US ERA ARCHIVE DOCUMENT



Empirical relationships between nitrogen loading and ecosystem response in Buzzards Bay embayments: Is there transferability for TMDLs elsewhere?

> Dr. Joe Costa Buzzards Bay Project National Estuary Program

> > May 5, 2004 2:30-3:00

"A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and allocates pollutant loadings among point and nonpoint pollutant sources." US EPA

Additional Information at www.BuzzardsBay.org

Talk Outline

Brief historical overview of our original approach

Philosophy on TMDLs (science versus management)

Describe the new ongoing effort of the Massachusetts Estuary Program to establish Nitrogen TMDLS

Discuss the log-normal ecosystem response to nitrogen loading and the high temporal variability in ecosystem response

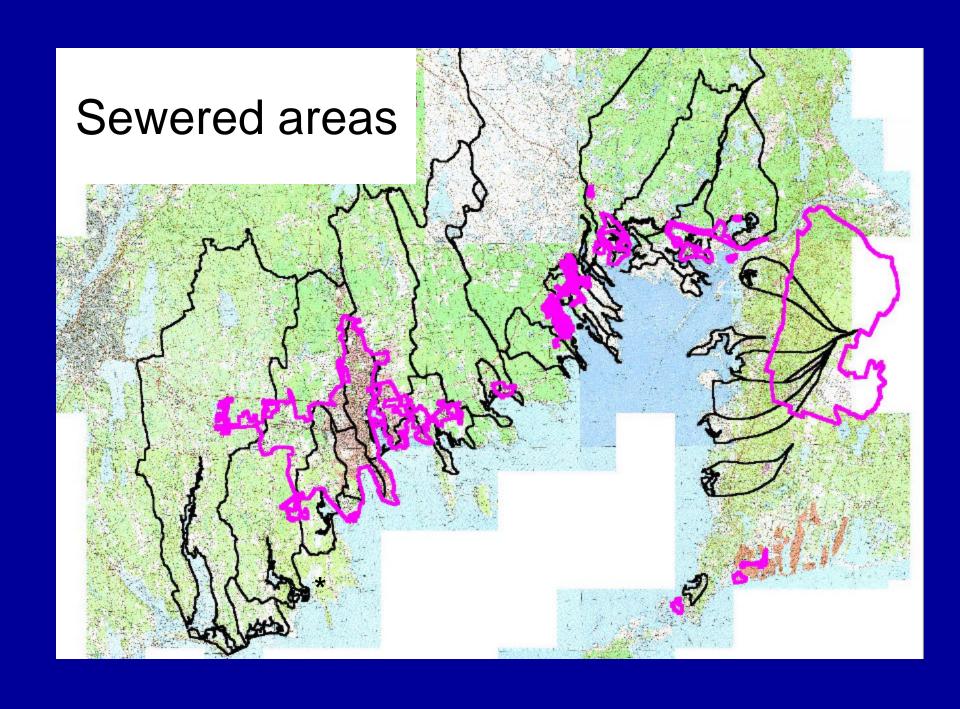
Introduce the concept of a 10 second TMDL

The Problem & Motivation.



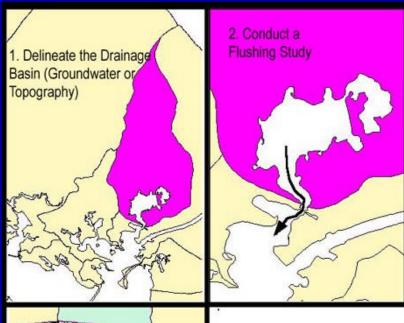
Buzzards Bay, a National Estuary Program established in 1985, has dozens of coastal embayments, many of which are threatened or impacted by anthropogenic nitrogen loading. Previous studies focused on bay-wide conditions. Most embayments threatened by cumulative impacts of NPS pollution. Management Plan developed in 1991.

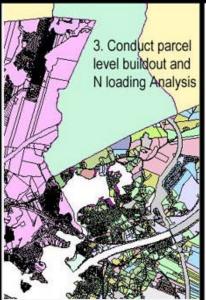
24 of 28 embayments had no large point sources of nitrogen.

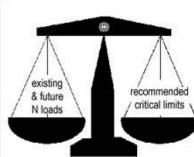


Buzzards Bay Project Nitrogen Management Strategy

- -Novel "TMAL" strategy adopted in 1991. Limits based on empirical relationships between loading and ecosystem response.
- -Mass Loading standard, not water quality standards
- parcel level evaluation recommended
- new embayment specific models
 needed where large \$ decisions involved
- -Proposed loading standards incorporated:
- o flushing (Vollenweider term)
- o volume
- o bathymetry
- o water quality classifications (SA, SB, ORW, etc.)







 Compare existing and future loadings to recommended critical limits. Develop management recommendations on findings.

1991 proposed Nitrogen Management Strategy

- -For impacted bays, do historical assessment to find loading target
- -For bays with large \$ decisions (like STF designs), do a bay-specific loading model
- -For other bays, used tiered approach below

Original app	Outstanding		
Embayment type Shallow ^c	SB Waters ^b	SA Waters ^b	Resource Waters ^b
-flushing: ≤4. 5 days -flushing: >4. 5 days Deep	350 mg m ⁻³ Vr ⁻¹ 30 g m ⁻² yr ⁻¹	200 mg m ⁻³ Vr ⁻¹ 15 g m ⁻² y ^{r-1}	100 mg m ⁻³ Vr ⁻¹ 5 g m ⁻² yr ⁻¹
-lesser of	500 mg m ⁻³ Vr ⁻¹ or 45 g m ⁻² y ^{r-1}	260 mg m ⁻³ Vr ⁻¹ or 20 g m ⁻² y ^{r-1}	130 mg m ⁻³ Vr ⁻¹ or 10 g m ⁻² yr

Volumetric limit • volume at half tide (in m³) • $(1+\tau_w^{1/2})/\tau_w \div 1,000,000$ where τ_w is the hydraulic turnover time in years.

Copland	Wareham River	Watershe	dareas i	n Hectare	sewered	sewere	sewered	424000
Pasture 10.2 9.3 2.0 9.5 Porest 92089 9646 722.0 101 Non-forested welland 1777 1956 72.0 101 Non-forested welland 1777 1956 72.0 101 Non-forested welland 1777 1956 72.0 101 Non-forested welland 1779 55.0 12.1 2.0 Padicipatory recreation 10.0 0.0 0.0 Water based recreation 15.0 12.4 2.5 10 Ric residential multi-family 12.2 12.2 0.0 1.5 1.6 0.0 68 Ric residential multi-family 12.2 12.2 0.0 1.5 1.6 0.0 68 Ric residential - 4% acre lots 2185 1463 72.1 69.5 64.5 1.1 933 Ric Residential - 4% acre lots 239.3 199.5 192.6 78.0 78.0 0.0 114 Ric Residential - 4% acre lots 239.3 39.5 192.6 78.0 78.0 0.0 114 Ric Residential - 4% acre lots 239.3 39.7 140.1 7.3 7.3 0.3 36 Ric Residential - 4% acre lots 239.3 39.7 140.1 7.3 7.3 0.3 36 Ric Residential - 4% acre lots 239.3 39.7 140.1 7.3 7.3 0.3 36 Ric Residential - 4% acre lots 239.3 39.7 140.1 7.3 7.3 0.3 36 Ric Residential - 4% acre lots 239.3 39.7 140.1 7.3 7.3 0.3 36 Ric Residential - 4% acre lots 239.3 39.7 140.1 7.3 7.3 0.3 36 Ric Residential - 4% acre lots 239.3 39.7 39.7 30.0 36 36 30 30 30 30 30 3	Landuse type				whole	lower	upper	N (kg
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Non-forested wetland	Forest	9298.9	984.6	7322.3				1015
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R0: residential multi-family								
R1: Residential - 4/4 acre lots								
R2: Residential - V4-W acre lots								855
R3: Residential - 1/4 acre lots	R1: Residential- <1/4 acre lots	218.5	145.3	72.1	65.6			9239
Sat marsh	R2: Residential- <¼-¼ acre lots	392.3	199.5	192.8	78.0	78.0	0.0	11413
Commercial 69.9 68.3 1.6 24.6 24.0 6.5 564 industrial 01.6 37.4 14.3 14.0 14.0 0.0 90	R3: Residential- <1/4 acre lots	239.7	99.7	140.1	7.3	7.3	0.0	3829
Industrial	Salt marsh	120.9	93.5	27.5				- 1
Industrial	Commercial	69.9	68.3	1.6	24.5	24.0	0.6	5647
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Powerlines (part of #8)								- (
Sativater Beach (part of #9)								
Golf (part of #7)	Powerlines (part of #6)	142.0	14.5	127.5				17
Tidal Salt Marsh (part of #14)	Saltwater Beach (part of #9)	0.0	0.0	0.0				
Irreg. Flooded Sat Marsh (part of ≠14 0.0 0.0 0.0 0.0 0.0 Marins (part of ≠9) 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	Gulf (part of ¥7)	39.6	0.0	39.6				818
Irreg. Flooded Sat Marsh (part of ≠14 0.0 0.0 0.0 0.0 0.0 Marins (part of ≠9) 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	Tidal Salt Marsh (part of #14)	0.0	0.0	0.0				- (
Marrine (part of #9) 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0		0.0	0.0					- 1
New Ocean								- 1
Urban Public (part of ≠17) 40.9 20.9 20.0 Transportation Facility (part of ≠18) 5.0 5.0 0.0 Heath (part of ≠17) 0.0 0.0 0.0 Cemetaries (part of ≠17) 14.1 14.1 0.0 41 Orchard (part of ≠21) 0.0 0.0 0.0 0.0 Nursery (part of ≠21) 1.6 1.6 0.0 0.0 Forested Vivaliand (part of ≠3) 0.0 0.0 0.0 TOTAL LAND AREA (ha) 115753 24058 8724.6 Major road length, km 21.3 20.5 0.8 Al Roads, km 436.4 133.6 8 Secondary Road length, km 415.1 115.1 300.0 Road Ayaa (ha) 367.9 126.5 241.3 216 Embaryment area (ha) 249.00 181 161 Total Loading based on landuse, pre-adjustments 5914 292 2.2 2.2 Reported dunits (existing) 4914 2942 207 severed units <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>								
Transportation Facility (part of #18) 5.0 5.0 0.0 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1	1 A T. C.							
Heath (part of #17)								
Cernetaries (part of #17)								76
Orchard (part of ≠21)								- 1
Nursery (part of ≠21)	Cemetaries (part of #17)			0.0				416
TOTAL LAND AREA (ha)	Orchard (part of #21)	0.0	0.0	0.0				्र
TOTAL LAND AREA (ha) 11575.3 2405.8 9724.6	Nursery (part of #21)	1.6	1.6	0.0				33
Major road length, km	Forested Wetland (part of #3)	0.0	0.0	0.0				
Major road length, km	TOTAL LAND AREA (ba)	115753	2405.8	97246				
All Roads, km								
Secondary Road length, lem				0.0				
Road Area (ha) 367.8 126.5 241.3 210				200.0				
Sembayment area (ha) 249.00 181								
Total Loading based on landuse, pre-adjustments S914			120.5	241.3				
Reported Area occupancy 2.7 2.2 2.2								
Predicted units (existing)		adjustm		9295				59143
actual units (1990 census) 5091 3550 1541.0 1408 1408 0 roof+lawn loading from census units 5210 1583 27.7% 39.7% 0.0% 879 Unit density (per scree) 0.2 0.5 0.1	Reported Area occupancy							
1583 27.7% 39.7% 0.0% 679	Predicted units (existing)	4914	2842	2072	sewered	units		
Unit density (per acre)	actual units (1998 census)	5091	3550	1541.0	1408	1408	. 0	
Unit density (per acre)	roof+lawn loading from census units		5210	1583	27.7%	39.7%	0.0%	8793
Predicted population (edisting) 10712 6196 4516 Actual population (1990 Census) 10030 6230 3800.0 2022 2022 0 Population will especial adjustment 11698 7798 3900 2529 2529 0 septic loading from census pop, data actual reading population of the control of the contro			0.5	0.1	100000	7 1007 0000	20-20-	
Actual population (1990 Census) 10030 6230 3800.0 2022 2022 0 Population will seasonal adjustment 11698 7788 3800 2528 2529 0 septic loading from census pop. data saturalises unadiance annualized occupar 2.3 2.2 2.6 Total Loading based land use, census units, cenus pop. and actual roads 6797 Animal units 0.0 0.0 0.0 0.0 0.0 Point sources (MOD, ppm) 24667.5 0.0 0.0 Other Special 0.0 0.0 0.0 Sewering adjustment units 0.0 0.0 0.0 United to the special 0.0 0.0 0.0 0.0 United to the special 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.								
Population w/ seasonal adjustment 11698 7798 3900 2529 2529 0					2022	2022	0	
septite loading from census pop. data 2.3 2.2 2.6 actual/assumed annualized corupar 2.3 2.2 2.6 Total Loading based land use, census units, census pop, and actual roads 6797 Animal units 0.0 0.0 0.0 0.0 Point sources (MOD, ppm) 24667.5 0.0 0.0 2486 Other Special 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>								
artual/assumed annualized occupar 2.3 2.2 2.5 Total Loading based land use, census units, census pop, and actual roads Animal units 0.0 0.0 0.0 0.0 0.0 Point sources (MOD, ppm) 24667.5 0.0 0.0 2466 Other Special: 0.0 0.0 0.0 Sewering adjustment units 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0			1788	3800	20.28	2528	U	
Total Loading based land use, census units, census pop, and actual roads								2139
Animal units 0.0 0.0 0.0 0.0 0.0 2486 Point sources (MOD, ppm) 24667.5 0.0 0.0 2486 Other Special 0.0 0.0 0.0 Sewering adjustment units 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0								
Point sources (MOD, ppm) 24667.5 0.0 24666 Other Special 0.0 0.0 Sewering adjustment units 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Total Loading based land use, cens	us units, o	enus po	, and act	ual roads			6797
Point sources (MOD, ppm) 24667.6 0.0 2466 Other Special 0.0 0.0 3 Sewering adjustment units 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Animal units	0.0	0.0	0.0	0.0	0.0		
Other Special: 0.0 0.0 Sewering adjustment units 0 0 Upper watershed adjustment (kg) Tower watershed adjustment (kg)	Point sources (MOD, parn)							2486
Sewering adjustment units 0 0 upperwatershed adjustment (kg) lower watershed adjustment (kg)								-5/100
upperwatershed adjustment (kg) lowerwatershed adjustment (kg)								
lower watershed adjustment (kg)			- 0	- 0				
								9283

Most Loading Models are structured matrices in spreadsheets

Total Loading based on landuse, pre	adjustm	ents					59143
Reported Area occupancy	2.2	2.2	2.2	92			
Predicted units (existing)	4914	2842	2072	sewered	units	45	
actual units (1990 census)	5091	3550	1541.0	1408	1408	0	
roof+lawn loading from census units		5210	1583	27.7%	39.7%	0.0%	6793
Unit density (per acre)	0.2	0.5	0.1				
Predicted population (existing)	10712	6196	4516	8			
Actual population (1990 Census)	10030	6230	3800.0	2022	2022	0	
Population w/ seasonal adjustment	11588	7788	3800	2528	2528	0	
septic loading from census pop. data							21384
actual/assumed annualized occupar	2.3	2.2	2.5				
Total Loading based land use, censu	s units, c	enus pop	and act	ual roads			64142
Animal units	0.0	0.0	0.0	0.0	0.0		0
Point sources (MGD, ppm)		24867.5	0.0	92			24867
Other Special:		0.0	0.0	92			0
Sewering adjustment units		0	0	92			
upper watershed adjustment (kg)							0
lower watershed adjustment (kg)							0
Final Adjusted Loading, landuse/cens	us base	d					89009

Loading Summaries	
Residential NPS:	31.7%
Indust.+Comm.+Rds	11.3%
Cropland:	19.8%
Farm Animals:	0.0%
Point Sources:	27.9%
Forest	1.1%
Other Sources	8.2%
Total	100%

Note: Management vs. Science Occupancy rates

e a	ding Summaries	
0	Residential NPS:	61.3%
6	Indust.+Comm.+Rds	19.2%
6	Cropland:	2.3%
	Farm Animale:	0.0%

 Farm Animals:
 0.0%

 Point Sources:
 0.0%

 Forest
 0.4%

 Other Sources
 16.8%

 Total
 100%

History and future of practical nitrogen management in Massachusetts

1980s Starting Point: Freshwater Pond and Lake Phosphorus loading studies, GW nitrogen loading studies of Long Island and CCPEDC, coastal studies in RI, and Town of Falmouth water quality standards for Total Nitrogen in coastal waters

We liked the Falmouth loading approach, but reliance existing water quality (no accounting for lag time), inappropriate methods for measuring TN was unacceptable, as well as the piecemeal management approach.

We sought to pull out the WQ element and have management decisions focus exclusively on the easier to manage annual nitrogen loads from new development.

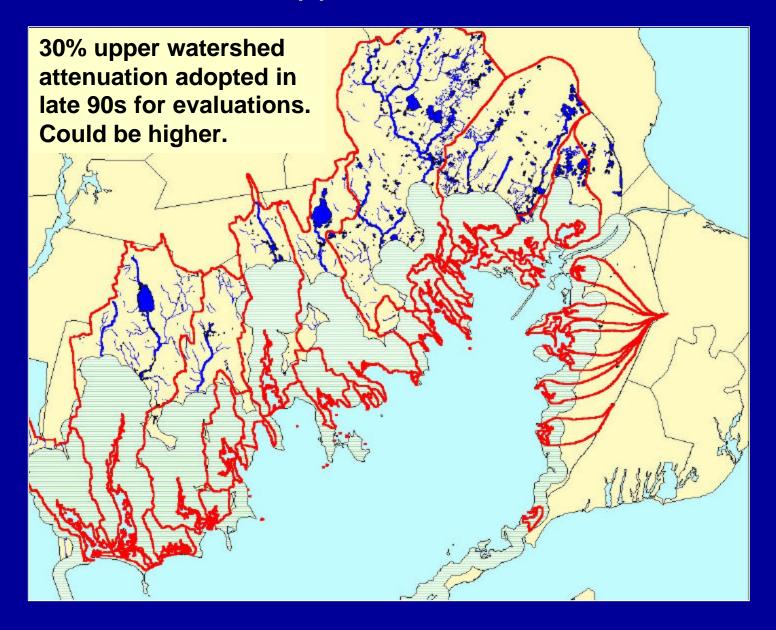
Our limits were initially hard to defend because we had little good embayment water quality (used eelgrass loss and a few good stuies in SE Mass and RI.) We were also hamstrung because there were few good ecosystem response models, and little money to implement more ambitious assessments.

1991 Strategy Weaknesses

(and how they were addressed)

- Inadequate baseline WQ data (addressed with WQ monitoring program commencing in 1991)
- Inadequate description of conditions expected for given loading (addressed with WQ monitoring program commencing in 1991, we proposed water quality standards in 1998)
- No attenuation or loss terms for upper watershed or groundwater/wetland losses
 (30% loss for upper watershed, unless better documentation)
- No Atmospheric N for Forest or other undeveloped (adopted 1.5 uM N groundwater background)
- Disagreement with certain loading terms (e.g. Septic systems)
 (ok to use different loading models, but don't use our standards)
- Adequately Protective? (loading limits halved)

BB Sub-basins: Upper and lower watersheds



Our effort is now superceded by MA DEP's "Massachusetts Estuaries Project"

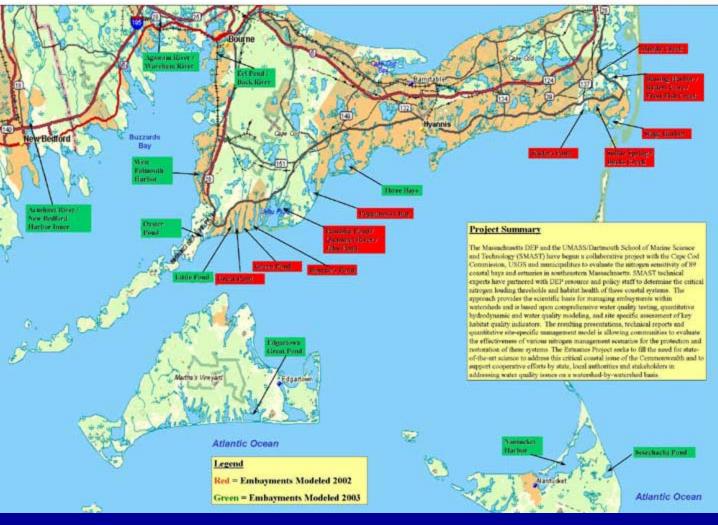
- -Started in 2000. Meets our 1991 vision of the way things should be done.
- -Study of 89 embayments (Loading -Flushing –Modeling) with recommended TMDLs and evaluation effectiveness of selected management options.
- -original projection \$13 Million or \$158,500 per embayment, more likely around \$200,000 or more?
- -Original estimate was 6 years to complete, but may be closer to 10 years and will be largely determined by funding levels. First draft evaluations released in Spring 2004.
- -Completion of study will identify management options, but regulatory tools for managing cumulative impacts of NPS have changed little in the past 20 years (i.e. zoning and sewering still leading options, innovative waste disposal requirements, non point source management still difficult to manage at state and federal level.)

Massachusetts Estuaries Project Round 1 Prioritization



Massachusetts Department of Environmental Protection



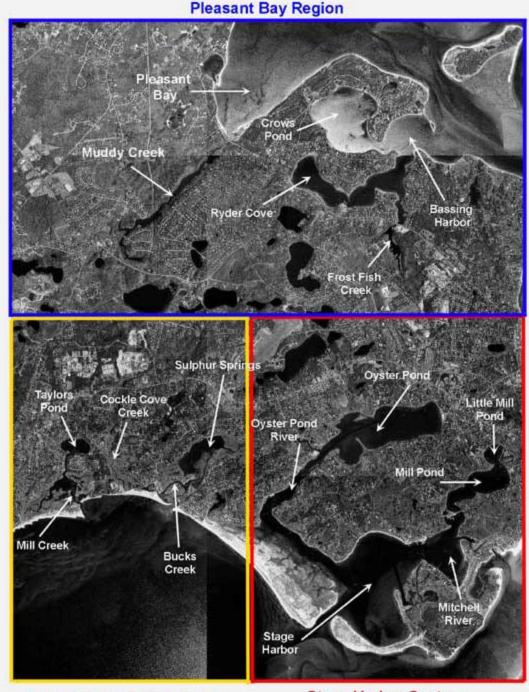


Chatham estuaries draft TMDLs just released

Massachusett s Estuaries Project:

Chatham Report Released

Primary Tool used by Dr. Howes is SMS (surface water modelling system) that links a hydrodynamic model (RMA-2) to a water quality model (RMA4).



South Coast Embayments

Stage Harbor System

Is any part of the BBP 1990s approach transferable to areas where dollars and time are not on your side?

Yes, certain concepts....

The correct management solution for development and implementation N TMDLS for NPS pollution:

- 1) Good water quality monitoring data sets for the scale watershed you are trying to manage
- 2) Appropriate Water and Living resource Goals
- Good model for predicting changes in WQ parameters (reductions or increases)
- 4) Implementation will most often focus on wastewater management. TMDLs will require application of mass loading limits (lb/s per acre) for new development using codified loading standards, and remediation strategies for existing development to meet certain targets.

1998 proposed water quality standards

Table 1. Proposed water quality standards, for various surrogate measures of nitrogen loading, that correspond to the proposed TMALs for nitrogen. Targets are mean summertime concentrations when critical conditions are most likely to occur. Based on best professional judgment.

(Formerly ORW SA SB)

<u>Parameter</u>	Excellent	Good	Fair	Poor
Eutrophication Index	70	60	50	40
Alternate Eutroph.Index (no 0_2)	65	55	45	30
Total N (ppm)	0.39	0.45	0.54	0.65
Chl a (mg/l)	4.0	6.0	7.0	9.0
Secchi depth (m)	2.0	1.7	1.5	1.3
Eelgrass to core habitat ratio	0.9	0.7	0.5	0.3

Point #1: Establishing TMDLs is more of a management process than a scientific exercise.

- •It is really translating science into a regulatory and management standard.
- •Reality: Ecosystem response is a continuum, and highly variable in time space, even in one embayment.
- •Scientists can define and document a problem. They can predict ecosystem response if you reduce a pollutant load. They can predict pollutant reductions with certain actions. But there is uncertainty in these evaluations.
- •EPA TMDLs are numerical limits water quality or habitat criteria and goals. Even if these standards are numeric, are based on value judgments of what is "good" and "bad", and evaluations beneficial uses. EPA TMDLs are required only for 303(d) list or Category V listed waters.
- •Some municipalities (or counties) may want to adopt TMDLs even when a body of water is not listed. Or they don't want to wait for the state or EPA.

Point #2: The best you can hope for: Management decisions are made, and regulations adopted that are based on the best <u>available</u> scientific information.

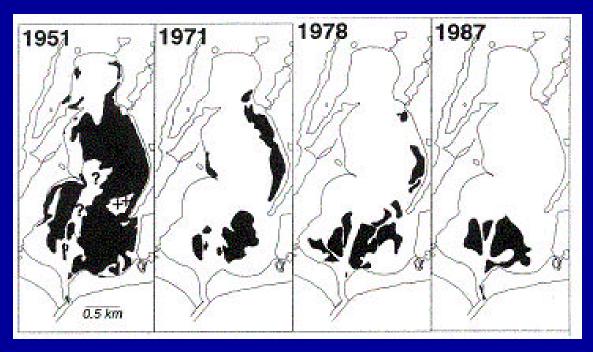
Scientific knowledge continually changes, models improve, standards will change, and ideally regulations will change to reflect new scientific data.

Management decisions and new development will not wait for you to develop the perfect TMDL model.

Principle 15 of the 1992 Rio Declaration on the Environment: "...lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". Example: CCC: No Net Increase in nitrogen

Most inappropriately used statement by scientists about management decisions: "But will it stand up in court?" Environmental laws have changed considerably during past 20 years- a case law model, with most decisions overturned because of procedural errors, or lack of objective or consistently applied criteria, design standards, or performance standards.

Example: Waquoit Bay Eelgrass Loss



Near complete loss by the 1990s

Eelgrass critical loading about 1971, with 1450 homes in the watershed.

Management action was stymied because of endless debate on loading models.

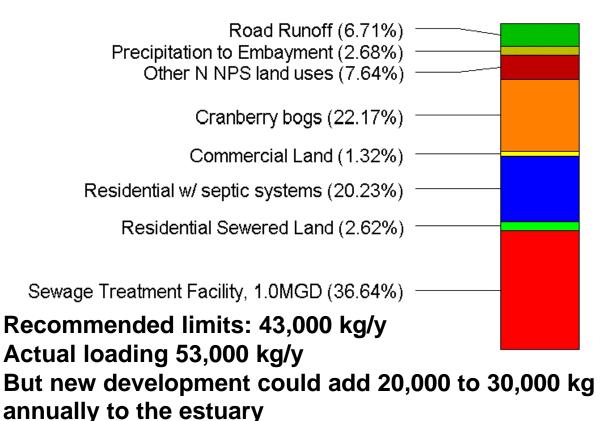
Loading models may differ by factor of 2, but many missed the fact that conclusions and management recommendations were robust if loading models and regulatory calculations are equivalent (with additional margin of safety if desired).

That is, the nitrogen load from the equivalent of 1450 residential units (and associated roads) represented the critical limit for eelgrass habitat in Waquoit Bay.

Example: Wareham STF

discharge	conc	kg/y	kg savings
4	ppm	9947	14920
5	ppm	12434	12434
6	ppm	14920	9947
7	ppm	17407	7460
8	ppm	19894	4973
10	ppm	24867	0
12	ppm	29841	
16	ppm	39788	
18	ppm	44761	

N sources in the Wareham River Estuary



Town accepted 3
ppm TN limit during
warm weather and 5
ppm in winter as the
new limits. Why?
Non-N upgrades
=\$22 million, N
upgrades, an extra \$3
million.

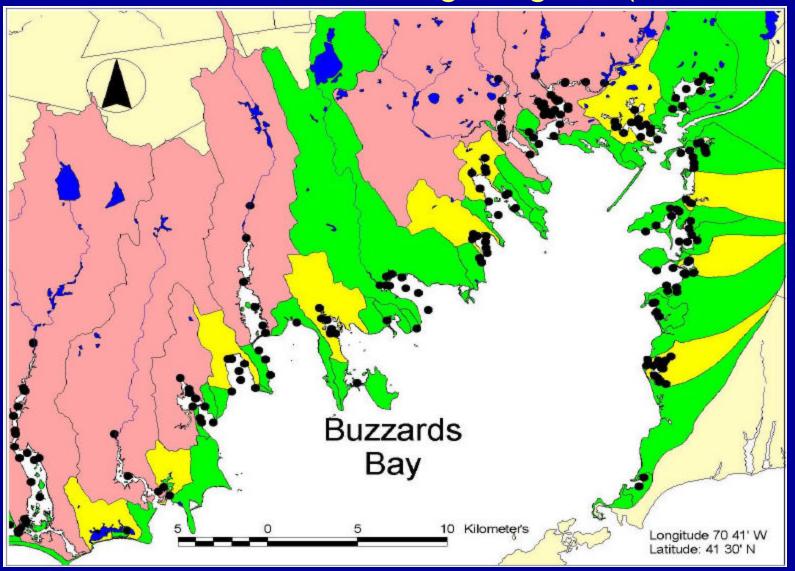
What about new development?

Point #3: TMDL implementation is a management process, not a scientific process.

"We often look to a panel of scientific experts to not just identify the problems, but also the solutions. They may not be the ones to best figure out how to repair the watershed, in fact, they can be downright naive."

Dr. Sari Sommarstrom, President Watershed Management Council

Empirical relationships: the need for data satisfied with a Citizen Monitoring Program (stations below)



4x summer: TN

DON

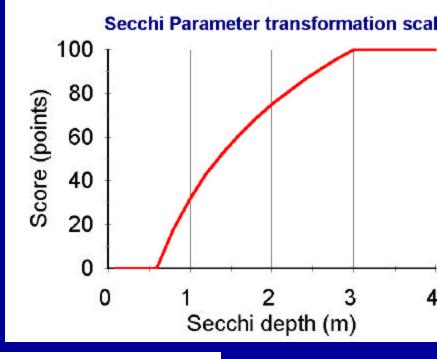
DIN

Chl a

Secchi Secchi

Early AM O2

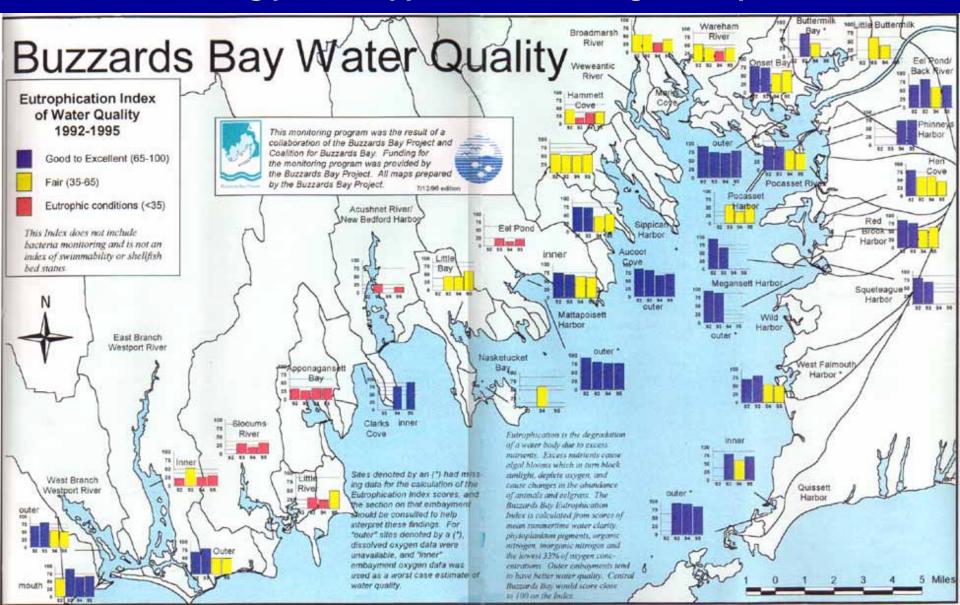
Eutrophication Index



Parameter		0 point value	100 poi	nt value	
Oxygen saturation (mean of lowest 33%)		40	%	90	%
Transparency	0.6	m	3.0	m	
Chlorophyll		10.0	:g/l	3.0	:g/l
DIN		10.0	:M	1.0	:M
Organic N		0.60	ppm	0.28	ppm

Score=(ln(value)-ln(0 pt. value))/(ln (100 pt. value)-ln(0 pt. value))

Citizens Monitoring Program 1996 report was very effective in raising awareness, building public support, and initiating municipal actions.



Eelgrass Grows underwater, both in quite water and the open coast, down to 20 feet or more.





Shallow bed (to 0.5 ft MLW in protected areas)

Deep Bed
Often to 22 feet MLW,
rarely to 50 ft+ in clearest waters





Eutrophic Conditions

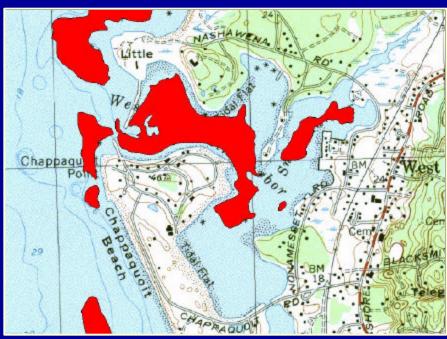
1980s

Eelgrass History:
Wasting disease
loss in the 1930s,
recovery by the
1960s and 1970s
in most areas.
New declines in
1970 to to 1990s i
in areas of heavy
development

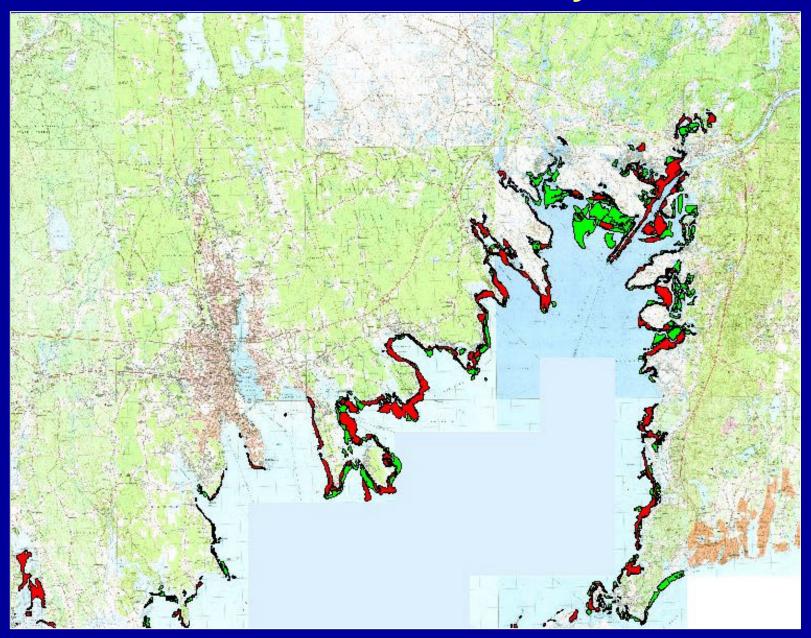
1990s

Example: West Falmouth Harbor

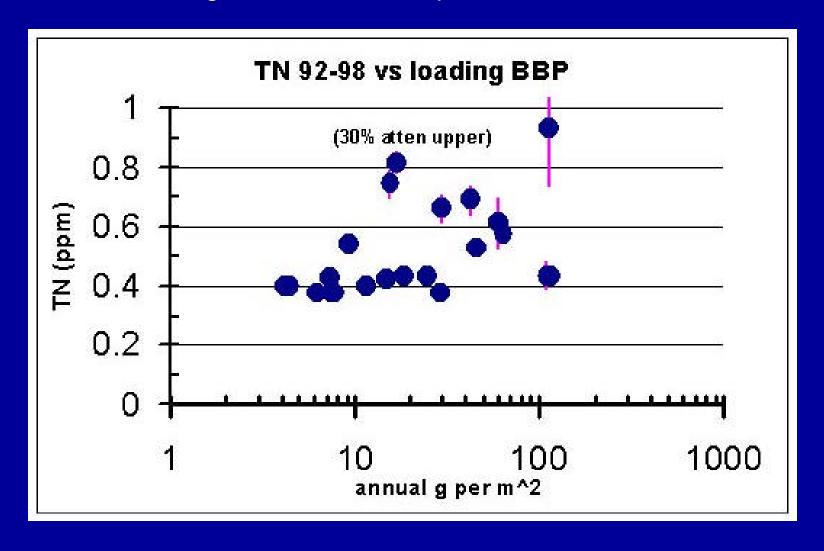




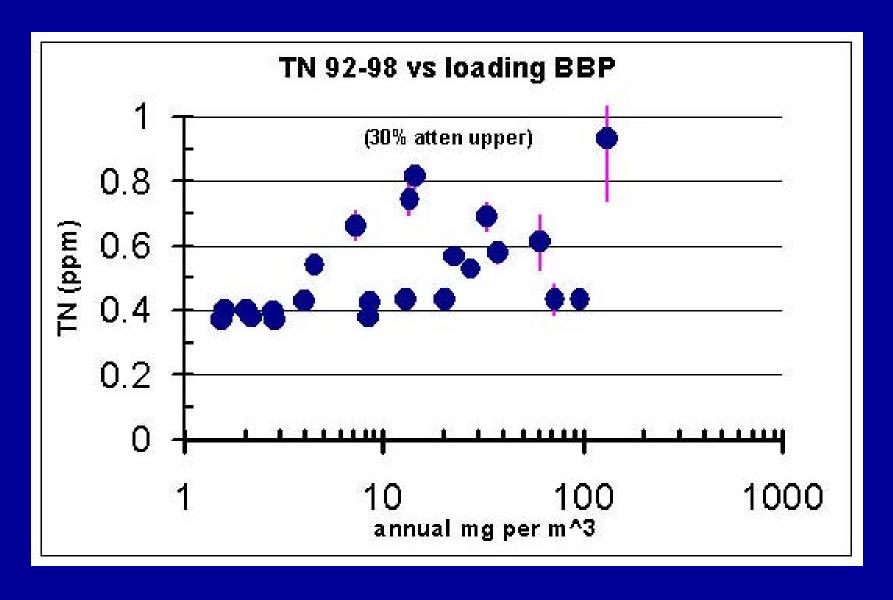
1980s vs 1996 Surveys

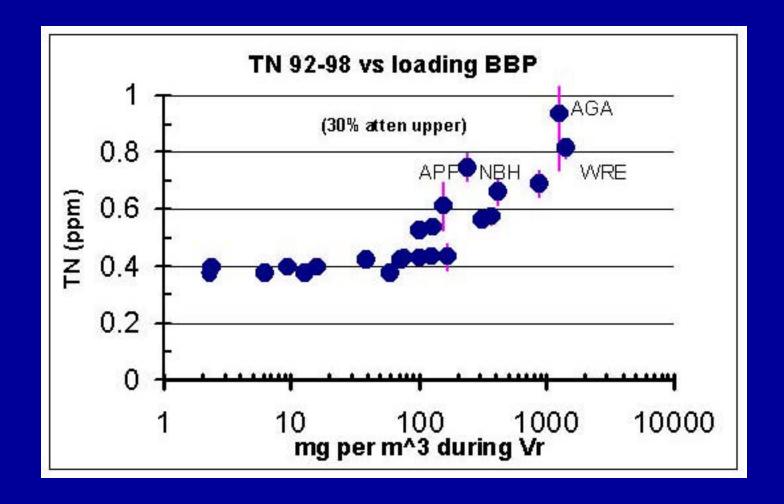


Loading Characterization: per unit area

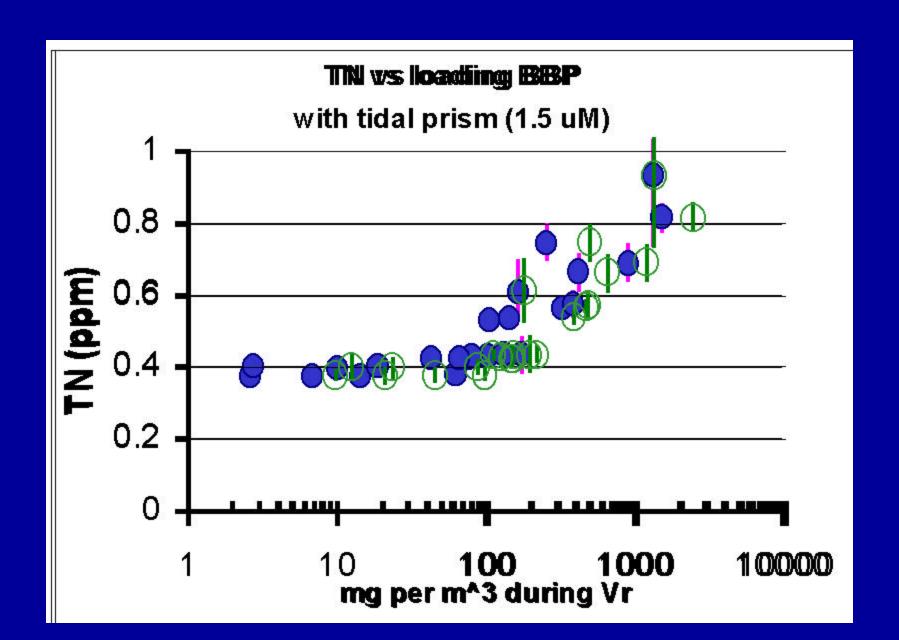


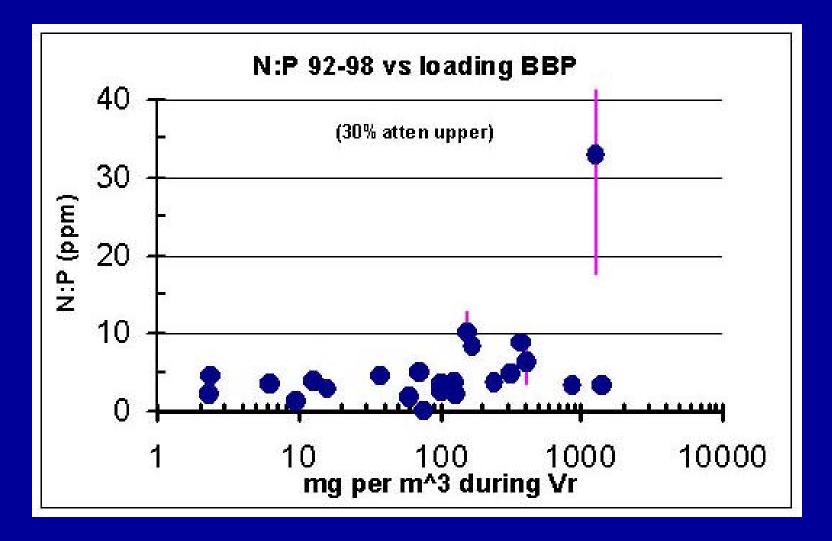
Loading Characterization: per unit volume



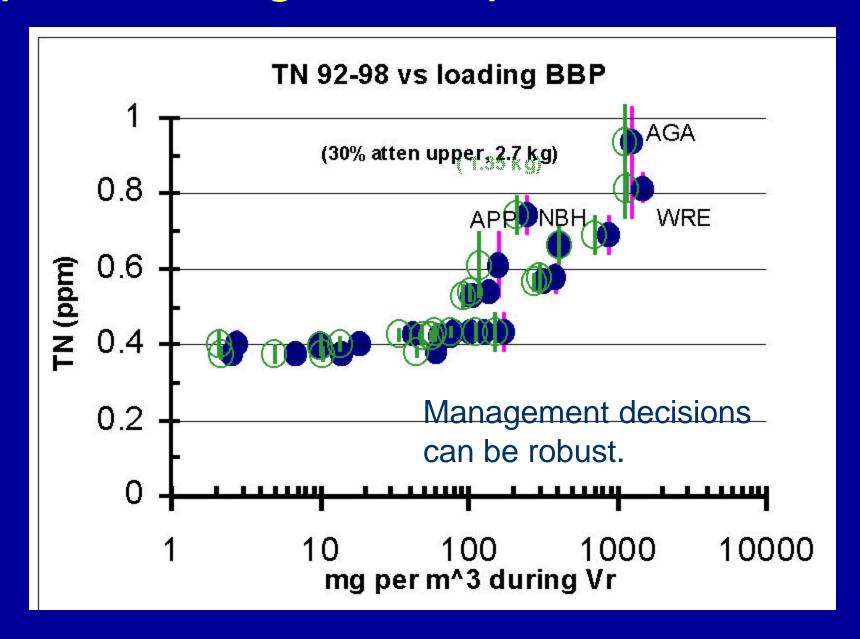


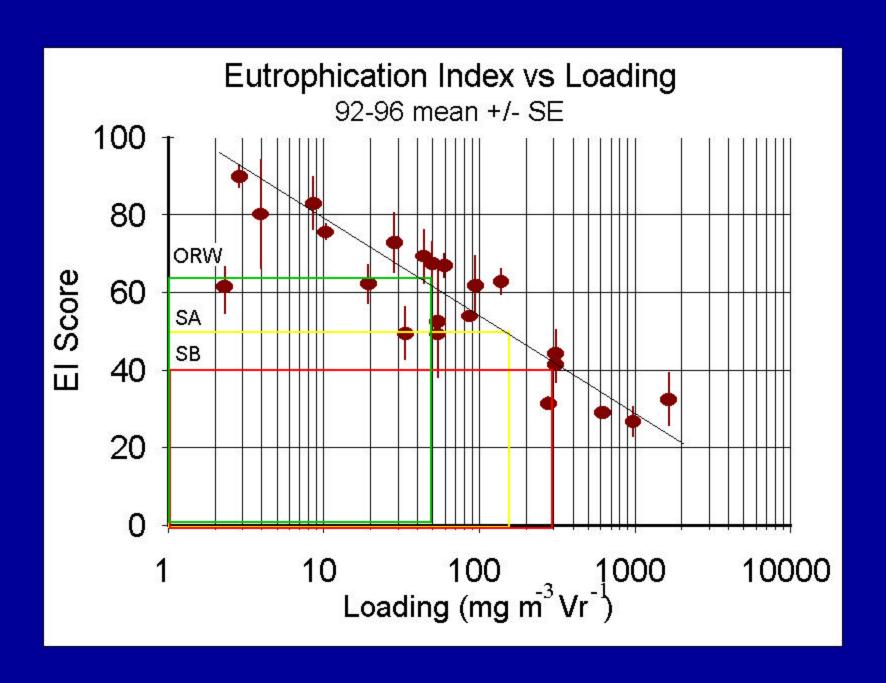
Tidal Prism DIN





Septic loading assumptions

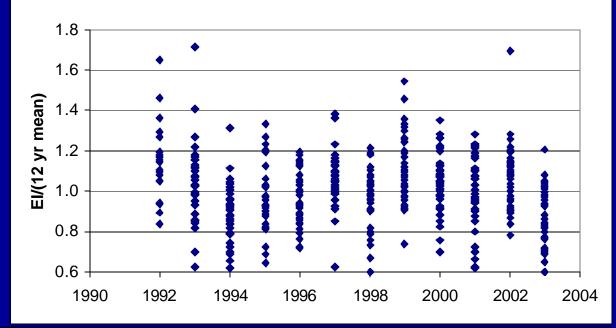


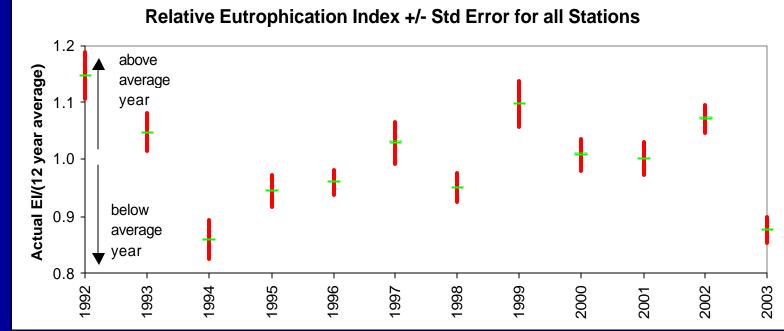


Eutrophication Index variability

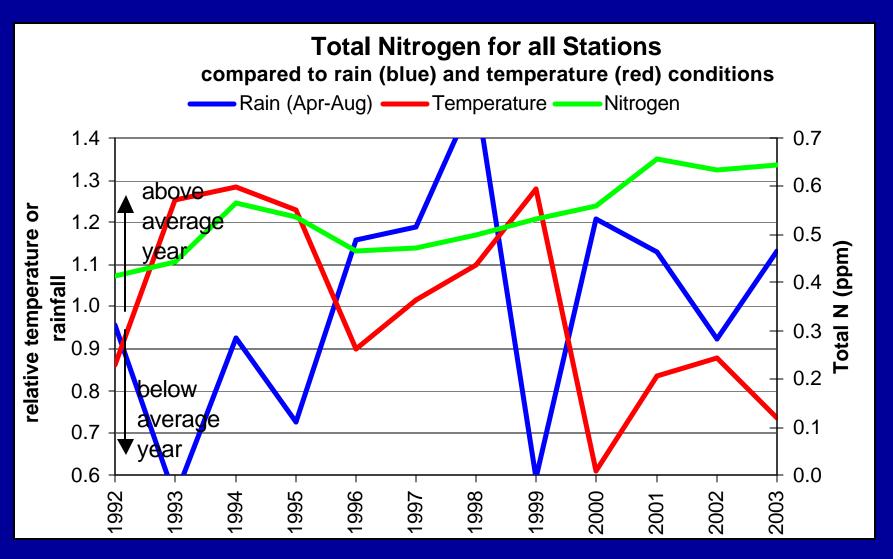
Seasonal rainfall, Temperature, conditions around sampling time.

Eutrophication Index relative to 12 Year mean

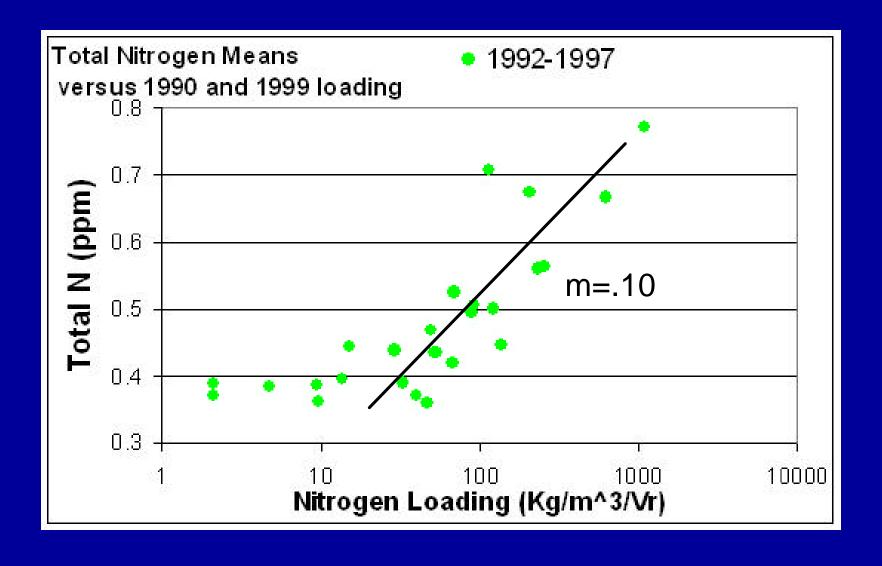




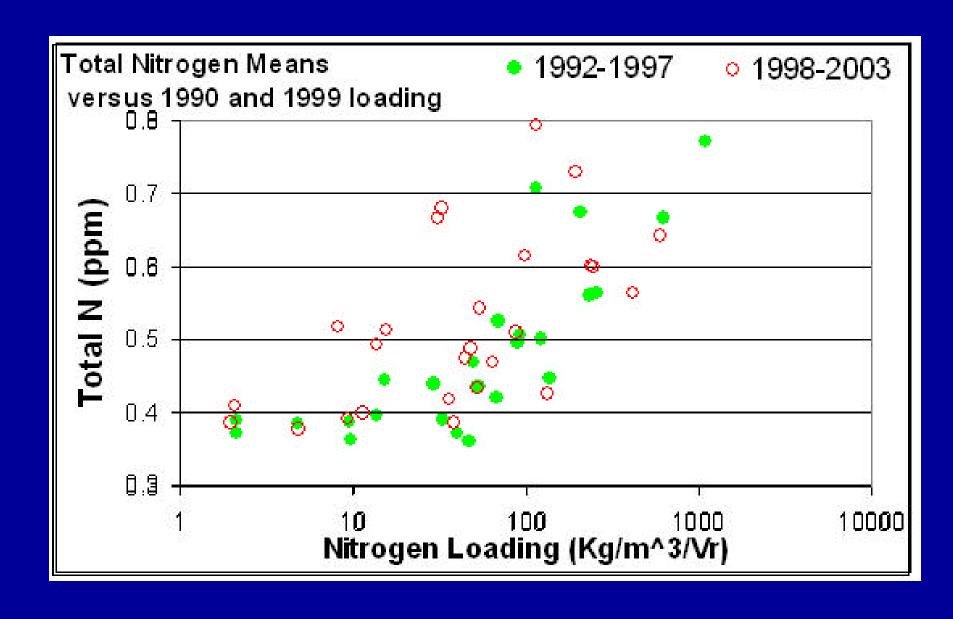
Total Nitrogen variability



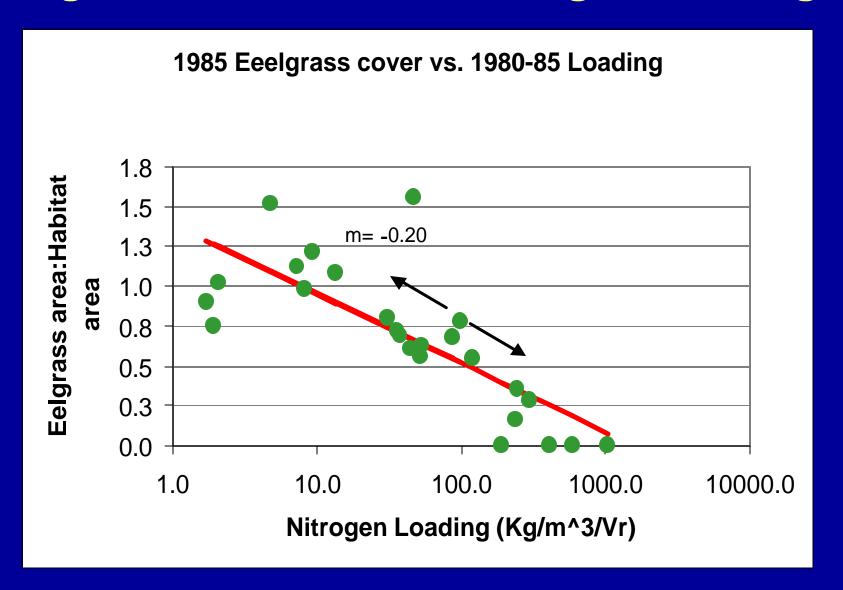
TN during 1992-1997 versus 1998-2003



TN during 1992-1997 versus 1998-2003

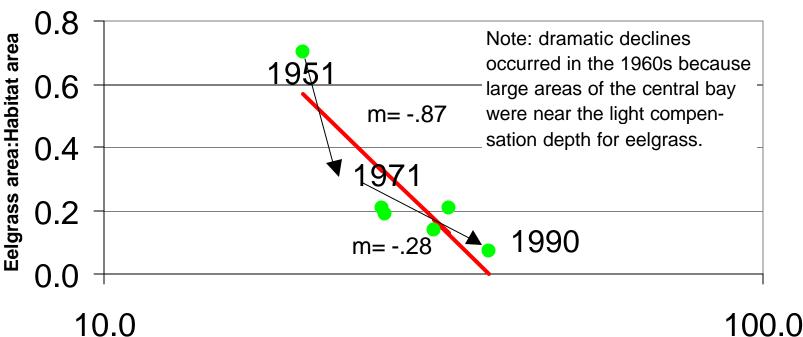


Eelgrass Cover versus Nitrogen Loading



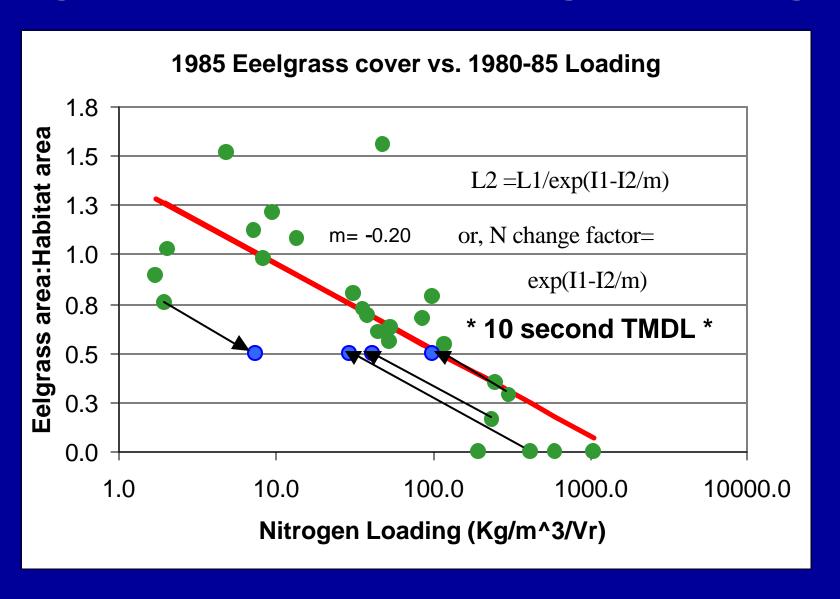
Waquoit Eelgrass versus Nitrogen Loading



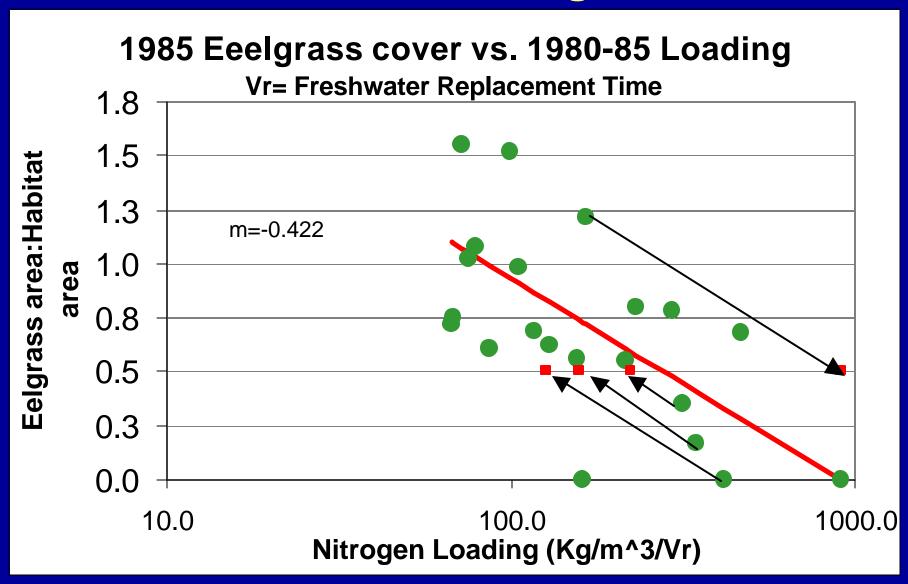


Nitrogen Loading (Kg/m³/Vr)

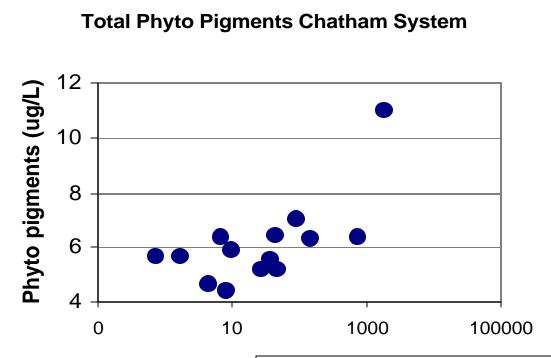
Eelgrass Cover versus Nitrogen Loading



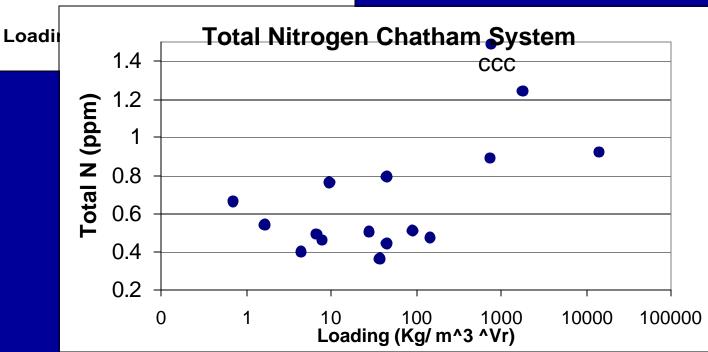
Alternative Flushing Scale



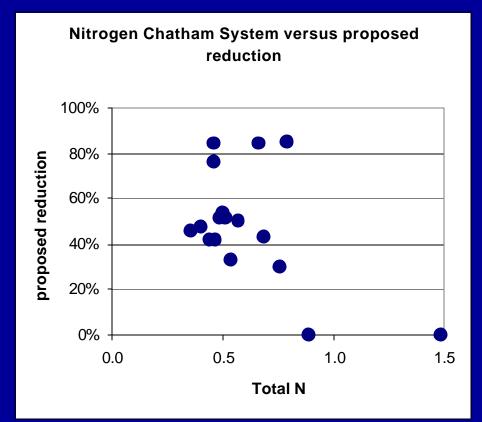
Simple alternative to residence time: Freshwater replacement time

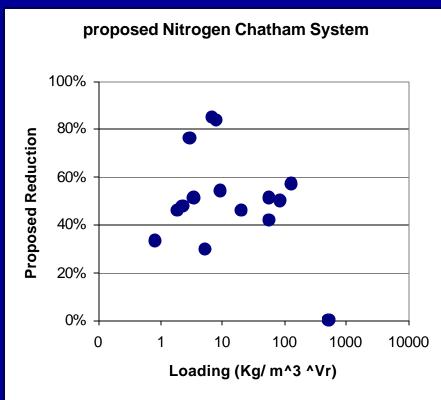


Chatham Comparison



Chatham Recommended reductions





Does not match Buzzards Bay Project model (nor should it)

Large areas will need to be sewered to meet water quality goals

Conclusion

During the past two decades, ecosystem models have advanced considerably, but local regulatory tools for controlling NPS nitrogen changed little. In some cases, the science is well ahead of the management and political capacity to address the problem.

Do not confuse scientific and management issues when developing TMDLs.

Good modeling takes time, money, and measurements of tidal flow. However, an assessment of existing conditions (summertime for nitrogen loading) is generally the first step in any TMDL process. This of course a role for EMAP.

TMDLS based on existing conditions and known empirical relationships between loading and ecosystem response among similar embayments can be an important start, and providing a reasonable first approximation of the <u>magnitude</u> of nitrogen reductions needed for impacted sites.