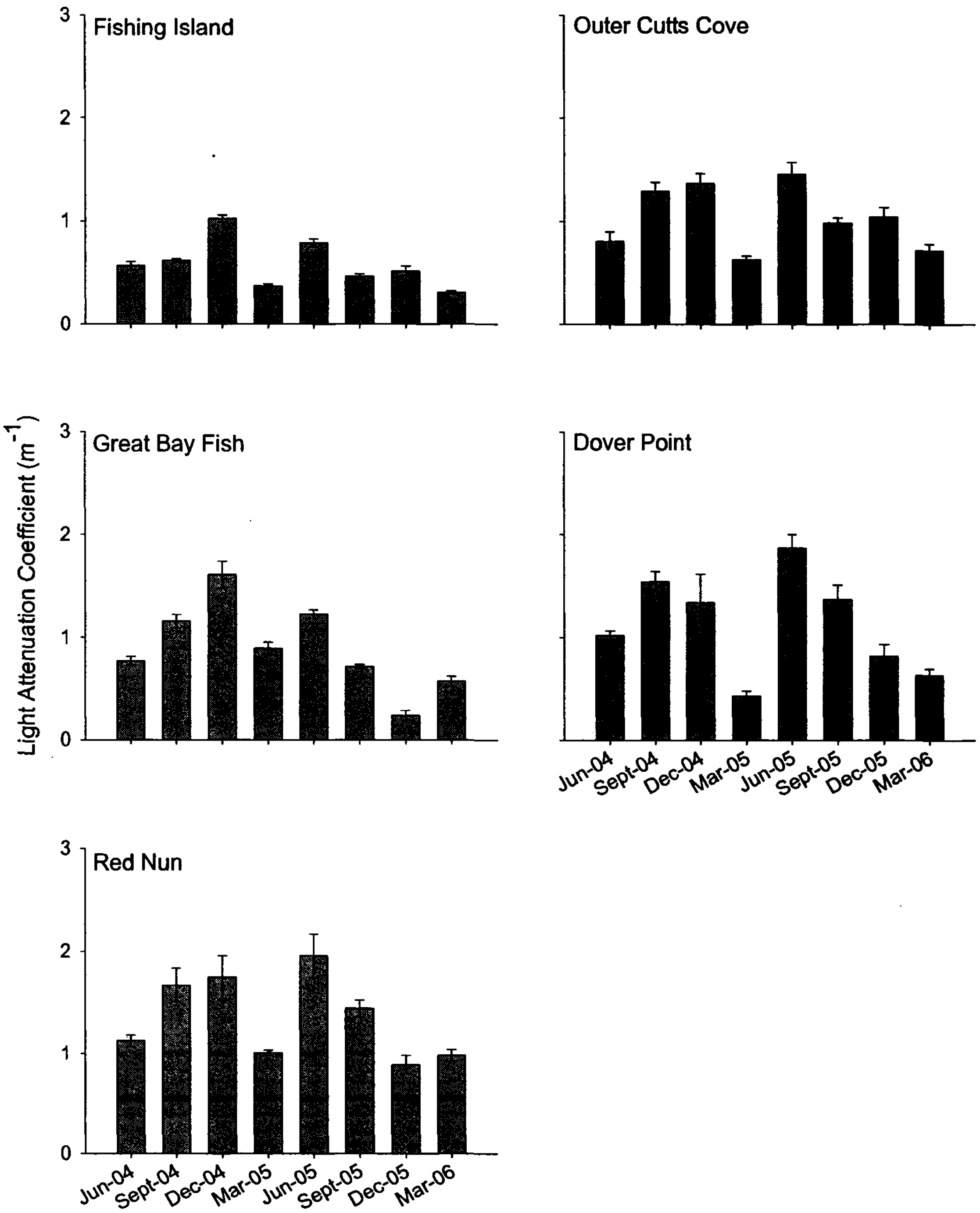


Figure 10: Percent surface light (± SE) reaching a depth in the water column equal to the June 2004 deep edge depth at each site. Bars represent daily average irradiance over one week (n = 7) for each sampling period. The dashed line represents an estimated 11% minimum light requirement for seagrasses (Duarte 1991).

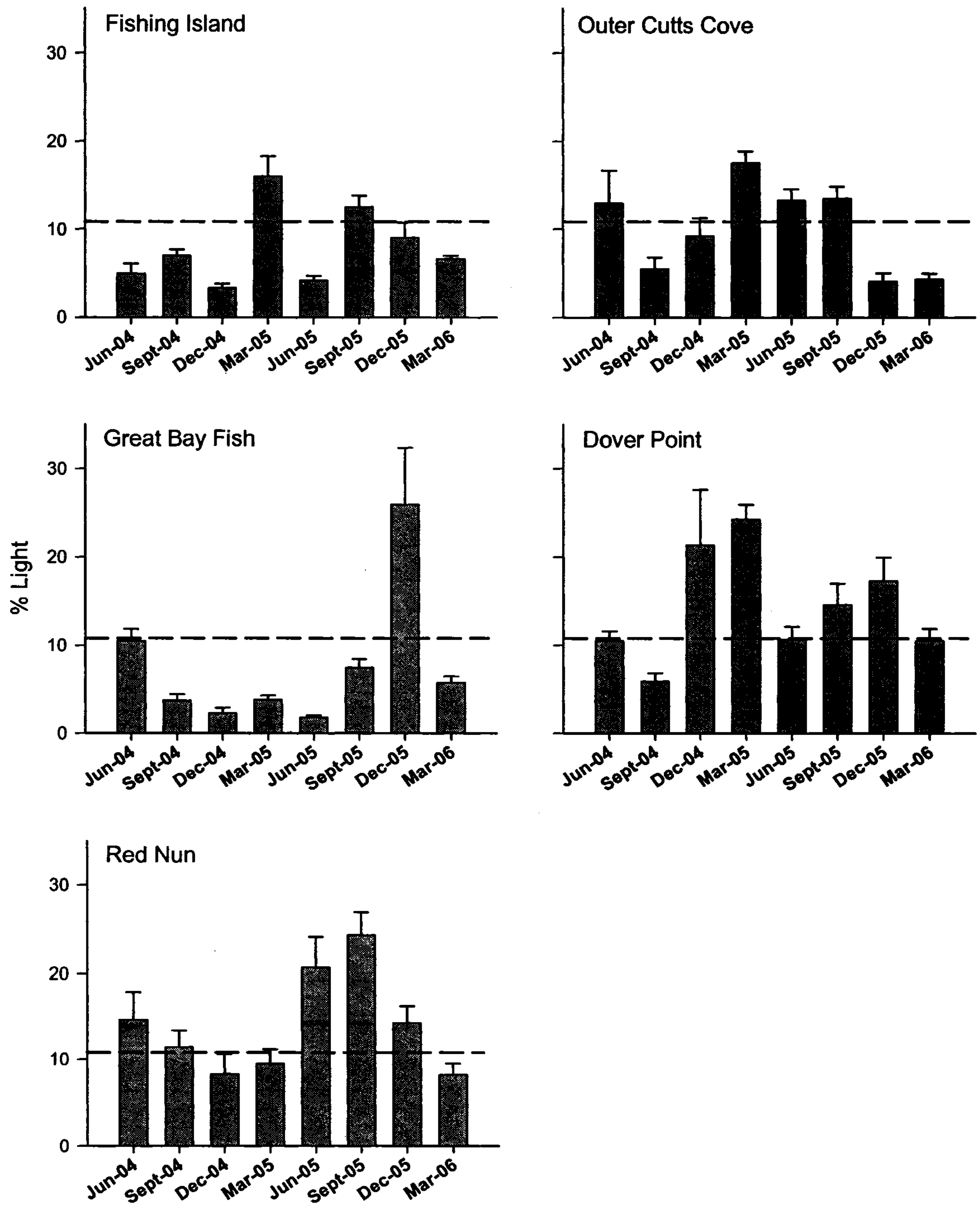
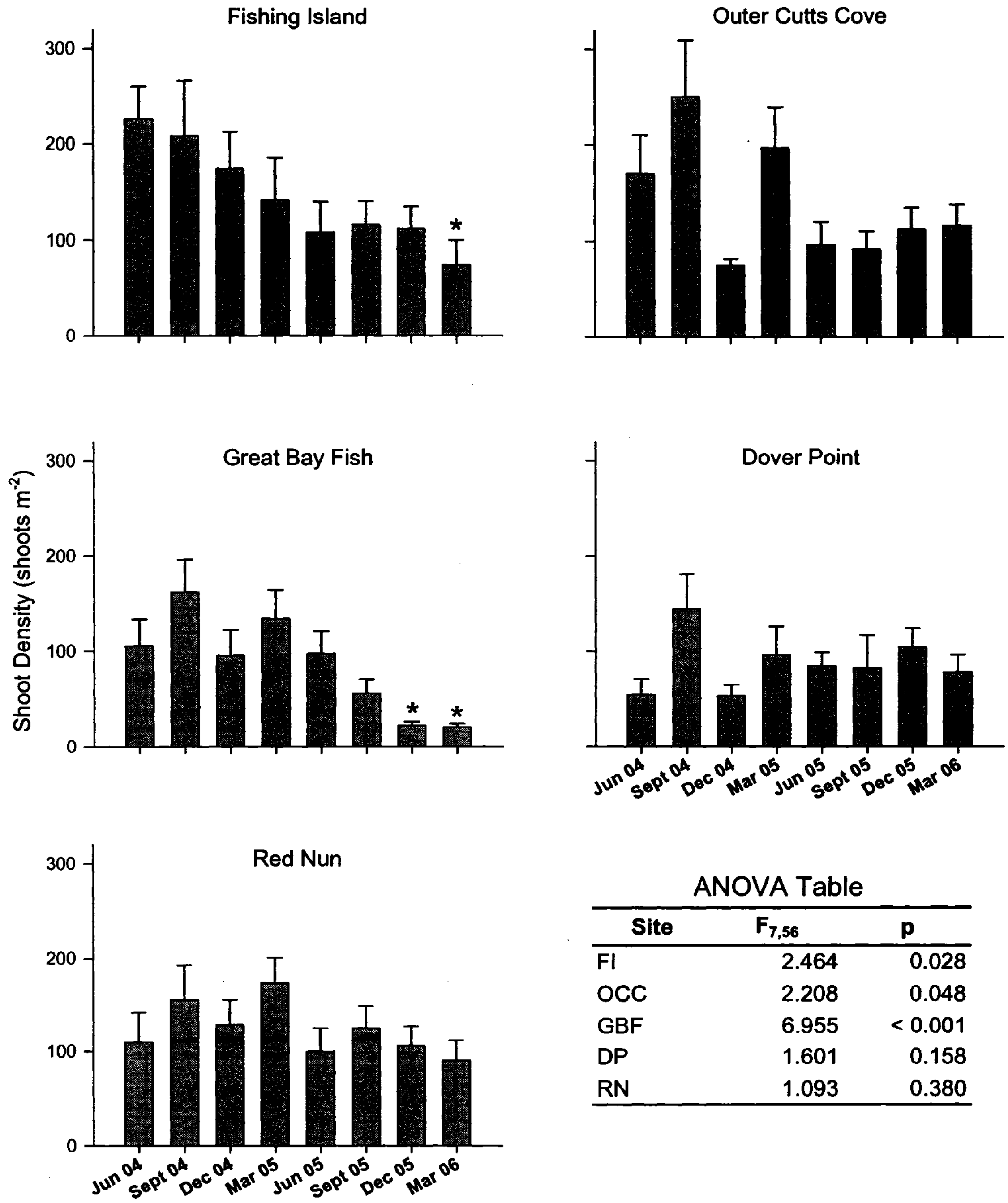


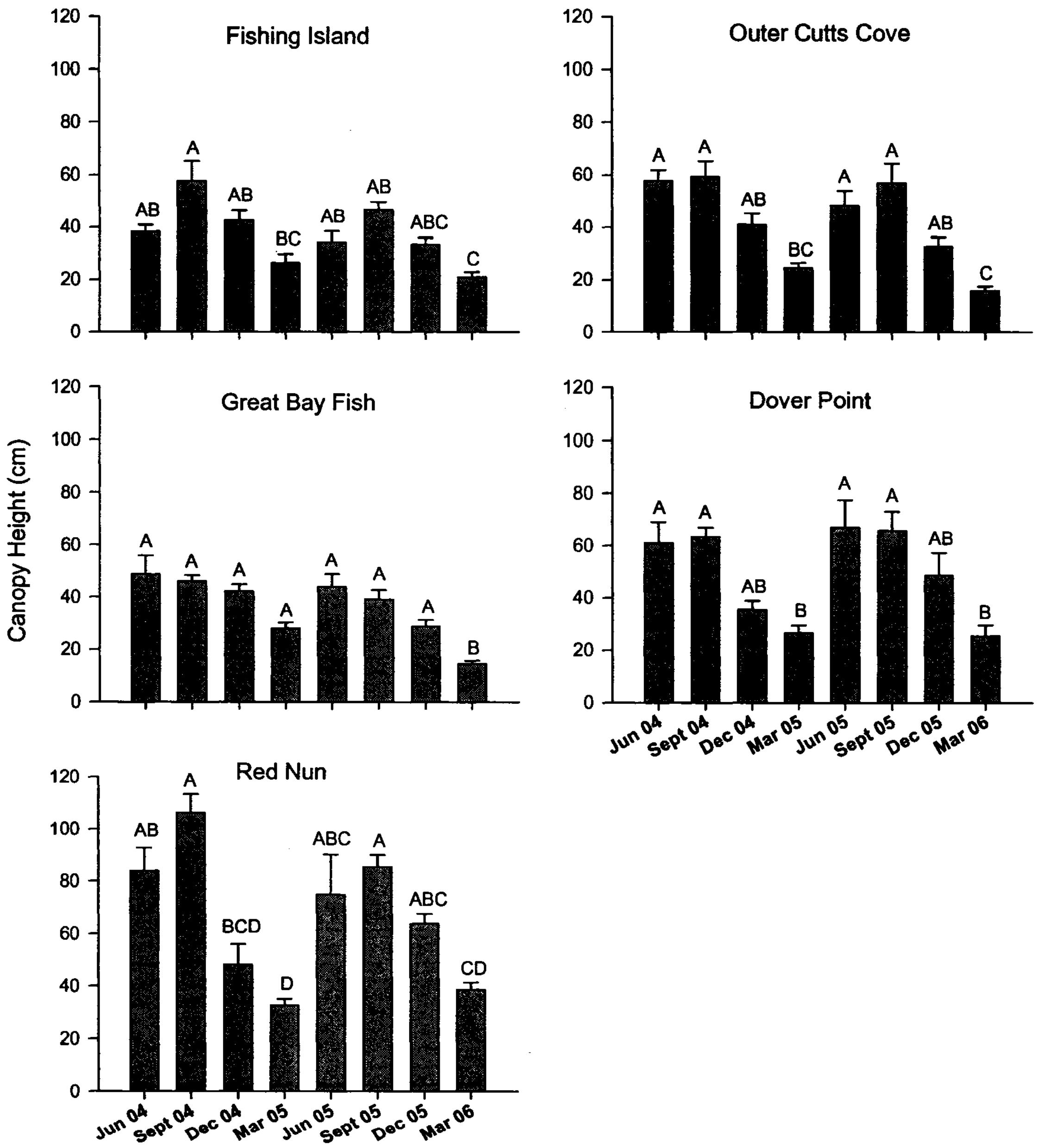
Figure 11: Quarterly mean shoot density (± SE, n ranges from 6 to 8) at the deep edge of eelgrass meadows from June 2004 to March 2006. Results of one-way ANOVAs conducted for each site, comparing shoot density data among sampling periods. Asterisks (*) indicate significant declines ($p < 0.05$) in shoot density compared to peak values.



ANOVA Table

Site	$F_{7,56}$	p
FI	2.464	0.028
OCC	2.208	0.048
GBF	6.955	< 0.001
DP	1.601	0.158
RN	1.093	0.380

Figure 12: Quarterly mean eelgrass canopy height (± SE, n ranges from 6 to 8) at the deep edge of meadows from June 2004 to March 2006. Within a site, columns with the same letters are not significantly different ($p > 0.05$).



Discussion

The calculated light attenuation coefficients confirm that the five monitoring sites follow the decreasing gradient of water clarity from the coast to the interior of the estuary (Chadwick *et al.* 1993). Light attenuation during each sampling period was consistently lower at FI, located at the mouth of the estuary, than at RN, located in the interior. The depth of the eelgrass meadow deep edges in the Great Bay Estuary also followed the estuarine gradient of water clarity (Figure 6), with shallower deep edges occurring in the upper estuary where water is more turbid. The one exception was site OCC, where the deep edge depth was shallower than the next site along the gradient, GBF. OCC is the remaining portion of a previously larger meadow that was partially dredged during the construction of a commercial pier (Evans and Short 2005). The meadow at OCC ends abruptly on a slope leading to a commercial shipping lane. During the first year of monitoring, neither the depth nor the location of the meadow deep edge changed significantly on a seasonal basis at any of the monitoring sites. At the OCC, DP and RN sites, the depth and location of the deep edge were seasonally stable over the two year duration of the study, in spite of dynamic fluctuation at individual points along the meadow edge. In contrast, the meadow edge became substantially shallower at the FI and GBF sites during the second year of monitoring. Although stable during the first year, by the end of the study the average location of the meadow edge at these two sites had receded nearly three meters from its initial location. The loss of eelgrass at these sites resulted in the meadow edge becoming 0.5 m shallower at GBF and 0.75 m shallower at FI.

The change in eelgrass distribution at the study sites was compared to the amount of surface irradiance reaching the plants. Duarte (1991) estimated that seagrasses in general require an average of 11% surface irradiance to survive. For eelgrass specifically, the minimum light requirement in some systems has been estimated to be as high as 20% surface irradiance (Dennison *et al.* 1993; Gallegos 1994). For this study, the 11% light requirement was used as a point of comparison for the light levels reaching the eelgrass depth limit at the five monitoring sites. At FI and GBF, the two sites which experienced a decline in eelgrass, the percent surface irradiance reaching deep edge plants was at or below the 11% threshold throughout the first three sampling periods (Figure 8). Eelgrass is capable of surviving short periods of reduced light by relying on belowground carbon stores for growth and metabolism (Zimmerman and Alberte 1996; Brun *et al.* 2003b). However, prolonged periods of insufficient light can result in a negative plant carbon balance and ultimately cause plant death (Hemminga 1998; Alcoverro *et al.* 1999). The FI and GBF meadows experienced a nine-month period of insufficient light, long enough to have caused complete mortality of plants exposed to such conditions in other studies (Backman and Barilotti 1976; Bulthuis 1983; Fitzpatrick and Kirkman 1995). At the remaining sites, the amount of light reaching the deep edge plants sometimes fell below the 11% threshold but recovered to above-threshold levels within six months. Light was never below the threshold value for extended periods at OCC, DP or RN, and the average light reaching the eelgrass deep edge at these sites was sufficient for plant survival.

A comparison of the percent light reaching the eelgrass deep edge (Figure 8) and the depth-corrected percent light (Figure 10) highlights the differences in eelgrass survival between the monitoring sites. At OCC, DP and RN, the depth of the eelgrass meadow changed little between sampling periods, indicating that the plants were receiving sufficient light for survival. At these sites, both the percent light at the eelgrass deep edge and the depth-corrected percent light show that light levels never fell below the 11% threshold for more than two consecutive sampling periods. At the FI and GBF sites, the eelgrass deep edge receded to shallower depths from September 2005 to March 2006. The percent light reaching the eelgrass deep edge during this time period was often above the 11% threshold. As the deep edge receded to shallower depths in the water column, the amount of light reaching deep edge plants increased as a result of the change in water depth. During the same time period, the depth-corrected percent light reaching the initial deep edge location was mostly below the 11% threshold at FI and GBF. Eelgrass plants at the FI and GBF deep edges were exposed to insufficient light for prolonged time periods, and the meadow response was that the deep edge receded to a shallower depth where sufficient light could be obtained.

The prolonged periods of insufficient light that were observed at the FI and GBF meadows were likely part of an estuary-wide trend of decreasing water clarity. A water quality monitoring program in the Great Bay Estuary tracked nutrient concentrations, chlorophyll, and total suspended solids (TSS) from 1988 to 2004 (Trowbridge 2002, 2006). In the past decade, TSS concentrations have shown an increasing trend throughout the estuary (Trowbridge 2006). When compared to TSS concentrations from the 1970s (Norall *et al.* 1982; Loder *et al.* 1983), present TSS concentrations in the estuary have increased by 80% (Trowbridge 2006). Total suspended solids are a well-known factor affecting light attenuation in the water column (Gallegos 1994, 2001) and increases in TSS have been implicated in the loss of eelgrass from some systems (Orth and Moore 1983; Moore *et al.* 1997).

Eelgrass canopy height at the meadow deep edge (Figure 12) fell within the same range as canopy heights at intertidal and shallow subtidal meadows in the estuary (Lee *et al.* 2004; Evans and Short 2005). Canopy height at most sites also demonstrated the same seasonal pattern observed at other eelgrass meadows in the system (Rivers and Short in press). Eelgrass shoot density was similar at the five monitoring sites in this study, and was consistently less than 250 shoots m^{-2} (Figure 11). Shoot density is a typical seagrass acclimation response to light limiting conditions (Philippart 1995; Short *et al.* 1995). Seagrass shoot density decreases from shallow subtidal depths towards the deep edge (Dennison and Alberte 1985; Krause-Jensen *et al.* 2000; Olesen *et al.* 2002). Intertidal meadows in the Great Bay Estuary have shoot densities reaching 3000 shoots m^{-2} (FT Short, unpublished data), and the densities at the meadow deep edges in my study were substantially less throughout the two years of monitoring.

The fluctuating increases and decreases in meadow area along the transects (Figure 5) were related to the patchy growth of eelgrass at the deep edge. At all of the monitoring sites, the eelgrass meadow at the deep edge exhibited a sparse shoot density clustered in patches. New eelgrass patches form when seedlings become established

(Olesen and Sand-Jensen 1994; Harwell and Orth 2002). Seedlings develop into a primary or terminal shoot, from which several offshoots or lateral shoots may develop during a growing season (Bak 1980). In Great Bay Estuary, eelgrass patches at the meadow deep edges were small and consisted of one or two terminal shoots with their associated lateral shoots. Patch survival has been linked to patch size; low-density patches have a greater mortality rate than high-density patches (Olesen and Sand-Jensen 1994; Vidondo *et al.* 1997). At the meadow deep edge, it was not uncommon to observe newly established patches during one sampling period, only to find they had disappeared by the subsequent period. Since patches were separated by up to a meter, the gain or loss of individual patches had a large effect on the location of the meadow edge, and thus meadow area.

The greatest positive and negative changes in meadow area occurred at DP, the site with the gentlest slope (Figure 7, Table 2). Eelgrass at the DP meadow deep edge was in a greater state of flux than meadows with steeper slopes, suggesting that a long-term change in light at the DP meadow would cause a larger change in eelgrass meadow area compared to the other sites. A long-term change in light alters the maximum depth at which eelgrass can survive, but the effect of extended or decreased maximum depth on overall meadow area depends on the slope of a site (Nielsen *et al.* 2002). At sites with a steep slope, the meadow edge only has to move a short distance before the new maximum depth is reached. At sites with a gentle slope however, the meadow edge may move several meters before reaching the new maximum depth (Nielsen *et al.* 2002), resulting in substantial change in meadow area.

The use of permanent reference transects provides a simple and accurate method for monitoring the location of the seagrass deep edge as an indicator variable. The locations of the eelgrass meadow edges in this study were highly variable at individual points due to patchy growth. However, averaging several measurements along a transect incorporates this variation and yields a useful indicator value capable of detecting changes of as little as 1.3 m distance. Direct measurements of meadow depth must account for highly variable environmental conditions such as currents, waves and surge, and tidal stage. In contrast, permanent transects provide a stable reference point from which data can be immediately compared between sampling periods. Measuring the location of the deep edge may also allow significant responses to be detected faster than direct measurements of meadow depth. In this study, detectable changes in deep edge location at two of the sites occurred one season earlier than detectable changes in deep edge depth.

Conclusions

My study confirms the suitability of the seagrass deep edge as an indicator of water clarity by demonstrating that the deep edge is sensitive and responds specifically to long-term changes in light. The average depth and location of the deep edge are not influenced by seasonal variation in environmental conditions, and significant changes in the deep edge were detected only at sites exposed to prolonged light reduction. An advantage of using seagrass as a water quality indicator is that the plants effectively integrate all environmental parameters affected by light (Dennison *et al.* 1993). Many water quality parameters directly influence water clarity including nitrogen, total suspended solids, chlorophyll, and pollutants, and these parameters are highly variable over time (Hubertz and Cahoon 1999; Banas *et al.* 2005). The dominant parameter controlling water clarity can be different from one system to the next (Gallegos 1994). Also, parameters often have unequal influence on water clarity; a change in one parameter doesn't necessarily lead to a change in light penetration (Gallegos 1994). My study showed that using the seagrass deep edge as an integrative indicator allowed water clarity changes to be detected without monitoring multiple parameters.

As a management tool, the eelgrass deep edge provides a relatively simple and reliable indicator for detecting changing light conditions in estuarine systems. When using this indicator, only eelgrass meadows where the deep edge is controlled by light should be selected as monitoring sites. The recommended method for monitoring the deep edge is to measure the location of the meadow edge in relation to permanent reference transects. The transect method reduces variability caused by environmental conditions and is able to detect reduced water clarity earlier than direct measurements of depth. An initial effort is required to install the reference transects, but once transects are established, several sites can be monitored within the course of a day. It is important to monitor the average deep edge location based on multiple point measurements along the transect. At some sites, the eelgrass deep edge shows a high degree of variability at individual points, but the average location of the meadow edge provides a robust indicator variable.

Many efforts to track seagrass distribution in relation to changing light environments use annual measurements to compare seagrass distribution over several years (Krause-Jensen *et al.* 2000; Krause-Jensen *et al.* 2005; Steward *et al.* 2005). My study demonstrated that the meadow deep edge is seasonally stable, allowing changes caused by light reduction to be detectable within a three month time period. While annual assessments of the deep edge will provide a useful measure of water clarity change, more frequent assessments will allow the earlier detection of significant water clarity changes. The sensitivity and relatively rapid response of the seagrass deep edge to changes in light make it an ideal indicator variable for at-risk systems.

CHAPTER III

TESTING THE SENSITIVITY OF EELGRASS ALONG A DEPTH GRADIENT TO A REDUCTION IN LIGHT: A LITERATURE REVIEW AND EXPERIMENTAL DESIGN.

Introduction

Seagrass meadows have commonly been monitored as a way of assessing coastal ecosystem health (Orth and Moore 1983; Onuf 1996; Short and Burdick 1996). The usefulness of seagrasses as indicators of ecosystem health stems from their role in coastal communities. Seagrass meadows are widely acknowledged as highly productive ecosystems that provide important functions to coastal environments (Hemminga and Duarte 2000; Green and Short 2003). As primary producers, seagrasses support coastal food webs (Asmus and Asmus 2000; Valentine *et al.* 2002) and seagrass meadows provide habitat for a variety of organisms (Bell *et al.* 1984; Heck *et al.* 1995). The loss of seagrass from a system also implies the loss of these functions, and thus seagrass health provides a useful reference for the overall health of the ecosystem. Another advantage of seagrasses as indicators is that seagrasses are sensitive to changes in light. The leading mechanism of seagrass decline is the deterioration of ambient light conditions in the ecosystem (Duarte 2002), which is often attributed to coastal development or other human activities (Cambridge *et al.* 1986; Short and Burdick 1996; Short and Wyllie-Echeverria 1996). Seagrasses respond to a reduction in light by increasing leaf area and decreasing shoot density (Czerny and Dunton 1995; Philippart 1995). Under prolonged light reduction, seagrasses may decline, reducing total meadow area (Orth and Moore 1983; Onuf 1996). These responses are easily detected by monitoring or mapping programs (Short *et al.* 2002; Steward *et al.* 2005) and can be used to signal deteriorating light conditions caused by water quality problems.

Declining seagrass abundance, measured as percent cover, shoot density or areal distribution of meadows (Duarte and Kirkman 2001; McKenzie *et al.* 2001), has been monitored in several systems to indicate deteriorating environmental conditions caused by anthropogenic influences (Orth and Moore 1983; Short and Burdick 1996). Often, a reduced light environment is a direct result of increased levels of suspended solids or phytoplankton in the water column, which reduce light penetration (Gallegos 1994). In Chesapeake Bay, USA, increased input of suspended sediments and nutrients into the estuary resulted in large-scale declines of aquatic vegetation (Orth and Moore 1983; 1984). In many estuaries, reduced light environments result from eutrophication due to heavy shoreline development (Short and Wyllie-Echeverria 1996). In Waquoit Bay, Massachusetts, eutrophication from increased coastal development was implicated in the loss of eelgrass from that estuary (Short and Burdick 1996; Hauxwell *et al.* 2003).

Where seagrass abundance is used as an indicator of light reduction, problems are generally detected only after substantial meadow loss has occurred (Orth and Moore 1983; Short and Burdick 1996). An indicator variable capable of early detection of light reduction events may be a more useful tool for protecting ecosystem health. The seagrass meadow deep edge, defined as the deepest occurrence of seagrass at a given meadow, has been considered as a more precise indicator of light reduction than seagrass abundance alone (Dennison et al. 1993). The maximum depth of seagrass growth is predominantly controlled by light (Dennison 1987; Duarte 1991; Olesen 1996) and plants growing at the deep edge receive the minimum average amount of light necessary for survival (Duarte 1991; Kenworthy and Fonseca 1996). Therefore, plants at the meadow deep edge are presumably more sensitive to light reduction than shallower portions of the meadow.

In this chapter, I review the literature concerning the physiology of light limitation on seagrass growth and survival, and I explore the reasons why monitoring deep edge plants may provide an earlier indicator of changes in light than shallower portions of the meadow. I then present the design of an experiment to test the responses of seagrass along a depth gradient to a reduction in light. The experimental design tests the hypothesis that deep edge plants respond earlier to a reduction in light than shallower plants. A preliminary test of the experimental method was conducted, and results of the trial run are discussed. Although the full experiment was not carried out, the anticipated results are discussed in the context of applying the meadow deep edge as an indicator of reduced water clarity.

Literature Review

Seagrass Survival Under Low Light

Photosynthetic carbon fixation and oxygen production in seagrasses are directly regulated by the intensity and duration of light reaching the plants (Zimmerman *et al.* 1995; Zimmerman and Alberte 1996). The daily period at which shoots receive enough light for maximum photosynthesis (hours of saturation, H_{sat}) affects whether carbon and oxygen requirements are met. H_{sat} is the time period of maximum carbon fixation in seagrasses (Dennison 1987), and it delimits the period when belowground tissues function aerobically (Kraemer and Alberte 1995; Connell *et al.* 1999). Changes in the light regime that decrease H_{sat} also reduce daily carbon fixation and oxygen production levels (Zimmerman *et al.* 1995; Alcoverro *et al.* 1999). Seagrasses must supply oxygen to belowground tissues for respiration and metabolism, and to protect belowground tissues from anoxic sediments (Smith *et al.* 1988; Pregnall 2004). Since seagrasses have insufficient access to dissolved oxygen in the water column, most of the plants' oxygen is obtained from photosynthesis (Iizumi *et al.* 1980; Smith *et al.* 1984). Plants use the carbon fixed during photosynthesis to maintain a positive carbon balance, where the amount of carbon fixed is greater than the amount required for respiration and growth. If carbon gains from photosynthesis are not sufficient to meet requirements, the plant must mobilize soluble carbon stored in belowground tissues (Hemminga 1998; Brun *et al.* 2003a).

Both H_{sat} and light attenuation have been used to explain the maximum depth of seagrass growth (Dennison 1987; Krause-Jensen *et al.* 2000). Light attenuation in the water column affects H_{sat} along a depth gradient (Dennison and Alberte 1985). The time period of H_{sat} begins when there is enough light present to cause saturating photosynthesis in plants (Dennison 1987). Light attenuation results in decreased light with depth, and for plants growing at the deep edge, saturating photosynthesis begins later in the day and ends earlier (Dennison and Alberte 1985). The substantially reduced H_{sat} of seagrasses growing at the deep edge causes these plants have lower carbon and oxygen supplies to meet their requirements. In summer months, H_{sat} is high, and carbon stored during this period is used to help the plant survive through the winter, when H_{sat} is low and carbon balances are often negative (Alcoverro *et al.* 1999). For plants growing at the deep edge, the carbon stored during summer is enough to compensate for winter carbon losses (Dennison 1987; Alcoverro *et al.* 1999), but further strains on the carbon balance might cause plant mortality. Eelgrass (*Zostera marina)* seedlings regularly establish beyond the deep edge of the meadow, but do not persist due to carbon starvation (Dennison and Alberte 1986).

Seagrasses growing at the deep edge are able to persist in spite of extreme light limitation, and have several adaptive mechanisms to regulate their carbon balance under these conditions. These plants maximize their photosynthetic efficiency while at the same time decreasing their daily carbon requirements. Shoot density decreases with depth (Dennison and Alberte 1985; Krause-Jensen *et al.* 2000; Olesen *et al.* 2002), which reduces self-shading by the canopy and increases the light received by individual shoots

(Dalla Via et al. 1998). Photosynthetic efficiency of shoots is enhanced by extending leaf area, either through increased canopy height (Dennison and Alberte 1985; Krause-Jensen *et al.* 2000) or leaf width (Dalla Via *et al.* 1998; Olesen *et al.* 2002). Leaf pigment concentration increases with depth (Dalla Via *et al.* 1998; Olesen *et al.* 2002; Silva and Santos 2003), improving photosynthetic efficiency by increasing the total light absorbed (Enriquez *et al.* 1992; Enríquez *et al.* 1994). Seagrasses growing in deep environments have lower maximum rates of photosynthesis than shallow plants (Durako *et al.* 2003; Silva and Santos 2003), extending the duration of H_{sat} during which carbon fixation is highest. Under low-light conditions, much of the carbon fixed during photosynthesis is used to promote leaf growth (Durako and Hall 1992), reducing the amount of carbon translocated to the rhizome (Zimmerman and Alberte 1996). Plant growth rates are dramatically reduced (Short *et al.* 1995; Olesen *et al.* 2002) and production of roots is suppressed (Alcoverro et al. 1999). The reduced root growth and diminished carbon storage in the rhizomes results in decreased belowground biomass, as indicated by an increase in the above/belowground biomass ratio with depth (Dennison and Alberte 1985; Krause-Jensen *et al.* 2000; Olesen *et al.* 2002). The reduced respiratory demand of belowground tissues, combined with enhanced photosynthetic performance of aboveground tissues, decreases the duration of negative carbon balances and allows the plant to survive at low light levels.

Seagrass Decline Due to Insufficient Light

Light reductions in seagrass environments decrease the photosynthetic rate of the plants and can cause a negative plant carbon balance, where photosynthetic carbon fixation is less than the carbon demand for respiration and growth (Zimmerman *et al.* 1995; Zimmerman and Alberte 1996). Seagrasses respond to the negative carbon balance by acclimating to low light conditions using the same mechanisms employed by seagrasses surviving at the deep edge. The initial response of plants exposed to a reduction in light is to decrease shoot density, increase leaf area, and decrease growth rates (Gordon *et al.* 1994; Philippart 1995; Short *et al.* 1995). These mechanisms reduce plant carbon requirements while increasing photosynthetic efficiency, and help seagrasses survive short-term periods of light limitation (Moore *et al.* 1997; Longstaff and Dennison 1999).

Prolonged exposure to insufficient light leads to seagrass death from carbon starvation (Lee and Dunton 1997; Ruiz and Romero 2001). The negative carbon balances that seagrasses endure under low light are complicated by sediment anoxia. Oxygen transfer to belowground tissues is severely restricted soon after respiration exceeds photosynthesis (Smith *et al.* 1984; Kraemer and Alberte 1995; Pedersen *et al.* 1998), and a decrease in H_{sat} results in longer exposure to anoxic conditions. Under light limitation, sucrose and starch reserves in the rhizome are mobilized to sustain leaf growth (Zimmerman *et al.* 1995; Peralta *et al.* 2002). Anoxic conditions inhibit the transfer of sucrose from leaves to roots and rhizomes, creating a sucrose sink in belowground tissues

(Peralta *et al.* 2002; Brun *et al.* 2003a). If light reduction is short-term, normal photosynthetic oxygen and carbon production resume and the sucrose sink drives the transfer of fixed carbon to belowground tissues (Brun *et al.* 2003a). However under prolonged light stress, roots and rhizomes do not receive enough sucrose from leaves and must instead rely on their stored carbon to meet their metabolic needs (Alcoverro *et al.* 1999; Brun *et al.* 2003a). The reduced oxygen flow to belowground tissues increases the rates of anaerobic metabolism (Smith et al. 1984), putting further strain on carbon stores. Once the carbon stores are depleted and metabolic rates are reduced, the belowground tissues are susceptible to decay (Kraemer and Alberte 1995; Alcoverro *et al.* 1999).

The decreased oxygen production that results from prolonged light stress also increases seagrass exposure to sediment phytotoxins (Goodman et al. 1995). Seagrass sediments are continually flooded and highly anoxic, and many bacterial species inhabiting these sediments use sulfates for anaerobic respiration (Pollard and Moriarty 1991; Isaksen and Finster 1996; Blaabjerg and Finster 1998). Sulfate reducing bacteria produce hydrogen sulfide as a waste-product, which at high levels can be toxic to seagrasses (Goodman *et al.* 1995; Holmer and Laursen 2002). Seagrasses protect themselves from exposure to phytotoxins by releasing oxygen from belowground tissues, creating an oxidized zone around the rhizome (Sand-Jensen *et al.* 1982; Connell *et al.* 1999). When oxygen production is suppressed in low-light conditions, the oxidized rhizosphere becomes diminished, exposing the plants to sulfides (Pedersen et al. 1998). Hydrogen sulfide reduces the rate of photosynthesis in seagrasses (Goodman et al. 1995), further depressing oxygen production. In addition, the reduced rates of photosynthesis from phytotoxin exposure put further strain on the plant carbon balance by creating and then prolonging periods of anaerobic metabolism in the belowground tissues (Lee and Dunton 1997; Ruiz and Romero 2001).

The rate of seagrass decline from light reduction depends on the plants' ability to cope with periods of negative carbon balance. The timing and intensity of light reduction affect the duration of H_{sat} and are compounding factors in determining seagrass survival during a light reduction event. The intensity of light reduction affects the degree to which H_{sat} is shortened, and determines the exposure of seagrasses to negative carbon balances. Greater light reduction causes increased rates of shoot decline (Table 3), and even short periods of intense shading may result in complete shoot mortality (Bulthuis 1983, 1984; Longstaff *et al.* 1999). Seagrass carbon balances are affected by seasonal changes in H_{sat} (Dennison 1987); seagrasses store carbon during the summer months and drain carbon stores during winter months when daily photoperiods are shorter (Alcoverro et al. 1999). The magnitude of the effects of light reduction depends on the season when the light reduction event occurs. The most rapid declines in shoot density result from a light reduction in spring or early summer (Table 3); in summer, seagrasses have fewer carbon stores to mobilize because much of their stored carbon was used for winter survival (Alcoverro et al. 1999). A light reduction initiated in autumn or winter takes longer to have an effect on shoot survival, (Bulthuis 1983; Fitzpatrick and Kirkman 1995) possibly because plants already have adequate carbon stores.

The seagrass deep edge has been suggested as a useful indicator for changes in light because plants at the deep edge are surviving at the minimum light threshold (Dennison *et al.* 1993), and have lower carbon stores than shallower plants. A reduction in light would presumably cause deep edge plants to use their carbon stores earlier than shallower plants, resulting in earlier plant death. If this assumption is true, then monitoring the deep edge would allow for earlier detection of a light reduction event than monitoring shallower portions of the meadow. Shade experiments have demonstrated the sensitivity of seagrass to light reduction at a variety of depths (Backman and Barilotti 1976; Czerny and Dunton 1995; Fitzpatrick and Kirkman 1995; Ruiz and Romero 2001) including the deep edge (Dennison and Alberte 1982). However, direct comparisons between the responses of deep edge plants and shallower plants to light reduction have not been made. Here I present the design for an experiment to test the sensitivity of eelgrass (*Z. marina*) plants along a depth gradient to a controlled reduction in light. The hypothesis being tested is that a 20% decrease in light will cause earlier shoot decline at the deep edge of an eelgrass meadow than at middle or shallow depths.

Table 3: Summary of shoot mortality response times for light manipulation experiments. Response times are listed as the number of months after the start of light manipulation until 100% shoot mortality; values with asterisks (*) represent treatments where the experiment ended before 100% shoot mortality was reached. Light levels are presented as the percentage of ambient light reaching the canopy of untreated plants. †Mesocosm experiment.

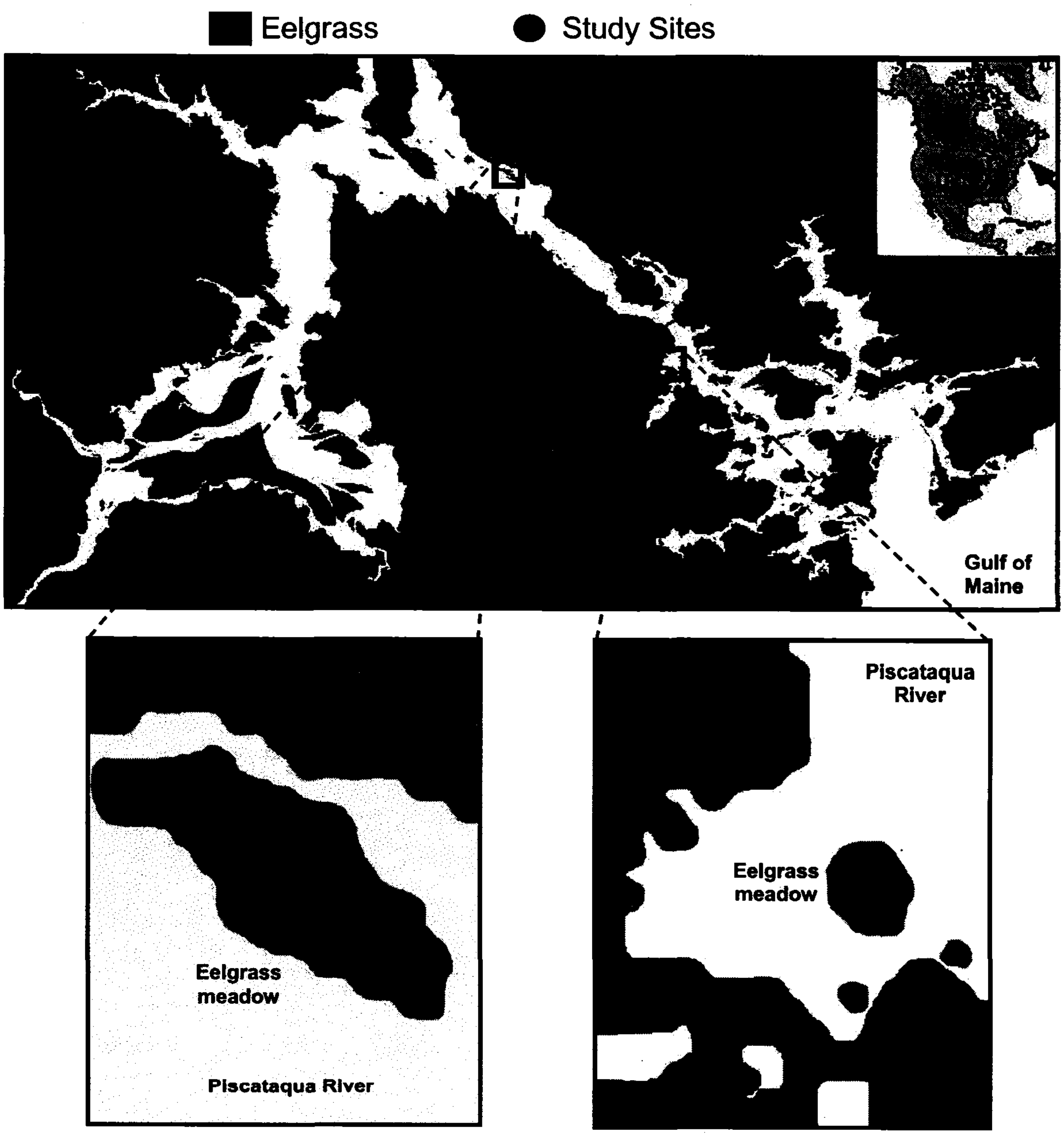
Reference	Location	Species	Experiment Initiated	Light level (% ambient)	Months to Shoot mortality
Czerny and Dunton 1995	Corpus Christi Bay, Texas, USA	*Halodule wrightii*	October (autumn)	32% 26%	10 10
Longstaff et al 1999	Queensland, Australia†	*Halophila ovalis*	October (spring)	7%	1
Bulthuis 1983	Western Port, Victoria, Australia	*Heterozostera tasmanica*	February (summer)	35% 25% 9% 2%	14* 14* 10 4
Bulthuis 1983	Western Port, Victoria, Australia	*Heterozostera tasmanica*	August (winter)	35% 9% 2%	8* 4* 4
Bulthuis 1983	Western Port, Victoria, Australia	*Heterozostera tasmanica*	December (summer)	9% 2%	4* 4
Bulthuis 1984	Corio Bay, Victoria, Australia	*Heterozostera tasmanica*	January (summer)	88% 28% 0%	3 3 1
Fitzpatrick and Kirkman 1995	Jervis Bay, New South Wales, Australia	*Posidonia australis*	December (summer)	< 10%	8
Ruiz and Romero 2001	Fraile Island, Aguilas, Spain	*Posidonia oceanica*	May (spring)	60% 30%	17* 4
Czerny and Dunton 1995	Corpus Christi Bay, Texas, USA	*Thalassia testudinum*	October (autumn)	28% 20%	10 10
Lee and Dunton 1997	Corpus Christi Bay, Texas, USA	*Thalassia testudinum*	April (spring)	30% 11%	16 7
Backman and Barilotti 1976	San Diego, Califiornia, USA	*Zostera marina*	March (spring)	37%	8
van Lent et al 1995	Grevelingen and Veerse Meer, Netherlands	*Zostera marina*	June (summer)	30%	2

Methods

Site Description

Two subtidal eelgrass meadows within the Great Bay Estuary were selected for this experimental design (Figure 13). The 1 ha Outer Cutts Cove (OCC) meadow is located in the Piscataqua River approximately 4 km from the coast (N 43°05.188 W 070°45.818). The 7 ha Adlington Creek (AC) meadow is located in the Piscataqua River between Portsmouth Harbor and Little Bay (N 43°07.188 W 07°48.474), approximately 11 km from the coast. Water temperature in the Great Bay Estuary ranges from 1 – 19 °C and salinity ranges from 25 – 34 (Short 1992). Tidal range in the estuary is approximately 3 m. The OCC meadow spans a depth of 0.5 to 2.0 m at MLW and depth at AC ranges from 0.25 to 3.0 m at MLW. Eelgrass in the estuary experiences seasonal fluctuations in growth (Gaeckle and Short 2002) and biomass (Burdick *et al.* 1993). In addition to being easily accessible, the OCC and AC sites were selected for specific physical features of the meadows. Both sites are wide enough to support the three separate depth treatments used in the experiment, and both meadows have had relatively stable ranges of eelgrass biomass and percent cover in the past decade (Evans and Short 2005).

Figure 13: The Great Bay Estuary on the border of New Hampshire and Maine, USA. The Adlington Creek (AC) and Outer Cutts Cove (OCC) subtidal eelgrass meadows were selected as sites for the proposed light manipulation experiment.



Experimental Design

Each eelgrass meadow is separated into three depth categories: deep, middle and shallow. Although the sites span a different range of depths, depth categories are proportional within a site; the middle treatment occurs exactly halfway between the depth of the deep and shallow treatments. A 30 m transect is established at each depth category, and sampling takes place at six plots along each transect. Plots are 2 m^2, and successive plots are separated by 3 m of undisturbed meadow. Plots are randomly assigned a screen treatment, control or shade, with three control and three shade plots per transect (Figure 14). Control plots for each depth treatment are undisturbed patches of eelgrass meadow at that depth. At shaded plots, ambient light is reduced by 20% through the use of PVC frames covered by black mesh (Table 4). Negative controls (frames with clear plastic or frames with no covering) are not used in this experiment to minimize the logistical complexity. Previous shade experiments have shown that negative controls have no significant impact on seagrass parameters at subtidal meadows (Fitzpatrick and Kirkman 1995; Lee and Dunton 1997).

The experiment is initiated in April (spring) and sampling occurs monthly. The experiment is concluded in October, or when there is 100% shoot mortality at the deep shade plots. Eelgrass parameters monitored include shoot density, leaf length, leaf width, and sheath length. Shaded plots may not have complete shoot mortality during the course of the experiment if shading is moderate (Table 3), and eelgrass morphological parameters are likely to show a response even with 20% light reduction (Short et al.

1995). Light is measured monthly at each depth and shade treatment, and water depth is measured at all plots once during the experiment.

Shade Construction

Shade units are 4 m^2 frames covered with black mesh material and supported by stand pipes. Frames are composed of a PVC structure designed for stability in high tidal currents. Stand pipes are installed underwater at each shade plot, and shade frames are interchangeable between stand pipes to facilitate replacement and cleaning of fouled shades. The interchangeable design also simplifies the construction process, as stand pipes and frames can be mass produced using the same basic equipment.

A total of 72 stand pipes (Figure 15) are constructed for the experiment; 4 stand pipes for each shade plot, with 9 shade plots at each of 2 eelgrass meadows (Figure 14). The stand pipes are constructed from 1 m lengths of 3 in diameter PVC pipe. Two 5 cm deep notches are cut on opposite sides of the top of the stand pipes. The notches are wide and deep enough to comfortably accommodate the shade frame structure. A hole is drilled in each of the remaining tabs of PVC on either side of the notches. The holes are positioned at the top of the tabs and lined up directly across from each other. When the stand pipes are installed underwater, zip ties fit through the holes to secure the shade frame to the stand pipes.

Table 4: Light reduction capacities of shade materials. Shade materials tested were green plastic-coated wire mesh, orange construction fencing, and black garden fencing.

Shade Material	Wire Width (cm)	Mesh Size (cm^2)	Light Reduction
Green	0.2	2.3	39.2%
Orange	0.4	7.3	37.9%
Black	0.1	6.5	18.4%
Control	n/a	n/a	11.3%

Figure 14: Experimental design for a light manipulation experiment at a subtidal eelgrass meadow. The eelgrass meadow is represented by the grey figure, shade plots are hatched squares and control plots are demarked at the corners with circles. Parallel cross-transects are established at each of three depth levels: deep edge (D) middle (M) and shallow (S). Shade and control treatments are randomly assigned at each depth, and experimental plots are labeled according to depth and position along the cross-transect. Distance along the cross-transect (m) is indicated at the bottom of the figure.

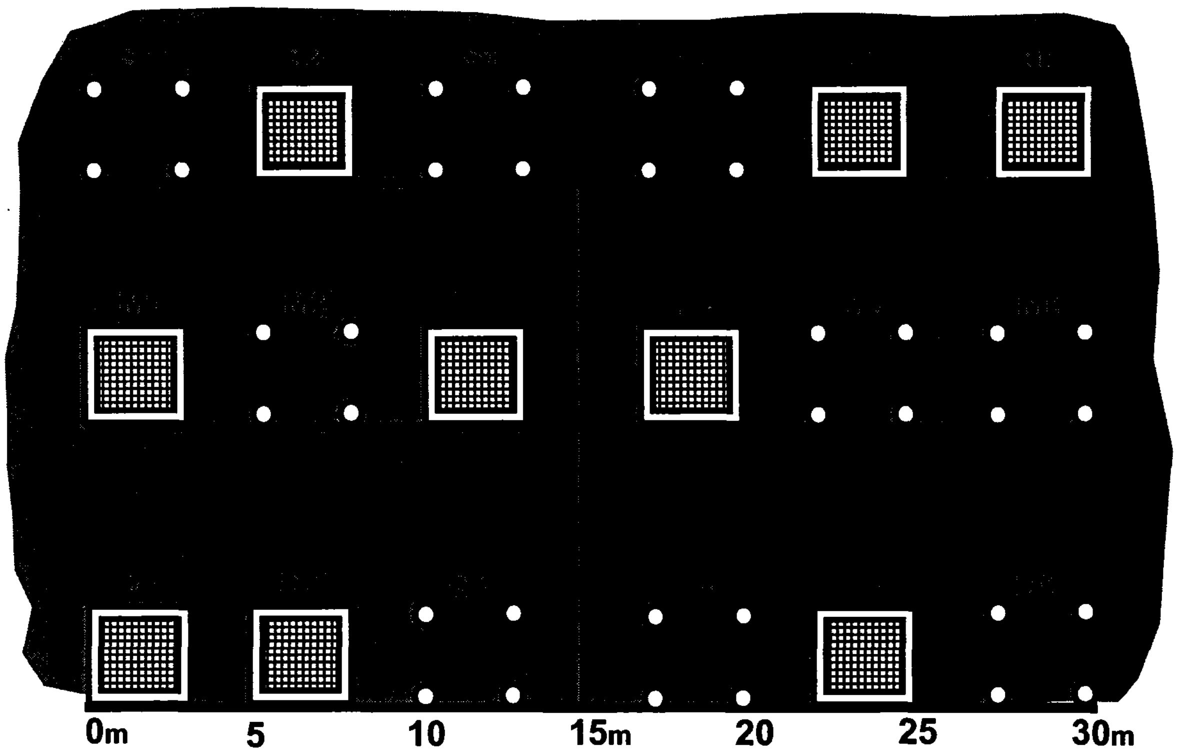
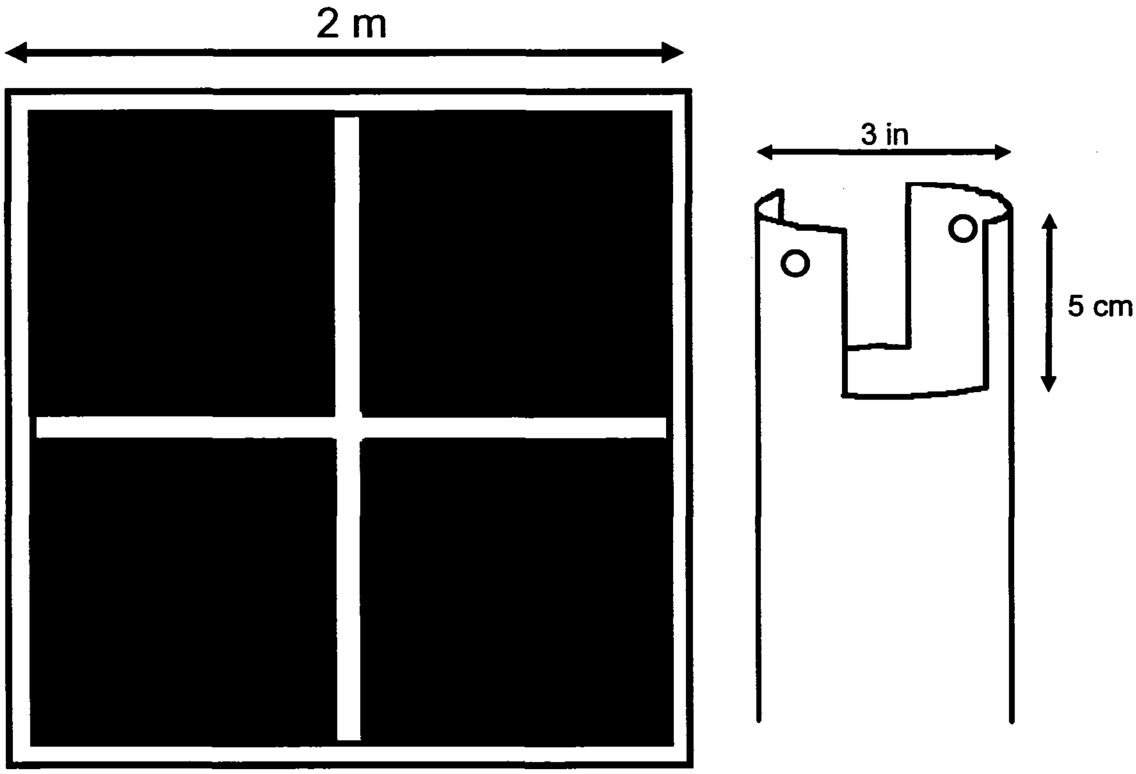


Figure 15: Shade frame and stand pipe design schematic. Shade frames are constructed from segments of 1.0 in diameter PVC pipe, and shade material is held on with zip ties. Stand pipes are constructed from 3.0 in diameter PVC pipe, and a notch is cut in the top to accommodate the shade frame. Four stand pipes are required to support one frame. The frame is secured to the stand pipe with a zip tie looped through the holes at the top of the notch. Black fencing with 1.7 cm^2 mesh was used as shade material. Figure is not to scale.



Thirty-six shade frames are constructed for the experiment. Eighteen frames are deployed in the field at one time, and a spare set is made to simplify the replacement of fouled frames. Frames are built from 1m long sections of 1 in diameter PVC pipe, laid out to form four interconnected squares (Figure 15). Sections of pipe are held together with standard PVC connectors. Finished frames are 2 m on a side with a crossbar support in the middle. Black 6.5 cm^2 mesh fence material is laid out over the frames and held on with zip ties. A variety of shade materials were tested for their light reducing capacities, and black mesh yielded the desired 20% reduction (Table 4).

Field Setup: Marking Plots and Installing Shades

Sampling transects are established at deep, middle and shallow depths at each field site using SCUBA. To determine transect placement, divers locate the deep edge of the eelgrass meadow and arbitrarily create a 30 m transect parallel to the meadow edge. The center of the deep transect is marked with a screw anchor. Divers then create a new perpendicular transect starting at the center of the deep transect and heading into the eelgrass meadow. The perpendicular transect extends from the deep edge to the shallow edge of the meadow. Additional 30 m transects are established at the shallow edge of the meadow and at the middle of the meadow, half-way between the deep and shallow edges. The deep, middle, and shallow transects are parallel to each other, and the center of each transect (15 m) is intersected by the perpendicular transect. In addition, the center of each transect is marked with a screw anchor connected to a surface toggle.

Sampling plots are established at 5 m intervals along the length of each transect, and plots are designated shade or control according to a pre-determined random design (Figure 14). All plots are 2 m x 2 m with one edge parallel to the transect, and all four corners falling within the bounds of the eelgrass meadow. Control plots are demarked with small PVC posts at the corners, while shade plots are demarked at the corners with stand pipes. Stand pipes are installed using a battery operated sea water pump to loosen the sediment around the base of the pipes, allowing the stand pipes to slide into position. Stand pipes are driven half their length into the sediment, with 50 cm remaining above the sediment surface. Shade frames are placed into the notches of the stand pipes and secured with zip ties. However, before shade frames are secured into place, an initial monitoring assessment is conducted at all plots (see *Eelgrass Monitoring and Shade Maintenance*).

Eelgrass Monitoring and Shade Maintenance

Monitoring eelgrass responses at the sampling plots occurs monthly, and at the same time shades are cleaned of fouling organisms to maintain the desired level of light reduction. Divers remove fouled shade frames by cutting the zip ties holding them in place. Fouled stand pipes are cleaned with a wire brush, and clean frames are attached to the stand pipes. Fouled shades are returned to the laboratory for thorough cleaning, and are used as replacement frames during the next sampling period.

Before attaching clean shades to the stand pipes, divers monitor the eelgrass at all plots. Eelgrass shoot density, leaf count (number of leaves per shoot), sheath length, leaf length, and leaf width are measured from a 0.0625 m^2 quadrat placed at the center of each plot. Sampling at the center of the plots accounts for light intrusion under the side of the shades, which causes uneven light conditions at the edges of the shaded plots (Fitzpatrick and Kirkman 1995). Sheath length is defined as the distance from the shoot meristem to the sheath bundle scar; leaf length is the distance from the shoot meristem to the tip of the longest mature leaf; and leaf width is measured just above the sheath bundle on the longest mature leaf. Ten replicate measurements of leaf count, leaf length, sheath length and leaf width are measured from within each plot, or all shoots are measured if the density is less than ten. Sample plots are labeled by depth and location (Figure 14), and measurements for each plot are recorded on a field data sheet (Figure 16).

Light is monitored monthly at each depth for shade and control plots, as well as above the water surface. By monitoring light simultaneously at the surface and underwater, the percent surface irradiance (% SI) can be calculated. Onset Hobo™ light sensors are installed in the center of one shade plot and one control plot at each depth transect, level with the canopy height of the surrounding eelgrass. An additional Hobo™ sensor is installed on land near the sampling site. The sensors are set to record instantaneous irradiance in lumens ft^{-2} at 30 minute intervals, and are left in place until the next sampling period.

Water depth is measured at each sampling plot once during the experiment. Measurements are made by securing a tape measure to a small buoy, where the buoyancy of the buoy causes the measuring tape to remain vertical with tension applied. Depths are measured on a low-current day to minimize drag on the boat fender. Divers record the depth to the sediment surface at the center of each plot, and depths are later calibrated in reference to mean low water to allow comparisons between transects and sites.

Statistical Analysis

The experimental design is a split-plot ANOVA with one blocking factor and two treatments (Table 5). The blocking factor is site (Outer Cutts Cove and Adlington Creek), depth was the main-plot treatment (shallow, middle, deep) and the sub-plot treatment was screen (control and shade) (Zar 2001).

Although the sites are sampled on a monthly basis, sampling period is not included as an experimental factor. Instead, a rate of change is calculated for each eelgrass parameter using an appropriate time period. Short term effects, such as change in leaf length or width, may be calculated after the first month, whereas long term effects, such as shoot density decline, may be calculated after several months.

The experimental model addresses the hypothesis by testing for a significant interaction between the depth and screen factors. Using eelgrass shoot density as an example, a significant interaction would indicate that the rate of shoot density decline under reduced light depends on depth.

Table 5: (A) Treatment categories for a light manipulation experiment. The experimental design calls for three depth treatments (shallow, middle, deep), two screen treatments (shade or control), and uses two sites as blocking factors. Plot ID refers to the treatment combination. (B) Source of variation table for the light manipulation experiment showing degrees of freedom for each treatment combination.

(A)

Plot ID	(Block Factor) Site	(3 levels) Depth	(2 levels) Screen
SC	Outer Cutts Cove	Shallow	Control
SS	Outer Cutts Cove	Shallow	Shade
MC	Outer Cutts Cove	Middle	Control
MS	Outer Cutts Cove	Middle	Shade
DC	Outer Cutts Cove	Deep	Control
DS	Outer Cutts Cove	Deep	Shade
SC	Adlington Creek	Shallow	Control
SS	Adlington Creek	Shallow	Shade
MC	Adlington Creek	Middle	Control
MS	Adlington Creek	Middle	Shade
DC	Adlington Creek	Deep	Control
DS	Adlington Creek	Deep	Shade

(B)

Source of Variation	DF
Total	35
Depth	2
Site(Depth)	3
Screen	1
Depth * Screen	3
Error	26

Figure 16: Field data sheet to sample eelgrass parameters for a light manipulation experiment at a subtidal eelgrass meadow. Divers sample every other plot, evens and odds; this data sheet is for one diver.

Plot	**Shoot Density** (total shoots and reproductive shoots)	**Sheath Length** (meristem to sheath scar, 10 shoots)	**Leaf Length** (sheath scar to tip of longest leaf, 10 shoots)	**Leaf Width** (leaf width just above sheath scar, 10 shoots)	**Leaf Count** (number of leaves per shoot, 10 shoots)
S1					
S3					
S5					
M1					
M3					
M5					
D1					
D3					
D5					

Preliminary Test of Shades

A preliminary test was conducted to assess the effectiveness of the shade design and the impact of the shades on eelgrass plants growing at the deep edge. The test run was conducted at the Fishing Island (FI) eelgrass meadow (Figure 1), located at the mouth of the Great Bay Estuary. Two shades were constructed using the methods described in the *Shade Construction* section above. The shaded plots were installed 20 m downriver from the FI deep edge transect described in Chapter 2. Stand pipes were installed using a battery operated sea water pump and frames were connected to the stand pipes using zip ties, as detailed in the *Field Setup* section above. Shade plots were 4 m^2 and the plots were situated approximately 5 m apart. Shades were installed in September 2005 and were revisited in October 2005, December 2005 and March 2006. During each visit, observations were collected concerning the condition of the shades and the status of shaded eelgrass. Although direct measurements of eelgrass parameters were not recorded, the relative condition of shaded eelgrass compared to nearby, untreated eelgrass was noted.

Results and Discussion

Preliminary Test of Shades

The shade design proved to be simple and effective; construction of two shades took half a day, with the majority of time spent learning how to fashion individual parts.

If parts were mass produced, it is estimated that construction of the 36 shade frames (including 18 replacement frames) and 72 stand pipes required for the full experiment could be accomplished in a week. The proposed method for installing the shades using a sea water pump also proved effective in the field. The sea water pump allowed stand pipes to be easily and quickly driven 50 cm deep into the sediment; an attempt was made to install one stand pipe using a mallet, but only succeeded in driving the stand pipe a short distance into the sediment. While installing the stand pipes, it was not possible to precisely measure the location of the stand pipes relative to each other. As a result, the stand pipes were sometimes misaligned, and either the stand pipes or shade frames had to be bent in order to get the frame to fit properly into the grooves of the stand pipe. The shade frames were somewhat difficult to maneuver underwater, and it is recommended that installation be conducted at slack tide to minimize drag from tidal currents.

The shades were durable enough to withstand the effects of tides, current and surge; however fouling became a problem during the course of the trial experiment. In October 2005, one month after the shades were initially installed, the mesh material of both shades was moderately fouled with red filamentous algae. In December 2005, one shade frame was missing and appeared to have been torn from the stand pipes, possibly by a lobster boat. All the stand pipes remained in the sediment, but the tabs had been broken off two of them. The remaining shade had heavy fouling on both the mesh shade material and on the PVC frame; the density of fouling organisms was substantially greater than in October 2005. In December 2005, the fouling community consisted of predominately invertebrate organisms including tunicates, bryozoans, and some barnacles and limpets. In March 2006, the extent of fouling and the type of fouling community remained essentially the same as it was in December 2005.

When the shades were initially installed in September 2005, the shoot density of eelgrass at the FI meadow deep edge was approximately 120 shoots m^{-2} (Figure 8). In October 2005 shoot density had changed little from initial levels, but curiously, the shaded eelgrass shoots carried substantially more epiphytes than neighboring, unshaded shoots. In December 2005 shoot density under the shaded plots was less than half the initial density, and by March 2006, no shoots remained in the shaded plots. The eelgrass meadow at the FI deep edge transect (Chapter 2) receded upslope between September 2005 and March 2006 (Figure 4). By March 2006, eelgrass shoot density at the meadow deep edge near the shade plots had also declined substantially from September levels, although some shoots remained.

The decline in eelgrass shoot density at the FI deep edge was part of a meadow-wide light reduction event that had been impacting the meadow since September 2005 (Chapter 2 of this thesis). Reduced water clarity at the FI site was attributed to increased levels of total suspended solids (TSS) in the Great Bay Estuary (Chapter 2, Trowbridge 2006). The decline of eelgrass at the shaded plots during the trial experiment was likely compounded by the meadow-wide light reduction event. Eelgrass plants under the shaded treatments were in effect exposed to two simultaneous light reduction events: the decrease in water clarity and the shade itself. In addition, the extensive fouling of the shade units likely furthered the light reduction of eelgrass at the shaded plots. The increased light reduction at FI may have resulted in faster eelgrass decline than would have occurred if the experiment had been conducted at an unimpacted site.

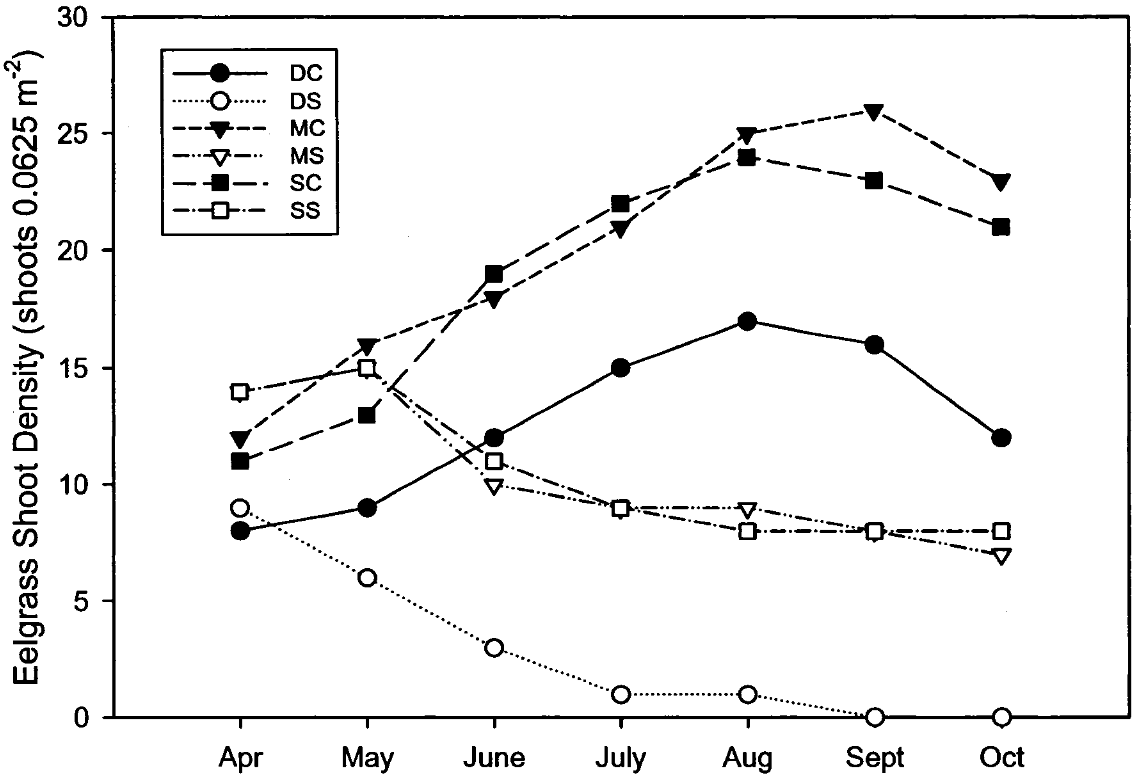
Several important differences occurred between the methods used for the preliminary shade test and the recommended methods for the full experiment, which may have affected the outcome of the preliminary test. First, the preliminary test was conducted at the FI site, which was experiencing a loss of eelgrass from the meadow deep edge during the course of the trial run. It is recommended that the full experiment be conducted at the OCC and AC sites, which have relatively stable populations of eelgrass. The loss of eelgrass from control plots at the meadow deep edge would make it difficult to interpret the effects of the shade treatment on deep edge eelgrass. Second, the shades utilized for the preliminary test were not cleaned or replaced during the course of the experiment. The rapid accumulation of fouling organisms on the shades likely resulted in a light reduction that was substantially greater than the 20% reduction yielded by clean shades. In order to minimize the effect of fouling organisms on the outcome of the experiment, it is recommended that fouled shades be replaced with clean ones on a monthly basis. Finally, the preliminary test was initiated in September (late summer) when eelgrass in the Great Bay Estuary is close to peak biomass (Short 1992). The timing of the test experiment may have actually prolonged the survival of eelgrass shoots relative to how long they might have survived in a different season. Eelgrass plants accumulate carbon stores during the summer months, and rely on those stores to survive winter months of seasonally low light and reduced carbon production (Alcoverro *et al.* 1999). During the preliminary shade test, eelgrass plants at FI had likely accumulated carbon stores throughout the summer and were able to utilize those stores to persist under the imposed shade treatment. In contrast, the full experiment proposed to commence in April (spring), a time period when eelgrass plants may have reduced carbon stores (Alcoverro *et al.* 1999). If eelgrass plants do not have sufficient carbon reserves during the full experiment, they may not be able to persist under imposed shading causing shoot decline to occur earlier than it would in September.

Full Experiment: Anticipated Results

As stated in the hypothesis, the expected difference between depths is that eelgrass shoot density will decline earlier at the deep edge, reaching 100% shoot mortality by the end of the experiment (Figure 17). Eelgrass shoots growing at the deep edge receive the minimum amount of light required for long-term survival (Dennison *et al.* 1993; Olesen 1996). When shading is initiated in April (spring), the shoots have already used much of their stored carbon to survive through the winter (Alcoverro et al. 1999). The reduction in light will cause an overall negative carbon balance for these plants, resulting in steady shoot decline at the deep edge (Figure 17).

It is anticipated that the shallow and middle shade treatments will show a decline in shoot density during the course of the experiment, but will not reach 100% shoot mortality (Figure 17). A reduction in shoot density is a known adaptation of eelgrass to reduced light conditions (Backman and Barilotti 1976; Short *et al.* 1995; van Lent *et al.* 1995). Since the intensity of shading in this experiment is a moderate 20% reduction in light, the amount of light reaching the shallow and middle shade treatments will likely

Figure 17: Graph showing anticipated results of light manipulation experiment at one of the subtidal eelgrass meadows. Treatments are deep control (DC), deep shade (DS), middle control (MC), middle shade (MS), shallow control (SC) and shallow shade (SS). Graph does not represent actual data.



not fall below the minimum threshold necessary for eelgrass survival. Eelgrass at these depths will adapt to the new light levels through a reduction in shoot density, but shoot density will stabilize during the course of the experiment.

Shoot density at control plots (Figure 17) is expected to follow the same seasonal pattern of shoot density that is observed at other meadows in the Great Bay Estuary (Short 1992; Gaeckle and Short 2002). In the Great Bay Estuary, shoot density peaks in late summer (Gaeckle and Short 2002), but may begin to decline by the end of the experiment in October. Eelgrass shoot density follows a bell-shaped curve with depth (Backman and Barilotti 1976; Krause-Jensen *et al.* 2000). Although shoot density at all control treatments is expected to show a seasonal pattern, shoot density at the deep edge will be consistently less than at the middle or shallow depths (Figure 17).

The inclusion of site as a blocking factor in the experimental design allows the results to be more broadly generalized to other eelgrass meadows within the estuary. The two sites, OCC and AC, occur along a gradient of water clarity (Short 1992; Chadwick *et al.* 1993), and both eelgrass meadows span a different range of depths. As such, the factor depth is a category, where depths are proportional to each other within a site, but deep at OCC is not equal to deep at AC. Using site as a blocking factor incorporates this variability into the analysis, and the detection of a significant interaction would confirm the broader applicability of the results.

The primary purpose of monitoring light for this experiment is to categorize the depth treatments by the range of light they receive. % SI is compared between depths for each sampling period, ensuring that the depth categories are proportionate to each other in terms of the amount of light they receive. The quantity of light reaching the eelgrass varies depending on season (Olesen and Sand-Jensen 1993) and water column light attenuation (Gallegos 1994). Determining the range of light reaching each depth category validates the use of depth as an ordinal treatment in the statistical analysis.

The anticipated results will demonstrate that the deep edge of the eelgrass meadow responds earlier to light reduction than shallower areas of the meadow. Eelgrass at the deep edge shaded treatments is expected to show 100% shoot mortality over the course of the experiment, which would cause the meadow deep edge at shaded plots to recede to a shallower depth. The deep edge plants will respond to a moderate 20% reduction in light, and the change in location of the meadow edge will be a clear response that is easy to detect. In contrast, eelgrass at the middle and shallow depths are expected to show a decrease in shoot density, but not 100% mortality. Such a response may not be detectable without intense, meadow-wide monitoring of shoot density. The change in location of the deep edge requires less intense monitoring than meadow-wide shoot density estimates, and the response could be observed from one season to the next (Chapter 2). The eelgrass deep edge is expected to show a clear response to a moderate light reduction event, an event that may not be easily detectable at shallower depths.

The experiment outlined in this chapter contributes to assessing the suitability of the eelgrass deep edge as an indicator of water clarity by examining the sensitivity of deep edge eelgrass to light reduction compared to eelgrass growing at shallower depths. The preliminary test of this experiment demonstrated a clear response of deep edge eelgrass to light reduction, and the full experiment would likely confirm that the deep edge in indeed a more sensitive indicator of water clarity than eelgrass at shallower portions of the meadow. The sensitivity of deep edge eelgrass, combined with its demonstrated responsiveness specifically to long-term changes in light (Chapter 2), confirm the suitability of the eelgrass deep edge as an indicator of light reduction events. Monitoring changes in the eelgrass deep edge over time will be an ideal indicator for the early detection of light reduction events, and can be used as an early warning system for water quality problems that affect light.

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APPENDIX A

ORIGINAL DATA

Eelgrass deep edge location. (A) Distance from the reference transect markers to the eelgrass deep edge. (B) Distance from the reference transect markers to the furthest (deepest) eelgrass shoot or seedling outside the bounds of the continuous meadow. The continuous meadow was defined as shoots occurring no more than 1 m apart. Positive values indicate an upslope direction; negative values indicate a downslope direction. N/A indicates that data was unavailable.

Fishing Island

(A) Distance to Deep Edge (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	55	21	129	380	23	36	13	0
Sept 2004	52	72	116	373	-30	54	-27	1
Dec 2004	205	58	133	314	-23	28	-37	-5
Mar 2005	53	0	109	336	-26	25	-38	0
Jun 2005	202	23	131	281	-6	24	-36	-10
Sept 2005	192	365	312	298	510	88	130	96
Dec 2005	204	339	314	385	552	525	297	92
Mar 2006	199	359	185	407	446	611	554	322

(B) Distance to Furthest Shoot / Seedling (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	-232	-80	-654	-180	-810	-383	-626	-613
Sept 2004	-350	-567	n/a	n/a	-529	-377	-566	-461
Dec 2004	47	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mar 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Jun 2005	-412	-700	n/a	n/a	-481	-500	-148	-300
Sept 2005	-482	n/a	138	29	65	n/a	n/a	-17
Dec 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mar 2006	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Eelgrass deep edge location. (A) Distance from the reference transect markers to the eelgrass deep edge. (B) Distance from the reference transect markers to the furthest (deepest) eelgrass shoot or seedling outside the bounds of the continuous meadow. The continuous meadow was defined as shoots occurring no more than 1 m apart. Positive values indicate an upslope direction; negative values indicate a downslope direction. N/A indicates that data was unavailable.

Outer Cutts Cove

(A) Distance to Deep Edge (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	100	15	-17	-6	-16	15	205	54
Sept 2004	97	0	-26	-42	-23	0	141	145
Dec 2004	69	91	-30	8.5	-35	65	98	175
Mar 2005	65	62	-29	-37	-34	-16	51	n/a
Jun 2005	78	17	-30	-36	-29	-16	144	n/a
Sept 2005	72	9	-27	-60	-29	-22	141	n/a
Dec 2005	33	5	-30	24	-28	-20	120	135
Mar 2006	45	41	25	22	1	69	74	119

(B) Distance to Furthest Shoot / Seedling (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sept 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dec 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mar 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Jun 2005	n/a	-100	n/a	-110	n/a	-108	n/a	n/a
Sept 2005	-125	n/a	n/a	n/a	-170	n/a	n/a	n/a
Dec 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mar 2006	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Eelgrass deep edge location. (A) Distance from the reference transect markers to the eelgrass deep edge. (B) Distance from the reference transect markers to the furthest (deepest) eelgrass shoot or seedling outside the bounds of the continuous meadow. The continuous meadow was defined as shoots occurring no more than 1 m apart. Positive values indicate an upslope direction; negative values indicate a downslope direction. N/A indicates that data was unavailable.

Great Bay Fish

(A) Distance to Deep Edge (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	73	7	77	80	-9	113	21	14
Sept 2004	30	39	67	62	24	126	13	23
Dec 2004	24	36	62	73	18	110	9	38
Mar 2005	21	34	61	100	18	100	41	50
Jun 2005	20	27	71	50	17	95	87	12
Sept 2005	69	176	177	46	140	114	92	59
Dec 2005	252	259	97	152	119	181	194	169
Mar 2006	459	337	367	141	225	312	389	161

(B) Distance to Furthest Shoot / Seedling (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	n/a	n/a	n/a	n/a	n/a	-115	-102	n/a
Sept 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dec 2004	n/a	n/a	n/a	n/a	n/a	-77	-115	n/a
Mar 2005	n/a	n/a	n/a	n/a	n/a	-80	n/a	n/a
Jun 2005	n/a	n/a	n/a	-190	n/a	-60	n/a	-150
Sept 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dec 2005	100	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mar 2006	258	n/a	200	n/a	n/a	n/a	n/a	n/a

Eelgrass deep edge location. (A) Distance from the reference transect markers to the eelgrass deep edge. (B) Distance from the reference transect markers to the furthest (deepest) eelgrass shoot or seedling outside the bounds of the continuous meadow. The continuous meadow was defined as shoots occurring no more than 1 m apart. Positive values indicate an upslope direction; negative values indicate a downslope direction. N/A indicates that data was unavailable.

Dover Point

(A) Distance to Deep Edge (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	364	460	-128	-128	-20	55	30	141
Sept 2004	222	100	46	-104	148	47	116	414
Dec 2004	31	470	170	-222	43	43	20	61
Mar 2005	n/a	297	440	-172	38	96	136	60
Jun 2005	n/a	329	330	-167	39	57	6	53
Sept 2005	n/a	8	298	61	43	-167	157	-62
Dec 2005	n/a	n/a	54	408	425	33	310	1
Mar 2006	n/a	408	309	-177	80	25	271	6

(B) Distance to Furthest Shoot / Seedling (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	n/a	n/a	n/a	-238	n/a	-400	-140	n/a
Sept 2004	10	n/a	n/a	n/a	-142	n/a	n/a	313
Dec 2004	n/a	n/a	-99	n/a	n/a	n/a	n/a	n/a
Mar 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Jun 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sept 2005	n/a	n/a	-94	n/a	n/a	n/a	n/a	n/a
Dec 2005	-235	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mar 2006	n/a	n/a	n/a	n/a	n/a	n/a	-25	n/a

Eelgrass deep edge location. (A) Distance from the reference transect markers to the eelgrass deep edge. (B) Distance from the reference transect markers to the furthest (deepest) eelgrass shoot or seedling outside the bounds of the continuous meadow. The continuous meadow was defined as shoots occurring no more than 1 m apart. Positive values indicate an upslope direction; negative values indicate a downslope direction. N/A indicates that data was unavailable.

Red Nun

(A) Distance to Deep Edge (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	1	193	156	147	211	193.5	31	35
Sept 2004	54	181	152	225	203	136	28	28
Dec 2004	33	211	77	136	196	124	15	17
Mar 2005	25	190	183	288	186	123	20	18
Jun 2005	41	193	136	292	187	161	61	29
Sept 2005	198	195	262	255	166	100	124	329
Dec 2005	220	210	230	157	235	167	154	194
Mar 2006	203	235	210	243	169	131	117	266

(B) Distance to Furthest Shoot / Seedling (cm)

	Transect Marker							
	1	2	3	4	5	6	7	8
Jun 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sept 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dec 2004	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mar 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Jun 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sept 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dec 2005	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mar 2006	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Eelgrass canopy height. Eelgrass canopy height (cm) measured at the deep edge near each reference transect marker. N/A indicates data was unavailable.

		Transect Marker								
		1	2	3	4	5	6	7	8	Mean ± SE
Fishing Island	Jun 2004	47	28	39	38	32	33	48	42	38 ± 3
	Sept 2004	24	51	53	88	44	82	46	72	58 ± 8
	Dec 2004	52	35	35	44	31	54	32	58	43 ± 4
	Mar 2005	14	23	19	31	22	36	35	33	27 ± 3
	Jun 2005	53	24	36	44	20	39	21	39	34 ± 4
	Sept 2005	43	62	52	43	43	42	37	52	47 ± 3
	Dec 2005	27	22	39	42	31	38	38	32	34 ± 2
	Mar 2006	28	17	29	23	14	20	16	21	21 ± 2
Outer Cutts Cove	Jun 2004	68	75	58	50	36	58	65	52	58 ± 4
	Sept 2004	91	55	67	47	58	46	40	71	59 ± 6
	Dec 2004	56	41	40	25	27	48	38	55	41 ± 4
	Mar 2005	34	19	25	27	20	19	28	28	25 ± 2
	Jun 2005	76	46	37	33	51	38	58	n/a	48 ± 6
	Sept 2005	67	44	40	34	87	54	73	n/a	57 ± 7
	Dec 2005	41	28	18	43	30	22	33	47	33 ± 4
	Mar 2006	25	14	15	15	10	15	13	21	16 ± 2
Great Bay Fish	Jun 2004	72	30	84	28	34	36	53	52	49 ± 7
	Sept 2004	41	48	48	34	49	55	50	44	46 ± 2
	Dec 2004	45	38	37	49	34	49	52	32	42 ± 3
	Mar 2005	35	23	25	25	24	23	41	29	28 ± 2
	Jun 2005	50	36	49	33	39	39	73	32	44 ± 5
	Sept 2005	28	33	33	43	45	28	53	49	39 ± 3
	Dec 2005	28	31	18	38	17	33	31	34	29 ± 3
	Mar 2006	11	11	11	20	15	15	16	16	14 ± 1
Dover Point	Jun 2004	87	52	69	70	11	65	63	71	61 ± 8
	Sept 2004	71	65	65	62	68	76	44	56	63 ± 3
	Dec 2004	37	34	28	24	30	35	51	45	36 ± 3
	Mar 2005	n/a	29	40	20	22	20	21	32	27 ± 3
	Jun 2005	n/a	103	97	69	54	64	18	64	67 ± 11
	Sept 2005	n/a	87	62	82	70	47	79	35	66 ± 7
	Dec 2005	n/a	n/a	41	34	72	29	79	36	49 ± 9
	Mar 2006	n/a	39	31	19	19	18	39	13	25 ± 4
Red Nun	Jun 2004	73	114	90	46	90	119	56	82	84 ± 9
	Sept 2004	111	131	86	130	100	122	79	91	106 ± 7
	Dec 2004	45	92	27	41	48	70	35	29	48 ± 8
	Mar 2005	42	35	23	27	37	41	28	27	33 ± 3
	Jun 2005	57	24	48	160	93	98	81	36	75 ± 15
	Sept 2005	80	82	95	100	59	82	87	98	85 ± 5
	Dec 2005	63	56	53	82	74	55	69	59	64 ± 4
	Mar 2006	43	48	30	37	32	30	47	43	39 ± 3

Eelgrass shoot density. Eelgrass shoot density (shoots 0.0625 m^{-2}) measured at the deep edge near each reference transect marker. N/A indicates data was unavailable.

Site		Transect Marker 1	2	3	4	5	6	7	8	Mean ± SE
Fishing Island	Jun 2004	21	12	7	16	15	15	5	22	14 ± 3
	Sept 2004	5	4	26	4	8	14	12	31	13 ± 4
	Dec 2004	11	3	22	9	3	14	7	18	11 ± 2
	Mar 2005	3	5	4	4	4	17	10	24	9 ± 3
	Jun 2005	2	2	17	8	2	13	7	3	7 ± 2
	Sept 2005	6	6	10	2	7	2	10	15	7 ± 2
	Dec 2005	2	12	11	3	6	3	11	8	7 ± 1
	Mar 2006	1	6	1	15	3	5	5	1	5 ± 2
Outer Cutts Cove	Jun 2004	13	14	3	23	11	14	2	5	11 ± 2
	Sept 2004	31	24	5	10	11	24	1	19	16 ± 4
	Dec 2004	6	4	5	5	6	5	2	4	5 ± 0.5
	Mar 2005	13	18	5	7	9	25	9	20	13 ± 2
	Jun 2005	10	7	2	6	3	12	2	n/a	6 ± 1
	Sept 2005	10	9	5	6	2	6	2	n/a	6 ± 1
	Dec 2005	6	8	4	5	16	5	8	4	7 ± 1
	Mar 2006	3	4	7	7	9	9	4	15	7 ± 1
Great Bay Fish	Jun 2004	3	8	9	6	5	17	3	2	7 ± 2
	Sept 2004	10	6	17	10	11	5	2	20	10 ± 2
	Dec 2004	7	1	13	2	9	11	1	4	6 ± 2
	Mar 2005	6	6	11	7	11	19	1	6	8 ± 2
	Jun 2005	3	5	2	8	11	12	7	1	6 ± 1
	Sept 2005	8	4	5	1	1	1	5	3	4 ± 1
	Dec 2005	1	1	1	1	3	1	2	1	1 ± 0.3
	Mar 2006	3	1	1	1	1	1	1	1	1 ± 0.3
Dover Point	Jun 2004	1	4	8	7	1	4	1	1	3 ± 1
	Sept 2004	18	9	15	4	16	1	5	4	9 ± 2
	Dec 2004	1	6	2	3	3	2	1	6	3 ± 1
	Mar 2005	n/a	3	17	5	4	4	4	5	6 ± 2
	Jun 2005	n/a	4	10	6	6	3	4	4	5 ± 1
	Sept 2005	n/a	6	4	17	6	1	1	1	5 ± 2
	Dec 2005	n/a	n/a	6	5	2	7	8	11	7 ± 1
	Mar 2006	n/a	6	5	2	4	3	11	3	5 ± 1
Red Nun	Jun 2004	19	5	2	1	6	7	11	4	7 ± 2
	Sept 2004	9	5	4	23	11	15	7	4	10 ± 2
	Dec 2004	14	8	7	16	5	4	3	8	8 ± 2
	Mar 2005	5	7	5	15	14	12	18	11	11 ± 2
	Jun 2005	5	3	5	17	6	7	2	5	6 ± 2
	Sept 2005	5	9	13	2	14	9	7	4	8 ± 1
	Dec 2005	6	3	9	5	14	5	9	2	7 ± 1
	Mar 2006	7	4	12	2	7	9	3	1	6 ± 1

Fishing Island Irradiance Instantaneous irradiance (Lumens ft^{-2}) measured using Onset Hobo™ light sensors. Irradiance measured at the eelgrass deep edge (A) was compared to surface irradiance (B) to calculate a percentage of surface irradiance (C) reaching the deep edge plants.

Fishing Island June 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04	18-Jun-04	19-Jun-04
10:00	16.92	13.03	10.99	27.28	23.96	10.06	12.50
11:00	31.06	11.46	59.90	57.00	31.06	14.25	8.43
12:00	57.00	6.80	74.44	74.44	21.98	9.60	4.59
13:00	74.44	5.99	45.95	77.35	10.99	7.44	11.46
14:00	31.06	5.23	84.33	59.90	8.84	11.46	57.00

(B) Surface Irradiance (Lumens ft^{-2})

Time	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04	18-Jun-04	19-Jun-04
10:00	1271.00	430.00	133.00	1116.00	824.00	378.00	693.00
11:00	1878.00	331.00	1448.00	1327.00	490.00	256.00	291.00
12:00	1649.00	317.00	1448.00	1166.00	331.00	215.00	197.00
13:00	1722.00	189.00	145.00	1166.00	165.00	189.00	412.00
14:00	1327.00	197.00	1448.00	980.00	165.00	412.00	789.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04	18-Jun-04	19-Jun-04
10:00	1.33%	3.03%	8.26%	2.44%	2.91%	2.66%	1.80%
11:00	1.65%	3.46%	4.14%	4.30%	6.34%	5.57%	2.90%
12:00	3.46%	2.15%	5.14%	6.38%	6.64%	4.46%	2.33%
13:00	4.32%	3.17%	31.69%	6.63%	6.66%	3.94%	2.78%
14:00	2.34%	2.66%	5.82%	6.11%	5.36%	2.78%	7.22%

Fishing Island September 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04	9-Sep-04
10:00	17.02	17.02	17.02	31.27	14.94	11.49	2.74
11:00	18.57	24.10	32.65	46.13	25.14	8.47	4.82
12:00	25.14	19.35	31.27	42.33	27.38	14.25	9.67
13:00	32.65	4.23	32.65	24.10	42.33	16.33	14.25
14:00	32.65	28.59	31.27	28.59	14.94	4.82	14.94

(B) Surface Irradiance (Lumens ft^{-2})

Time	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04	9-Sep-04
10:00	693.00	331.00	331.00	558.00	215.00	245.00	69.00
11:00	1024.00	789.00	1166.00	1327.00	362.00	103.00	98.00
12:00	899.00	378.00	1166.00	1166.00	469.00	189.00	189.00
13:00	608.00	46.90	789.00	724.00	534.00	215.00	256.00
14:00	152.00	98.00	224.00	245.00	224.00	82.00	245.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04	9-Sep-04
10:00	2.46%	5.14%	5.14%	5.60%	6.95%	4.69%	3.97%
11:00	1.81%	3.05%	2.80%	3.48%	6.94%	8.22%	4.92%
12:00	2.80%	5.12%	2.68%	3.63%	5.84%	7.54%	5.12%
13:00	5.37%	9.02%	4.14%	3.33%	7.93%	7.59%	5.57%
14:00	21.48%	29.18%	13.96%	11.67%	6.67%	5.88%	6.10%

Fishing Island Irradiance continued

Fishing Island December 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	3.69	4.79	10.04	5.45	3.86	1.48	3.39
10:30	2.20	4.79	7.35	15.51	4.21	2.50	7.08
11:00	2.20	4.39	7.08	22.96	9.24	6.46	7.35
11:30	1.36	3.86	6.19	7.08	5.45	8.07	8.79
12:00	4.79	2.97	4.79	4.21	5.69	6.19	11.48
12:30	4.79	2.84	5.00	5.69	3.39	6.46	11.48
13:00	3.25	3.25	2.61	3.86	2.84	4.39	11.93
13:30	3.39	2.61	1.77	2.20	1.69	4.21	8.79
14:00	2.01	2.20	1.55	0.74	0.88	2.97	4.39

(B) Surface Irradiance (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	1024.00	469.00	279.00	469.00	317.00	534.00	317.00
10:30	558.00	378.00	245.00	824.00	317.00	724.00	430.00
11:00	635.00	362.00	245.00	1327.00	635.00	279.00	378.00
11:30	469.00	331.00	279.00	558.00	331.00	224.00	412.00
12:00	693.00	291.00	245.00	469.00	331.00	197.00	378.00
12:30	430.00	256.00	245.00	635.00	279.00	173.00	317.00
13:00	430.00	245.00	224.00	430.00	245.00	165.00	378.00
13:30	430.00	224.00	197.00	430.00	173.00	152.00	331.00
14:00	291.00	245.00	197.00	197.00	112.00	145.00	256.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	0.36%	1.02%	3.60%	1.16%	1.22%	0.28%	1.07%
10:30	0.39%	1.27%	3.00%	1.88%	1.33%	0.35%	1.65%
11:00	0.35%	1.21%	2.89%	1.73%	1.45%	2.31%	1.95%
11:30	0.29%	1.16%	2.22%	1.27%	1.65%	3.60%	2.13%
12:00	0.69%	1.02%	1.95%	0.90%	1.72%	3.14%	3.04%
12:30	1.11%	1.11%	2.04%	0.90%	1.21%	3.73%	3.62%
13:00	0.75%	1.32%	1.16%	0.90%	1.16%	2.66%	3.16%
13:30	0.79%	1.16%	0.90%	0.51%	0.98%	2.77%	2.65%
14:00	0.69%	0.90%	0.79%	0.37%	0.78%	2.05%	1.72%

Fishing Island Irradiance continued

Fishing Island March 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	324.70	285.64	114.93	249.94	80.34	28.56	19.30
10:30	324.70	311.31	124.97	249.94	100.42	42.18	24.99
11:00	403.92	353.71	249.94	239.90	91.50	109.35	19.30
11:30	285.64	369.33	249.94	193.03	88.15	42.18	76.99
12:00	273.37	324.70	311.31	273.37	100.42	54.67	23.99
12:30	193.03	249.94	273.37	273.37	148.40	67.84	21.98
13:00	161.79	169.60	210.89	239.90	124.97	54.67	23.99
13:30	109.35	114.93	142.82	148.40	76.99	54.67	62.26
14:00	67.84	76.99	88.15	91.50	70.85	45.97	52.33

(B) Surface Irradiance (Lumens ft^{-2})

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	1878.00	1722.00	724.00	1722.00	608.00	534.00	534.00
10:30	1722.00	1512.00	635.00	1722.00	789.00	608.00	789.00
11:00	1878.00	1722.00	2138.00	1649.00	635.00	3756.00	469.00
11:30	1649.00	1649.00	1512.00	1512.00	635.00	534.00	693.00
12:00	1448.00	1327.00	1512.00	1448.00	899.00	724.00	331.00
12:30	1512.00	1448.00	1512.00	1271.00	1116.00	635.00	256.00
13:00	1024.00	980.00	1271.00	1024.00	558.00	534.00	279.00
13:30	534.00	490.00	724.00	608.00	430.00	490.00	1116.00
14:00	197.00	189.00	291.00	215.00	469.00	430.00	362.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	17.29%	16.59%	15.87%	14.51%	13.21%	5.35%	3.61%
10:30	18.86%	20.59%	19.68%	14.51%	12.73%	6.94%	3.17%
11:00	21.51%	20.54%	11.69%	14.55%	14.41%	2.91%	4.12%
11:30	17.32%	22.40%	16.53%	12.77%	13.88%	7.90%	11.11%
12:00	18.88%	24.47%	20.59%	18.88%	11.17%	7.55%	7.25%
12:30	12.77%	17.26%	18.08%	21.51%	13.30%	10.68%	8.59%
13:00	15.80%	17.31%	16.59%	23.43%	22.40%	10.24%	8.60%
13:30	20.48%	23.45%	19.73%	24.41%	17.90%	11.16%	5.58%
14:00	34.44%	40.74%	30.29%	42.56%	15.11%	10.69%	14.46%

Fishing Island Irradiance continued

Fishing Island June 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05	16-Jun-05
10:00	7.88	17.25	11.67	24.43	2.78	6.33	3.30
10:30	7.88	13.26	16.45	14.46	1.52	6.33	6.06
11:00	10.27	12.76	10.27	22.34	4.29	7.88	7.18
11:30	19.64	10.27	8.18	12.76	3.77	12.76	7.88
12:00	33.00	17.25	5.56	24.43	4.68	7.88	8.97
12:30	33.00	22.34	4.68	14.46	3.61	8.18	6.88
13:00	29.02	31.61	12.76	8.97	2.14	5.32	4.68
13:30	27.82	31.61	10.27	22.34	3.16	3.77	8.97
14:00	29.02	25.53	13.26	17.25	4.11	3.16	8.97

(B) Surface Irradiance (Lumens ft^{-2})

Time	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05	16-Jun-05
10:00	189.00	197.00	317.00	189.00	31.70	224.00	173.00
10:30	291.00	412.00	490.00	173.00	17.30	224.00	245.00
11:00	145.00	693.00	412.00	362.00	98.00	224.00	279.00
11:30	899.00	724.00	430.00	256.00	98.00	412.00	317.00
12:00	1116.00	724.00	331.00	824.00	173.00	291.00	331.00
12:30	291.00	789.00	256.00	430.00	215.00	412.00	245.00
13:00	980.00	980.00	490.00	362.00	145.00	279.00	245.00
13:30	980.00	789.00	317.00	534.00	279.00	331.00	558.00
14:00	899.00	608.00	362.00	256.00	279.00	291.00	490.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05	16-Jun-05
10:00	4.17%	8.76%	3.68%	12.93%	8.78%	2.83%	1.91%
10:30	2.71%	3.22%	3.36%	8.36%	8.76%	2.83%	2.47%
11:00	7.08%	1.84%	2.49%	6.17%	4.38%	3.52%	2.57%
11:30	2.18%	1.42%	1.90%	4.99%	3.85%	3.10%	2.48%
12:00	2.96%	2.38%	1.68%	2.96%	2.70%	2.71%	2.71%
12:30	11.34%	2.83%	1.83%	3.36%	1.68%	1.98%	2.81%
13:00	2.96%	3.23%	2.60%	2.48%	1.48%	1.91%	1.91%
13:30	2.84%	4.01%	3.24%	4.18%	1.13%	1.14%	1.61%
14:00	3.23%	4.20%	3.66%	6.74%	1.47%	1.09%	1.83%

Fishing Island Irradiance continued

Fishing Island September 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	2.36	29.32	45.03	4.34	94.99	73.03	13.45
10:30	3.49	30.64	39.54	7.03	79.62	45.03	17.41
11:00	7.03	34.87	56.56	8.35	103.78	25.75	18.18
11:30	7.96	53.81	53.81	10.82	79.62	26.91	22.62
12:00	10.82	56.56	53.81	7.30	53.81	20.76	29.32
12:30	8.35	64.24	70.28	9.06	64.24	9.50	23.61
13:00	10.38	53.81	53.81	8.35	56.56	10.82	19.88
13:30	10.38	45.03	34.87	11.81	39.54	10.82	14.06
14:00	6.42	30.64	33.39	22.62	34.87	10.82	9.06

(B) Surface Irradiance (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	49.00	69.00	60.80	37.80	69.00	152.00	173.00
10:30	60.80	189.00	103.00	72.00	128.00	256.00	197.00
11:00	112.00	317.00	256.00	112.00	279.00	224.00	224.00
11:30	112.00	490.00	412.00	133.00	534.00	279.00	189.00
12:00	173.00	534.00	490.00	98.00	558.00	224.00	245.00
12:30	112.00	693.00	534.00	90.00	693.00	103.00	197.00
13:00	112.00	608.00	490.00	98.00	724.00	133.00	215.00
13:30	117.00	469.00	412.00	152.00	635.00	145.00	145.00
14:00	112.00	362.00	378.00	165.00	469.00	173.00	117.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	4.82%	42.50%	74.06%	11.48%	137.67%	48.05%	7.78%
10:30	5.73%	16.21%	38.38%	9.76%	62.20%	17.59%	8.84%
11:00	6.28%	11.00%	22.09%	7.45%	37.20%	11.50%	8.11%
11:30	7.11%	10.98%	13.06%	8.13%	14.91%	9.64%	11.97%
12:00	6.25%	10.59%	10.98%	7.45%	9.64%	9.27%	11.97%
12:30	7.45%	9.27%	13.16%	10.07%	9.27%	9.22%	11.99%
13:00	9.27%	8.85%	10.98%	8.52%	7.81%	8.13%	9.25%
13:30	8.87%	9.60%	8.46%	7.77%	6.23%	7.46%	9.69%
14:00	5.74%	8.46%	8.83%	13.71%	7.43%	6.25%	7.74%

Fishing Island Irradiance continued

Fishing Island December 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05	23-Dec-05
10:00	4.91	4.33	5.63	9.12	14.03	17.45	22.58
10:30	5.63	5.13	6.98	9.47	15.31	18.23	18.23
11:00	5.63	9.47	9.12	11.75	14.03	12.32	29.35
11:30	6.41	3.06	10.33	15.31	18.23	13.46	22.58
12:00	6.98	2.69	12.32	15.96	20.73	15.96	17.45
12:30	7.34	3.80	14.03	15.96	20.73	17.45	15.96
13:00	6.98	5.84	15.31	15.96	26.92	19.87	15.31
13:30	7.34	4.91	10.83	15.96	20.73	20.73	17.45
14:00	2.69	4.33	3.80	15.96	13.46	10.83	18.23

(B) Surface Irradiance (Lumens ft^{-2})

Time	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05	23-Dec-05
10:00	133.00	224.00	331.00	173.00	197.00	378.00	279.00
10:30	112.00	128.00	317.00	145.00	152.00	635.00	197.00
11:00	79.00	90.00	128.00	98.00	103.00	608.00	317.00
11:30	69.00	72.00	98.00	82.00	112.00	693.00	331.00
12:00	72.00	152.00	98.00	82.00	112.00	693.00	291.00
12:30	72.00	133.00	173.00	90.00	103.00	608.00	362.00
13:00	72.00	189.00	362.00	82.00	279.00	608.00	362.00
13:30	72.00	152.00	215.00	133.00	245.00	317.00	197.00
14:00	60.80	72.00	173.00	112.00	128.00	165.00	165.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05	23-Dec-05
10:00	3.70%	1.93%	1.70%	5.27%	7.12%	4.62%	8.09%
10:30	5.02%	4.01%	2.20%	6.53%	10.08%	2.87%	9.26%
11:00	7.12%	10.53%	7.12%	11.99%	13.62%	2.03%	9.26%
11:30	9.29%	4.25%	10.54%	18.68%	16.28%	1.94%	6.82%
12:00	9.70%	1.77%	12.57%	19.46%	18.51%	2.30%	6.00%
12:30	10.19%	2.86%	8.11%	17.73%	20.12%	2.87%	4.41%
13:00	9.70%	3.09%	4.23%	19.46%	9.65%	3.27%	4.23%
13:30	10.19%	3.23%	5.04%	12.00%	8.46%	6.54%	8.86%
14:00	4.43%	6.01%	2.20%	14.25%	10.52%	6.56%	11.05%

Fishing Island Irradiance continued

Fishing Island March 2006

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	48.42	54.90	60.24	68.63	74.73	60.24	85.40
10:30	97.60	68.63	62.53	68.63	97.60	110.56	97.60
11:00	21.27	48.42	110.56	101.41	97.60	144.11	115.90
11:30	54.90	78.54	144.11	115.90	115.90	74.73	144.11
12:00	68.63	78.54	125.81	186.81	144.11	78.54	163.94
12:30	74.73	150.21	150.21	150.21	144.11	150.21	163.94
13:00	163.94	60.24	131.91	144.11	163.94	115.90	150.21
13:30	163.94	46.36	101.41	163.94	144.11	78.54	125.81
14:00	125.81	115.90	101.41	125.81	131.91	68.63	125.81

(B) Surface Irradiance (Lumens ft^{-2})

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	469.00	291.00	291.00	317.00	362.00	430.00	430.00
10:30	430.00	608.00	430.00	469.00	558.00	558.00	824.00
11:00	145.00	490.00	490.00	635.00	724.00	558.00	899.00
11:30	430.00	469.00	608.00	724.00	980.00	824.00	1116.00
12:00	534.00	534.00	362.00	412.00	490.00	980.00	635.00
12:30	224.00	724.00	215.00	245.00	362.00	824.00	534.00
13:00	197.00	412.00	165.00	197.00	245.00	430.00	291.00
13:30	98.00	362.00	133.00	189.00	173.00	558.00	197.00
14:00	103.00	469.00	173.00	197.00	215.00	412.00	245.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	10.32%	18.87%	20.70%	21.65%	20.64%	14.01%	19.86%
10:30	22.70%	11.29%	14.54%	14.63%	17.49%	19.81%	11.84%
11:00	14.67%	9.88%	22.56%	15.97%	13.48%	25.83%	12.89%
11:30	12.77%	16.75%	23.70%	16.01%	11.83%	9.07%	12.91%
12:00	12.85%	14.71%	34.75%	45.34%	29.41%	8.01%	25.82%
12:30	33.36%	20.75%	69.87%	61.31%	39.81%	18.23%	30.70%
13:00	83.22%	14.62%	79.95%	73.15%	66.91%	26.95%	51.62%
13:30	167.28%	12.81%	76.25%	86.74%	83.30%	14.07%	63.86%
14:00	122.15%	24.71%	58.62%	63.86%	61.35%	16.66%	51.35%

Outer Cutts Cove Irradiance Instantaneous irradiance (Lumens ft^{-2}) measured using Onset Hobo™ light sensors. Irradiance measured at the eelgrass deep edge (A) was compared to surface irradiance (B) to calculate a percentage of surface irradiance (C) reaching the deep edge plants.

Outer Cutts Cove June 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04
10:00	143.14	212.25	194.48	28.73	8.88	6.27	4.63
11:00	150.05	186.58	131.30	28.73	10.17	8.10	5.27
12:00	110.57	131.30	115.50	2.21	8.88	8.10	3.73
13:00	52.72	60.02	80.95	1.26	2.21	9.67	2.21
14:00	35.74	31.29	37.32	1.26	6.27	6.81	1.02

(B) Surface Irradiance (Lumens ft^{-2})

Time	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04
10:00	789.00	693.00	412.00	279.00	608.00	558.00	317.00
11:00	824.00	789.00	724.00	112.00	63.50	608.00	145.00
12:00	789.00	693.00	558.00	103.00	534.00	608.00	145.00
13:00	317.00	362.00	82.00	133.00	245.00	256.00	103.00
14:00	133.00	152.00	189.00	224.00	128.00	128.00	69.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04
10:00	18.14%	30.63%	47.20%	10.30%	1.46%	1.12%	1.46%
11:00	18.21%	23.65%	18.14%	25.65%	16.01%	1.33%	3.64%
12:00	14.01%	18.95%	20.70%	2.15%	1.66%	1.33%	2.57%
13:00	16.63%	16.58%	98.72%	0.95%	0.90%	3.78%	2.15%
14:00	26.87%	20.59%	19.74%	0.56%	4.90%	5.32%	1.47%

Outer Cutts Cove Irradiance continued

Outer Cutts Cove September 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	14.50	31.60	39.07	15.80	39.07	12.18	8.21
11:00	14.50	27.75	27.75	13.87	39.07	21.41	4.64
12:00	21.41	23.33	23.33	44.74	35.96	34.43	8.21
13:00	18.74	21.41	20.50	24.35	27.75	26.56	5.10
14:00	15.80	17.95	7.25	18.74	18.74	11.16	2.66

(B) Surface Irradiance (Lumens ft^{-2})

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	279.00	197.00	112.00	490.00	33.10	152.00	112.00
11:00	469.00	608.00	378.00	215.00	608.00	224.00	165.00
12:00	173.00	693.00	279.00	1271.00	789.00	128.00	117.00
13:00	789.00	693.00	534.00	1166.00	724.00	103.00	145.00
14:00	724.00	608.00	79.00	899.00	824.00	224.00	60.80

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	5.20%	16.04%	34.89%	3.22%	118.05%	8.01%	7.33%
11:00	3.09%	4.56%	7.34%	6.45%	6.43%	9.56%	2.81%
12:00	12.37%	3.37%	8.36%	3.52%	4.56%	26.90%	7.02%
13:00	2.38%	3.09%	3.84%	2.09%	3.83%	25.79%	3.51%
14:00	2.18%	2.95%	9.18%	2.09%	2.27%	4.98%	4.37%

Outer Cutts Cove Irradiance continued

Outer Cutts Cove December 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	14.08	30.79	45.55	16.80	11.36	10.00	10.88
10:30	16.02	30.79	54.19	27.10	14.76	7.96	18.36
11:00	14.76	27.10	47.59	45.55	16.02	14.76	18.36
11:30	10.00	27.10	41.76	23.79	18.36	16.80	18.36
12:00	14.08	23.79	36.71	20.88	19.13	20.88	21.75
12:30	8.74	14.76	14.76	16.02	14.08	21.75	24.86
13:00	9.52	11.36	19.13	12.43	10.88	24.86	30.79
13:30	8.74	7.67	12.92	11.36	7.67	27.10	27.10
14:00	5.90	6.17	7.67	4.18	5.42	24.86	24.86

(B) Surface Irradiance (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	1024.00	469.00	279.00	469.00	317.00	534.00	317.00
10:30	558.00	378.00	245.00	824.00	317.00	724.00	430.00
11:00	635.00	362.00	245.00	1327.00	635.00	279.00	378.00
11:30	469.00	331.00	279.00	558.00	331.00	224.00	412.00
12:00	693.00	291.00	245.00	469.00	331.00	197.00	378.00
12:30	430.00	256.00	245.00	635.00	279.00	173.00	317.00
13:00	430.00	245.00	224.00	430.00	245.00	165.00	378.00
13:30	430.00	224.00	197.00	430.00	173.00	152.00	331.00
14:00	291.00	245.00	197.00	197.00	112.00	145.00	256.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	1.38%	6.56%	16.33%	3.58%	3.58%	1.87%	3.43%
10:30	2.87%	8.14%	22.12%	3.29%	4.66%	1.10%	4.27%
11:00	2.32%	7.49%	19.42%	3.43%	2.52%	5.29%	4.86%
11:30	2.13%	8.19%	14.97%	4.26%	5.55%	7.50%	4.46%
12:00	2.03%	8.18%	14.98%	4.45%	5.78%	10.60%	5.76%
12:30	2.03%	5.77%	6.03%	2.52%	5.05%	12.58%	7.84%
13:00	2.21%	4.64%	8.54%	2.89%	4.44%	15.07%	8.14%
13:30	2.03%	3.43%	6.56%	2.64%	4.43%	17.83%	8.19%
14:00	2.03%	2.52%	3.89%	2.12%	4.84%	17.15%	9.71%

Outer Cutts Cove Irradiance continued

Outer Cutts Cove March 2005

(A) **Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})**

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	259.74	270.61	141.35	95.44	118.39	64.51	56.66
10:30	382.97	99.06	135.31	351.56	154.64	64.51	86.98
11:00	351.56	337.06	124.43	309.27	154.64	141.35	35.16
11:30	382.97	183.63	270.61	270.61	154.64	86.98	43.73
12:00	309.27	118.39	295.98	295.98	183.63	51.95	45.67
12:30	295.98	309.27	135.31	228.33	209.00	108.73	67.41
13:00	228.33	141.35	175.17	199.34	118.39	86.98	67.41
13:30	160.68	135.31	124.43	160.68	99.06	56.66	135.31
14:00	118.39	141.35	141.35	108.73	86.98	45.67	76.71

(B) **Surface Irradiance (Lumens ft^{-2})**

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	1878.00	1722.00	724.00	1722.00	608.00	534.00	534.00
10:30	1722.00	1512.00	635.00	1722.00	789.00	608.00	789.00
11:00	1878.00	1722.00	2138.00	1649.00	635.00	3756.00	469.00
11:30	1649.00	1649.00	1512.00	1512.00	635.00	534.00	693.00
12:00	1448.00	1327.00	1512.00	1448.00	899.00	724.00	331.00
12:30	1512.00	1448.00	1512.00	1271.00	1116.00	635.00	256.00
13:00	1024.00	980.00	1271.00	1024.00	558.00	534.00	279.00
13:30	534.00	490.00	724.00	608.00	430.00	490.00	1116.00
14:00	197.00	189.00	291.00	215.00	469.00	430.00	362.00

(C) **Percent Surface Irradiance at Eelgrass Deep Edge (% SI)**

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	13.83%	15.72%	19.52%	5.54%	19.47%	12.08%	10.61%
10:30	22.24%	6.55%	21.31%	20.42%	19.60%	10.61%	11.02%
11:00	18.72%	19.57%	5.82%	18.76%	24.35%	3.76%	7.50%
11:30	23.22%	11.14%	17.90%	17.90%	24.35%	16.29%	6.31%
12:00	21.36%	8.92%	19.58%	20.44%	20.43%	7.18%	13.80%
12:30	19.58%	21.36%	8.95%	17.96%	18.73%	17.12%	26.33%
13:00	22.30%	14.42%	13.78%	19.47%	21.22%	16.29%	24.16%
13:30	30.09%	27.61%	17.19%	26.43%	23.04%	11.56%	12.12%
14:00	60.10%	74.79%	48.57%	50.57%	18.55%	10.62%	21.19%

Outer Cutts Cove June 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	17.21	26.58	48.89	39.28	33.11	4.30	8.19
10:30	13.29	63.37	51.03	42.96	29.07	3.04	7.22
11:00	5.10	33.11	48.89	33.11	37.62	8.54	10.68
11:30	7.22	51.03	44.86	33.11	39.28	7.54	17.21
12:00	12.22	48.89	37.62	20.53	66.22	7.22	9.73
12:30	55.66	44.86	33.11	13.29	37.62	9.37	17.21
13:00	58.15	55.66	25.51	19.58	29.07	6.34	18.04
13:30	66.22	66.22	37.62	15.78	42.96	8.54	8.54
14:00	81.88	63.37	39.28	23.38	13.88	6.62	8.54

(B) Surface Irradiance (Lumens ft^{-2})

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	215.00	189.00	197.00	317.00	189.00	31.70	224.00
10:30	362.00	291.00	412.00	490.00	173.00	17.30	224.00
11:00	145.00	145.00	693.00	412.00	362.00	98.00	224.00
11:30	215.00	899.00	724.00	430.00	256.00	98.00	412.00
12:00	362.00	1116.00	724.00	331.00	824.00	173.00	291.00
12:30	1116.00	291.00	789.00	256.00	430.00	215.00	412.00
13:00	1024.00	980.00	980.00	490.00	362.00	145.00	279.00
13:30	1024.00	980.00	789.00	317.00	534.00	279.00	331.00
14:00	899.00	899.00	608.00	362.00	256.00	279.00	291.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	8.00%	14.06%	24.82%	12.39%	17.52%	13.55%	3.66%
10:30	3.67%	21.78%	12.39%	8.77%	16.81%	17.56%	3.22%
11:00	3.52%	22.83%	7.06%	8.04%	10.39%	8.72%	4.77%
11:30	3.36%	5.68%	6.20%	7.70%	15.34%	7.69%	4.18%
12:00	3.38%	4.38%	5.20%	6.20%	8.04%	4.17%	3.34%
12:30	4.99%	15.41%	4.20%	5.19%	8.75%	4.36%	4.18%
13:00	5.68%	5.68%	2.60%	4.00%	8.03%	4.37%	6.47%
13:30	6.47%	6.76%	4.77%	4.98%	8.04%	3.06%	2.58%
14:00	9.11%	7.05%	6.46%	6.46%	5.42%	2.37%	2.94%

Outer Cutts Cove September 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	2.35	58.43	97.78	3.95	82.28	55.92	19.67
10:30	3.95	55.92	66.54	9.42	97.78	39.47	25.64
11:00	6.37	43.16	82.28	13.95	116.86	26.71	26.71
11:30	5.84	45.07	72.50	13.95	82.28	30.53	23.49
12:00	8.59	43.16	49.13	9.78	66.54	22.54	30.53
12:30	9.42	30.53	34.70	9.78	49.13	19.67	26.71
13:00	10.73	29.21	22.54	8.59	37.80	23.49	15.86
13:30	8.23	26.71	26.71	15.86	29.21	15.26	13.95
14:00	8.59	22.54	22.54	19.67	22.54	19.67	12.28

(B) Surface Irradiance (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	49.00	69.00	60.80	37.80	69.00	152.00	173.00
10:30	60.80	189.00	103.00	72.00	128.00	256.00	197.00
11:00	112.00	317.00	256.00	112.00	279.00	224.00	224.00
11:30	112.00	490.00	412.00	133.00	534.00	279.00	189.00
12:00	173.00	534.00	490.00	98.00	558.00	224.00	245.00
12:30	112.00	693.00	534.00	90.00	693.00	103.00	197.00
13:00	112.00	608.00	490.00	98.00	724.00	133.00	215.00
13:30	117.00	469.00	412.00	152.00	635.00	145.00	145.00
14:00	112.00	362.00	378.00	165.00	469.00	173.00	117.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	4.79%	84.68%	160.82%	10.44%	119.24%	36.79%	11.37%
10:30	6.49%	29.59%	64.60%	13.08%	76.39%	15.42%	13.01%
11:00	5.69%	13.62%	32.14%	12.46%	41.88%	11.92%	11.92%
11:30	5.22%	9.20%	17.60%	10.49%	15.41%	10.94%	12.43%
12:00	4.96%	8.08%	10.03%	9.98%	11.92%	10.06%	12.46%
12:30	8.41%	4.40%	6.50%	10.86%	7.09%	19.10%	13.56%
13:00	9.58%	4.80%	4.60%	8.76%	5.22%	17.66%	7.38%
13:30	7.03%	5.70%	6.48%	10.43%	4.60%	10.53%	9.62%
14:00	7.67%	6.23%	5.96%	11.92%	4.81%	11.37%	10.50%

Outer Cutts Cove December 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05	23-Dec-05
10:00	4.33	3.97	5.13	10.83	14.03	11.75	17.45
10:30	3.49	5.84	4.52	10.83	13.46	14.03	15.96
11:00	3.49	5.13	6.98	10.33	14.03	9.47	17.45
11:30	3.97	3.34	6.41	9.12	13.46	11.75	17.45
12:00	3.80	1.60	5.84	9.47	11.75	12.32	14.03
12:30	3.80	3.34	7.98	9.47	10.83	10.33	13.46
13:00	3.80	1.82	7.34	9.12	14.03	9.12	15.31
13:30	3.97	2.26	4.33	7.98	9.47	7.98	8.33
14:00	4.52	2.26	2.93	6.41	5.63	6.41	7.98

(B) Surface Irradiance (Lumens ft^{-2})

Time	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05	23-Dec-05
10:00	133.00	224.00	331.00	173.00	197.00	378.00	279.00
10:30	112.00	128.00	317.00	145.00	152.00	635.00	197.00
11:00	79.00	90.00	128.00	98.00	103.00	608.00	317.00
11:30	69.00	72.00	98.00	82.00	112.00	693.00	331.00
12:00	72.00	152.00	98.00	82.00	112.00	693.00	291.00
12:30	72.00	133.00	173.00	90.00	103.00	608.00	362.00
13:00	72.00	189.00	362.00	82.00	279.00	608.00	362.00
13:30	72.00	152.00	215.00	133.00	245.00	317.00	197.00
14:00	60.80	72.00	173.00	112.00	128.00	165.00	165.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05	23-Dec-05
10:00	3.26%	1.77%	1.55%	6.26%	7.12%	3.11%	6.25%
10:30	3.12%	4.56%	1.43%	7.47%	8.86%	2.21%	8.10%
11:00	4.42%	5.70%	5.45%	10.54%	13.62%	1.56%	5.51%
11:30	5.76%	4.64%	6.54%	11.12%	12.02%	1.70%	5.27%
12:00	5.28%	1.05%	5.96%	11.55%	10.49%	1.78%	4.82%
12:30	5.28%	2.51%	4.61%	10.53%	10.51%	1.70%	3.72%
13:00	5.28%	0.96%	2.03%	11.12%	5.03%	1.50%	4.23%
13:30	5.52%	1.49%	2.01%	6.00%	3.87%	2.52%	4.23%
14:00	7.44%	3.14%	1.70%	5.72%	4.40%	3.89%	4.84%

Outer Cutts Cove March 2006

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06	21-Mar-06
10:00	40.72	37.36	32.79	42.55	52.61	68.63	101.41
10:30	52.61	46.36	46.36	40.72	60.24	27.60	85.40
11:00	78.54	54.90	52.61	52.61	31.42	78.54	78.54
11:30	46.36	52.61	54.90	54.90	22.19	68.63	74.73
12:00	32.79	60.24	54.90	68.63	37.36	62.53	62.53
12:30	24.17	62.53	52.61	60.24	28.82	68.63	62.53
13:00	27.60	60.24	52.61	42.55	24.17	48.42	48.42
13:30	60.24	46.36	46.36	35.76	35.76	40.72	40.72
14:00	28.82	25.24	31.42	31.42	14.41	28.82	27.60

(B) Surface Irradiance (Lumens ft^{-2})

Time	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06	21-Mar-06
10:00	291.00	291.00	317.00	362.00	430.00	430.00	378.00
10:30	608.00	430.00	469.00	558.00	558.00	824.00	534.00
11:00	490.00	490.00	635.00	724.00	558.00	899.00	635.00
11:30	469.00	608.00	724.00	980.00	824.00	1116.00	789.00
12:00	534.00	362.00	412.00	490.00	980.00	635.00	430.00
12:30	724.00	215.00	245.00	362.00	824.00	534.00	256.00
13:00	412.00	165.00	197.00	245.00	430.00	291.00	189.00
13:30	362.00	133.00	189.00	173.00	558.00	197.00	117.00
14:00	469.00	173.00	197.00	215.00	412.00	245.00	145.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06	21-Mar-06
10:00	13.99%	12.84%	10.34%	11.75%	12.24%	15.96%	26.83%
10:30	8.65%	10.78%	9.88%	7.30%	10.80%	3.35%	15.99%
11:00	16.03%	11.20%	8.29%	7.27%	5.63%	8.74%	12.37%
11:30	9.88%	8.65%	7.58%	5.60%	2.69%	6.15%	9.47%
12:00	6.14%	16.64%	13.33%	14.01%	3.81%	9.85%	14.54%
12:30	3.34%	29.08%	21.47%	16.64%	3.50%	12.85%	24.42%
13:00	6.70%	36.51%	26.71%	17.37%	5.62%	16.64%	25.62%
13:30	16.64%	34.86%	24.53%	20.67%	6.41%	20.67%	34.80%
14:00	6.15%	14.59%	15.95%	14.61%	3.50%	11.76%	19.04%

Great Bay Fish Irradiance Instantaneous irradiance (Lumens ft^{-2}) measured using Onset Hobo™ light sensors. Irradiance measured at the eelgrass deep edge (A) was compared to surface irradiance (B) to calculate a percentage of surface irradiance (C) reaching the deep edge plants.

Great Bay Fish June 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04	18-Jun-04
10:00	89.38	97.55	11.61	58.07	40.83	16.42	12.66
11:00	68.96	89.38	16.42	85.75	68.96	24.23	6.90
12:00	74.86	60.34	14.38	78.49	78.49	24.23	8.94
13:00	53.08	10.16	11.12	53.08	68.96	12.66	5.81
14:00	25.32	32.67	12.66	27.58	40.83	7.85	8.94

(B) Surface Irradiance (Lumens ft^{-2})

Time	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04	18-Jun-04
10:00	693.00	635.00	291.00	608.00	534.00	693.00	215.00
11:00	693.00	412.00	279.00	608.00	558.00	317.00	133.00
12:00	789.00	724.00	112.00	63.50	608.00	145.00	189.00
13:00	693.00	558.00	103.00	534.00	608.00	145.00	90.00
14:00	362.00	82.00	133.00	245.00	256.00	103.00	103.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04	17-Jun-04	18-Jun-04
10:00	12.90%	15.36%	3.99%	9.55%	7.65%	2.37%	5.89%
11:00	9.95%	21.69%	5.89%	14.10%	12.36%	7.64%	5.19%
12:00	9.49%	8.33%	12.84%	123.61%	12.91%	16.71%	4.73%
13:00	7.66%	1.82%	10.79%	9.94%	11.34%	8.73%	6.45%
14:00	6.99%	39.84%	9.52%	11.26%	15.95%	7.62%	8.68%

Great Bay Fish September 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	7.82	13.17	14.98	11.53	14.98	6.87	6.00
11:00	10.58	13.17	13.17	7.82	20.29	12.04	11.53
12:00	9.31	11.53	9.31	6.87	22.11	9.31	9.31
13:00	10.58	10.58	4.26	6.00	19.42	9.31	5.53
14:00	10.15	10.15	10.58	10.58	9.31	9.31	3.56

(B) Surface Irradiance (Lumens ft^{-2})

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	279.00	197.00	112.00	490.00	33.10	152.00	112.00
11:00	469.00	608.00	378.00	215.00	608.00	224.00	165.00
12:00	173.00	693.00	279.00	1271.00	789.00	128.00	117.00
13:00	789.00	693.00	534.00	1166.00	724.00	103.00	145.00
14:00	724.00	608.00	79.00	899.00	824.00	224.00	60.80

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	2.80%	6.68%	13.38%	2.35%	45.27%	4.52%	5.36%
11:00	2.26%	2.17%	3.48%	3.64%	3.34%	5.37%	6.99%
12:00	5.38%	1.66%	3.34%	0.54%	2.80%	7.27%	7.96%
13:00	1.34%	1.53%	0.80%	0.51%	2.68%	9.04%	3.81%
14:00	1.40%	1.67%	13.40%	1.18%	1.13%	4.16%	5.86%

Great Bay Fish Irradiance continued

Great Bay Fish December 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	3.30	6.06	7.52	4.28	6.06	6.29	4.28
10:30	4.67	6.91	8.98	8.59	4.87	9.82	8.59
11:00	4.67	6.91	10.21	7.52	4.28	13.28	11.13
11:30	4.67	6.29	4.10	6.29	6.91	12.66	11.13
12:00	5.30	6.06	22.33	6.29	8.59	15.12	13.28
12:30	4.28	4.87	7.52	8.59	5.53	21.41	8.59
13:00	2.54	3.76	5.53	4.87	4.87	19.65	11.66
13:30	1.33	2.43	4.28	5.30	4.10	11.13	11.66
14:00	1.02	1.72	3.60	2.23	2.90	14.50	10.21

(B) Surface Irradiance (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	1024.00	469.00	279.00	469.00	317.00	534.00	317.00
10:30	558.00	378.00	245.00	824.00	317.00	724.00	430.00
11:00	635.00	362.00	245.00	1327.00	635.00	279.00	378.00
11:30	469.00	331.00	279.00	558.00	331.00	224.00	412.00
12:00	693.00	291.00	245.00	469.00	331.00	197.00	378.00
12:30	430.00	256.00	245.00	635.00	279.00	173.00	317.00
13:00	430.00	245.00	224.00	430.00	245.00	165.00	378.00
13:30	430.00	224.00	197.00	430.00	173.00	152.00	331.00
14:00	291.00	245.00	197.00	197.00	112.00	145.00	256.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	0.32%	1.29%	2.70%	0.91%	1.91%	1.18%	1.35%
10:30	0.84%	1.83%	3.66%	1.04%	1.54%	1.36%	2.00%
11:00	0.73%	1.91%	4.17%	0.57%	0.67%	4.76%	2.94%
11:30	0.99%	1.90%	1.47%	1.13%	2.09%	5.65%	2.70%
12:00	0.76%	2.08%	9.11%	1.34%	2.60%	7.67%	3.51%
12:30	1.00%	1.90%	3.07%	1.35%	1.98%	12.38%	2.71%
13:00	0.59%	1.53%	2.47%	1.13%	1.99%	11.91%	3.09%
13:30	0.31%	1.09%	2.17%	1.23%	2.37%	7.32%	3.52%
14:00	0.35%	0.70%	1.83%	1.13%	2.59%	10.00%	3.99%

Great Bay Fish Irradiance continued

Great Bay Fish March 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	18-Mar-05	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05
10:00	216.36	216.36	207.67	159.37	41.53	69.54	58.73
10:30	167.10	167.10	146.82	140.06	66.65	53.90	86.93
11:00	123.64	123.64	113.01	108.18	61.33	45.30	58.73
11:30	76.31	79.20	79.20	76.31	53.90	45.30	61.33
12:00	53.90	58.73	61.33	53.90	41.53	45.30	58.73
12:30	34.97	39.80	41.53	36.51	31.97	36.51	47.33
13:00	23.66	23.66	28.11	24.73	23.66	39.80	36.51
13:30	14.68	16.71	11.30	15.94	14.68	24.73	28.11
14:00	7.63	10.82	5.87	7.63	7.92	6.66	12.85

(B) Surface Irradiance (Lumens ft^{-2})

Time	18-Mar-05	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05
10:00	1271.00	1878.00	1722.00	724.00	1722.00	608.00	534.00
10:30	1327.00	1722.00	1512.00	635.00	1722.00	789.00	608.00
11:00	1722.00	1878.00	1722.00	2138.00	1649.00	635.00	3756.00
11:30	1722.00	1649.00	1649.00	1512.00	1512.00	635.00	534.00
12:00	4096.00	1448.00	1327.00	1512.00	1448.00	899.00	724.00
12:30	430.00	1512.00	1448.00	1512.00	1271.00	1116.00	635.00
13:00	1722.00	1024.00	980.00	1271.00	1024.00	558.00	534.00
13:30	608.00	534.00	490.00	724.00	608.00	430.00	490.00
14:00	215.00	197.00	189.00	291.00	215.00	469.00	430.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	18-Mar-05	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05
10:00	18.62%	10.13%	13.74%	20.28%	12.56%	11.44%	9.66%
10:30	21.18%	14.36%	15.65%	34.07%	13.74%	11.02%	9.66%
11:00	20.31%	14.97%	14.36%	10.12%	17.05%	14.91%	2.65%
11:30	4.43%	17.05%	17.05%	14.31%	18.59%	17.04%	13.02%
12:00	2.43%	21.15%	21.18%	13.73%	14.34%	14.29%	8.47%
12:30	26.28%	18.59%	19.41%	13.73%	14.97%	12.55%	15.67%
13:00	12.06%	21.13%	22.08%	16.34%	15.56%	7.44%	13.02%
13:30	23.04%	31.29%	34.10%	20.28%	23.04%	15.50%	11.00%
14:00	46.27%	62.76%	65.42%	38.84%	50.32%	13.08%	10.54%

Great Bay Fish June 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	6.91	15.12	18.76	17.28	17.28	0.93	3.31
10:30	5.33	13.30	19.66	16.48	18.76	2.78	4.11
11:00	2.91	27.85	18.76	18.76	22.39	8.18	9.32
11:30	3.17	25.46	17.28	13.30	19.66	4.11	11.71
12:00	17.28	6.91	16.48	10.23	36.03	3.76	7.84
12:30	17.28	8.18	14.55	7.22	17.28	4.30	8.18
13:00	21.48	21.48	4.68	8.98	11.71	3.31	8.18
13:30	27.85	21.48	13.30	8.18	16.48	4.68	4.68
14:00	36.03	27.85	11.71	9.32	7.22	3.60	4.68

(B) Surface Irradiance (Lumens ft^{-2})

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	215.00	189.00	197.00	317.00	189.00	31.70	224.00
10:30	362.00	291.00	412.00	490.00	173.00	17.30	224.00
11:00	145.00	145.00	693.00	412.00	362.00	98.00	224.00
11:30	215.00	899.00	724.00	430.00	256.00	98.00	412.00
12:00	362.00	1116.00	724.00	331.00	824.00	173.00	291.00
12:30	1116.00	291.00	789.00	256.00	430.00	215.00	412.00
13:00	1024.00	980.00	980.00	490.00	362.00	145.00	279.00
13:30	1024.00	980.00	789.00	317.00	534.00	279.00	331.00
14:00	899.00	899.00	608.00	362.00	256.00	279.00	291.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	3.21%	8.00%	9.52%	5.45%	9.14%	2.94%	1.48%
10:30	1.47%	4.57%	4.77%	3.36%	10.84%	16.10%	1.84%
11:00	2.01%	19.21%	2.71%	4.55%	6.19%	8.35%	4.16%
11:30	1.48%	2.83%	2.39%	3.09%	7.68%	4.20%	2.84%
12:00	4.77%	0.62%	2.28%	3.09%	4.37%	2.17%	2.70%
12:30	1.55%	2.81%	1.84%	2.82%	4.02%	2.00%	1.99%
13:00	2.10%	2.19%	0.48%	1.83%	3.23%	2.28%	2.93%
13:30	2.72%	2.19%	1.69%	2.58%	3.09%	1.68%	1.41%
14:00	4.01%	3.10%	1.93%	2.57%	2.82%	1.29%	1.61%

Great Bay Fish September 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	3.60	36.00	41.11	7.84	41.11	41.11	16.47
10:30	3.60	37.59	48.83	11.70	48.83	42.93	25.44
11:00	5.33	37.59	48.83	13.29	72.11	27.82	24.42
11:30	4.88	29.07	42.93	17.26	81.76	46.79	22.37
12:00	7.84	27.82	37.59	13.29	63.37	27.82	27.82
12:30	7.84	24.42	24.42	15.10	42.93	36.00	29.07
13:00	8.97	24.42	22.37	10.22	37.59	27.82	15.10
13:30	7.21	27.82	31.68	14.54	31.68	21.46	16.47
14:00	6.90	29.07	27.82	22.37	31.68	22.37	17.26

(B) Surface Irradiance (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	49.00	69.00	60.80	37.80	69.00	152.00	173.00
10:30	60.80	189.00	103.00	72.00	128.00	256.00	197.00
11:00	112.00	317.00	256.00	112.00	279.00	224.00	224.00
11:30	112.00	490.00	412.00	133.00	534.00	279.00	189.00
12:00	173.00	534.00	490.00	98.00	558.00	224.00	245.00
12:30	112.00	693.00	534.00	90.00	693.00	103.00	197.00
13:00	112.00	608.00	490.00	98.00	724.00	133.00	215.00
13:30	117.00	469.00	412.00	152.00	635.00	145.00	145.00
14:00	112.00	362.00	378.00	165.00	469.00	173.00	117.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	7.35%	52.17%	67.61%	20.73%	59.58%	27.05%	9.52%
10:30	5.92%	19.89%	47.41%	16.25%	38.15%	16.77%	12.91%
11:00	4.76%	11.86%	19.07%	11.86%	25.85%	12.42%	10.90%
11:30	4.36%	5.93%	10.42%	12.98%	15.31%	16.77%	11.84%
12:00	4.53%	5.21%	7.67%	13.56%	11.36%	12.42%	11.36%
12:30	7.00%	3.52%	4.57%	16.78%	6.19%	34.95%	14.76%
13:00	8.01%	4.02%	4.57%	10.43%	5.19%	20.92%	7.02%
13:30	6.16%	5.93%	7.69%	9.56%	4.99%	14.80%	11.36%
14:00	6.16%	8.03%	7.36%	13.56%	6.76%	12.93%	14.75%

Great Bay Fish December 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	3.58	66.01	121.13	232.01	264.05	314.04	342.24
10:30	8.52	71.78	92.93	71.78	264.05	357.62	464.01
11:00	12.11	66.01	85.24	126.26	232.01	389.67	300.58
11:30	6.60	52.55	62.81	105.75	157.02	342.24	406.97
12:00	2.76	46.14	44.22	110.88	157.02	232.01	505.67
12:30	12.11	46.14	52.55	105.75	126.26	186.50	389.67
13:00	9.74	44.22	26.41	71.78	110.88	212.14	212.14
13:30	4.61	38.97	26.41	38.97	92.93	157.02	203.17
14:00	2.12	9.74	20.32	21.21	62.81	57.68	110.88

(B) Surface Irradiance (Lumens ft^{-2})

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	29.10	133.00	224.00	331.00	173.00	197.00	378.00
10:30	53.40	112.00	128.00	317.00	145.00	152.00	635.00
11:00	90.00	79.00	90.00	128.00	98.00	103.00	608.00
11:30	27.90	69.00	72.00	98.00	82.00	112.00	693.00
12:00	21.50	72.00	152.00	98.00	82.00	112.00	693.00
12:30	55.80	72.00	133.00	173.00	90.00	103.00	608.00
13:00	72.00	72.00	189.00	362.00	82.00	279.00	608.00
13:30	53.40	72.00	152.00	215.00	133.00	245.00	317.00
14:00	37.80	60.80	72.00	173.00	112.00	128.00	165.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	12.29%	49.63%	54.08%	70.09%	152.63%	159.41%	90.54%
10:30	15.96%	64.09%	72.60%	22.64%	182.10%	235.28%	73.07%
11:00	13.46%	83.56%	94.71%	98.64%	236.74%	378.32%	49.44%
11:30	23.66%	76.16%	87.23%	107.91%	191.49%	305.57%	58.73%
12:00	12.82%	64.09%	29.09%	113.14%	191.49%	207.15%	72.97%
12:30	21.71%	64.09%	39.51%	61.13%	140.29%	181.07%	64.09%
13:00	13.53%	61.42%	13.97%	19.83%	135.21%	76.04%	34.89%
13:30	8.64%	54.12%	17.37%	18.12%	69.87%	64.09%	64.09%
14:00	5.61%	16.02%	28.22%	12.26%	56.08%	45.06%	67.20%

Great Bay Fish March 2006

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06	21-Mar-06
10:00	57.23	44.15	46.08	50.26	35.47	87.88	77.16
10:30	87.88	50.26	50.26	52.51	84.66	87.88	96.45
11:00	59.80	57.23	52.51	57.23	31.19	84.66	87.88
11:30	50.26	65.16	65.16	65.16	57.23	77.16	87.88
12:00	44.15	84.66	73.95	68.05	40.51	84.66	77.16
12:30	52.51	87.88	84.66	73.95	46.08	84.66	77.16
13:00	77.16	84.66	77.16	77.16	46.08	77.16	77.16
13:30	50.26	65.16	84.66	77.16	38.80	68.05	68.05
14:00	59.80	96.45	73.95	65.16	50.26	57.23	57.23

(B) Surface Irradiance (Lumens ft^{-2})

Time	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06	21-Mar-06
10:00	291.00	291.00	317.00	362.00	430.00	430.00	378.00
10:30	608.00	430.00	469.00	558.00	558.00	824.00	534.00
11:00	490.00	490.00	635.00	724.00	558.00	899.00	635.00
11:30	469.00	608.00	724.00	980.00	824.00	1116.00	789.00
12:00	534.00	362.00	412.00	490.00	980.00	635.00	430.00
12:30	724.00	215.00	245.00	362.00	824.00	534.00	256.00
13:00	412.00	165.00	197.00	245.00	430.00	291.00	189.00
13:30	362.00	133.00	189.00	173.00	558.00	197.00	117.00
14:00	469.00	173.00	197.00	215.00	412.00	245.00	145.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06	21-Mar-06
10:00	19.67%	15.17%	14.54%	13.88%	8.25%	20.44%	20.41%
10:30	14.45%	11.69%	10.72%	9.41%	15.17%	10.66%	18.06%
11:00	12.20%	11.68%	8.27%	7.90%	5.59%	9.42%	13.84%
11:30	10.72%	10.72%	9.00%	6.65%	6.95%	6.91%	11.14%
12:00	8.27%	23.39%	17.95%	13.89%	4.13%	13.33%	17.94%
12:30	7.25%	40.87%	34.56%	20.43%	5.59%	15.85%	30.14%
13:00	18.73%	51.31%	39.17%	31.49%	10.72%	26.52%	40.83%
13:30	13.88%	48.99%	44.80%	44.60%	6.95%	34.54%	58.16%
14:00	12.75%	55.75%	37.54%	30.31%	12.20%	23.36%	39.47%

Dover Point Irradiance Instantaneous irradiance (Lumens ft^{-2}) measured using Onset Hobo™ light sensors. Irradiance measured at the eelgrass deep edge (A) was compared to surface irradiance (B) to calculate a percentage of surface irradiance (C) reaching the deep edge plants.

Dover Point June 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	10-Jun-04	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04
10:00	37.09	50.22	48.09	38.75	20.25	32.59	32.59
11:00	26.18	44.13	64.85	56.94	20.25	34.01	29.90
12:00	54.57	62.48	50.22	62.48	10.12	48.09	32.59
13:00	202.47	101.24	81.46	54.57	7.75	48.09	37.09
14:00	136.83	101.24	101.24	14.95	12.02	25.07	38.75

(B) Surface Irradiance (Lumens ft^{-2})

Time	10-Jun-04	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04
10:00	331.00	724.00	693.00	635.00	291.00	608.00	534.00
11:00	279.00	789.00	693.00	412.00	279.00	608.00	558.00
12:00	789.00	824.00	789.00	724.00	112.00	63.50	608.00
13:00	724.00	789.00	693.00	558.00	103.00	534.00	608.00
14:00	117.00	317.00	362.00	82.00	133.00	245.00	256.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	10-Jun-04	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04	16-Jun-04
10:00	11.21%	6.94%	6.94%	6.10%	6.96%	5.36%	6.10%
11:00	9.38%	5.59%	9.36%	13.82%	7.26%	5.59%	5.36%
12:00	6.92%	7.58%	6.37%	8.63%	9.04%	75.73%	5.36%
13:00	27.97%	12.83%	11.76%	9.78%	7.53%	9.01%	6.10%
14:00	116.95%	31.94%	27.97%	18.23%	9.04%	10.23%	15.14%

Dover Point Irradiance continued

Dover Point September 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	29.99	31.32	17.85	18.64	18.64	7.15	1.56
11:00	40.44	55.24	55.24	26.34	35.51	12.63	1.56
12:00	18.64	57.70	44.39	65.60	65.60	16.32	2.03
13:00	34.03	38.96	15.63	20.32	57.70	16.32	2.31
14:00	24.17	27.52	6.56	24.17	44.39	12.08	1.56

(B) Surface Irradiance (Lumens ft^{-2})

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	279.00	197.00	112.00	490.00	33.10	152.00	112.00
11:00	469.00	608.00	378.00	215.00	608.00	224.00	165.00
12:00	173.00	693.00	279.00	1271.00	789.00	128.00	117.00
13:00	789.00	693.00	534.00	1166.00	724.00	103.00	145.00
14:00	724.00	608.00	79.00	899.00	824.00	224.00	60.80

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	10.75%	15.90%	15.94%	3.80%	56.32%	4.70%	1.40%
11:00	8.62%	9.09%	14.61%	12.25%	5.84%	5.64%	0.95%
12:00	10.78%	8.33%	15.91%	5.16%	8.31%	12.75%	1.74%
13:00	4.31%	5.62%	2.93%	1.74%	7.97%	15.85%	1.60%
14:00	3.34%	4.53%	8.30%	2.69%	5.39%	5.39%	2.57%

Dover Point Irradiance continued

Dover Point December 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	9.05	33.32	31.95	6.39	6.96	13.40	8.24
10:30	19.81	53.71	53.71	17.41	1.98	15.23	15.23
11:00	22.56	79.01	49.24	11.22	4.15	9.05	18.89
11:30	12.83	82.45	93.90	15.23	9.05	21.64	19.81
12:00	19.81	37.90	112.22	21.64	14.66	33.32	6.11
12:30	11.22	63.90	25.65	33.32	11.79	36.30	14.66
13:00	7.27	43.28	93.90	22.56	14.66	31.95	21.64
13:30	9.39	31.95	63.90	28.05	11.79	37.90	21.64
14:00	5.37	15.23	25.65	11.79	10.31	12.83	22.56

(B) Surface Irradiance (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	279.00	152.00	117.00	378.00	245.00	317.00	224.00
10:30	331.00	145.00	98.00	430.00	279.00	430.00	279.00
11:00	317.00	117.00	53.40	245.00	279.00	133.00	245.00
11:30	430.00	112.00	79.00	412.00	317.00	103.00	215.00
12:00	245.00	98.00	224.00	378.00	412.00	82.00	165.00
12:30	173.00	90.00	90.00	362.00	215.00	69.00	189.00
13:00	103.00	82.00	145.00	215.00	245.00	63.50	224.00
13:30	103.00	82.00	82.00	279.00	152.00	63.50	224.00
14:00	128.00	90.00	79.00	112.00	112.00	69.00	197.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	3.24%	21.92%	27.31%	1.69%	2.84%	4.23%	3.68%
10:30	5.98%	37.04%	54.80%	4.05%	0.71%	3.54%	5.46%
11:00	7.12%	67.53%	92.21%	4.58%	1.49%	6.80%	7.71%
11:30	2.98%	73.61%	118.86%	3.70%	2.85%	21.01%	9.21%
12:00	8.09%	38.68%	50.10%	5.73%	3.56%	40.64%	3.71%
12:30	6.49%	71.00%	28.50%	9.21%	5.49%	52.61%	7.76%
13:00	7.06%	52.79%	64.76%	10.49%	5.98%	50.31%	9.66%
13:30	9.12%	38.96%	77.92%	10.06%	7.76%	59.69%	9.66%
14:00	4.20%	16.92%	32.47%	10.53%	9.20%	18.59%	11.45%

Dover Point Irradiance continued

Dover Point March 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	259.28	295.27	270.92	227.53	118.53	83.61	140.75
10:30	307.97	436.02	350.30	270.92	140.75	95.25	335.48
11:00	643.45	383.10	335.48	400.04	140.75	76.20	383.10
11:30	1037.13	455.07	383.10	436.02	153.45	103.71	45.51
12:00	1181.06	518.57	400.04	400.04	227.53	153.45	86.78
12:30	766.21	672.02	496.34	295.27	295.27	153.45	67.20
13:00	565.13	590.53	436.02	295.27	153.45	123.82	153.45
13:30	643.45	455.07	455.07	307.97	123.82	76.20	200.02
14:00	835.00	383.10	350.30	259.28	118.53	64.34	103.71

(B) Surface Irradiance (Lumens ft^{-2})

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	1878.00	1722.00	724.00	1722.00	608.00	534.00	534.00
10:30	1722.00	1512.00	635.00	1722.00	789.00	608.00	789.00
11:00	1878.00	1722.00	2138.00	1649.00	635.00	3756.00	469.00
11:30	1649.00	1649.00	1512.00	1512.00	635.00	534.00	693.00
12:00	1448.00	1327.00	1512.00	1448.00	899.00	724.00	331.00
12:30	1512.00	1448.00	1512.00	1271.00	1116.00	635.00	256.00
13:00	1024.00	980.00	1271.00	1024.00	558.00	534.00	279.00
13:30	534.00	490.00	724.00	608.00	430.00	490.00	1116.00
14:00	197.00	189.00	291.00	215.00	469.00	430.00	362.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	13.81%	17.15%	37.42%	13.21%	19.50%	15.66%	26.36%
10:30	17.88%	28.84%	55.16%	15.73%	17.84%	15.67%	42.52%
11:00	34.26%	22.25%	15.69%	24.26%	22.17%	2.03%	81.69%
11:30	62.89%	27.60%	25.34%	28.84%	24.17%	19.42%	6.57%
12:00	81.57%	39.08%	26.46%	27.63%	25.31%	21.20%	26.22%
12:30	50.68%	46.41%	32.83%	23.23%	26.46%	24.17%	26.25%
13:00	55.19%	60.26%	34.31%	28.83%	27.50%	23.19%	55.00%
13:30	120.50%	92.87%	62.85%	50.65%	28.80%	15.55%	17.92%
14:00	423.86%	202.70%	120.38%	120.60%	25.27%	14.96%	28.65%

Dover Point Irradiance continued

Dover Point June 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	23.90	27.18	32.37	18.33	19.22	0.52	3.53
10:30	19.22	80.29	41.85	16.82	27.18	4.78	3.24
11:00	16.82	52.09	45.77	45.77	36.79	13.02	5.93
11:30	24.91	91.04	52.09	28.32	41.85	7.06	7.06
12:00	41.85	99.89	54.37	30.98	59.30	4.19	5.44
12:30	54.37	36.79	61.96	27.18	52.09	7.69	11.38
13:00	45.77	21.87	40.08	30.98	76.88	9.10	14.79
13:30	36.79	52.09	41.85	45.77	45.77	9.10	13.02
14:00	30.98	14.79	32.37	24.91	32.37	13.02	13.02

(B) Surface Irradiance (Lumens ft^{-2})

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	215.00	189.00	197.00	317.00	189.00	31.70	224.00
10:30	362.00	291.00	412.00	490.00	173.00	17.30	224.00
11:00	145.00	145.00	693.00	412.00	362.00	98.00	224.00
11:30	215.00	899.00	724.00	430.00	256.00	98.00	412.00
12:00	362.00	1116.00	724.00	331.00	824.00	173.00	291.00
12:30	1116.00	291.00	789.00	256.00	430.00	215.00	412.00
13:00	1024.00	980.00	980.00	490.00	362.00	145.00	279.00
13:30	1024.00	980.00	789.00	317.00	534.00	279.00	331.00
14:00	899.00	899.00	608.00	362.00	256.00	279.00	291.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	11.11%	14.38%	16.43%	5.78%	10.17%	1.64%	1.57%
10:30	5.31%	27.59%	10.16%	3.43%	15.71%	27.63%	1.45%
11:00	11.60%	35.93%	6.60%	11.11%	10.16%	13.29%	2.65%
11:30	11.59%	10.13%	7.20%	6.59%	16.35%	7.20%	1.71%
12:00	11.56%	8.95%	7.51%	9.36%	7.20%	2.42%	1.87%
12:30	4.87%	12.64%	7.85%	10.62%	12.11%	3.58%	2.76%
13:00	4.47%	2.23%	4.09%	6.32%	21.24%	6.28%	5.30%
13:30	3.59%	5.32%	5.30%	14.44%	8.57%	3.26%	3.93%
14:00	3.45%	1.65%	5.32%	6.88%	12.64%	4.67%	4.48%

Dover Point September 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	6.19	87.18	90.97	5.93	59.26	40.05	3.68
10:30	9.98	90.97	168.05	10.36	90.97	21.86	5.93
11:00	11.37	147.83	113.72	13.01	80.23	13.01	5.21
11:30	9.98	87.18	161.73	23.88	168.05	30.96	5.43
12:00	10.36	67.47	87.18	16.80	76.82	19.21	6.75
12:30	7.68	54.33	99.82	28.30	87.18	13.01	7.68
13:00	6.75	54.33	45.74	20.85	67.47	16.17	4.78
13:30	4.57	40.05	52.06	20.85	52.06	19.21	4.57
14:00	4.57	30.96	24.89	30.96	36.77	14.78	4.18

(B) Surface Irradiance (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	49.00	69.00	60.80	37.80	69.00	152.00	173.00
10:30	60.80	189.00	103.00	72.00	128.00	256.00	197.00
11:00	112.00	317.00	256.00	112.00	279.00	224.00	224.00
11:30	112.00	490.00	412.00	133.00	534.00	279.00	189.00
12:00	173.00	534.00	490.00	98.00	558.00	224.00	245.00
12:30	112.00	693.00	534.00	90.00	693.00	103.00	197.00
13:00	112.00	608.00	490.00	98.00	724.00	133.00	215.00
13:30	117.00	469.00	412.00	152.00	635.00	145.00	145.00
14:00	112.00	362.00	378.00	165.00	469.00	173.00	117.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	12.64%	126.35%	149.63%	15.68%	85.88%	26.35%	2.13%
10:30	16.42%	48.13%	163.15%	14.39%	71.07%	8.54%	3.01%
11:00	10.15%	46.63%	44.42%	11.62%	28.76%	5.81%	2.32%
11:30	8.91%	17.79%	39.25%	17.96%	31.47%	11.10%	2.87%
12:00	5.99%	12.64%	17.79%	17.15%	13.77%	8.57%	2.75%
12:30	6.86%	7.84%	18.69%	31.45%	12.58%	12.64%	3.90%
13:00	6.02%	8.94%	9.33%	21.27%	9.32%	12.16%	2.22%
13:30	3.91%	8.54%	12.64%	13.72%	8.20%	13.24%	3.15%
14:00	4.08%	8.55%	6.58%	18.76%	7.84%	8.55%	3.57%

Dover Point December 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	1.87	21.31	27.69	44.63	34.44	57.85	39.20
10:30	3.92	21.31	27.69	30.16	44.63	60.42	50.81
11:00	3.92	20.46	26.55	34.44	46.62	78.02	39.20
11:30	2.33	17.98	24.36	31.49	39.20	98.00	60.42
12:00	0.78	17.98	20.46	34.44	35.97	78.02	75.17
12:30	2.44	14.46	16.46	18.74	30.16	57.85	57.85
13:00	6.04	13.80	12.18	7.80	26.55	60.42	44.63
13:30	4.09	12.18	9.32	9.32	14.46	35.97	46.62
14:00	2.44	11.13	9.32	8.56	15.70	15.70	31.49

(B) Surface Irradiance (Lumens ft^{-2})

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	29.10	133.00	224.00	331.00	173.00	197.00	378.00
10:30	53.40	112.00	128.00	317.00	145.00	152.00	635.00
11:00	90.00	79.00	90.00	128.00	98.00	103.00	608.00
11:30	27.90	69.00	72.00	98.00	82.00	112.00	693.00
12:00	21.50	72.00	152.00	98.00	82.00	112.00	693.00
12:30	55.80	72.00	133.00	173.00	90.00	103.00	608.00
13:00	72.00	72.00	189.00	362.00	82.00	279.00	608.00
13:30	53.40	72.00	152.00	215.00	133.00	245.00	317.00
14:00	37.80	60.80	72.00	173.00	112.00	128.00	165.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	6.44%	16.03%	12.36%	13.48%	19.91%	29.37%	10.37%
10:30	7.34%	19.03%	21.63%	9.52%	30.78%	39.75%	8.00%
11:00	4.36%	25.90%	29.50%	26.91%	47.58%	75.75%	6.45%
11:30	8.36%	26.06%	33.83%	32.14%	47.81%	87.50%	8.72%
12:00	3.63%	24.98%	13.46%	35.15%	43.86%	69.66%	10.85%
12:30	4.37%	20.09%	12.38%	10.84%	33.51%	56.17%	9.52%
13:00	8.39%	19.16%	6.44%	2.16%	32.37%	21.66%	7.34%
13:30	7.66%	16.92%	6.13%	4.34%	10.87%	14.68%	14.71%
14:00	6.44%	18.31%	12.95%	4.95%	14.02%	12.27%	19.09%

Dover Point Irradiance continued

Dover Point March 2006

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	71.49	81.40	105.18	170.73	300.31	373.48	443.60
10:30	42.53	125.00	120.43	195.12	231.71	390.25	443.60
11:00	48.32	109.76	109.76	149.39	178.35	120.43	300.31
11:30	32.77	48.32	105.18	65.55	157.01	85.06	125.00
12:00	81.40	42.53	96.80	120.43	137.20	157.01	92.68
12:30	178.35	71.49	96.80	92.68	120.43	137.20	109.76
13:00	195.12	50.46	105.18	81.40	81.40	48.32	96.80
13:30	137.20	62.81	96.80	62.81	57.62	42.53	71.49
14:00	120.43	65.55	81.40	55.18	55.18	42.53	48.32

(B) Surface Irradiance (Lumens ft^{-2})

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	469.00	291.00	291.00	317.00	362.00	430.00	430.00
10:30	430.00	608.00	430.00	469.00	558.00	558.00	824.00
11:00	145.00	490.00	490.00	635.00	724.00	558.00	899.00
11:30	430.00	469.00	608.00	724.00	980.00	824.00	1116.00
12:00	534.00	534.00	362.00	412.00	490.00	980.00	635.00
12:30	224.00	724.00	215.00	245.00	362.00	824.00	534.00
13:00	197.00	412.00	165.00	197.00	245.00	430.00	291.00
13:30	98.00	362.00	133.00	189.00	173.00	558.00	197.00
14:00	103.00	469.00	173.00	197.00	215.00	412.00	245.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	15.24%	27.97%	36.15%	53.86%	82.96%	86.86%	103.16%
10:30	9.89%	20.56%	28.01%	41.60%	41.52%	69.94%	53.84%
11:00	33.33%	22.40%	22.40%	23.53%	24.63%	21.58%	33.40%
11:30	7.62%	10.30%	17.30%	9.05%	16.02%	10.32%	11.20%
12:00	15.24%	7.96%	26.74%	29.23%	28.00%	16.02%	14.60%
12:30	79.62%	9.87%	45.02%	37.83%	33.27%	16.65%	20.55%
13:00	99.05%	12.25%	63.75%	41.32%	33.23%	11.24%	33.26%
13:30	140.00%	17.35%	72.78%	33.23%	33.31%	7.62%	36.29%
14:00	116.92%	13.98%	47.05%	28.01%	25.67%	10.32%	19.72%

Red Nun Irradiance Instantaneous irradiance (Lumens ft^{-2}) measured using Onset Hobo™ light sensors. Irradiance measured at the eelgrass deep edge (A) was compared to surface irradiance (B) to calculate a percentage of surface irradiance (C) reaching the deep edge plants.

Red Nun June 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	9-Jun-04	10-Jun-04	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04
10:00	56.01	20.66	37.86	45.14	33.32	19.70	45.14
11:00	123.00	26.75	58.52	45.14	58.52	13.38	39.53
12:00	267.50	107.48	94.34	63.77	45.14	6.66	8.60
13:00	197.04	225.70	117.03	107.48	49.20	4.51	43.23
14:00	94.34	123.00	133.75	133.75	20.66	6.66	8.60

(B) Surface Irradiance (Lumens ft^{-2})

Time	9-Jun-04	10-Jun-04	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04
10:00	378.00	331.00	724.00	693.00	635.00	291.00	608.00
11:00	412.00	279.00	789.00	693.00	412.00	279.00	608.00
12:00	412.00	789.00	824.00	789.00	724.00	112.00	63.50
13:00	362.00	724.00	789.00	693.00	558.00	103.00	534.00
14:00	189.00	117.00	317.00	362.00	82.00	133.00	245.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	9-Jun-04	10-Jun-04	11-Jun-04	12-Jun-04	13-Jun-04	14-Jun-04	15-Jun-04
10:00	14.82%	6.24%	5.23%	6.51%	5.25%	6.77%	7.42%
11:00	29.86%	9.59%	7.42%	6.51%	14.20%	4.79%	6.50%
12:00	64.93%	13.62%	11.45%	8.08%	6.23%	5.95%	13.54%
13:00	54.43%	31.17%	14.83%	15.51%	8.82%	4.38%	8.10%
14:00	49.92%	105.13%	42.19%	36.95%	25.19%	5.01%	3.51%

Red Nun Irradiance continued

Red Nun September 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	88.79	8.88	22.14	10.12	22.14	9.22	8.88
11:00	77.55	92.16	77.55	14.39	37.20	24.16	16.30
12:00	40.69	71.37	80.92	77.55	60.02	27.54	11.58
13:00	35.63	55.07	55.07	80.92	71.37	19.44	14.95
14:00	24.16	35.63	46.30	52.71	48.33	48.33	8.88

(B) Surface Irradiance (Lumens ft^{-2})

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	279.00	197.00	112.00	490.00	33.10	152.00	112.00
11:00	469.00	608.00	378.00	215.00	608.00	224.00	165.00
12:00	173.00	693.00	279.00	1271.00	789.00	128.00	117.00
13:00	789.00	693.00	534.00	1166.00	724.00	103.00	145.00
14:00	724.00	608.00	79.00	899.00	824.00	224.00	60.80

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	2-Sep-04	3-Sep-04	4-Sep-04	5-Sep-04	6-Sep-04	7-Sep-04	8-Sep-04
10:00	31.82%	4.51%	19.77%	2.06%	66.89%	6.06%	7.93%
11:00	16.53%	15.16%	20.52%	6.69%	6.12%	10.79%	9.88%
12:00	23.52%	10.30%	29.00%	6.10%	7.61%	21.51%	9.89%
13:00	4.52%	7.95%	10.31%	6.94%	9.86%	18.88%	10.31%
14:00	3.34%	5.86%	58.61%	5.86%	5.87%	21.57%	14.60%

Red Nun December 2004

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	16.79	19.99	14.76	4.96	2.00	2.48	2.48
10:30	24.75	25.84	21.78	7.03	2.48	3.36	5.62
11:00	28.26	28.26	8.74	6.17	2.83	5.39	3.83
11:30	32.17	29.51	8.04	12.88	2.83	6.40	5.39
12:00	21.78	25.84	11.32	14.76	3.83	8.04	7.65
12:30	21.78	22.72	6.17	19.13	2.58	10.38	6.40
13:00	16.79	19.99	21.78	17.49	4.75	12.88	8.04
13:30	8.04	14.76	19.99	21.78	3.83	11.32	8.74
14:00	4.75	10.38	11.87	9.14	2.95	14.76	8.74

(B) Surface Irradiance (Lumens ft^{-2})

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	279.00	152.00	117.00	378.00	245.00	317.00	224.00
10:30	331.00	145.00	98.00	430.00	279.00	430.00	279.00
11:00	317.00	117.00	53.40	245.00	279.00	133.00	245.00
11:30	430.00	112.00	79.00	412.00	317.00	103.00	215.00
12:00	245.00	98.00	224.00	378.00	412.00	82.00	165.00
12:30	173.00	90.00	90.00	362.00	215.00	69.00	189.00
13:00	103.00	82.00	145.00	215.00	245.00	63.50	224.00
13:30	103.00	82.00	82.00	279.00	152.00	63.50	224.00
14:00	128.00	90.00	79.00	112.00	112.00	69.00	197.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	3-Dec-04	4-Dec-04	5-Dec-04	6-Dec-04	7-Dec-04	8-Dec-04	9-Dec-04
10:00	6.02%	13.15%	12.61%	1.31%	0.82%	0.78%	1.10%
10:30	7.48%	17.82%	22.23%	1.63%	0.89%	0.78%	2.01%
11:00	8.92%	24.16%	16.38%	2.52%	1.01%	4.05%	1.56%
11:30	7.48%	26.35%	10.18%	3.13%	0.89%	6.22%	2.51%
12:00	8.89%	26.37%	5.05%	3.90%	0.93%	9.81%	4.64%
12:30	12.59%	25.25%	6.85%	5.28%	1.20%	15.05%	3.39%
13:00	16.30%	24.38%	15.02%	8.13%	1.94%	20.29%	3.59%
13:30	7.81%	18.00%	24.38%	7.81%	2.52%	17.83%	3.90%
14:00	3.71%	11.54%	15.02%	8.16%	2.64%	21.39%	4.44%

Red Nun March 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	148.46	87.90	42.00	67.39	42.00	36.92	80.09
10:30	192.41	100.60	77.16	70.32	42.00	40.24	62.02
11:00	218.78	125.02	70.32	80.09	42.00	45.81	21.00
11:30	209.99	168.97	95.72	70.32	40.24	30.96	21.00
12:00	218.78	168.97	114.27	77.16	45.81	27.25	16.90
12:30	419.98	168.97	109.39	87.90	52.16	35.36	32.33
13:00	309.61	192.41	129.90	95.72	45.81	32.33	23.93
13:30	209.99	184.60	141.62	77.16	40.24	21.88	25.00
14:00	192.41	184.60	109.39	77.16	36.92	18.46	40.24

(B) Surface Irradiance (Lumens ft^{-2})

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	1878.00	1722.00	724.00	1722.00	608.00	534.00	534.00
10:30	1722.00	1512.00	635.00	1722.00	789.00	608.00	789.00
11:00	1878.00	1722.00	2138.00	1649.00	635.00	3756.00	469.00
11:30	1649.00	1649.00	1512.00	1512.00	635.00	534.00	693.00
12:00	1448.00	1327.00	1512.00	1448.00	899.00	724.00	331.00
12:30	1512.00	1448.00	1512.00	1271.00	1116.00	635.00	256.00
13:00	1024.00	980.00	1271.00	1024.00	558.00	534.00	279.00
13:30	534.00	490.00	724.00	608.00	430.00	490.00	1116.00
14:00	197.00	189.00	291.00	215.00	469.00	430.00	362.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	19-Mar-05	20-Mar-05	21-Mar-05	22-Mar-05	23-Mar-05	24-Mar-05	25-Mar-05
10:00	7.91%	5.10%	5.80%	3.91%	6.91%	6.91%	15.00%
10:30	11.17%	6.65%	12.15%	4.08%	5.32%	6.62%	7.86%
11:00	11.65%	7.26%	3.29%	4.86%	6.61%	1.22%	4.48%
11:30	12.73%	10.25%	6.33%	4.65%	6.34%	5.80%	3.03%
12:00	15.11%	12.73%	7.56%	5.33%	5.10%	3.76%	5.10%
12:30	27.78%	11.67%	7.23%	6.92%	4.67%	5.57%	12.63%
13:00	30.24%	19.63%	10.22%	9.35%	8.21%	6.05%	8.58%
13:30	39.32%	37.67%	19.56%	12.69%	9.36%	4.46%	2.24%
14:00	97.67%	97.67%	37.59%	35.89%	7.87%	4.29%	11.12%

Red Nun Irradiance continued

Red Nun June 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	60.14	50.56	74.62	26.39	26.39	1.37	3.57
10:30	35.71	84.68	120.28	52.77	46.39	8.84	2.75
11:00	40.62	100.64	186.55	50.56	44.43	12.64	4.64
11:30	38.91	186.55	186.55	60.14	68.48	8.84	4.44
12:00	84.68	60.14	212.32	68.48	163.23	6.01	8.84
12:30	100.64	31.42	177.96	68.48	177.96	13.75	14.36
13:00	74.62	96.96	120.28	65.54	77.93	23.20	21.23
13:30	57.56	84.68	77.93	68.48	143.59	26.39	18.65
14:00	34.24	77.93	65.54	34.24	57.56	26.39	23.20

(B) Surface Irradiance (Lumens ft^{-2})

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	215.00	189.00	197.00	317.00	189.00	31.70	224.00
10:30	362.00	291.00	412.00	490.00	173.00	17.30	224.00
11:00	145.00	145.00	693.00	412.00	362.00	98.00	224.00
11:30	215.00	899.00	724.00	430.00	256.00	98.00	412.00
12:00	362.00	1116.00	724.00	331.00	824.00	173.00	291.00
12:30	1116.00	291.00	789.00	256.00	430.00	215.00	412.00
13:00	1024.00	980.00	980.00	490.00	362.00	145.00	279.00
13:30	1024.00	980.00	789.00	317.00	534.00	279.00	331.00
14:00	899.00	899.00	608.00	362.00	256.00	279.00	291.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	9-Jun-05	10-Jun-05	11-Jun-05	12-Jun-05	13-Jun-05	14-Jun-05	15-Jun-05
10:00	27.97%	26.75%	37.88%	8.32%	13.96%	4.34%	1.59%
10:30	9.87%	29.10%	29.19%	10.77%	26.82%	51.08%	1.23%
11:00	28.02%	69.41%	26.92%	12.27%	12.27%	12.90%	2.07%
11:30	18.10%	20.75%	25.77%	13.99%	26.75%	9.02%	1.08%
12:00	23.39%	5.39%	29.33%	20.69%	19.81%	3.48%	3.04%
12:30	9.02%	10.80%	22.55%	26.75%	41.39%	6.39%	3.49%
13:00	7.29%	9.89%	12.27%	13.38%	21.53%	16.00%	7.61%
13:30	5.62%	8.64%	9.88%	21.60%	26.89%	9.46%	5.64%
14:00	3.81%	8.67%	10.78%	9.46%	22.48%	9.46%	7.97%

Red Nun Irradiance continued

Red Nun September 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	8.72	103.61	32.35	13.01	35.25	47.76	12.38
10:30	21.86	168.05	123.82	20.85	52.06	41.82	16.80
11:00	21.86	70.50	80.23	28.30	47.76	30.96	19.21
11:30	16.80	61.91	70.50	40.05	61.91	45.74	21.86
12:00	13.01	80.23	45.74	36.77	87.18	32.35	30.96
12:30	16.17	70.50	87.18	52.06	90.97	76.82	45.74
13:00	11.37	67.47	54.33	45.74	99.82	67.47	41.82
13:30	7.68	54.33	61.91	35.25	99.82	41.82	41.82
14:00	9.10	47.76	61.91	36.77	80.23	54.33	41.82

(B) Surface Irradiance (Lumens ft^{-2})

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	49.00	69.00	60.80	37.80	69.00	152.00	173.00
10:30	60.80	189.00	103.00	72.00	128.00	256.00	197.00
11:00	112.00	317.00	256.00	112.00	279.00	224.00	224.00
11:30	112.00	490.00	412.00	133.00	534.00	279.00	189.00
12:00	173.00	534.00	490.00	98.00	558.00	224.00	245.00
12:30	112.00	693.00	534.00	90.00	693.00	103.00	197.00
13:00	112.00	608.00	490.00	98.00	724.00	133.00	215.00
13:30	117.00	469.00	412.00	152.00	635.00	145.00	145.00
14:00	112.00	362.00	378.00	165.00	469.00	173.00	117.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	20-Sep-05	21-Sep-05	22-Sep-05	23-Sep-05	24-Sep-05	25-Sep-05	26-Sep-05
10:00	17.79%	150.16%	53.20%	34.43%	51.09%	31.42%	7.16%
10:30	35.95%	88.91%	120.22%	28.96%	40.67%	16.34%	8.53%
11:00	19.52%	22.24%	31.34%	25.27%	17.12%	13.82%	8.57%
11:30	15.00%	12.64%	17.11%	30.12%	11.59%	16.39%	11.57%
12:00	7.52%	15.02%	9.33%	37.52%	15.62%	14.44%	12.64%
12:30	14.44%	10.17%	16.33%	57.84%	13.13%	74.58%	23.22%
13:00	10.15%	11.10%	11.09%	46.67%	13.79%	50.73%	19.45%
13:30	6.57%	11.58%	15.03%	23.19%	15.72%	28.84%	28.84%
14:00	8.12%	13.19%	16.38%	22.28%	17.11%	31.40%	35.75%

Red Nun Irradiance continued

Red Nun December 2005

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	3.28	26.38	26.38	65.28	38.98	55.12	44.42
10:30	4.44	23.21	48.41	38.98	32.82	32.82	62.56
11:00	4.44	17.86	42.52	44.42	3.00	8.16	48.41
11:30	2.53	13.78	30.01	48.41	30.01	32.82	88.85
12:00	1.50	14.96	30.01	28.74	48.41	55.12	74.34
12:30	3.28	12.06	17.13	17.86	38.98	48.41	74.34
13:00	3.43	3.43	11.60	19.49	32.82	34.27	62.56
13:30	1.79	9.34	9.34	6.26	23.21	23.21	44.42
14:00	0.72	5.51	8.16	4.84	13.15	15.68	28.74

(B) Surface Irradiance (Lumens ft^{-2})

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	29.10	133.00	224.00	331.00	173.00	197.00	378.00
10:30	53.40	112.00	128.00	317.00	145.00	152.00	635.00
11:00	90.00	79.00	90.00	128.00	98.00	103.00	608.00
11:30	27.90	69.00	72.00	98.00	82.00	112.00	693.00
12:00	21.50	72.00	152.00	98.00	82.00	112.00	693.00
12:30	55.80	72.00	133.00	173.00	90.00	103.00	608.00
13:00	72.00	72.00	189.00	362.00	82.00	279.00	608.00
13:30	53.40	72.00	152.00	215.00	133.00	245.00	317.00
14:00	37.80	60.80	72.00	173.00	112.00	128.00	165.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	16-Dec-05	17-Dec-05	18-Dec-05	19-Dec-05	20-Dec-05	21-Dec-05	22-Dec-05
10:00	11.28%	19.84%	11.78%	19.72%	22.53%	27.98%	11.75%
10:30	8.32%	20.72%	37.82%	12.30%	22.63%	21.59%	9.85%
11:00	4.94%	22.61%	47.24%	34.71%	3.06%	7.92%	7.96%
11:30	9.07%	19.97%	41.68%	49.40%	36.60%	29.30%	12.82%
12:00	6.96%	20.78%	19.74%	29.33%	59.04%	49.22%	10.73%
12:30	5.88%	16.75%	12.88%	10.32%	43.32%	47.00%	12.23%
13:00	4.76%	4.76%	6.14%	5.38%	40.02%	12.28%	10.29%
13:30	3.34%	12.97%	6.14%	2.91%	17.45%	9.47%	14.01%
14:00	1.89%	9.07%	11.33%	2.80%	11.74%	12.25%	17.42%

Red Nun Irradiance continued

Red Nun March 2006

(A) Irradiance at Eelgrass Deep Edge (Lumens ft^{-2})

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	58.45	39.73	36.43	112.66	69.46	207.54	280.39
10:30	53.79	34.90	36.43	94.88	146.55	268.53	146.55
11:00	51.50	24.65	39.73	66.92	139.77	76.24	349.01
11:30	26.85	16.01	21.69	76.24	122.83	160.10	47.27
12:00	39.73	20.75	30.67	58.45	108.43	83.02	166.88
12:30	51.50	28.04	30.67	47.27	87.25	60.99	128.76
13:00	39.73	18.98	36.43	9.91	58.45	51.50	112.66
13:30	58.45	24.65	32.02	13.98	41.51	51.50	94.88
14:00	51.50	4.73	28.04	32.02	36.43	36.43	76.24

(B) Surface Irradiance (Lumens ft^{-2})

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	469.00	291.00	291.00	317.00	362.00	430.00	430.00
10:30	430.00	608.00	430.00	469.00	558.00	558.00	824.00
11:00	145.00	490.00	490.00	635.00	724.00	558.00	899.00
11:30	430.00	469.00	608.00	724.00	980.00	824.00	1116.00
12:00	534.00	534.00	362.00	412.00	490.00	980.00	635.00
12:30	224.00	724.00	215.00	245.00	362.00	824.00	534.00
13:00	197.00	412.00	165.00	197.00	245.00	430.00	291.00
13:30	98.00	362.00	133.00	189.00	173.00	558.00	197.00
14:00	103.00	469.00	173.00	197.00	215.00	412.00	245.00

(C) Percent Surface Irradiance at Eelgrass Deep Edge (% SI)

Time	14-Mar-06	15-Mar-06	16-Mar-06	17-Mar-06	18-Mar-06	19-Mar-06	20-Mar-06
10:00	12.46%	13.65%	12.52%	35.54%	19.19%	48.27%	65.21%
10:30	12.51%	5.74%	8.47%	20.23%	26.26%	48.12%	17.78%
11:00	35.52%	5.03%	8.11%	10.54%	19.31%	13.66%	38.82%
11:30	6.24%	3.41%	3.57%	10.53%	12.53%	19.43%	4.24%
12:00	7.44%	3.89%	8.47%	14.19%	22.13%	8.47%	26.28%
12:30	22.99%	3.87%	14.26%	19.29%	24.10%	7.40%	24.11%
13:00	20.17%	4.61%	22.08%	5.03%	23.86%	11.98%	38.72%
13:30	59.64%	6.81%	24.08%	7.40%	23.99%	9.23%	48.16%
14:00	50.00%	1.01%	16.21%	16.25%	16.94%	8.84%	31.12%