LONG-TERM (1985-2007) MONITORING STUDIES OF EELGRASS (*ZOSTERA MARINA* L.) POPULATION DYNAMICS IN EASTERN LONG ISLAND SOUND

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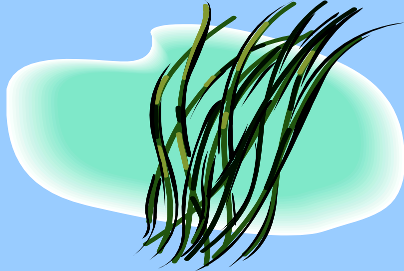
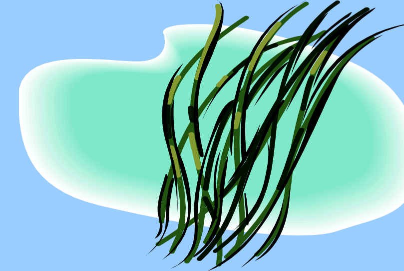


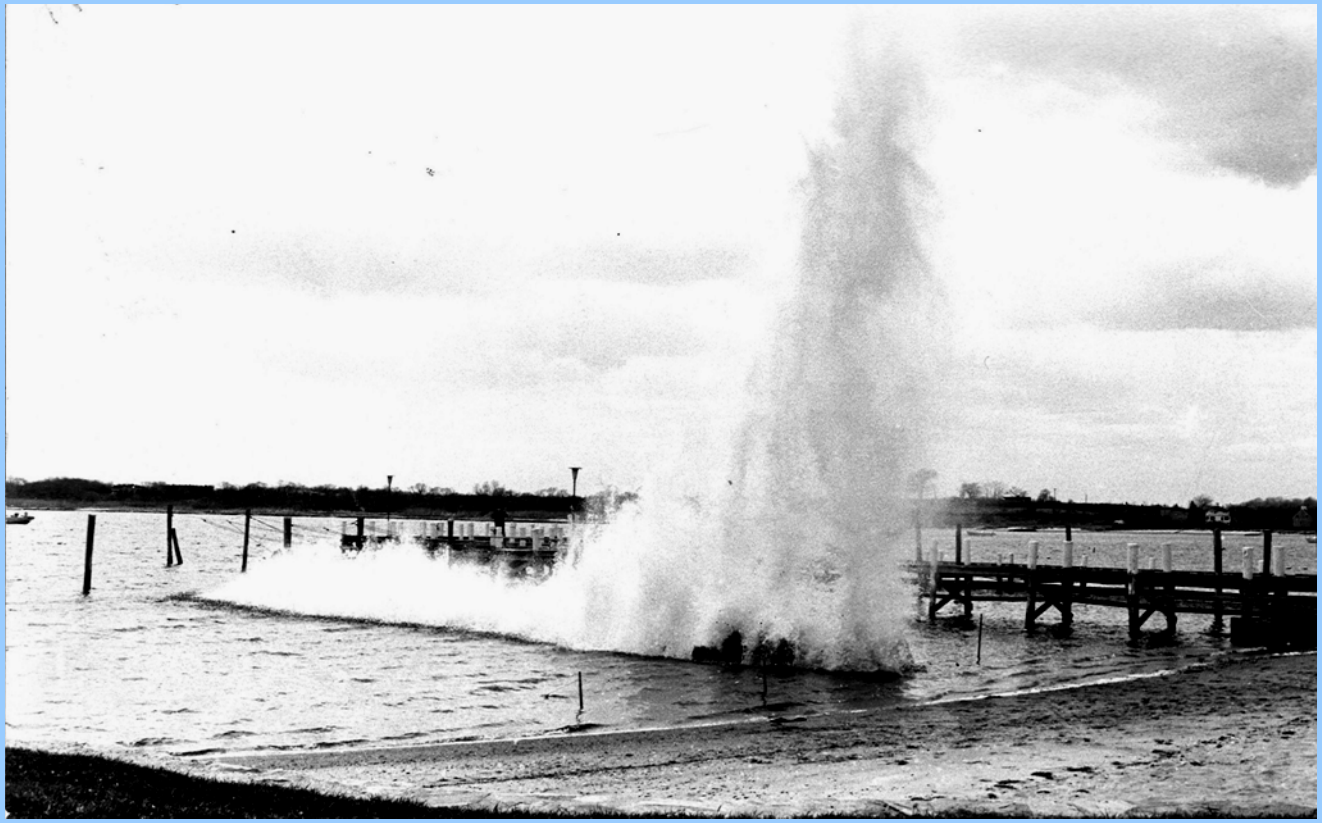
Abstract



Eelgrass (*Zostera marina* L.) shoot density, proportion of seed-bearing shoots, shoot length, standing stock biomass were monitored during summer months from 1985 to 2007 at three locations in eastern Long Island Sound (LIS) near Millstone Power Station (MPS), Waterford, Connecticut, USA. While all three monitoring sites currently support healthy populations, some degree of long-term decline was detected at all three areas monitored. Two populations in Jordan Cove (JC and WP) near the fringes of the thermal plume (<1.5 km from the MPS discharge to LIS) exhibited only slight declines in some population parameters over the 23-yr study period and thermal input from MPS to these sites was minimal (<1^{o}C above ambient conditions). By comparison, heavy, often sudden, eelgrass losses were documented in the Niantic River (NR), located >2 km from the MPS thermal plume, requiring establishment of new sampling locations within the river. While the causes were not always determined, nutrient loading from surface run-off and groundwater sources, and an increase in ambient seawater temperature of ~1.4^{o}C over the last 30 years may have contributed to observed declines. Short-term declines in eelgrass abundance were directly associated with fouling and overgrowth of eelgrass on three occasions: once by blue mussels at NR and twice by blooms of green algae (*Cladophora*) at WP. Another abrupt decline at NR was concurrent with a sharp increase in sediment silt/clay content, presence of thick mats of the red macroalga *Agardhiella* and unusually high summer seawater temperatures (27^{o}C). Following these and other unexplained die-off events, steady recovery of the Niantic River eelgrass population has been observed from 2001 to the present, possibly related to expansion of the municipal sewage network within the watershed.

Millstone Eelgrass Study
Historical Background

- **Widespread declines in 1930s slow were attributed to a ‘wasting disease’ now identified as *Labyrinthula***
- **Recovery was slow, but by the 1960s, beds in SE Connecticut were once again extensive, and considered by some a “nuisance”**



Eelgrass removal using explosives at a swimming beach in Stonington (CT) Harbor (ca. 1973)

Millstone Eelgrass Study

Historical Background

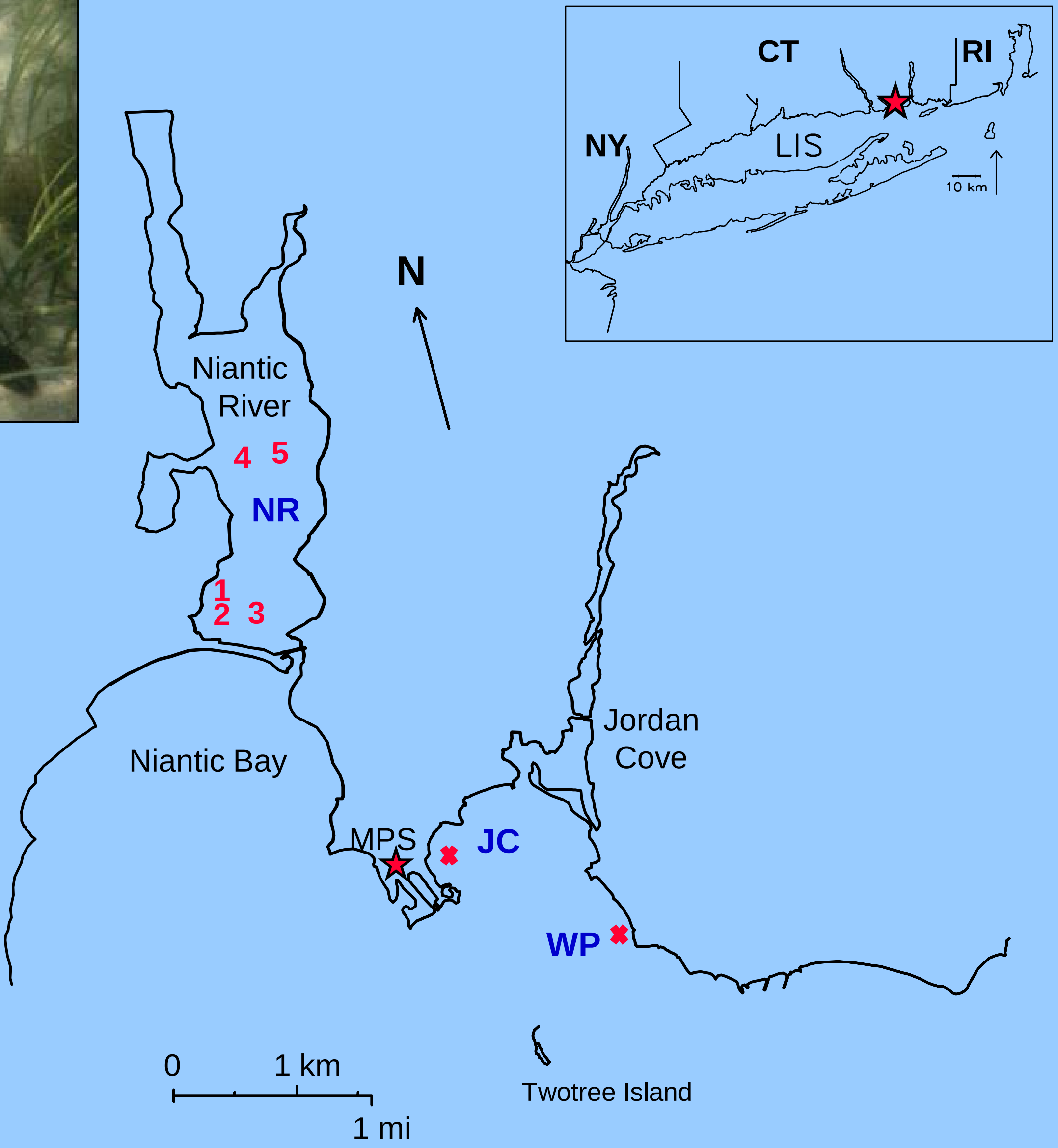
- Large accumulations of eelgrass blades on local beaches in Jordan Cove in early 1970s raised concerns about possible MPS impacts
- Study sponsored by MPS showed no evidence of thermal plume effects under 2-unit operation, but suggested some could be observed in the future with 3 units operating
- Regional declines noted since the early 1980s have received much attention from researchers and environmental managers - degraded water quality suspected
- Present study initiated in 1985 prior to Unit 3 start-up

Monitoring Stations

3 sites sampled monthly in summer (June – Sept.)

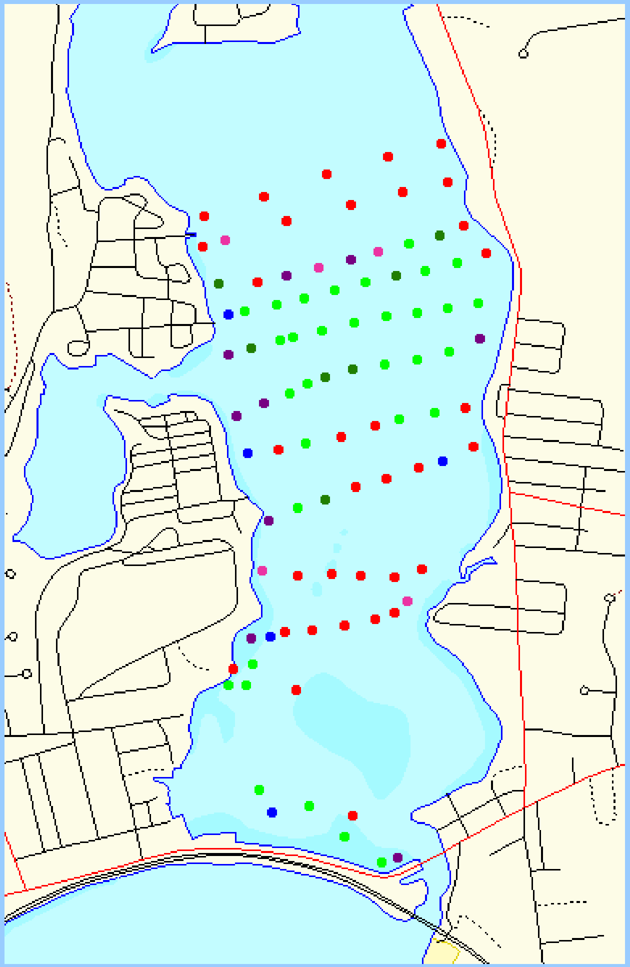
- **JC (1985-present)**
- **WP (1985-present)**
- **NR**
  - **1 (1985-86, 1993-94)**
  - **2 (1986)**
  - **3 (1987-92)**
  - **4 (1995-99)**
  - **5 (2000-present)**

Niantic River site relocated 5x due to bed die-offs

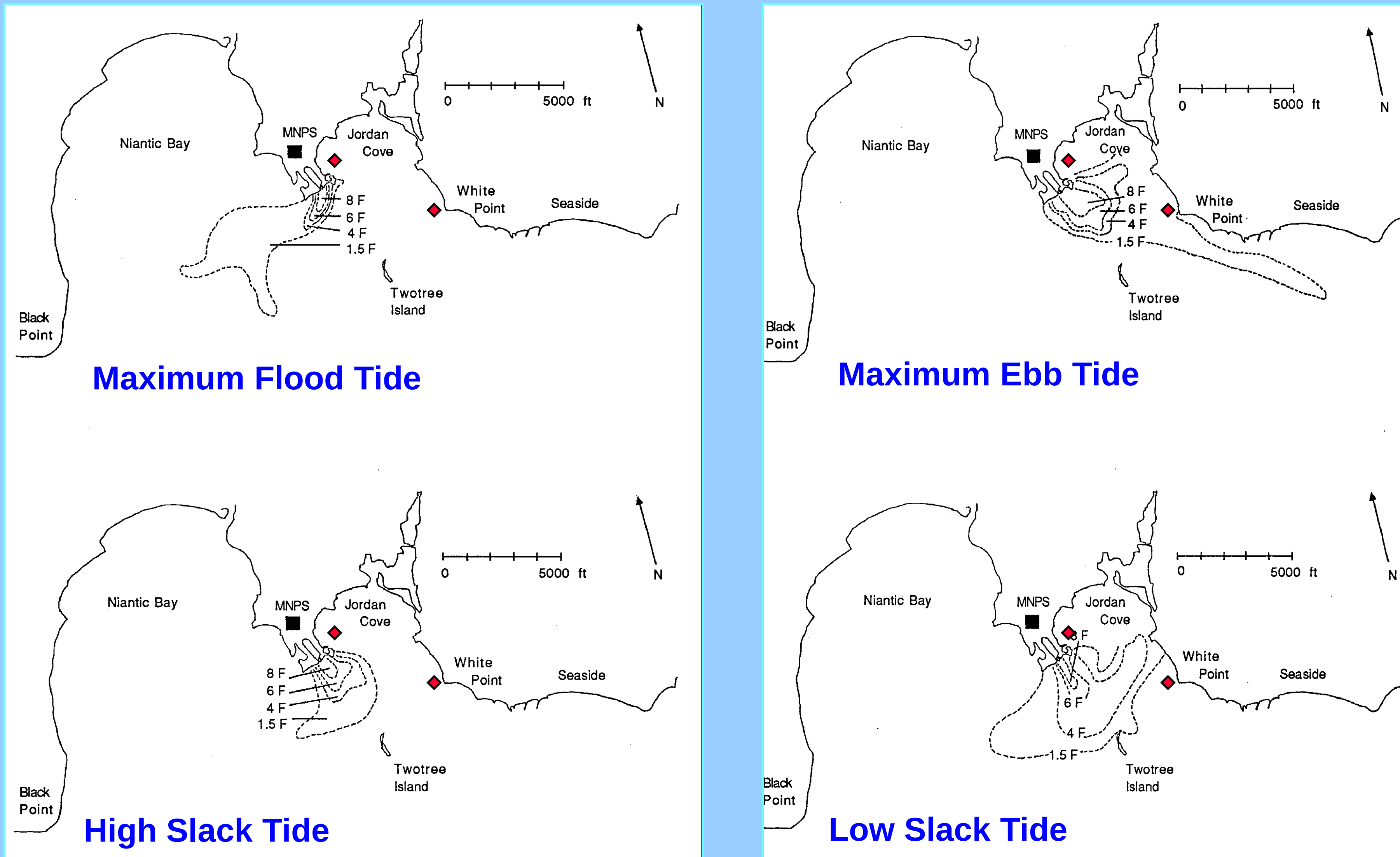


Methodology

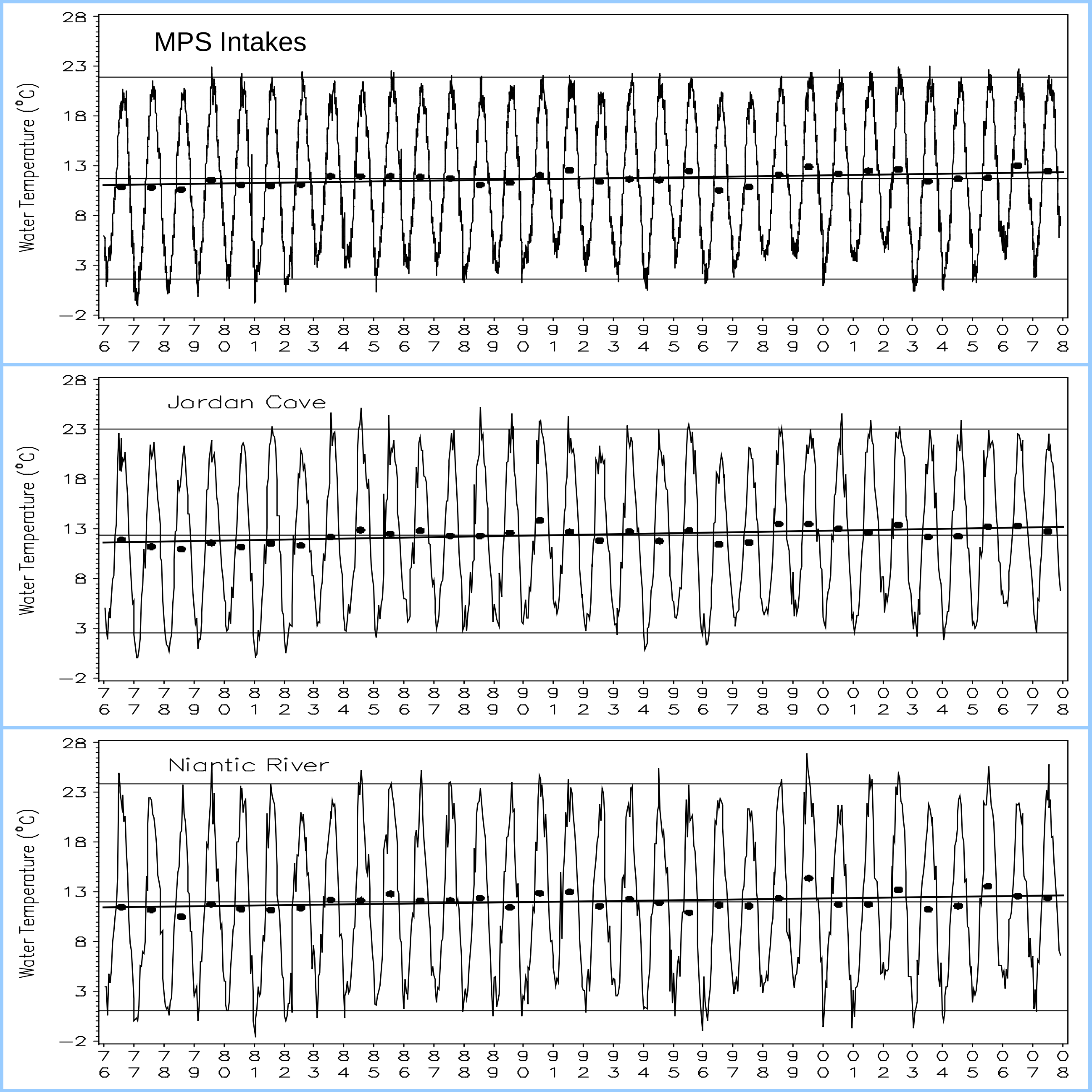
- 3 sites sampled monthly in summer (June – Sept.)
- Shoots harvested from 16 randomly placed quadrats (25x25 cm)
- Population parameter estimates include:
  - total shoot density
  - shoot length
  - standing stock biomass
  - seed-bearing shoot density
- Sediments characterized



- Periodic distribution surveys
  - visual mapping (1985-2001)
  - GPS/GIS (2002-07)



Locations of three-unit thermal plume isotherms (1.5°F, 4°F, 6°F, and 8°F) at four indicated tidal conditions.

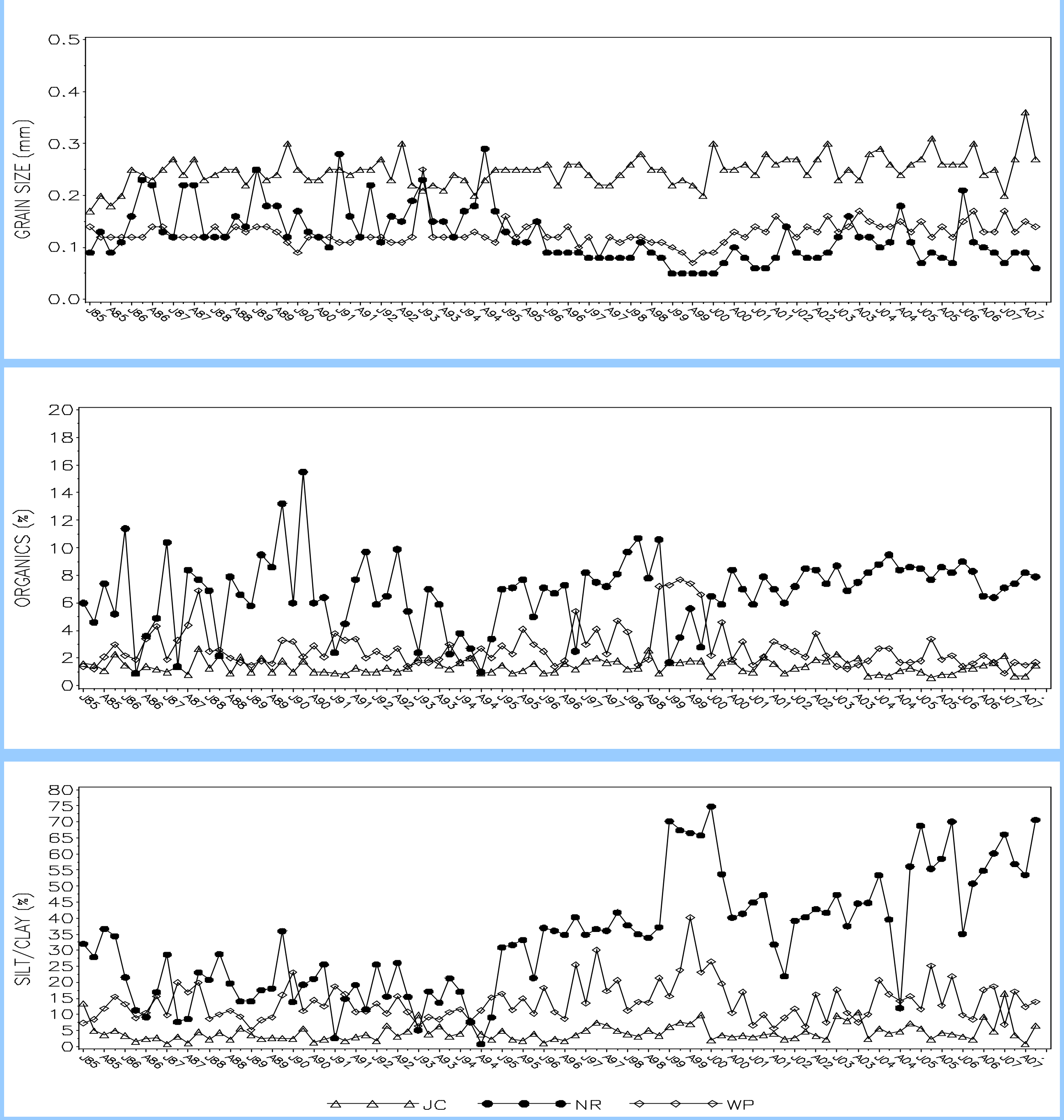


Slope = 0.041°C/yr; p=0.0005*
<u>1.3°C increase</u> over 32-yr period

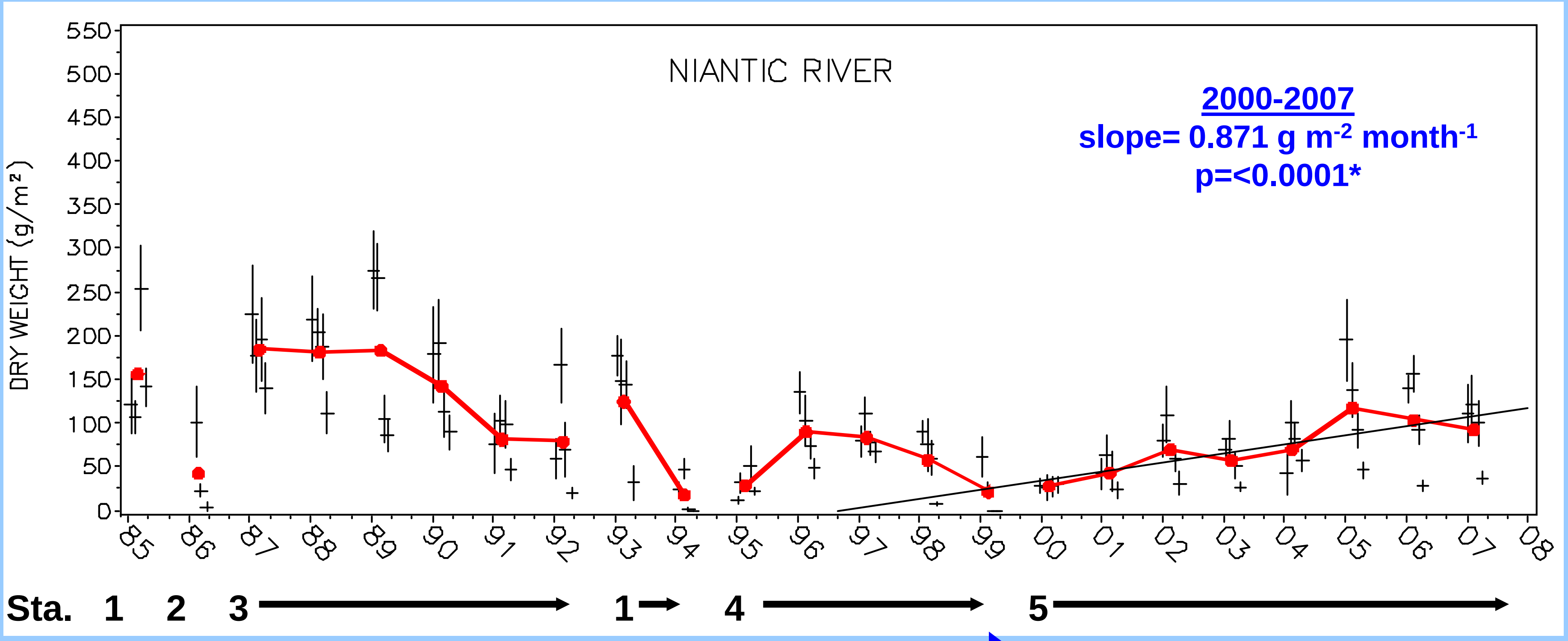
Slope = 0.048°C/yr; p=0.0004*
<u>1.5°C increase</u> over 32-yr period

Slope = 0.036°C/yr; p=0.0193*
<u>1.2°C increase</u> over 32-yr period

Mean annual seawater temperatures ( ) for the period 1976-2007, based on daily means at the MPS intakes and biweekly measurements made in Jordan Cove and the Niantic River. Horizontal reference lines represent the overall mean, and mean annual minimum and maximum temperatures at each site for the entire period.



Sediment mean grain size, organic content, and silt/clay content at MPS eelgrass monitoring stations.



Blue mussel overgrowth

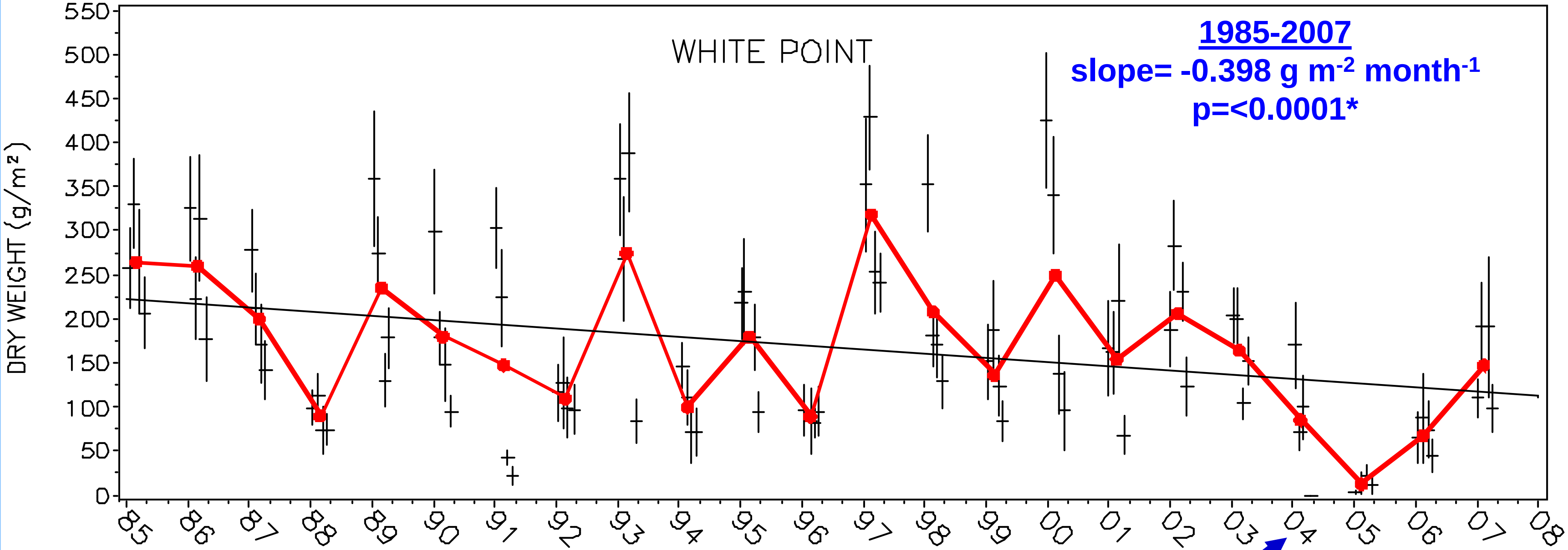
?

-Siltation

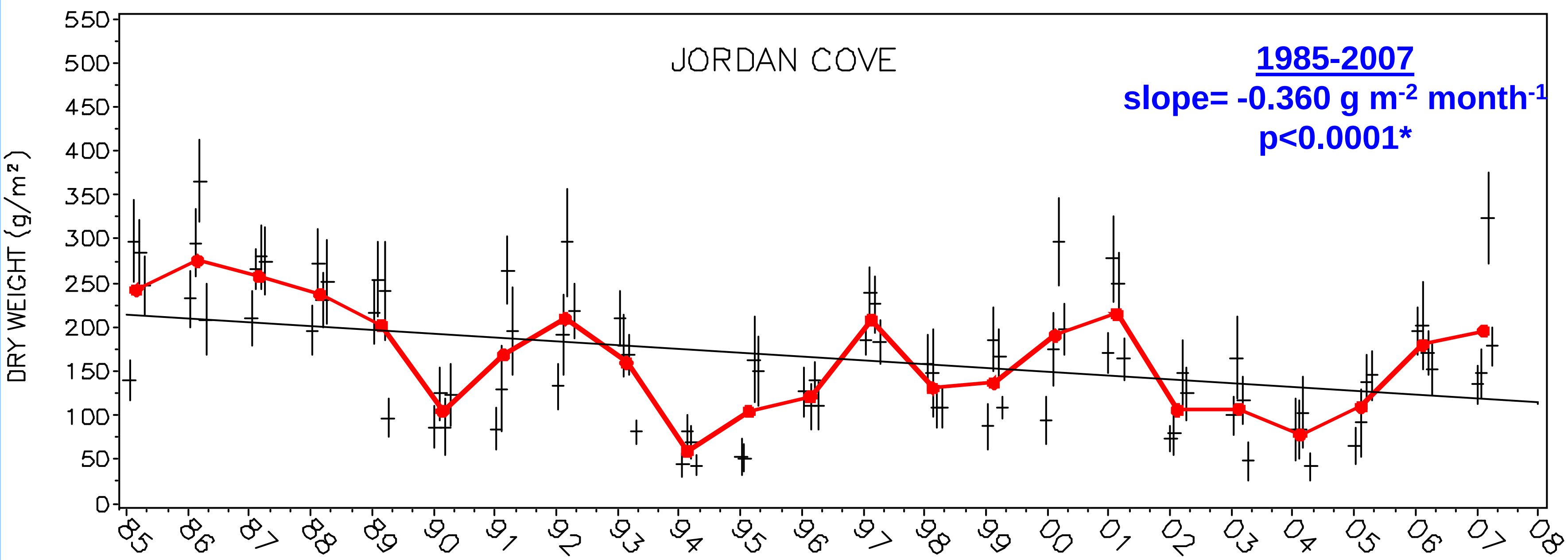
-*Agardhiella* bloom

-High temps. (25-27°C)

Monthly mean standing stock biomass (± 95% C.I.) and annual mean biomass at MPS eelgrass monitoring sites. Die-off events are indicated by arrows. Breaks in annual mean time series (red line) at NR indicate complete eelgrass bed mortality necessitating station relocation.

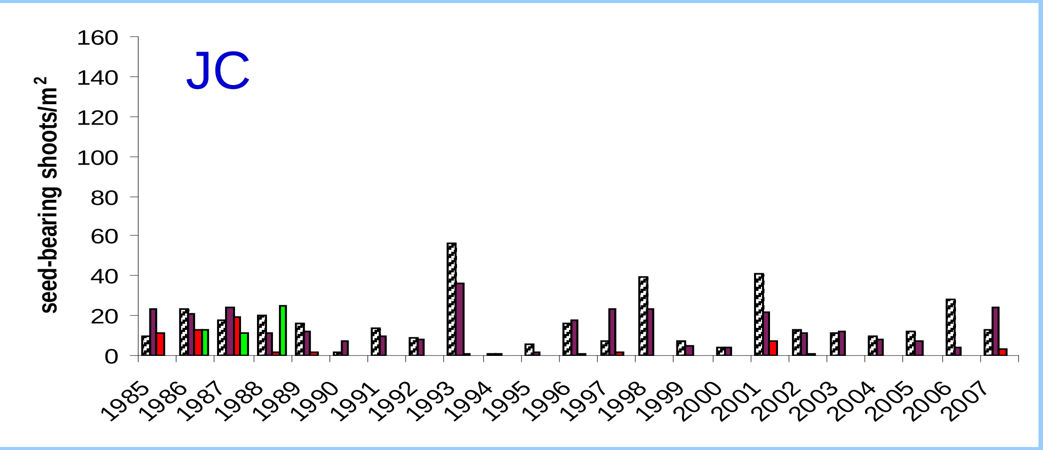


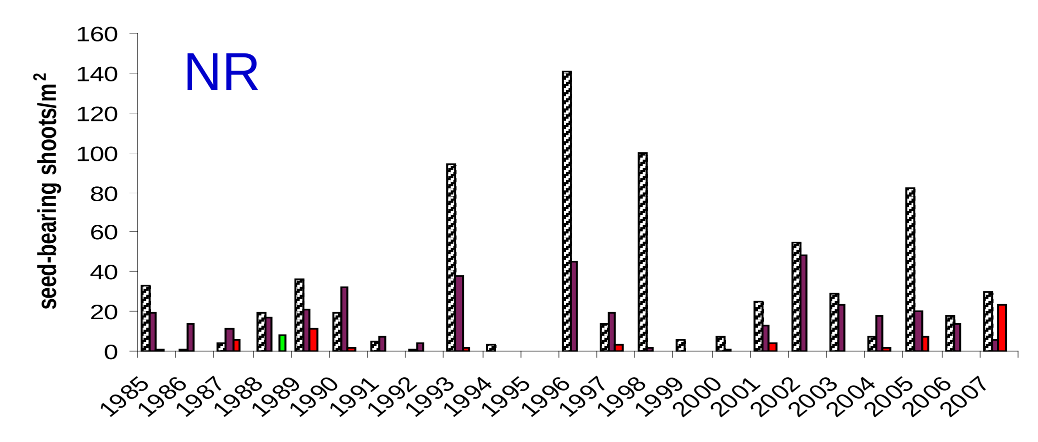
Cladophora
bloom/overgrowth

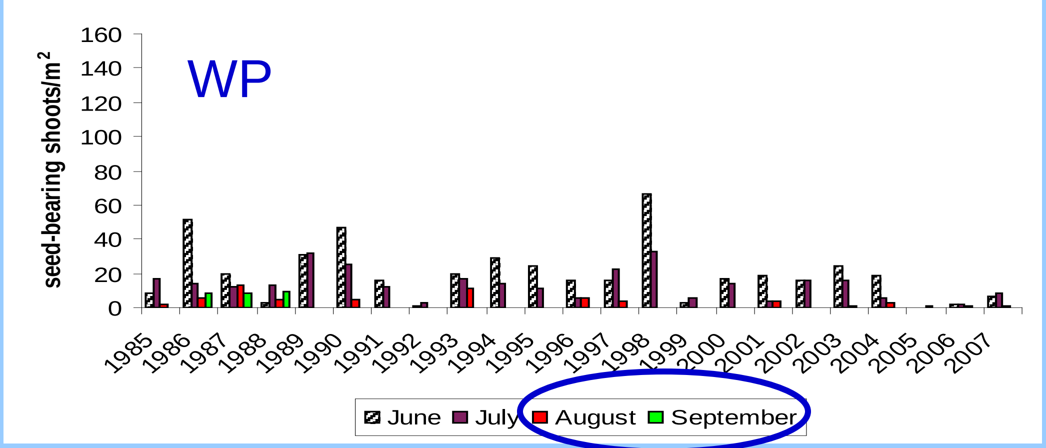

JORDAN COVE
1985-2007
slope= -0.360 g m-2 month-1
p<0.0001*
DRY WEIGHT (g/m²)
550
500
450
400
350
300
250
200
150
100
50
0
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08

Seed-Bearing Shoots

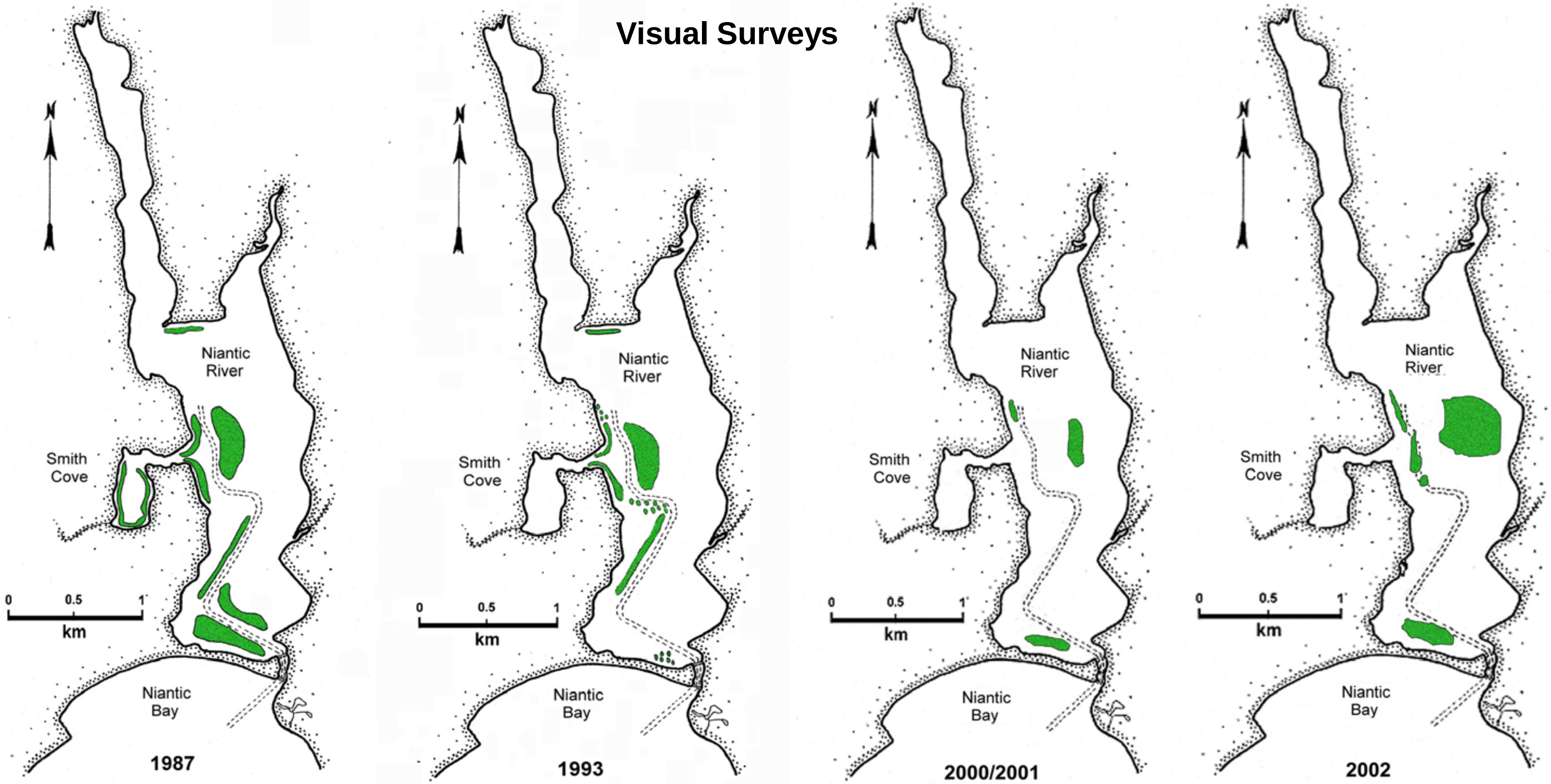
- Found commonly throughout the summer until ~1990.
- Since then, rarely found in Aug., absent in Sept.
- Shift in reproductive season may be related to ambient seawater temperature rise.





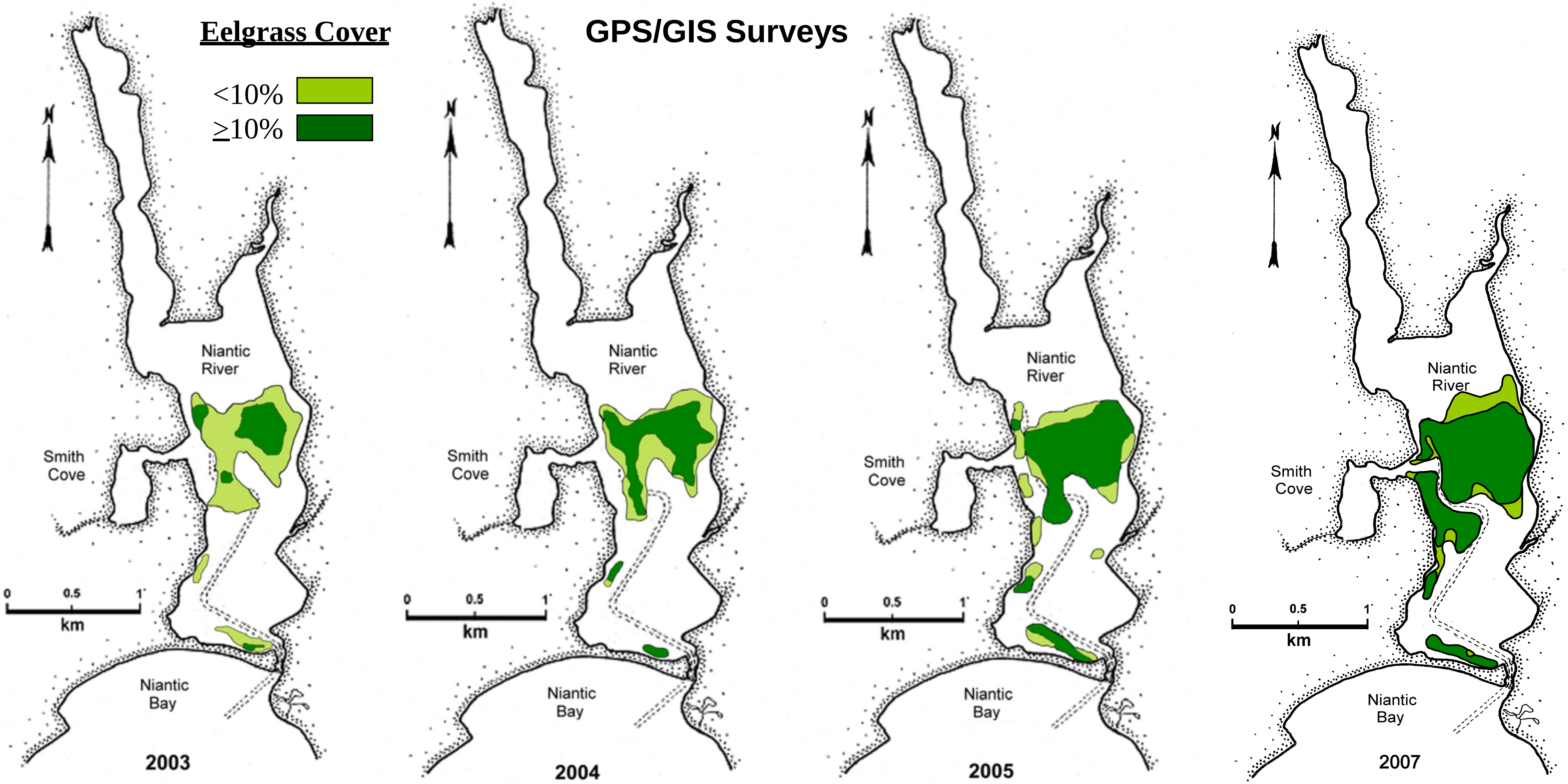


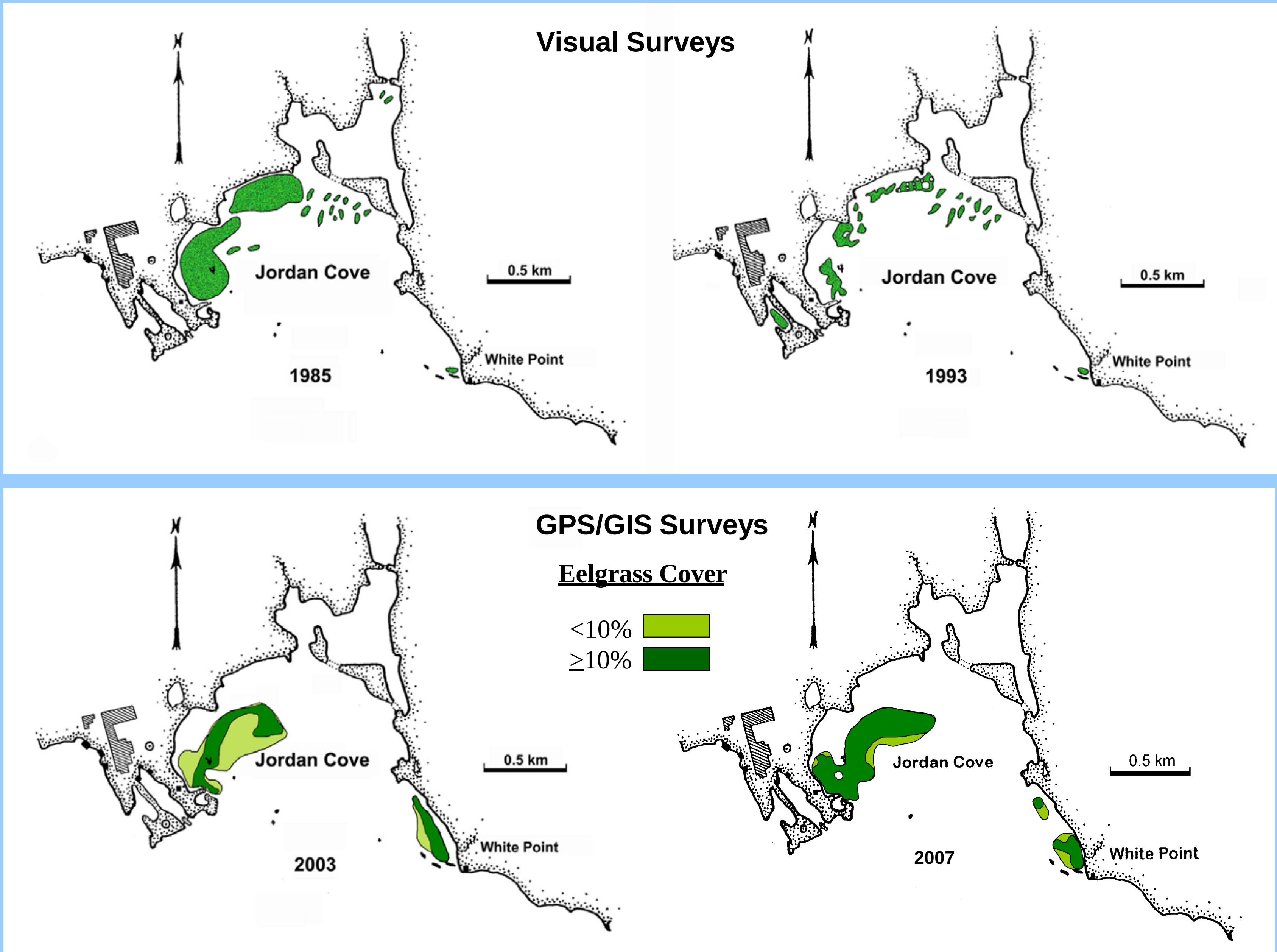
Visual Surveys



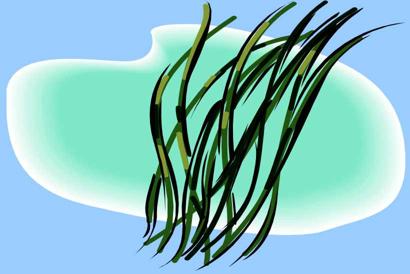
Eelgrass distribution in the Niantic River, Waterford and East Lyme, CT 1987-2007

GPS/GIS Surveys

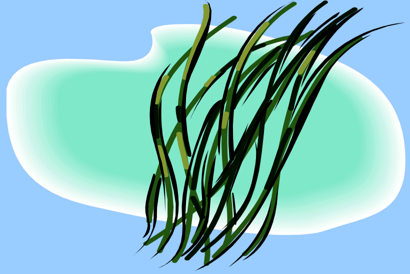




Eelgrass distribution in Jordan Cove, Waterford, CT, 1987-2007



Conclusions



- Most recent surveys (2007) revealed healthy populations at three monitoring locations
- While some indications of declines in biomass and/or shoot density over the study period seen at all sites, sites nearest MPS (JC and WP) support the most stable populations - no thermal plume effects observed
- NR population most variable, with long-term decline and bed die-offs noted through 2001 - expansion and increased density observed through 2007, possibly due to municipal sewer extensions within the watershed
- Some short-term declines attributed to fouling/macroalgal blooms, and possibly high summer seawater temperatures/siltation
- Ambient seawater temperature has increased by ~1.4^{o}C over last 30 yrs. – shift in reproductive season noted
- Causes of NR eelgrass instability (nutrients, waterfowl grazing, ambient temp. rise?) and its effect on other NR populations (winter flounder, scallop declines?) not fully understood - some studies are underway or proposed as NPDES permit conditions.