

***Hypothetical Case Study for Using Extractive Technologies for Meeting Nutrient Criteria Goals for the Great Bay Estuary, New Hampshire***



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# *Presentation Outline*

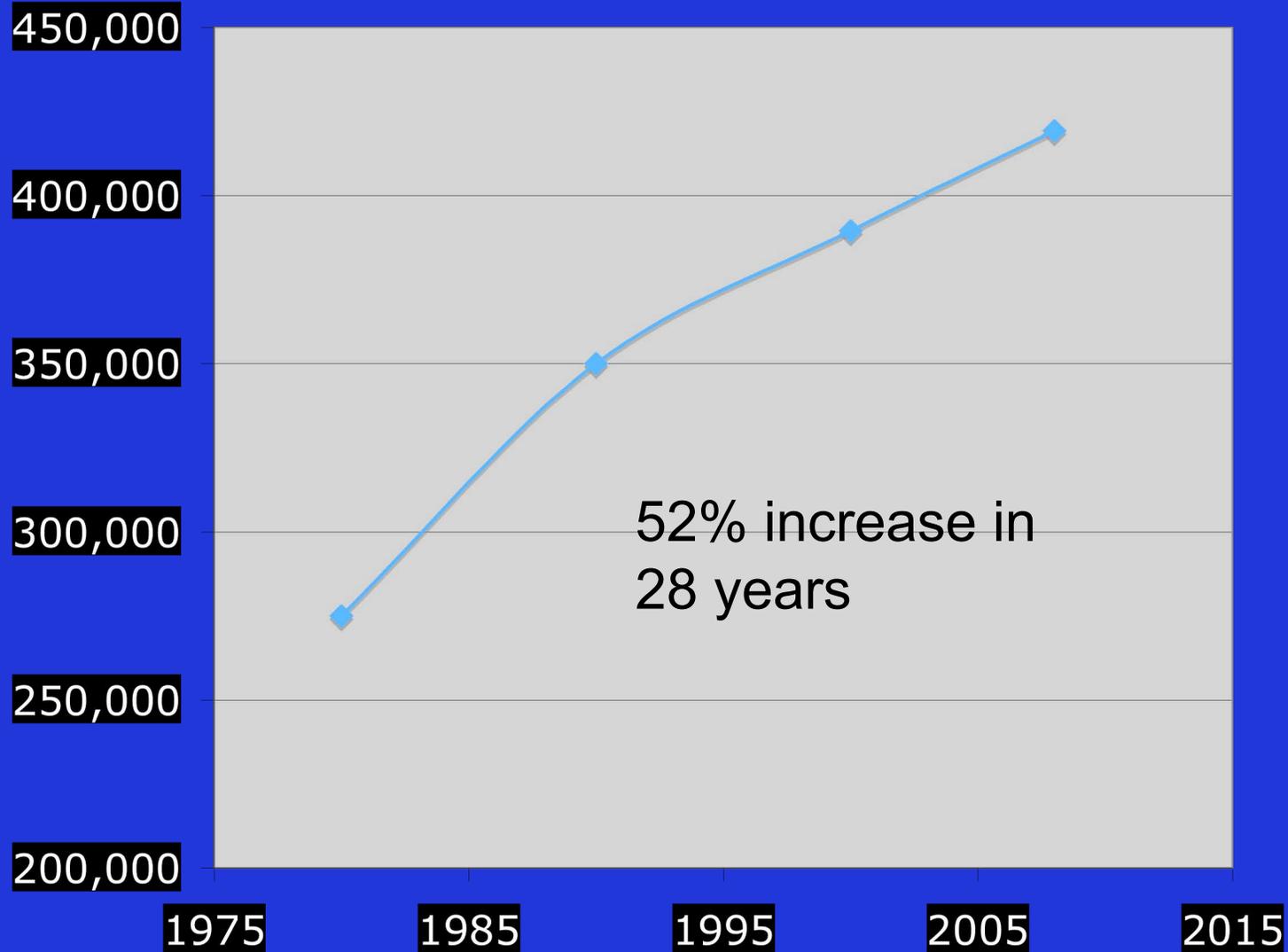
- *Location and context for case study*
- *Source reduction options*
  - *EBNR at WWTFs*
  - *NPS/Stormwater controls*
- *Extractive strategies*
  - *Bivalve mollusc aquaculture and restoration*
  - *Microalgal biomass production*
- *Opportunities and constraints for implementation*
  - *Economic*
  - *Ecological*
  - *Regulatory*
  - *Social*

# Piscataqua Region Watershed

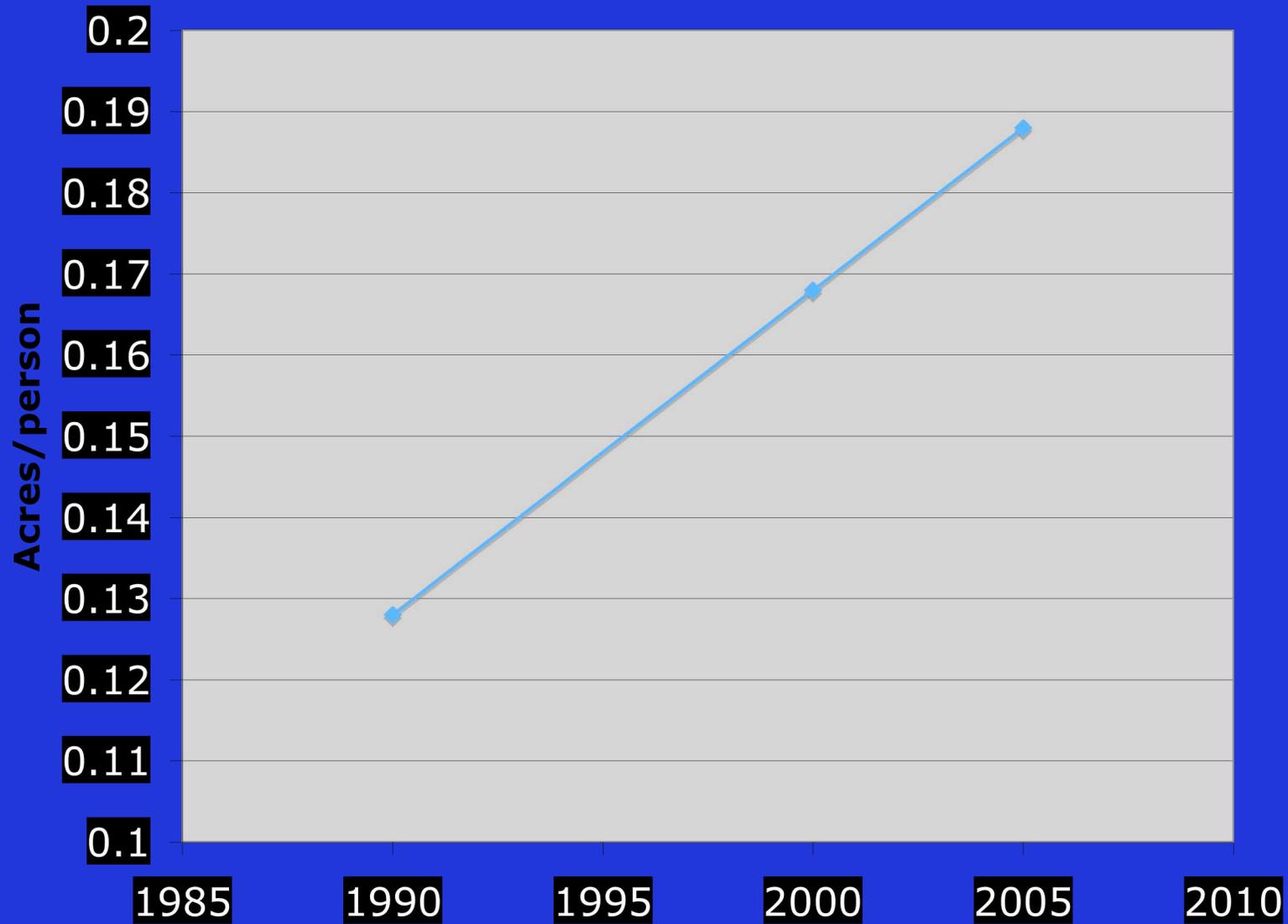
- 1,082 square miles
- 52 towns in Maine and NH
- 32 % of NH population
- 93% of the drainage goes to the Great Bay Estuary
- 7,300 acres of tidal waters



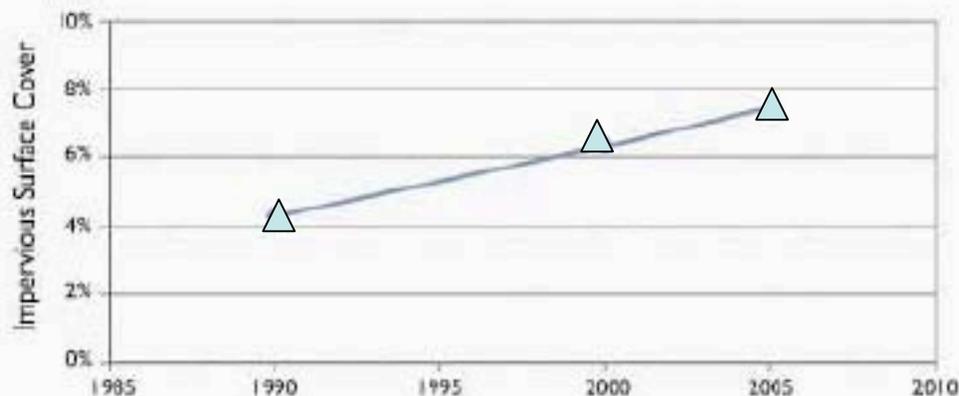
# *Population in GBE Watershed towns*



# *Per capita Impervious surface area*



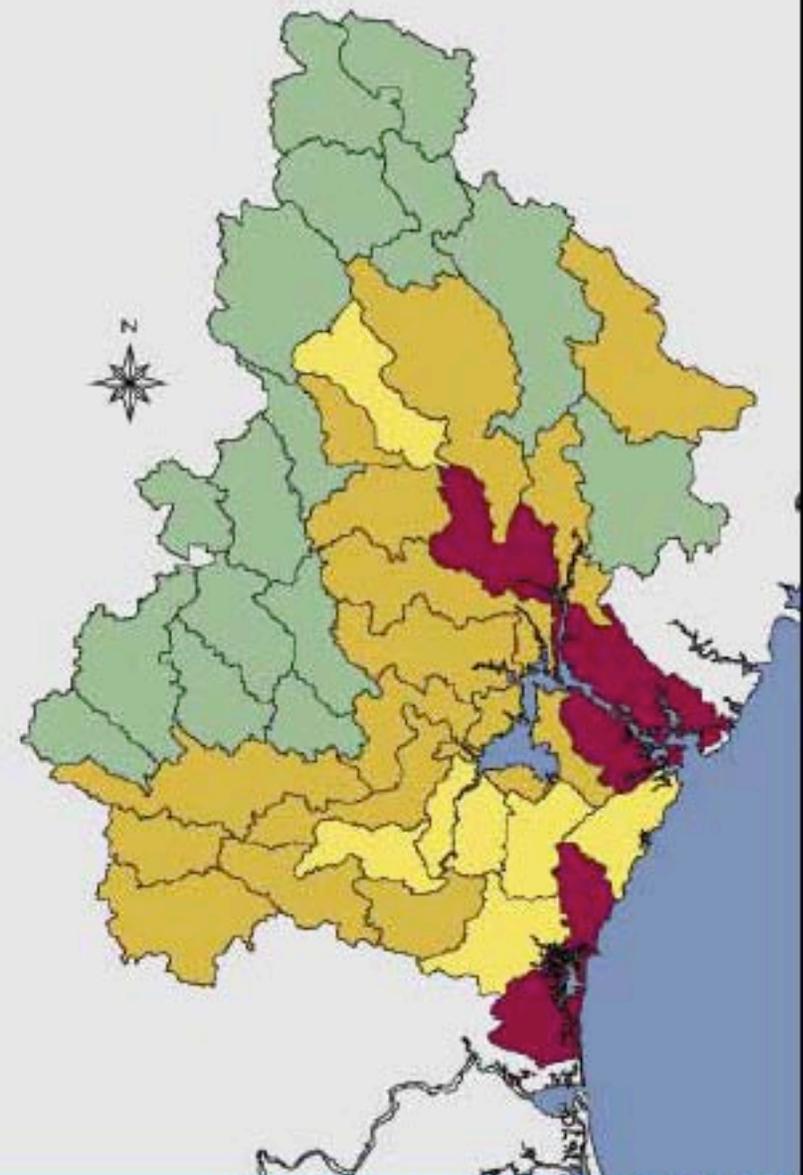
# Impervious Surfaces in the Piscataqua Region Watershed



**1990**  
28,710 acres  
4.3%

**2000**  
42,618 acres  
6.3%

**2005**  
50,351 acres  
7.5%



Data Source: UNH CSRC

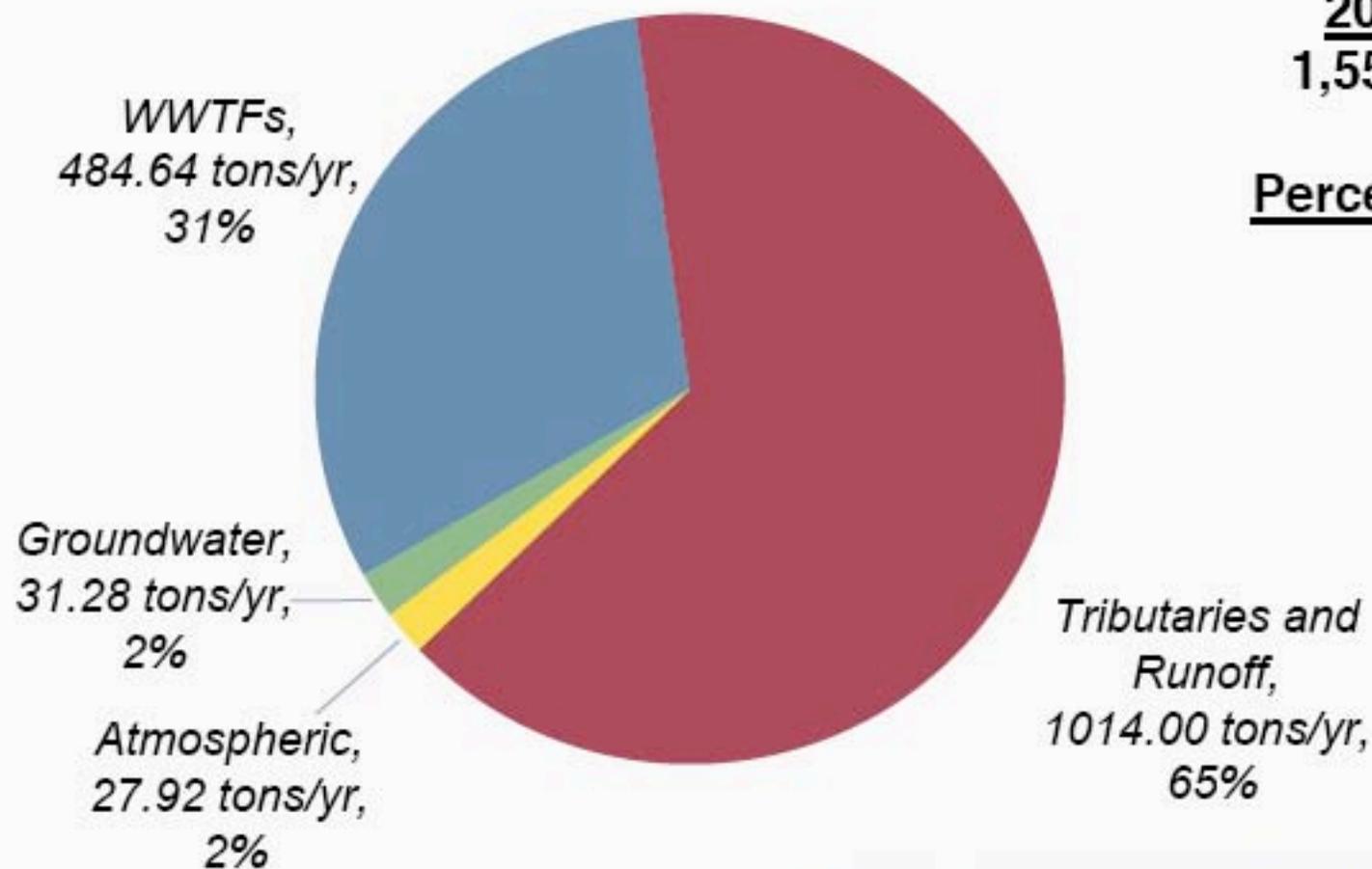
# Nitrogen Loads to the Great Bay Estuary

Total N load

2002-2004  
1,097 tons/yr

2006-2008  
1,558 tons/yr

Percent Change  
42%

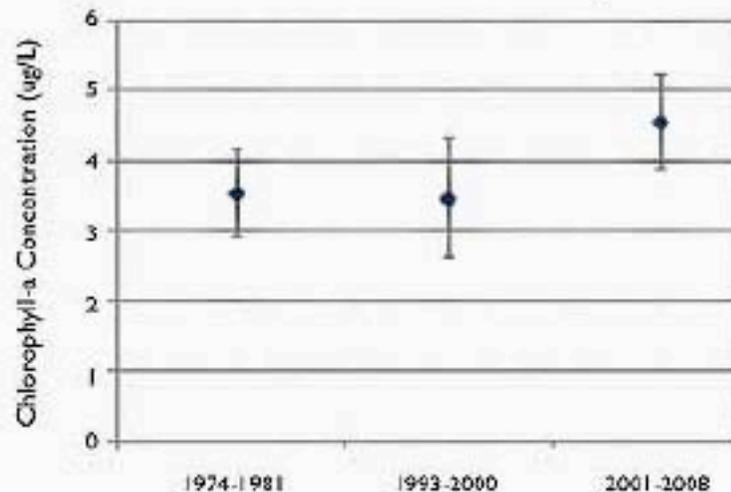


Data Source: PREP

# Nitrogen, Suspended Solids, and Chlorophyll-a in Great Bay

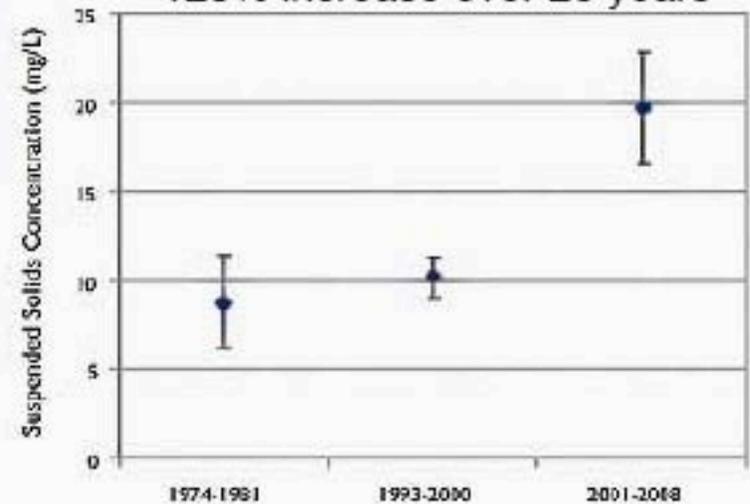
## Chlorophyll-a

28% increase over 28 years



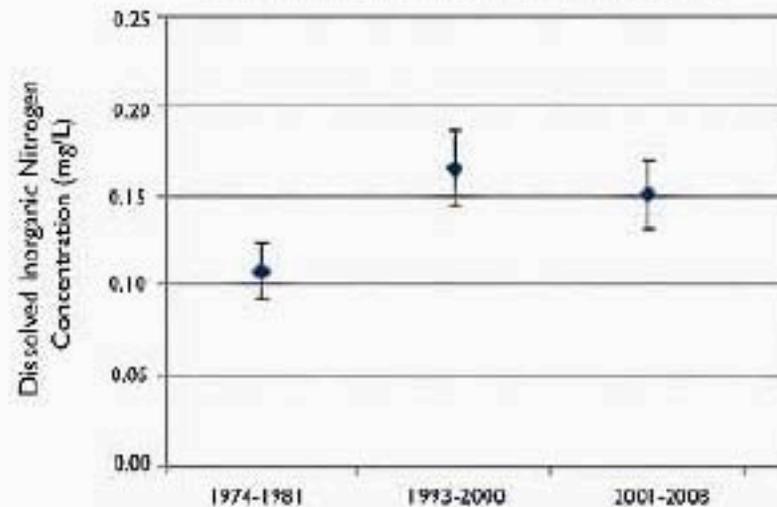
## Suspended Solids

123% increase over 28 years



## Dissolved Inorganic Nitrogen

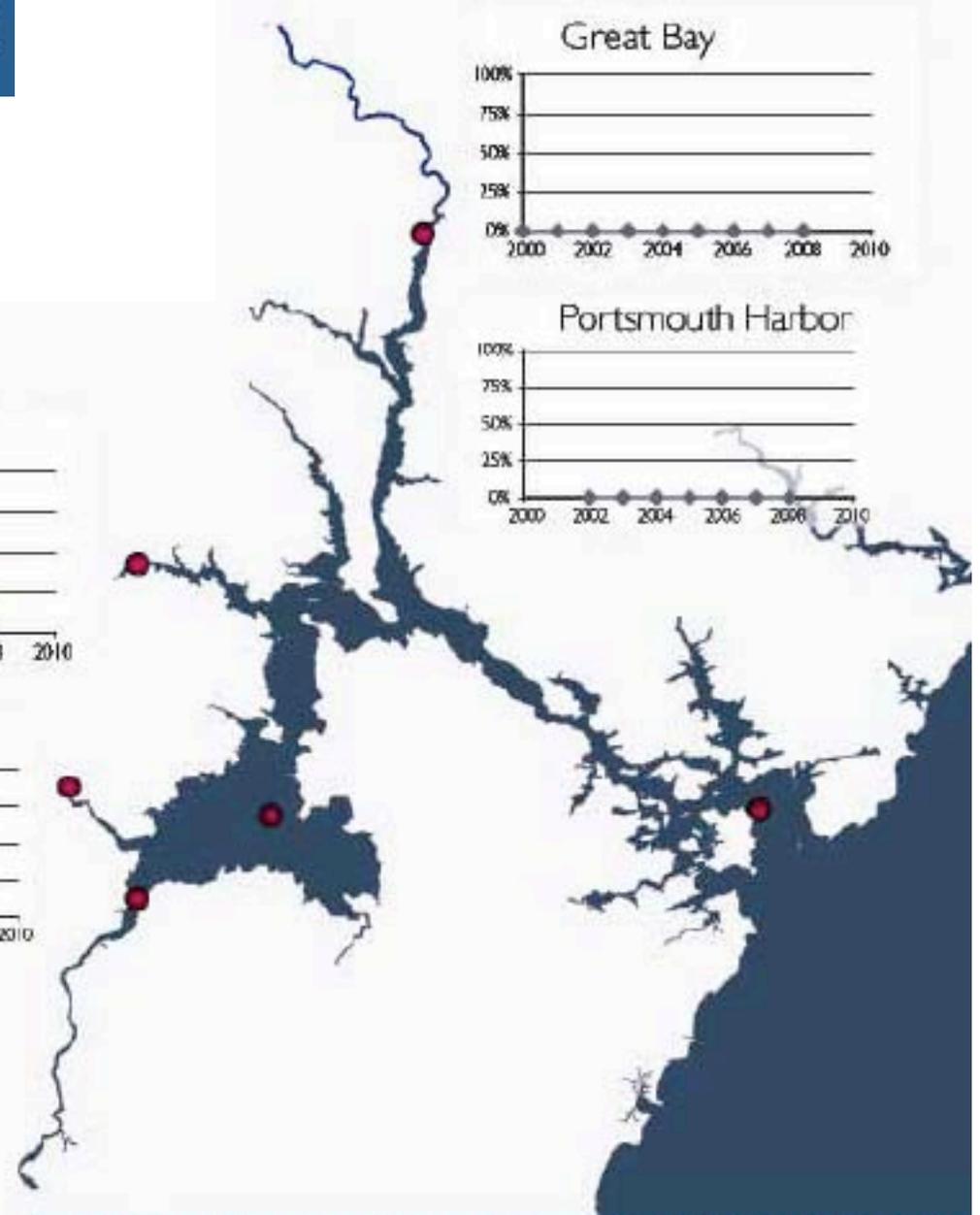
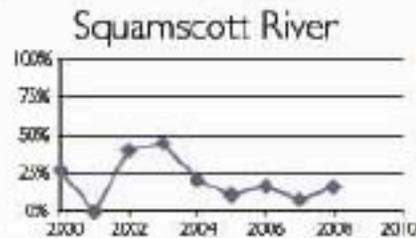
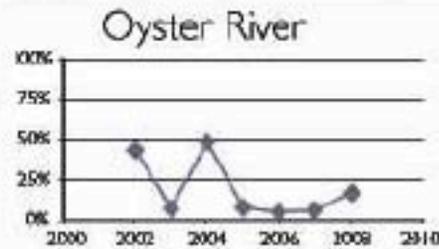
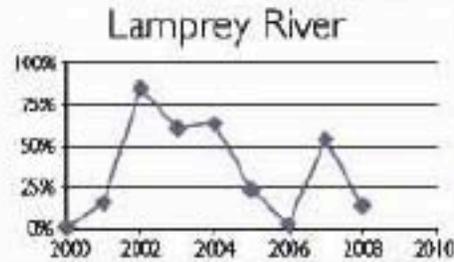
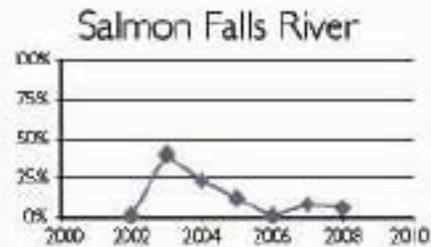
44% increase over 28 years



Data Source: UNH JEL

# Dissolved Oxygen

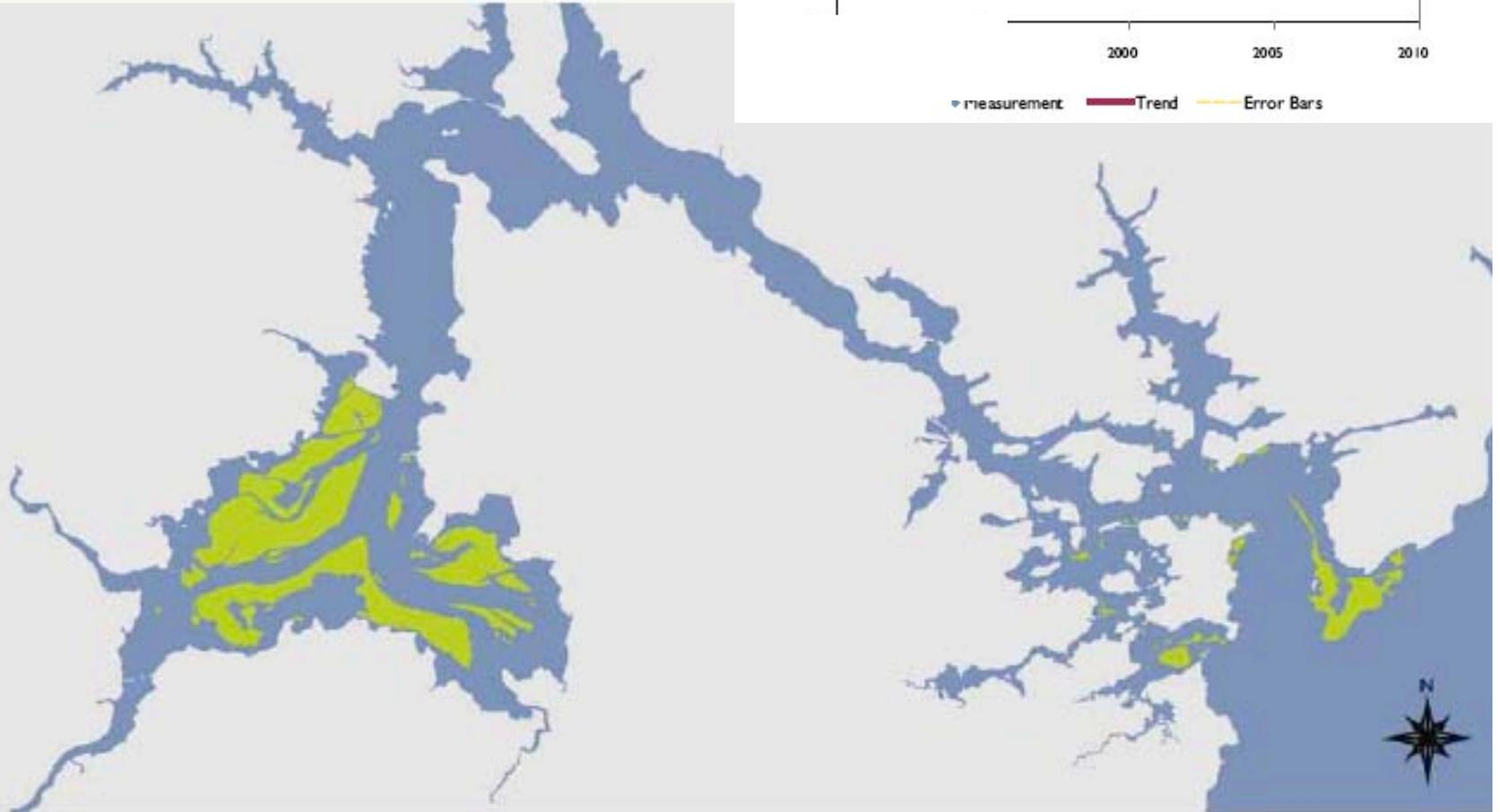
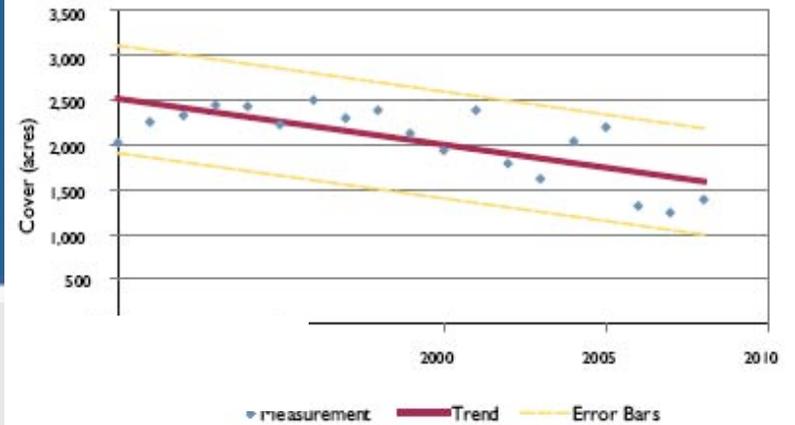
% of days where DO < 75% saturation



Data Source: Great Bay NERR, UNH JEL

# Eelgrass in Great Bay in 2008

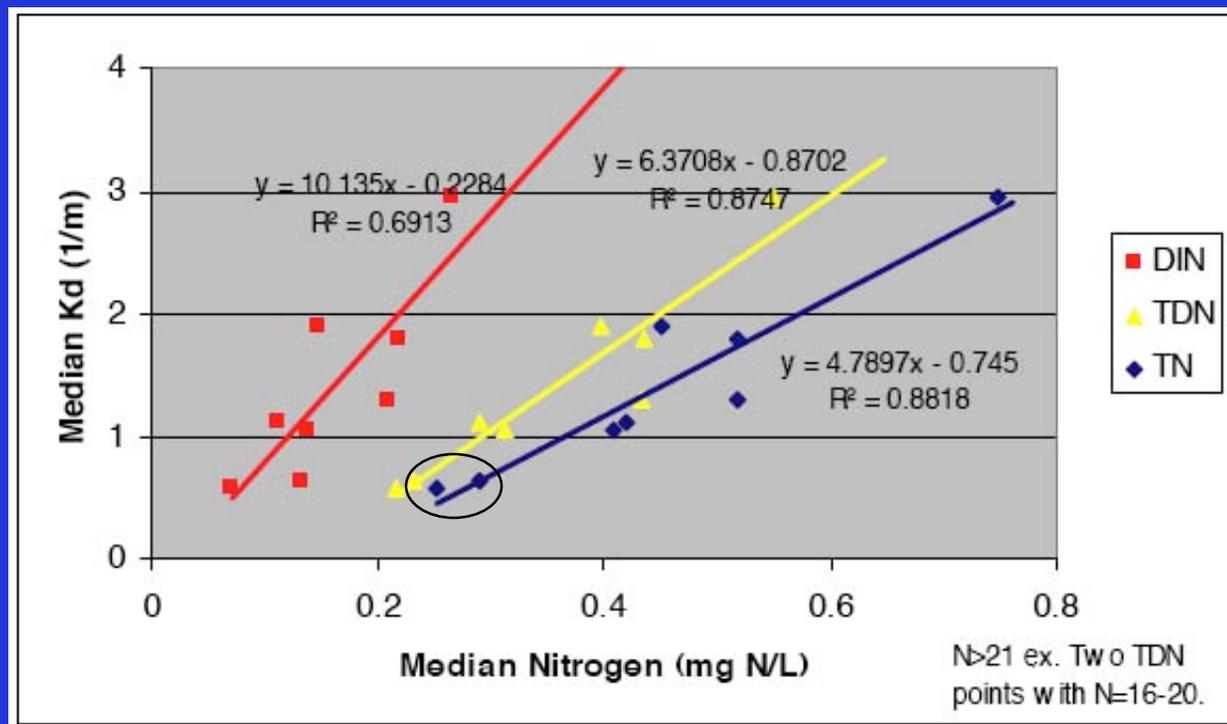
Eelgrass cover in Great Bay (Figure 14)



Data Source: UNH Seagrass Ecology Group

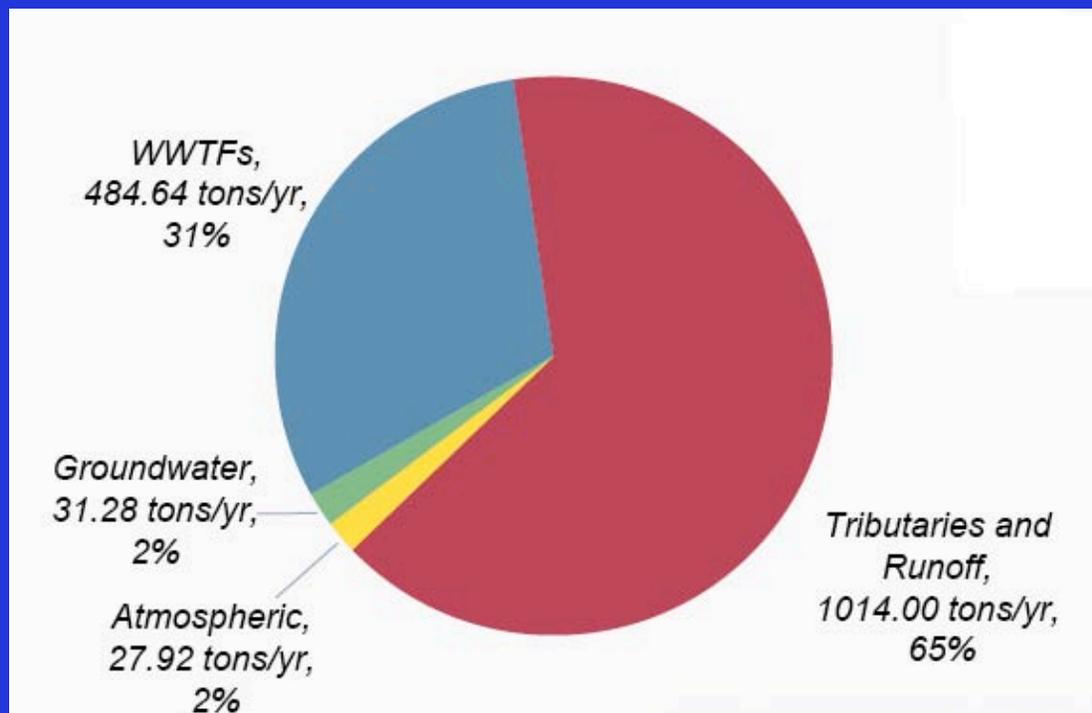
# Nutrient Criteria

- For DO > 5mg/L and > 75% Saturation = .45 mg/L TN
- For water clarity (0.5-0.75 kD) to support eelgrass = .25-.30 mg/L TN



# Meeting Nutrient Criteria

- **Model projections indicate a reduction of 750 tons TN/yr would be required**



*EBNR can remove 85% or 407 tons of N from WWTF effluent*

*At \$40/lb cost = \$32 M*

*Cost of removal from stormwater/NPS ??*

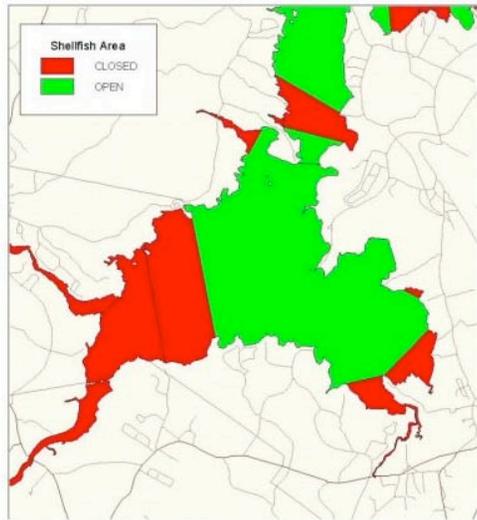
# ***Extractive Alternatives***

- ***Private Aquaculture***
- ***Restoration***
- ***Microalgal Biomass Production***

# Private Aquaculture

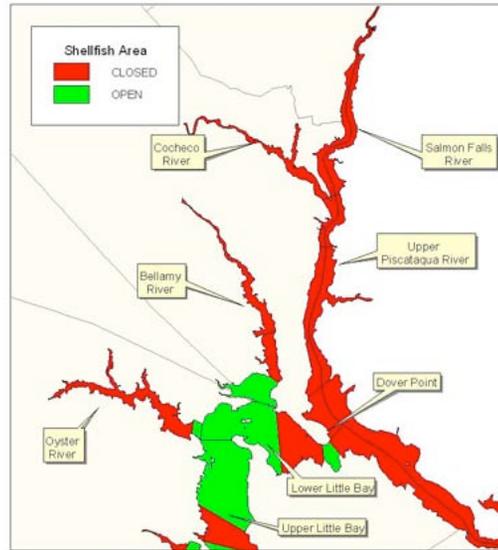
## SHELLFISH CLASSIFICATIONS: GREAT BAY ESTUARY (south)

For all OPEN areas, certain weather conditions or other factors may trigger a temporary closure. Call the Clam Hotline at 1-800-43-CLAMS for regular updates (weekly updates normally posted by 3PM on Fridays during the harvesting season).



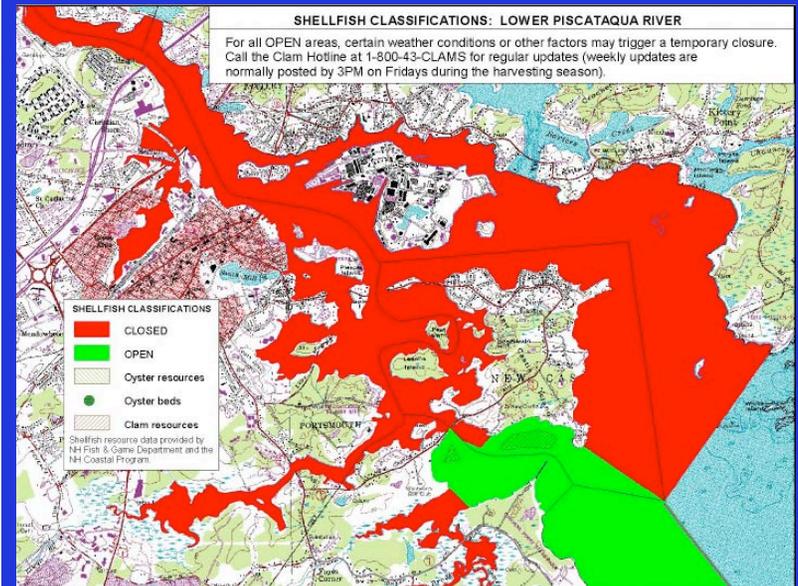
## SHELLFISH CLASSIFICATIONS: Great Bay Estuary (north)

For all OPEN areas, certain weather conditions or other factors may trigger a temporary closure. Call the Clam Hotline at 1-800-43-CLAMS for regular updates (weekly updates normally posted by 3PM on Fridays during the harvesting season).



## SHELLFISH CLASSIFICATIONS: LOWER PISCATAQUA RIVER

For all OPEN areas, certain weather conditions or other factors may trigger a temporary closure. Call the Clam Hotline at 1-800-43-CLAMS for regular updates (weekly updates are normally posted by 3PM on Fridays during the harvesting season).



# Oyster Culture

- **Bottom Culture**

- 120 acres of suitable bottom
- Density of 200 / m<sup>2</sup>
- 1/3 harvested annually = 33 M
- 33 M x (0.5 gm N harvest + .50 gm N b+dn) = 36 tons

- **Off Bottom Culture**

- 50 acres
- Density of 400 / m<sup>2</sup> (multi-tiered cages)
- 1/3 harvested annually = 27 M
- 27 M (0.5 gm harvest + .50 gm b+dn) = 29 tons

**Total N removal via harvest = 65 tons**

# Oyster Production Methods and Locations

60 M oysters = 120 M seed

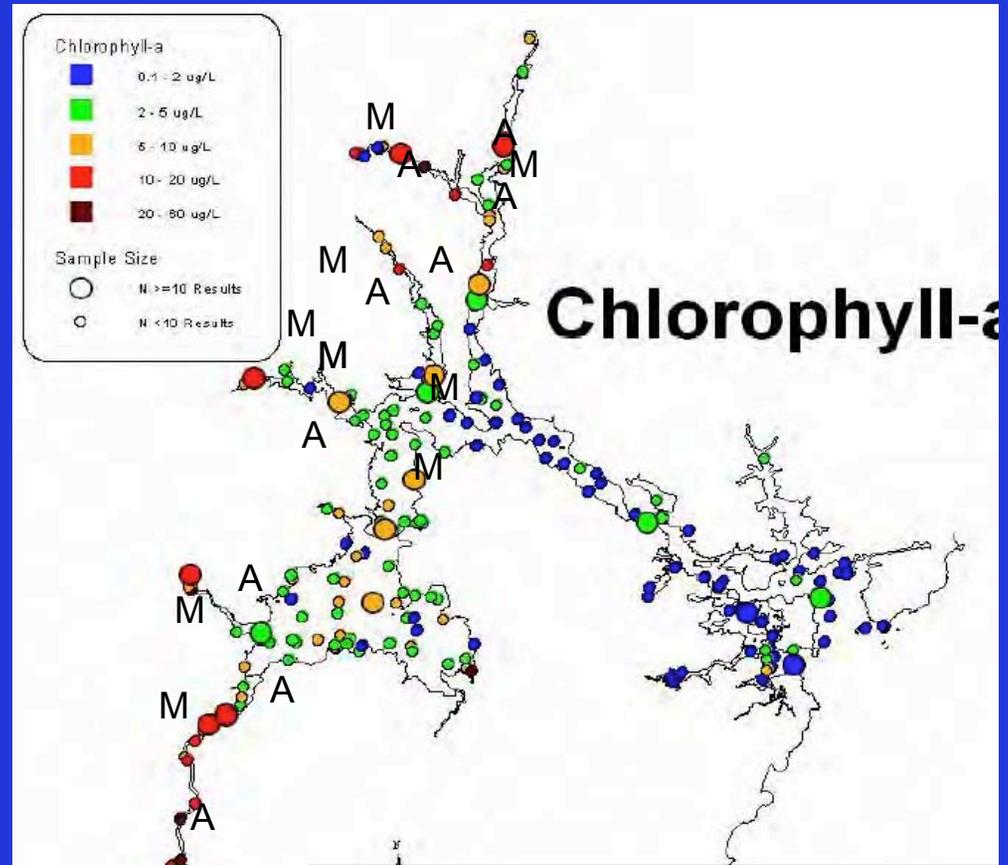


Floating Upweller: 2 M (25 mm) oysters = 60 upwellers

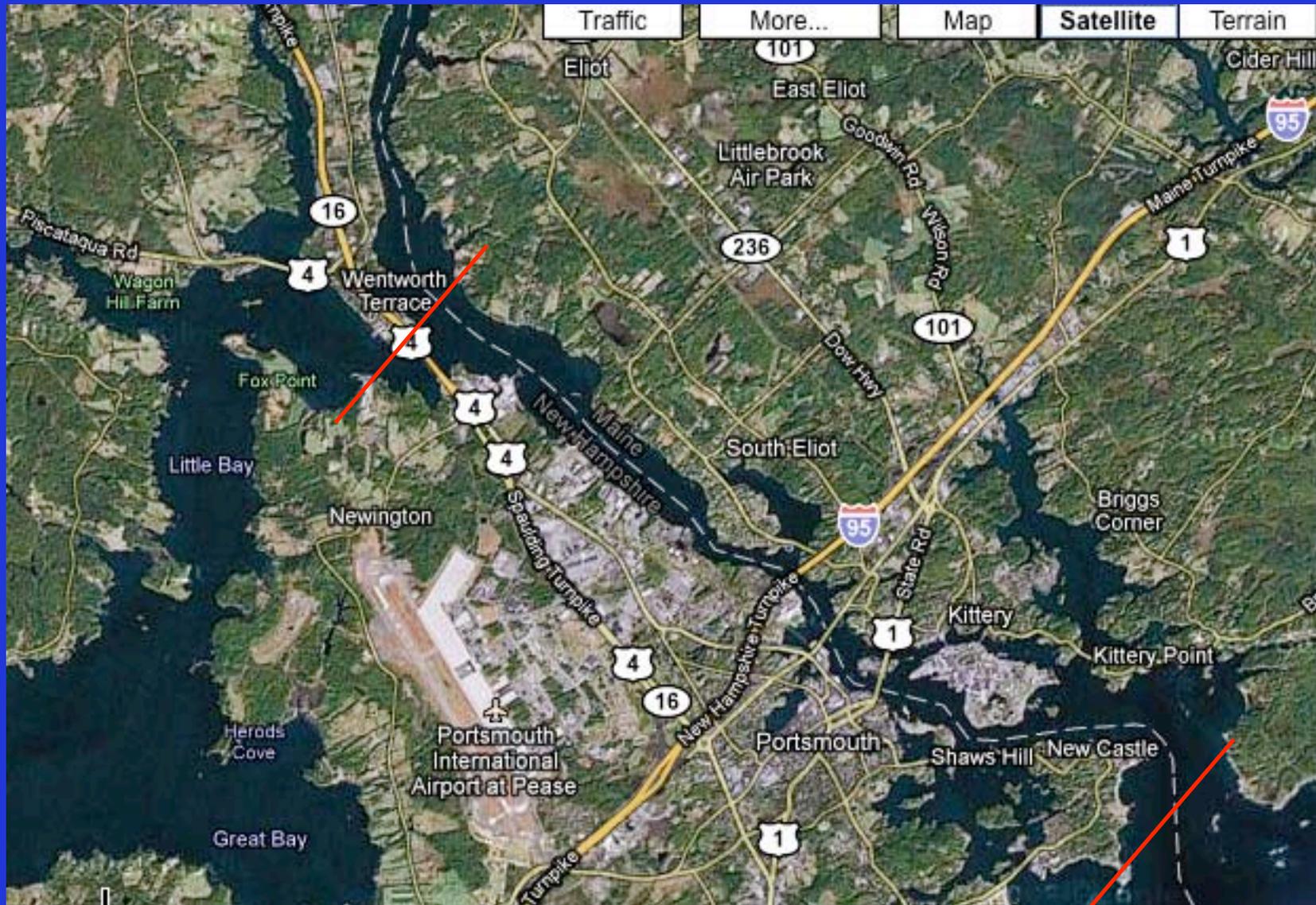
Marinas 35 upwellers

Private Docks 15 upwellers

Anchored 10 upwellers



# Mussel Seed Production



# *Mussel Seed Collection*

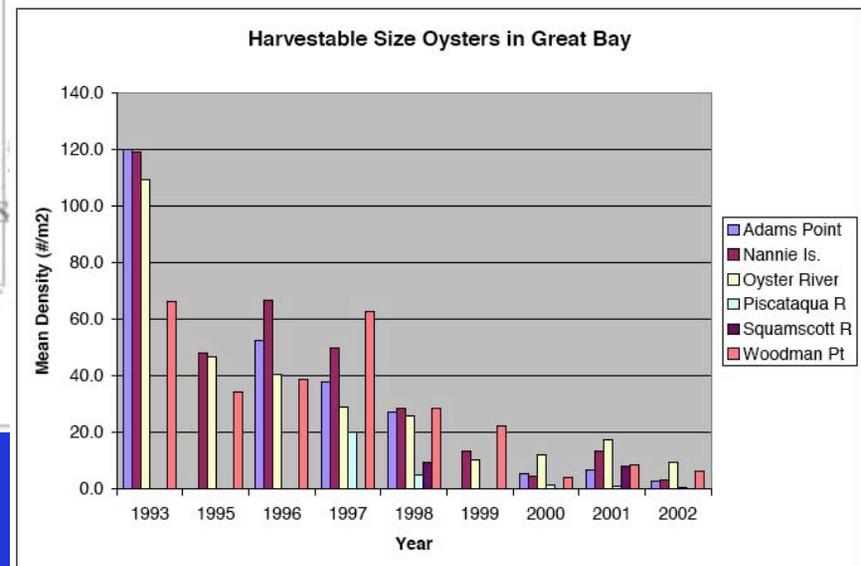
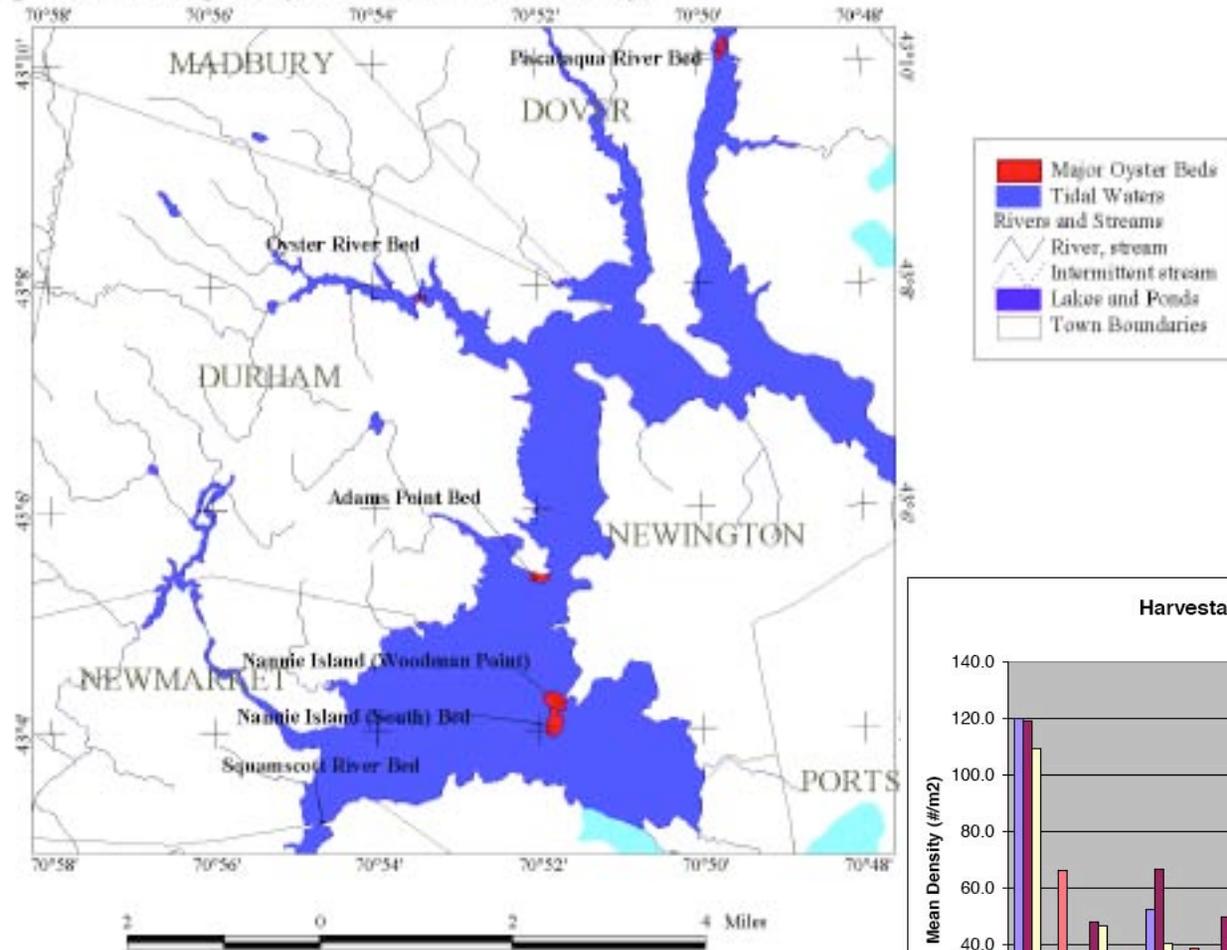
- *Potential for large scale seed collection and sale to offshore growers*



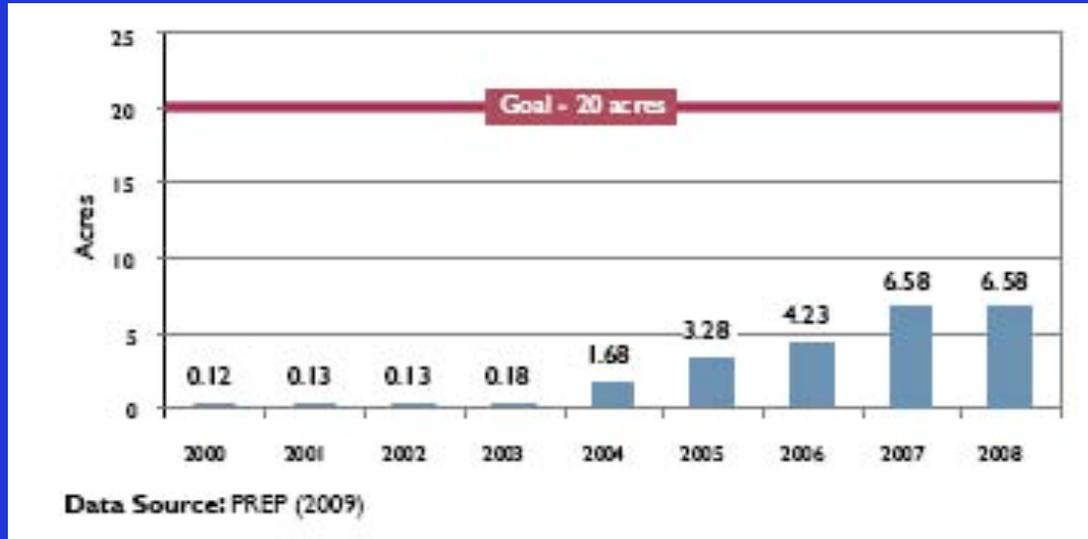
Seed to supply 3 large offshore farms = 1.44 M lbs = 11.5 tons N

# Restoration

Figure 5-1: Major Oyster Beds in Great Bay.



# Restoration Goal



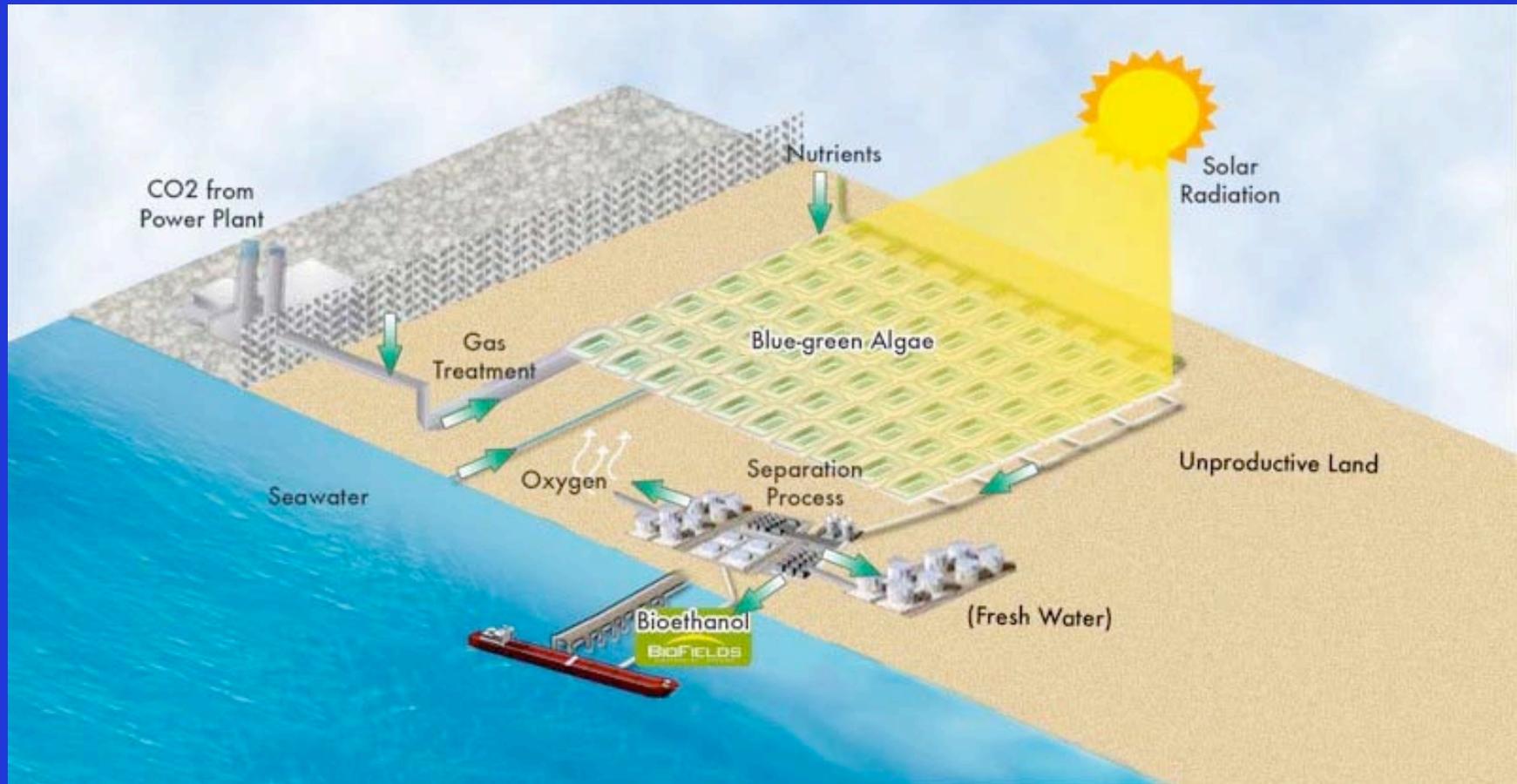
$20 \text{ Acres} \times 200 \text{ m}^2 \times 1.2 \text{ gm TN seq} + \text{b} + \text{dn} = 22 \text{ tons TN}$

## *Extraction Summary (AQ + Res)*

- *Private Aquaculture*
  - *Bottom Culture* 36.0
  - *Off-bottom Culture* 29.0
  - *Mussel Seed Production* 11.5
- *Restoration* 22.0

*Total Removal* 92.5 tons

# Microalgal Biomass Production?



# Possible Plant Locations



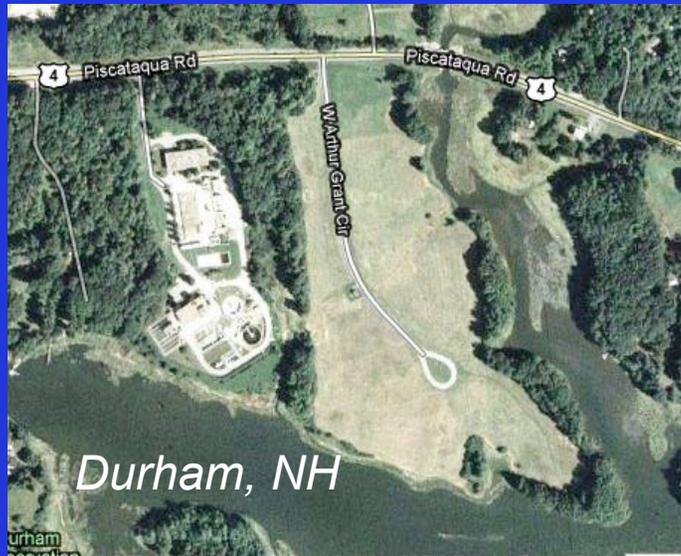
Dover, NH



Newington +  
PSNH



Portsmouth, NH



Durham, NH



Exeter, NH

Collectively contribute 330 tons TN

# ***Extraction/Production Potential\****

- ***Assumption***
  - ***5 Photobioreactor plants covering 12 acres***
  - ***Total biomass = 1,000,000 kg/yr***
- ***Extraction (annual)***
  - ***100,000 kg TN = 110 tons TN***
  - ***1,830,000 kg (2,013 tons) C***
- ***Production (annual)***
  - ***146,666 gallons of biodiesel***
  - ***50,000 kg of biosolids***
- ***Cost***
  - ***\$2.95/kg biomass = \$2,950,000/yr***

\* Chisti, Y. 2007. Biodiesel from Microalgae. *Biotechnology Advances* 25 (2007) 294–306

# *Bioextraction Summary*

• <i>Private Aquaculture</i>	
– <i>Bottom Culture</i>	<i>36.0</i>
– <i>Off-bottom Culture</i>	<i>29.0</i>
– <i>Mussel Seed Production</i>	<i>11.5</i>
• <i>Restoration</i>	<i>22.0</i>
• <i>Microalgal biomass</i>	<i><u>110.0</u></i>
<i>Total</i>	<i>208.5 tons</i>

# Opportunities and Constraints

- **Economic**

- **Value of cultured shellfish and microalgae**

• Oysters (\$0.40 ea)	\$24,000,000
• Mussel Seed	\$ 432,000
• Biodiesel (@ \$2.66/gal)	\$ 390,131
• Algal biosolids??	<u>\$ ???</u>
<b>Total</b>	<b>\$24,832,131</b>

- **Costs**

• Oyster Seed Production	\$1,272,000
• Oyster Restoration*	\$1,080,000
• Biofuels/biosolids (ops)	\$2,950,000
• Biofuels/biosolids (Cap)	<u>\$ ???</u>
<b>Total</b>	<b>\$5,302,000</b>

- **Savings via bioextraction**

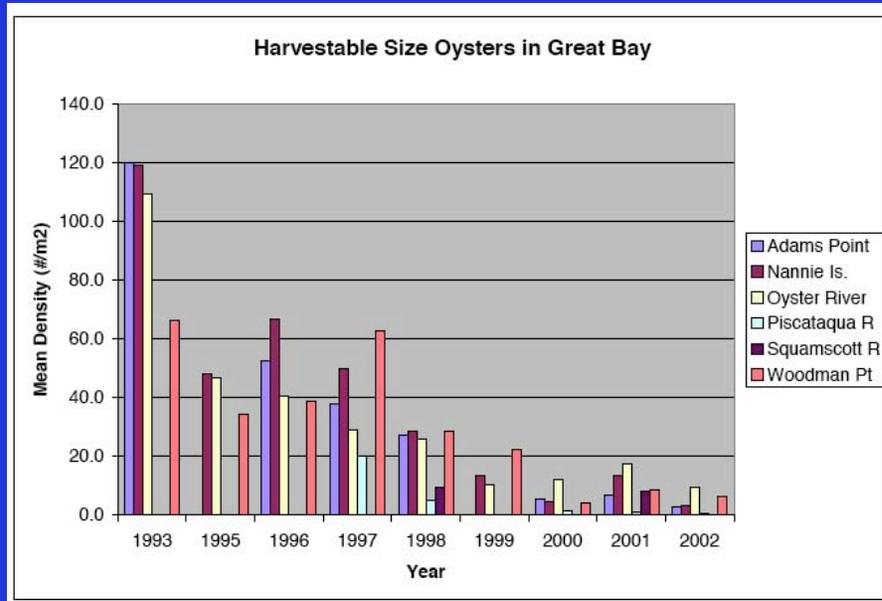
• 208.5 tons via EBNR (@\$40/lb)	\$16,680,000
• Carbon credits (2,013 tons @ \$30)	<u>\$ 60,390</u>
<b>Total</b>	<b>\$16,740,390</b>

# *Economic Externalities*

- *Shellfish markets*
- *Supply and costs of fuel alternatives*
- *Investment/operators for private aquaculture*
- *Investment for biomass production facilities*
- *Alternative uses/markets for algae lipids*
- *Market for biosolids*
- *Employment opportunities in competing fields*

# Ecological Considerations

- **Carrying Capacity**
  - **Addition of 197 M oysters + mussel seed**



*1993 total pop 138 M*

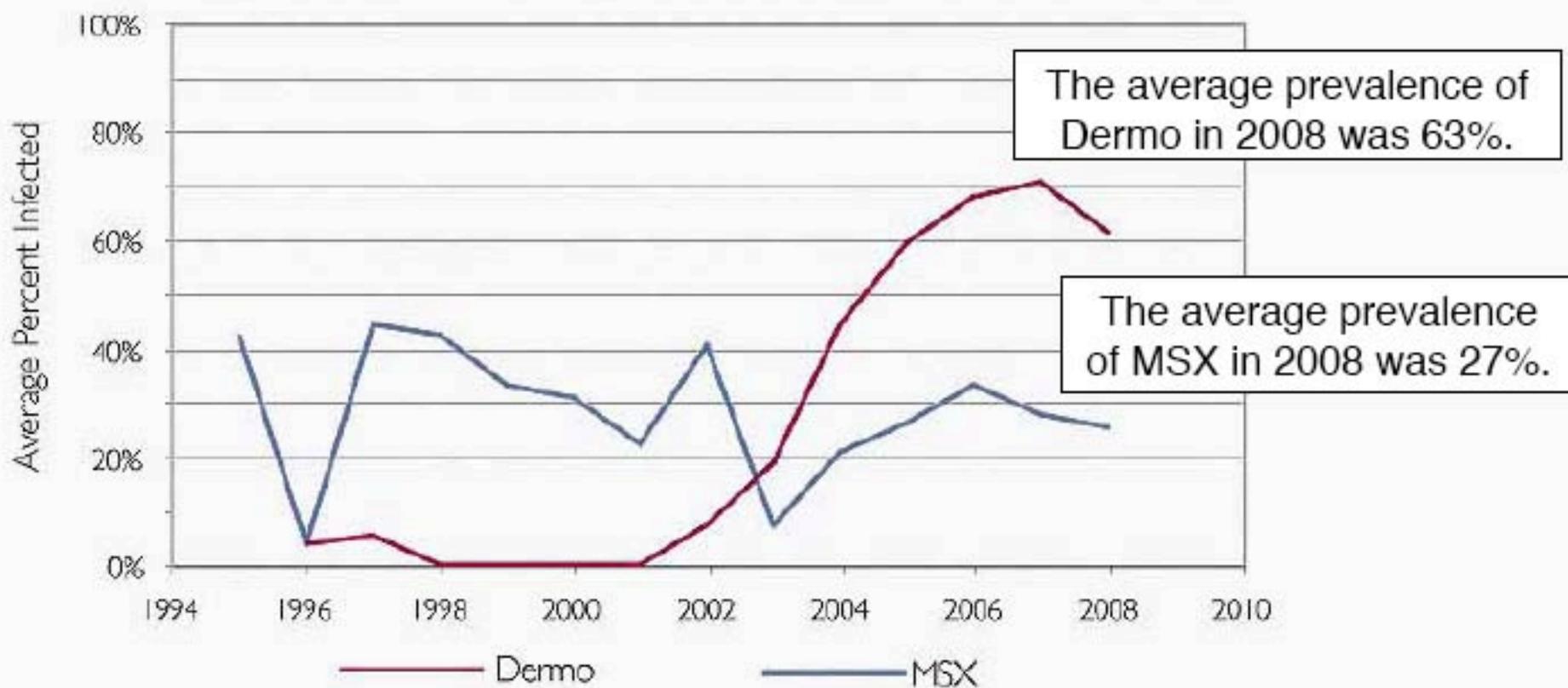
*2002 pop est 4 M*

*Will bioextraction for  
microalgal production  
affect primary productivity  
and carrying capacity?*

# *Ecological/Environmental Considerations*

- *Carrying Capacity*
- *Benthic and water column impacts of dredge harvesting 120 acres?*
- *Benthic impacts of off-bottom culture?*
- *Flow alteration from upwellers?*
- *Oxygen demand from oyster respiration*
- *Increased incidence of MSX, Dermo, and Vibrio due to climate change?*
- *Increased transmission of MSX and Dermo due to increased density?*

# Infection Prevalence in Oysters



Data Source: NHFGD

# ***Potential Regulatory Constraints***

- ***Will NH and federal agencies grant leases for 170 acres of oyster production and 10 acres of seed mussel collection and nursery culture?***
- ***Will DES impose offsets and will municipalities agree to pay?***
- ***Will NH DES (Shellfish Program) permit oyster seed production in closed areas?***
- ***Will extent of closed areas increase because of climate change and continued development?***

# ***Social Constraints***

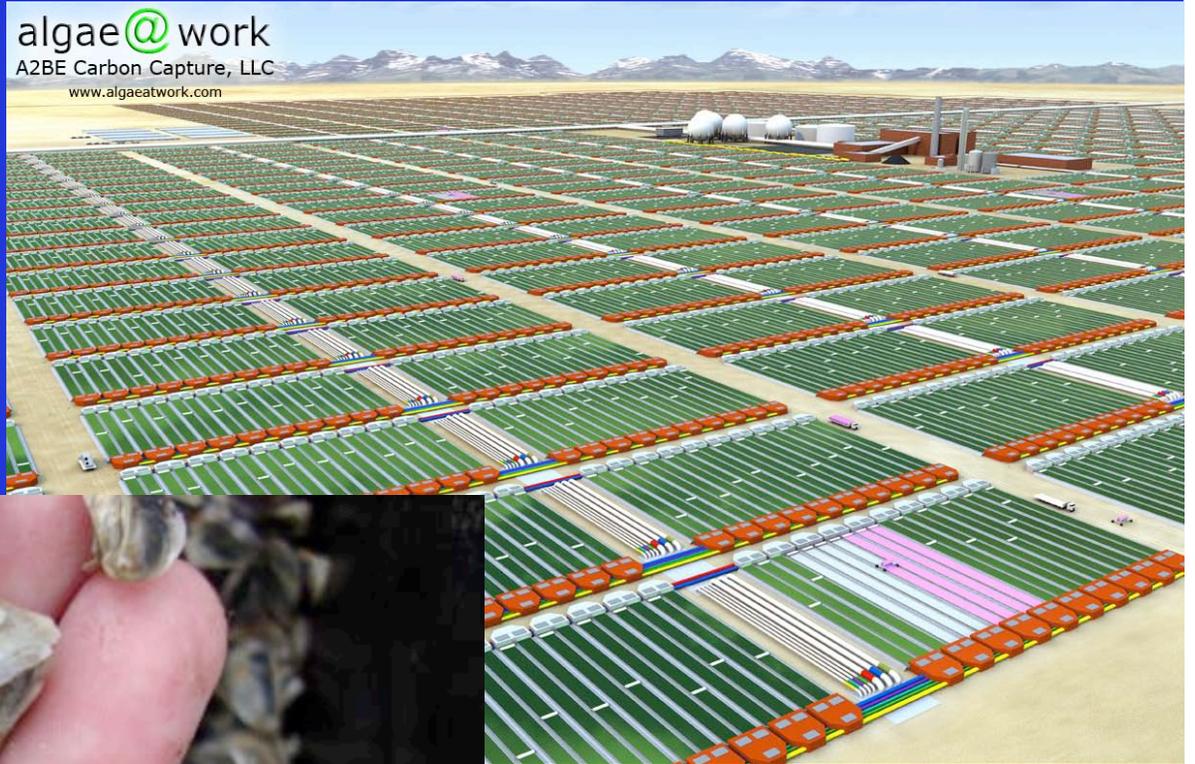
- ***Opposition from commercial fishermen?-  
not likely***
- ***Opposition from recreational fishermen?-  
possibly***
- ***Opposition from recreational boaters? -  
likely***
- ***Opposition from shorefront property  
owners?- you bet!***

# *Summary*

- *Potential to remove 28% of TN needed to meet numerical nitrogen criteria at considerable savings*
- *Potential to generate substantial economic activity*
- *Cautions:*
  - *Projections are very preliminary*
  - *Many assumptions- validation is needed*
  - *Model is subject to a number of externalities*

*Thank You*

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A2BE Carbon Capture, LLC  
[www.algaeatwork.com](http://www.algaeatwork.com)



*Questions?*