Peconic Estuary Program 2006 Eelgrass (*Zostera marina*) Long-Term Monitoring Program

Progress Report 8
April 8, 2008

Submitted To:

The Peconic Estuary Program Office
The Suffolk County Department of Health Services
Office of Ecology

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Summary

The Peconic Estuary Program's Long-Term Eelgrass Monitoring Program was continued by Cornell Cooperative Extension's Marine Program in 2006. The six monitoring beds were sampled during the period of 14 August 2006 to 21 August 2006. Divers conducted 60 quadrat counts of eelgrass shoot density and macroalgae percent cover at each monitoring site. Temperature data from data loggers and PEP Routine Marine Surface Water Monitoring Program were analyzed to elucidate differences in surface versus bottom temperatures and annual temperature trends. Significant changes in the shoot density and extent of the six monitoring sites were observed in 2006. Twenty-five (25) out of a total of 36 stations (6 stations per each of the 6 sites) no longer supported eelgrass within the 10 m radius of the station coordinates. Macroalgal percent cover showed mixed results, with only Orient Harbor and Three Mile Harbor exhibiting significant increase. Areal extent has increased significantly in Bullhead Bay, with eelgrass moving back into two previously unvegetated stations, while Southold Bay and Three Mile Harbor have lost all eelgrass within their respective monitoring areas. Gardiners Bay and Northwest Harbor also experienced loss in areal extent. The temperature data continued to be a useful tool in monitoring annual trends and identifying localized periods of high water temperature which is important for eelgrass health and planning of restoration activities in the estuary.

No single causative factors have been directly linked to the losses that have continued at a majority of the monitoring sites. At this time, physical disturbance (both natural and anthropogenic) continues to be the most likely cause of the losses that have been documented. It is likely that no one source is responsible for the damage/losses in the monitoring sites, but rather a combination of stressors are responsible.

Eelgrass Introduction

The decline of eelgrass (*Zostera marina* L.) in the Peconic Estuary over the last 70 years has contributed to the degradation of the estuary as a whole. This submerged, marine plant is inextricably linked to the health of the Estuary. Eelgrass provides an important habitat in near-shore waters for shellfish and finfish and is a food source for organisms ranging from bacteria to waterfowl. To better manage this valuable resource, a baseline of data must be collected to identify trends in the health of the eelgrass meadows and plan for future conservation/management and restoration activities in the Peconic Estuary. The more data that is collected on the basic parameters of eelgrass, the better able the Peconic Estuary Program will be to implement policies to protect and nurture the resource.

The basic purpose of a monitoring program is to collect data on a regularly scheduled basis to develop a basic understanding of the ecology of the target species. Since its inception, the Peconic Estuary Program's Submerged Aquatic Vegetation Monitoring Program, contracted to Cornell Cooperative Extension's Marine Program, has focused on collecting data pertaining to the health of the eelgrass beds in the Peconic Estuary. The development of this program reflects the unique ecology and demography of the eelgrass in the Peconic estuary and varies significantly from other monitoring programs like the Chesapeake and other areas on the east coast, which tend to focus more on remote sensing techniques (i.e., aerial photography) for monitoring.

Methods

Table 1. The six reference eelgrass beds and the townships in which the beds are located.

Bullhead Bay (BH)	Southampton
Gardiners Bay (GB)	Shelter Island
Northwest Harbor (NWH)	East Hampton
Orient Harbor (OH)	Southold
Southold Bay (SB)	Southold
Three Mile Harbor (TMH)	East Hampton

The PEP SAV Monitoring Program includes six eelgrass beds located throughout the estuary and represents a range of environmental factors. The name and township location of each of the reference beds are listed in Table 1, with a corresponding aerial perspective of each site found in Appendix 1. Included with each image are the locations of the six sampling stations within the bed and the GPS coordinates for each station.

The monitoring program has evolved its methodologies from its beginnings in 1997; however the basic parameter of eelgrass health, shoot density, has always been the focus of the program, thus allowing for comparisons between successive years. In the beginning, sampling consisted of the destructive collection of three (four in Bullhead Bay) 0.25 m^2 (50cm x 50cm) quadrats of eelgrass including below ground and above ground biomass that was returned to the laboratory for analysis. The sampling in 1998 and 1999 continued to utilize destructive sampling to collect data, however, sample size was increased to a total of twelve quadrats and there was a decrease in the size of the quadrats to 0.0625 m^2 (12.5 x 12.5 cm).

In 2000, the methodology for the monitoring program was amended to increase the statistical significance of the data collected. The adjustments reflected an increase in the number of sampling stations per site (from 3 to 6), the number of replicate samples per station (from 4 to 10) and the size of the quadrats. However, the 2000 methodology included an increase number of destructively sampled quadrats (24 quadrats) for use in biomass estimations. The 2001 protocols maintained the higher number of replicate samples per bed (60 quadrats) but eliminated the destructive sampling aspect of the program. Beginning in 2004, water temperature was collected at several of the monitoring sites using submersible temperature loggers. The specific monitoring protocol for 2004 is outlined below.

Water Temperature Monitoring

In an effort to better describe the relationship between water temperature and the life cycle of eelgrass, temperature loggers were deployed in several eelgrass beds in the Peconics, including two of the long-term monitoring sites and one eelgrass restoration site. The loggers were set to record temperature at six-hour intervals.

The following sites were monitored for 2006: Bullhead Bay, Sag Harbor, Northwest Harbor, Cornelius Point (Shelter Island) and Orient Point (near Cross Island Ferry).

The loggers, Onset Tidbit® and Onset StowAway®, were deployed in March and April 2006 and retrieved in December 2006.

The March-December deployment was designed to track the rise and fall of water temperature through 15°C, a temperature thought to influence flowering and seed germination. This period also allows for peak water temperature, the most stressful time of the year for eelgrass, to be recorded.

Temperature data was exported from the loggers into spreadsheets. The data was nalyzed and graphed using SigmaStat® and SigmaPlot® (SPSS Inc., 1997) software.

Eelgrass Monitoring

The 2006 monitor was initiated on 14 August and completed on 21 August.

Sampling at each site was distributed among six stations that have been referenced using GPS. At each of the six stations, divers conducted a total of 10 random, replicate counts of eelgrass stem density and algal percent cover in 0.10 m^2 quadrats. Divers also made observations on blade lengths and overall health of plants that they observed. The divers stayed within a 10 meter radius of the GPS station point while conducting the survey. Algae within the quadrats were identified by genus and if it was epiphytic or non-epiphytic on the eelgrass. Divers were careful not to disturb the eelgrass, so as not to cause plants to be uprooted or otherwise damaged.

Data was incorporated into a spreadsheet and statistically analyzed using SigmaStat software (SPSS Inc., 1997). The trends, within sites, were analyzed by comparing the 2006 data with the data from the previous years.

Bed Delineation

The deep edge delineations for the 2006 season utilized Microsoft's Virtual Earth™ aerial photography. The Virtual Earth™ aerial photography uses oblique angled photographs that, while not preferred for delineating eelgrass, were sufficient for most of the monitoring sites. The 2006

Table 2. Descriptive statistics for eelgrass stem density for 2006.

Location	Sample Size (n)	# Stations w/ No Grass	Mean Stem Density (shoots/m^2)	Standard Error
Bullhead Bay (BH)	60	2	171	±34.3
Gardiner's Bay (GB)	60	2	178	±30.6
Northwest Harbor (NWH)	60	4	8	±3.2
Orient Harbor (OH)	60	5	27	±12.3
Southold Bay (SB)	60	6	0	±0.0
Three Mile Harbor (TMH)	60	6	0	±0.0

delineations were incorporated into GIS layers that included the 2002, 2004 and 2005 delineations and were overlaid on 2004 true-color aerial photographs for each site.

Results

Statistical analysis reports are included as a separate set of appendices and include basic descriptive statistics as well as one-way ANOVAs. *P*-values, when not stated, may be found in these appendices. The attached appendices (Appendices 1-4) present graphical data directly referred to in this report.

Water Temperature Monitoring

The graphs for the water temperature data are included in Appendix 1. The data represented in the graphs are the mean daily water temperature (°C) at each site.

For the second straight year, the temperature logger in Bullhead Bay could not be found at the end of the season for offloading of the data. The loss of the logger and TERF frame that anchored it could only be attributed to human interference/removal.

The remaining loggers were recovered and offloaded with the data represented in the graphs (1a-1d) in Appendix 1. Overall, water temperature for 2006 peaked in early August for all sites. The shallow waters of Northwest Harbor reached the highest mean daily temperature of 28.3°C, followed by Sag Harbor and Cornelius Point with highs of 27.8°C and 26.5°C, respectively. Orient Point was the coolest of the sites with a high of 25.3°C.

Eelgrass Shoot Density and Areal Extent

The basic descriptive statistics for the eelgrass shoot densities for the 2006 season are represented in Table 2. Included in the table are the sample sizes (replicates), number of stations without eelgrass, mean stem density, and standard error of the means. Appendix 2 includes trend analysis graphs of the mean shoot density data for the six monitoring sites from 1997(1999)-2006.

Bullhead Bay

The 2006 mean shoot density for Bullhead Bay was found to be 171 shoots/m^2 (Table 2), which did not represent a significant increase in mean shoot density

from 2005; though it was more than a threefold increase in shoot density. The areal extent of the bed was found to have expanded to recolonize parts of Stations 2 and 6, which had been unvegetated since 2002 (Appendix 3).

Gardiners Bay

Gardiners Bay saw a significant loss in shoot density from 2005 to 2006. The 2006 mean shoot density of 178 shoots/m^2 (Table 2), is a 56% decrease from the density of 320 shoots/m^2 in 2005 (Appendix 2b). The decline in shoot density in 2006 represents the first significant change since 2000 in at this site.

While the areal extent of this bed has always been dynamic in previous years, the 2006 monitoring season found a loss of eelgrass in 2 stations (Appendix 3b). The loss in these stations represents the first significant changes in this site since monitoring began in 1999.

Northwest Harbor

Northwest Harbor showed a total loss of eelgrass. The decline of this site's eelgrass population was significant from 2005 to 2006 (176 shoots/m^2 to 8 shoots/m^2) (Append 2c). Only one station still supports eelgrass at this site, and that station's eelgrass population was very patchy.(Appendix 3c).

Orient Harbor

Since the major loss of eelgrass in Orient Harbor in 2002, the bed has not shown any significant indications of recovery. The mean shoot density for 2006 was 27 shoots/m^2, but was down only slightly from the 2005 density of 36 shoots/m^2 (Appendix 2d). Station 5 continues to be the only station that supports eelgrass(Appendix 3d).

Southold Bay

Southold Bay did not support eelgrass at any station in 2006 (Table 2). This complete loss of eelgrass in the monitoring station was preceded by a significant decline of mean shoot density from 2004 to 2005 (Appendix 2e).

The eelgrass population in Southold Bay is nearly lost. Though sparse patches of eelgrass were observed near Station 4, the density of these patches are not likely high enough to sustain the population.

Three Mile Harbor

The Three Mile Harbor mean shoot density for 2006 was zero (Table 2). Unlike Southold Bay, where eelgrass was observed in areas adjacent to sampling stations, no eelgrass was observed during the 2006 visit. The nearest extant eelgrass population to this site would be near the Boys-Girls Harbor property, several hundred meters to the east southeast.

Algal Percent Cover

Algal percent cover was quantified for each quadrat within the six beds. Table 3 contains the mean percent coverage of macroalgae for each bed. Graphs for the individual sites are included in Appendix 4.

Bullhead Bay

The macroalgae percent cover for 2006 showed an insignificant decrease of 47% from 5(Appendix 4a). The macroalgae population was dominated by the red, filamentous alga, *Spyridia filamentosa* and the green filamentous alga *Cladophora*. Unvegetated areas were covered with diatomaceous and cyanobacterial mats.

Gardiners Bay

Gardiners Bay showed a significant

Table 3. Mean macroalgal percent coverage (m^{-2}).

Eelgrass Bed	Percent Macroalgae Cover
Bullhead Bay	17.4
Gardiners Bay	38.8
Northwest Harbor	7.9
Orient Harbor	8.2
Southold Bay	3.2
Three Mile Harbor	19.7

decline in macroalgae percent cover from 2005 to 2006 (56.7% to 38.8%).The mean percent macroalgae cover for the site more than declined by almost one-third between the two years (Appendix 4b). The species diversity at this site displayed no significant change from previous years.

Northwest Harbor

Northwest Harbor's macroalgal percent cover declined significantly since 2005. Macroalgae cover in this bed for 2005 was 90.9% (Appendix 4c), while the 2006 mean percent cover was only 7.9% (Table 3). The macroalgal population at this site was observed to be only two species, *Spyridia filamentosa* and *Agardhiella subulata*.

Orient Harbor

The macroalgae community in Orient Harbor was found to have decreased slightly from 2005 to 2006. The 2006 mean percent macroalgal cover was 8.2% and consisted of *Spyridia filamentosa* and *Agardhiella subulata*. A small bloom of the diatom *Cochlodinium* was observed between Stations 4 and 5. Presence of this species in Orient Harbor was later confirmed by SCDHS.

Southold Bay

The percent cover of macroalgae declined significantly from 38.7% in 2005 to 3.2% in 2006 (Appendix 4e). Macroalgal mats continue to colonize areas that were once dominated by eelgrass at this site.

Three Mile Harbor

Three Mile Harbor experienced a slight increase in macroalgal cover, from 16.6% (2005) to 19.7% (2006) (Appendix 4f). There continues to be no significant change in the macroalgal population since 2004.

Discussion

Water Temperature

Water temperature continues to follow a predictable pattern in the Peconic Estuary with the warmest waters located in the western Estuary and the cooler areas located to the east. The highest mean daily temperature recorded was in Northwest Harbor, although Bullhead Bay would certainly have exceeded the 28.3°C high if the logger could have been recovered. The upper temperature tolerance of eelgrass in the Peconics is assumed to be around 30°C, but an exact limit is not known. Brief periods of high water temperature would likely have little effect on the eelgrass populations, however extended durations in high water temperatures could have a significant detrimental effect on eelgrass. Eelgrass loss due to high water temperatures, like those experienced in the Chesapeake Bay, warrant the continued monitoring of water temperatures throughout the Estuary.

Long-Term Eelgrass Monitoring

Bullhead Bay

Bullhead Bay exhibited a measure of recovery from 2002 with a large, but

statistically insignificant increase from 2005. Eelgrass recovery in the bed reclaimed two stations that had not supported eelgrass in several years. The spread of eelgrass into Stations 2 and 6 was likely the result of natural seed recruitment and may present a successful model for reestablishing the remaining unvegetated stations in the bay. Optimistic projections for the full recovery of these Stations and the rest of the bed should be tempered by the fact that the patches in these recolonize areas were small and of relatively low density which makes them more susceptible to bioturbation and other disturbances. The results from the 2007 monitoring season will allow for better projection of the long-term recovery of this site's eelgrass population.

Gardiners Bay

Gardiners Bay experienced its first significant decline in eelgrass shoot density and areal extent. The complete loss of eelgrass in Stations 1 and 5 accounted for most of the decline at this site. However, Station 2 exhibited some erosion resulting in more fragmentation of the eelgrass at this station.

Physical disturbance at the site continues to be the most significant factor influencing the eelgrass population. Shellfishing activities (*i.e.*, clamming) and prop scars from boat traffic have increased.

Northwest Harbor

The Northwest Harbor eelgrass population continued its decline that started in 2005. The population in the monitoring area is centered around two stations and it is very sparse. With an average shoot density, for those two stations, of only 23 shoots/m2, it is likely that the population does not have the critical density to recover at this site.

As recorded in previous years, disturbance by crabs(particularly spider crabs), whelks and clamming activities have contributed to the decline and eventual loss of this bed.

Orient Harbor

There continues to be little sign of recovery in Orient Harbor since the loss documented in 2004. However, there also has been no indication that the population left around Station 5 is continuing to decline. It is possible that the eelgrass population at this Station, with a density of 164 shoots/m^2, has the critical mass to maintain and, eventually, expand the bed.

Southold Bay

The almost total loss of eelgrass at this site marks the extinction of this eelgrass bed. Even though minimal eelgrass was observed during monitoring activities, there was not a high enough concentration of shoots to sustain the bed. Without outside help (i.e., restoration) this site will not revive due to its relative isolation from other extant eelgrass populations and continued physical disturbance from nearby boat channels and periodic dredging activities.

Three Mile Harbor

The eelgrass in Three Mile Harbor outside of Hand's Creek has lost its eelgrass population. Many factors have likely attributed to this loss, but human activity was that most obvious factor influencing the health and extent of the eelgrass population here. The presence of a mooring field, and its expansion in successive years, presented a significant disturbance source for the inshore areas of the former eelgrass bed. Dragging mooring chains and prop dredging were likely factors influencing the decline of the inshore portion of the bed. Outside of

the mooring field, eelgrass was subjected to boat traffic from the designated water skiing area that was expanded into the eelgrass bed. With water depths of 5-7 feet, boats did not directly impact the eelgrass by prop dredging/scarring, but with the mucky sediment at this site being easily resuspended, eelgrass could potentially have faced periods of light limitation that could have contributed to its decline.

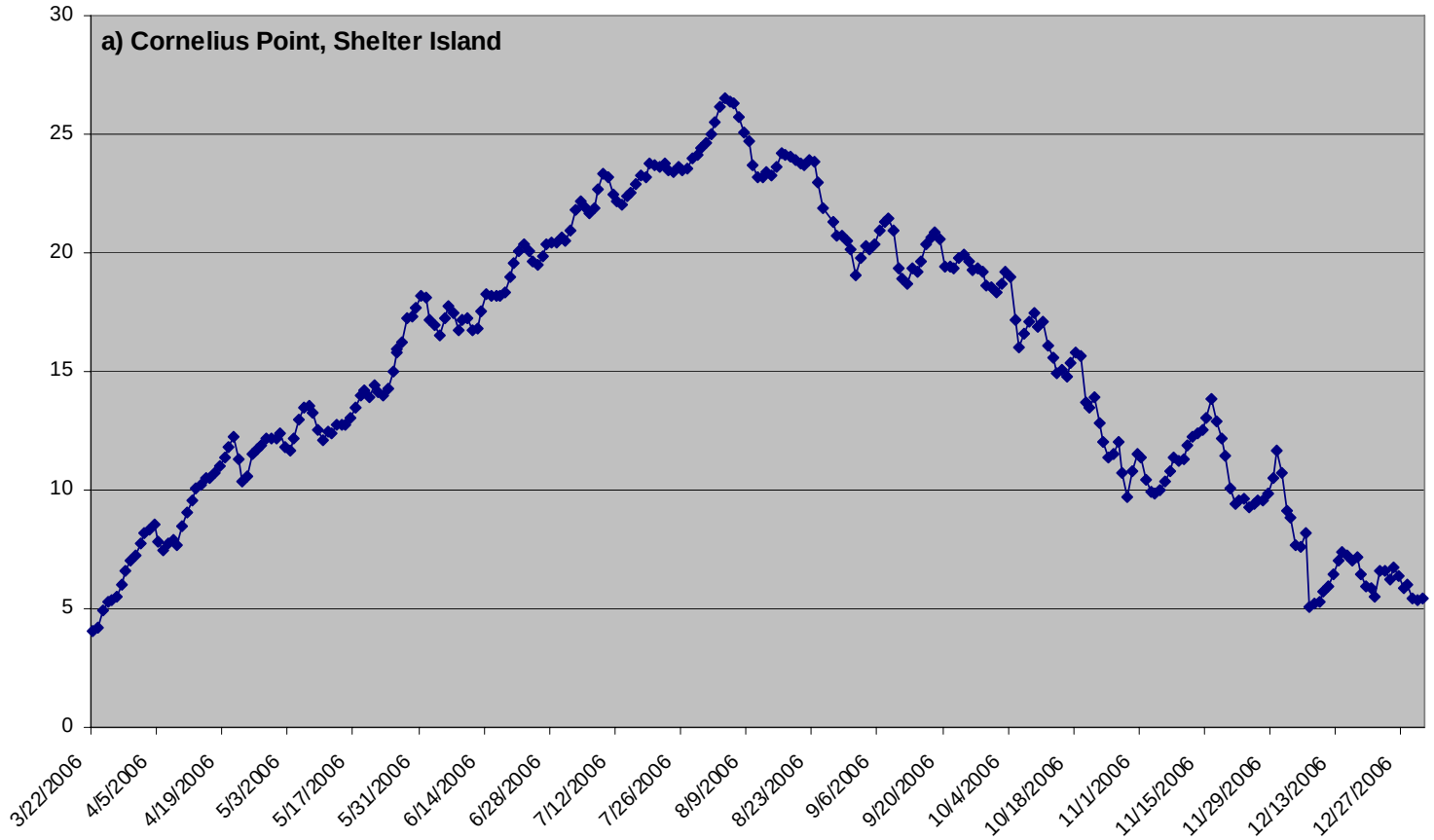
Overview

The 2006 monitoring season recorded the complete loss of eelgrass at two of the monitoring sites (Southold Bay and Three Mile Harbor) and significant losses in shoot density at two other sites (Gardiners Bay and Northwest Harbor). Orient Harbor has not shown evidence of recovery since its decline in 2002-2003, although the remaining eelgrass population seems to have stabilized and may have a high enough population density at the remaining station to sustain and eventually repopulate the bed. Bullhead Bay is the only bed in the LTEMP to show signs of recovery with an increase in mean shoot density and expansion of eelgrass into stations that had no eelgrass for several years.

The primary cause(s) of the declines observed during monitoring have not all been identified, but physical disturbance, both natural and anthropogenic, rank high. Bioturbation by crabs, whelks and moon snails, can have a large impact on an eelgrass bed by uprooting plants and causing fragmentation. Grazing by swans and geese could have an impact on shallow eelgrass beds by both uprooting plants and consumption of eelgrass seeds needed for regeneration of the beds.

Human activities, specifically shellfishing and boating, potentially pose the greatest threat to eelgrass meadows in the Estuary. A single clammer digging in an eelgrass bed not only digs up plants, but also creates openings in the bed that can lead to erosion or serve to fragment the beds. Damage from boats results in disturbance similar to that of clamming, with the initial impact on the eelgrass bed being loss of plants, but prop scars also open up the bed to erosional processes and fragmentation. Physical disturbance should be considered one of the top factors in eelgrass loss in the Peconic Estuary.

Appendix 1. Water temperature graphs for selected sites within the Peconic Estuary. Datasets are represented as daily mean temperatures for 2006.


a) Cornelius Point, Shelter Island
30
25
20
15
10
5
0
3/22/2006
4/5/2006
4/19/2006
5/3/2006
5/17/2006
5/31/2006
6/14/2006
6/28/2006
7/12/2006
7/26/2006
8/9/2006
8/23/2006
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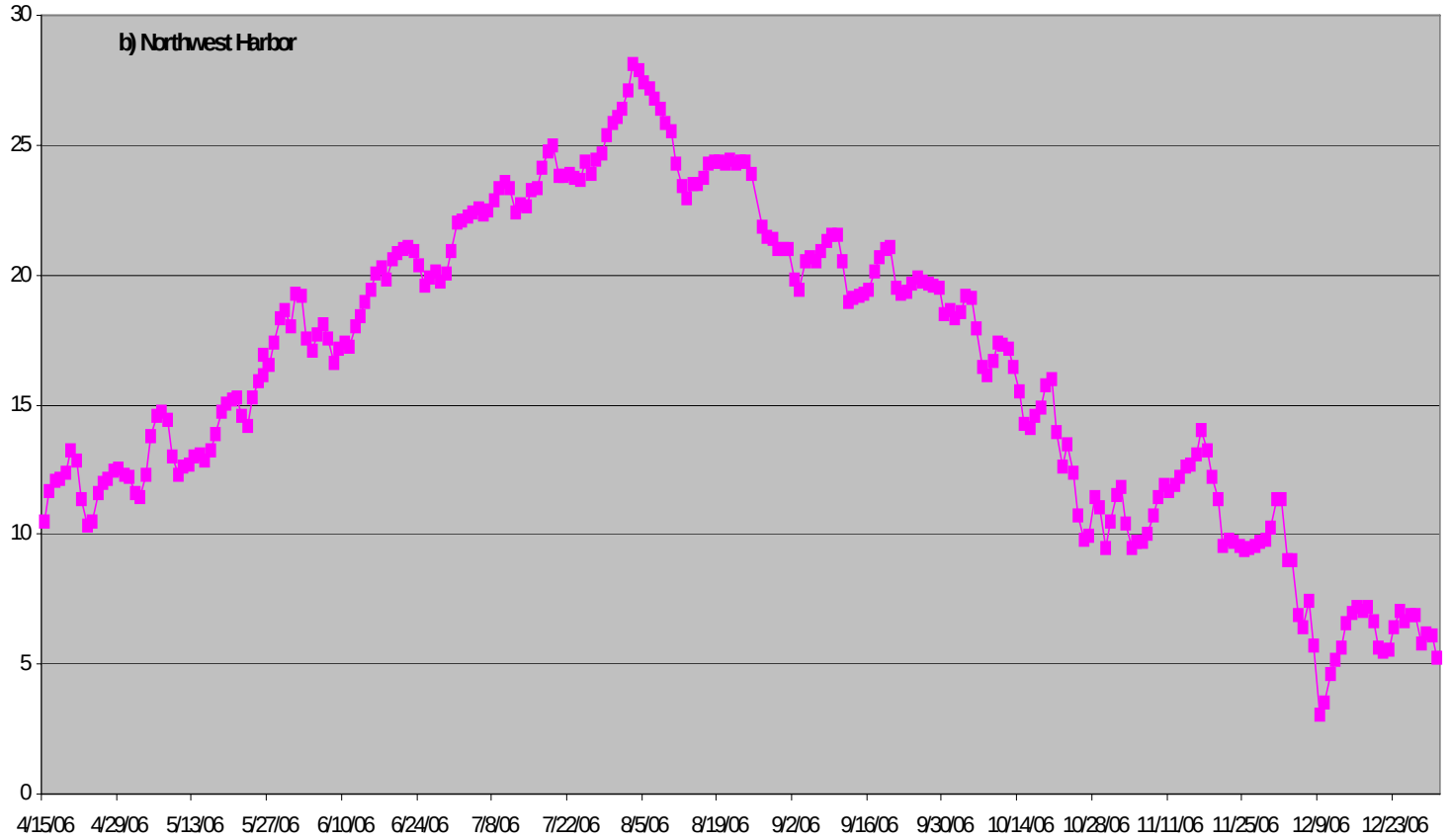
11/29/2006
12/13/2006
12/27/2006


b) Northwest Harbor
30
25
20
15
10
5
0
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
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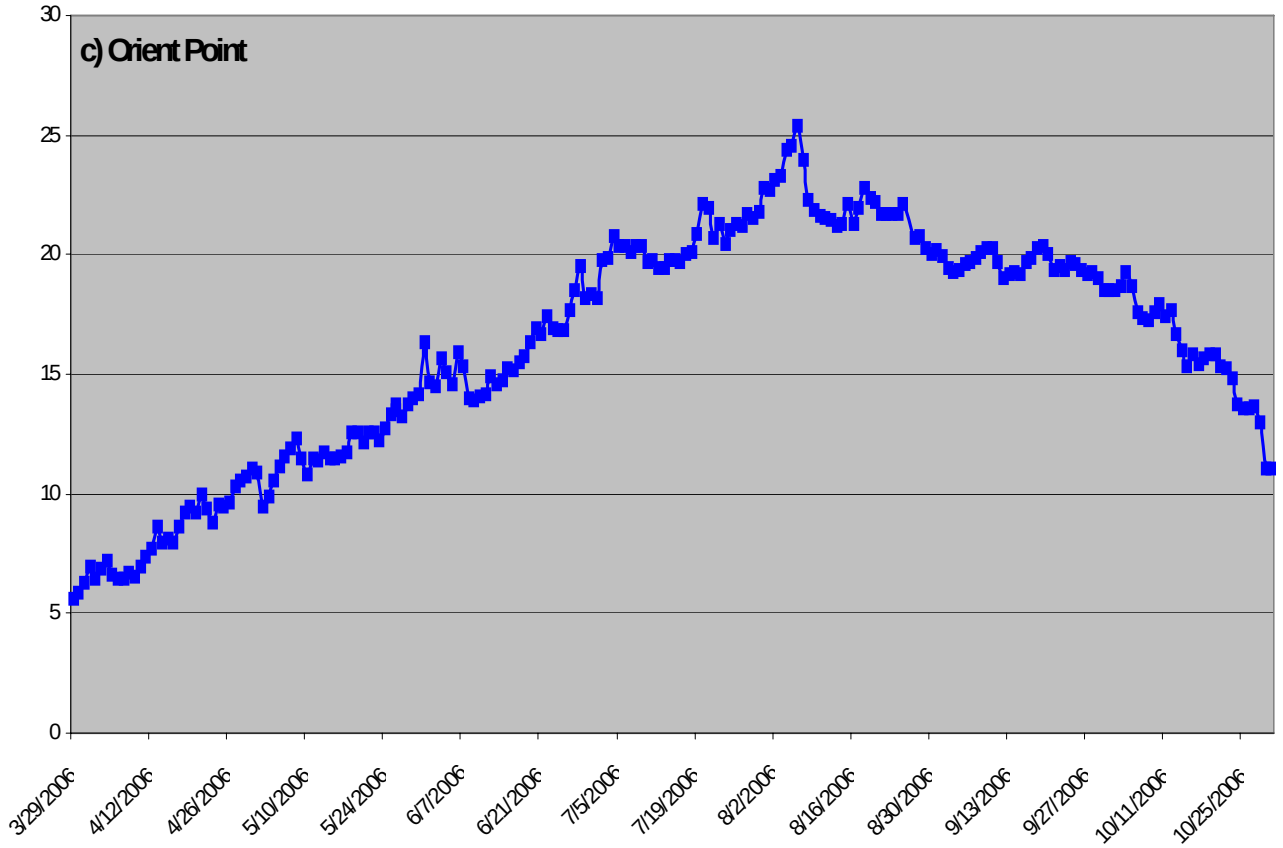
11/11/06
11/25/06
12/9/06
12/23/06


c) Orient Point
30
25
20
15
10
5
0
3/29/2006
4/12/2006
4/26/2006
5/10/2006
5/24/2006
6/7/2006
6/21/2006
7/5/2006
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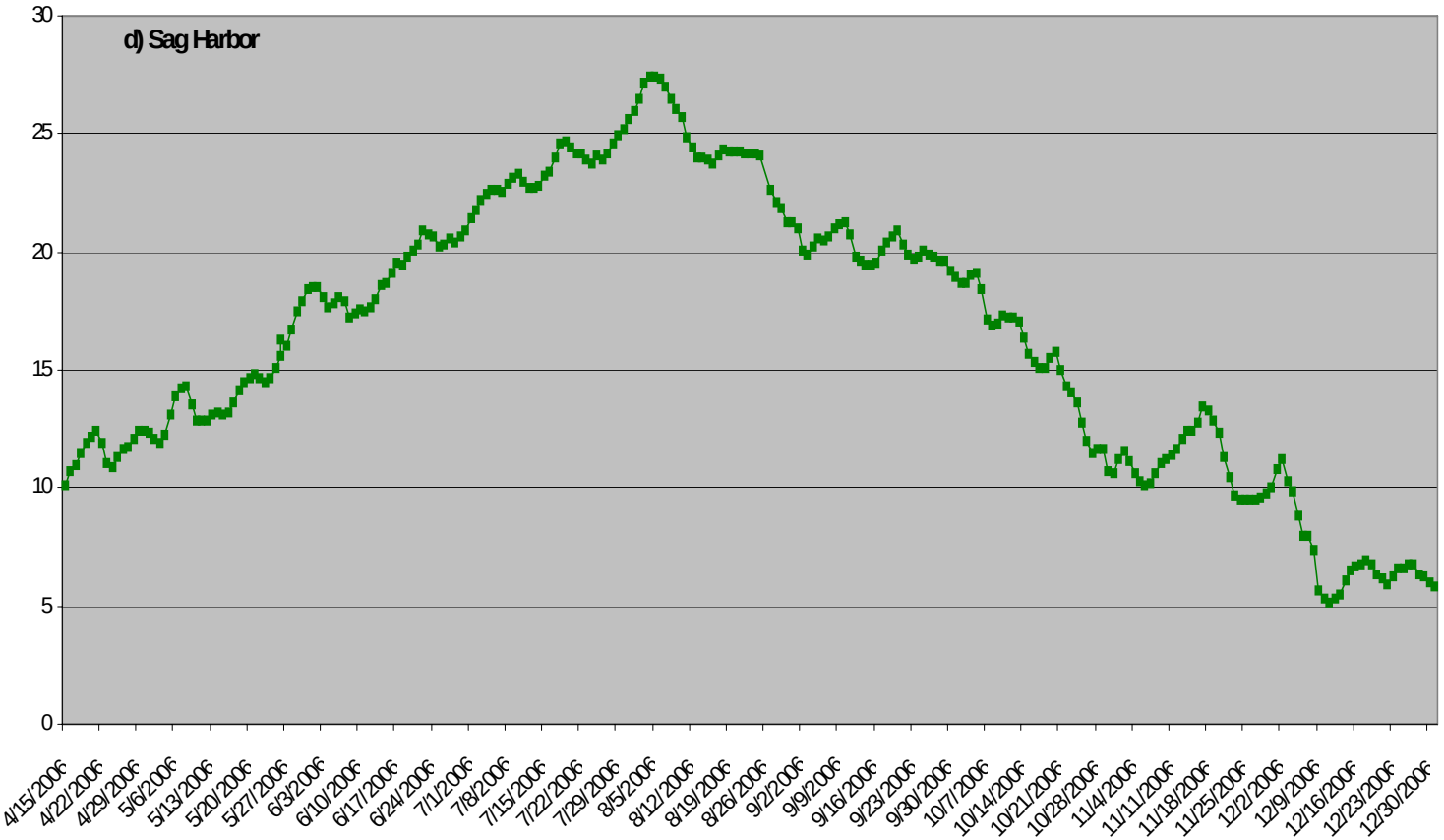
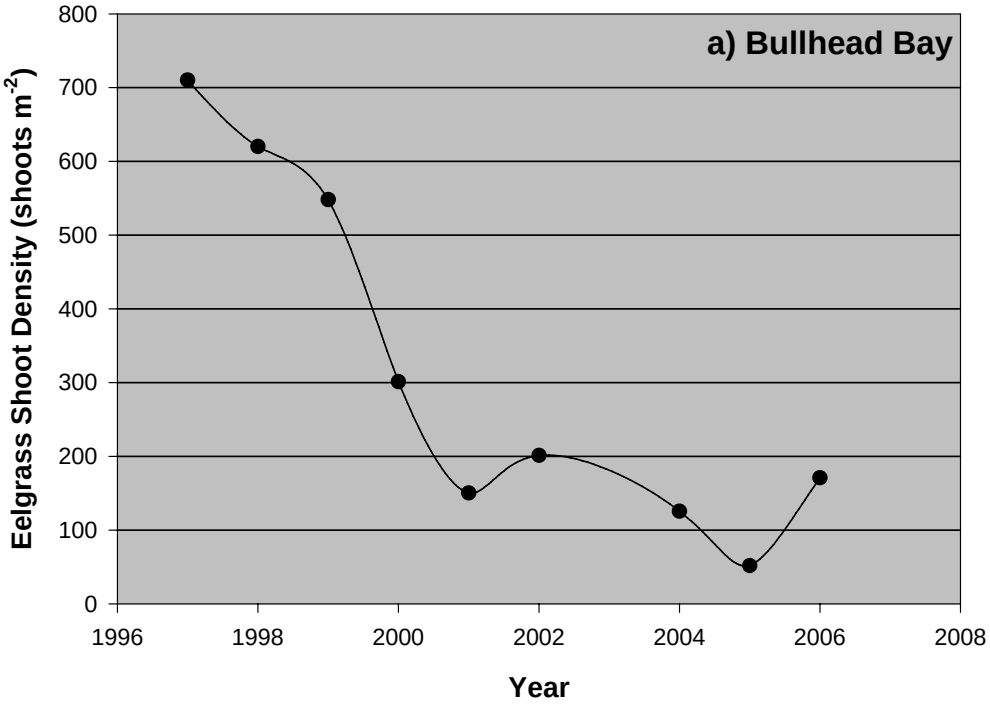
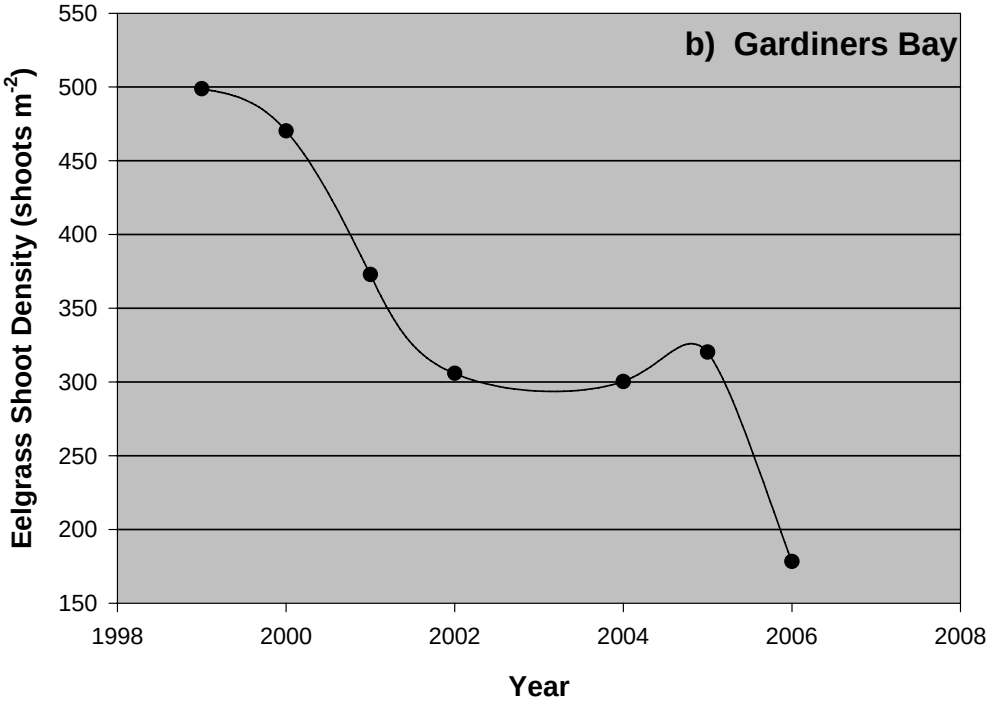
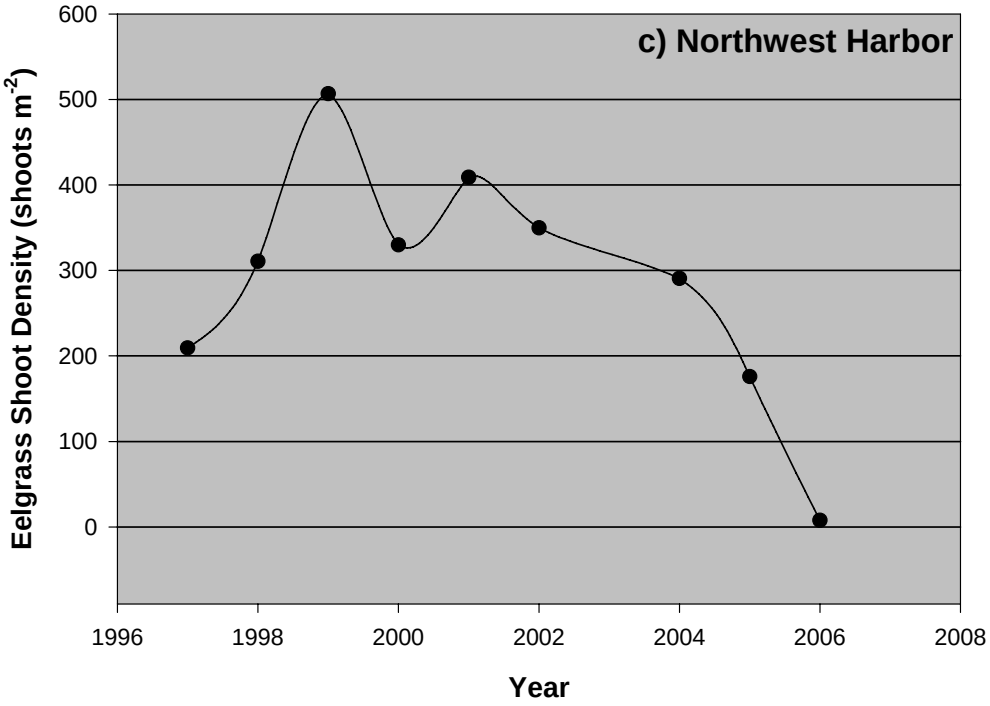
9/13/2006
9/27/2006
10/11/2006
10/25/2006

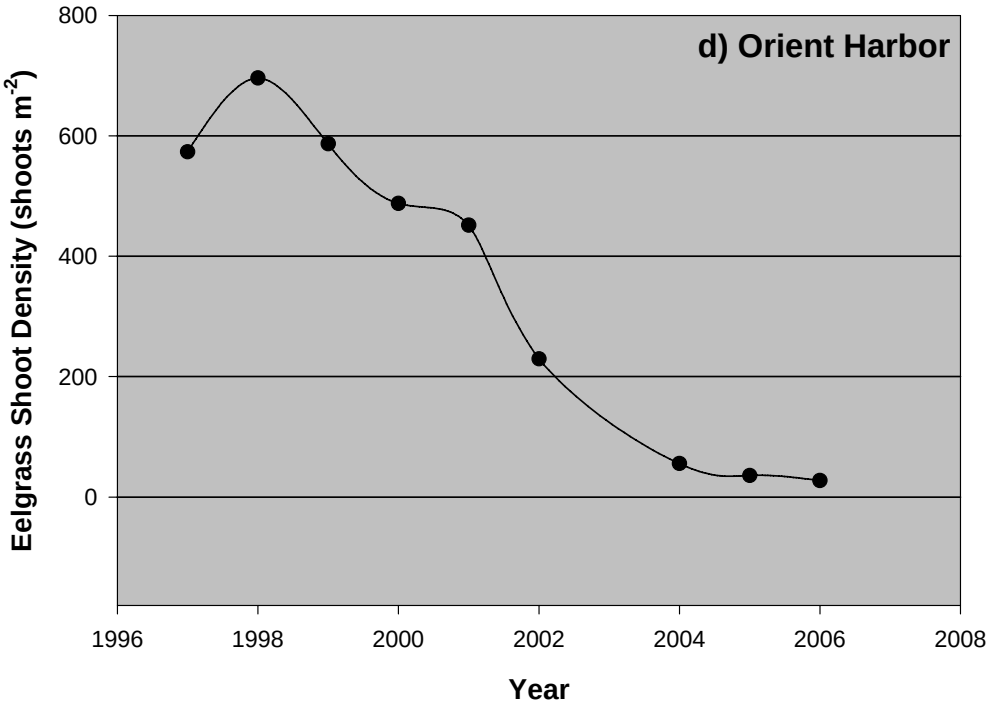

d) Sag Harbor
30
25
20
15
10
5
0
4/15/2006
4/22/2006
4/29/2006
5/6/2006
5/13/2006
5/20/2006
5/27/2006
6/3/2006
6/10/2006
6/17/2006
6/24/2006
7/1/2006
7/8/2006
7/15/2006
7/22/2006
7/29/2006
8/5/2006
8/12/2006
8/19/2006
8/26/2006
9/2/2006
9/9/2006
9/16/2006
9/23/2006
9/30/2006
10/7/2006
10/14/2006
10/21/2006
10/28/2006
11/4/2006
11/11/2006
11/18/2006
11/25/2006
12/2/2006
12/9/2006
12/16/2006
12/23/2006
12/30/2006

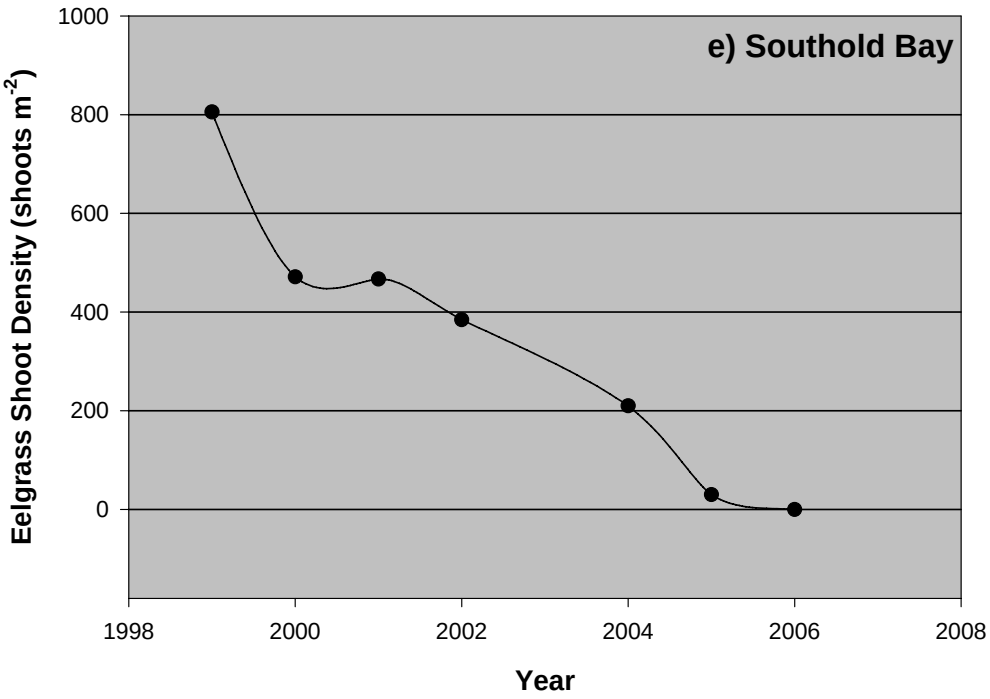
Appendix 2. Graphs of the mean eelgrass shoot densities for the six long-term monitoring sites. (Shoot density is expressed as shoots m^{-2}).

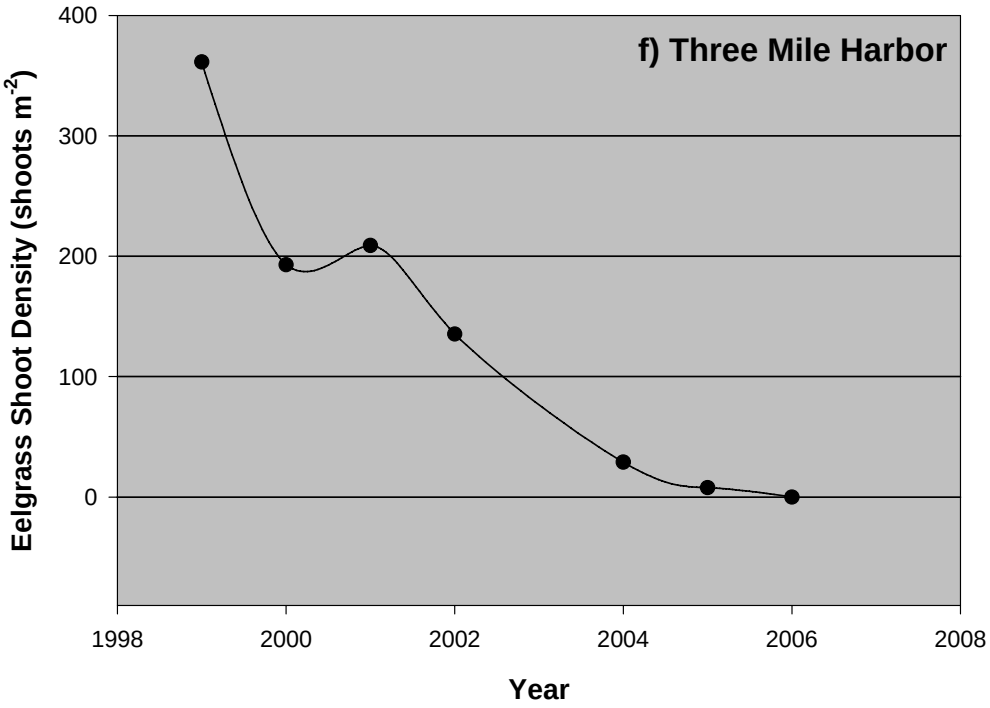



b) Gardiners Bay
Eelgrass Shoot Density (shoots m-2)
550
500
450
400
350
300
250
200
150
1998
2000
2002
2004
2006
2008
Year

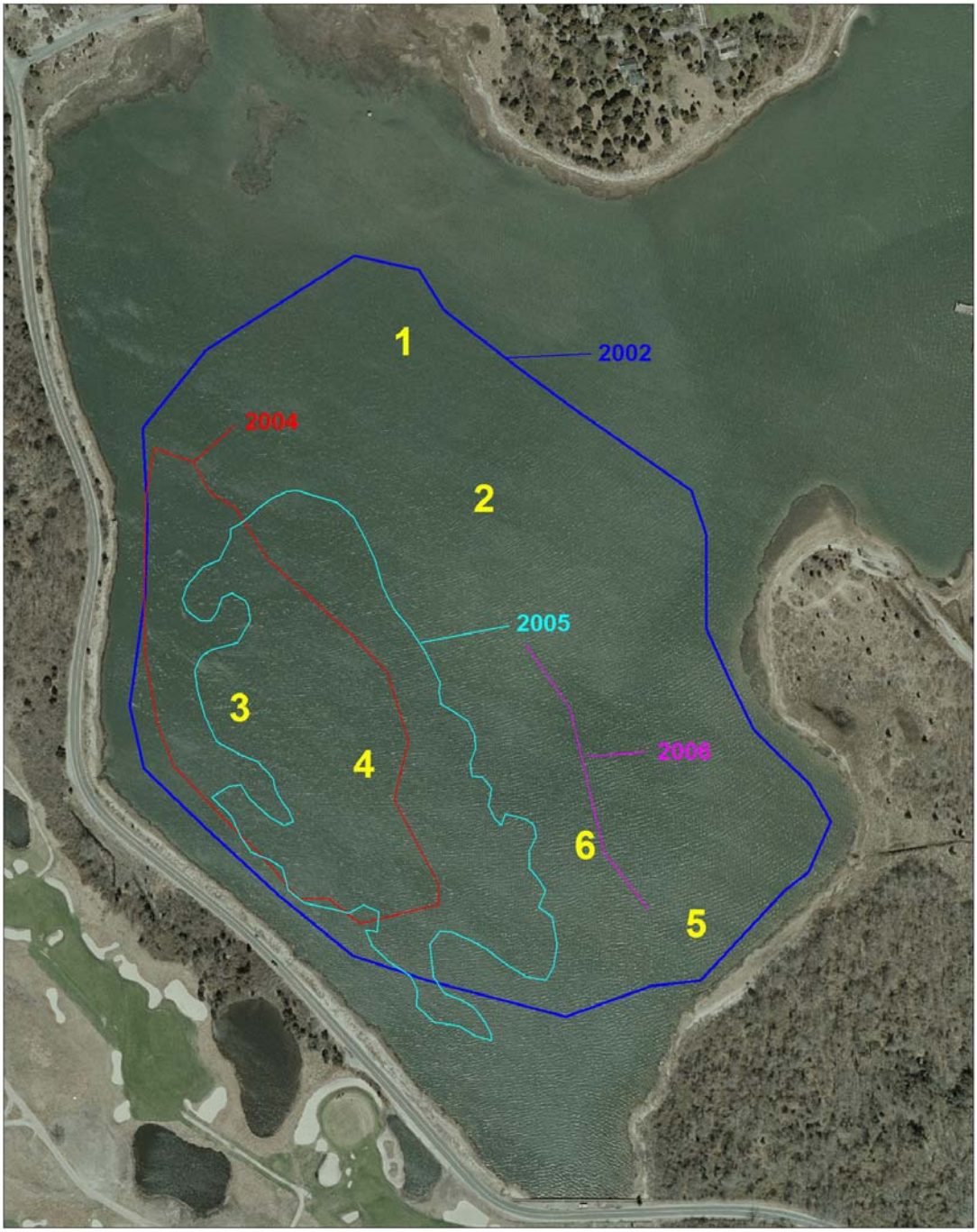

c) Northwest Harbor
Eelgrass Shoot Density (shoots m-2)
600
500
400
300
200
100
0
1996
1998
2000
2002
2004
2006
2008
Year


d) Orient Harbor
Eelgrass Shoot Density (shoots m-2)
800
600
400
200
0
1996
1998
2000
2002
2004
2006
2008
Year


e) Southold Bay
Eelgrass Shoot Density (shoots m-2)
1000
800
600
400
200
0
1998
2000
2002
2004
2006
2008
Year

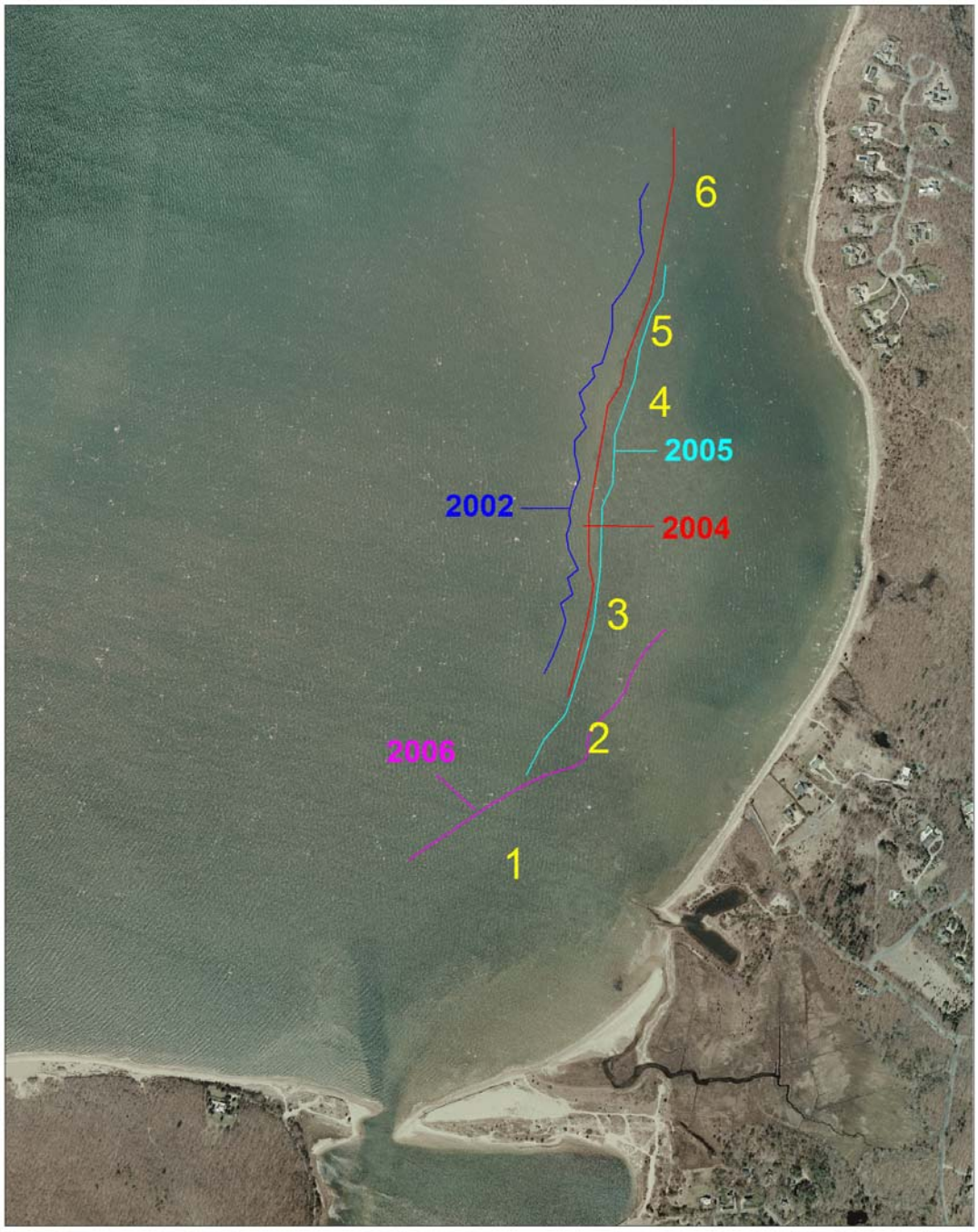

f) Three Mile Harbor
Eelgrass Shoot Density (shoots m-2)
400
300
200
100
0
1998
2000
2002
2004
2006
2008
Year

Appendix 3. Aerial photographs, with deep edge delineations, of the six monitoring sites for 2004. Monitoring stations are indicated by numbers (1-6) for each site.
a) **Bullhead Bay**

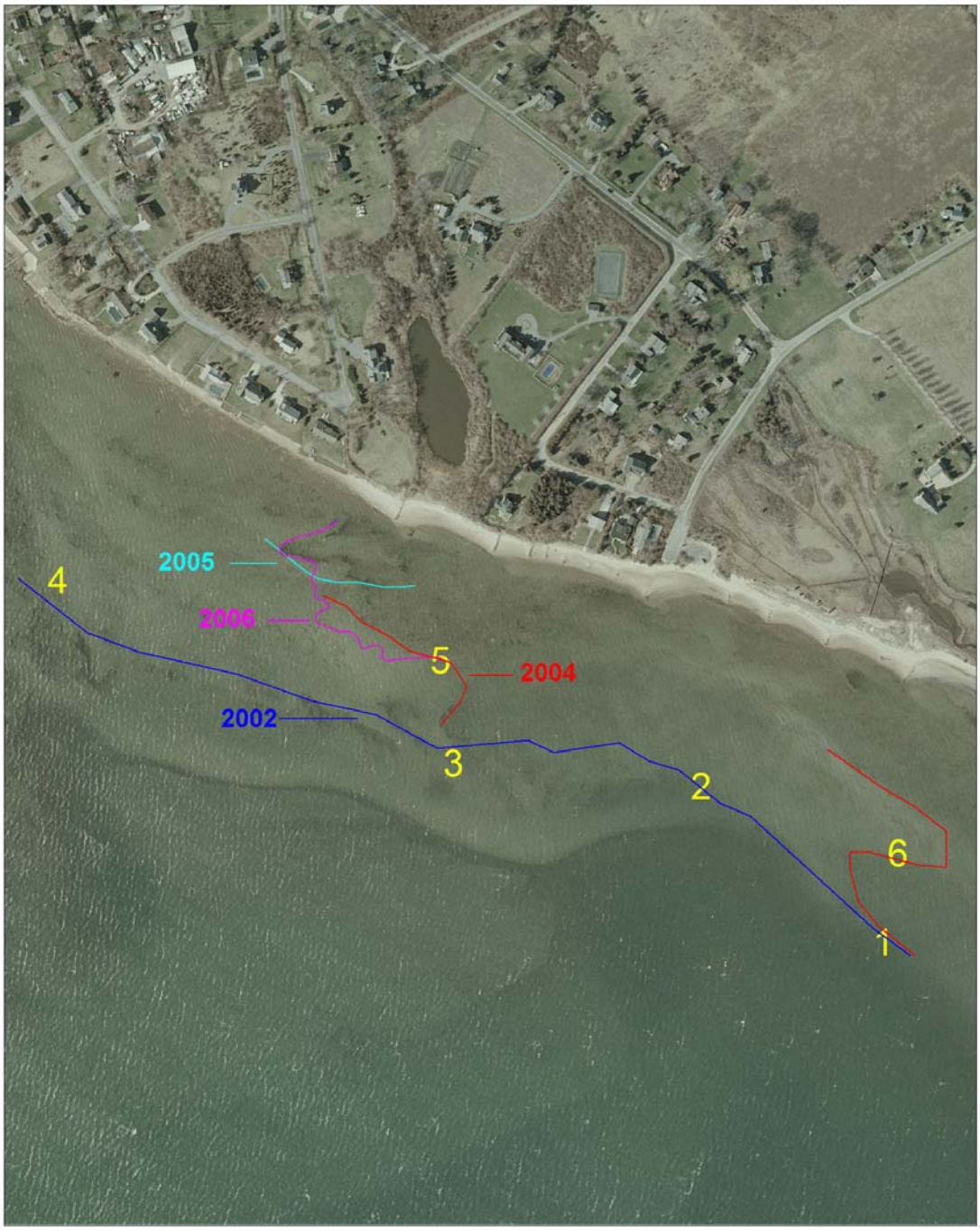


b) **Gardiner's Bay**

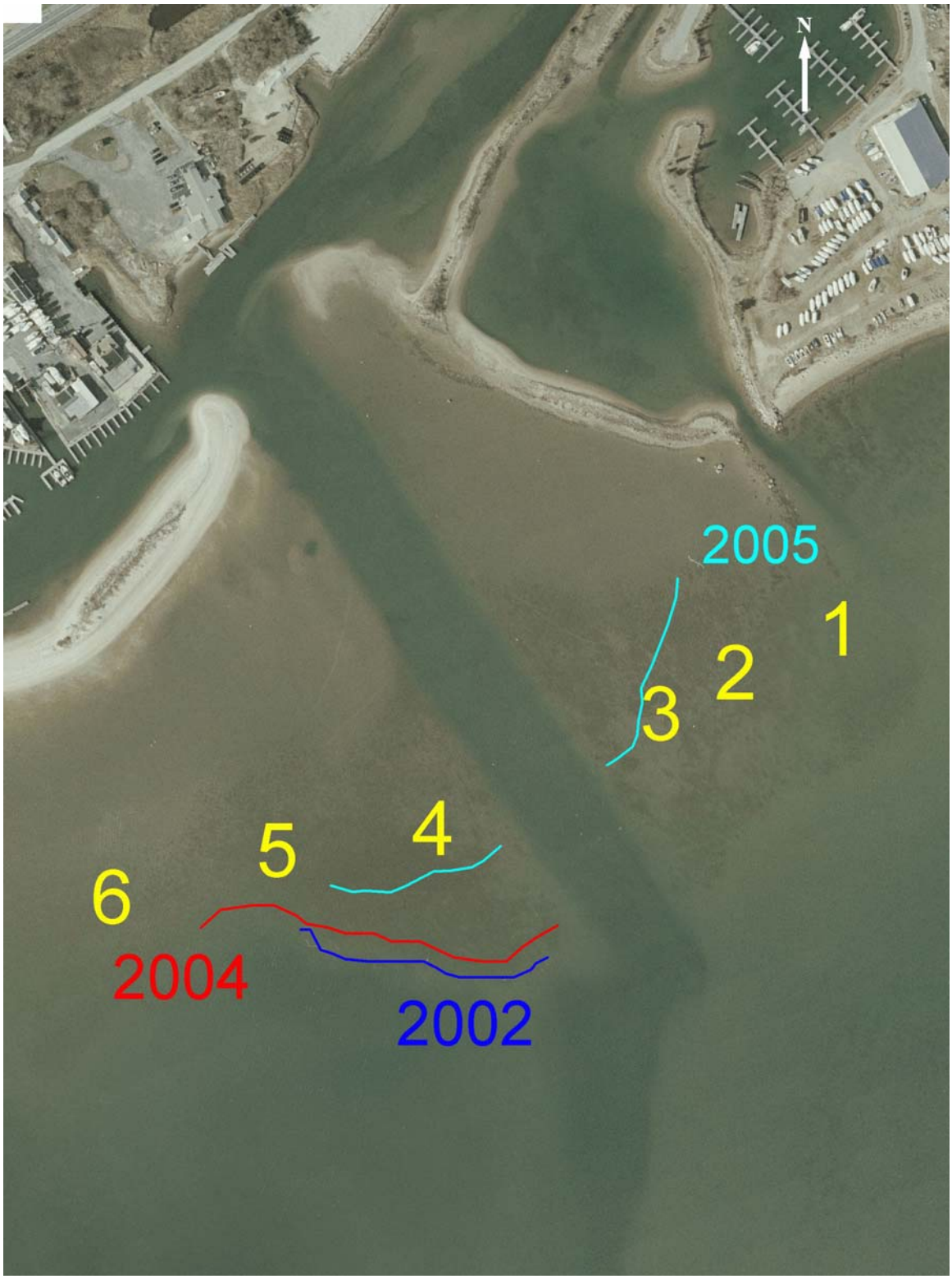
c) **Northwest Harbor**



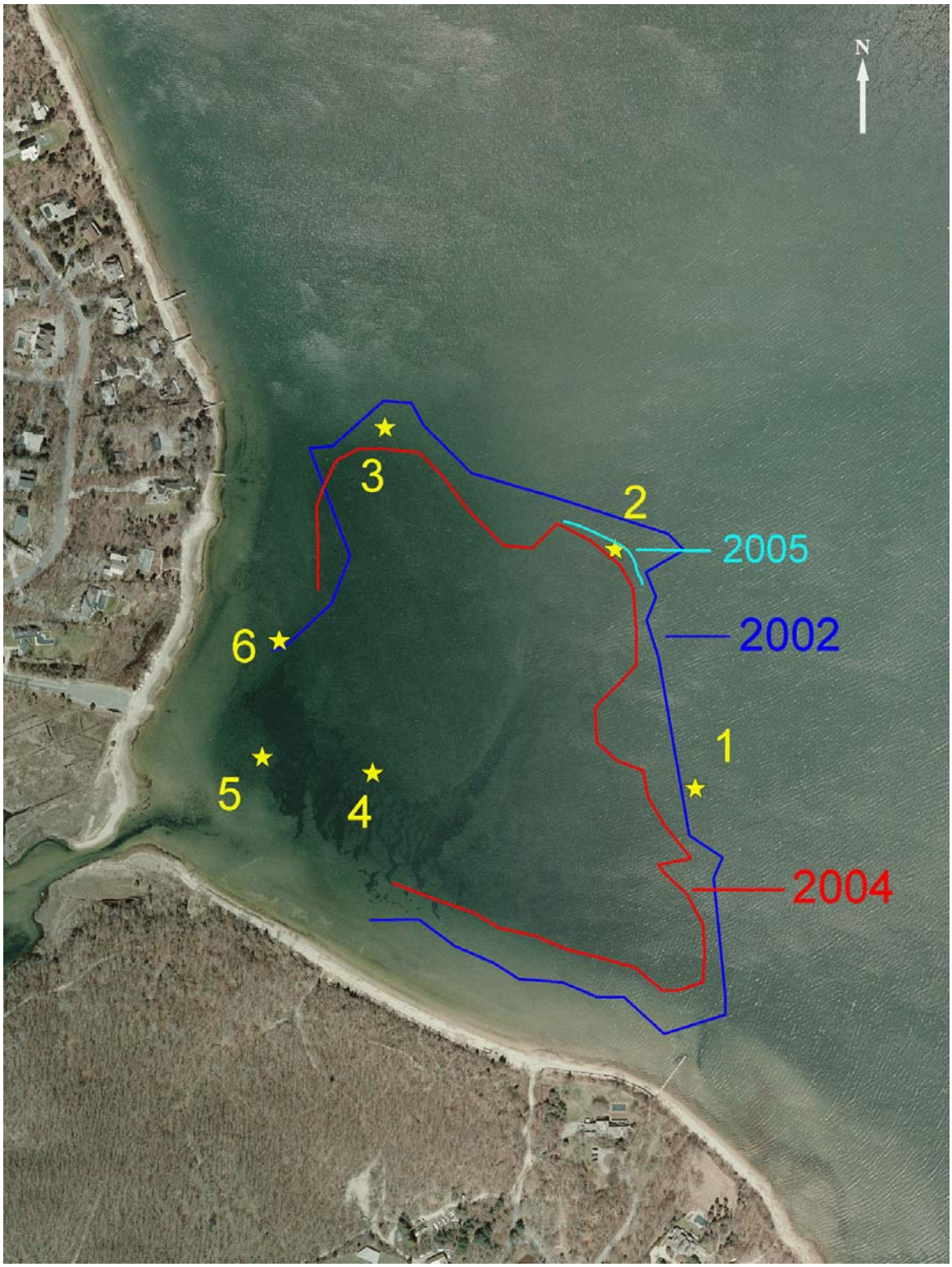
d) **Orient Harbor**



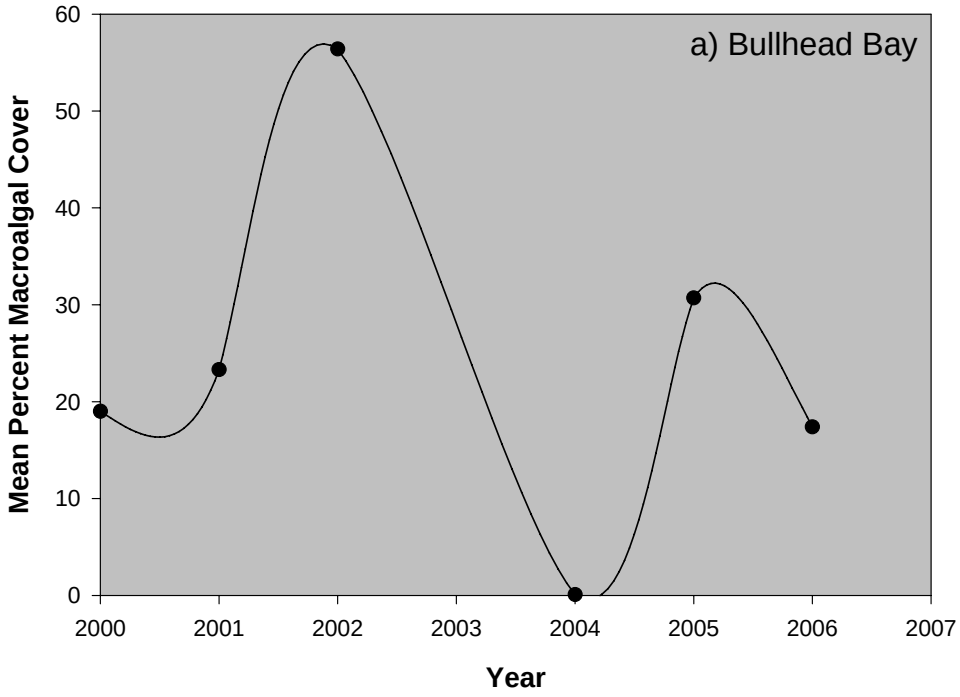
e) **Southold Bay** (note that there is no deep edge for 2006 due to almost complete loss of eelgrass)

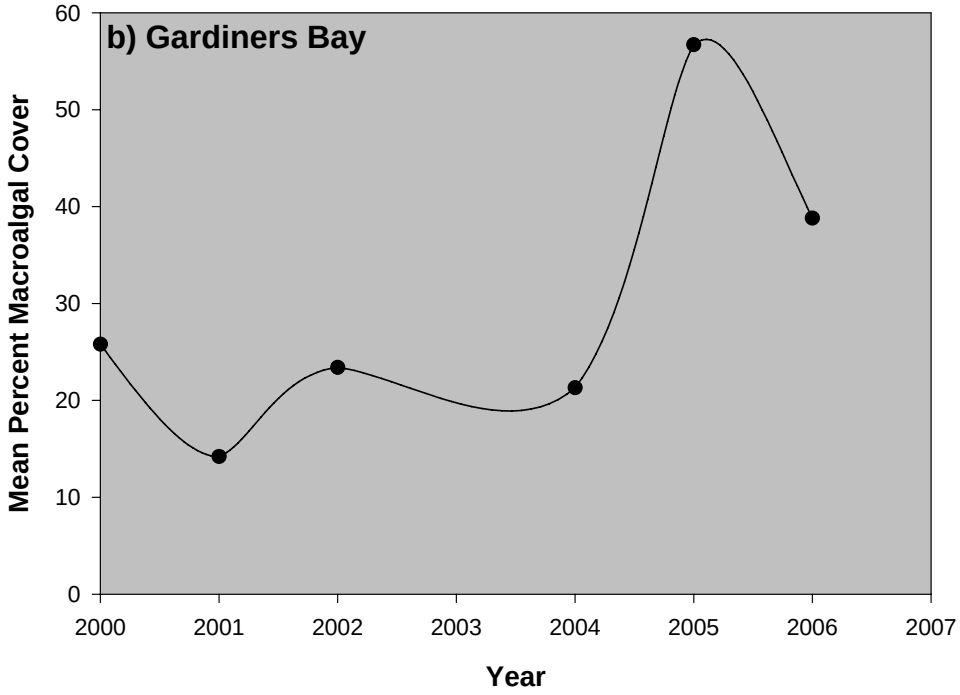


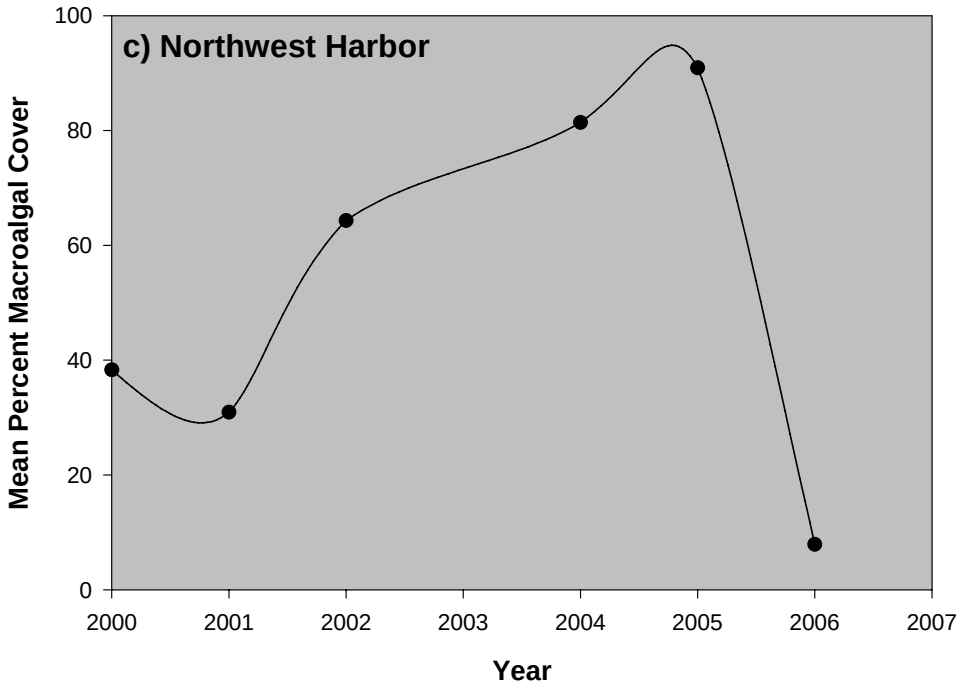
f) **Three Mile Harbor** (note that there is no 2006 delineation due to complete loss of eelgrass within monitoring area)

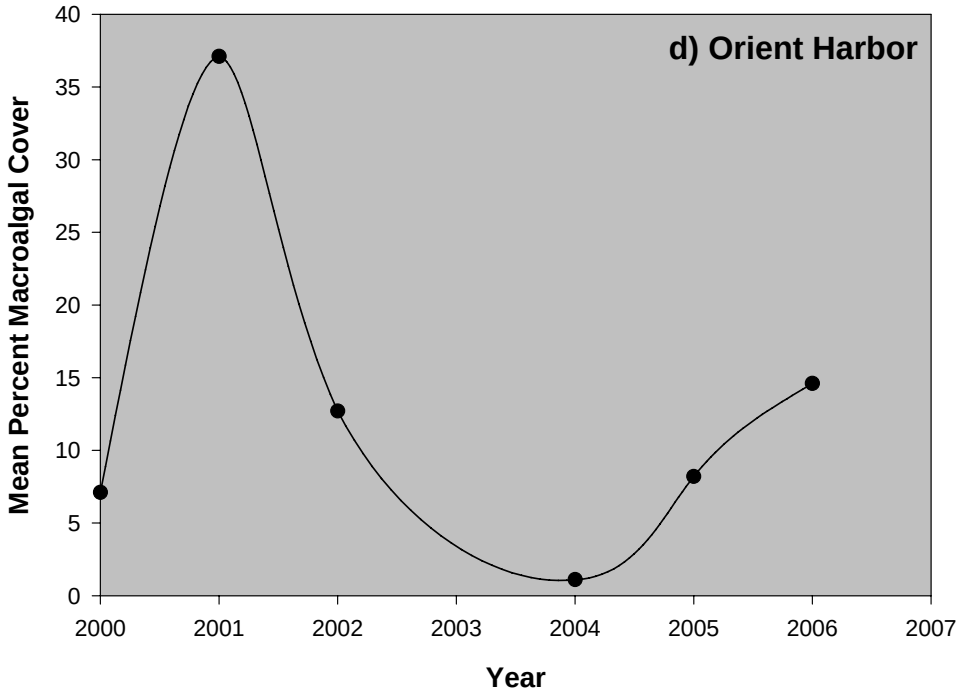


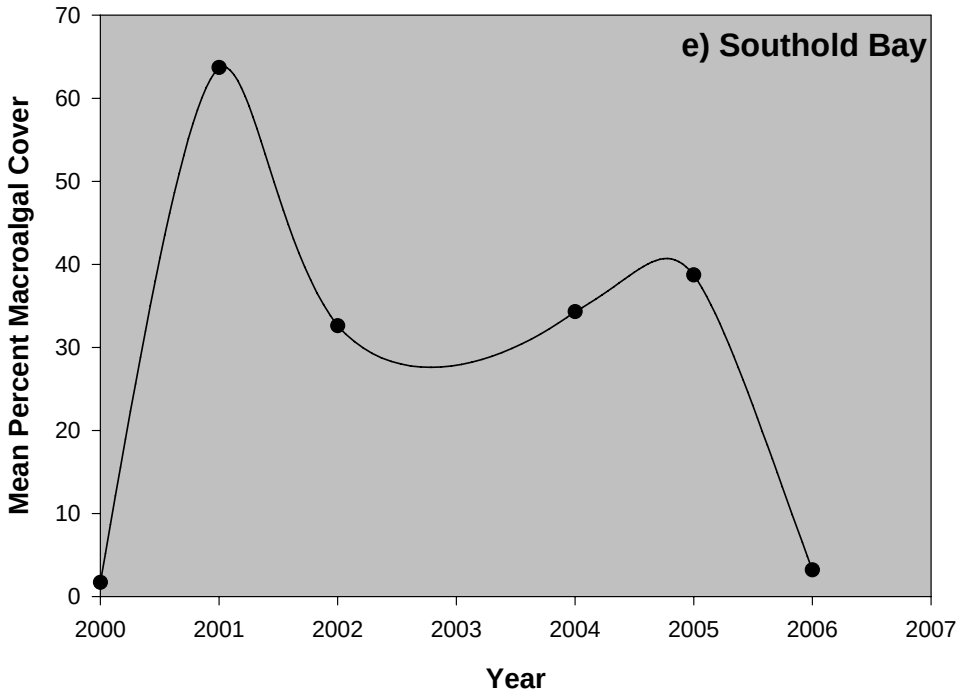
Appendix 4. Graphs representing the mean percent macroalgal cover at the six sites from 2000 to 2004.

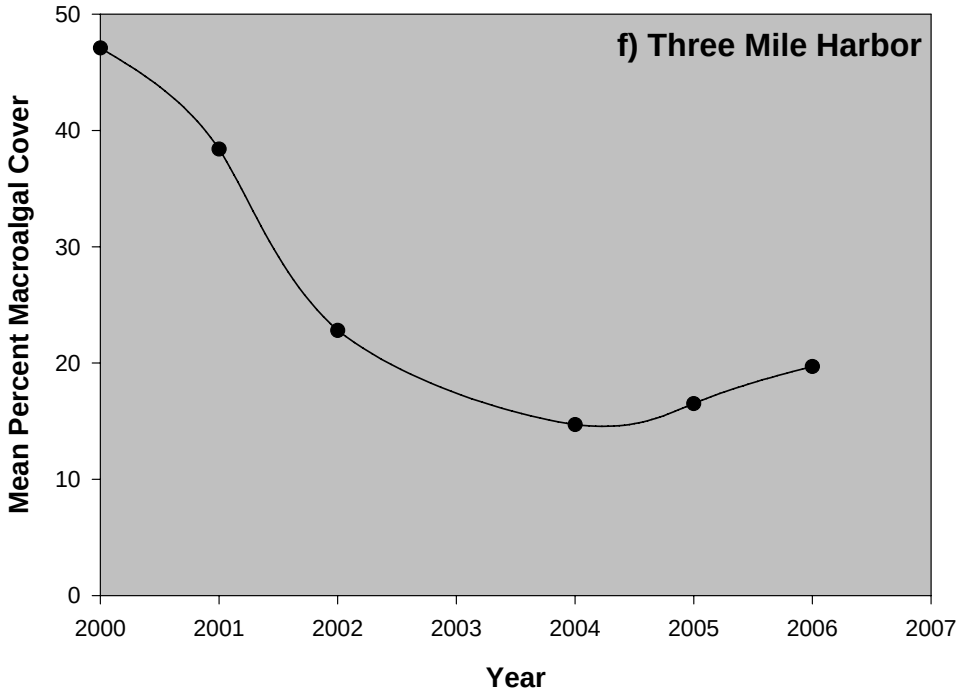



b) Gardiners Bay
Mean Percent Macroalgal Cover
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
2007
Year


c) Northwest Harbor
Mean Percent Macroalgal Cover
100
80
60
40
20
0
2000
2001
2002
2003
2004
2005
2006
2007
Year


d) Orient Harbor
Mean Percent Macroalgal Cover
0
5
10
15
20
25
30
35
40
2000
2001
2002
2003
2004
2005
2006
2007
Year


e) Southold Bay
Mean Percent Macroalgal Cover
0
10
20
30
40
50
60
70
2000
2001
2002
2003
2004
2005
2006
2007
Year


f) Three Mile Harbor
Mean Percent Macroalgal Cover
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
2007
Year