Assessment of Estuarine Trophic Status (ASSETS)

DRAFT Results

Synthesis of SWMP Data for ASSETS
Eutrophication Assessment of the
North Atlantic Region NERR Systems

RARGOM November 2006

CICEET Project:
Synthesis of SWMP Data for ASSETS Eutrophication Assessment of the North Atlantic Region NERR Systems

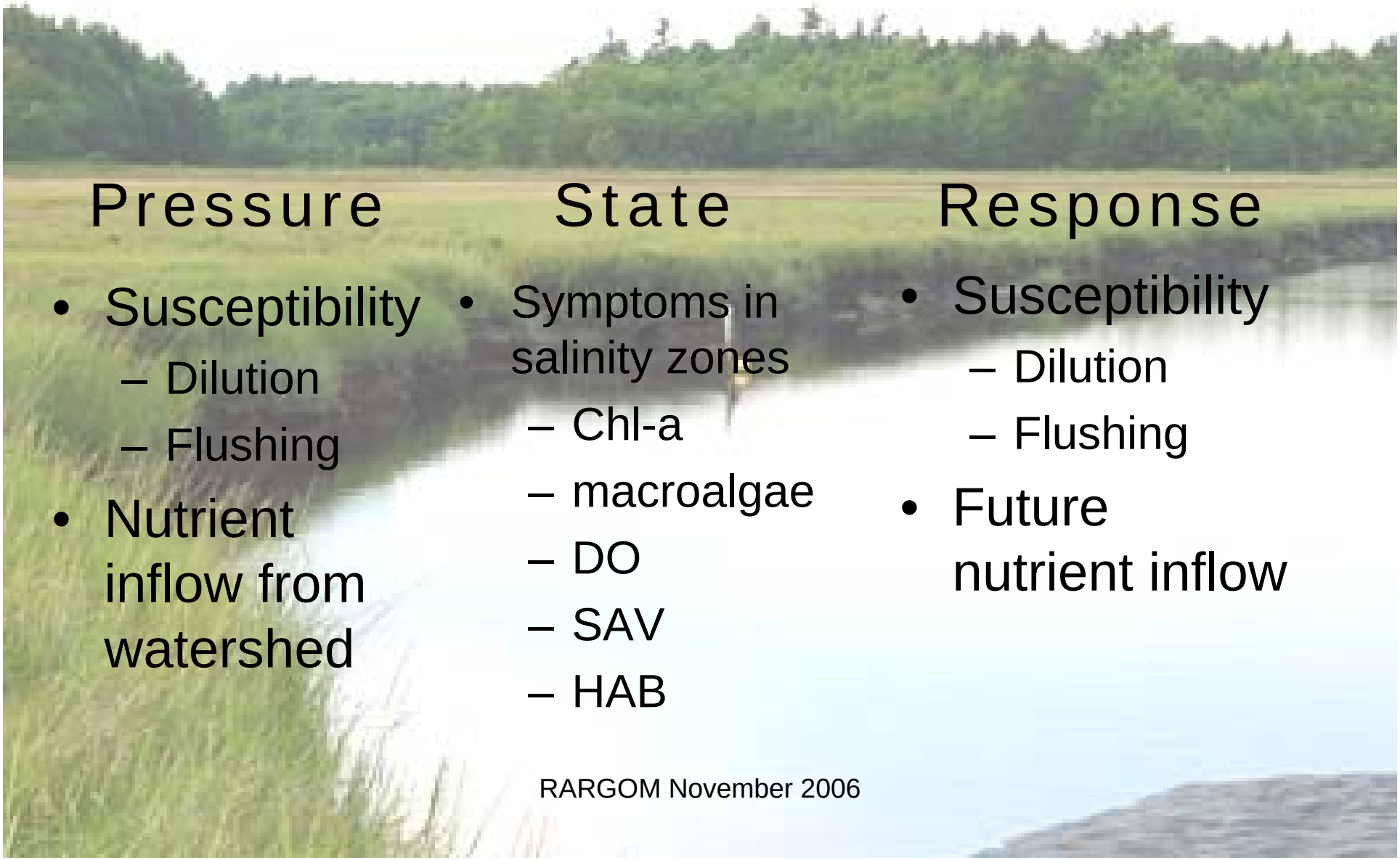
Presentation by Cayce Dalton,
On contract with Wells NERR, Wells ME
e-mail: cayce@wellsnerr.org
phone: 207-646-8645, x103

Principal Investigators:
Dr Suzanne Bricker, NOAA NCCOS, Silver Spring MD
Dr Michele Dionne, Wells NERR, Wells ME

Additional Project Member:
Fred Dillon, FB Environmental, Portland, ME

RARGOM November 2006

ASSETS has three parts



Pressure

- Susceptibility
  - Dilution
  - Flushing
- Nutrient inflow from watershed

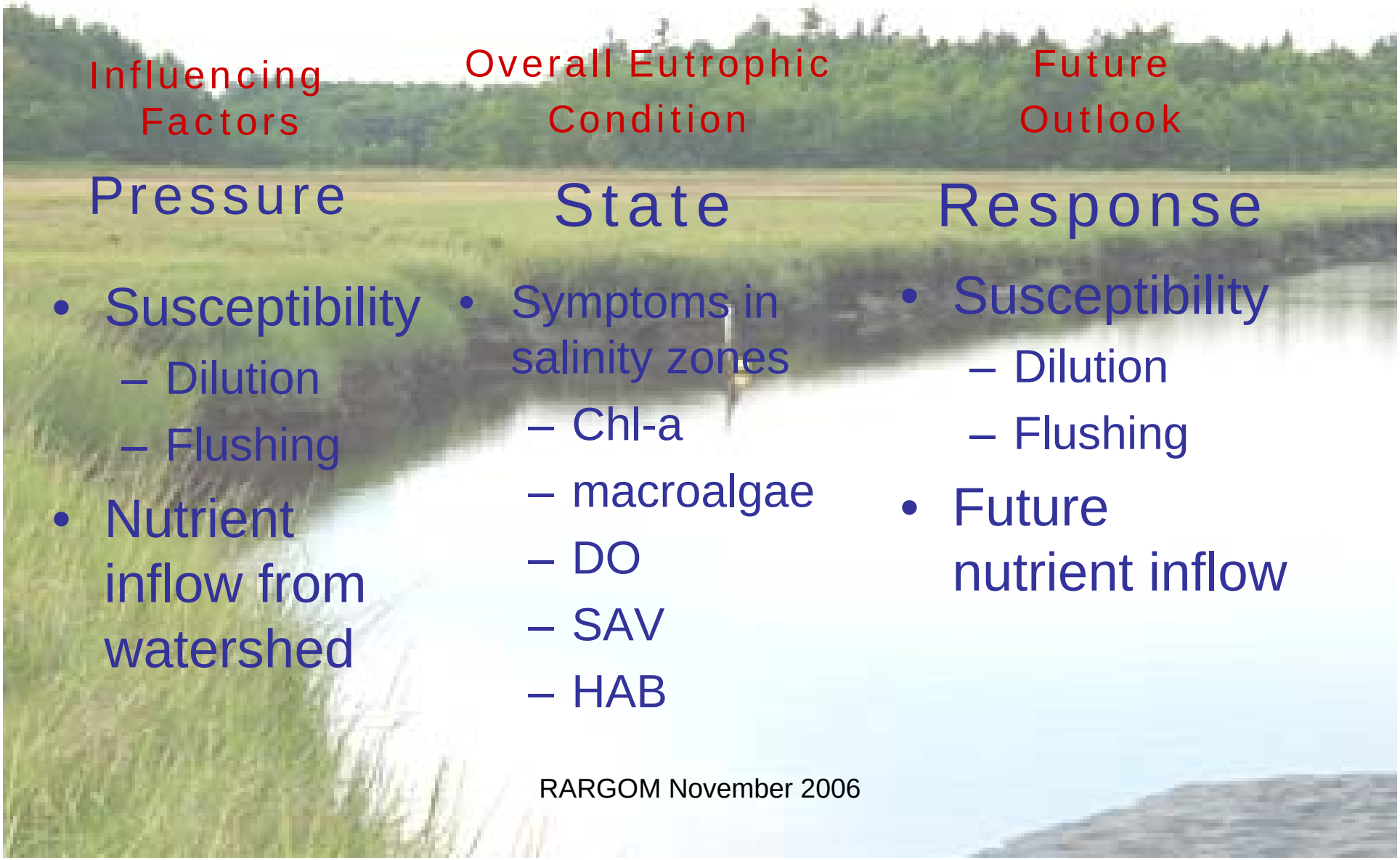
State

- Symptoms in salinity zones
  - Chl-a
  - macroalgae
  - DO
  - SAV
  - HAB

Response

- Susceptibility
  - Dilution
  - Flushing
- Future nutrient inflow

ASSETS has three parts



Influencing Factors

Pressure

- Susceptibility
  - Dilution
  - Flushing
- Nutrient inflow from watershed

Overall Eutrophic Condition

State

- Symptoms in salinity zones
  - Chl-a
  - macroalgae
  - DO
  - SAV
  - HAB

Future Outlook

Response

- Susceptibility
  - Dilution
  - Flushing
- Future nutrient inflow

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Ecological Modelling 169 (2003) 39–60

ELSEVIER

ECOLOGICAL MODELLING

www.elsevier.com/locate/ecolmodel

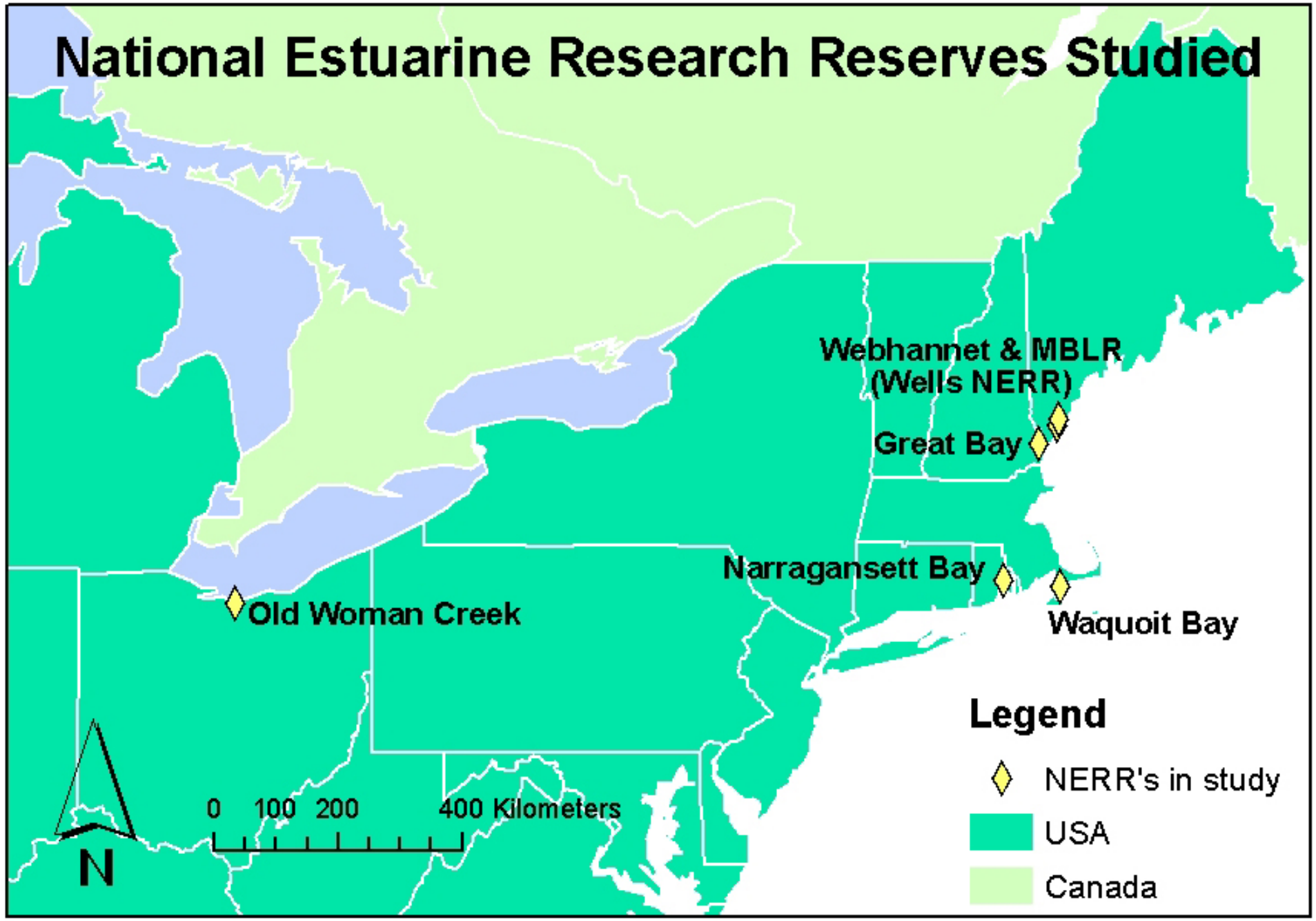
An integrated methodology for assessment of estuarine trophic status

S.B. Bricker[a,*], J.G. Ferreira[b], T. Simas[b]

[a] *NOAA—National Ocean Service, National Centers for Coastal Ocean Science, 1305 East West Highway, Silver Spring, MD 20910, USA*

[b] *IMAR—Institute of Marine Research, Centre for Ecological Modelling, DCEA-FCT, Qta. Torre, 2829-516 Monte de Caparica, Portugal*

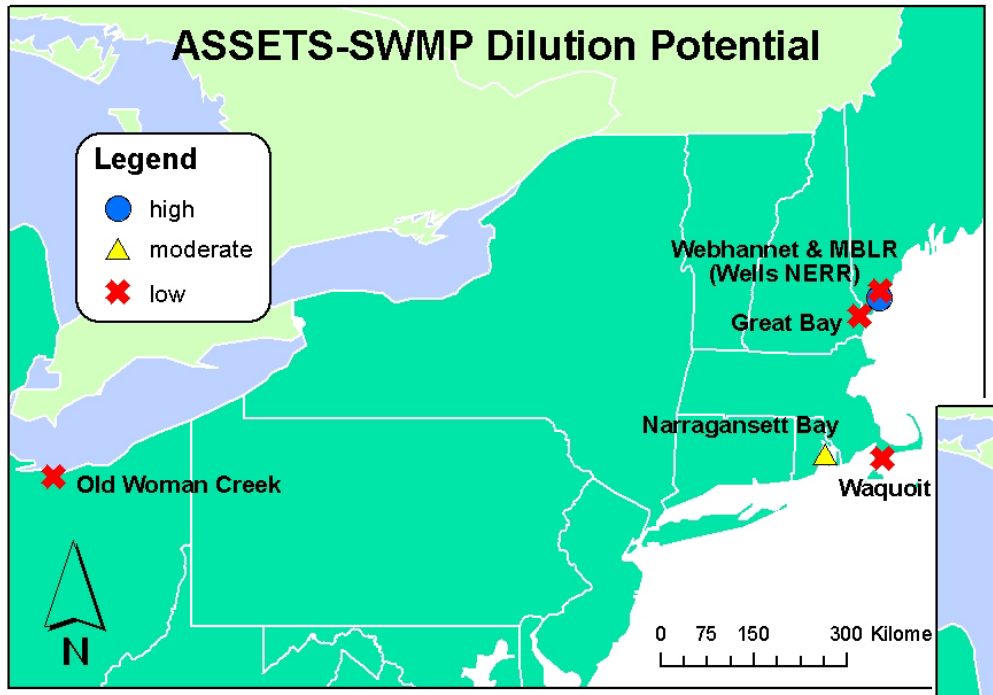
Received 30 July 2002; received in revised form 16 April 2003; accepted 12 May 2003

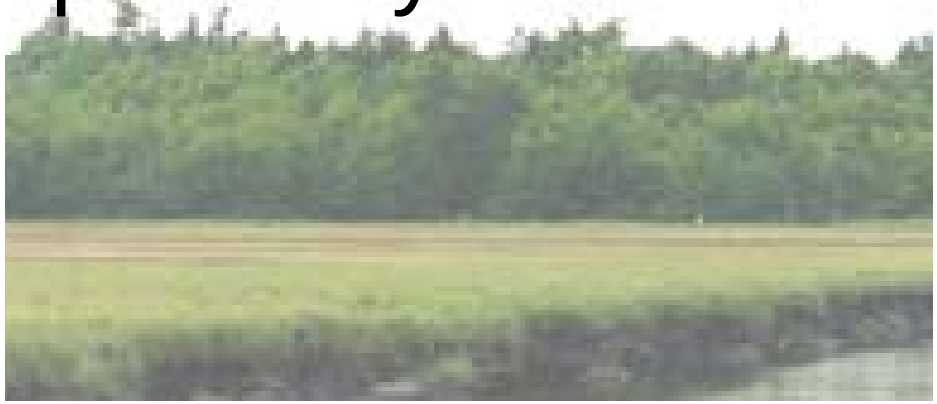

National Estuarine Research Reserves Studied
Webhannet & MBLR
(Wells NERR)
Great Bay
Narragansett Bay
Waquoit Bay
Old Woman Creek
N
0 100 200 400 Kilometers
Legend
NERR's in study
USA
Canada

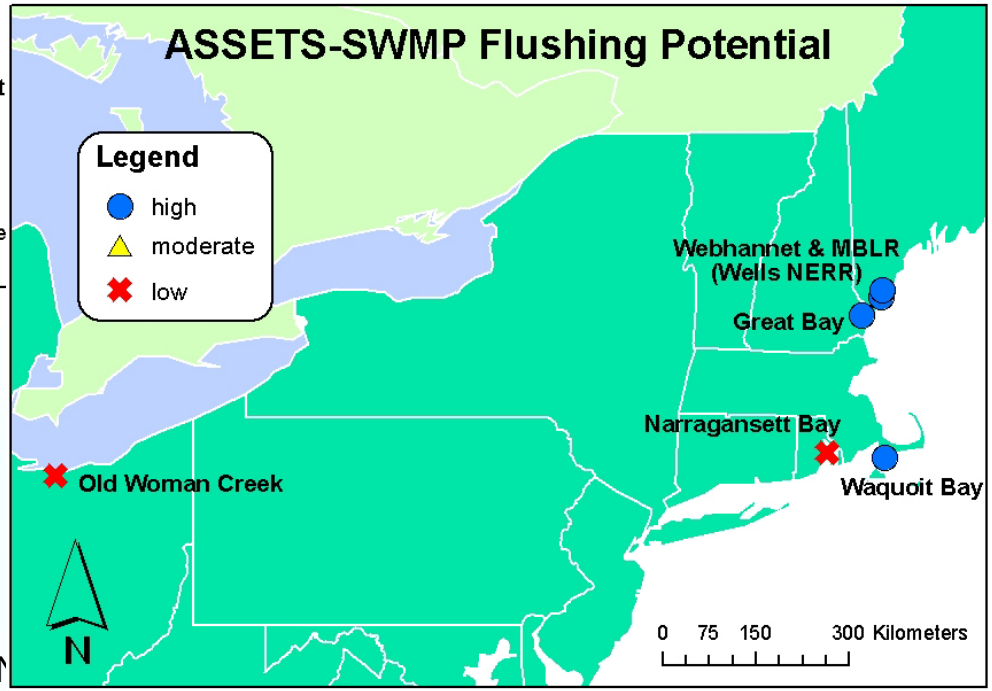
June Workshop

RARGOM November 2006

Pressure: Dilution & Flushing Give Susceptibility





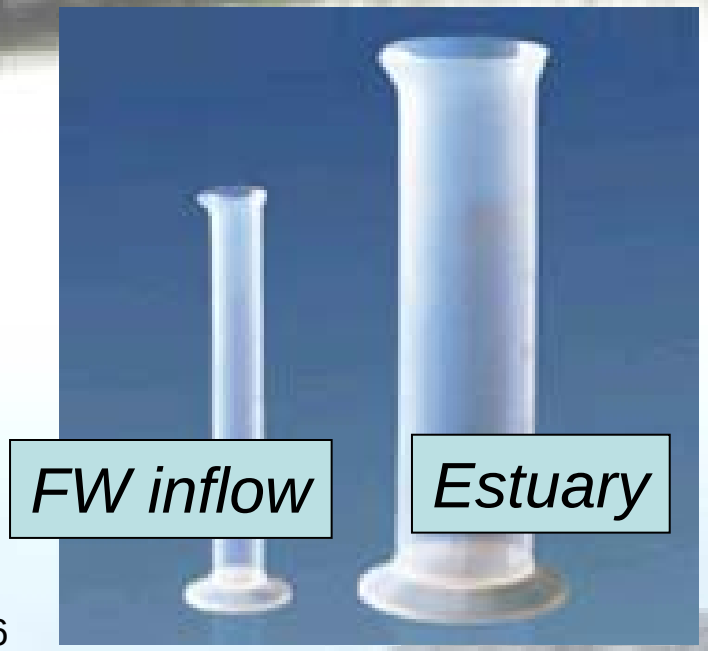


RARGOM

Pressure: Dilution

Dilution potential:

Considers only estuary volume, not amount of FW inflow.

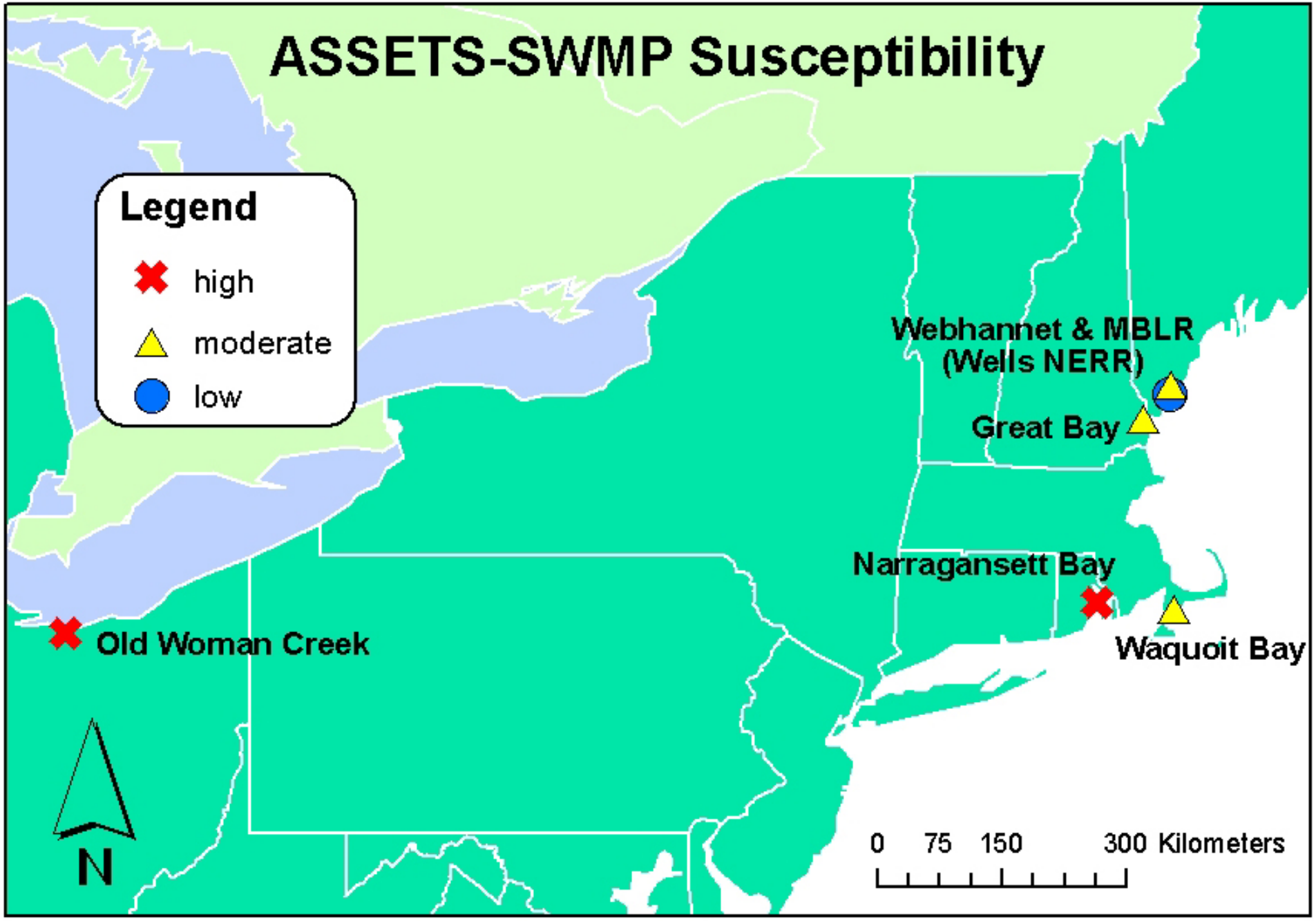


Dilution Potential Table

1. Decision Rules for DILUTION Potential. This analysis assumes that a larger portion of the water column is potentially available to dilute nutrient loads in a vertically homogenous estuary than in a vertically stratified system. The assumption is that for stratified systems, nutrients are most often retained in the upper portion (freshwater fraction) of the water column. In contrast, downward transport (more complete mixing) is likely in vertically homogenous systems. Type B estuaries are generally vertically homogenous, although stratification is observed (confined) in narrow navigation channels or the extreme upper reaches of an estuary. In this case, nutrients are assumed to be diluted throughout the entire water column.

Type	IF: Vertical Stratification	THEN: Dilution Volume	IF: Dilution Value	**Dilution Potential**	Number of Estuaries
A	Vertically Homogenous •all year •throughout estuary	$1 / VOL_{estuary}$	10^{-13} 10^{-12}	**HIGH**	30
B	Minor Vertical Stratification •navigation channels •upper estuary	$1 / VOL_{estuary}$	10^{-11}	**MODERATE**	63
C	Vertically Stratified •most of year •most of estuary	$1 / VOL_{fwf}$ (fwf = freshwater fraction)	10^{-10} 10^{-09}	**LOW**	45

RARGOM November 2006


ASSETS-SWMP Susceptibility
Legend
high
moderate
low
Webhannet & MBLR
(Wells NERR)
Great Bay
Narragansett Bay
Waquoit Bay
Old Woman Creek
N
0 75 150 300 Kilometers

Pressure: Influencing Factors Formula

Measures nutrient pressure:

Considers a ratio…

DIN from watershed
to
Total expected DIN from offshore & watershed

RARGOM November 2006

Pressure: Influencing Factors Formula

IF Formula results

MBLR:	moderate
Webhannet:	moderate
Great Bay:	moderate high
Waquoit:	moderate
Narragansett:	high

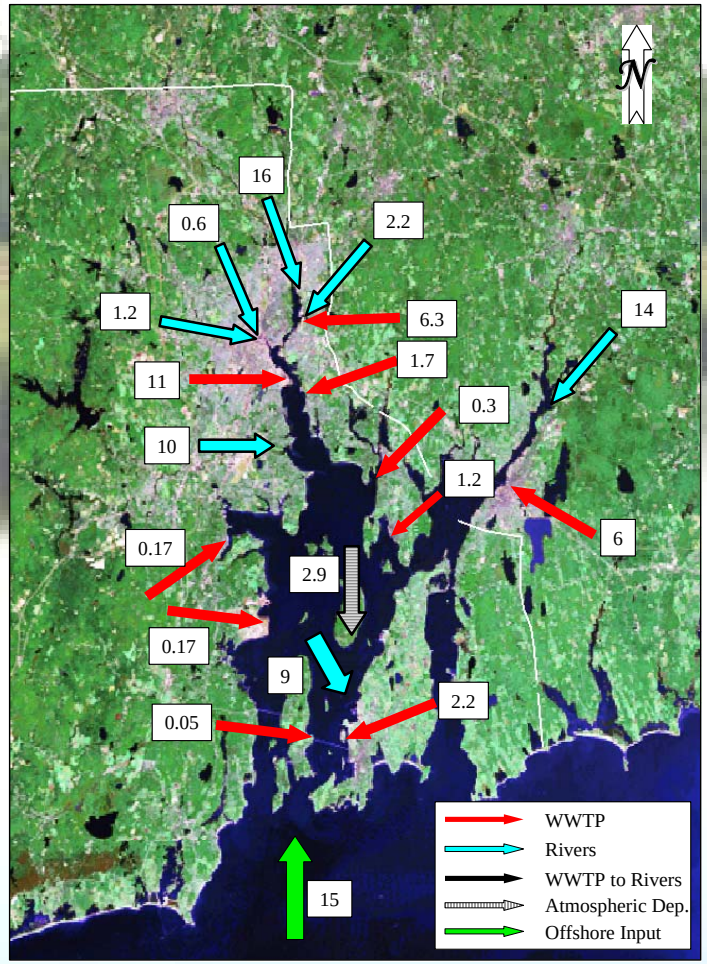
Ratio of...

DIN from watershed

to

Total DIN

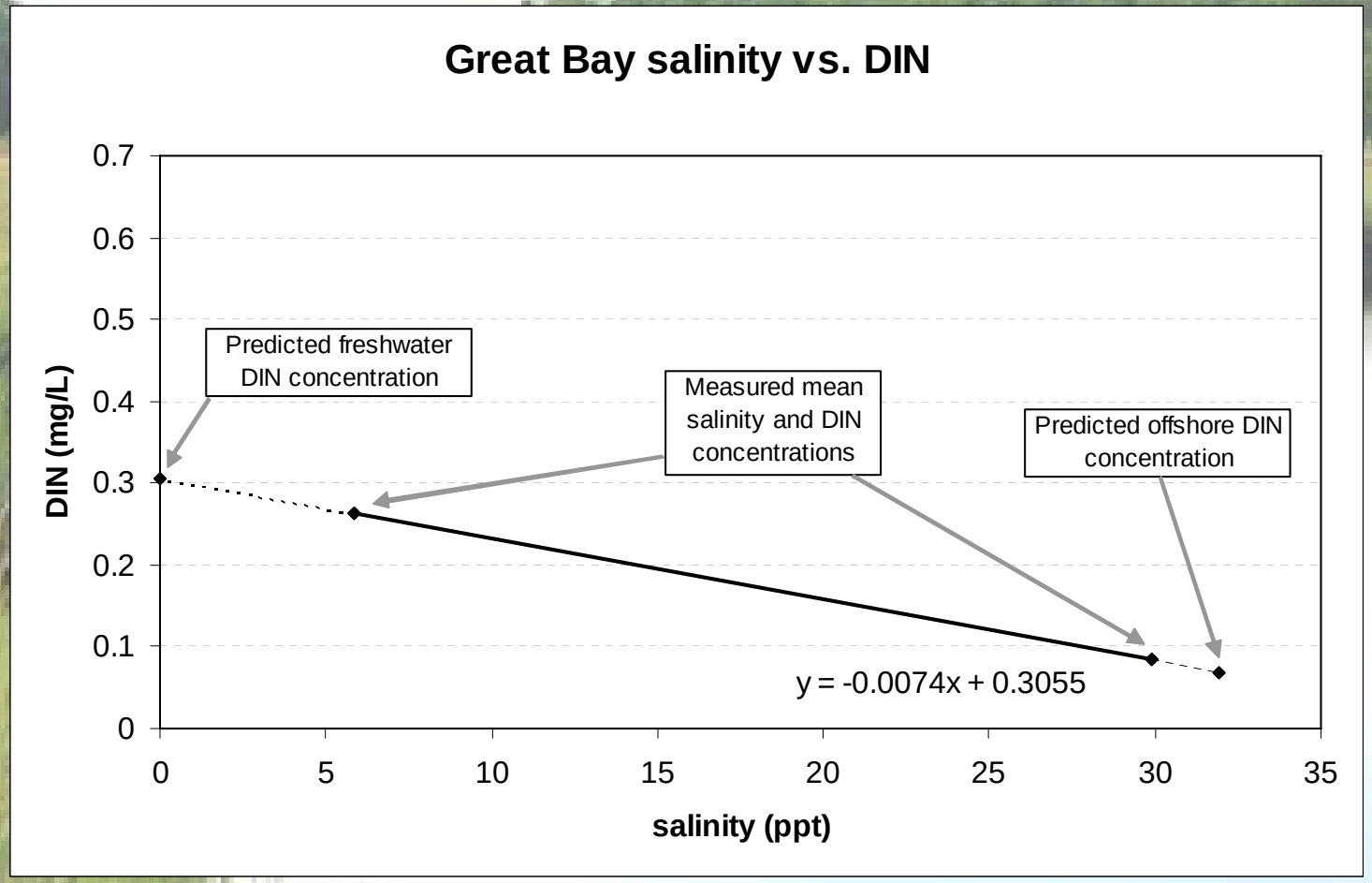
offshore + watershed



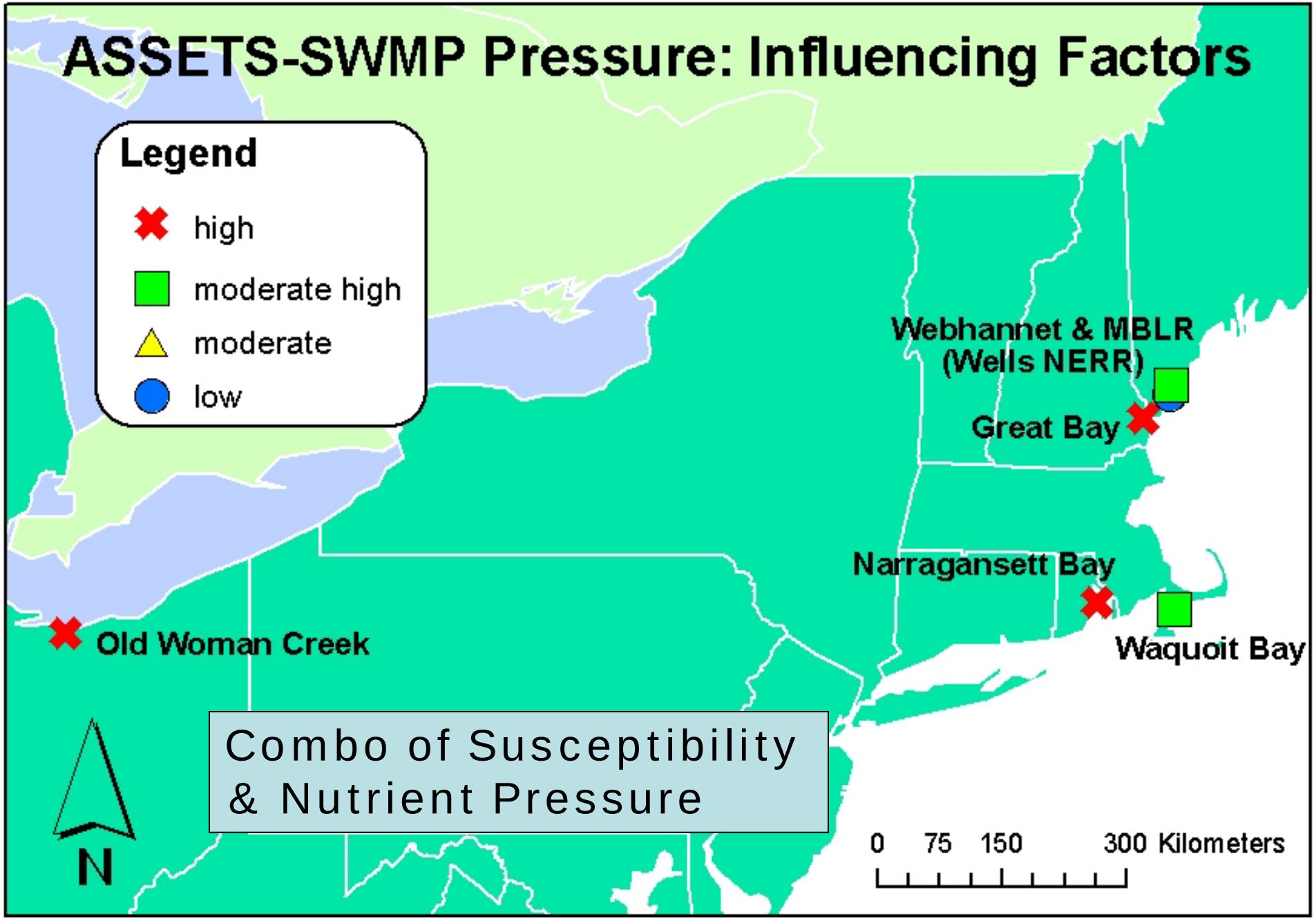
From Scott Nixon's Keynote Presentation to Narragansett Bay Symposium, 2004

RARGOM November 2006

Estimating DIN End Members

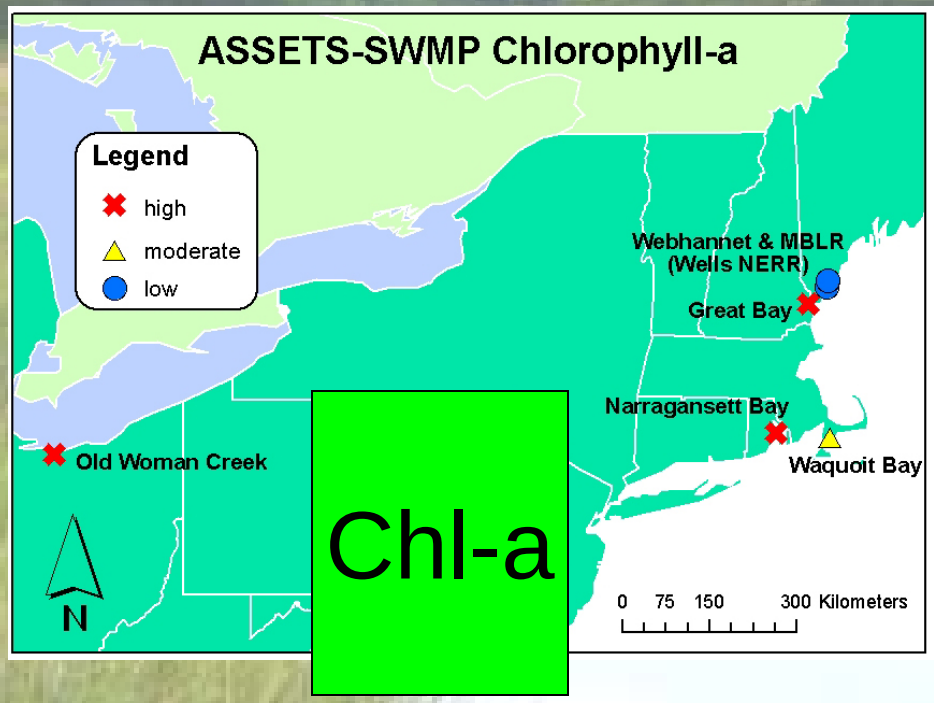


RARGOM November 2006

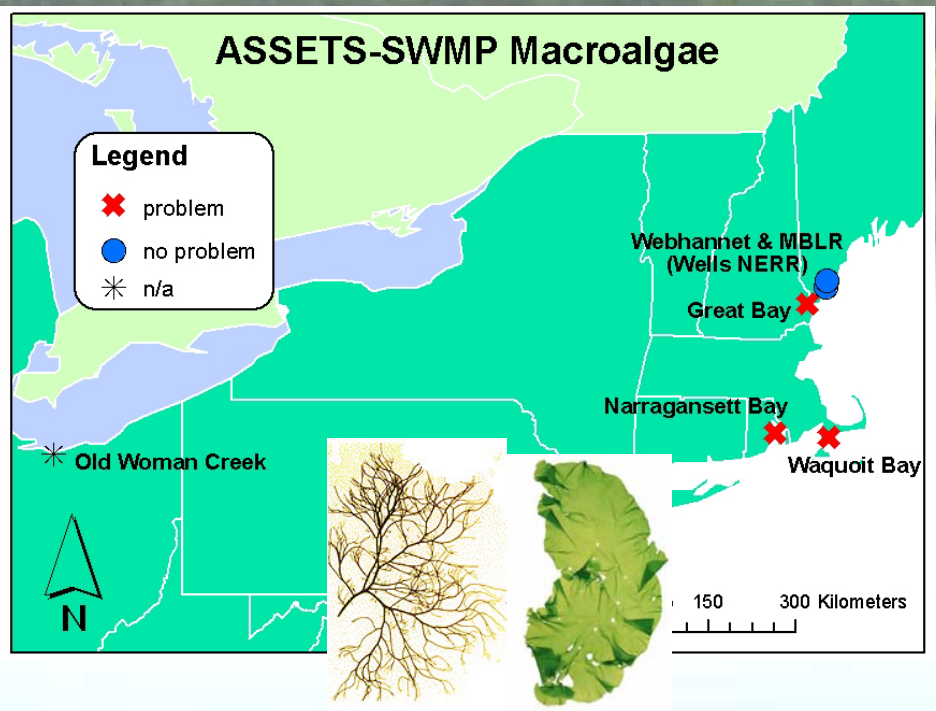

ASSETS-SWMP Pressure: Influencing Factors
Legend
high
moderate high
moderate
low
Webhannet & MBLR
(Wells NERR)
Great Bay
Narragansett Bay
Waquoit Bay
Old Woman Creek
Combo of Susceptibility
& Nutrient Pressure
N
0 75 150 300 Kilometers

State: Overall Eutrophic Condition

Primary symptoms are Chl-a & macroalgae:



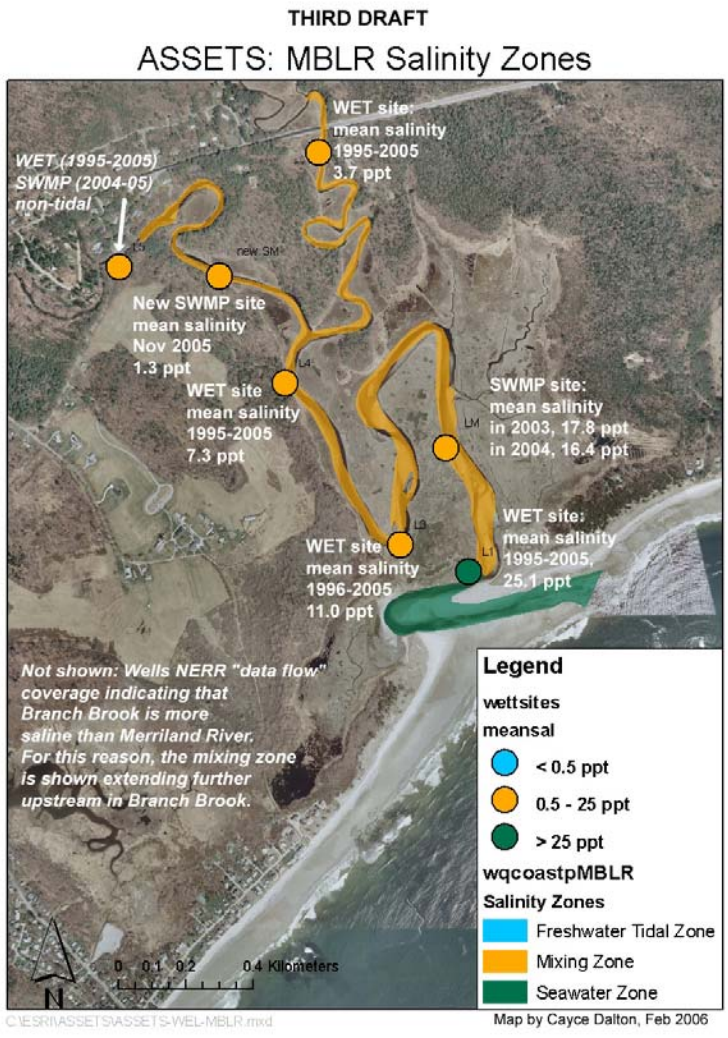
Chl-a



Both show worsening trends as you go south.

Other Results of this Study

- Created salinity zones for MBLR.

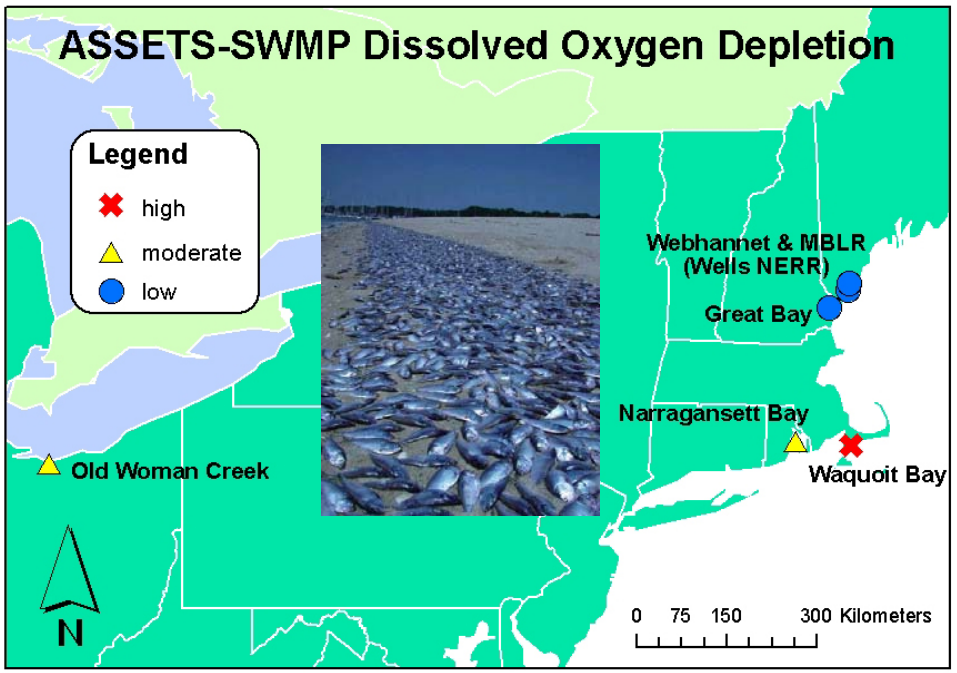


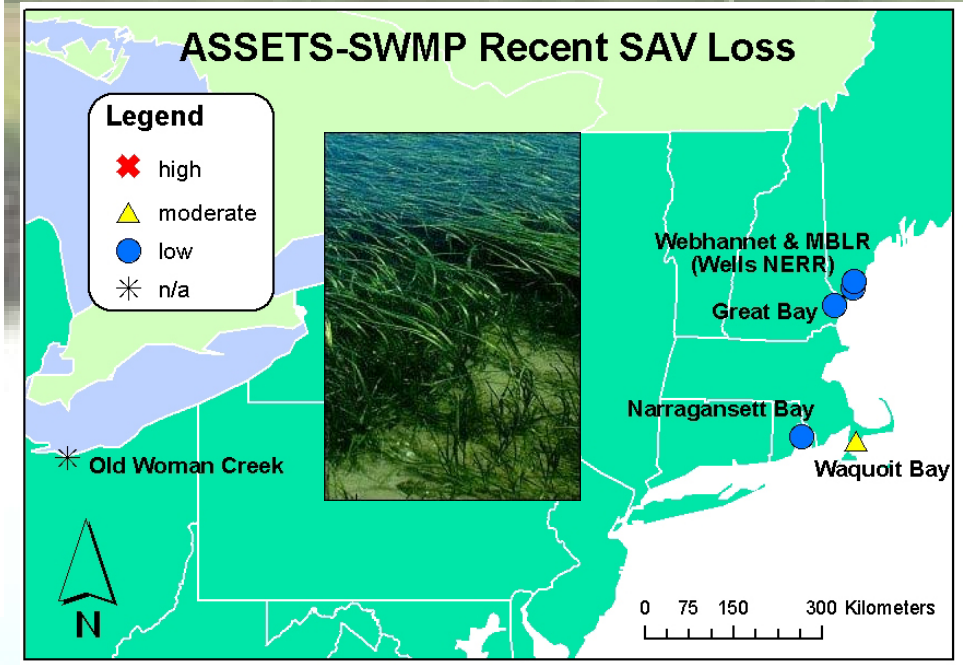
RAR

State: Overall Eutrophic Condition

Secondary symptoms are DO, SAV loss & HAB's:

(HAB's no problem at any estuary)

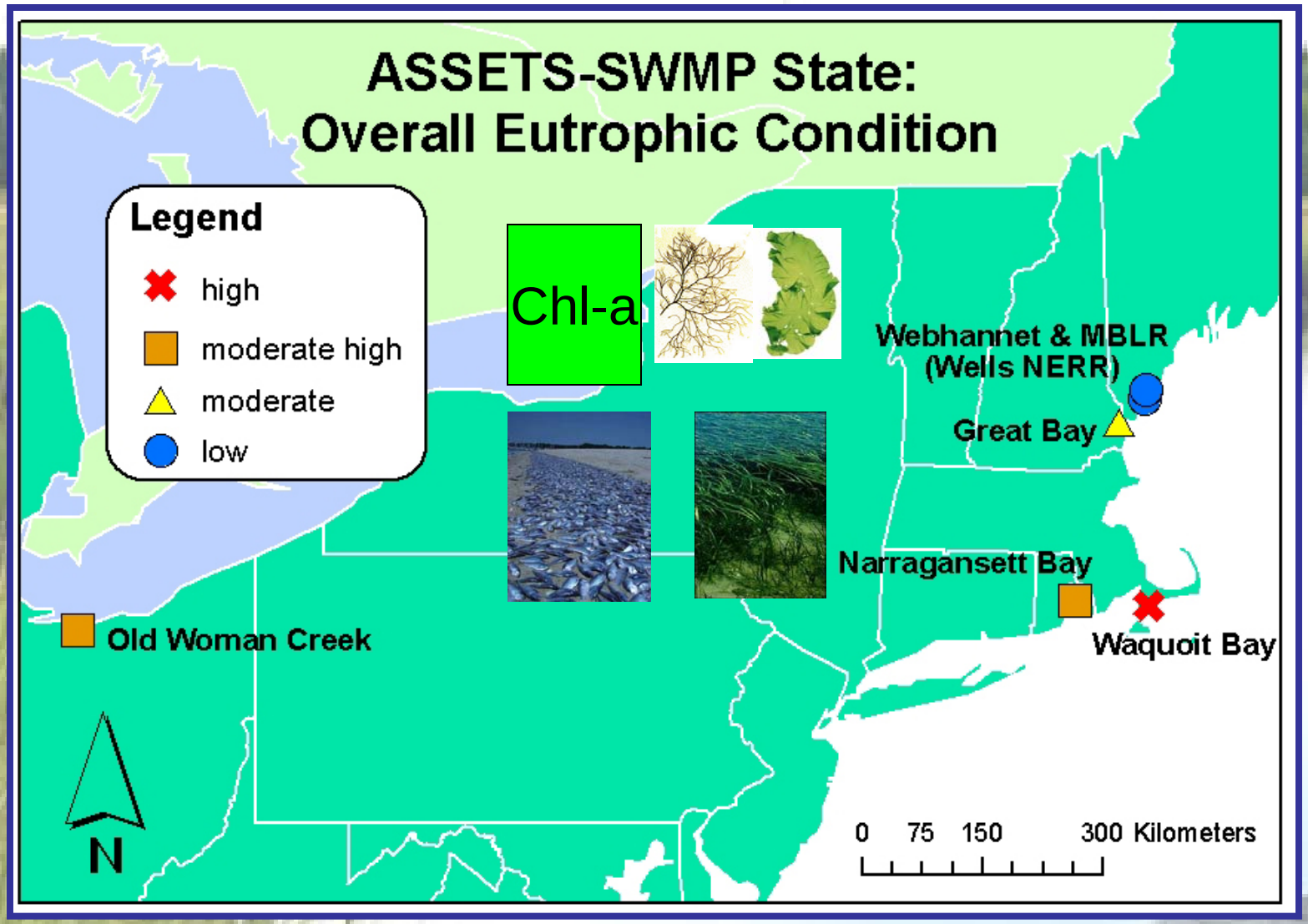




Narragansett, Waquoit, OWC show secondary symptoms

RARGOM November 2006

State: Overall Eutrophic Condition



Response: Future Outlook

Mirrors pressure, except estimates future nutrient loading in place of current loading.

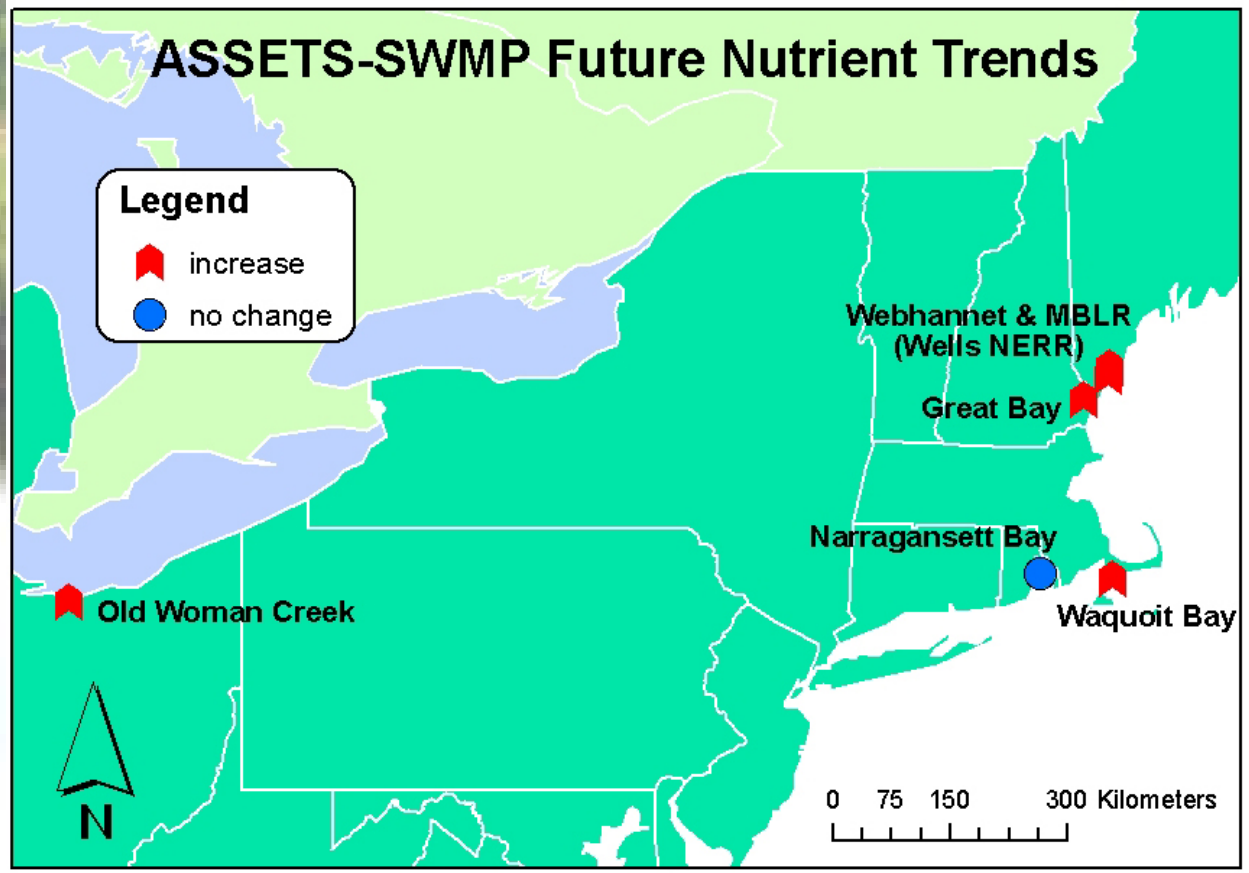
Future Outlook is a combination of

- Susceptibility
- Future nutrient trends

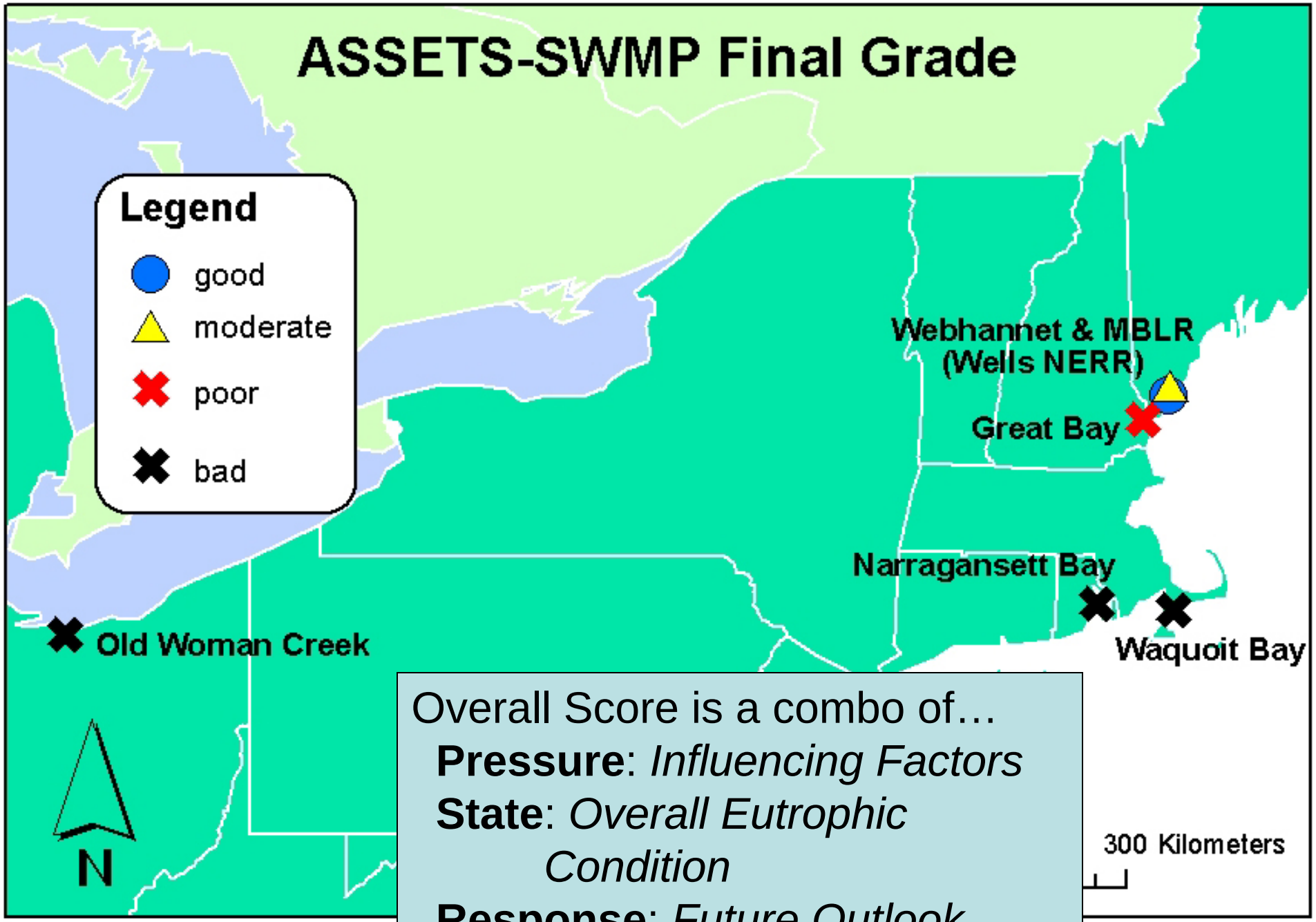
Response: Future Outlook

Most nutrient trends rising due to higher population and development.

Narragansett Bay is exception, better wastewater treatment appears to keep nutrient trends flat.



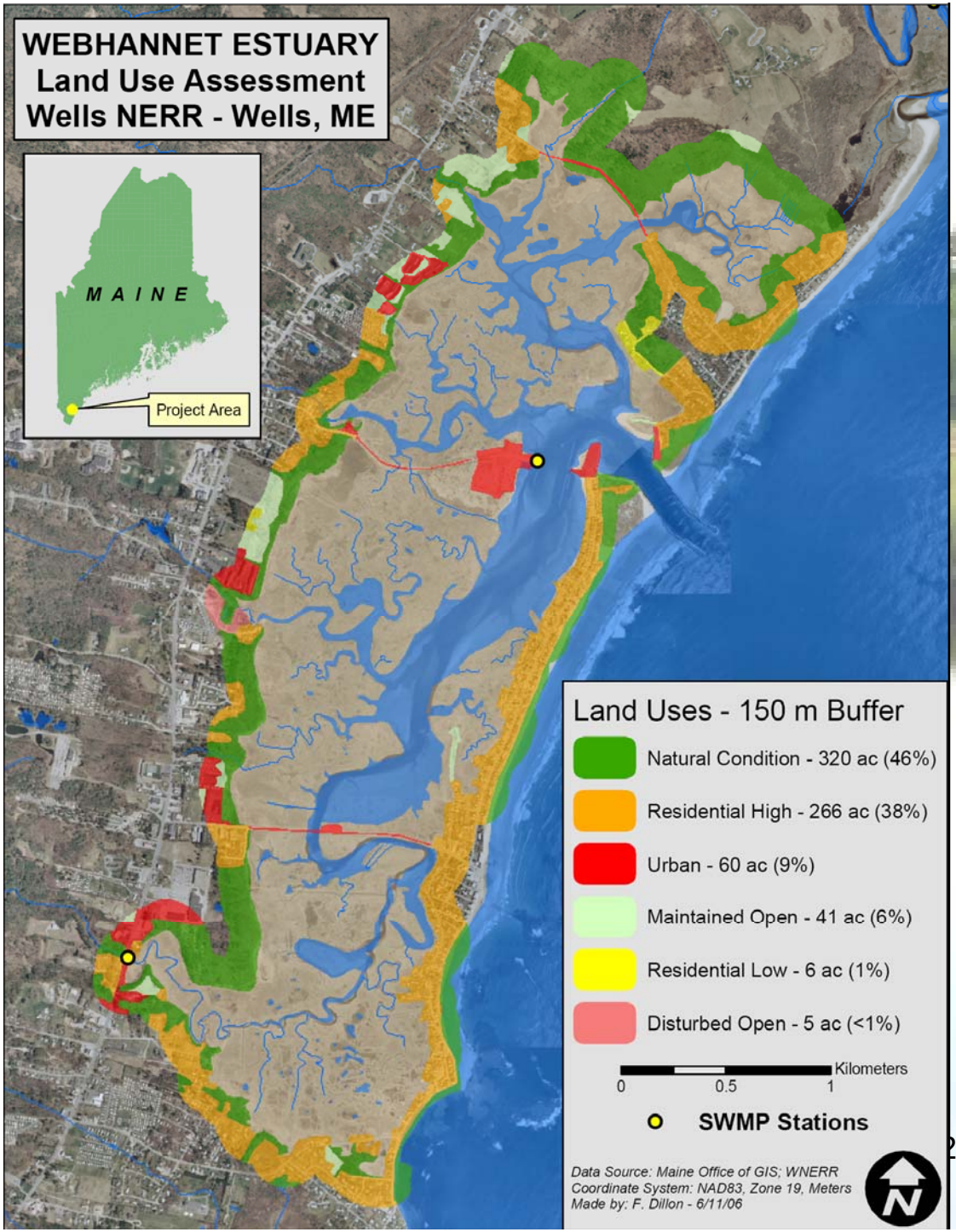
RARGOM November 2006


ASSETS-SWMP Final Grade
Legend
good
moderate
poor
bad
Webhannet & MBLR
(Wells NERR)
Great Bay
Narragansett Bay
Waquoit Bay
Old Woman Creek
N
300 Kilometers
Overall Score is a combo of…
Pressure: Influencing Factors
State: Overall Eutrophic Condition
Response: Future Outlook

2005 Rapid Assessment Method for N.E. Salt Marshes

Characterizes study site in terms of geomorphology, types and degree of stressors and disturbances, and the relative integrity of selected biotic and abiotic salt marsh components.

Incorporates indicators derived from mapping and remote sensing techniques and indicators that are completed through field-based observations and measurements.



Land Use	Acres	LUI Coeff.	LUI Adj.
Natural Condition Total	319.5	0.95	303.6
Residential High Total	266.0	0.25	66.5
Urban Total	60.4	0.23	13.9
Maintained Open Total	40.5	0.83	33.6
Residential Low Total	6.3	0.66	4.2
Disturbed Open Total	5.3	0.86	4.6
	698.2		426.4
		LUI GIS-based score:	**0.61**

ASSETS Classification

OHI: Moderate*

OEC: Mod.-high**

DFO: Worsen-high

Overall Grade: Mod.-poor***

* Moderate-high using linear algebra method

** Secondary symptoms low for 2002&03; high for 2004

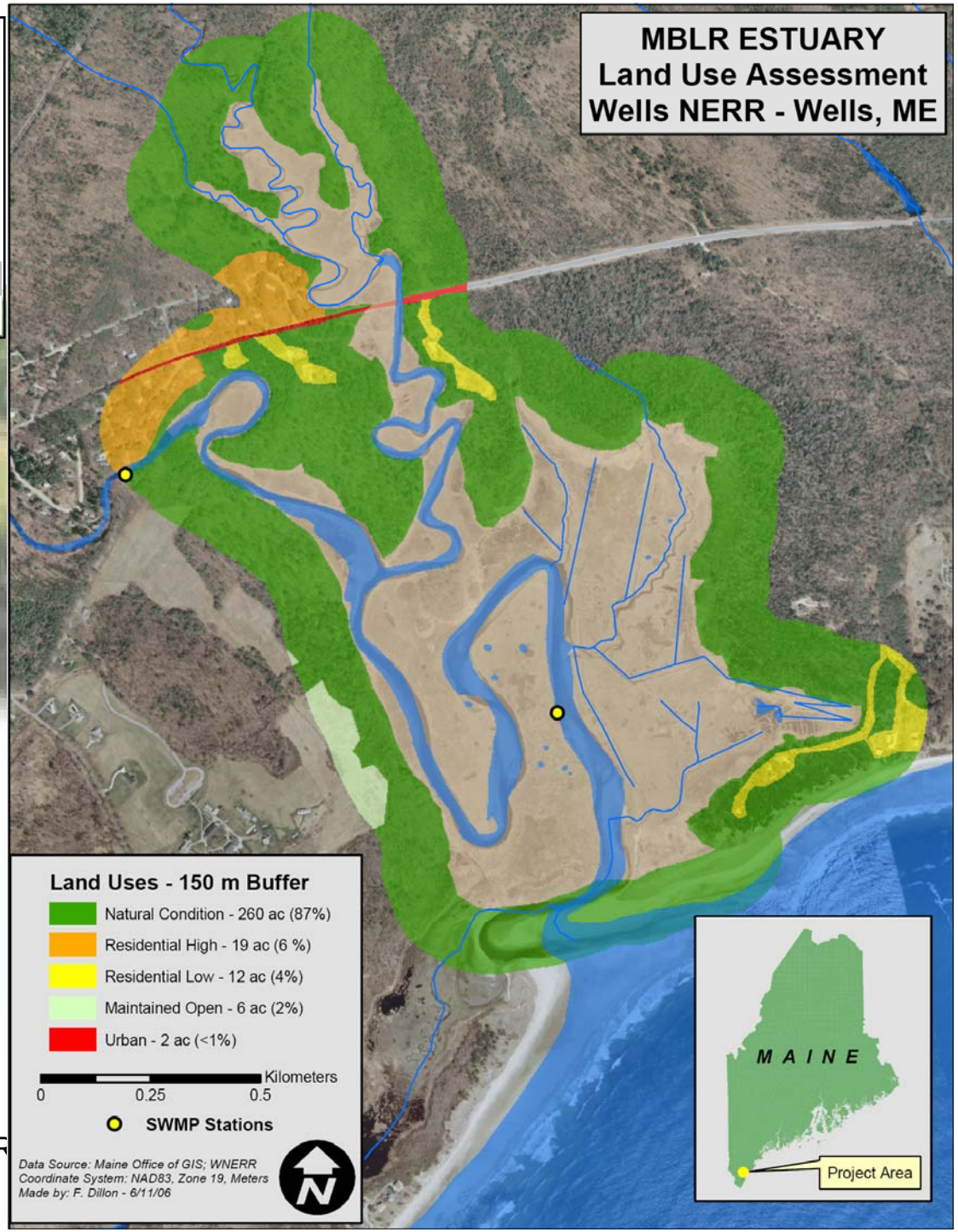
*** Moderate for 2002&03; poor for 2004

2006

Land Use	Acres	LUI Coeff	LUI Adj.
Natural Condition Total	260.1	0.95	247.1
Residential High Total	18.5	0.25	4.6
Residential Low Total	11.5	0.66	7.6
Maintained Open Total	5.9	0.83	4.9
Urban Total	2.2	0.23	0.5
	298.2		264.7
		LUI GIS-based Score:	**0.89**

ASSETS Classification

OHI:	Moderate-low
OEC:	Low
DFO:	Worsen-high
Overall Grade:	**Good**



RAR

Assessment of Estuarine Trophic Status (ASSETS): evaluation of eutrophication impacts

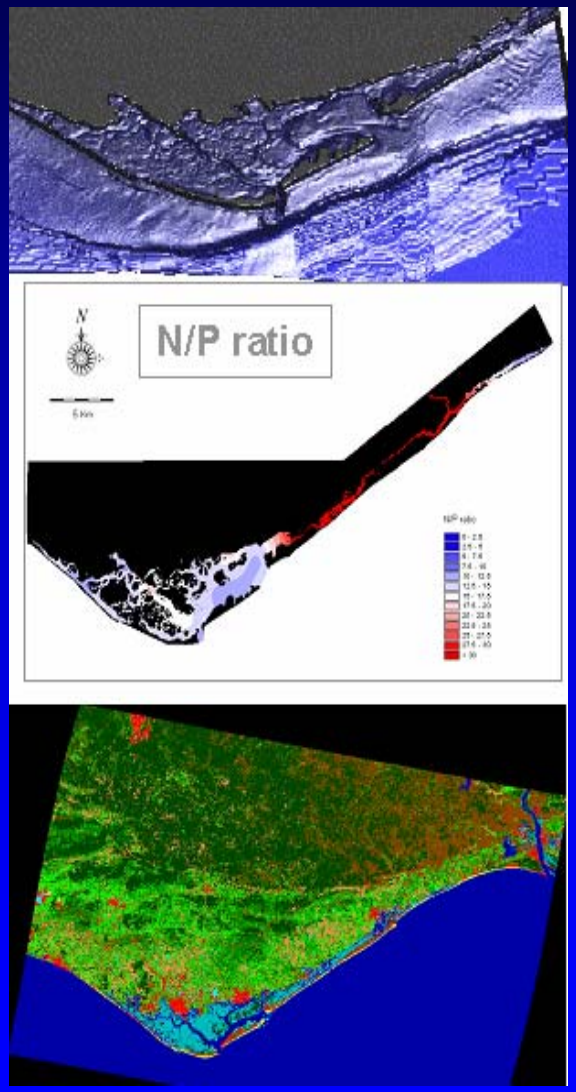
C. Dalton, S. Bricker, F. Dillon and M. Dionne

ASSETS-SWMP DATA SYNTHESIS WORKSHOP
June 12-13, 2006
Wells National Estuarine Research Reserve, Wells, Maine
A CICEET funded research project

http://www.eutro.org
http://www.eutro.us

The Context and Guiding Legislation

- US Clean Water Act of 1972, US Harmful Algal Bloom and Hypoxia Research and Control Act of 1998
- EU Water Framework Directive (2000/60/EC), EU UWWTD and Nitrates Directives – Definition of Sensitive Areas and Vulnerable Zones
- Eutrophication is a significant problem worldwide (US, EU, Baltic, Mediterranean, Japan, Australia and elsewhere)

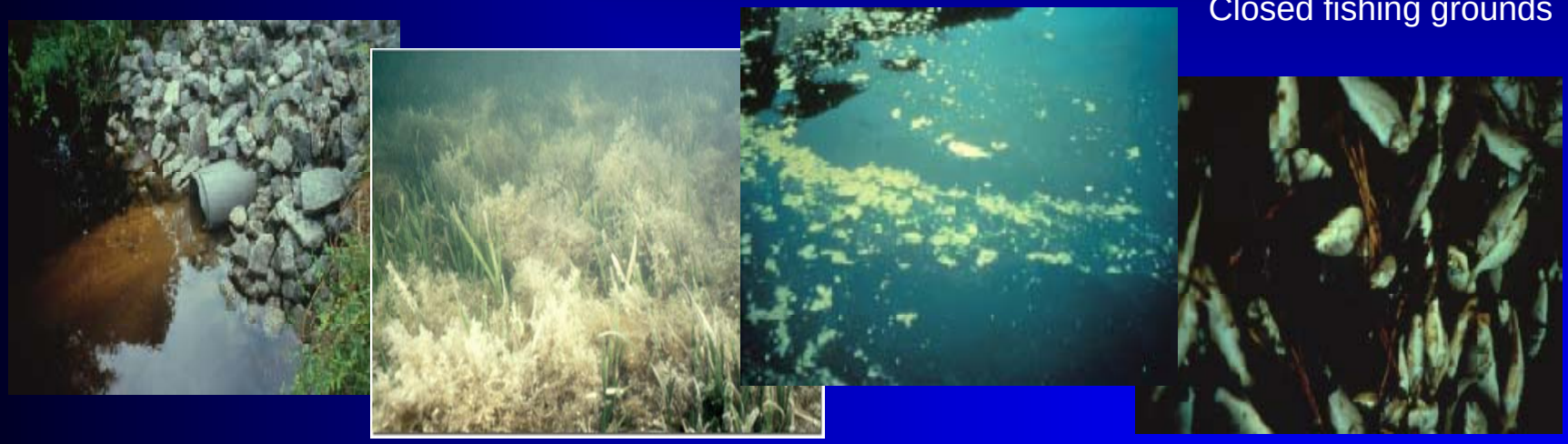


http://www.eutro.org
http://www.eutro.us

The Problem – The Assessment Approach

Symptoms and Consequences of Nutrient Enrichment

Nutrient Inputs and Processing	Primary Impacts	Secondary Impacts	Consequences of Symptoms
Increased N and P concentration	High algal production (Chl) Loss of water clarity Epiphyte problems Macroalgal problems	Loss of SAV Low D.O Nuisance/Toxic blooms (HABs)	Fish kills Loss of habitat Human health risks Loss of tourism Closed fishing grounds



ASSETS: Pressure - State - Response

P: Influencing Factors – Natural processing + Human Nutrient Load
S: Overall Eutrophic Condition – Condition of waterbody
R: Future Outlook – What will happen in the future?

http://www.eutro.org http://www.eutro.us

Key Aspects of the ASSETS approach

The NEEA approach may be divided into three parts:

- ✓ **Division of estuaries into homogeneous areas**
- ✓ **Evaluation of data completeness and reliability**
- ✓ **Application of indices**

- **Tidal freshwater (<0.5 psu)**
- **Mixing zone (0.5-25 psu)**
- **Seawater zone (>25 psu)**

Spatial and temporal quality of datasets (completeness)
Confidence in results (sampling and analytical reliability)

Overall Eutrophic Condition index ---------- State
Influence Factors index ---------- Pressure
Future Outlook index ---------- (Response)
ASSETS combined rating ---------- Overall

Indicators and Criteria

Susceptibility:

Flushing (tide ht, FW inflow/Est volume)

Dilution (Stratification, Dilution volume)

Nutrient Inputs:

from watershed, and ocean (ratio watershed/ oceanic)

Waterbody Condition:

Primary symptoms

- chlorophyll a (90^{th} percentile, spatial, frequency occurrence)
- macroalgae (detrimental impact to biology)

Secondary symptoms

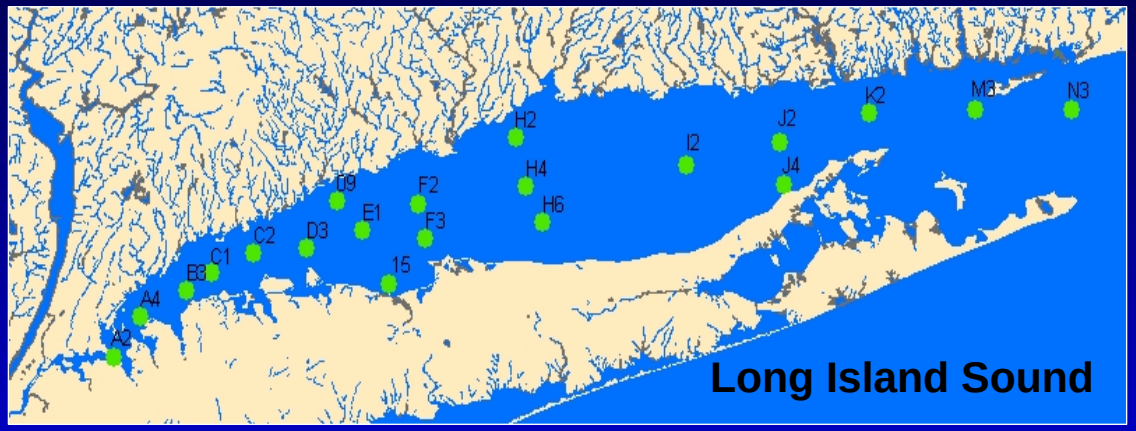
- dissolved oxygen (10^{th} percentile, spatial, frequency, occurrence)
- HAB occurrence (nuisance or toxic; duration, frequency occurrence)
- seagrass spatial distribution (change)

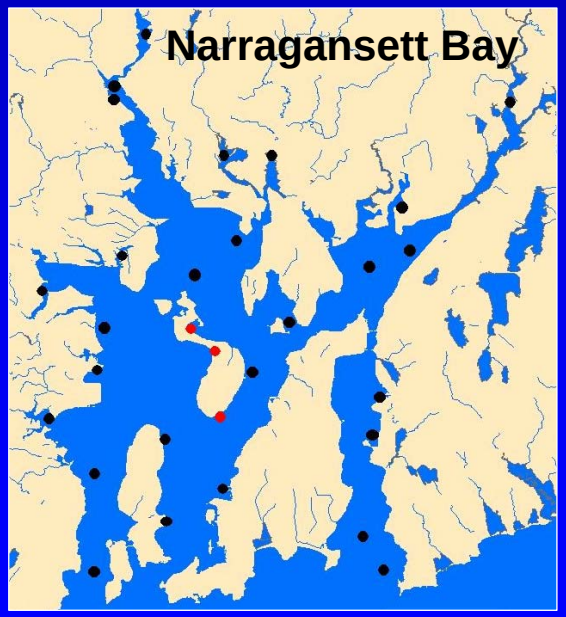
Data Sources and Issues

Who?
State / Federal Agencies
Universities
Non-Profit Organizations
Citizen Groups
(400+ participants in NEEA)

What?
Long-term monitoring studies
Several year academic projects
One time sampling efforts

How?
Survey questionnaire
Web accessible database
Literature search
Site visit





Long Island Sound

Long Island Sound Study
Since 1991
Monthly samples
20 stations

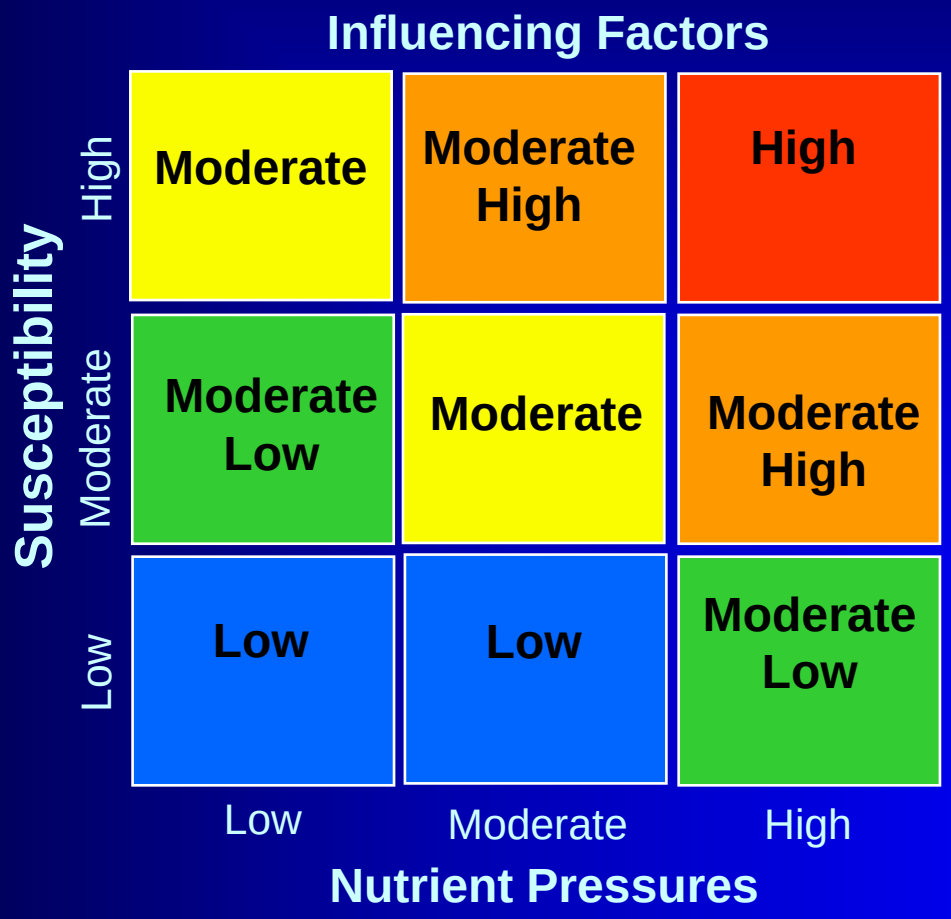
Narragansett Bay

NOAA NERR	EPA EMAP
DO since 1996	Since 2000
Chl a since 2001	
Daily (DO)	Index pd sample
Monthly (Chl a)	Index pd sample
3 stations	27 stations

Pressure: Influencing Factors

Susceptibility + Nutrient Inputs = Influencing Factors

dilution & flushing — land based or oceanic



Pressure: Influencing Factors

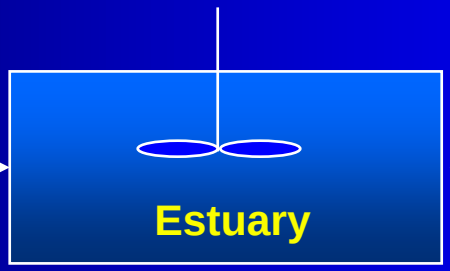
- m_h, expected nutrient concentration from land based sources (i.e. no ocean sources);
- m_b, expected background nutrient concentration from ocean (i.e. no land-based sources);
- IF = ratio of $m_h/(m_h+m_b)$;

Class	Thresholds
Low	0 to <0.2
Moderate low	0.2 to <0.4
Moderate	0.4 to < 0.6
Moderate high	0.6 to < 0.8
High	>0.8

Equations are based on a simple Vollenweider approach, modified to account for dispersive exchange:

Anthropogenic inputs

$$m_h = \frac{m_{in}(s_o - s_e)}{s_o}$$



Ocean inputs

$$m_b = \frac{m_{sea} s_e}{s_o}$$

Bricker, S.B., Ferreira, J.G. & Simas, T. 2003. An Integrated Methodology for Assessment of Estuarine Trophic Status. Ecological Modelling. 169:39-60.

State: Overall Eutrophic Condition

NEEA Methodology

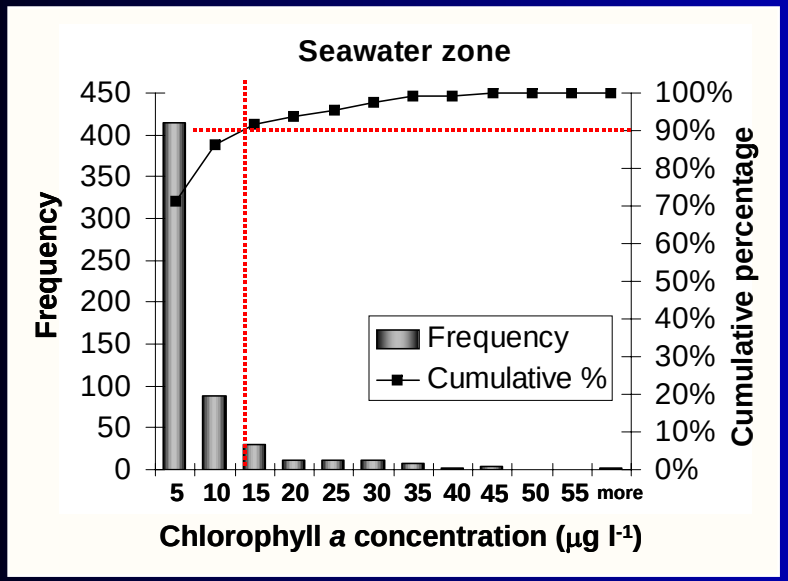
1) Determine **Chl a, macroalgae**, **D.O., SAV loss and HABs** condition for each zone (conc/observance, spatial coverage, frequency of occurrence)

2) Determine expression for primary (average symptom values) and secondary (highest symptom value)

3) Combine primary and secondary for estuary condition

$$S_l = \sum_{1}^{n} \left(\frac{A_z}{A_e} E_l \right)$$

Where:
A_z: Surface area of zone
A_e: Total estuarine surface area
E_l: Expression value at each zone
n: Number of estuarine zones



- Level of expression is based on data, cumulative frequency (Chl *a* = 90th percentile; DO = 10th percentile)
- GIS or GRID: Spatial area determined by GIS or Grid

Chla and Dissolved Oxygen

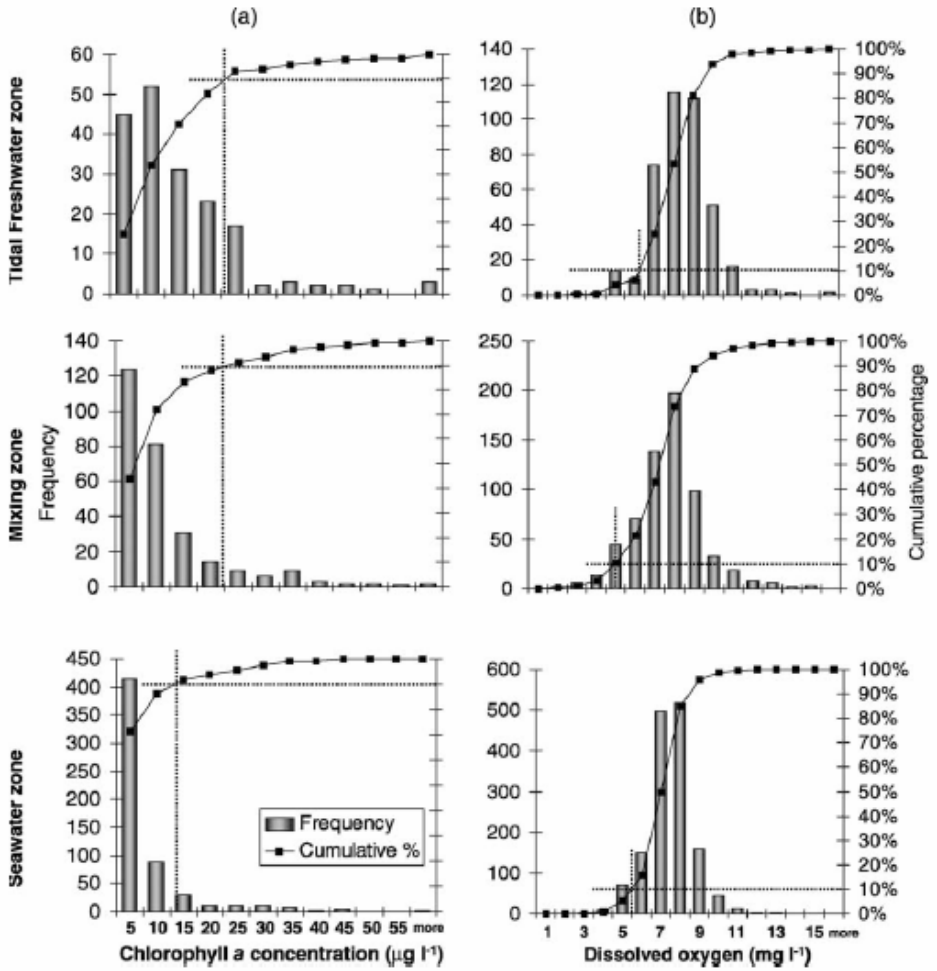


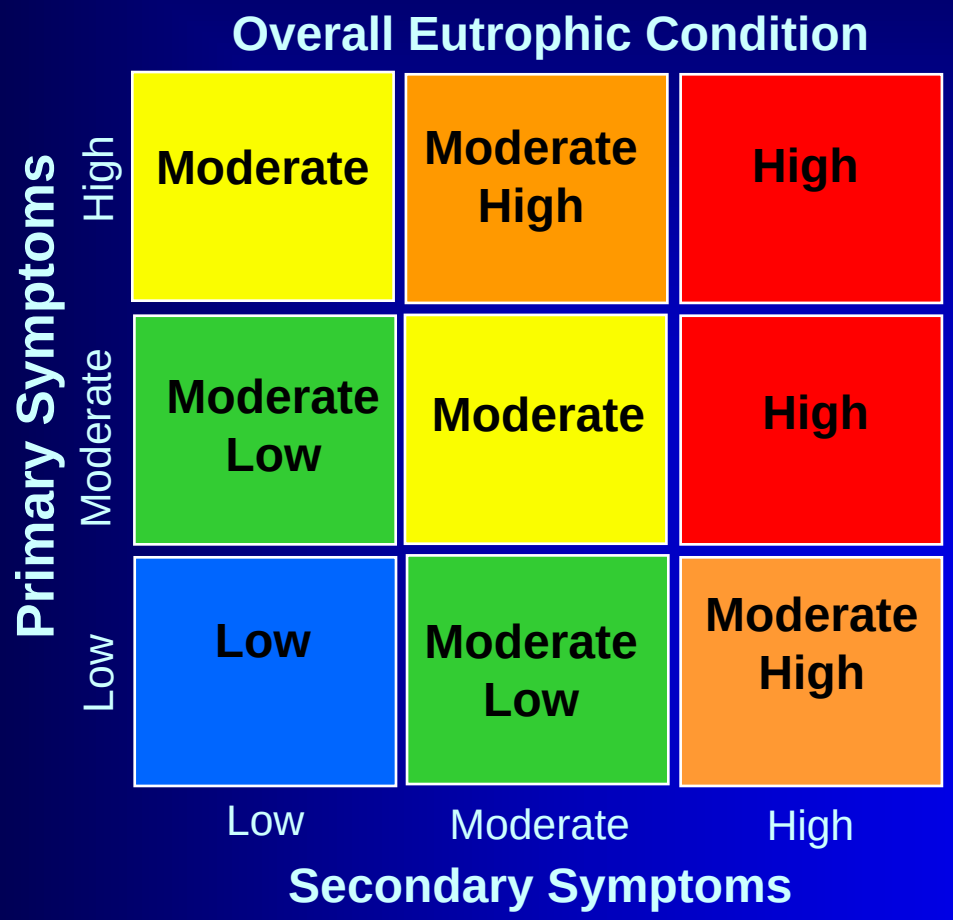
Fig. 9. (a) Percentile 90 for chlorophyll *a* values and (b) percentile 10 for the dissolved oxygen values, in the three salinity zones of the Tagus estuary.

Decision/Logic Example for Chl *a*

IF	AND	AND	THEN	
Concentration	Spatial Coverage	Frequency	Expression	Value
Hypereutrophic *or* High	High	Periodic	High	1
	Moderate	Periodic	High	1
	Low	Periodic	Moderate	0.5
	Very Low	Periodic	Moderate	0.5
	High	Episodic	High	1
	Moderate	Episodic	Moderate	0.5
	Low/Very Low	Episodic	Low	0.25
	Any Spatial Coverage	Unknown	Flag A	0.5
	Unknown	Any Frequency	Flag A	0.5

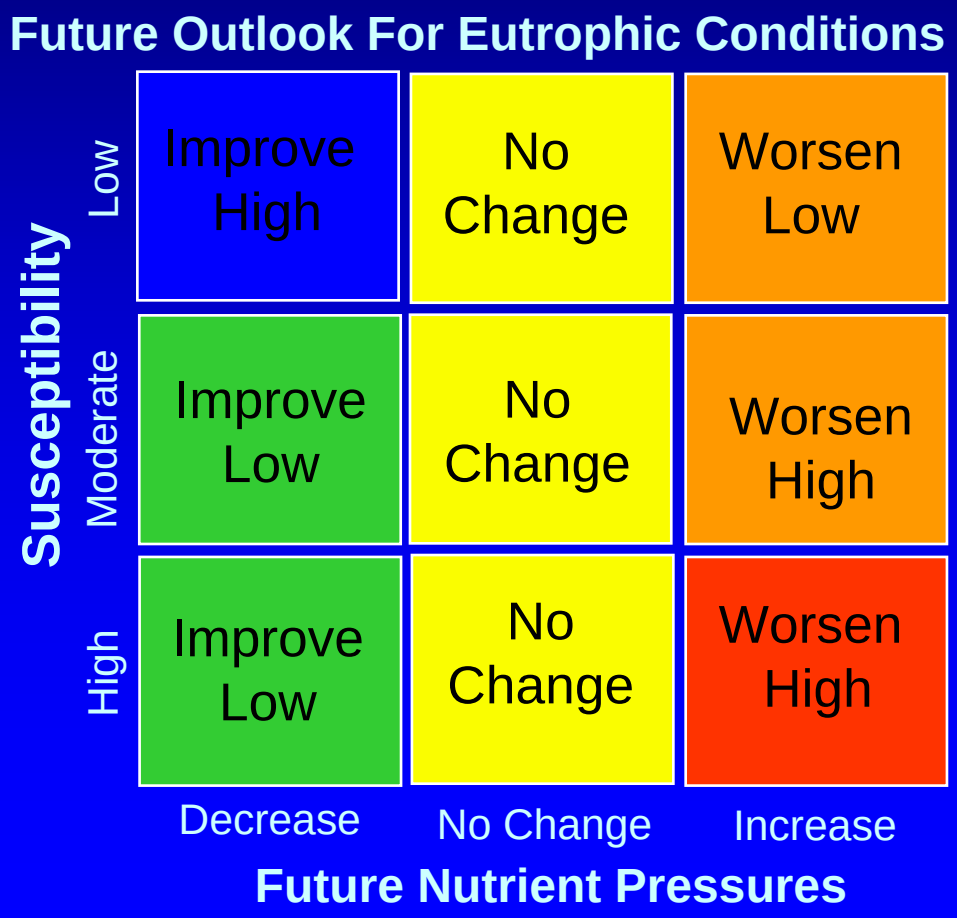
Flags are used to identify impacts for which not enough data was avaialbe for the components. In these cases, assumptions were made based on conservative estimates that unknown spatial coverage is at least 10 percent of the zone, unknown duration is at least days, and unknown freqency is at least episodic .

State: Overall Eutrophic Condition



Response: Future Outlook

Future outlook is based on susceptibility and projected changes in nutrient pressures:



Susceptibility is the capacity of a system to dilute or flush nutrients

Nutrient pressure changes are based on expected population changes, future treatment and remediation plans and changes in watershed use (particularly agricultural)

Influencing Factors

Region (No. systems)	Human Influence (M – H)	>50% NPS	Primary NPS from Ag*
No. Atlantic (18)	33	78	0
Mid Atlantic (22)	100	91	60
So. Atlantic (22)	81	100	81
Gulf of Mexico (38)	95	100	85
Pacific (39)	82	89	50
US Total (139)	68	92	56
Portugal (10)	30	89	67
China (4)	75	?	?

as percentage of systems
US from SPARROW model estimates, PT from Ferreira et al 2003
**for US: >30% though most are >70% from ag, for PT: ag is most significant nonpt source*

Assets Score

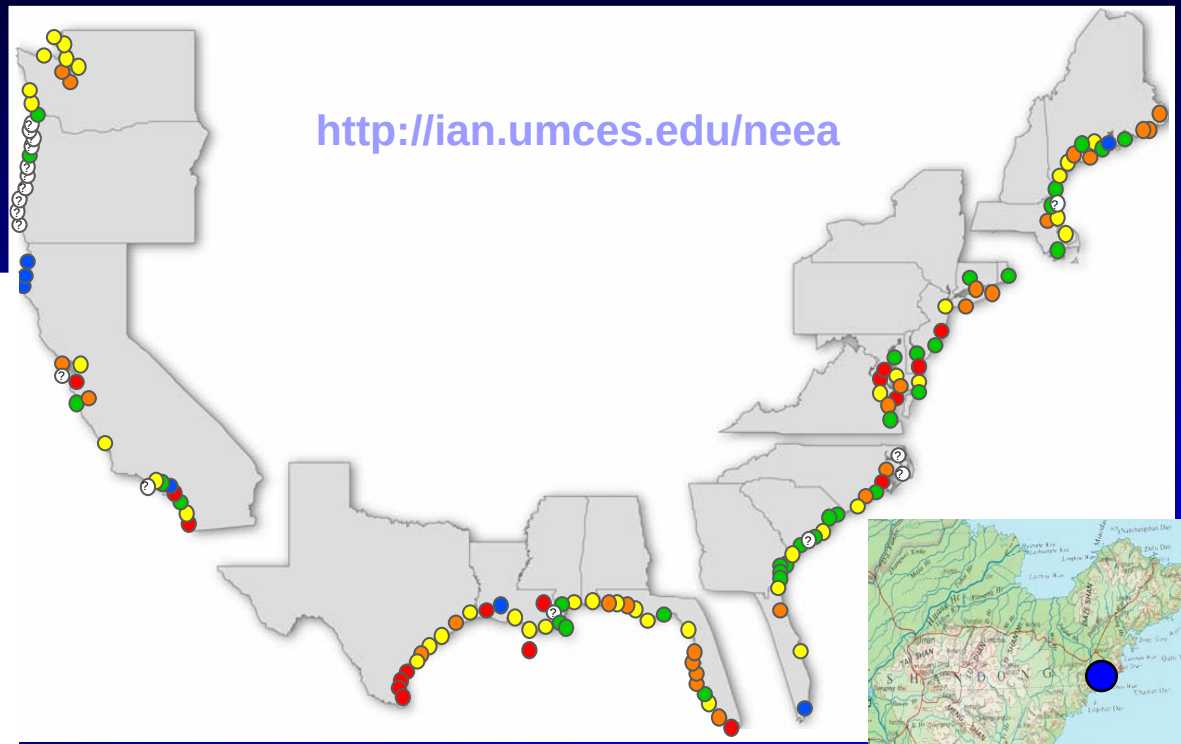
Table 6
Aggregation of pressure (OHI), state (OEC) and response (DFO) components to provide an overall classification grade[a]—percentage of total valid combinations shown in brackets

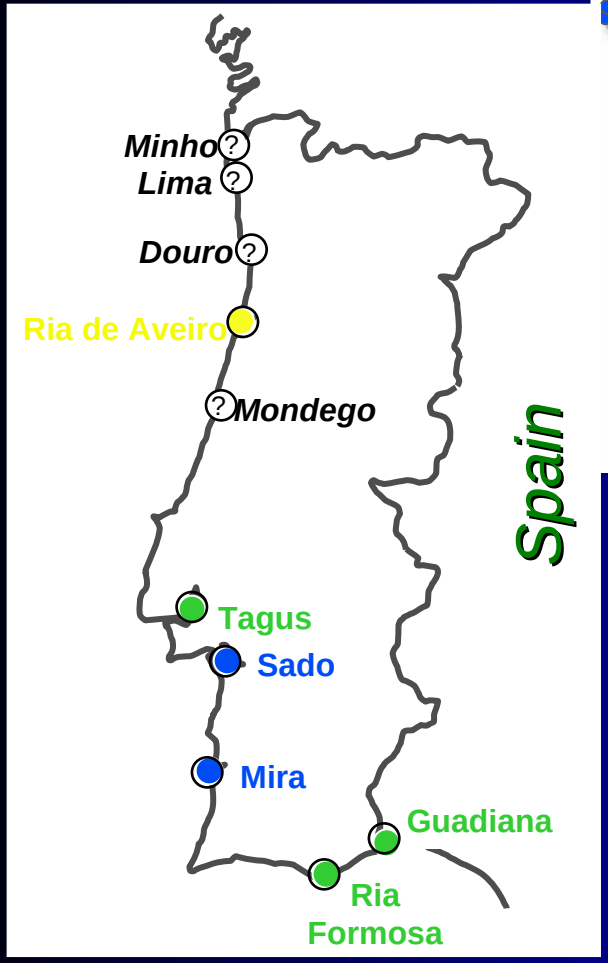
Grade	5	4	3	2	1
Pressure (OHI)	Low	Moderate low	Moderate	Moderate high	High
State (OEC)	Low	Moderate low	Moderate	Moderate high	High
Response (DFO)	Improve high	Improve low	No change	Worsen low	Worsen high

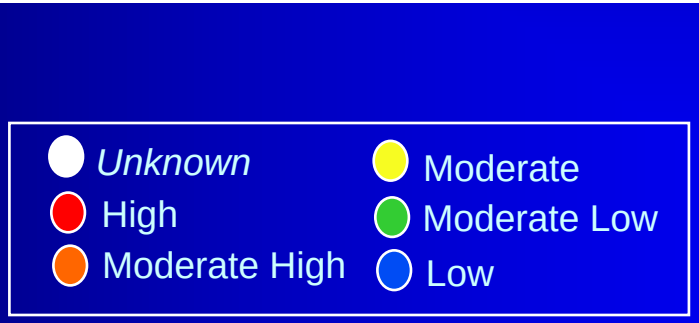
Metric	Combination matrix	Class
P	5 5 5 4 4 4	High (5%)
S	5 5 5 5 5 5	
R	5 4 3 5 4 3	
P	5 5 5 5 5 5 5 4 4 4 4 4 3 3 3 3 3 3	Good (19%)
S	5 5 4 4 4 4 4 5 5 4 4 4 5 5 5 4 4 4	
R	2 1 5 4 3 2 1 2 1 5 4 3 5 4 3 5 4 3	
P	5 5 5 5 5 4 4 4 4 4 4 4 3 3 3 3 3 3 3 2 2 2 2 2 2 2 2 1 1	Moderate (32%)
S	3 3 3 3 3 4 4 3 3 3 3 3 5 5 4 4 3 3 3 4 4 4 4 4 3 3 3 2 3 3	
R	2 1 5 4 3 2 1 5 4 3 2 1 2 1 2 1 5 4 3 5 4 3 2 1 5 4 3 5 5 4	
P	4 4 4 4 4 4 3 3 3 3 3 3 3 2 2 2 2 2 2 1 1 1 1 1	Poor (24%)
S	2 2 2 2 2 2 3 3 2 2 2 2 2 3 3 2 2 2 2 3 3 3 2 2	
R	5 4 3 2 1 2 1 5 4 3 2 1 2 1 4 3 2 1 3 2 1 5 4	
P	3 3 3 3 3 2 2 2 2 2 1 1 1 1 1 1 1 1	Bad (19%)
S	1 1 1 1 1 1 1 1 1 1 1 2 2 2 1 1 1 1 1	
R	5 4 3 2 1 5 4 3 2 1 3 2 1 5 4 3 2 1	

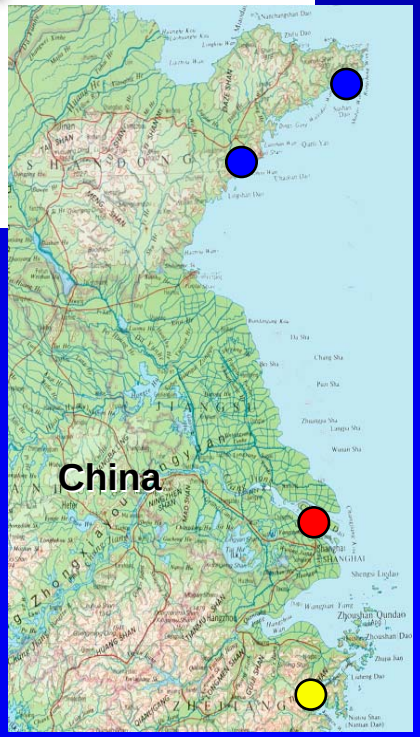
[a] Note that the NEEA classification has been changed in ASSETS so that the high score now corresponds to high status, rather than a high level of a problem symptom.

Overall Eutrophic Conditions









Future Directions

National and International partnerships to develop:

Type Classification

Improved Assessment Method

Human Use/Socioeconomic Assessment Method

Predictive capability

Tools/Recommendations for Research and Management

Growth of collaborations (natl. & intnatl.)

Periodic update reports (every 2 years? every 5 years?)