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Using Moored Arrays and Hyperspectral Aerial Imagery to Develop Eelgrass-based Nutrient Criteria for New Hampshire's Great Bay Estuary

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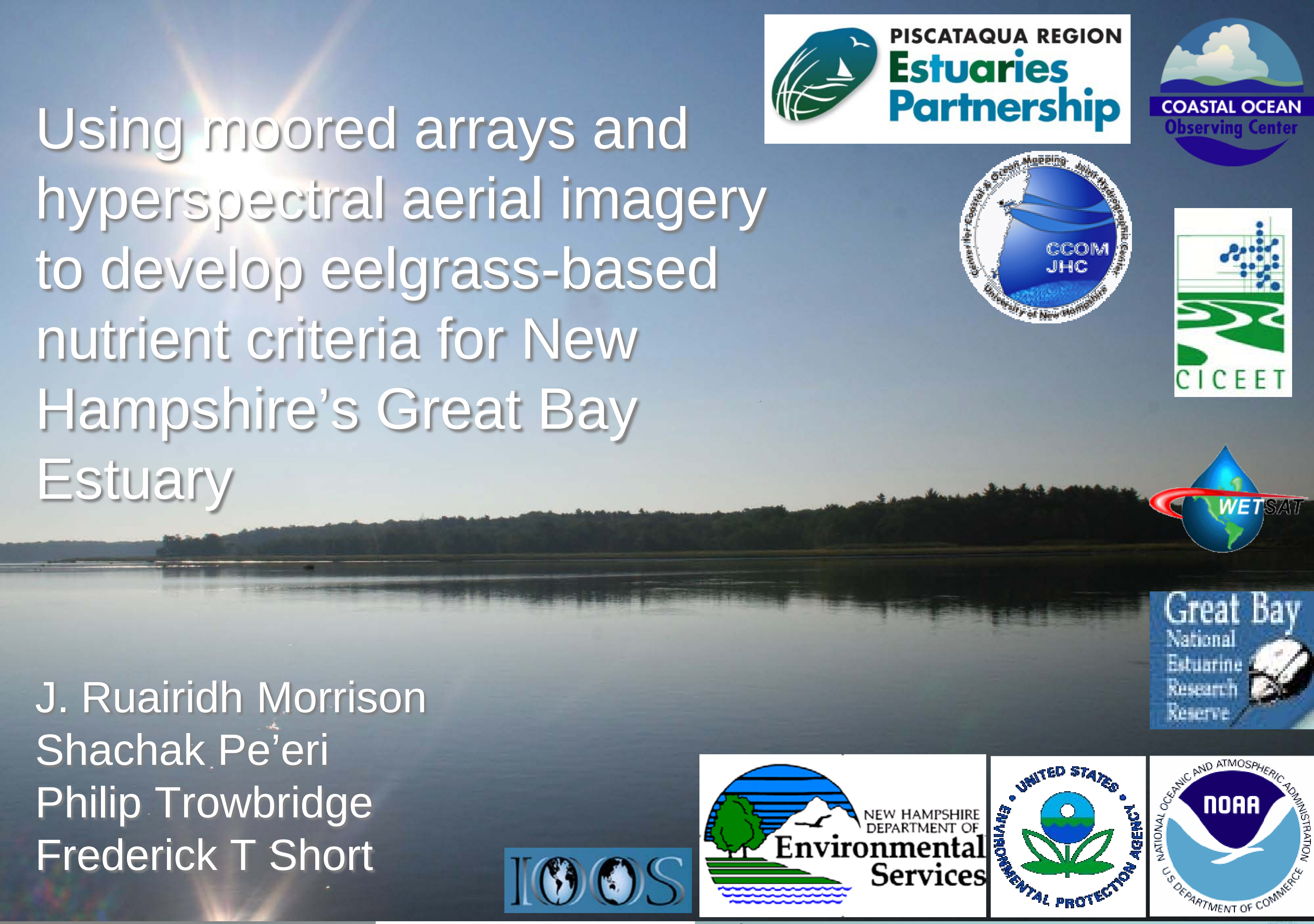

Using moored arrays and hyperspectral aerial imagery to develop eelgrass-based nutrient criteria for New Hampshire's Great Bay Estuary

PISCATAQUA REGION
Estuaries Partnership

COASTAL OCEAN
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Great Bay
National
Estuarine
Research
Reserve

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Shachak Pe'eri
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IOOS

NEW HAMPSHIRE
DEPARTMENT OF
Environmental
Services

Coastal GeoTools
March 4, 2009

NERACOOS
Northeastern Regional Association of Coastal Ocean Observing Systems

UNH Coastal Observing Center

IOOS Observation Registry

Sensor Platforms Map

NERACOOS
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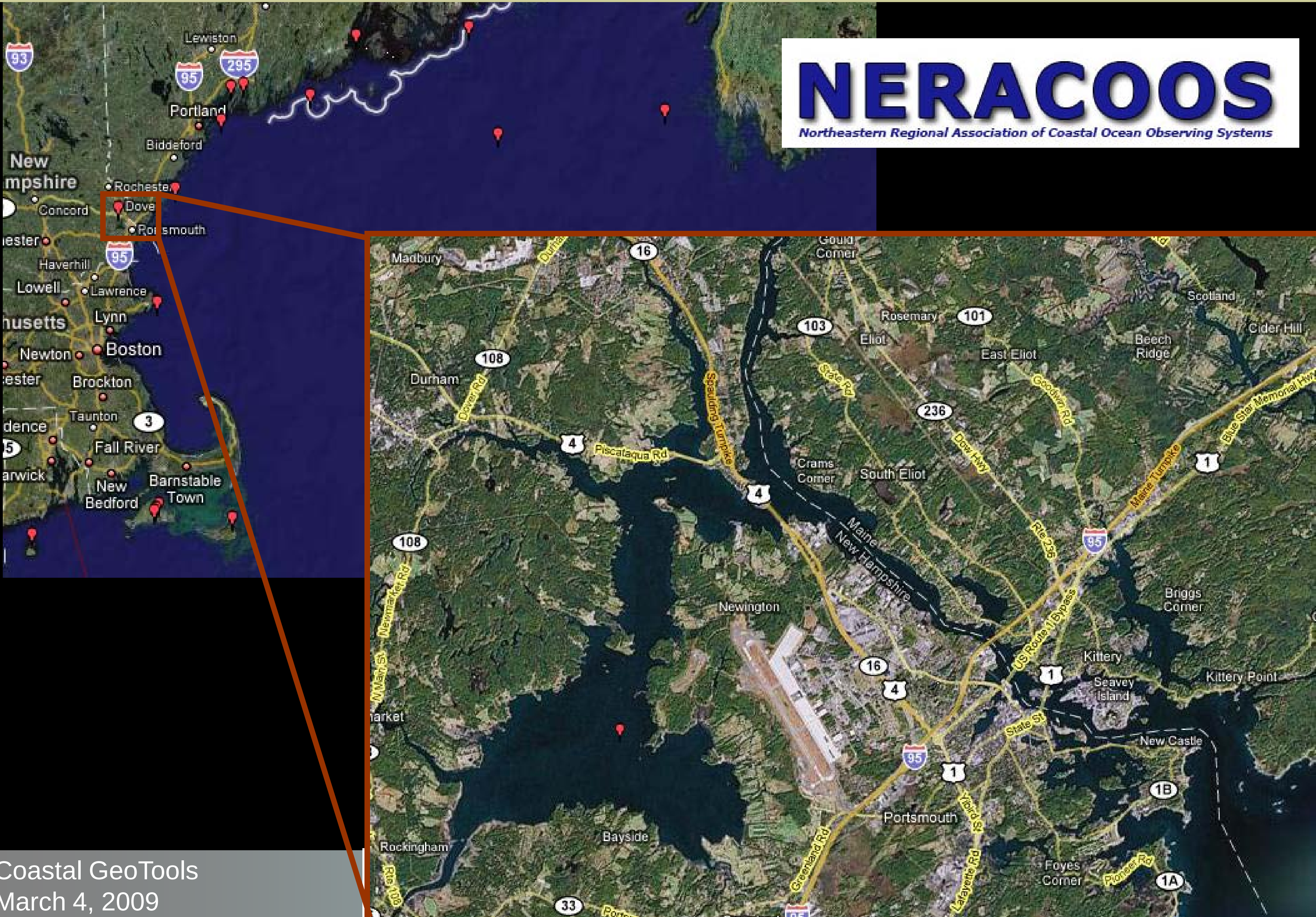

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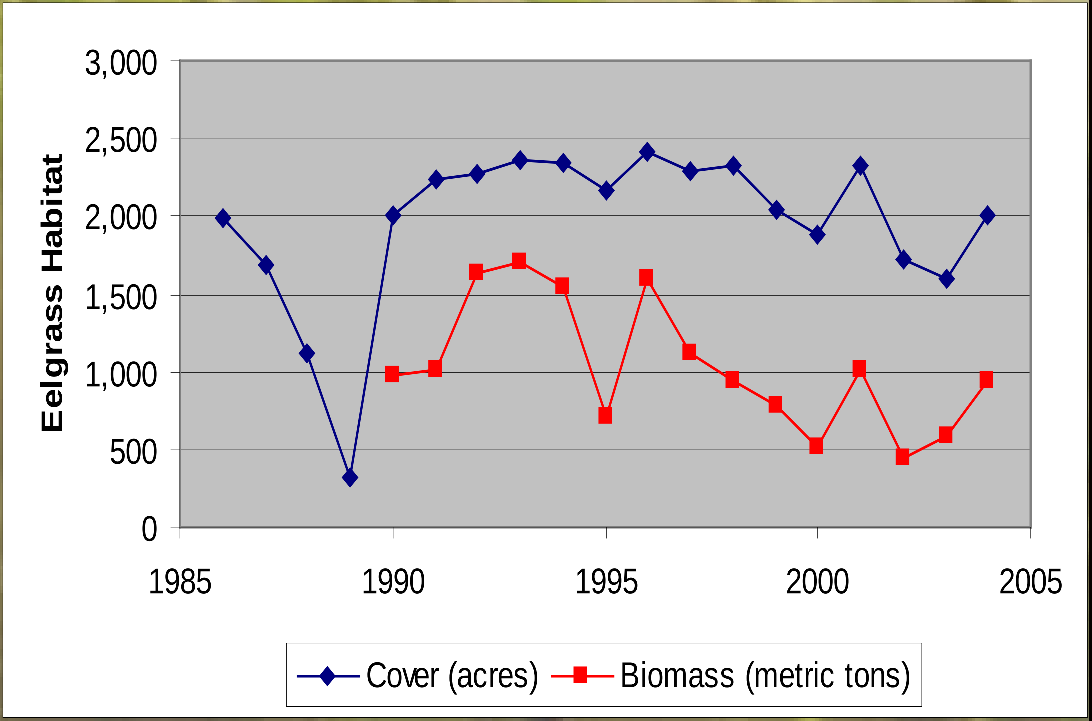
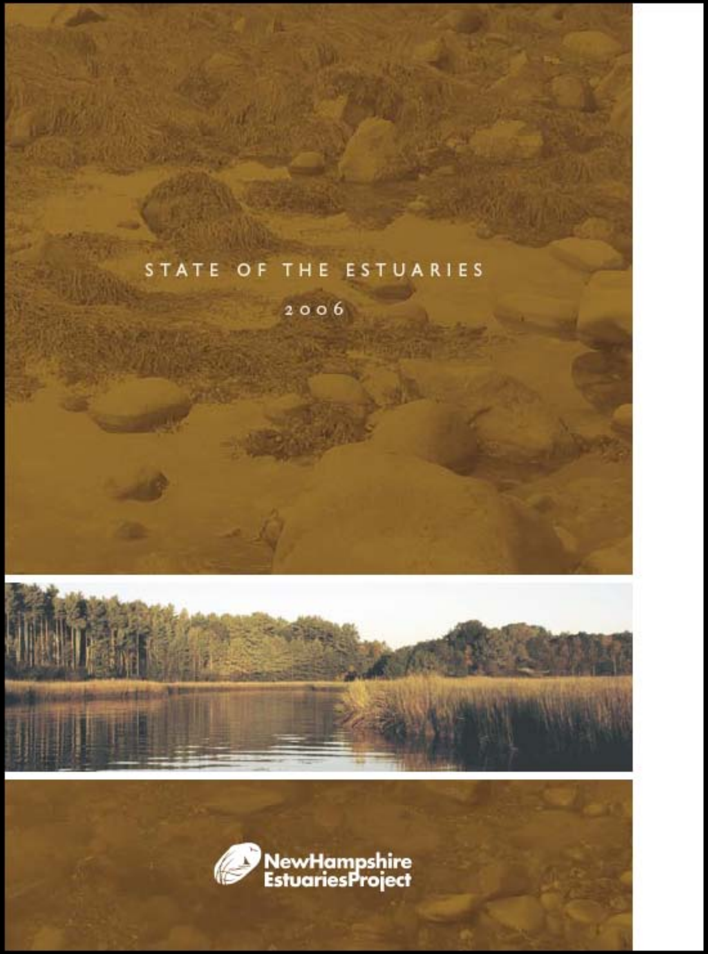
Motivation – Long term trends

- Eelgrass a critical habitat in Great Bay
- Trends mirror those in seagrass globally – declining
- PREP nutrient criteria development focused on eelgrass habitat protection

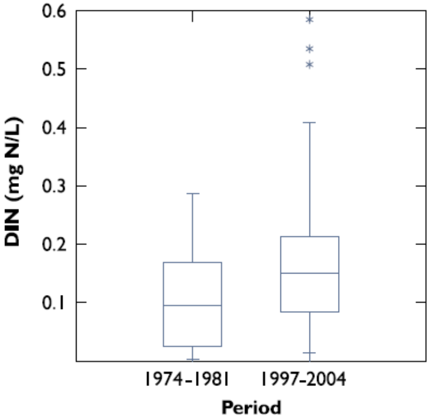


Motivation – Long term trends



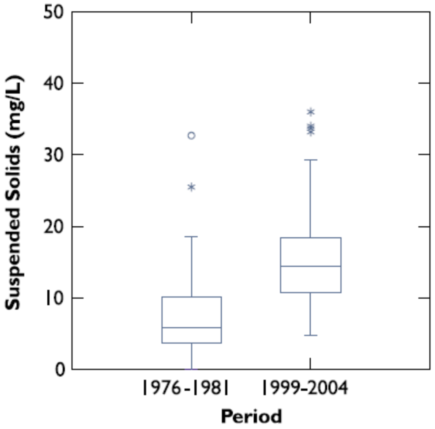
Dissolved inorganic nitrogen concentrations measured at Adams Point at low tide (Figure 6)

Data Source: UNH Jackson Estuarine Laboratory



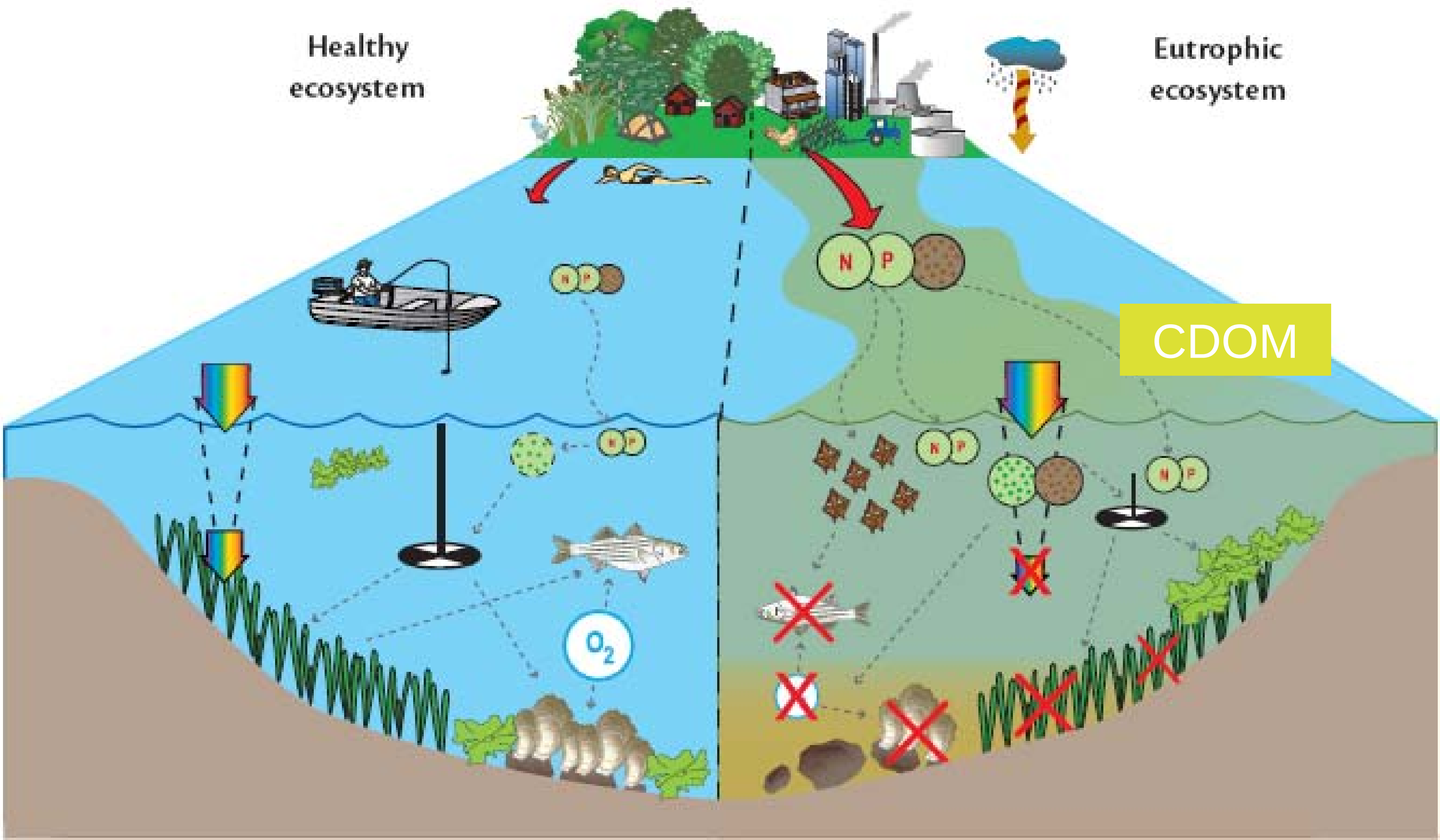
Suspended solids concentrations measured at Adams Point at low tide (Figure 7)

Data Source: UNH Jackson Estuarine Laboratory



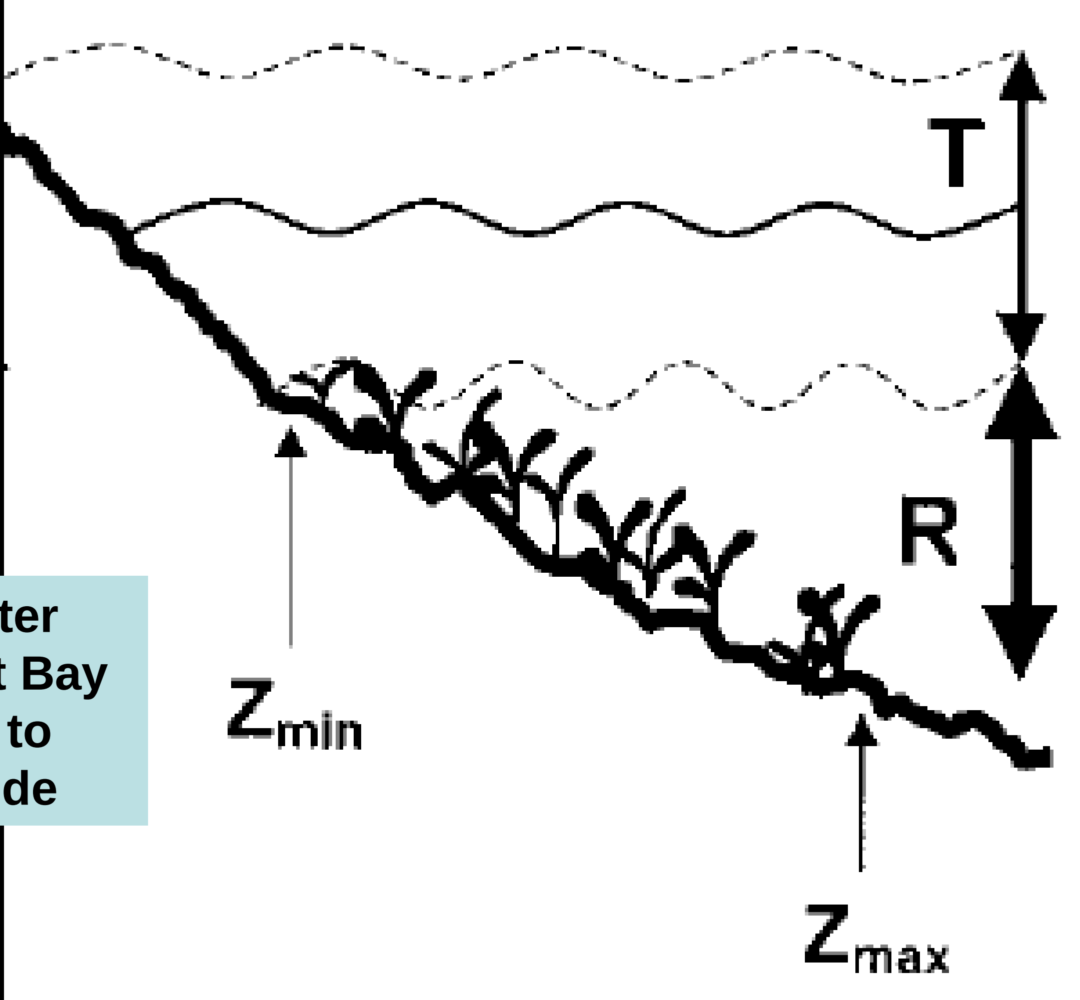
1974-1981 Data recovered as part of the buoy data discovery process

Conceptual Model of Eutrophication (Bricker et al. 2007)



CDOM

Minimum Water Clarity for Eelgrass Survival



Zmax should be >1 m below Zmin for viable eelgrass beds (i.e., Zmax>2 m)

22% of surface light at depth for eelgrass survival

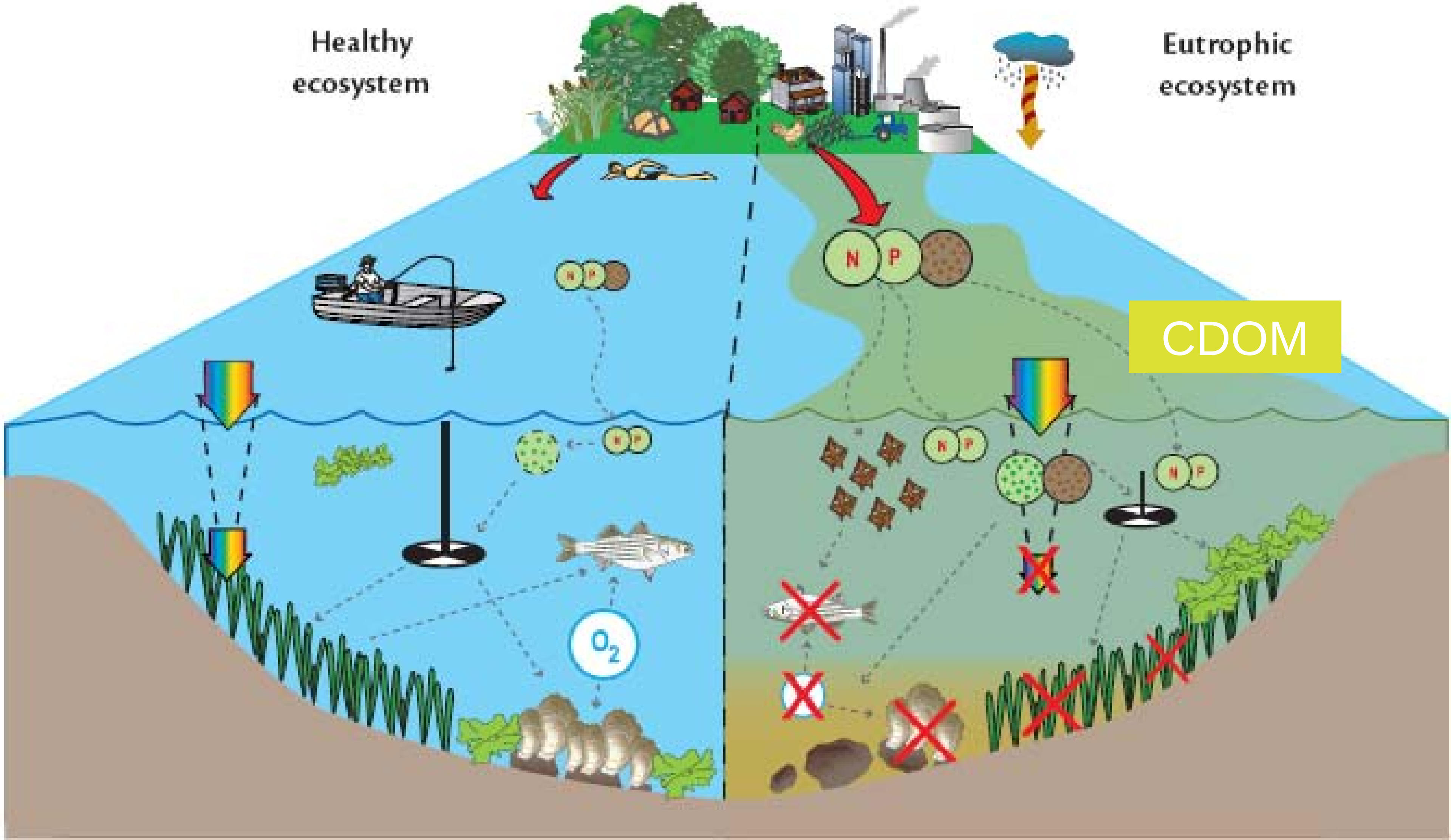
For Zmax=2 and Iz/Io=0.22, Kd should be 0.75 1/m.

Zmin = 1 meter for the Great Bay Estuary due to tidal amplitude

$$Z_{\max} = \frac{-\ln\left(\frac{I_z}{I_o}\right)}{K_d}$$

From Koch (2001)

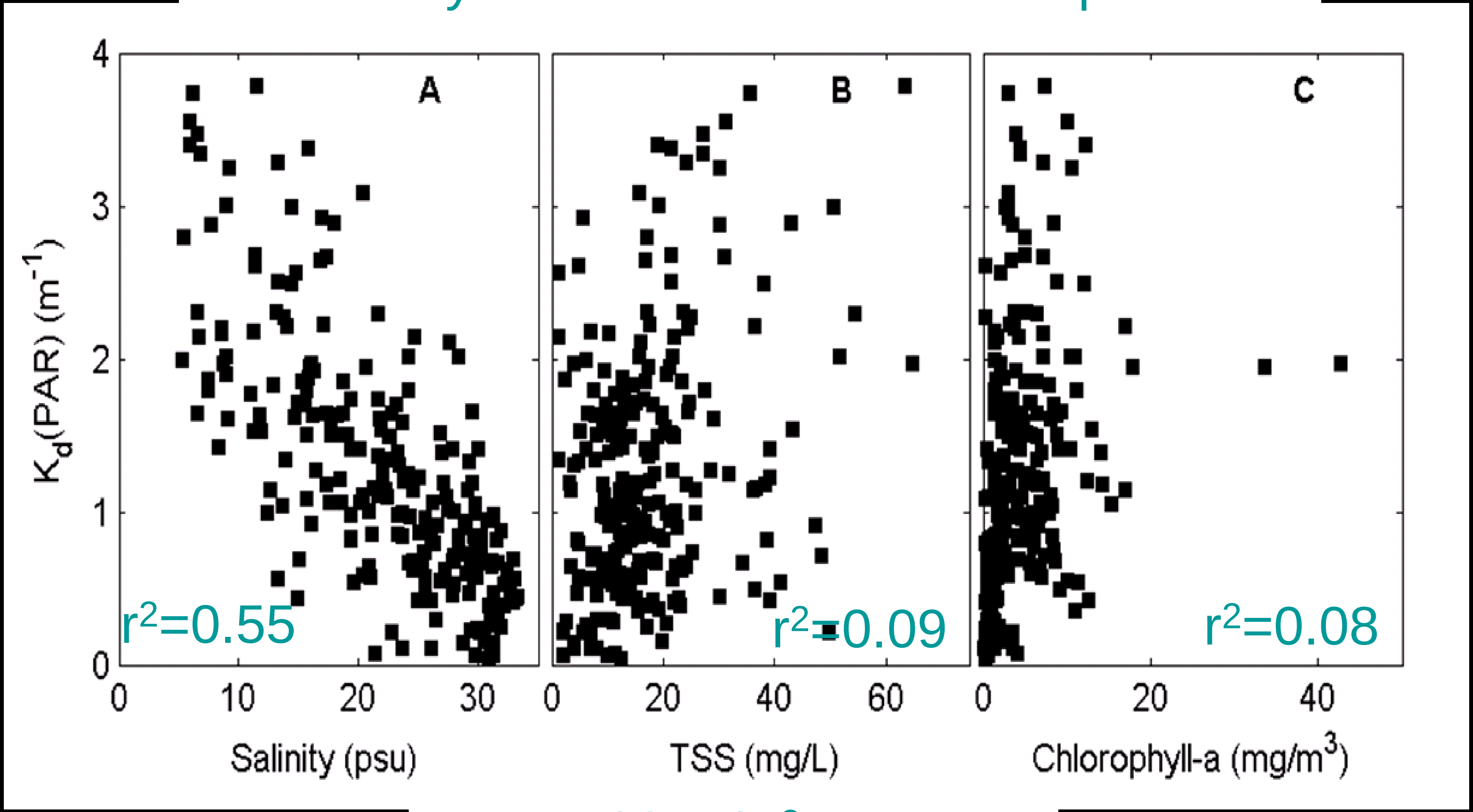
What attenuates light?



CDOM

Solution – Grab samples

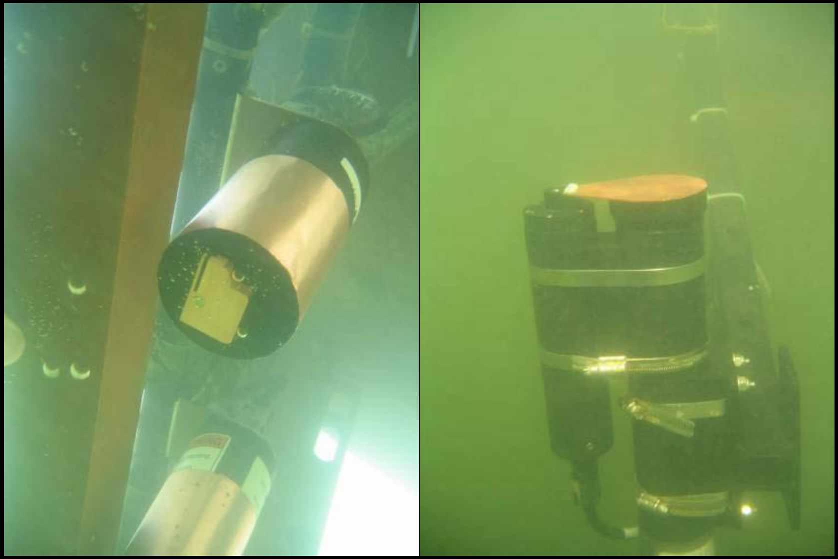
Great Bay NERR SWMP Grab sample data



Combined $r^2 = 0.62$

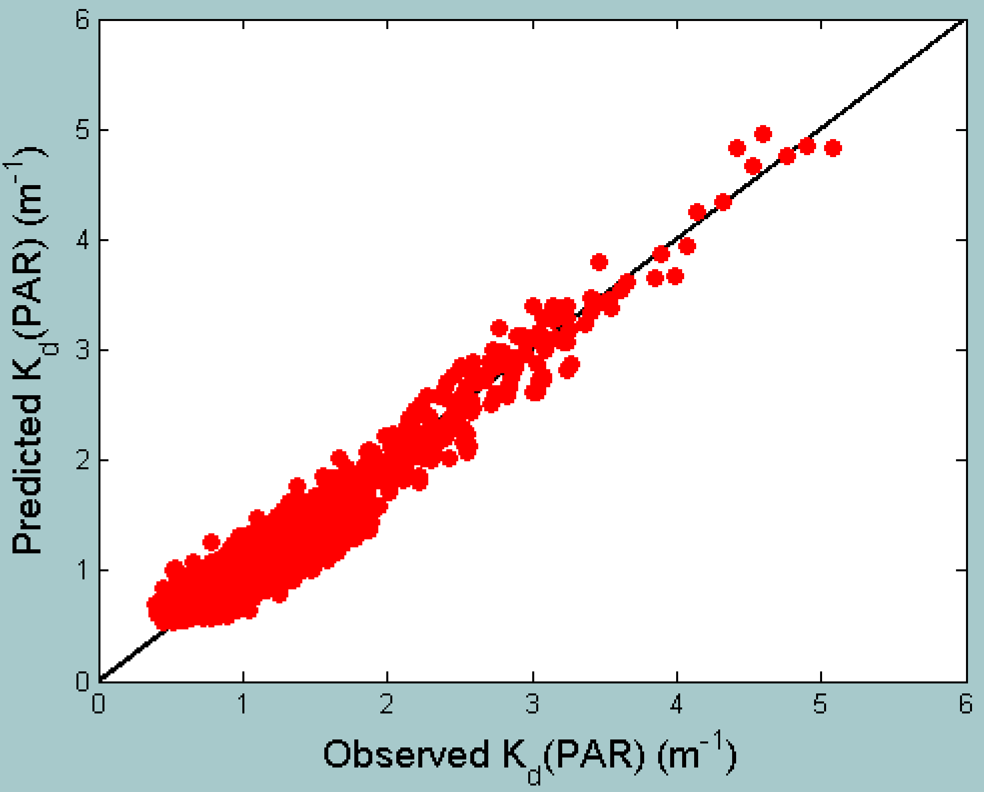
Solution – Buoy Measurements

- Surface Irradiance (Hyperspectral 350 nm – 800 nm)
- Subsurface Irradiance (1.1 m)
- FLNTUS – Chlorophyll and Turbidity
- FLCDS – CDOM



And much more……

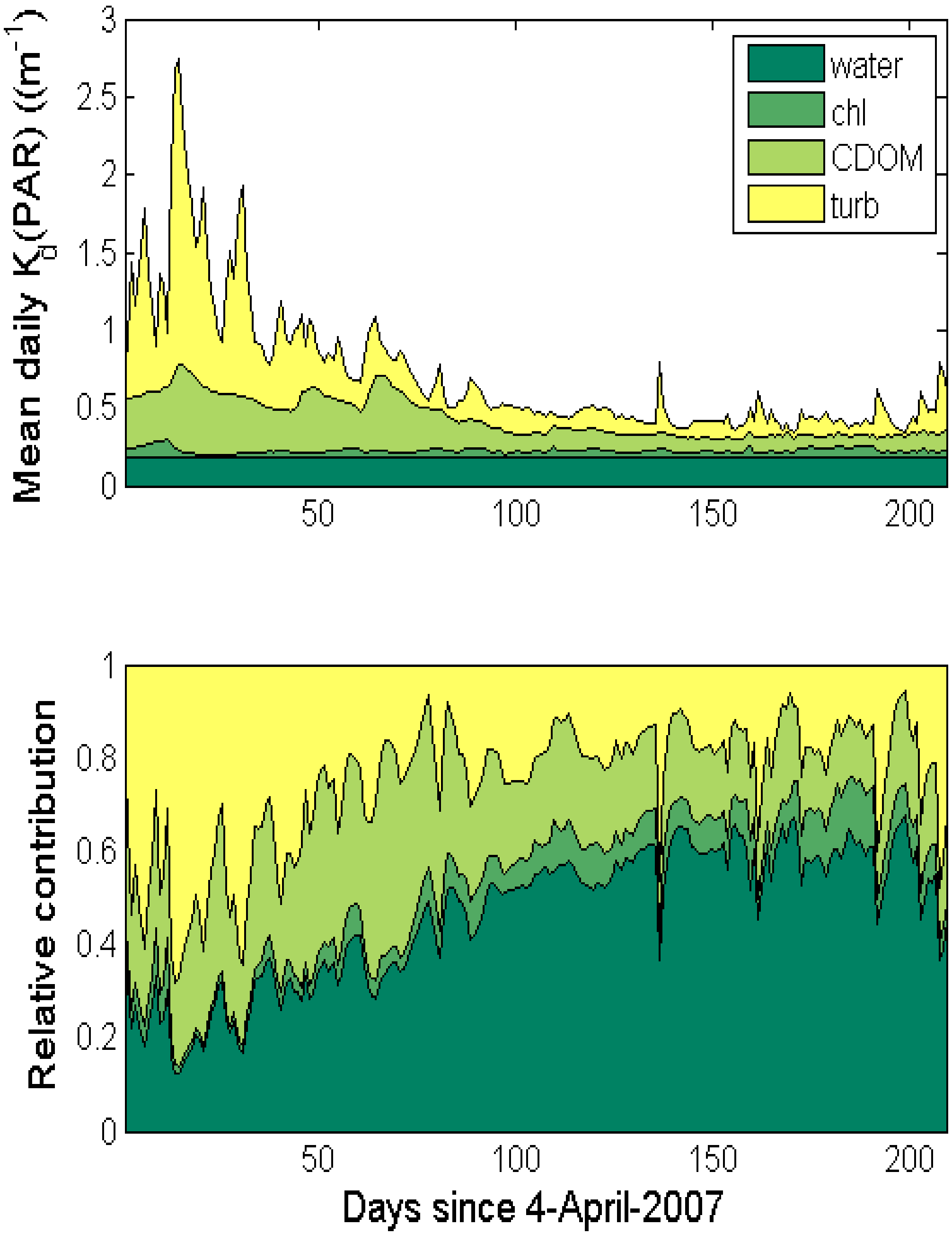
Buoy relationship –PAR

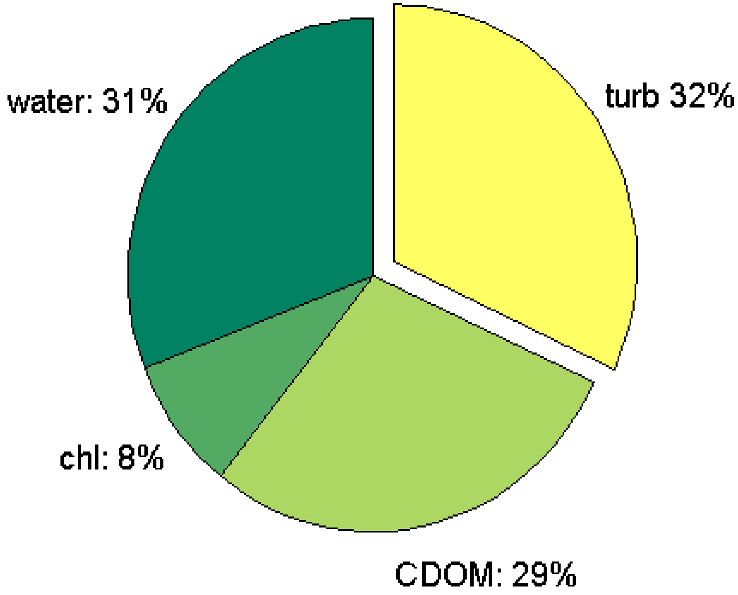


$$\frac{K_d(PAR)}{D_o} = 0.2449 + 0.0188.[Chl] + 0.0101.[CDOM] + 0.0784.[NAP]$$

$r^2 > 0.95$

Contributions to K_d(PAR)

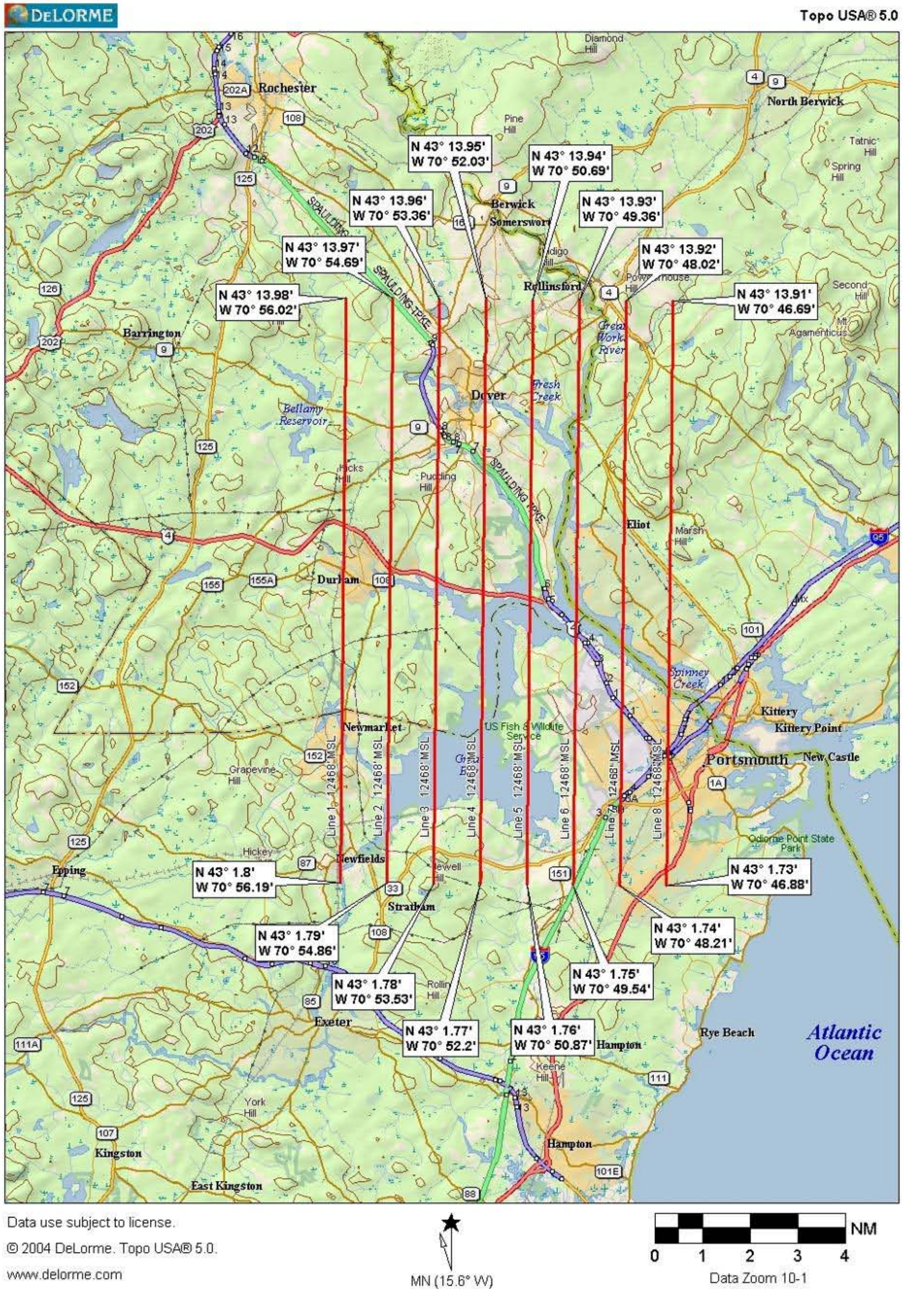




But just one location

Solution
HS imagery

- EPA grant with PREP
- Expand results from Great Bay Buoy with hyperspectral imagery
- SpecTIR collected imagery (2 flights between end of July and end of October)
- Grab samples and spatial survey underneath with multiple partners



Summary

- Well coordinated in-situ validation campaign
- Near-perfect conditions on August 29
- Imagery collection exactly as planned
- Atmospheric correction achieved with TAFKAA
- Algorithm developed

Remote Sensing Algorithm 101

- Rrs = $f[b_b/(a+b_b)]$ and $K_d = f[b_b + a]$
  - a – absorption, b_b – backscattering
- CDOM, phytoplankton, non-agal particles
- Started with 708 nm and assumed water

Based on Sound Bio-optical principles

  - Calculated b_{bp} at 708 nm
    - Turbidity = $f[b_{bp}(708)]$
  - Used this to calculate b_{bp} at 555 nm
  - Calculated a at 555 nm
- Calculated K_d at 555 nm
- $K_d(PAR) = f[K_d(555)]$


0 1 2 Kilometers
Kd(PAR) (1/m)
0.5
0.7
0.9
1.2
1.4
1.6
1.8
2

HS to in situ comparison

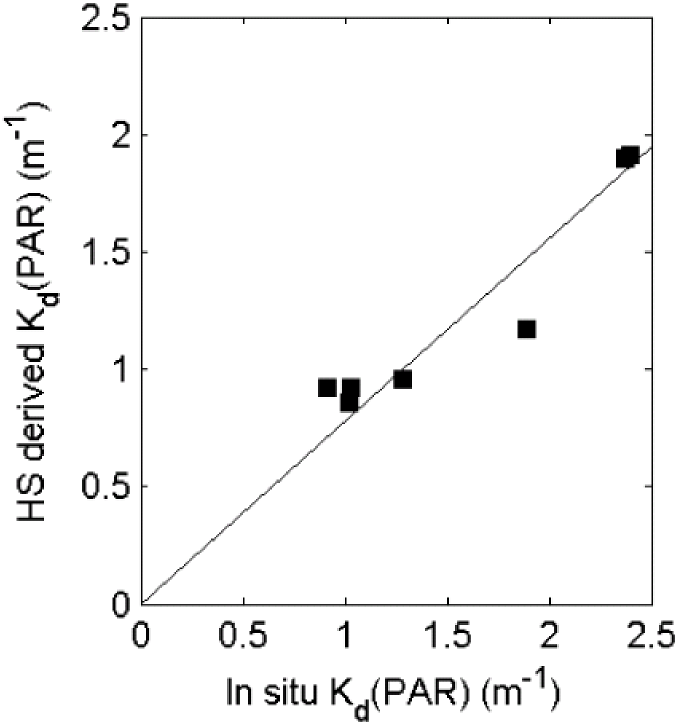
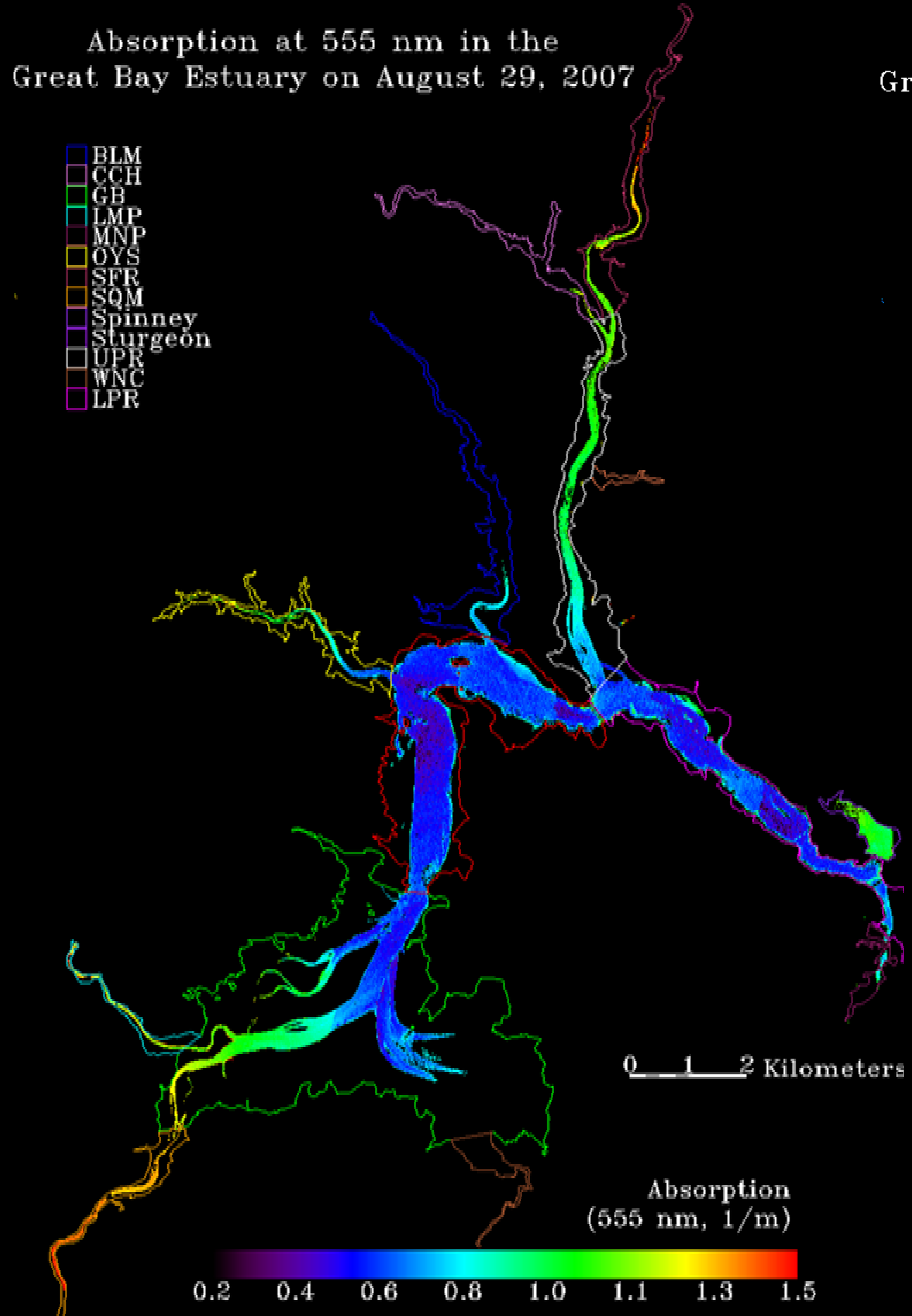
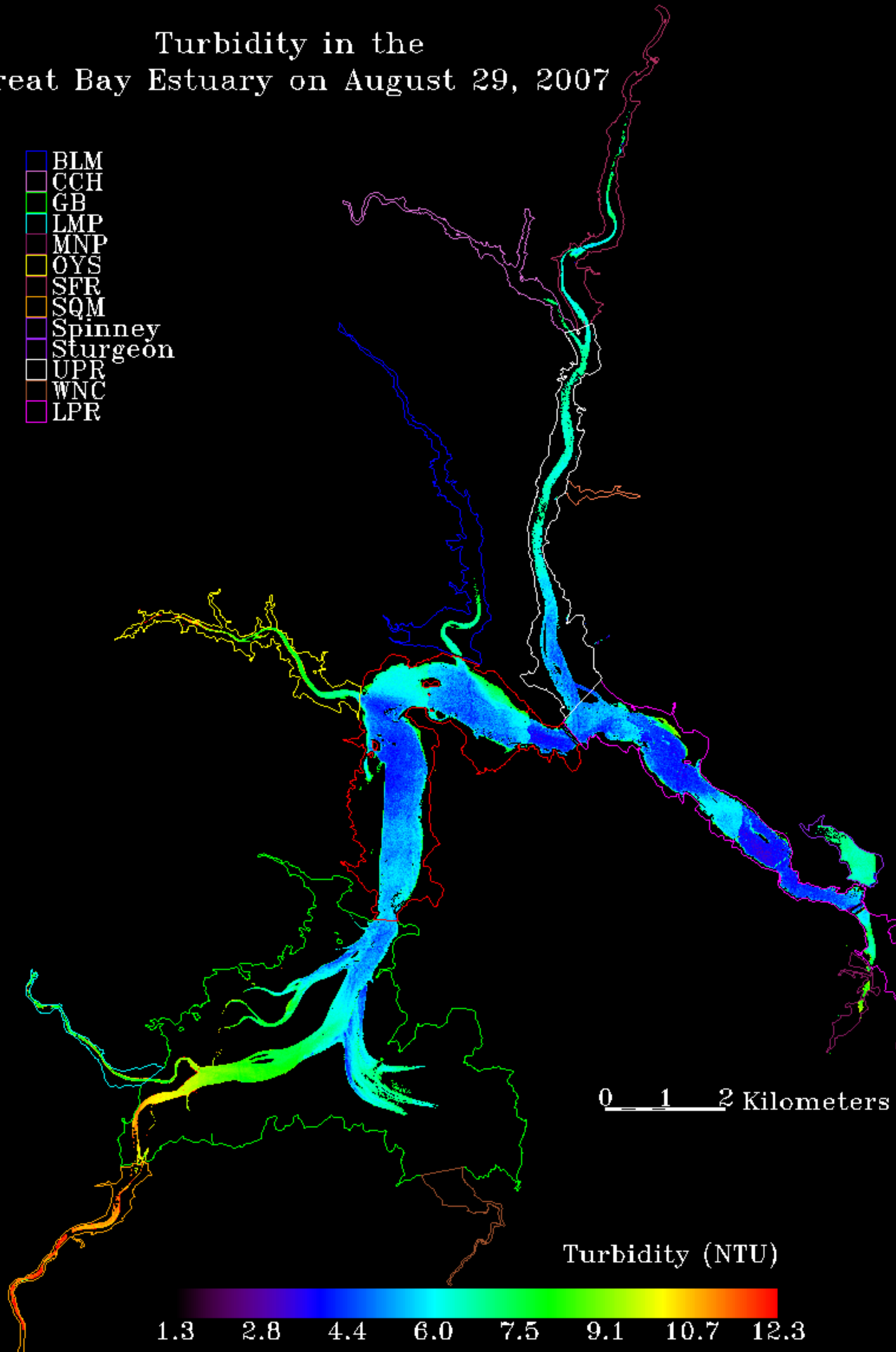


Figure 8.16 Comparison between the attenuation coefficient measured in-situ and that derived from the HS imagery. For this comparison data from GRBAP, GRBGB, GRBLR, GRBOR, collected by LeClair and GB4A, and GRBGB collected by Morrison et al. were used. Also included are the K_d(PAR) estimate from the 0900 local time at the Great Bay Coastal Buoy. Information from the Squamscott River and those collected by Edwards were excluded from this analysis as in situ measurements were either collected in close proximity to shading structures or later than other measurements. An initial linear regression analysis indicated that the intercept was not significantly different from zero giving that the HS K_d(PAR) = 0.78 in situ K_d(PAR) (r^2 = 0.88).



Absorption at 555 nm in the Great Bay Estuary on August 29, 2007



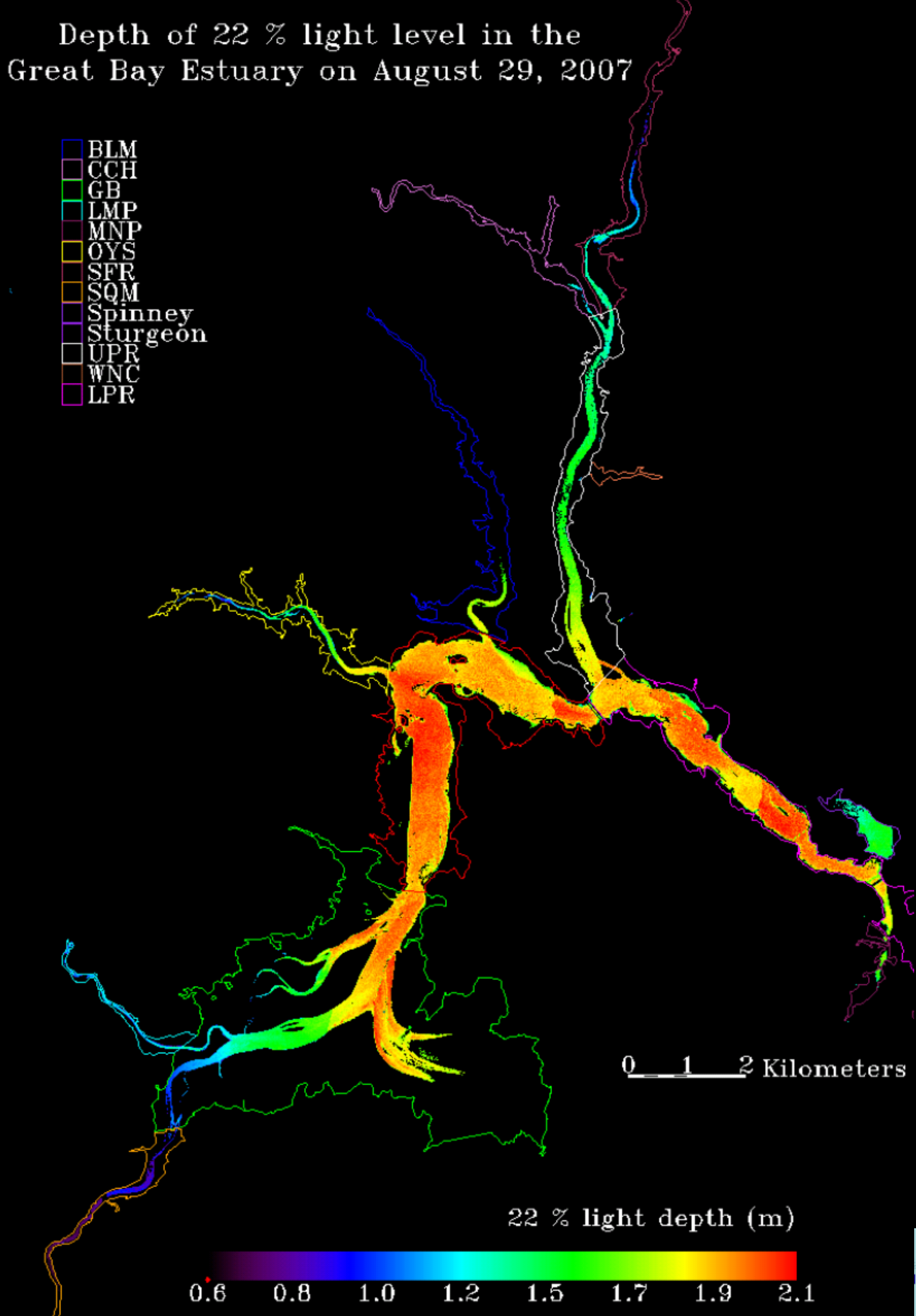
Turbidity in the Great Bay Estuary on August 29, 2007

Results Analyzed by Zone

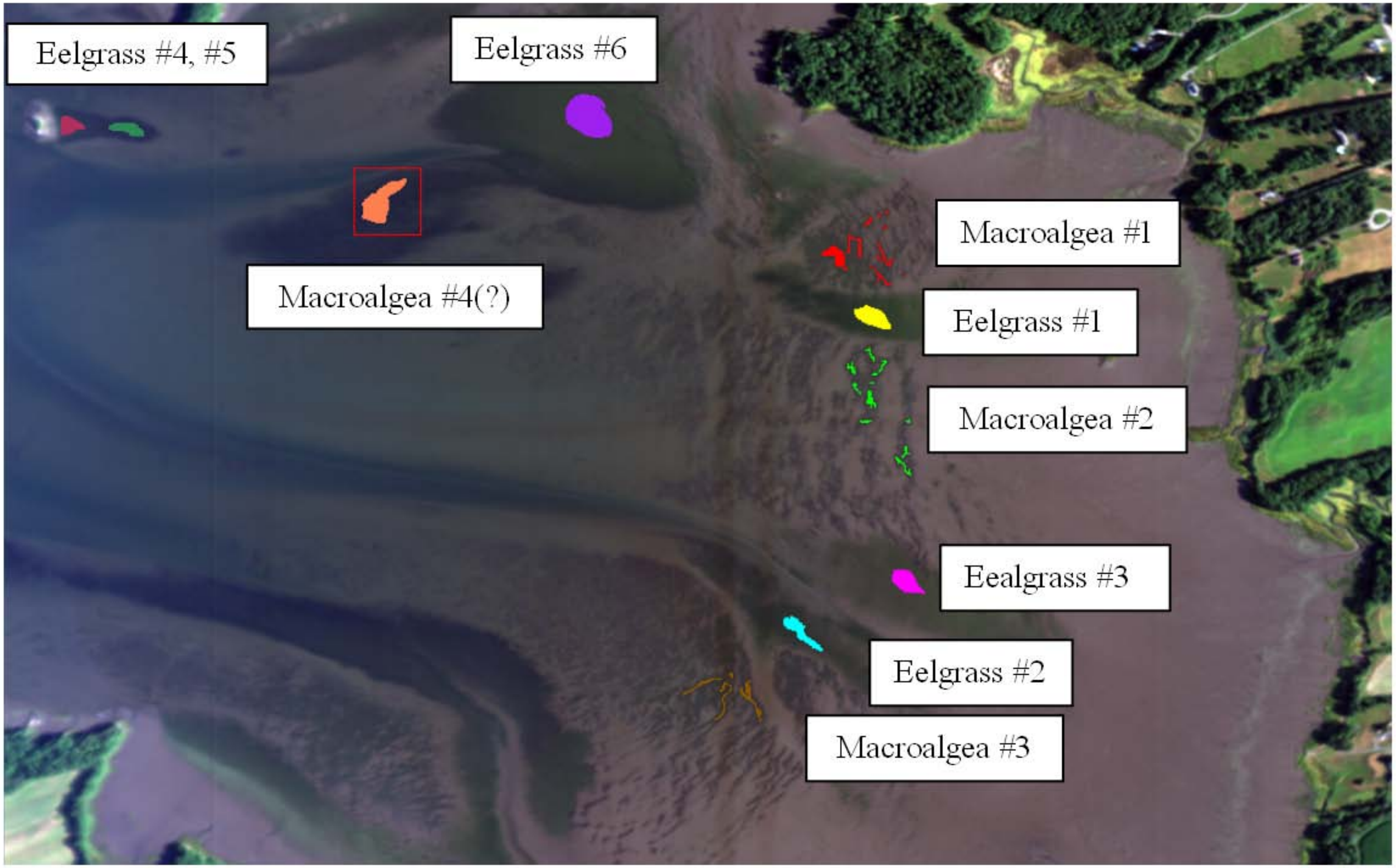
Assessment Zone		**BLM**	**CCH**	**GB**	**LB**	**LMP**	**LPR**	**NMP**	**OYS**	**SFR**	**SQM**	**Spinney**	**UPR**
Number		282872	114945	2729484	1181525	70600	695926	50993	208838	236631	116069	82745	526272
K_d(PAR)	**Min**	0.70	1.10	0.57	0.54	1.08	0.50	0.74	0.59	1.00	1.27	0.87	0.60
	Max	1.10	1.88	3.12	2.89	2.31	2.30	1.22	3.13	5.37	2.68	1.22	1.96
	Mean	**0.84**	**1.29**	**0.86**	**0.69**	**1.43**	**0.71**	**0.96**	**1.01**	**1.34**	**1.79**	**1.08**	**0.94**
	Stdev	0.06	0.09	0.24	0.08	0.20	0.10	0.11	0.29	0.24	0.12	0.07	0.15
Turbidity	**Min**	3.112	1.413	1.596	0.423	1.504	0.423	4.001	2.249	1.049	2.249	0.958	1.230
	Max	5.974	5.653	58.241	15.599	26.024	28.221	14.313	44.571	6.406	32.553	8.787	6.298
	Mean	**4.202**	**4.323**	**4.453**	**2.695**	**6.628**	**2.511**	**6.931**	**6.393**	**3.618**	**11.803**	**3.865**	**3.096**
	Stdev	0.535	0.510	2.221	0.699	1.926	0.954	1.414	2.679	0.654	0.914	0.418	0.594
b_b(555)/ a(555)	**Min**	0.147	0.032	0.096	0.027	0.034	0.019	0.129	0.065	0.007	0.049	0.029	0.042
	Max	0.337	0.147	1.650	0.898	0.641	3.487	0.976	1.453	0.132	0.773	0.315	0.200
	Mean	**0.238**	**0.123**	**0.237**	**0.203**	**0.170**	**0.179**	**0.351**	**0.283**	**0.098**	**0.247**	**0.138**	**0.140**
	Stdev	0.011	0.016	0.034	0.032	0.036	0.030	0.051	0.032	0.016	0.021	0.010	0.016
a(555)	**Min**	0.342	0.729	0.244	0.222	0.651	0.192	0.288	0.262	0.665	0.854	0.544	0.271
	Max	0.729	1.589	2.113	2.519	1.795	1.911	0.847	2.034	5.213	1.828	0.910	1.566
	Mean	**0.460**	**0.924**	**0.478**	**0.349**	**1.010**	**0.361**	**0.516**	**0.588**	**0.990**	**1.244**	**0.740**	**0.589**
	Stdev	0.051	0.092	0.187	0.066	0.169	0.081	0.086	0.226	0.239	0.114	0.063	0.146

Eelgrass Survival Depth.

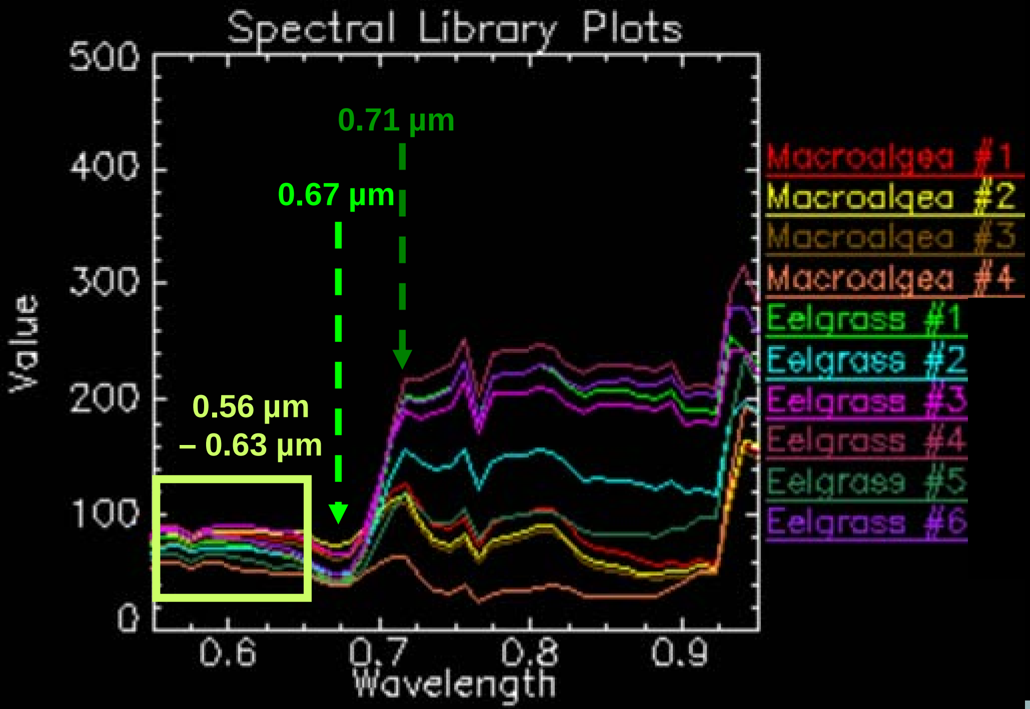
$$z_{survive} = \frac{\ln(22/100)}{K_d(PAR)}$$

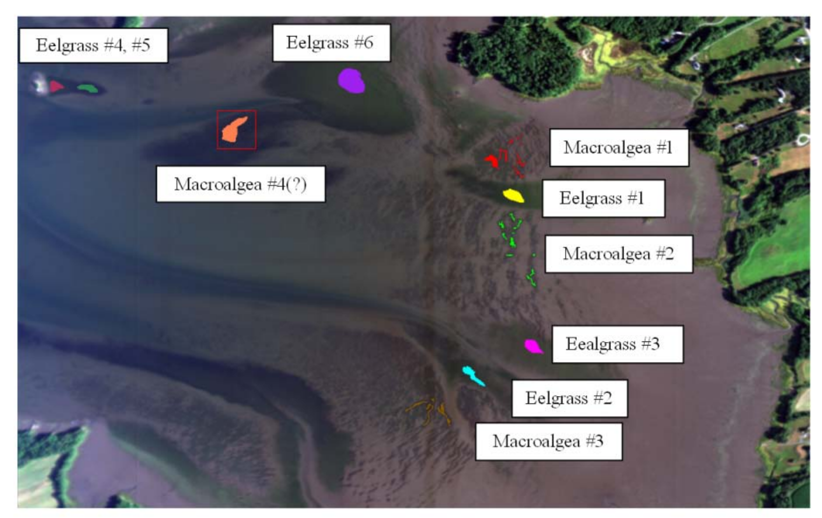


SAV mapping - Expert Defined Test Areas



Test area – Spectral Signatures





Great Bay Eelgrass & Macroalgae

🟩

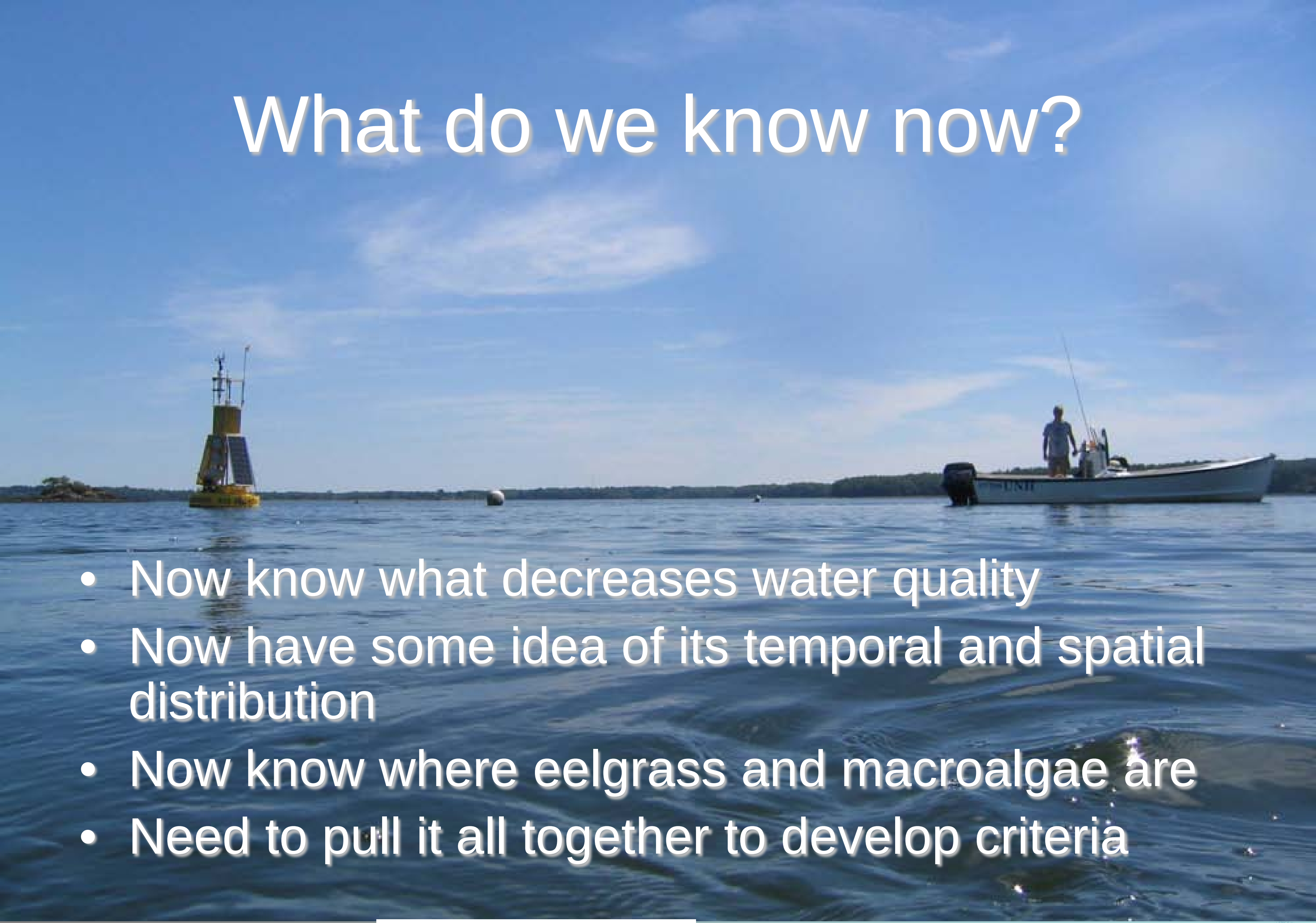
Eelgrass

🟨

Macroalgae

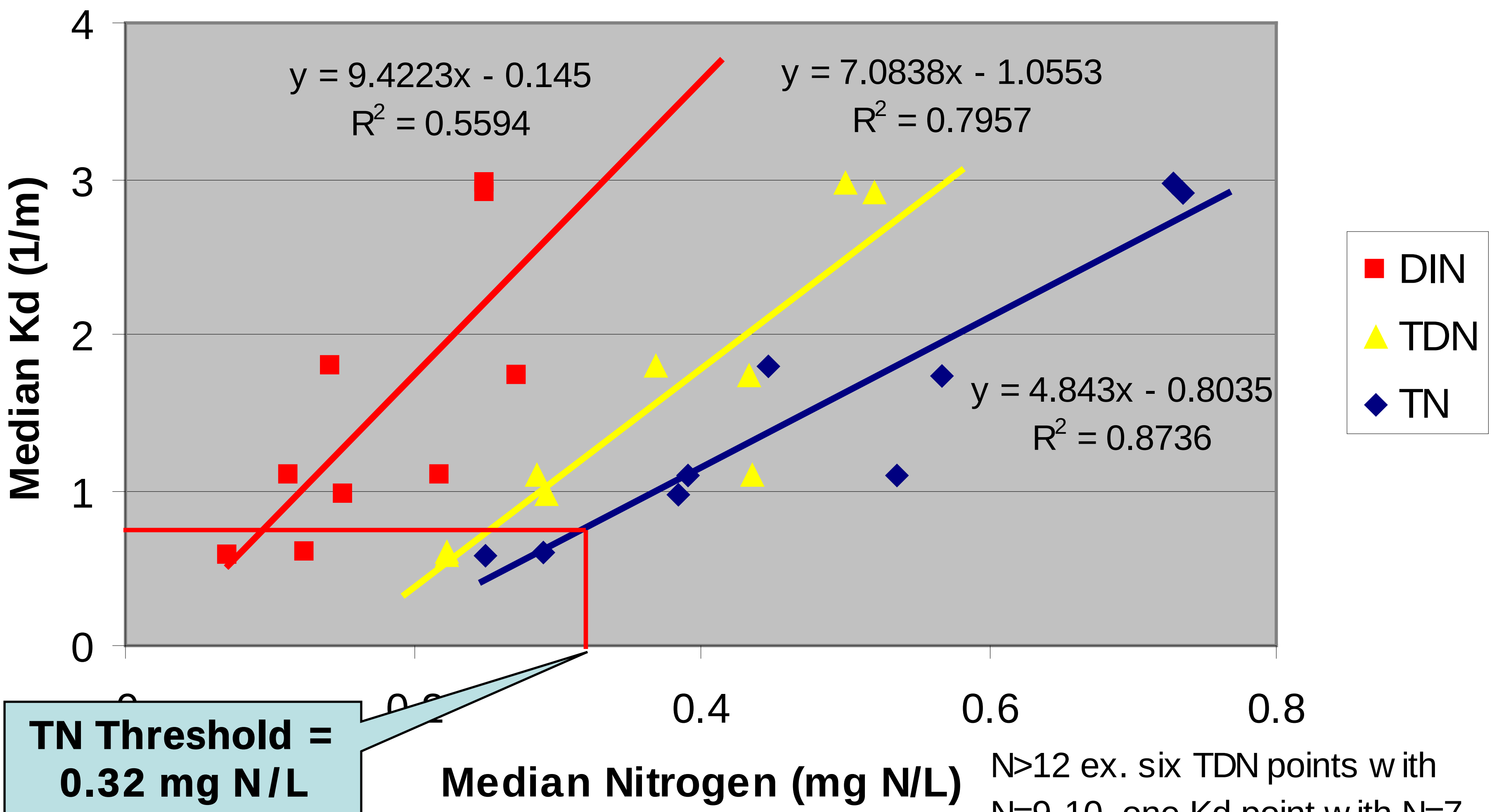
Macroalgae are beginning to proliferate in Great Bay

What do we know now?



- Now know what decreases water quality
- Now have some idea of its temporal and spatial distribution
- Now know where eelgrass and macroalgae are
- Need to pull it all together to develop criteria

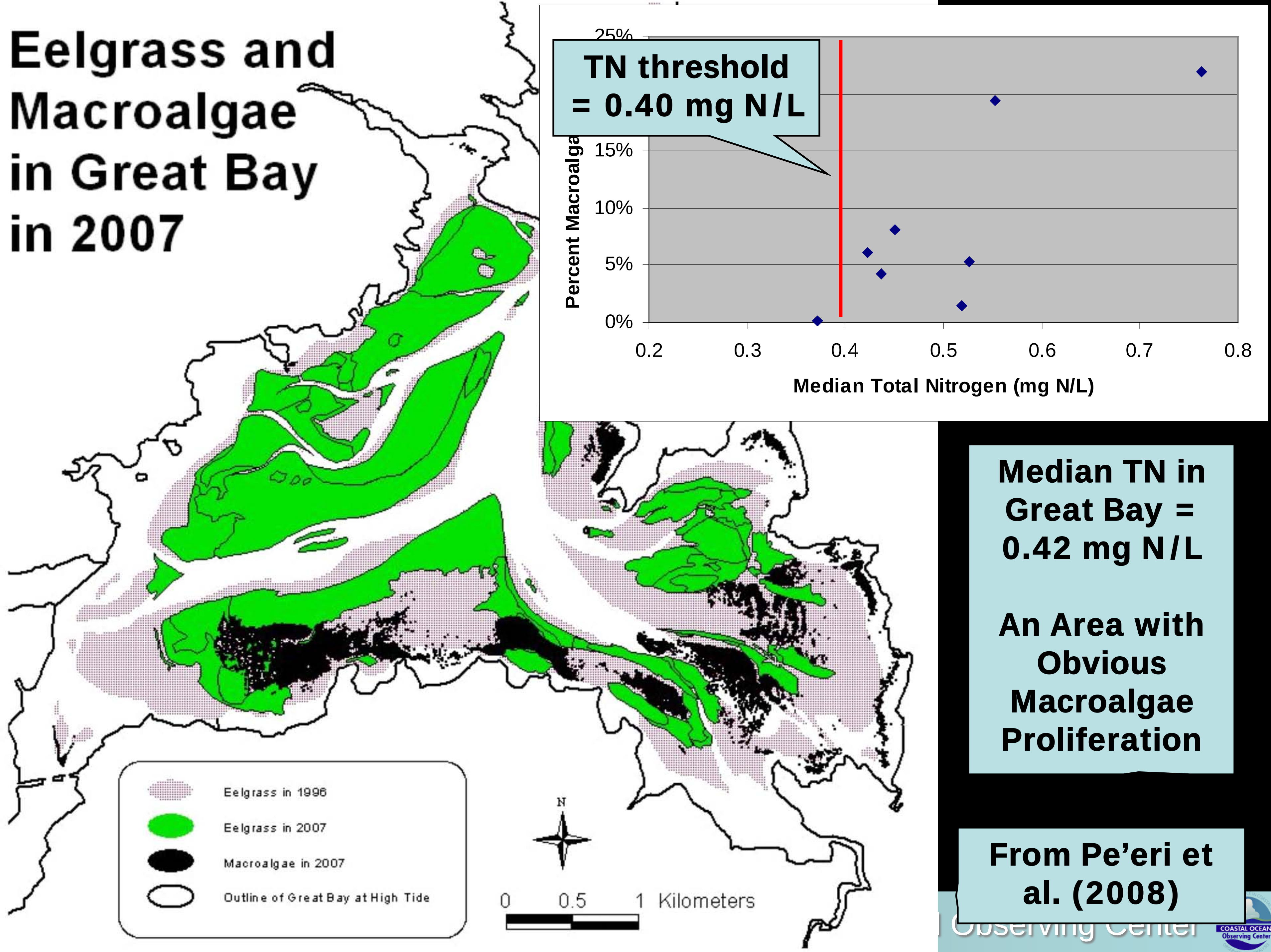
Water Clarity Decreases with Increasing Nitrogen Concentrations



TN Threshold = 0.32 mg N/L

N>12 ex. six TDN points with N=9-10, one Kd point with N=7

Eelgrass and Macroalgae in Great Bay in 2007



TN threshold = 0.40 mg N/L

Median TN in Great Bay = 0.42 mg N/L

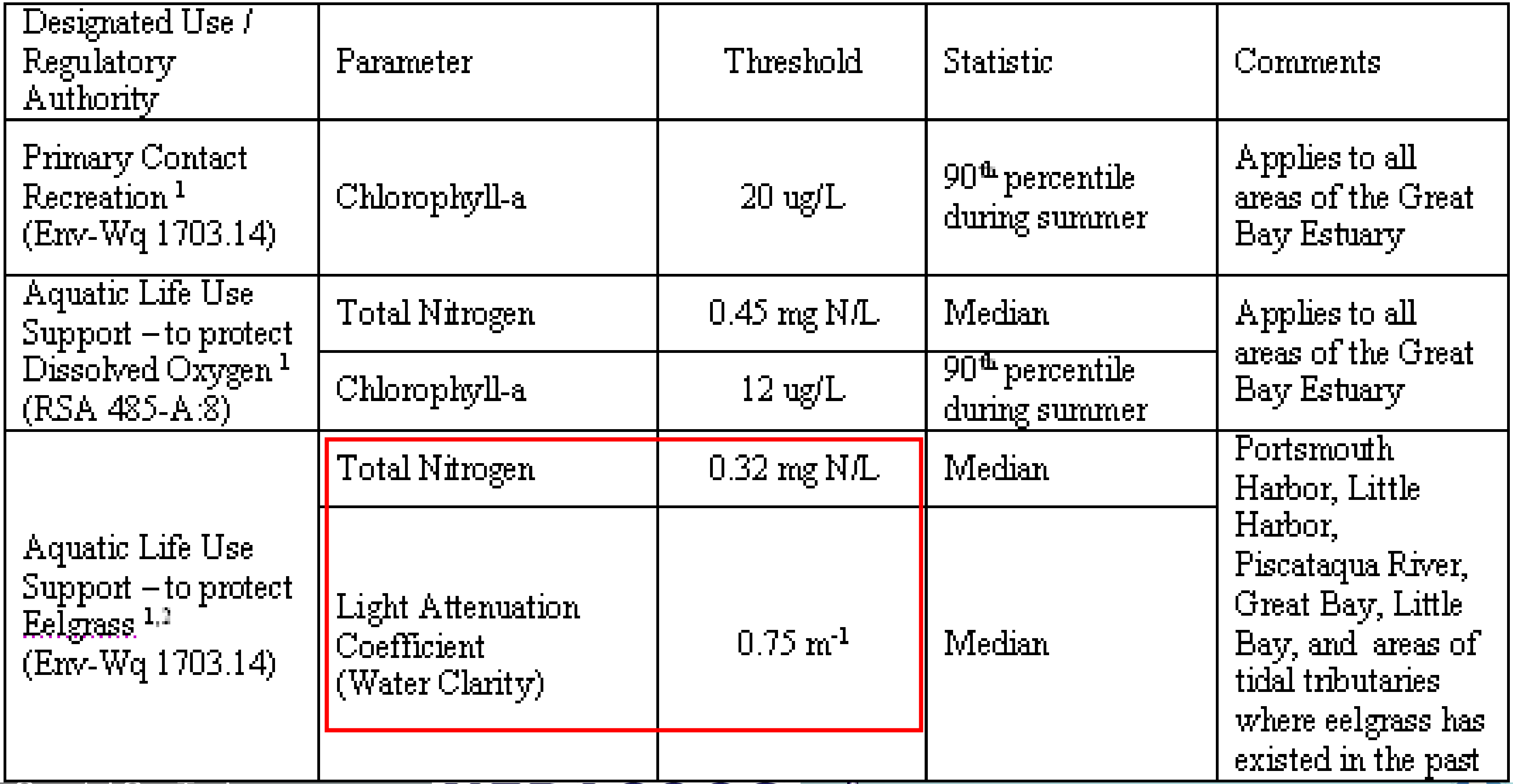
An Area with Obvious Macroalgae Proliferation

From Pe'eri et al. (2008)

Nutrient Criteria to Prevent Eelgrass Loss

- Maximum light attenuation coefficient to maintain eelgrass
  - Kd = 0.75 (1/m)
- TN associated with Kd threshold from regressions
  - TN = 0.32 mg N/L
- Macroalgae proliferation
  - No problems for TN<0.40 mg N/L
- Ocean background
  - TN = 0.24 mg N/L
- Reference concentration where eelgrass still exists (Portsmouth Hbr)
  - TN = 0.32 mg N/L (75th percentile)
- TN thresholds set for other estuaries in NE
  - TN = 0.35-0.38 mg N/L (Mass. Estuaries Project, Nantucket Sound)
- Weight of evidence threshold
  - TN threshold for eelgrass in GBE = 0.32 mg N/L

Proposed Numeric Nutrient Criteria for the Great Bay Estuary

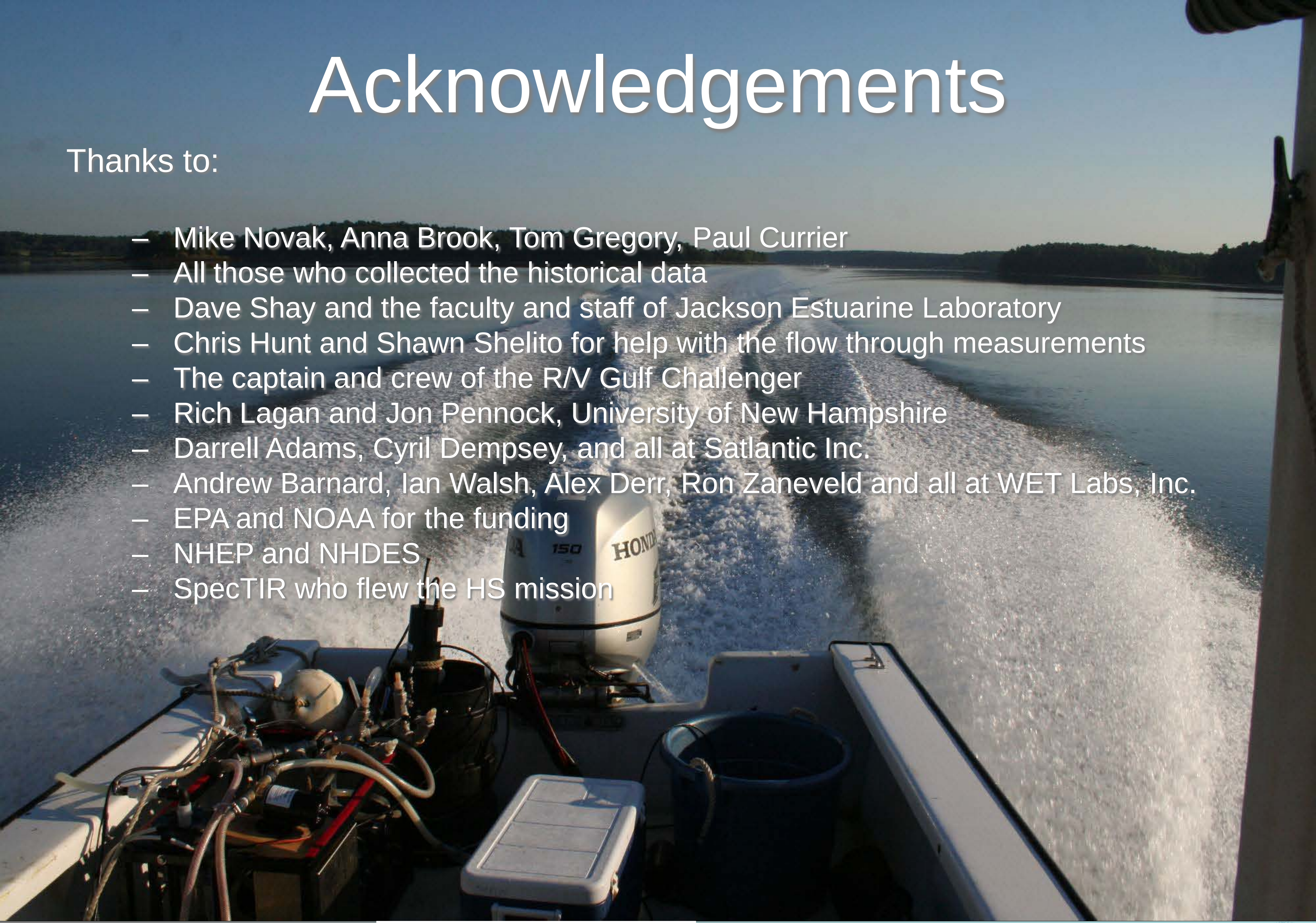


Designated Use / Regulatory Authority	Parameter	Threshold	Statistic	Comments
Primary Contact Recreation [1] (Env-Wq 1703.14)	Chlorophyll-a	20 ug/L	90th percentile during summer	Applies to all areas of the Great Bay Estuary
Aquatic Life Use Support – to protect Dissolved Oxygen [1] (RSA 485-A:8)	Total Nitrogen	0.45 mg N/L	Median	Applies to all areas of the Great Bay Estuary
	Chlorophyll-a	12 ug/L	90th percentile during summer	
Aquatic Life Use Support – to protect Eelgrass [1,2] (Env-Wq 1703.14)	Total Nitrogen	0.32 mg N/L	Median	Portsmouth Harbor, Little Harbor, Piscataqua River, Great Bay, Little Bay, and areas of tidal tributaries where eelgrass has existed in the past
	Light Attenuation Coefficient (Water Clarity)	0.75 m^{-1}	Median	

Management Implications for Nitrogen Impairments

- NPDES permitted sources for nitrogen must hold their loadings at the existing levels (e.g., WWTFs, MS4s).
- New permitted sources (e.g., AoT or CGP permittees) within the upstream watershed of an impaired waterbody would have to demonstrate zero additional loads of nitrogen or arrange for trading within the watershed.
- The “hold the load” restriction would continue until a TMDL is completed, at which point the load allocations from the TMDL would become effective. The TMDL allocations will likely require reductions in loading.

Acknowledgements



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