Final Report

To

Virginia Coastal Zone Management Program

By

THE VIRGINIA INSTITUTE OF MARINE SCIENCE
COLLEGE OF WILLIAM AND MARY

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Task 9.03 Restoration of Seagrasses in Virginia Seaside Bays – Year 4
(Oct. 1, 2005, to Sept. 30, 2006)

By

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INTRODUCTION

The system of barrier islands, coastal bays, and salt marshes along the Atlantic coast of Virginia's portion of the Delmarva Peninsula represent some of the most natural, unspoiled coastal habitat along the U.S. East Coast. Historically, finfish and shellfish resources in this region supported large fisheries. However, during the 1930s, this region underwent a dramatic ecological shift, and seafood harvests declined dramatically.

Seagrasses, primarily eelgrass, Zostera marina, were once very abundant in these coastal bays, covering most of the subaqueous bottom. In the 1930s eelgrass underwent a massive decline attributed to a wasting disease pathogen, Labyrinthula sp. (Rasmussen, 1977). The decline was pandemic, affecting not only populations in the coastal bays but also populations on both sides of the Atlantic. In August 1933, this region was affected by one of the most destructive hurricanes to influence the area in the twentieth century, contributing to the decimation of seagrasses in the bays. Natural recovery of seagrasses has been limited primarily to Chincoteague, Sinepuxent, Isle of Wight and Assawoman bays with little or no recovery in the Virginia coastal bays. This may be due to limited propagule supply and dispersal ability. Today, the Virginia coastal bays are primarily salt marsh and macroalgal dominated.

One of the most notable consequences of the loss of seagrass habitat in the coastal bays was the immediate collapse of a previously productive commercial bay scallop fishery, which is dependent on seagrasses as primary habitat. Almost certainly this loss of seagrass habitat resulted in declines in production of other commercially and ecologically important species, but little documentation of these impacts is available

We initiated a seagrass restoration program in the coastal bays, with efforts in Magothy Bay initiated in 1997, and South Bay in 1998, using test plots of adult transplants. The success of the test plots and the discovery of several natural patches in South Bay led us to conduct seed addition experiments there in 1999 and 2000. The success of the seed experiments and the sustained growth of previous transplants in South Bay led the Virginia Marine Resources Commission (VMRC) to designate a 400 acre area of subtidal habitat in South Bay to be set aside for seagrass restoration. In the fall of 2001, we broadcast 3.8 million seeds into 24-one acre parcels in the 400-acre set aside area. In addition we broadcast 600,000 seeds into 4 one-acre parcels in lower Cobb Island Bay and 600,000 seeds into 6 one-acre plots in Magothy Bay. We continued the large scale restoration of seagrass in South Bay in 2002 by broadcasting 1.8 million seeds into an additional 24 one acre plots at seed densities of 50 and 100K seeds (12 one acre areas at each seed density). In 2003 we broadcast 1.7 million seeds into 35 0.5 acre circular plots at 4 seed densities in both Cobb and Spider Crab bays. In 2004 we distributed approximately 7 million seeds in spring and fall plantings into 39 acres. In 2005, we broadcast 1.5 million seeds into 22 ½ acre plots (11 acres).

A notable milestone of the seaside restoration effort in 2005 was the request to, and subsequent approval by the Virginia Marine Resources Commission of a 500 acre set aside near High Shoal Marsh in Hog Island Bay for 5 years (Fig. 1). In 2006 VMRC approved the continuance of our set aside in South Bay along with a request for an additional 366.36 acres, giving us a total of 727.85 acres as set aside in South Bay. This mirrors the 400 acre set aside in South Bay that was approved in 2001, and allows the continuation of successful seagrass restoration efforts without issues relating to clam dredging and aquaculture leases. Much of the area in Hog Island Bay is leased either to aquaculture or to individuals involved in clam dredging, and little area in the public grounds is suitable for eelgrass restoration

This final report details accomplishments in each of the stated objectives for year 4 of the seagrass restoration program.

TASK 1 - ESTABLISHMENT OF TEST PLOTS FOR ADDITIONAL LARGE SCALE EFFORTS IN THE HOG ISLAND BAY AREA

Replicate test plots (1 m^2) of adult plants (8 planting units (PU) with 2 adult shoots each) and seeds (1000 seeds) were planted or broadcast in the fall, 2005, at three locations in the set aside area, as well as at three additional sites in the 'Public Grounds' area near Rams Horn Marsh, where 9 sets of test plots were planted in 2004 and monitored through 2005 (see below) (Fig. 1). Test plot locations were chosen to represent the range of depths across which we expect eelgrass to succeed in the coastal bays, based on bathymetric data collected by UVA's LTER research group for both the set aside area and public ground. The planting of adult plants and seeds followed previously established protocols established by VIMS and used in the 2002 and 2003 plantings.

TASK 2 – MONITOR SUCCESS OF TEST AND ESTABLISHED SEAGRASS AREAS

a.) Test Plots. Test plots of adult plants and seeds established in October 2005 in Hog Island Bay (Figure 1) were monitored in April, June, and September, 2006 (Figure 2). Plots in the new set-aside near High Shoal Marsh in Hog Island Bay were generally successful through September. Adult plants performed extremely well at shallow and middle depths, while seedlings expanded coverage through the summer only at the shallow site. Plots near Rams Horn Marsh did not survive through the summer of 2006, the second year in a row, suggesting this area may not be suitable for future seagrass restoration.

b.) Previously established large scale plots. Ground observations indicate substantial growth and expansion of restored areas in South Bay, both within and outside the boundaries of the original seed distribution plots. In April 2006, several transect surveys were performed to asses spread of eelgrass outside the original 2001 and 2002 distribution areas at the southern end of the restoration site. Results indicate extensive spread of eelgrass, probably by reproductive shoots floating away from the original plots, over hundreds of meters from the plot boundaries (Figure 3). In December 2006, we acquired low-level aerial photography of multiple restoration areas. Substantial fill-in of eelgrass between the original plots is evident (Figure 4). The repeated photography documents a previously unobserved interaction of the thickening eelgrass with sand movement at the restoration site: several areas of high density eelgrass visible in the 2004 photographs increased the deposition of sand sufficiently to cause localized shoaling, to the extent that we believe eelgrass became exposed at low tide and subsequently died back to form the "blowouts" visible as light patches in the 2006 photographs. Site visits during extreme low tides have confirmed that shoaled locations may become exposed.

TASK 3 – COLLECT SEEDS FOR 2006 EFFORTS

In 2006, many of our standard seed donor beds had no flowering shoots, because they were recovering from the 2005 dieback. The seedlings that allowed some recovery of these areas in 2006 do not produce flowering shoots until their second year. We chose not to use our mechanized harvester, in order to reduce impact on these recovering beds, and to better target high densities of reproductive shoots in beds instead collected seeds using only hand collections only. In total, we collected approximately 1.6 million seeds for distribution in Hog Island Bay. For the first time, we visited the previously restored beds in South Bay, and found substantial numbers of reproductive shoots bearing high densities of seeds. We collected approximately 8% of our season's total seed harvest from South Bay.

TASK 4 – WATER QUALITY MEASUREMENTS USING FIXED STATION CONTINUOUS MONITORS AND SURFACE MAPPING OF WATER QUALITY WITH DATAFLOW

During 2006, continuous underway sampling (DATAFLOW) and fixed station water quality measurements were made in the Virginia Coastal Bays restoration area. The DATAFLOW cruise track conducted in 2006 (Figure 5) traversed transplant restoration areas in South Bay, Cobb Bay, Spider Crab Bay, and Hog Island Bay. Cruises were conducted monthly throughout the seagrass growing season on March 30, April 17, May 16, June 29, July 14, August 28, October 11 and November 29. A YSI 6600 was deployed at a fixed monitoring station at the Wreck Island restoration site in South Bay at bi-monthly intervals throughout the growing season over the following range of dates; April 4 to April 25, June 16 to July 10, August 19 to September 4 and October 2 to October 18.

The DATAFLOW underway sampler recorded in vivo measurements of surface water quality taken at 2-3 second intervals (0.25 m depth; approximately every 50 m) along each cruise track. Measurements included turbidity (NTU), chlorophyll fluorescence, temperature, salinity, pH, dissolved oxygen, GPS location and depth using a YSI 6600 EDS sensor array (Yellow Springs Instruments, Inc.). In addition to the continuous underway sensor measurements, eight calibration and verification stations were sampled at discrete stations along each cruise track for total suspended solids, light attenuation profiles, secchi disk measurements, extracted pigment chlorophyll and dissolved oxygen via Winkler Titration. Concurrent with every other cruise (bi-monthly), two week deployments of a YSI 6600 EDS sensor array identical to that used in the DATAFLOW sampler were undertaken at the South Bay Wreck Island restoration site. Here, water quality was measured at 15-minute intervals throughout each 2-week deployment. These deployments bracketed, by approximately one week, each DATAFLOW water quality, monitoring cruise.

Figures 6, 7, 8, and 9 present the continuous underway DATAFLOW cruise tracks of water quality measurements for turbidity, chlorophyll, and salinity for the four monthly cruises that were paired with fixed monitoring station deployments during the SAV growing season in 2006. Results of the other cruises showed similar trends. The location of the fixed, continuous monitoring station is highlighted with a circle, and the transplant areas are highlighted with rectangles on each cruise figure.

Salinities were found to be very consistent over the course of the 2006 SAV growing season and rarely dropped below 30 ppt throughout the Coastal Bays area. This is similar to previous years' results and illustrates the relatively consistent salinity environment of near full strength seawater found here. Full strength seawater (salinity of 35 ppt) has been found to be near optimum for eelgrass growth. Salinities among the various transplants sites were very similar and typically were found to be within 1-2 ppt.

Low water column chlorophyll levels were typical of both the transplant sites and the coastal bay regions throughout 2006, with concentration typically below 5 ug/l. In the Chesapeake Bay chlorophyll levels of 15 µg/l or greater have been associated with SAV habitats that are under stress or in decline. As with salinity, chlorophyll levels appear consistent among the sites.

Turbidity levels varied throughout the region with highest levels often observed in the western Coastal Bays region near Oyster, VA, especially during the spring. Turbidity levels were usually lower over the four restoration areas. The Hog Island Bay site typically had the lowest turbidities. A region of high turbidity was observed between the South Bay and Hog Island Bay sites. This may have been related to inlet dynamics, which was typically a location of high wave and currents. Other regions of high turbidity were also observed through the area sampled by DATAFLOW. Most of these areas were associated with high turbidities within or near marsh creeks. We have determined that turbidity levels of 10 NTU or less in the Virginia Coastal Bays are equivalent to a light attenuation coefficient (K_d) of ≤ 1.5 m^{-1}. In the Chesapeake Bay these light attenuation levels have been associated with shallow water areas where SAV have been found growing to depths of 1m at MLW.

Continuous records of turbidity, chlorophyll, temperature and depth for the four, bi-monthly fixed monitoring station deployments are presented in Figures 10, 11, 12 and 13. Tides ranged from 1 – 2 meters. Higher than normal storm tide levels were evident in September and October and during these periods turbidity levels exceeded 100 NTU. Elevated chlorophyll levels as well as slight decreases in water temperature also characterized these stormy periods. The elevated water column chlorophyll levels were likely due to re-suspended benthic microalgae as their patterns of increase paralleled overall turbidity increases. Rapid declines also suggest re-settlement.

Tidal cycles and waves appear to play important roles in affecting both turbidity and the phytoplankton component of the turbidity in the South Bay restoration area again in 2006. There was a distinct tidal periodicity to the chlorophyll and turbidity levels with higher concentrations evident during high tides. On most low tides both turbidity and phytoplankton levels dropped (Figures 10, 11, 12, and 13), suggesting that a rapid settling of particles and clearing of the water was occurring. In addition, as in 2005, water temperatures did not exceed 30 C during the sampling periods and decreased 1-2 C with every high tide. This influx of cooler coastal water is in contrast to eelgrass beds in the

Chesapeake Bay where water temperatures may exceed 30 C during the summer, resulting in heat stress and other factors that negatively affect eelgrass survival.

Table 1 summarizes the turbidity and chlorophyll constituents of water quality at South Bay during the four bi-monthly sampling periods in 2006 as well as the three, intensive sampling periods for 2005. Mean values highlighted in red indicate they are above water quality habitat thresholds of 15 ug/l chlorophyll and 10 NTU. Extremely high, single point spikes that may have been due to sensor optical fouling or blockage were removed for these summaries. Mean values were high in both the August-September and October-November periods due in large part to storm events of 2 to 4 day duration. Turbidity levels were below the 10 NTU threshold in April but above for the other sampling periods. Turbidity levels were generally higher than predicted given the successful eelgrass growth results. Re-suspended inorganic particles common in the coastal bays, while increasing turbidity and light scatter, typically result in less light absorption of photosynthetically important wavelengths than organic particles found in the Chesapeake Bay. Therefore this increased light quality compensates for the relative higher turbidity. Also, the relatively high tidal ranges found in this region, provide for much shallower conditions at low tidal periods. Light availability at these low tidal periods would be high. In the Chesapeake Bay, period of low tides during the summer are also potential periods for high temperature stress. This does not appear to be a problem currently in the coastal bays.

TASK 5 – LARGE SCALE SEAGRASS RESTORATION

In 2006 we established 28 plots in Hog Island Bay, each covering either 0.5 or 1.0 acres and receiving either 50,000 or 100,000 seeds per acre (Fig. 1). A total of 1.6 million seeds were broadcast by hand across a total area of 21 acres. Plots were spaced across the High Shoal Marsh set-aside in a pattern that spread the various size and density combinations across shallow, medium, and deep sites, allowing future evaluation of optimal density and size for each depth zone.

TASK 6 – MAPPING OF SEAGRASS FROM OF AERIAL PHOTOGRAPHS

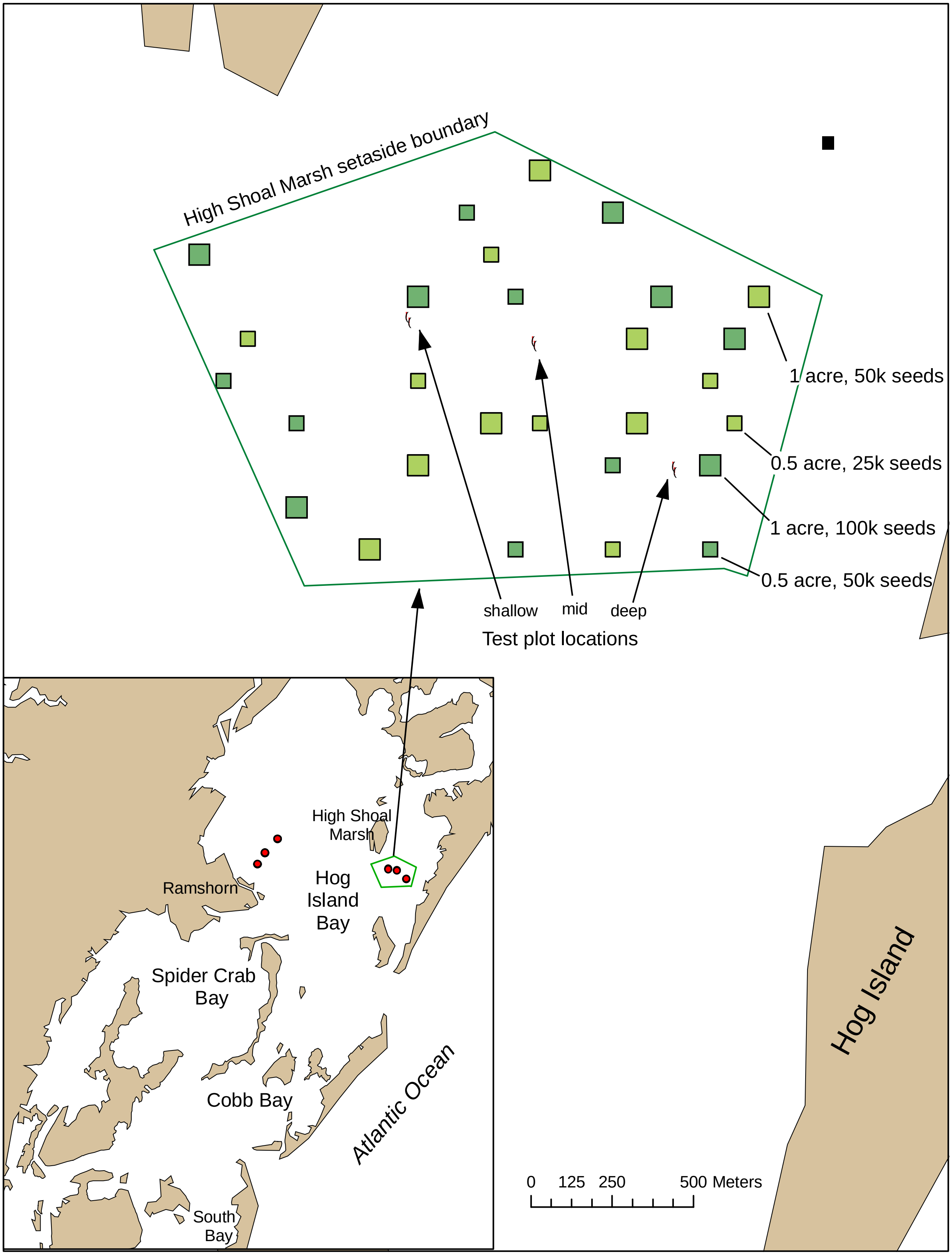
High-level black and white aerial photographs were taken in November 2005 and February 2006. The late photography was necessitated by poor atmospheric conditions earlier in the year, restricting the acquisition to a much later date than anticipated. Because of the late season dieback by eelgrass which was not as pronounced in the coastal bays a s it was in the Chesapeake Bay, eelgrass beds were not mapped as the lack of good 'grass' signatures precluded accurate mapping.

Table 1. Mean, minimum, and maximum values of turbidity and chlorophyll at the continuous monitoring station in South Bay for the dates of deployment in 2005 and 2006

Deployment Dates	Turbidity			Chlorophyll		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
May 19-June4, 2005	13.3	4.0	75.1	3.5	0.3	23.8
July 20-Aug 4, 2005	16.3	4.2	104.6	4.5	0.9	61.0
September 19-28, 2005	18.1	5.1	147.4	2.9	0.9	9.9
April 10-April 25, 2006	7.0	1.8	28.3	1.2	0.0	8.3
June 16-July 10, 2006	12.2	2.1	286.3	6.0	0.9	124.2
Aug 19-Sept 24, 2006	26.8	3.5	193.1	3.4	1.1	24.5
Oct 10-Nov 3, 2006	22.7	3.6	219.7	3.7	0.9	9.5

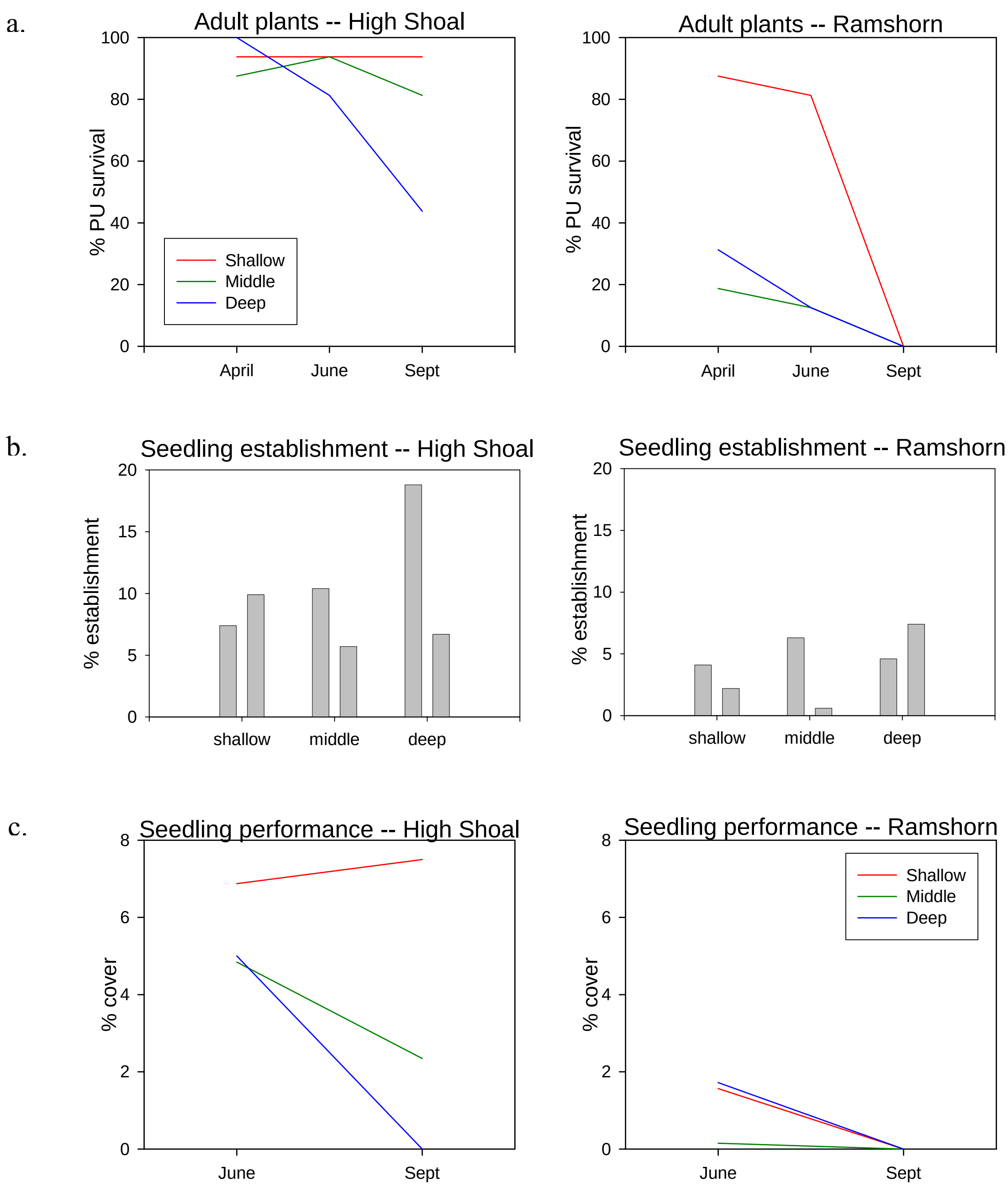
LIST OF FIGURES

Figure 1



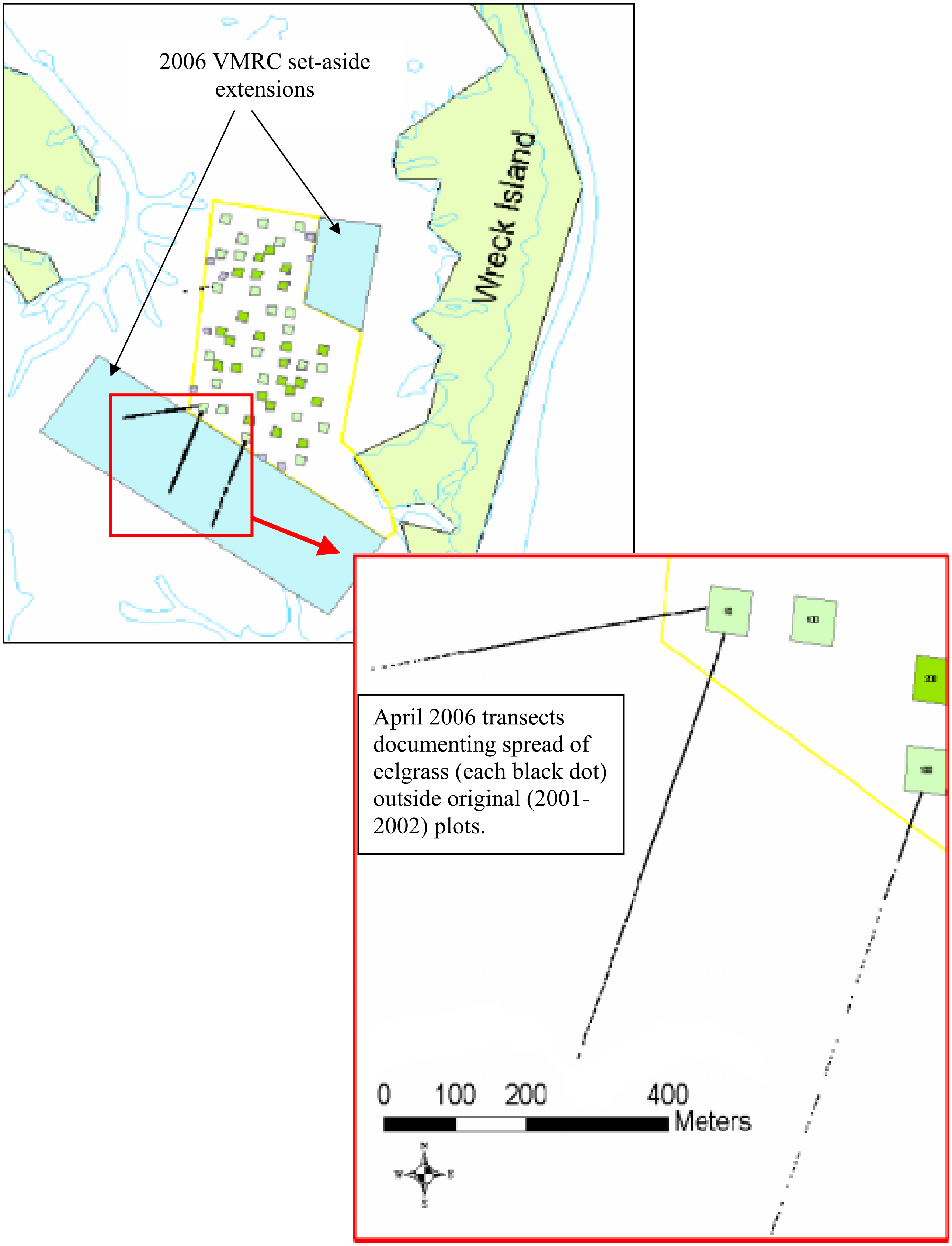
High Shoal Marsh setaside boundary
1 acre, 50k seeds
0.5 acre, 25k seeds
1 acre, 100k seeds
0.5 acre, 50k seeds
shallow
mid
deep
Test plot locations
High Shoal Marsh
Ramshorn
Hog Island Bay
Spider Crab Bay
Cobb Bay
Atlantic Ocean
South Bay
0 125 250 500 Meters
Hog Island

Figure 2



a.
Adult plants -- High Shoal
% PU survival
100
80
60
40
20
0
April
June
Sept
Shallow
Middle
Deep
Adult plants -- Ramshorn
% PU survival
100
80
60
40
20
0
April
June
Sept
b.
Seedling establishment -- High Shoal
% establishment
20
15
10
5
0
shallow
middle
deep
Seedling establishment -- Ramshorn
% establishment
20
15
10
5
0
shallow
middle
deep
c.
Seedling performance -- High Shoal
% cover
8
6
4
2
0
June
Sept
Seedling performance -- Ramshorn
% cover
8
6
4
2
0
June
Sept
Shallow
Middle
Deep

Figure 3

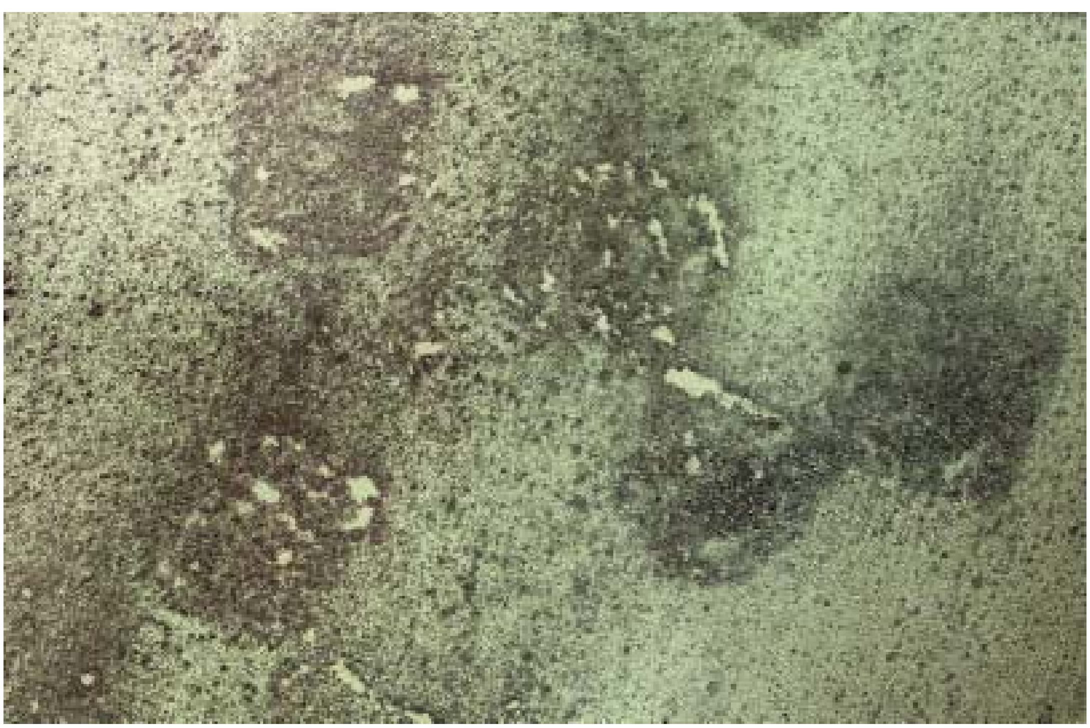


2006 VMRC set-aside extensions
Wreck Island
April 2006 transects documenting spread of eelgrass (each black dot) outside original (2001-2002) plots.
0
100
200
400
Meters

Figure 4

a.) 2004 low-level aerial photograph of South Bay plots seeded in 2001 or 2002

b.) December 2006 photograph of the same area



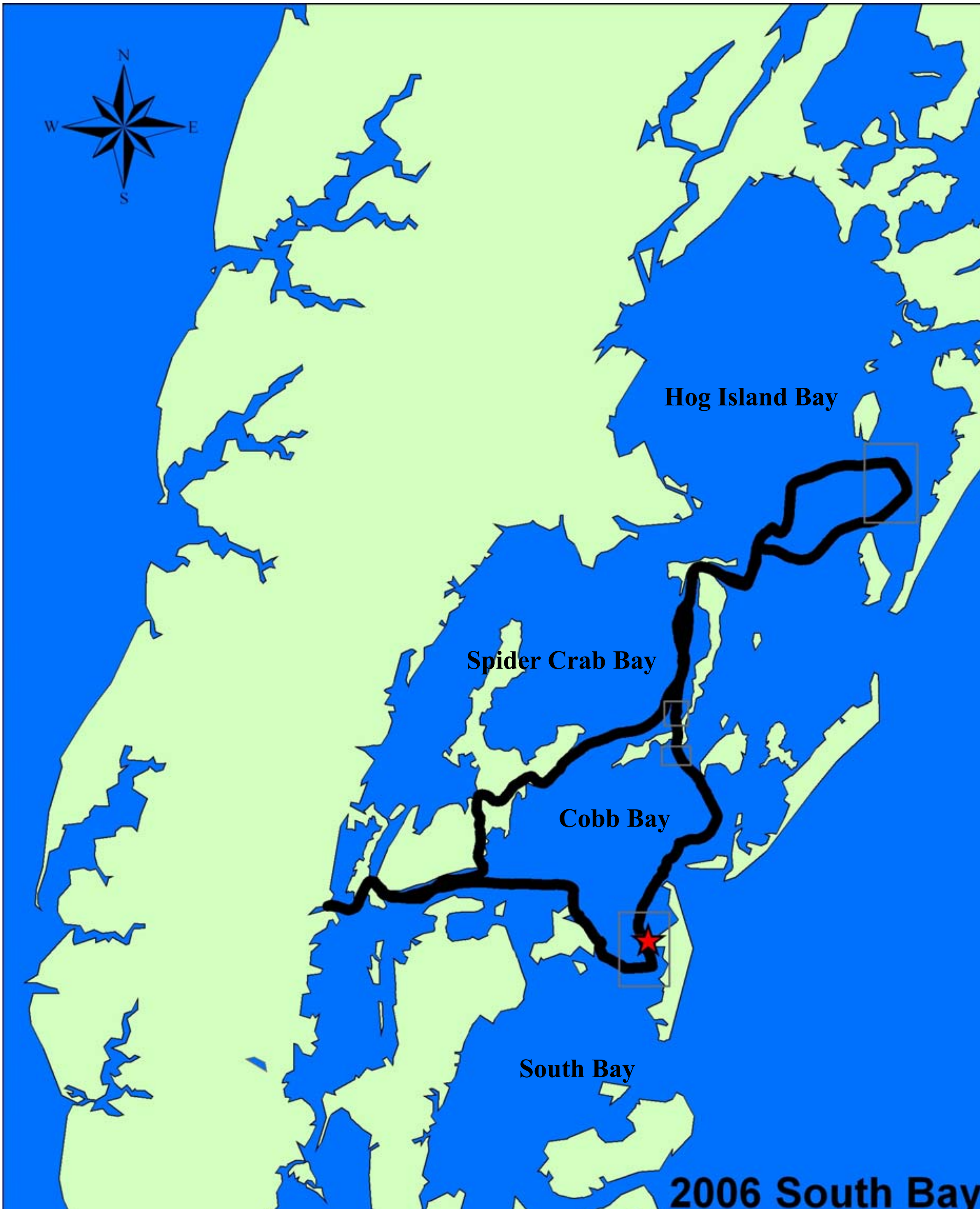
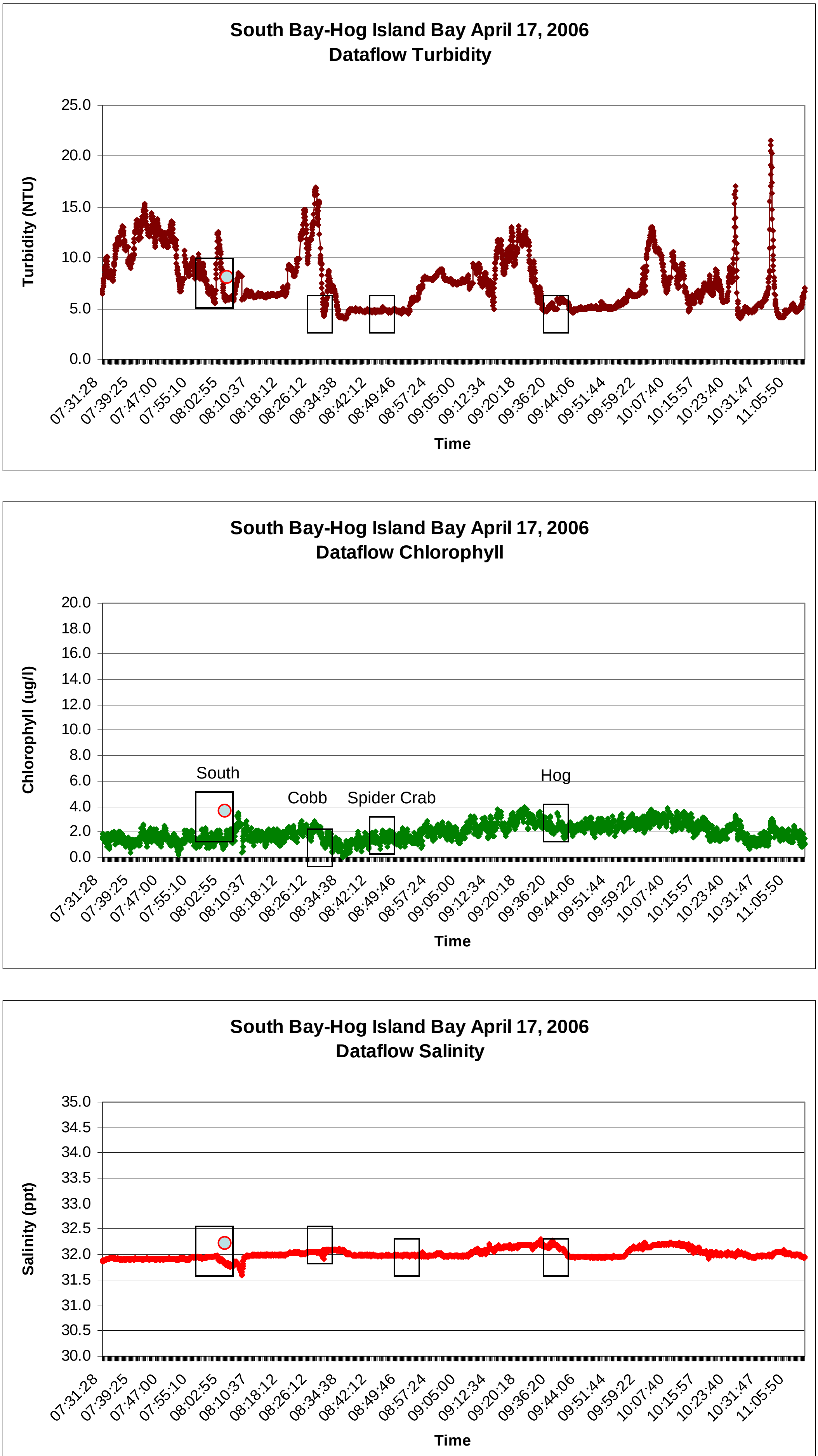

N
W
E
S
Hog Island Bay
Spider Crab Bay
Cobb Bay
South Bay
2006 South Bay
Fixed Station
Dataflow Track

FIG. 6



South Bay-Hog Island Bay April 17, 2006
Dataflow Turbidity
Turbidity (NTU)
25.0
20.0
15.0
10.0
5.0
0.0
07:31:28
07:39:25
07:47:00
07:55:10
08:02:55
08:10:37
08:18:12
08:26:12
08:34:38
08:42:12
08:49:46
08:57:24
09:05:00
09:12:34
09:20:18
09:36:20
09:44:06
09:51:44
09:59:22
10:07:40
10:15:57
10:23:40
10:31:47
11:05:50
Time
South Bay-Hog Island Bay April 17, 2006
Dataflow Chlorophyll
Chlorophyll (ug/l)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
South
Cobb
Spider Crab
Hog
07:31:28
07:39:25
07:47:00
07:55:10
08:02:55
08:10:37
08:18:12
08:26:12
08:34:38
08:42:12
08:49:46
08:57:24
09:05:00
09:12:34
09:20:18
09:36:20
09:44:06
09:51:44
09:59:22
10:07:40
10:15:57
10:23:40
10:31:47
11:05:50
Time
South Bay-Hog Island Bay April 17, 2006
Dataflow Salinity
Salinity (ppt)
35.0
34.5
34.0
33.5
33.0
32.5
32.0
31.5
31.0
30.5
30.0
07:31:28
07:39:25
07:47:00
07:55:10
08:02:55
08:10:37
08:18:12
08:26:12
08:34:38
08:42:12
08:49:46
08:57:24
09:05:00
09:12:34
09:20:18
09:36:20
09:44:06
09:51:44
09:59:22
10:07:40
10:15:57
10:23:40
10:31:47
11:05:50
Time

FIG. 7

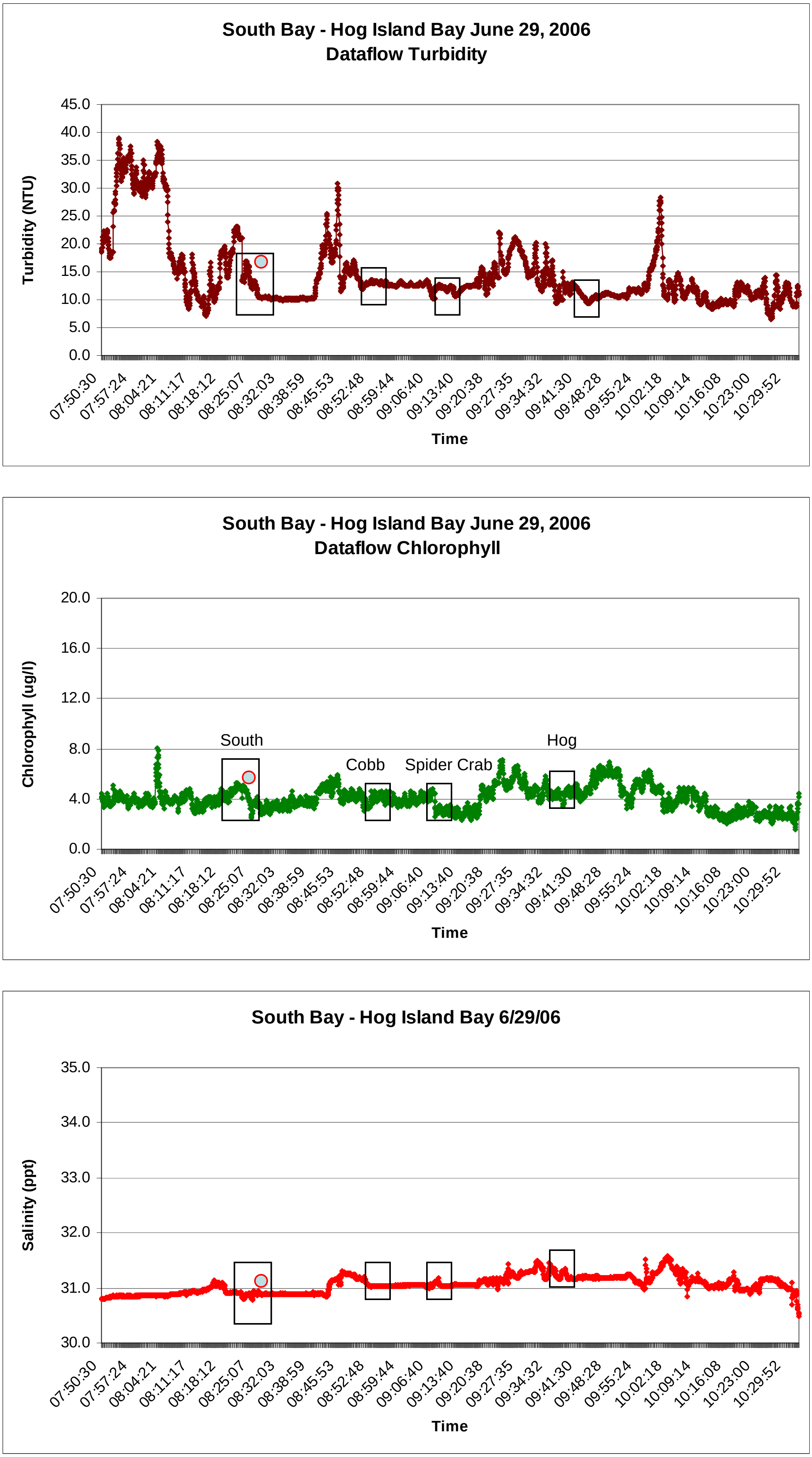

South Bay - Hog Island Bay June 29, 2006
Dataflow Turbidity
Turbidity (NTU)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
07:50:30
07:57:24
08:04:21
08:11:17
08:18:12
08:25:07
08:32:03
08:38:59
08:45:53
08:52:48
08:59:44
09:06:40
09:13:40
09:20:38
09:27:35
09:34:32
09:41:30
09:48:28
09:55:24
10:02:18
10:09:14
10:16:08
10:23:00
10:29:52
Time
South Bay - Hog Island Bay June 29, 2006
Dataflow Chlorophyll
Chlorophyll (ug/l)
20.0
16.0
12.0
8.0
4.0
0.0
South
Cobb
Spider Crab
Hog
07:50:30
07:57:24
08:04:21
08:11:17
08:18:12
08:25:07
08:32:03
08:38:59
08:45:53
08:52:48
08:59:44
09:06:40
09:13:40
09:20:38
09:27:35
09:34:32
09:41:30
09:48:28
09:55:24
10:02:18
10:09:14
10:16:08
10:23:00
10:29:52
Time
South Bay - Hog Island Bay 6/29/06
Salinity (ppt)
35.0
34.0
33.0
32.0
31.0
30.0
07:50:30
07:57:24
08:04:21
08:11:17
08:18:12
08:25:07
08:32:03
08:38:59
08:45:53
08:52:48
08:59:44
09:06:40
09:13:40
09:20:38
09:27:35
09:34:32
09:41:30
09:48:28
09:55:24
10:02:18
10:09:14
10:16:08
10:23:00
10:29:52
Time

FIG. 8

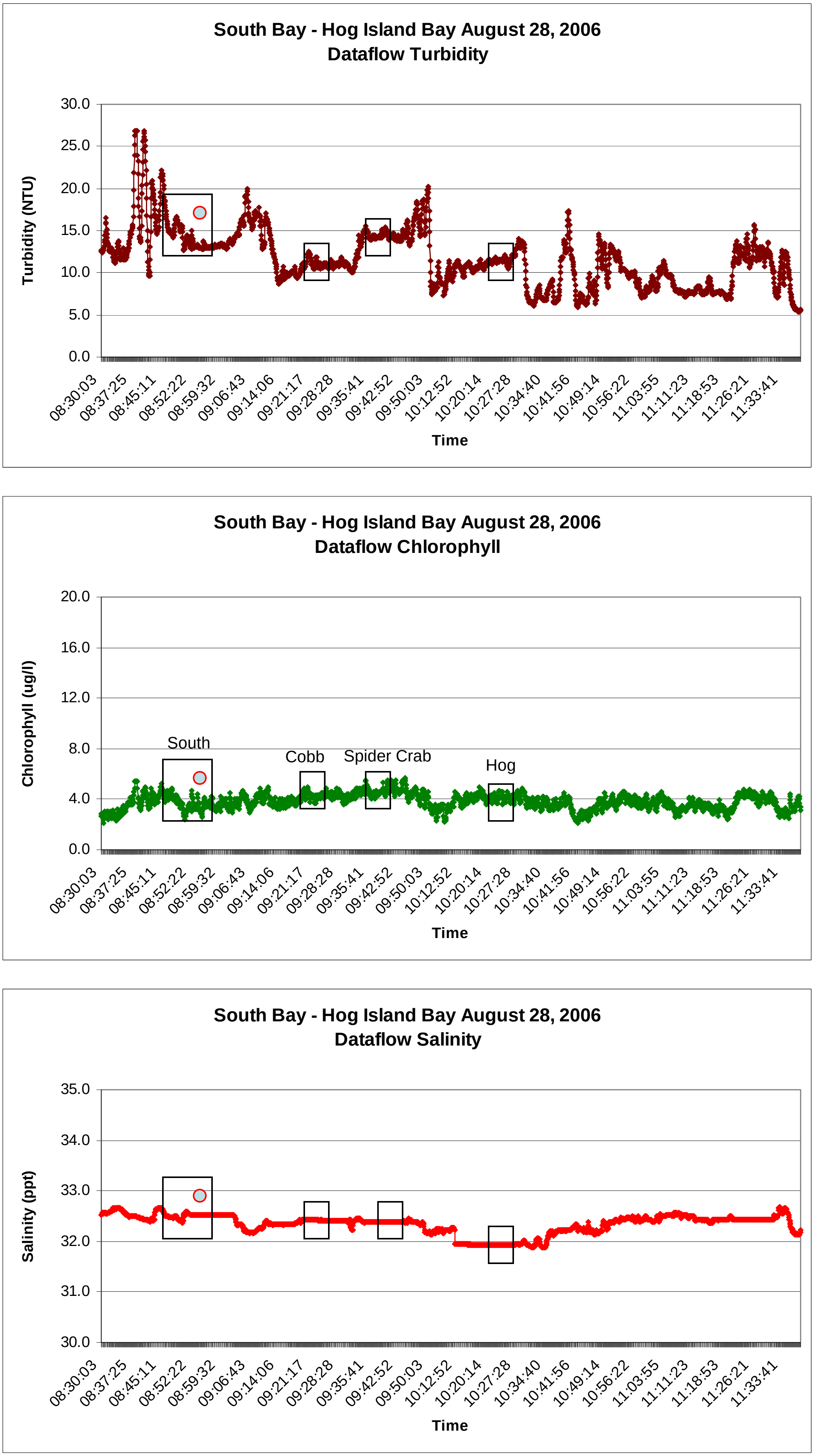
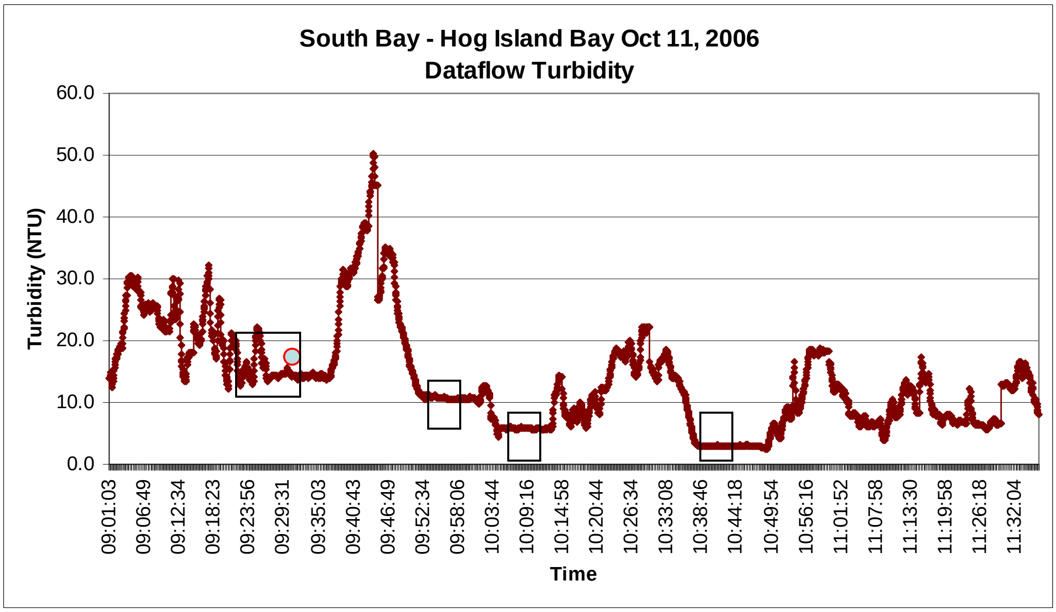

South Bay - Hog Island Bay August 28, 2006
Dataflow Turbidity
Turbidity (NTU)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
08:30:03
08:37:25
08:45:11
08:52:22
08:59:32
09:06:43
09:14:06
09:21:17
09:28:28
09:35:41
09:42:52
09:50:03
10:12:52
10:20:14
10:27:28
10:34:40
10:41:56
10:49:14
10:56:22
11:03:55
11:11:23
11:18:53
11:26:21
11:33:41
Time
South Bay - Hog Island Bay August 28, 2006
Dataflow Chlorophyll
Chlorophyll (ug/l)
20.0
16.0
12.0
8.0
4.0
0.0
South
Cobb
Spider Crab
Hog
08:30:03
08:37:25
08:45:11
08:52:22
08:59:32
09:06:43
09:14:06
09:21:17
09:28:28
09:35:41
09:42:52
09:50:03
10:12:52
10:20:14
10:27:28
10:34:40
10:41:56
10:49:14
10:56:22
11:03:55
11:11:23
11:18:53
11:26:21
11:33:41
Time
South Bay - Hog Island Bay August 28, 2006
Dataflow Salinity
Salinity (ppt)
35.0
34.0
33.0
32.0
31.0
30.0
08:30:03
08:37:25
08:45:11
08:52:22
08:59:32
09:06:43
09:14:06
09:21:17
09:28:28
09:35:41
09:42:52
09:50:03
10:12:52
10:20:14
10:27:28
10:34:40
10:41:56
10:49:14
10:56:22
11:03:55
11:11:23
11:18:53
11:26:21
11:33:41
Time

FIG. 9


South Bay - Hog Island Bay Oct 11, 2006
Dataflow Turbidity
Turbidity (NTU)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
09:01:03
09:06:49
09:12:34
09:18:23
09:23:56
09:29:31
09:35:03
09:40:43
09:46:49
09:52:34
09:58:06
10:03:44
10:09:16
10:14:58
10:20:44
10:26:34
10:33:08
10:38:46
10:44:18
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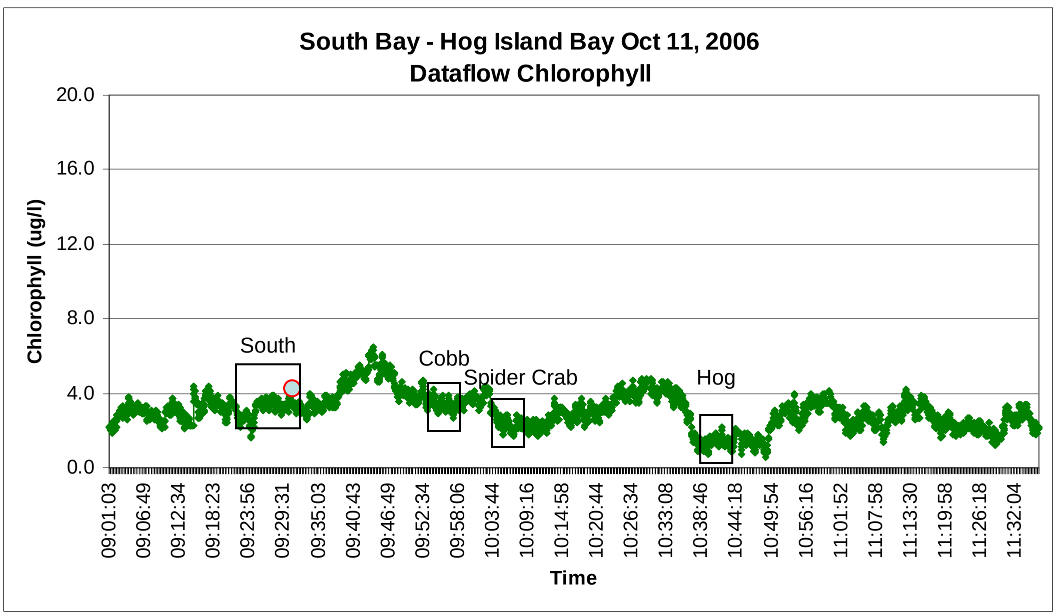
11:26:18
11:32:04
Time


South Bay - Hog Island Bay Oct 11, 2006
Dataflow Chlorophyll
Chlorophyll (ug/l)
20.0
16.0
12.0
8.0
4.0
0.0
South
Cobb
Spider Crab
Hog
09:01:03
09:06:49
09:12:34
09:18:23
09:23:56
09:29:31
09:35:03
09:40:43
09:46:49
09:52:34
09:58:06
10:03:44
10:09:16
10:14:58
10:20:44
10:26:34
10:33:08
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10:44:18
10:49:54
10:56:16
11:01:52
11:07:58
11:13:30
11:19:58
11:26:18
11:32:04
Time

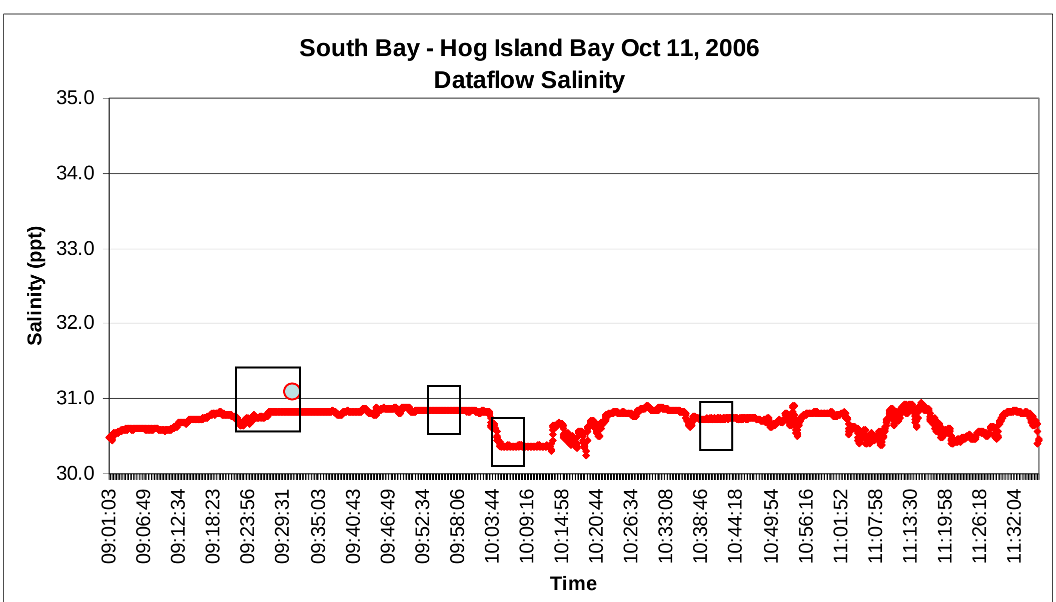
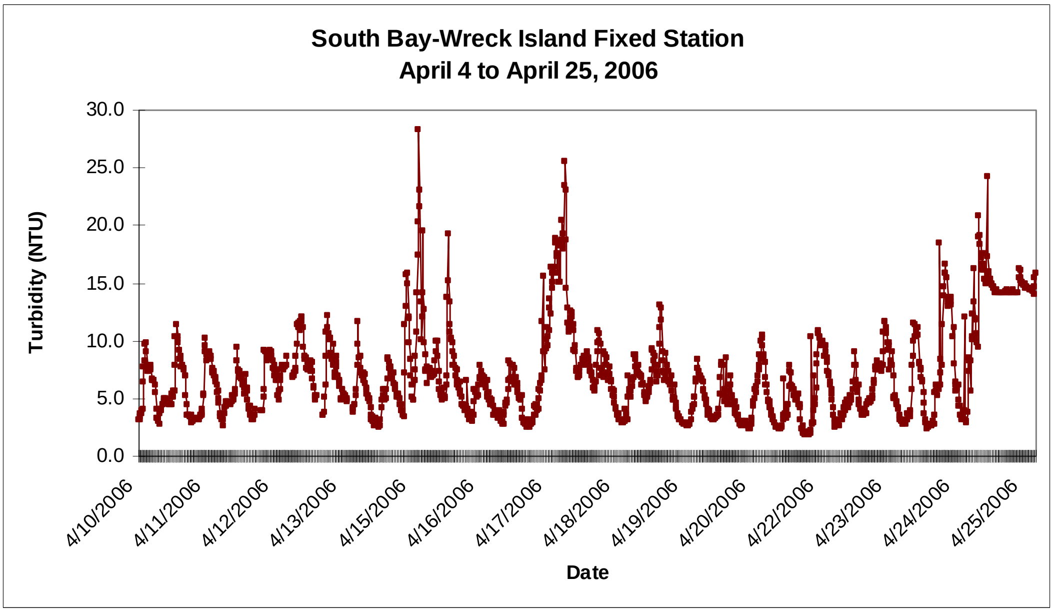
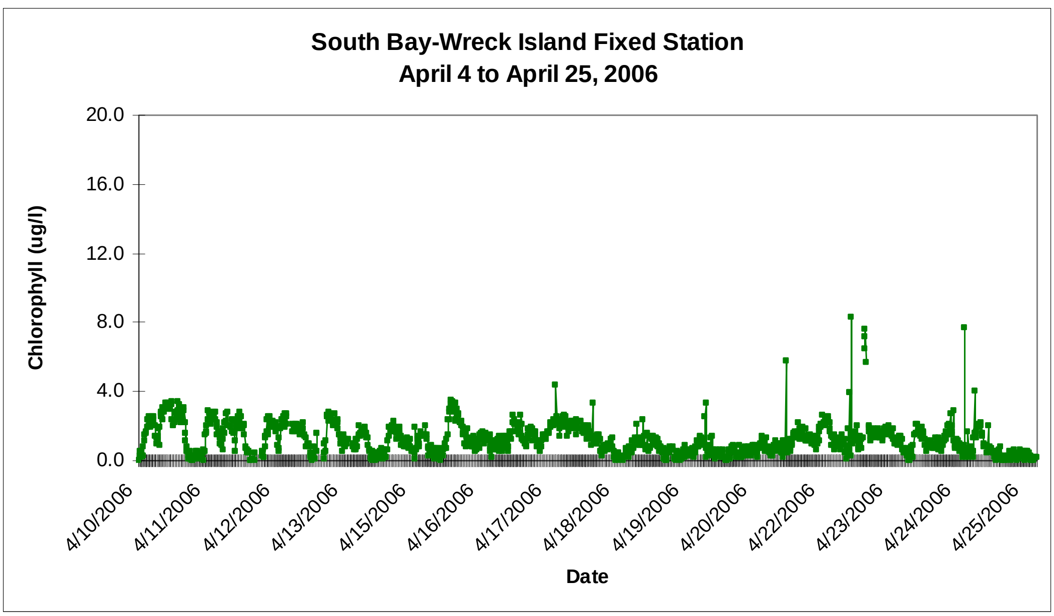

South Bay - Hog Island Bay Oct 11, 2006
Dataflow Salinity
Salinity (ppt)
35.0
34.0
33.0
32.0
31.0
30.0
09:01:03
09:06:49
09:12:34
09:18:23
09:23:56
09:29:31
09:35:03
09:40:43
09:46:49
09:52:34
09:58:06
10:03:44
10:09:16
10:14:58
10:20:44
10:26:34
10:33:08
10:38:46
10:44:18
10:49:54
10:56:16
11:01:52
11:07:58
11:13:30
11:19:58
11:26:18
11:32:04
Time

FIG 10


South Bay-Wreck Island Fixed Station
April 4 to April 25, 2006
Turbidity (NTU)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
4/10/2006
4/11/2006
4/12/2006
4/13/2006
4/15/2006
4/16/2006
4/17/2006
4/18/2006
4/19/2006
4/20/2006
4/22/2006
4/23/2006
4/24/2006
4/25/2006
Date


South Bay-Wreck Island Fixed Station
April 4 to April 25, 2006
Chlorophyll (ug/l)
20.0
16.0
12.0
8.0
4.0
0.0
4/10/2006
4/11/2006
4/12/2006
4/13/2006
4/15/2006
4/16/2006
4/17/2006
4/18/2006
4/19/2006
4/20/2006
4/22/2006
4/23/2006
4/24/2006
4/25/2006
Date

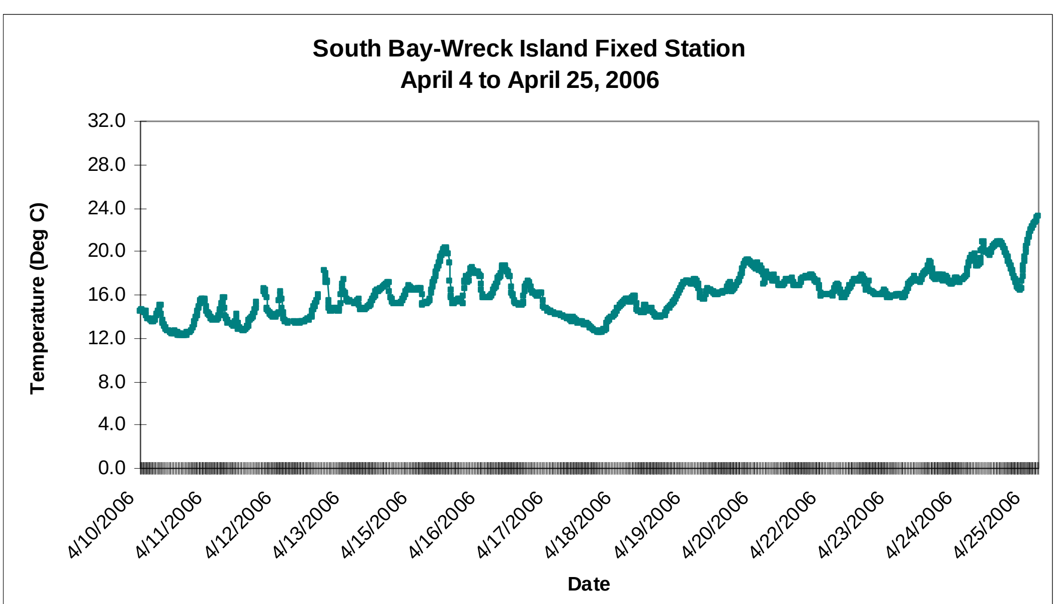
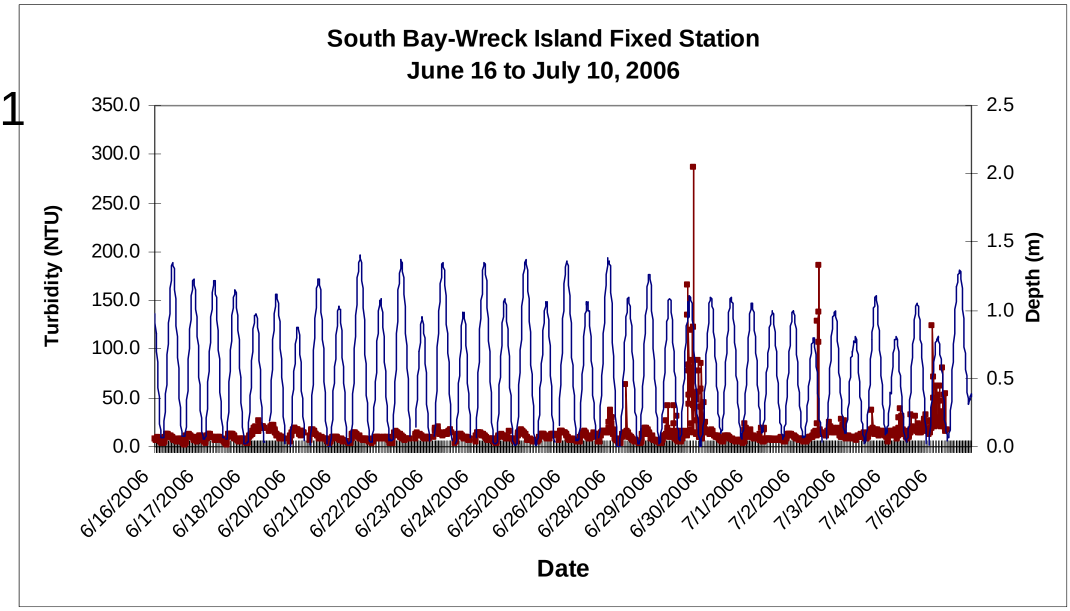
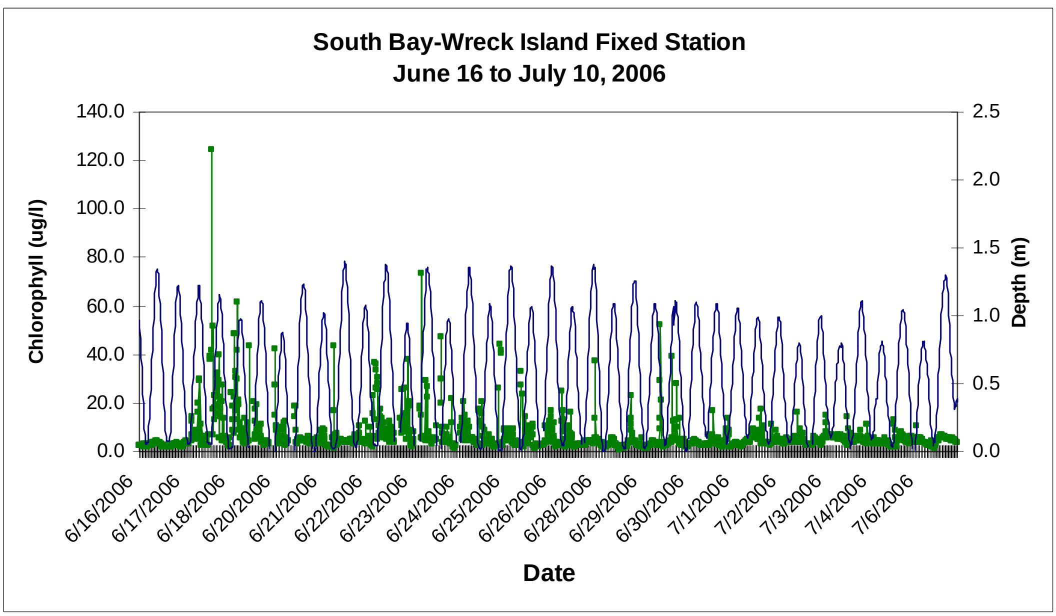

South Bay-Wreck Island Fixed Station
April 4 to April 25, 2006
Temperature (Deg C)
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
4/10/2006
4/11/2006
4/12/2006
4/13/2006
4/15/2006
4/16/2006
4/17/2006
4/18/2006
4/19/2006
4/20/2006
4/22/2006
4/23/2006
4/24/2006
4/25/2006
Date

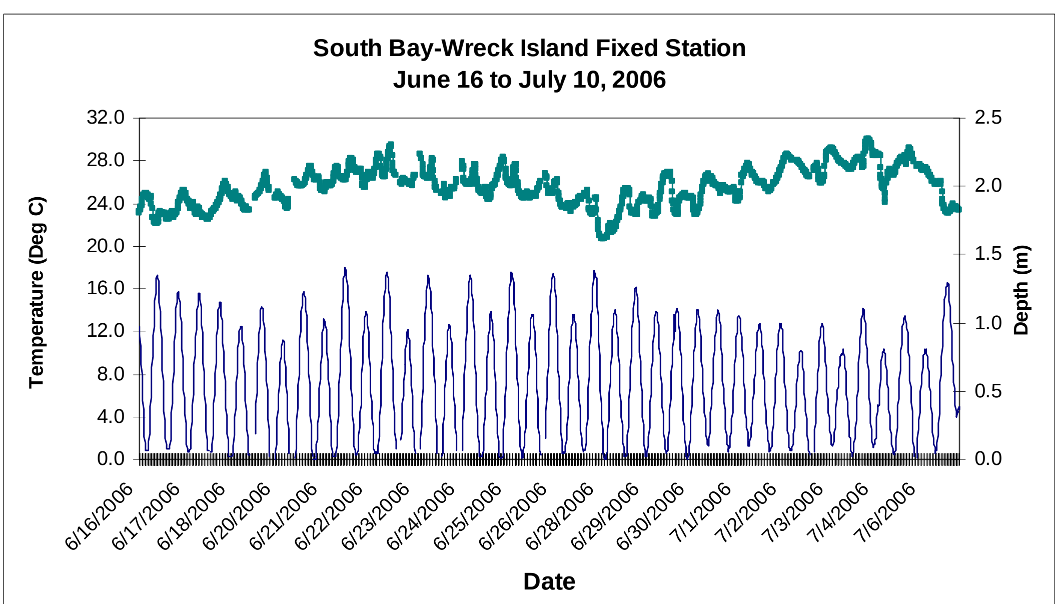
FIG. 11



South Bay-Wreck Island Fixed Station
June 16 to July 10, 2006
Turbidity (NTU)
Depth (m)
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
6/16/2006
6/17/2006
6/18/2006
6/20/2006
6/21/2006
6/22/2006
6/23/2006
6/24/2006
6/25/2006
6/26/2006
6/28/2006
6/29/2006
6/30/2006
7/1/2006
7/2/2006
7/3/2006
7/4/2006
7/6/2006
Date

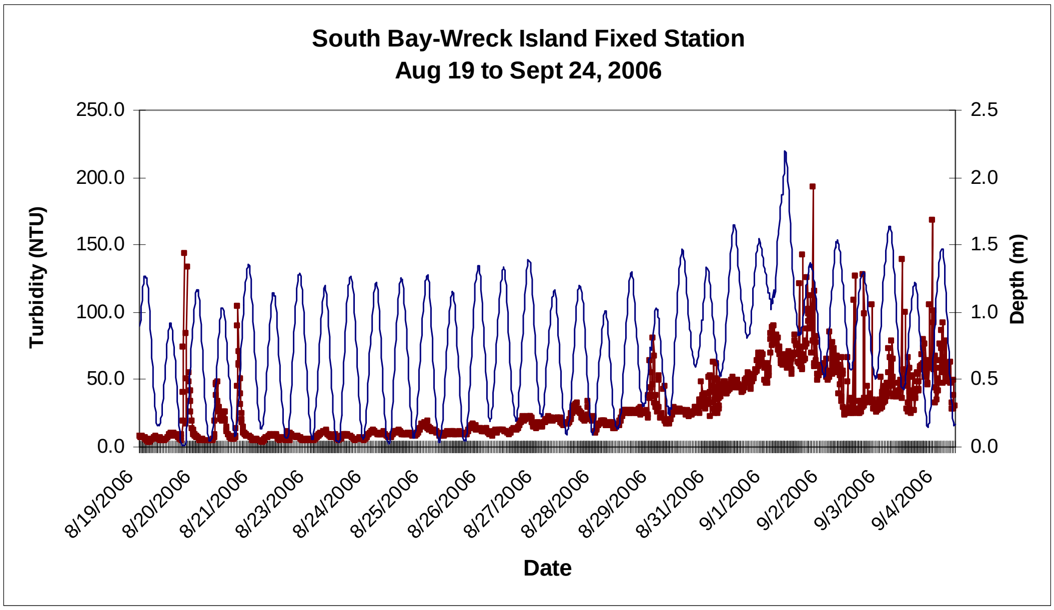


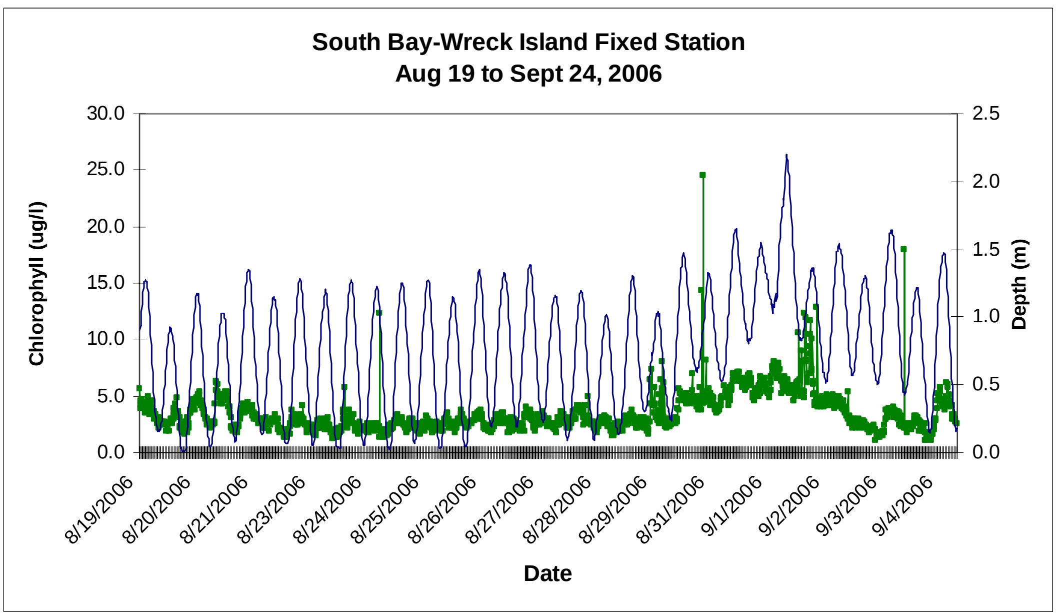
South Bay-Wreck Island Fixed Station
June 16 to July 10, 2006
Chlorophyll (ug/l)
Depth (m)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
6/16/2006
6/17/2006
6/18/2006
6/20/2006
6/21/2006
6/22/2006
6/23/2006
6/24/2006
6/25/2006
6/26/2006
6/28/2006
6/29/2006
6/30/2006
7/1/2006
7/2/2006
7/3/2006
7/4/2006
7/6/2006
Date



South Bay-Wreck Island Fixed Station
June 16 to July 10, 2006
Temperature (Deg C)
Depth (m)
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
6/16/2006
6/17/2006
6/18/2006
6/20/2006
6/21/2006
6/22/2006
6/23/2006
6/24/2006
6/25/2006
6/26/2006
6/28/2006
6/29/2006
6/30/2006
7/1/2006
7/2/2006
7/3/2006
7/4/2006
7/6/2006
Date

Fig. 12


South Bay-Wreck Island Fixed Station
Aug 19 to Sept 24, 2006
Turbidity (NTU)
Depth (m)
250.0
200.0
150.0
100.0
50.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
8/19/2006
8/20/2006
8/21/2006
8/23/2006
8/24/2006
8/25/2006
8/26/2006
8/27/2006
8/28/2006
8/29/2006
8/31/2006
9/1/2006
9/2/2006
9/3/2006
9/4/2006
Date


South Bay-Wreck Island Fixed Station
Aug 19 to Sept 24, 2006
Chlorophyll (ug/l)
Depth (m)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
8/19/2006
8/20/2006
8/21/2006
8/23/2006
8/24/2006
8/25/2006
8/26/2006
8/27/2006
8/28/2006
8/29/2006
8/31/2006
9/1/2006
9/2/2006
9/3/2006
9/4/2006
Date

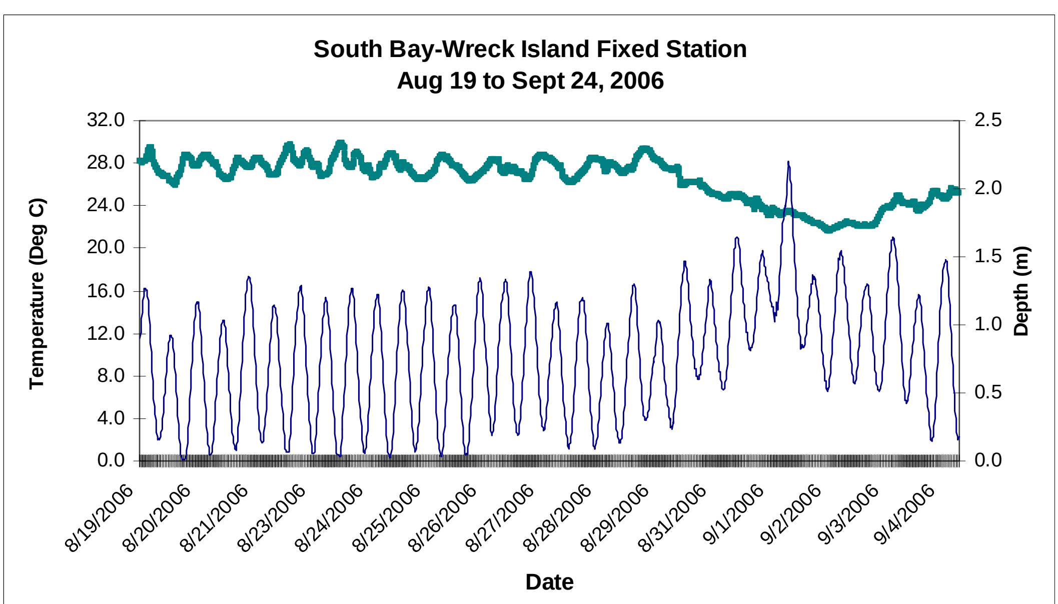
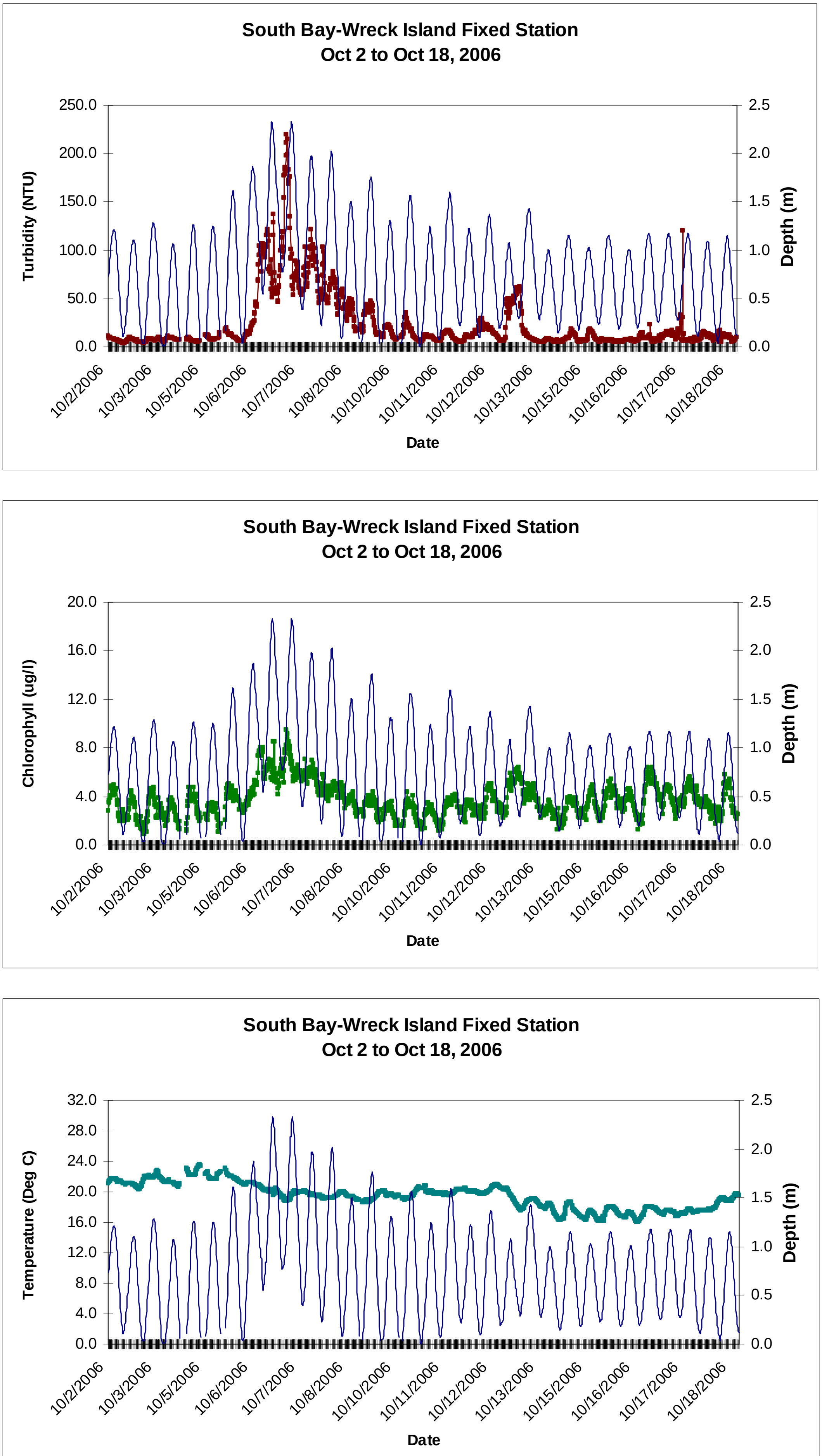

South Bay-Wreck Island Fixed Station
Aug 19 to Sept 24, 2006
Temperature (Deg C)
Depth (m)
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
8/19/2006
8/20/2006
8/21/2006
8/23/2006
8/24/2006
8/25/2006
8/26/2006
8/27/2006
8/28/2006
8/29/2006
8/31/2006
9/1/2006
9/2/2006
9/3/2006
9/4/2006
Date

FIG. 13


South Bay-Wreck Island Fixed Station
Oct 2 to Oct 18, 2006
Turbidity (NTU)
Depth (m)
250.0
200.0
150.0
100.0
50.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
10/2/2006
10/3/2006
10/5/2006
10/6/2006
10/7/2006
10/8/2006
10/10/2006
10/11/2006
10/12/2006
10/13/2006
10/15/2006
10/16/2006
10/17/2006
10/18/2006
Date
South Bay-Wreck Island Fixed Station
Oct 2 to Oct 18, 2006
Chlorophyll (ug/l)
Depth (m)
20.0
16.0
12.0
8.0
4.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
Date
South Bay-Wreck Island Fixed Station
Oct 2 to Oct 18, 2006
Temperature (Deg C)
Depth (m)
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
Date