BOSTON UNIVERSITY

GRADUATE SCHOOL

Dissertation

# DISTRIBUTION, PRODUCTION, AND HISTORICAL CHANGES IN ABUNDANCE OF EELGRASS (*ZOSTERA MARINA* L.) IN SOUTHEASTERN MASSACHUSETTS

by

JOSEPH EDWARD COSTA

B.A., University of California, Berkeley, 1980

Submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

1988

Approved by

First Reader ______________________________
Ivan Valiela, Ph.D.
Professor of Biology
Boston University

Second Reader ______________________________
Marshal Pregnall, Ph.D.
Assistant Professor of Biology
Vassar College

Third Reader ______________________________
Anne Giblin, Ph.D.
Assistant Scientist
Ecosystems Center, Woods Hole

## Acknowledgements

Various parts of my thesis work were funded by the following organizations and agencies: The Kathryn Lloyd Center for Environmental Studies, the NOAA National Sea Grant College Program, Dept. of Commerce, (Grant No. NA84AA-D-00033, Woods Hole Oceanographic Institution, Proj. No. R/B-68), New England Interstate Water Pollution Control Commission (as part of a study of Buzzards Bay by the Environmental Protection Agency), the Boston University and National chapters of Sigma Xi, and the BUMP Alumni.

I am indebted to numerous people. The late Tony Swain, showed me the importance of enthusiasm and critical thinking in doing science. I owe special thanks Judy Capuzzo, who not only let me use the raceways at ESL, but provided pivotal support and guidance during the early stages of my graduate career. Alan Hankin and the Lloyd Center gave both financial support, and the invaluable use of their boat and facilities. Phil Newmark, Helen Woodward, Stuart Cromarty, and many other field assistants and volunteers too numerous to mention, helped with the field sampling and laboratory processing. I have had many wonderful discussions with Ken Foreman, Bill Dennison, Bob Buchsbaum, John Wilson, Marshal Pregnall, Rainer Voigt, Gary Banta, Don Bryant, Rod Fujita, and Joe Ackerman on topics ranging from eelgrass to computers and everything in-between. Alan Poole and Sid Tamm kindly let me use their boats. Thanks to Anne Giblin, for doing sulfur analyses on several sediment cores, and to Brian Howes and John Teal for use of their GC. I want to thank my advisor, Ivan Valiela, for use of his laboratory facilities and many suggestions, as well as my other committee members, (Marshal Pregnall, Anne Giblin, Judy Capuzzo, and Gillian Cooper-Driver) for their valuable advice, proof reading, and moral support.

My dear and loving wife Maureen gave me the strength and encouragement for the final push. She also did a wonderful job putting together the many pages of graphics and references. I dedicate this thesis to my mother, Rose Costa, whose strong character and ideals made the person I am today.

EELGRASS (*ZOSTERA MARINA* L.) IN BUZZARDS BAY:

DISTRIBUTION, PRODUCTION, AND HISTORICAL CHANGES IN ABUNDANCE

(Order No. )

Joseph Edward Costa

Boston University, Graduate School, 1988

Major Professor: Ivan Valiela, Professor of Biology

Abstract

The past and present-day distribution of eelgrass (*Zostera marina* L.) was documented using aerial photographs, field surveys, nautical charts, sediment cores, and first-hand accounts. Eelgrass growth correlates with local temperature and insolation, and annual production is ≈350 g C $m^{-2}$ $yr^{-1}$. In Buzzards Bay, eelgrass beds cover 41 $km^2$ of substrate and account for 12% of primary production; in shallow bays, eelgrass equals 40% of production.

Prior to the "wasting disease" of 1931-32, eelgrass populations equaled or exceeded present-day abundance. Six to 10 years after the disease, eelgrass covered less than 10% of the present-day habitat area. The process of recolonization was similar in many areas: new beds initially appeared on bare substrates, beds expanded, new beds appeared, and some beds were removed by disturbance. A computer simulation modeled these events, and showed that rapid recolonization of eelgrass

populations is highly dependant on new bed recruitment, which in nature depends on seed dispersal. High disturbance rates slow eelgrass recolonization and lower peak cover.

Local changes in eelgrass abundance are driven by anthropogenic and natural disturbances which are superimposed on the regional pattern of catastrophic decline and gradual recovery. Hurricanes, ice scour, and freezing periodically destroyed eelgrass beds in some areas. Eelgrass populations in poorly flushed, developed bays, with declining water quality, never recovered from the wasting disease or showed new declines in recent years.

The distribution of eelgrass is light limited, and eelgrass beds may disappear in enriched areas because of increases in algal epiphytes and phytoplankton. To identify what levels of nutrient loading cause these changes, concentrations and inputs of dissolved inorganic nitrogen (DIN) in Buttermilk Bay were measured. Periphyton on eelgrass leaves and plastic screen strips on floats correlated well to mean DIN. Experimental floats released nutrients and demonstrated that small increases in DIN significantly increase periphyton abundance. The depth of eelgrass growth in Buttermilk Bay decreased by 9 cm for every 1 µM increase in DIN. Periphyton abundance is more important than phytoplankton concentrations in limiting eelgrass growth in Buttermilk Bay, because water in this bay has a short residence time, and phytoplankton gradients are less prominent.

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# Overview

## Introduction

Eelgrass (*Zostera marina* L.) is a subtidal marine angiosperm common in temperate waters in the Northern Hemisphere. It is one of more than 60 species of seagrasses that grow in the worlds oceans. In Buzzards Bay and Cape Cod, eelgrass beds are abundant, often forming extensive underwater meadows. The areal cover of eelgrass habitat is twice that of salt marshes in this region, but because these beds are subtidal, they are unnoticed, except by boaters, shellfisherman and divers.

Eelgrass beds are often inconspicuous from the surface, but they are productive and valuable resources. Eelgrass beds are ecologically important in coastal waters because they serve as nurseries, refuge, and feeding grounds for fish, waterfowl and invertebrates. Eelgrass meadows also bind, stabilize, and change the chemistry of sediments.

In Chapter 1, I describe in detail the present day distribution of eelgrass in Buzzards Bay, and in Chapter 2, I estimate the contribution of eelgrass growth to productivity in Buzzards Bay.

The wasting disease of 1931-32 destroyed virtually all eelgrass in the region, and most areas did not recover for many decades. In Chapter 3, I document this and other declines due to disease by analyzing eelgrass seed deposition in sediment cores. I also reanalyze the causes of the disease and the slow recolonization process in Chapter 4.

Superimposed on the collapse of eelgrass populations during this century are local patterns of decline and recolonization driven by both natural and anthropogenic disturbances, including storms, ice scour and freezing, and pollution. In Chapter 4, I also document 12 "case histories" of changing eelgrass abundance that involve these processes.

Because eelgrass beds are ecologically important, and are increasingly affected by anthropogenic perturbations, there is interest in resource management initiatives to protect these communities. In addition, the widespread distribution of eelgrass and its sensitivity to pollution make it a potential indicator species for changes in water quality. I address both these management concerns in Chapter 5.

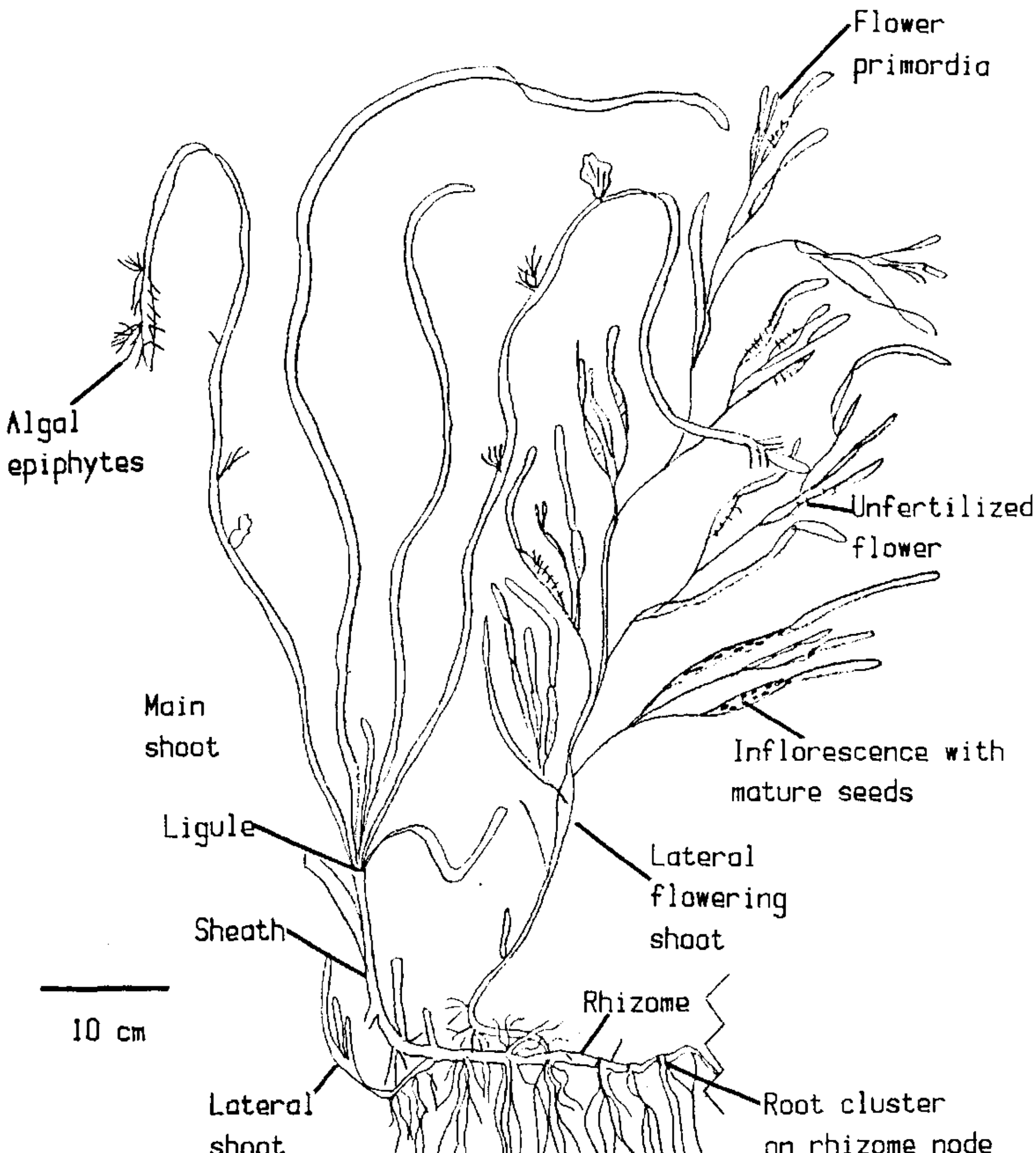
There are some excellent reviews of eelgrass biology and ecology available (e.g. Thayer et al., 1984) and certain topics are covered in detail elsewhere in this report, therefore I will outline only the more salient features of eelgrass biology below.

**General biology and ecology of eelgrass.**

Eelgrass is a vascular plant composed of 3-7 strap-like leaves, bound together in a sheath attached to an underground rhizome (Fig. 1). In this region, the leaves are less than 1 cm wide, and range 20 - 160 cm long. The leaves are adapted to the marine environment in several ways. The leaf cuticle is thin and multiperforate and allows the uptake of nitrogen, phosphorus, and inorganic carbon through the leaf surface (McRoy and Barsdate, 1970; Penhale and Thayer, 1980; Thursby and Harlin, 1982). Air compartments (lacunae) extend throughout the leaves and keep them buoyed in the water. Most chloroplasts are located in epidermal

Figure 1. General morphology of *Zostera marina*.

Eelgrass leaves are bound together in a sheath attached to an underground rhizome with clusters of roots on each rhizome node. Lateral vegetative or reproductive shoots may originate from within the sheath of the main shoot. The inflorescence on the lateral reproductive shoot contains both male and female flowers. Reproductive shoots may also originate from new seedlings or the main vegetative shoot may develop into a flowering shoot.


Flower
primordia
Algal
epiphytes
Unfertilized
flower
Main
shoot
Inflorescence with
mature seeds
Ligule
Lateral
flowering
shoot
Sheath
10 cm
Rhizome
Lateral
shoot
Root cluster
on rhizome node

cells of eelgrass, for efficient light absorption (Tomlinson, 1980; Dennison and Alberte, 1982).

A basal meristem, enclosed within the leaf sheath, produces new leaves, rhizome segments, and lateral shoots. Clusters of roots on each rhizome node, penetrate the sediment 30 cm or more. The roots function both in anchoring the plant and are the primary site of N and P uptake (Penhale and Thayer, 1980). As eelgrass grows, the base of the shoot pushes through the sediment.

Eelgrass is found in diverse habitats in temperate waters. Locally, the upper limit of growth is set by physical factors such as wave action, ice scour, and desiccation. The lower limit of eelgrass growth is set by the period of light intensity above photosynthetic saturation and compensation (Dennison and Alberte, 1985, 1986; Dennison, 1987). Thus in turbid bays without appreciable wave energy, eelgrass ranges from low intertidal to 2.0 m MLW or less; in wave-swept coasts with clear water, eelgrass begins at 1-2 m MLW and may grow as deep as 12-45 m (Sand-Jensen and Borum, 1983; Lee and Olsen, 1985, Cottam and Munroe, 1954). Mean secchi disk depth is a good predictor of maximum depth of eelgrass growth (Dennison, 1987).

All stages of the eelgrass life cycle occur underwater, including flowering, pollination, and seed germination (Ackerman, 1983; den Hartog, 1977, Taylor, 1957a+b). There is latitudinal variation in phenology, and in New England, peak flowering occurs in April and May (Silberhorn et al., 1983), but there is often variation among habitats.

Eelgrass is a perennial, and grows during winter, but plants in shallow water (<1 m MLW) are functional annuals because they are killed by ice scouring, freezing, or other stresses (Phillips et al. 1983; Robertson and Mann, 1984). Plants exposed to these conditions typically have a high incidence of flowering. There have been reports of genetically determined annual populations (Keddy and Patriquin, 1978; Keddy, 1987), but evidence for this hypothesis is not conclusive (Gagnon et al., 1980; Phillips et al., 1983).

Eelgrass grows in diverse habitats ranging from anoxic muds in poorly flushed areas to sand and gravel bottoms with current velocities up to 1.2-1.5 m $s^{-1}$ (2.3-2.9 kt; Fonseca et. al. 1982a, 1983; Pregnall et al., 1984). The morphology of eelgrass shows considerable plasticity in growth in response to physical energy of the environment and nutrient content of sediments (Kenworthy and Fonseca, 1977; Phillips et al, 1983; Short, 1983; Thayer et al., 1984). For example, plants growing in shallow, wave-swept bottoms tend to have short narrow leaves, grow in high densities (>1000 shoots $m^{-2}$), and produce dense root and rhizome clusters; whereas plants growing in deeper water have longer broader leaves, grow in lower densities (<200 $m^{-2}$), and produce less root and rhizome material.

Eelgrass beds are maintained and expand by vegetative lateral shoots and by recruitment of new seedlings. Because most shoots in a bed may be derived from vegetative growth of a few plants, it is often stated that eelgrass beds are large clonal populations. Bare areas not adjacent to existing eelgrass beds are colonized almost completely by new seedlings because uprooted plants float and tend to be cast ashore or washed out to sea.

Eelgrass aboveground production typically ranges 200-500 g C $m^{-2}$ $y^{-1}$ (Jacobs, 1979; Kentula and McIntire, 1986; Robertson and Mann, 1984; Thayer et. al, 1984; McRoy and McMillan, 1977) and may locally exceed production by phytoplankton and macroalgae in shallow bays (Sand-Jensen and Borum, 1983). Epiphytic algae often contribute sizably to the productivity of these communities (Penhale, 1977; Penhale and Smith, 1977; Mazella and Alberte, 1986). Most eelgrass production enters a detritus based food web (Harrison and Mann, 1975; Kenworthy and Thayer, 1984; Mann, 1972; Thayer et al., 1975), but direct consumption by herbivores such as waterfowl and isopod crustaceans may be locally significant (Nienhuis and Van Ireland, 1978; Nienhuis and Groenendijk, 1986).

Carbon fixation is just one role of eelgrass beds in coastal waters. Eelgrass meadows act as a nursery, feeding ground, and refuge for numerous animals (Adams, 1976; Heck and Orth, 1980a+b; Kickuchi, 1980; Lewis, 1931; Thayer and Stuart, 1974; Thayer et al., 1984;). When eelgrass colonizes an area, it changes the physical, chemical, and biotic properties of sediments (Kenworthy et al., 1982; Marshall and Lukas, 1970). As eelgrass biomass increases, so does organic matter, fine sediment fractions, and infaunal invertebrate diversity (Orth, 1973, 1977).

Eelgrass beds, like other seagrasses, bind, baffle, and stabilize sediments and may also influence coastal erosion (Burrell and Schubel, 1977; Churchill et al., 1978; Fonseca et al., 1982a, 1983; Fonseca and Kenworthy, 1987; Schubel, 1973). Eelgrass leaves reduce shear stress of water motion on sediments because current velocity at the top of an eelgrass canopy may exceed 1 m $s^{-1}$, whereas velocity at the base of the shoots is nil (Thayer et al., 1984; Fonseca et al., 1982a). When the wasting disease destroyed eelgrass beds in the 1930's, the physical characteristics of adjacent beaches often changed appreciably (Rasmussen, 1977).

Anthropogenic and natural disturbances play a significant role in regulating the abundance and distribution of eelgrass and other seagrasses. Certainly the most profound natural disturbance affecting eelgrass abundance during this century was the wasting disease of 1931-33 that eliminated at least 90% of the eelgrass in the North Atlantic, including Massachusetts (Cottam, 1933, 1934; den Hartog, 1987; Rasmussen, 1977). Many areas were not recolonized for decades, and in some locales, eelgrass is still expanding today (den Hartog, 1987). There is evidence that eelgrass populations periodically collapse (Cottam, 1934), and recent outbreaks of the wasting disease have been reported (Short et al., 1986). Other natural disturbances remove eelgrass including catastrophic storms, periodic storms, sediment transport, ice damage, and biological removal (Harlin et al., 1982; Jacobs et al., 1981; Nienhuis and van Ireland, 1978; Orth, 1975; Robertson and Mann, 1984).

Anthropogenic disturbances include physical removal, toxic pollution, and degradation of water quality (Borum, 1985; Cambridge, 1979; Cambridge and McComb, 1984; Fonseca et al., 1985; Kemp et. al., 1983; Larkum and West, 1982; Nienhuis, 1983; Orth and Moore, 1983b; Thayer, et al., 1975). While any of these human perturbations may be locally important, declining water quality has often resulted in the largest areal losses of eelgrass and other seagrasses (Cambridge, 1979; Cambridge and McComb, 1984; Lee and Olsen, 1985; Orth and Moore, 1983b; Nienhuis, 1983).

# Chapter 1

## The distribution of eelgrass (*Zostera marina* L.) in Buzzards Bay

## Introduction

Coastal regulators and biologists need accurate inventories of seagrass distribution to understand the biological role of these communities and to manage them. In Buzzards Bay, eelgrass (*Zostera marina* L.) is a major component of shallow waters, and an important habitat and nursery for many species, but knowledge of eelgrass distribution has been lacking. This report is intended to fill this void.

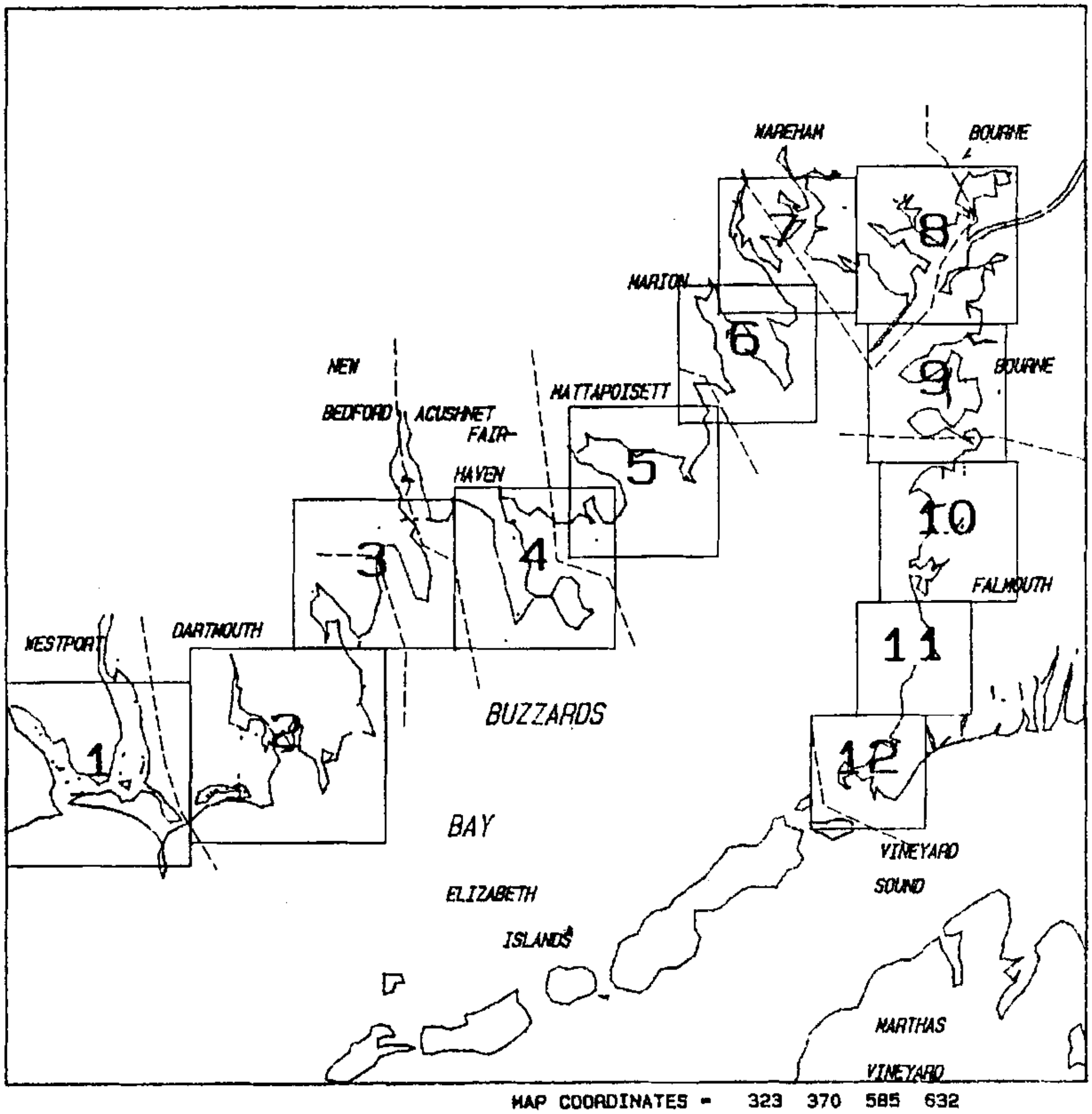
Elsewhere, seagrass distribution has been mapped over large geographic areas using aerial photographs together with field verification (Orth and Moore, 1983a). Under favorable conditions, such as good water clarity, low winds, and low tides, eelgrass beds can be seen easily on vertical aerial photographs. As with any remote sensing methods, photographs must be interpreted carefully; for example, annual beds in very shallow waters may be absent between December and early March. Nonetheless, photographs can provide a reliable and accurate record of eelgrass abundance, especially when several recent surveys are available for comparison.

## Methods

Eelgrass was mapped in Buzzards Bay using vertical aerial photographs and field validation. The region was subdivided into 12 subareas (Fig. 1), each of which are mapped and described in detail (Appendix II). The Elizabeth Islands were not mapped, but eelgrass abundance there was estimated from substrate area on maps (Appendix II).

Figure 1. Map of Southeastern Massachusetts.

The location of the 12 subareas individually mapped and described in Appendix II.


WAREHAM
BOURNE
MARION
NEW
BEDFORD
ACUSHNET
FAIR-
HAVEN
MATTAPOISETT
BOURNE
FALMOUTH
WESTPORT
DARTMOUTH
BUZZARDS
BAY
ELIZABETH
ISLANDS
VINEYARD
SOUND
MARTHAS
VINEYARD
1
2
3
4
5
6
7
8
9
10
11
12
MAP COORDINATES = 323 370 585 632

**Photograph interpretation**

The maps of the present-day distribution of eelgrass were based on existing black and white or color vertical aerial photographs taken by private and governmental agencies (Appendix I). Most of the photographs used were taken between Spring and Fall, during 1974 - 1981. Maps of eelgrass based on photographs taken during the 1970's are often representative of present-day eelgrass distribution because eelgrass had saturated available habitat in most areas by that time (refer to chapter 4). Because older photographs may lead to underestimates of new eelgrass losses or other recent changes, the dates of aerial surveys used to make each map are listed in Appendix II.

Field verification of photographs was accomplished either by skin- or SCUBA diving, or surface observations from boats in 1984-1986. In some embayments, interpretation of photographs was aided by information from shellfish wardens, other researchers, or local residents.

Older photographs and winter surveys were used to interpret recent photographs. For example, a submerged feature unchanging in area over several decades is either a rock field or peat reef, whereas a patch of dense vegetation that shows gradual expansion is eelgrass because only eelgrass beds change in this way. Submerged features in basins that show radical movement within one or two growing seasons are probably drift material. Vegetation present only on summer imagery is likely to be an annual eelgrass bed.

The lower boundaries of eelgrass beds could not be identified in some instances on any photographs and were estimated from bathymetry and typical depth of eelgrass growth for that area. These beds are listed in the results.

Eelgrass beds are rarely continuous patches of vegetation; instead there are bare areas within these beds of varying size. Some of these bare areas are apparent on photographs to the unaided eye, some become apparent when a photograph image is magnified, others are below the limit of resolution of a photograph and can only be measured in the field or on small scale aerial surveys. Alternatively, eelgrass may occur as numerous discrete patches too small and numerous to digitize. In all these cases, a perimeter was drawn around eelgrass beds or clusters of eelgrass beds on photographs, and the percent cover of this outlined "bed" --as viewed on a photograph with the unaided eye-- was estimated using a percent cover scale chart (Fig. 2, c.f. Orth and Moore, 1983a).

The accuracy of visually estimating percent cover was tested by placing a photograph under a dissecting scope with cross-hairs, and randomly moving the photograph between 50 and 100 times. The actual percent cover was calculated by dividing the number of times the cross-hair landed on eelgrass by the total number of observations. In general, visual estimates of large scale percent cover were accurate within 15% of this random count method.

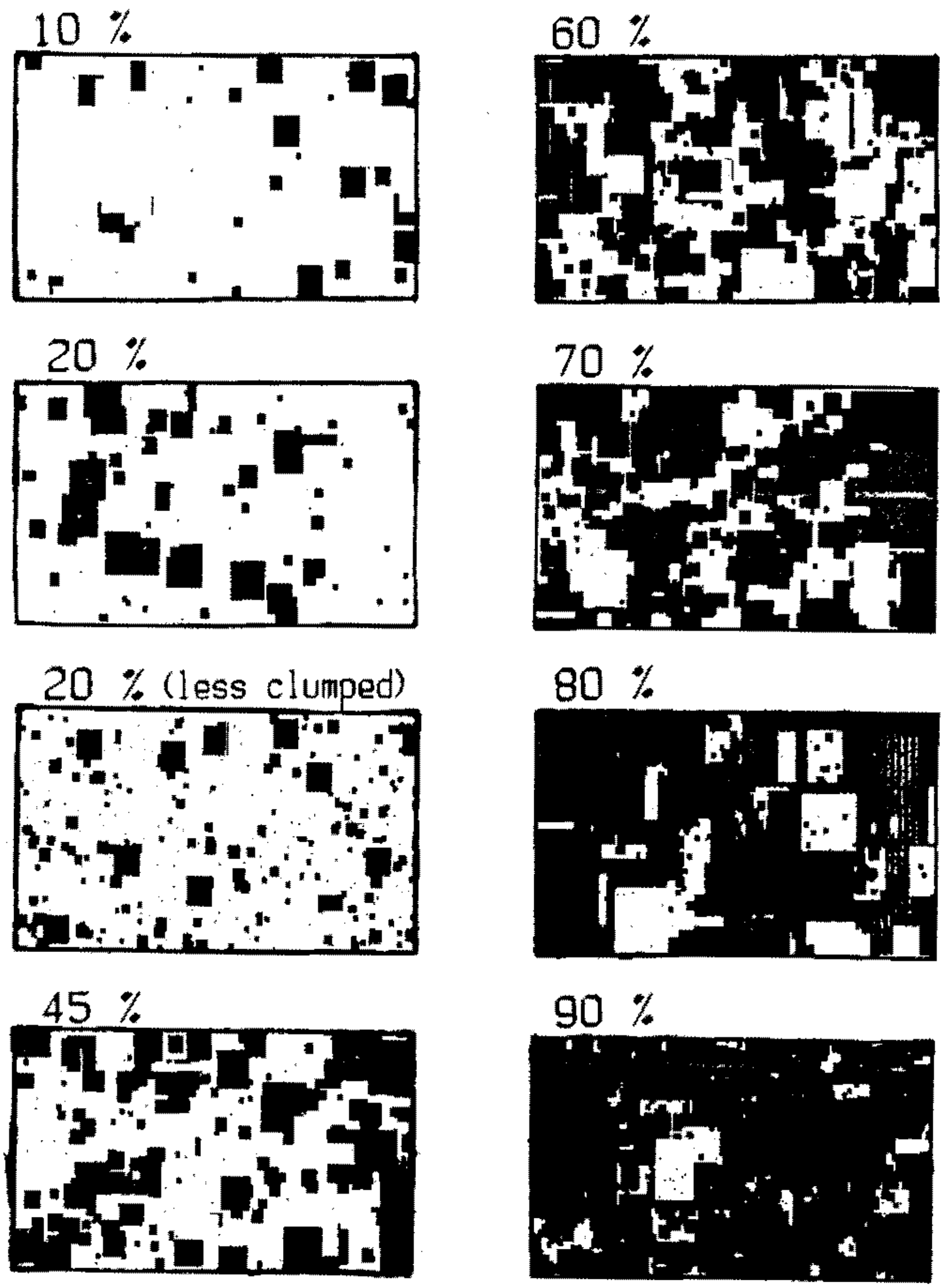
**Mapping techniques**

To map eelgrass beds, aerial prints were overlaid with a sheet of acetate, eelgrass beds were outlined, and other notes were recorded. The photographs and overlays were subsequently photographed with B&W

Figure 2. Percent cover scale.

This scale was used to visually estimate eelgrass cover of eelgrass beds outlined on photographs. The two 20% cover boxes showing different degree of clumping illustrate how patchiness may vary with the same degree of cover.

# PERCENT COVER SCALE



slide film, and this image was projected onto a map of 1:25,000 scale or smaller. The eelgrass beds were then redrawn by hand and distortions in the image were compensated for by eye or manipulating the image on a film enlarger. These bed outlines were re-traced using a digitizing pad connected to a microcomputer. Digitizing and mapping programs for a microcomputer were used for data storage, area analysis, and plotting at different scales.

The maps produced here have ≈25 m resolution. The process of projection, tracing, and digitizing, however, introduced random errors in bed position. These errors were small, and the position of eelgrass beds on the maps in this report were generally accurate within 40 m for beds adjacent to the shore, 60 m for beds within 0.5 km of shore, and within 80 m for eelgrass beds more than 0.5 km from any shoreline when compared to bed positions measured directly from the source photographs.

Each subarea is shown with political boundaries and site names and again with eelgrass beds drawn. In the latter, eelgrass beds are drawn with dashed lines and coastlines as solid lines. Bed areas were computed from the stored coordinates and reported as hectares [1 ha = 2.47 acres].

Not all areas were mapped because of inadequate aerial coverage. Areas where eelgrass is present, but its exact boundaries are unclear, are labeled "+". Areas where eelgrass is present, but has a patchy distribution covering less than 5% of the bottom over large areas, are labeled "SP". Areas where vegetation is present, but its identity is unclear, are labeled "?". These and other symbols used on the maps are summarized in Table 1. All maps are oriented with true north at the top.

## Results

### General features

The central portion of Buzzards Bay is too deep for eelgrass growth, however eelgrass meadows typically dominate shallow areas (refer to Appendix II for a detailed description of eelgrass in the Bay). On high energy coasts and well flushed areas, eelgrass typically grows on sand or sandy-mud to 3-6 m MLW; in protected embayments, eelgrass most often grows on mud bottoms to 1-2 m. In fact, eelgrass beds are a dominant feature in nearly all shallow areas in the region--often forming a continuous belt of vegetation for thousands of meters--except around New Bedford, and the heads of certain bays and estuaries (e.g. Apponagansett Bay, East Branch of the Westport River, the upper Wareham River, and coastal ponds in Falmouth).

Several features are apparent on aerial photographs that deserve discussion because they affect estimates of eelgrass cover. On the outer coast, eelgrass beds appear as dark patches on a light background (sand). In some exposed areas, algae covered rock and cobble dominate the bottom, as well. Algal diversity is high in this region, but *Fucus* and *Ascophyllum* are most common in the intertidal, and *Chondrus*, *Ceramium*, *Codium* and *Sargassum* in the subtidal. In addition, kelps are abundant in some deep, rocky areas with clear water, such as around the Elizabeth Islands and off Westport and Dartmouth. Most of these algae-

Table 1. Key to the symbols used on the maps.

On all maps in this report, the north-south meridian is parallel to the sides of the maps, and true north is at the top.

| | |
|---|---|
|  | Coastline (solid line) |
|  | Eelgrass bed (dashed lines or darkened area) |
| + | Eelgrass present, bed dimensions unclear |
| ± | Eelgrass distribution variable on recent photographs |
| ? | Submerged vegetation, possibly eelgrass |
| PA | Patches of eelgrass present |
| NA | Photograph coverage not available for area |
| NI | Area not included in survey |
| AA | Attached algae, usually on rock or cobble |
| DA | Drift algae may be present on some photographs |
| B | Location of shoot counts or biomass harvesting |
| PE | Salt marsh peat reef offshore |

BOPH5 Eelgrass bed ID #. The first two letters indicate town, the second two indicate local, then the number of the bed. In this case bed 5 in Phinneys Harbor in the town of Bourne. The town letters are omitted on the maps, but are included in Appendix III.

covered rock and cobble fields can be distinguished from eelgrass beds by their characteristic "texture".

In protected areas with mud bottoms, contrast between eelgrass and its background is reduced, but eelgrass can usually be discerned as a dark patch on a slightly lighter bottom. In some bays, benthic drift algae form large mats which can be mistaken for eelgrass beds, but eelgrass growing in these areas appear as slightly lighter patches on a dark background.

In moderate energy environments, with shell and gravel bottoms, the green alga *Codium* may be abundant within eelgrass beds. *Codium* can also dominate the bottom below depths of eelgrass growth, making it difficult to estimate eelgrass bed dimensions and percent cover of eelgrass in some areas. Even though *Codium* is common, it rarely covers the bottom in as large an area, or as densely as eelgrass beds.

Salt marsh peat reefs, remnants of salt marshes covered by migrating barrier beaches then re-exposed after sea-level rises, are common in some areas, usually near existing marshes. These reefs have a similar appearance to eelgrass beds, but usually can be identified on photographs, because, unlike eelgrass beds, they frequently appear in the surf zone.

Questionable areas that were not field validated are identified in Appendix II.

**Region wide summary**

Eelgrass coverage was broken down by town, including the estimate for the Elizabeth Islands (Table 2). On the mainland portion of the

Table 2. Eelgrass cover by town around Buzzards Bay.
All areas in ha, including eelgrass habitat area, area corrected for percent cover, and additional estimated area in unmapped regions, including the Elizabeth Islands.

| **Town** | **Total habitat area** | **Eelgrass beds (adj % cov.)** | **Additional bed area (est.)** | **Total (adj % cov.)** |
|---|---|---|---|---|
| Bourne | 656 | 447 | 30 | 477 |
| Dartmouth | >107 | 74 | 30 | 104 |
| Fairhaven | 450 | 346 | - | 346 |
| Falmouth (Bay shore) | 559 | 397 | - | 397 |
| Marion | 331 | 189 | - | 189 |
| Mattapoisett | 446 | 317 | - | 317 |
| New Bedford | 0.7 | 0.2 | - | 0.2 |
| Wareham | 918 | 564 | - | 564 |
| Westport | >180 | 125 | 140 | 265 |
| Elizabeth Islands (est) | 540 | 270 | - | 270 |
| TOTALS: | 4188 | 2729 | 200 | 2929 |

bay, there are 3600 hectares of eelgrass habitat. An additional 540 ha were added for production measurements as to account for eelgrass along the Elizabeth Islands (Appendix II). When these bed areas are corrected for percent cover, they amount to a total of 2670 ha of eelgrass bed cover in Buzzards Bay.

Several comparisons can be made between eelgrass habitat area and other substrate types. For example, in Buzzards Bay, eelgrass beds cover twice the area salt marshes (Table 3). To a large degree, the amount of eelgrass within a towns boundary depends on the area of suitable substrate. Bathymetric contours are drawn on nautical charts at 1.8, 3.6, and 5.4 m (6, 12, and 18 ft). Most (but not all), eelgrass grows in less than 3.6 m of water in Buzzards Bay, therefor this is the most meaningful reference contour.

The ratio of eelgrass habitat area to substrate area less than 3.6 m varies markedly in each town (Table 3), and this pattern of distribution can be explained by differences in hydrography, water quality, and disturbance levels in each part of the Bay. Three towns (New Bedford, Dartmouth, Westport) have substrate-eelgrass area ratios higher than other towns in Buzzards Bay which range 1.5-2.5. These higher ratios (e.g. 350 for New Bedford) can be explained in part by the loss of eelgrass bed area that I report in Chapter 4. If the substrate-eelgrass habitat area throughout Buzzards Bay equaled the mean ratio for the less polluted towns (2.1), then there would be 10% more eelgrass along the mainland portion of Buzzards Bay. This suggests that chronic pollution in Buzzards Bay has already eliminated 10% of potential eelgrass habitat.

Table 3. Eelgrass habitat area in Buzzards Bay compared to salt marsh area, and substrate less than 3.6 m MLW.

Eelgrass habitat areas in Dartmouth, Westport, and Bourne were adjusted for missing coverage. Salt marsh areas from (Hankin et al., 1985). The Elizabeth Islands are not included in totals. The mean substrate-eelgrass habitat area ratio was 2.1 (excluding New Bedford, Dartmouth, and Westport).

| **Town** | **Eelgrass habitat area** | **Substrate < 3.6 m area** | **Substrate -eelgrass ratio** | **Salt marsh area** |
|---|---|---|---|---|
| Bourne | 700 | 1130 | 1.6 | 121 |
| Dartmouth | 151 | 823 | 5.5 | 463 |
| Fairhaven | 450 | 1190 | 2.6 | 246 |
| Falmouth (Bay side) | 559 | 1397 | 2.5 | 106 |
| Marion | 331 | 870 | 2.6 | 124 |
| Mattapoisett | 446 | 630 | 1.4 | 142 |
| New Bedford | 0.7 | 240 | 343 | 0 |
| Wareham | 914 | 1480 | 1.6 | 364 |
| Westport | 389 | 1420 | 3.7 | 427 |
| TOTALS: | 3940 | 9180 | | 1993 |

Discussion

In Buzzards Bay today there are ≈4500 hectares of benthic habitat where eelgrass is a conspicuous biological component. When corrections are made for percent cover of this habitat as apparent on aerial photographs, as well as adjustments for unmapped area, there are approximately 2900 hectares of eelgrass bed cover.

In one sense, this is an underestimate, because this total does not take into account the eelgrass indicated with a "+" on the maps or other questionable areas. On the other hand, the eelgrass bed dimensions reported here were largely based on photographs between 1974 and 1981, and documentation in Chapter 4 suggests that eelgrass cover has declined in some areas and expanded in others in recent years. Nonetheless, given these errors and omissions, as well as including mistakenly identified submerged vegetation, this estimate of total eelgrass cover for Buzzards Bay is probably accurate within 300 hectares.

For mapping and data management purposes, this eelgrass coverage was subdivided approximately 400 "beds" as listed in Appendix III. Because eelgrass may grow continuously along several kilometers of shore with different levels of density, and sometimes span several photographs, the borders of the beds that I have drawn often reflect the scale of the imagery, extent of photograph coverage, and idiosyncrasies of the mapping process. Thus, it is not meaningful to say that town A has more eelgrass beds than town B; instead it is more appropriate to discuss the total eelgrass bed area in each town.

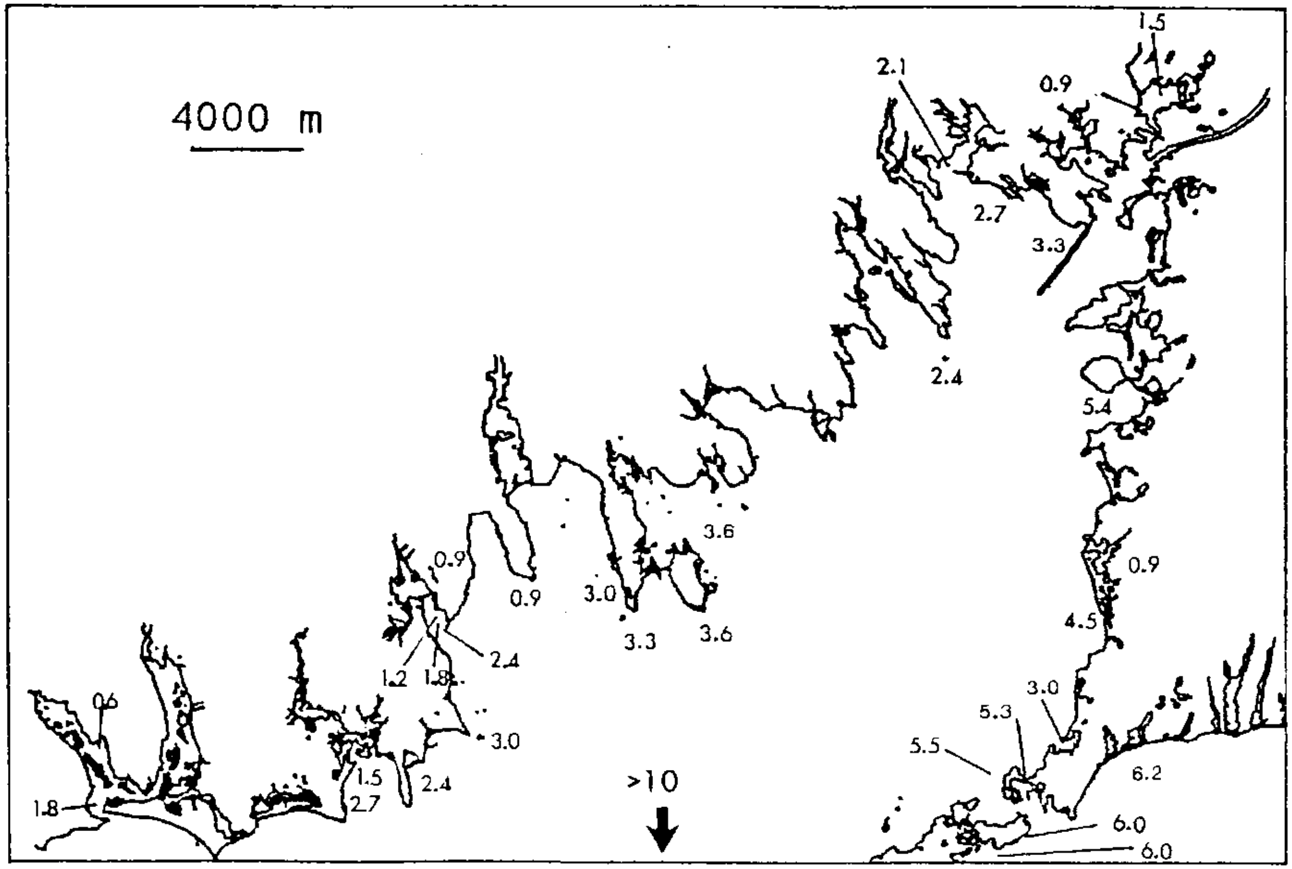
Less than one third of the eelgrass in Buzzards Bay occurs in shallow, protected bays and estuaries with restricted water flows; the remainder occurs in higher energy, better flushed offshore waters. Because water transparency is not good in shallow, poorly flushed embayments, particularly where there is considerable human development, eelgrass grows only to 0.6 - 1.8 m. In cleaner, offshore, well flushed waters, eelgrass grows to 3.0 to greater than 6.0 m (Fig. 3). This distinction is relevant because each of these areas are host to different communities of animals.

In shallow, quiescent lagoons, eelgrass grows as high as the low water mark, and annual plants may even occur on intertidal flats. Plants in shallow areas are available to, and important food sources for waterfowl, particularly Canada geese. These beds are also important habitats and nursery grounds for estuarine fish and invertebrates. In contrast, eelgrass growing along exposed beaches may begin 1.0 m MLW or deeper because of wave action, and leaves are generally not available to waterfowl. Furthermore, while there is considerable overlap of invertebrate species, larger fish such as striped bass, bluefish, tautog, flounder, and cownosed rays forage much more frequently in offshore eelgrass beds than beds in shallow embayments. Thus, the ecological consequences of loss of eelgrass habitat will greatly depend on the location of the bed.

The depth that eelgrass grows depends on light availability. Light availability is largely controlled by phytoplankton abundance and algal epiphyte cover (mostly determined by nutrient loading and flushing) and sediment resuspension (Dennison, 1987; Kemp et al., 1983;

Figure 3. Maximum depth (m MLW) of eelgrass in different parts of Buzzards Bay.

In general, water transparency is greater in the southern region of the Bay than northern parts, and better outside of small embayments than within.


4000 m
2.1
0.9
1.5
2.7
3.3
2.4
5.4
3.6
0.9
0.9
3.0
3.3
3.6
0.9
4.5
2.4
1.2
1.8
0.6
3.0
3.0
5.3
5.5
1.5
2.4
>10
6.2
1.8
2.7
6.0
6.0

Lee and Olsen, 1985; Orth and Moore, 1983b; Sand-Jensen and Borum, 1983). Figure 3 shows that light is less available to eelgrass in poorly flushed embayments than on more exposed shorelines, and water transparency is best near the southern and eastern shores of Buzzards Bay, than the northwestern end which is not as well flushed, and has moderate riverine and larger anthropogenic inputs.

The absence of eelgrass in the north ends of embayments such as New Bedford Harbor, Little Bay, Fairhaven, and Apponagansett Bay, Dartmouth does not correspond to physiological limits of eelgrass growth due to the low salinities or damage due to natural disturbances. Because eelgrass grew in these areas in the past (Chapter 4), alternate explanations must account for the absence of eelgrass, such as toxic pollution, sediment resuspension, or nutrient enrichment.