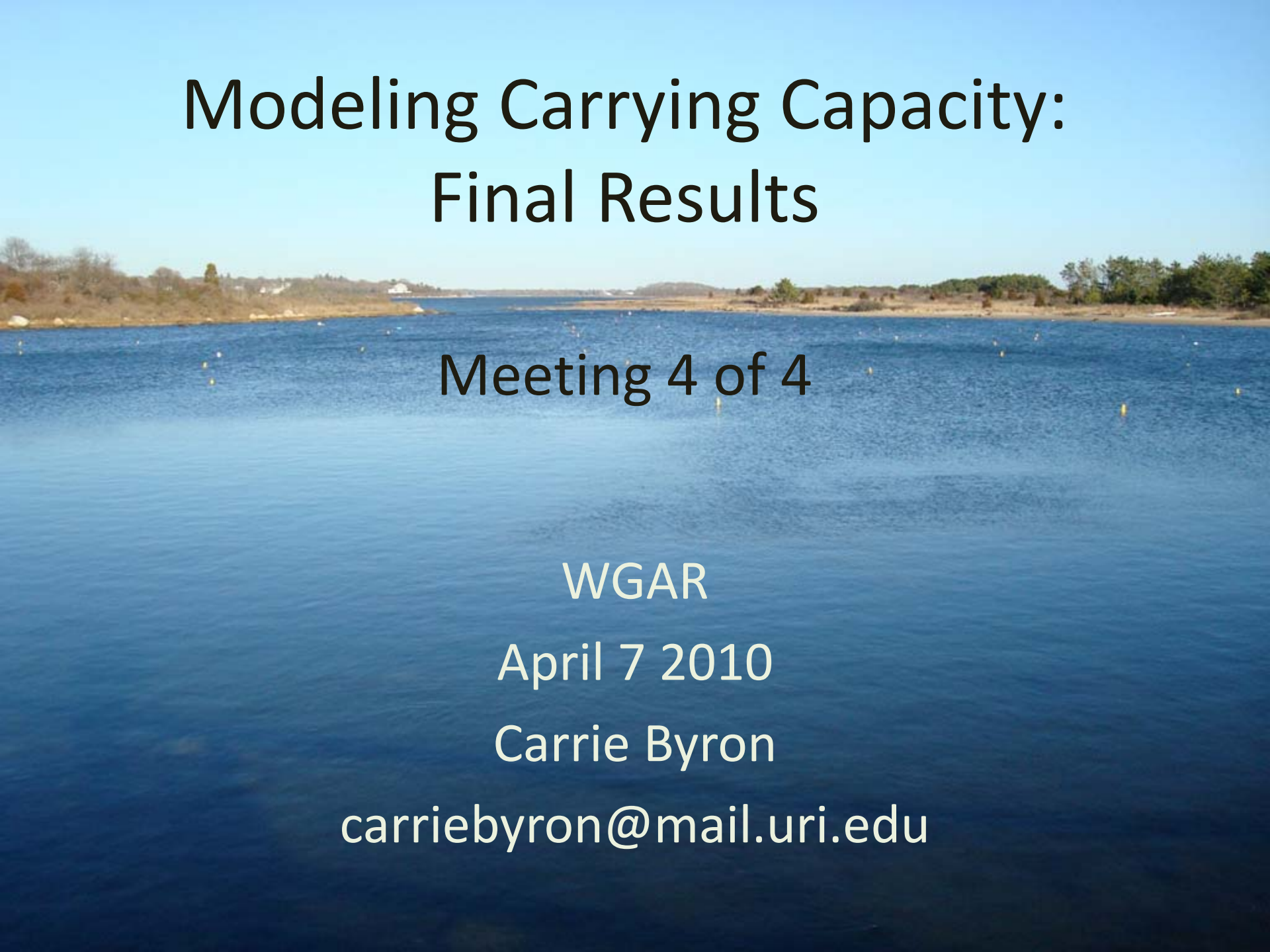
Modeling Carrying Capacity: Final Results



Meeting 4 of 4

WGAR

April 7 2010

Carrie Byron

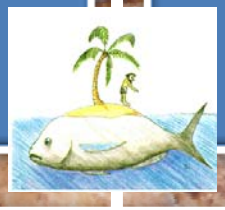
carriebyron@mail.uri.edu


Providence Journal March 2, 2008
5%

Ecological Modelers

Working Group

Policy Regulators



Ecological Carrying Capacity

Social Carrying Capacity

Long-term Plan

Carrying Capacity

- Physical: total area of marine farms that can be accommodated in the available physical space

Inglis *et al.* 2000, photo credit SPEAR

Carrying Capacity

- Production: the stocking density of bivalves at which harvests are maximized

Inglis *et al.* 2000

Carrying Capacity

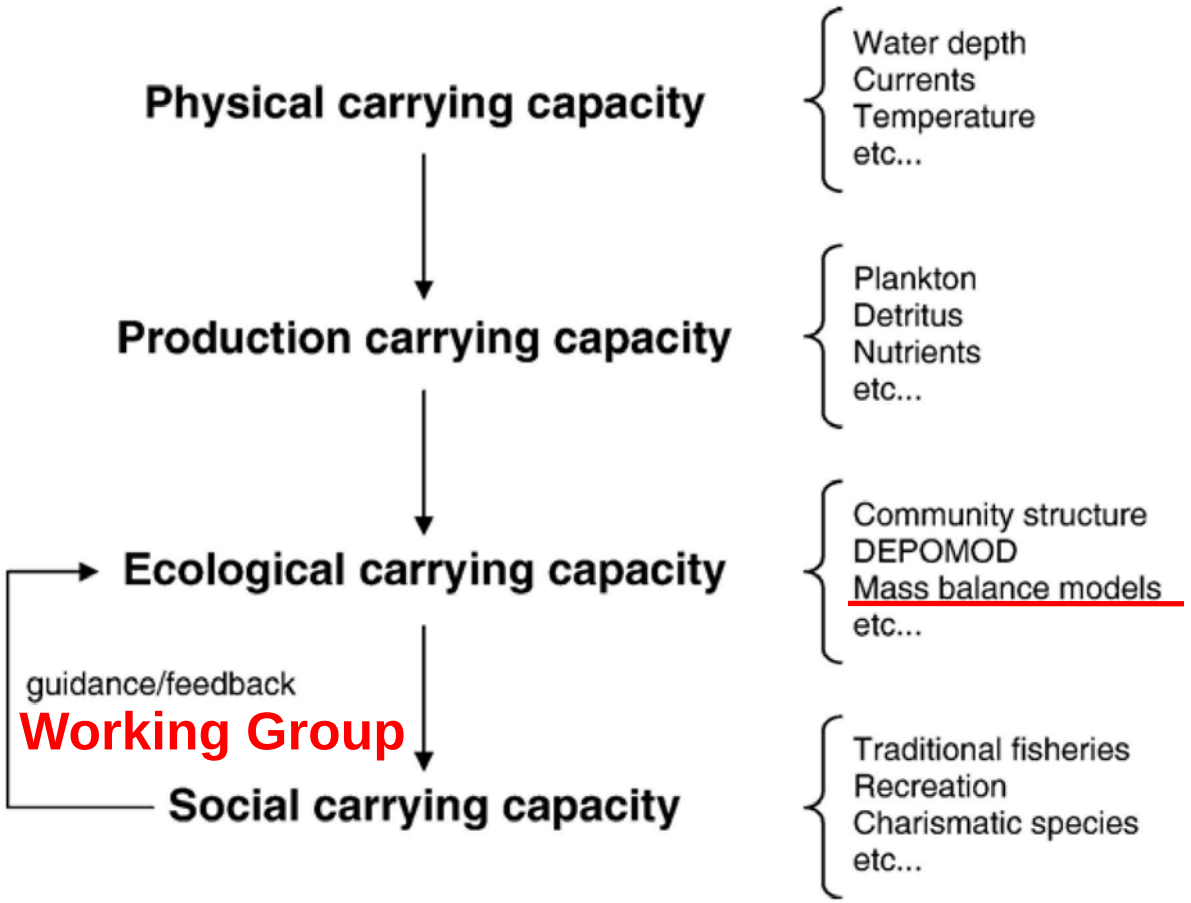
- Ecological: the stocking or farm density which causes unacceptable ecological impacts

Inglis *et al.* 2000

Carrying Capacity

- Social: the level of farm development that causes unacceptable social impacts

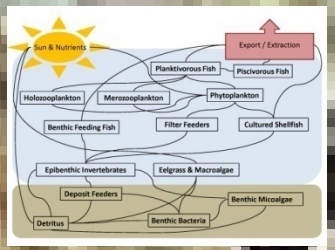
Inglis *et al.* 2000



McKindsey *et al.* 2006

Steps / Meetings

1. conceptual food-web diagram



2. sources of data used for parameter inputs to the model

3. balanced and validated model

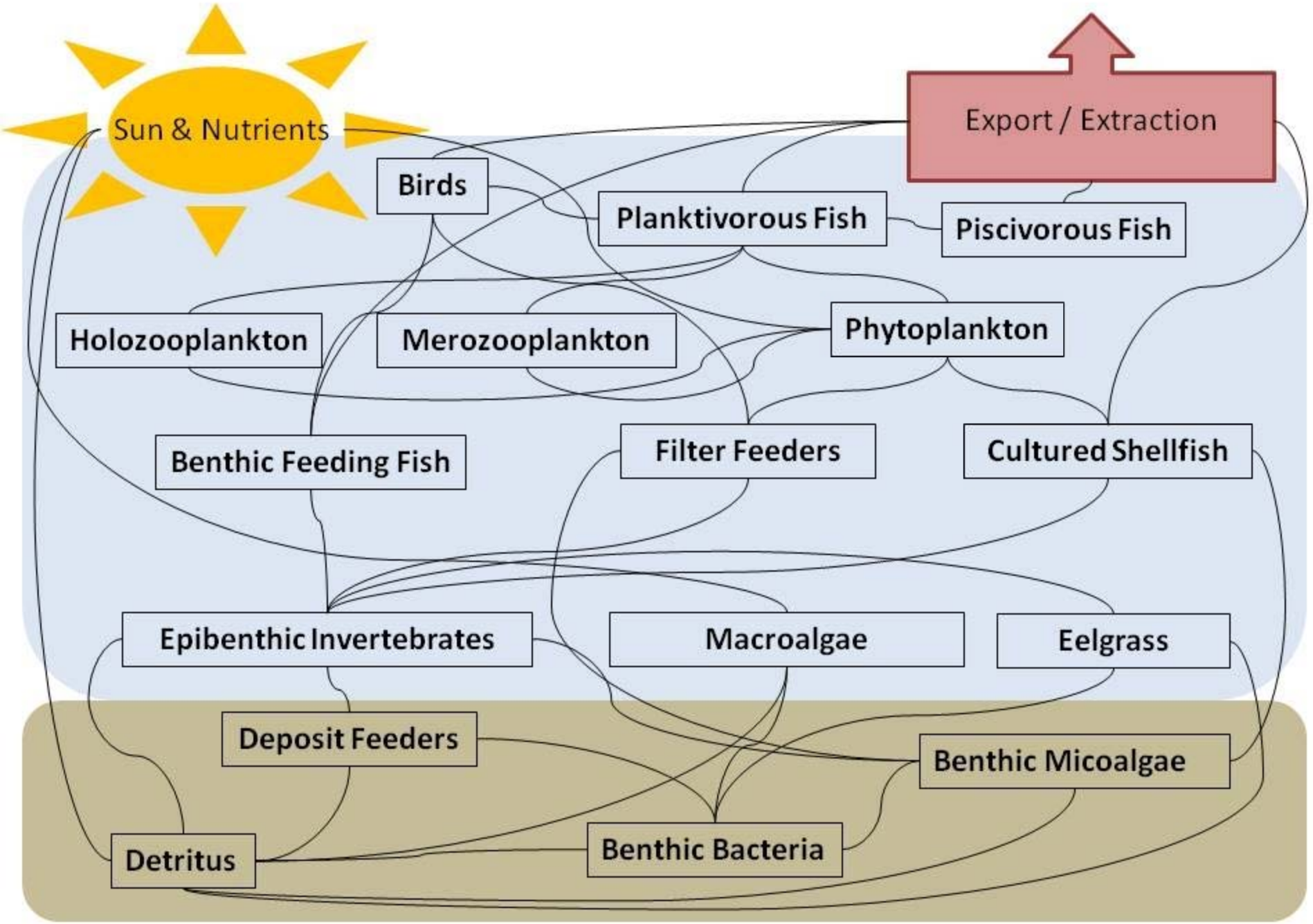
4. ecological carrying capacity

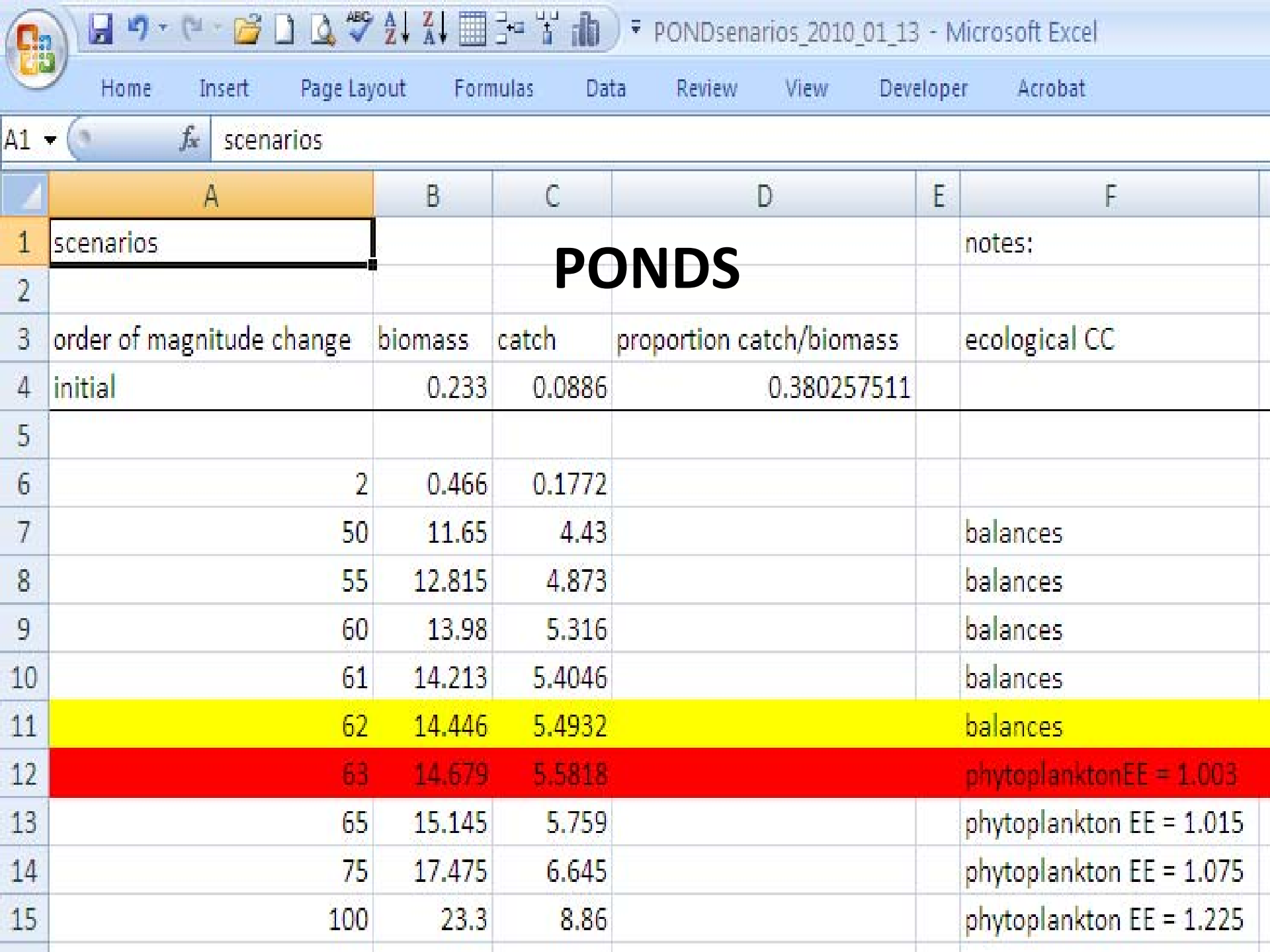
Extreme Events

- Extreme events are ecologically important
  - 2 static models: “normal” & extreme conditions
  - Simulation model over decade
- Seasonal variation
  - 4 static models: Fall, Winter, Spring, Summer
  - Simulation model over 1 year
- Limitations
  - Data!!
  - Need long term data sets that survey all biota
- Goal
  - Average using recent data (>2005)
  - Does include extreme events if present during this time frame

Sources of Confidence

- Data Sources
  - Good v Bad science
    - Questioned methods, talked to scientists directly
- Input Parameters
  - Diagnostics
    - Do parameters make sense ecologically compared to other parameters – Do puzzle pieces fit together?
- Mass-Balance Model
  - Did the model balance easily?
- Model Outputs
  - Do outputs match expectations of system?


Sun & Nutrients
Export / Extraction
Birds
Planktivorous Fish
Piscivorous Fish
Holozooplankton
Merozooplankton
Phytoplankton
Benthic Feeding Fish
Filter Feeders
Cultured Shellfish
Epibenthic Invertebrates
Macroalgae
Eelgrass
Deposit Feeders
Benthic Micoalgae
Detritus
Benthic Bacteria



	A	B	C	D	E	F
1	scenarios					notes:
2						
3	order of magnitude change	biomass	catch	proportion catch/biomass		ecological CC
4	initial	0.233	0.0886	0.380257511		
5						
6	2	0.466	0.1772			
7	50	11.65	4.43			balances
8	55	12.815	4.873			balances
9	60	13.98	5.316			balances
10	61	14.213	5.4046			balances
11	62	14.446	5.4932			balances
12	63	14.679	5.5818			phytoplanktonEE = 1.003
13	65	15.145	5.759			phytoplankton EE = 1.015
14	75	17.475	6.645			phytoplankton EE = 1.075
15	100	23.3	8.86			phytoplankton EE = 1.225

Narragansett Bay

Monaco & Ulanowicz 1997

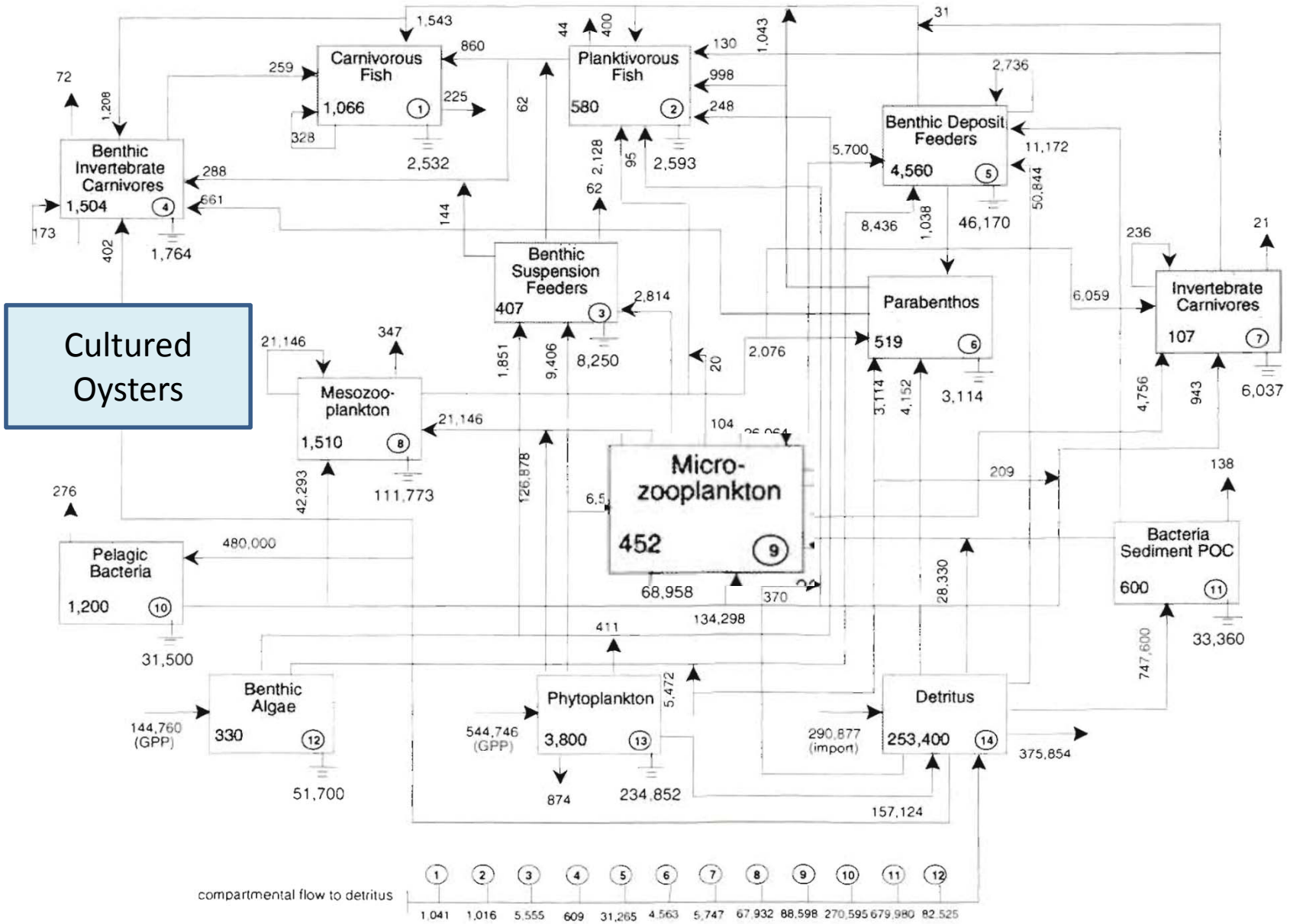
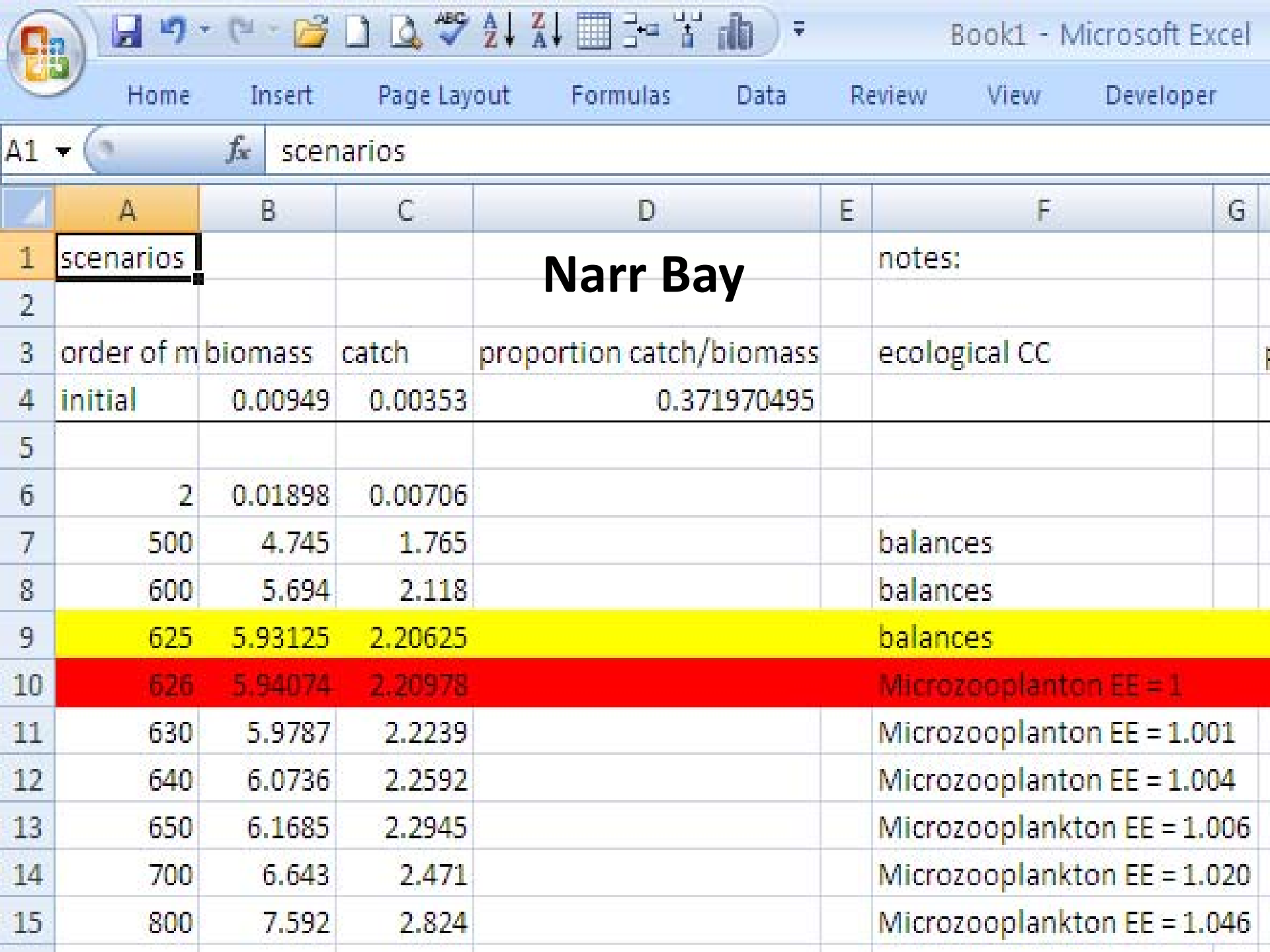


Fig. 2. Average annual energy flow (mg C m^{-2} yr^{-1}) and compartmental biomass (mg C m^{-2}) in Narragansett Bay


Book1 - Microsoft Excel
Home
Insert
Page Layout
Formulas
Data
Review
View
Developer
A1
scenarios
Narr Bay
notes:
order of m
biomass
catch
proportion catch/biomass
ecological CC
initial
0.00949
0.00353
0.371970495
2
0.01898
0.00706
500
4.745
1.765
balances
600
5.694
2.118
balances
625
5.93125
2.20625
balances
626
5.94074
2.20978
Microzooplanton EE = 1
630
5.9787
2.2239
Microzooplanton EE = 1.001
640
6.0736
2.2592
Microzooplanton EE = 1.004
650
6.1685
2.2945
Microzooplankton EE = 1.006
700
6.643
2.471
Microzooplankton EE = 1.020
800
7.592
2.824
Microzooplankton EE = 1.046

Potential for growth

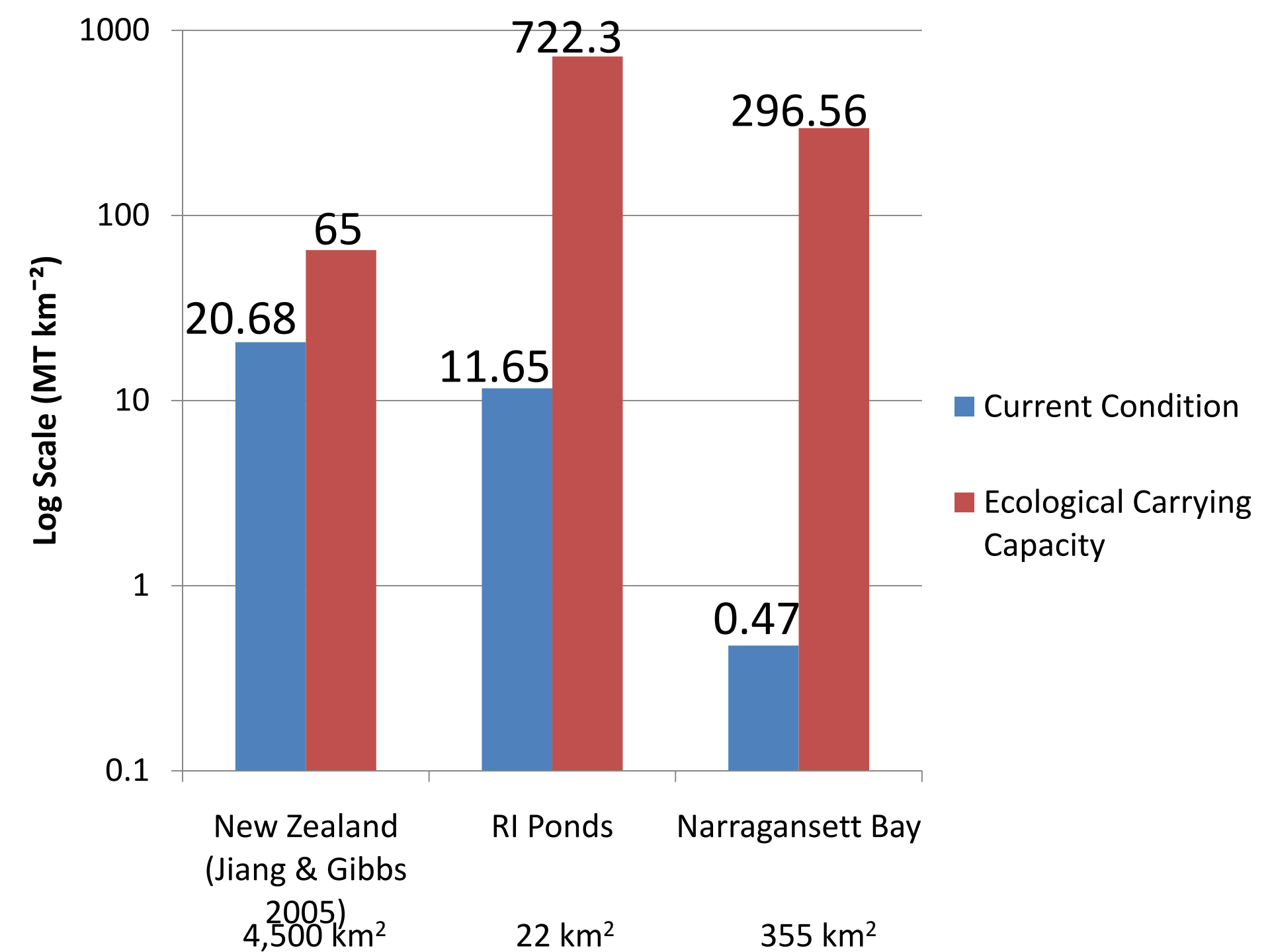
- Coastal Ponds
- Narr Bay

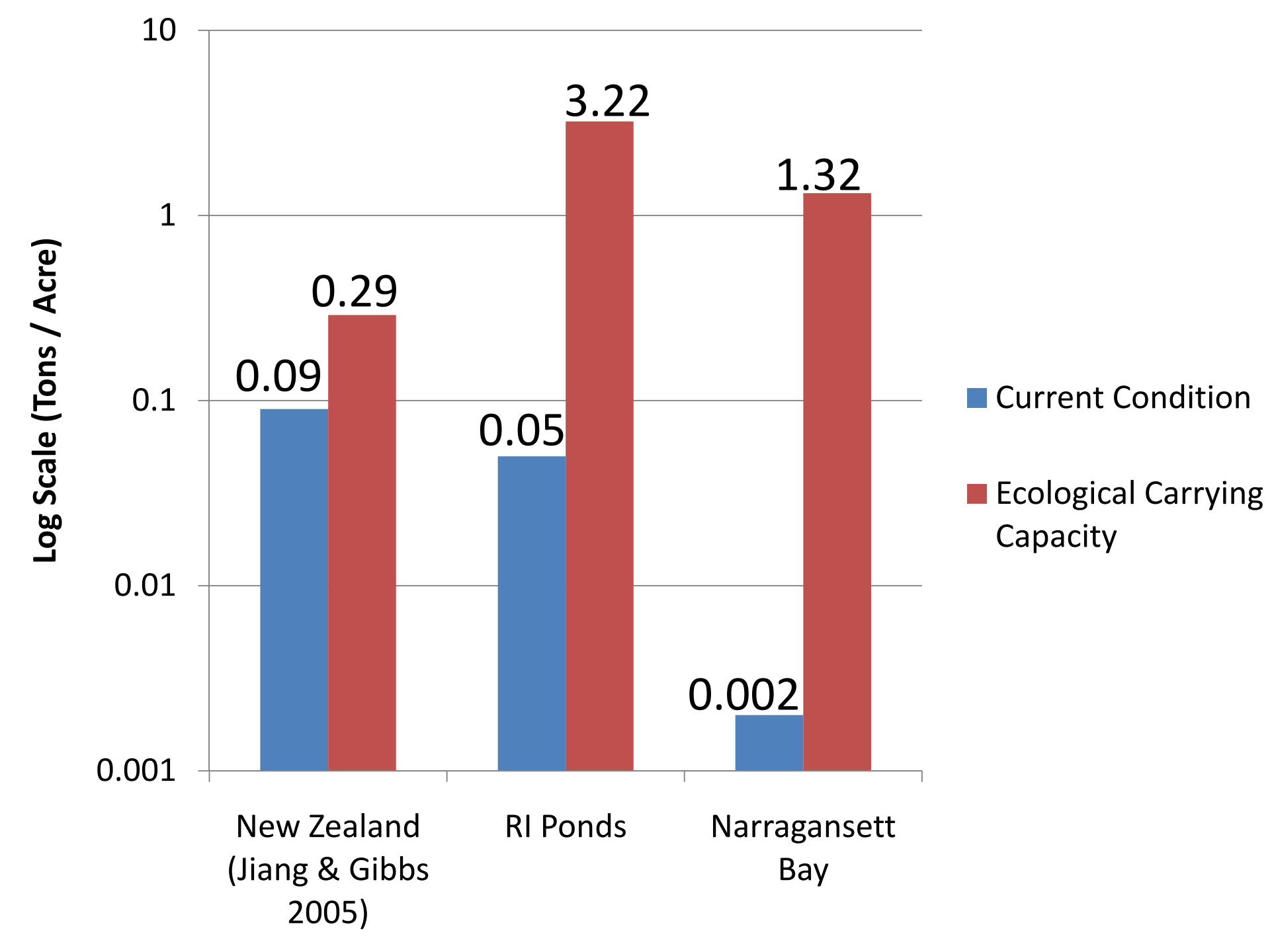
- 62x initial biomass
- 625x initial biomass

- New Zealand

- 3.14x initial biomass

Narr Bay has highest potential for aquaculture growth from current levels.


1000
100
10
1
0.1
Log Scale (MT km⁻²)
20.68
65
11.65
722.3
0.47
296.56
Current Condition
Ecological Carrying Capacity
New Zealand (Jiang & Gibbs 2005)
RI Ponds
Narragansett Bay
4,500 km²
22 km²
355 km²


10
1
0.1
0.01
0.001
Log Scale (Tons / Acre)
0.09
0.29
0.05
3.22
0.002
1.32
New Zealand (Jiang & Gibbs 2005)
RI Ponds
Narragansett Bay
Current Condition
Ecological Carrying Capacity

Ecological Carrying Capacity Summary

Coastal Ponds

- **3.22 tons / acre**
- Point Judith
  1,574 acres * 3.22 = **5,068 tons**
- Potter
  329 acres * 3.22 = **1,059 tons**
- Green Hill
  431 acres * 3.22 = **1,388 tons**
- Ninigret
  1,711 acres * 3.22 = **5,509 tons**
- Quonnie
  723 acres * 3.22 = **2,328 tons**
- Winnipaug
  446 acres * 3.22 = **1,436 tons**

Narragansett Bay

- **1.32 tons / acre**

87,723 * 1.32 = **115,794 total tons**

How does this compare to the 5% rule?

- Percent rule is misleading because it depends on level of production.

Predicted Ecological Carrying Capacity - The 5% Solution (Rheault)

(that biomass of cultured shellfish that could be added w/o significant impact)

from Jiang and Gibbs (2005) Aquaculture v244:171-185

Using a linear food web model based on a 4500km2 bay in

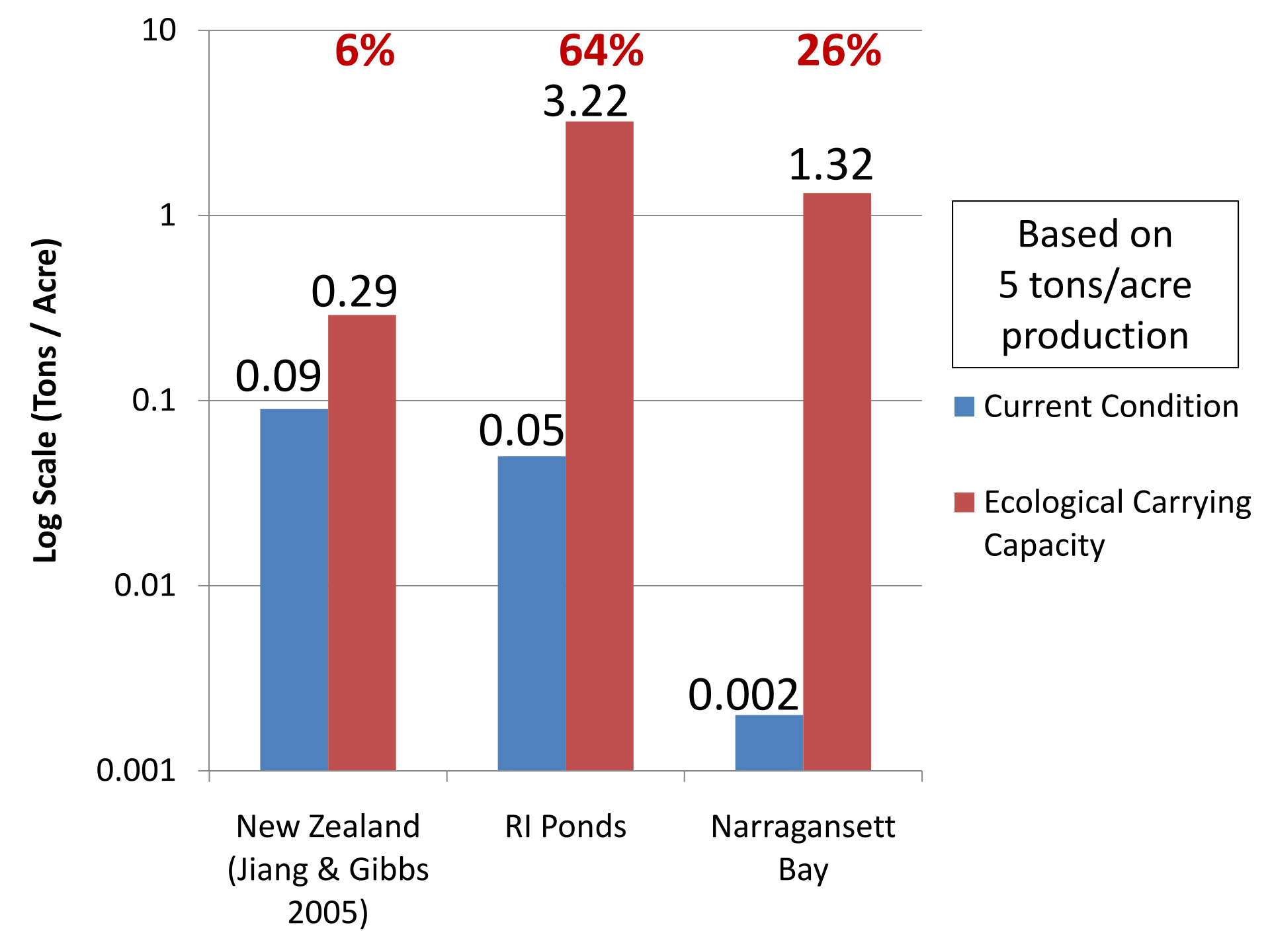
Authors predict that 65 tons per year ~~could be harvested annually~~ –"level of culture that could be introduced" from each km2

without "significantly changing the major energy fluxes or structure of the food web"

Area of Point Judith Pond = 1574 acres = 6.37 km2

65 tons/km2 x 6.37 km2 = 414 tons per year is theoretical max biomass for the pond at an average production biomass of **5 tons per acre** = 82.8 acres needed to produce 414 tons

82.8 / 1574 = 5.3%


10
1
0.1
0.01
0.001
Log Scale (Tons / Acre)
6%
64%
26%
0.09
0.29
0.05
3.22
0.002
1.32
New Zealand (Jiang & Gibbs 2005)
RI Ponds
Narragansett Bay
Based on 5 tons/acre production
Current Condition
Ecological Carrying Capacity

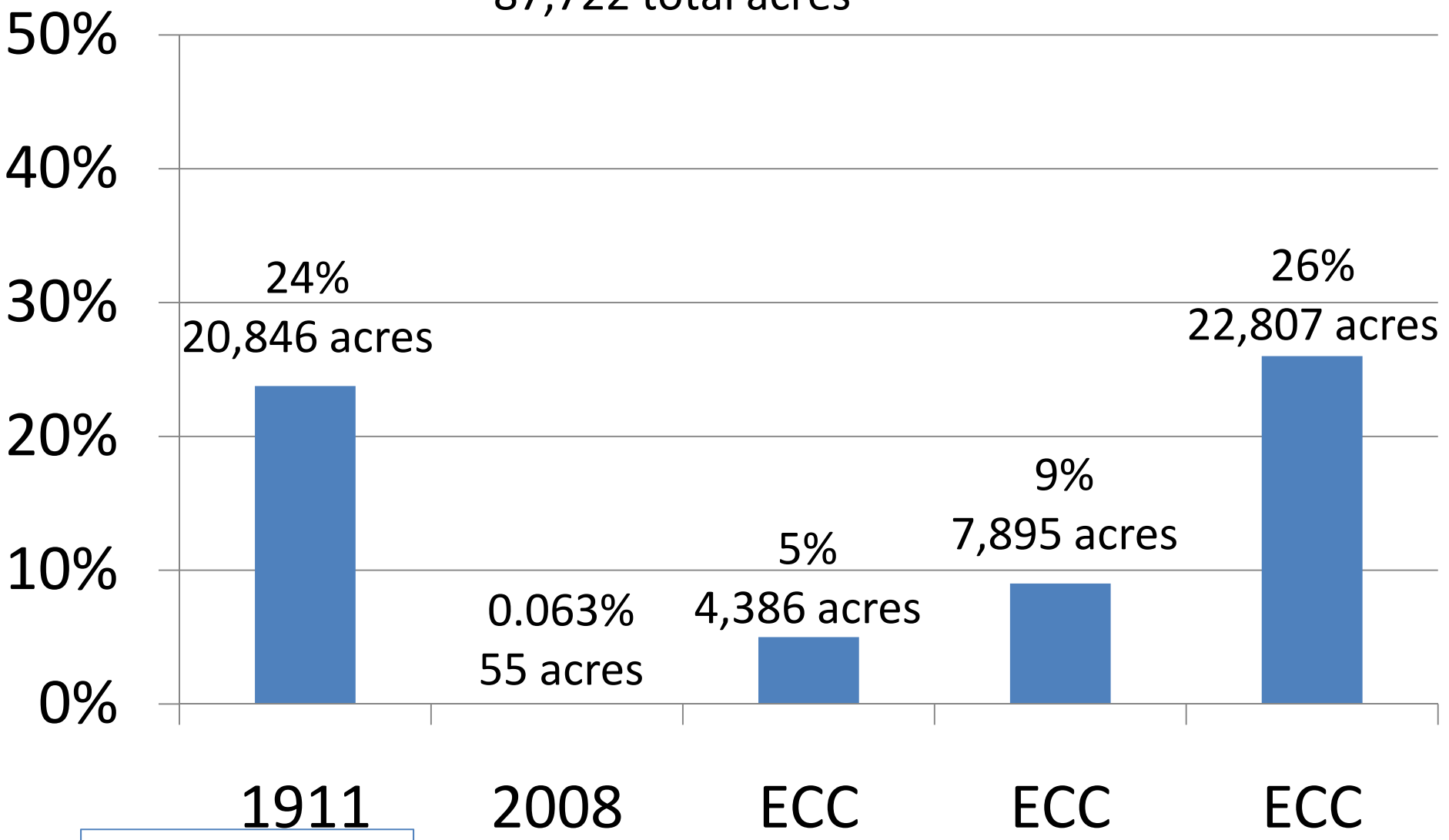
Production	% ponds covered w/farms	% NarrBay covered w/farms
Skid's initial 5 tons/acre	64%	26%
Ecopath Production Ponds= 6.96tons/acre NB= 15.53 tons/acre	46%	9%
Virginia 2.85 tons/acre	100%	46%
Maryland 34 tons/acre	9%	4%
Washington 38.12 tons/acre	8%	3%

Comparison w/ Historic Levels of Shellfish Harvest in Narr Bay

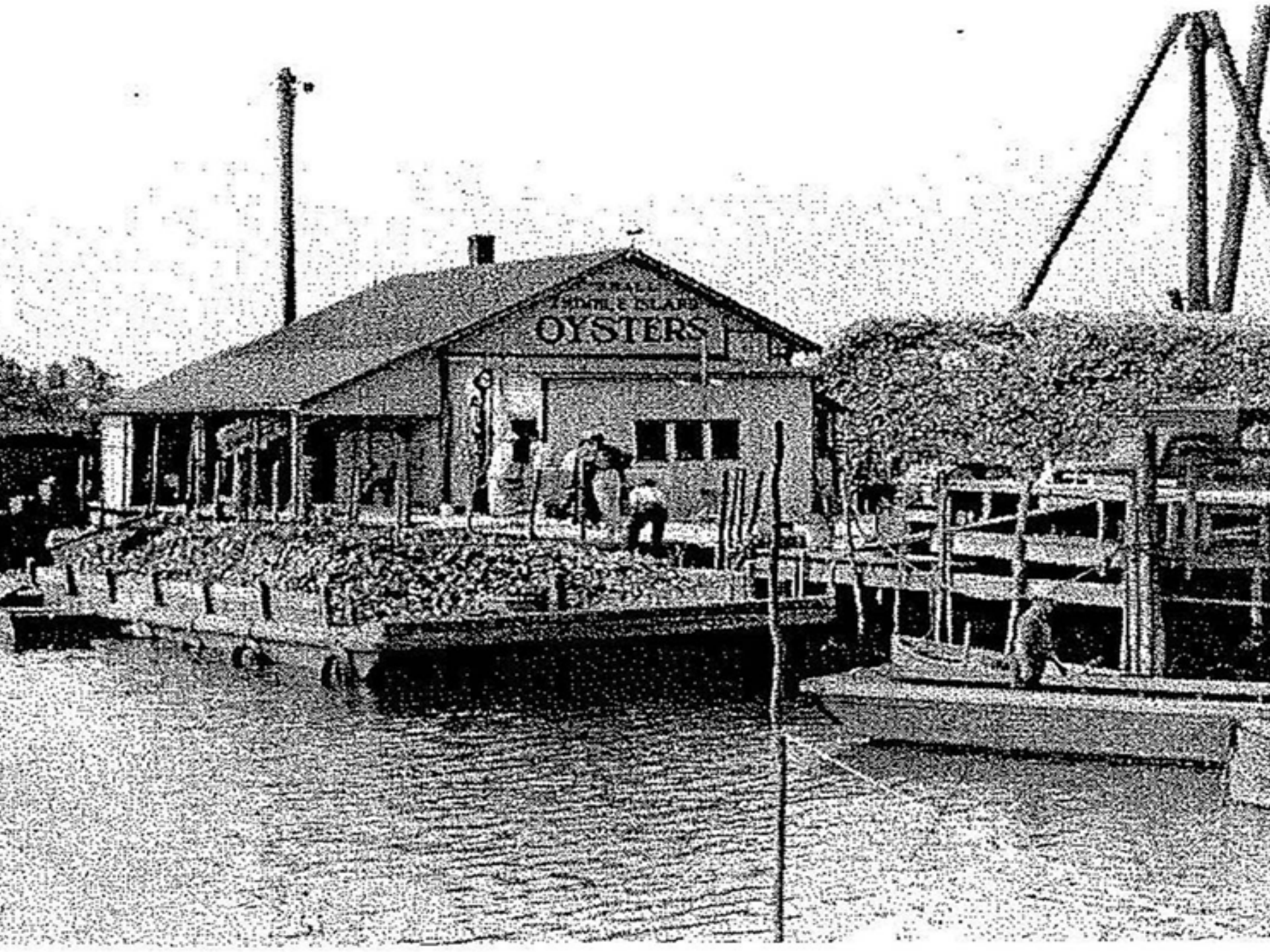
RIDEM

% of Narragansett Bay Leased

87,722 total acres



RI Commissioners of Shellfisheries, Pietros & Rice 2003	Beutel & Alves	5 tons/acre & NZ model	PCC from NarrBay model	5 tons/acre & NarrBay model


OYSTERS

Conclusions

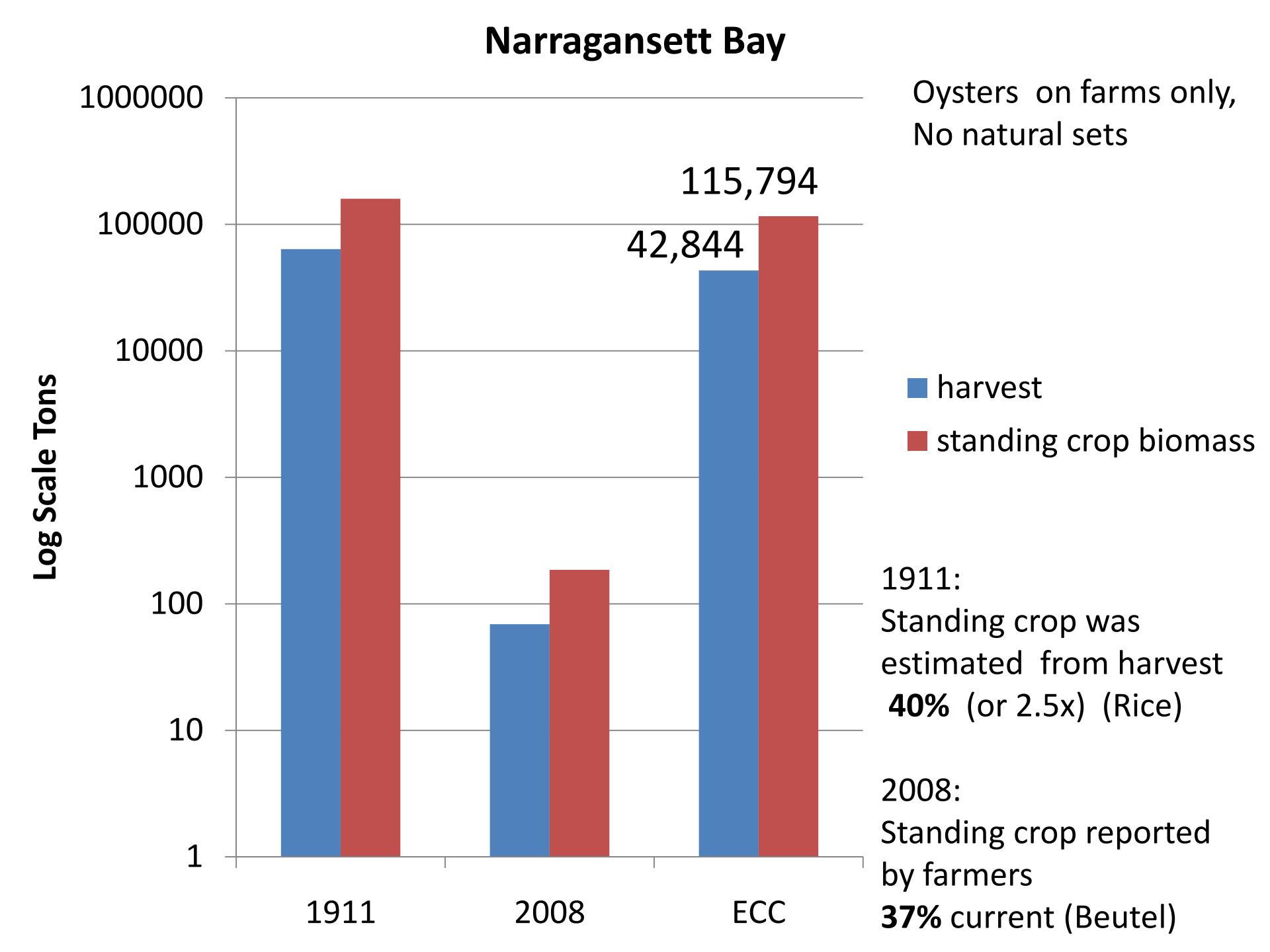
- %rule depends on level of production. What is realistic for each water body?

- Higher ECC in ponds than Bay (but lower PCC in ponds than Bay). Why?
  - Zooplankton have much bigger impact on stabilizing the structure of the Bay due to grazing on phytoplankton.

Standing Stock v. Harvest

- The numbers presented today are standing stock = the amount of oyster biomass can be in the water.

- Harvest is ~40% of standing stock.
  - (37% Narr Bay)
  - (38% coastal ponds)


Narragansett Bay
1000000
100000
10000
1000
100
10
1
Log Scale Tons
115,794
42,844
1911
2008
ECC
Oysters on farms only,
No natural sets
harvest
standing crop biomass
1911:
Standing crop was
estimated from harvest
40% (or 2.5x) (Rice)
2008:
Standing crop reported
by farmers
37% current (Beutel)

Reduction in Anthropogenic Nitrogen

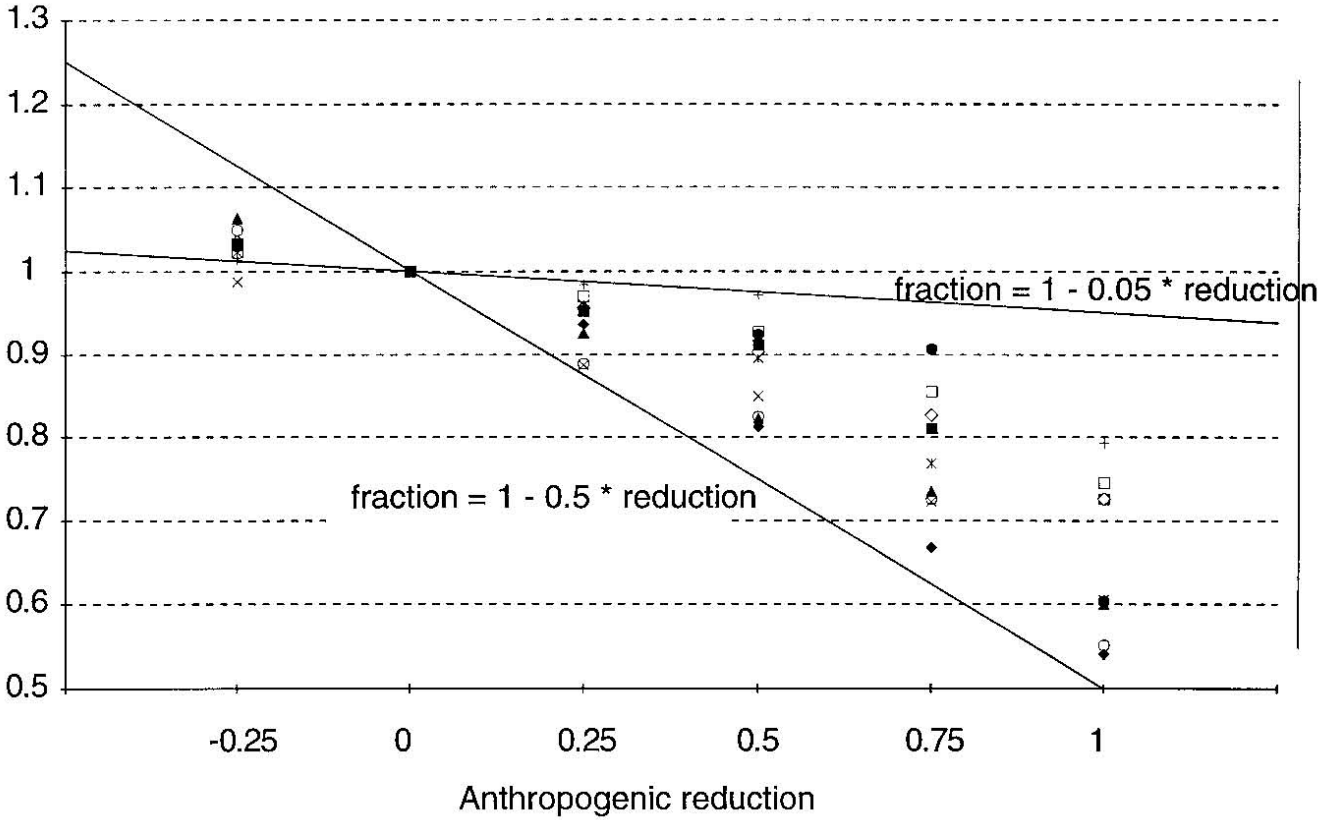


Figure 6. The effect of nutrient reduction scenarios on the carrying capacity of the Oosterschelde ecosystem for benthic suspension feeders. The carrying capacity is expressed as the ratio between the adapted benthic suspension feeder biomass for the different nutrient scenarios and the adapted biomass for the 0% nutrient scenario. The anthropogenic nutrient reduction scenarios are −25% (= extra nitrogen)), 0%, 25%, 50%, 75% and 100% (here shown as fractions). This model experiment was repeated with ten different (but equally good) calibrations of the model. Different symbols denote the results from these ten different calibration sets.

Taken from Van der Tol & Scholten 1998

Recommendations

- These results only consider the natural ecology, not social uses or values.
- Be conservative in management policy. This model is an average situation.
- Adopting production estimates from other systems is dangerous. Should be RI specific.
- As an ecologist, manage by biomass & production. As a manager, manage by area.