Working Toward Consensus:

Application of Carrying Capacity in Management of Bivalve Aquaculture

Carrie Byron

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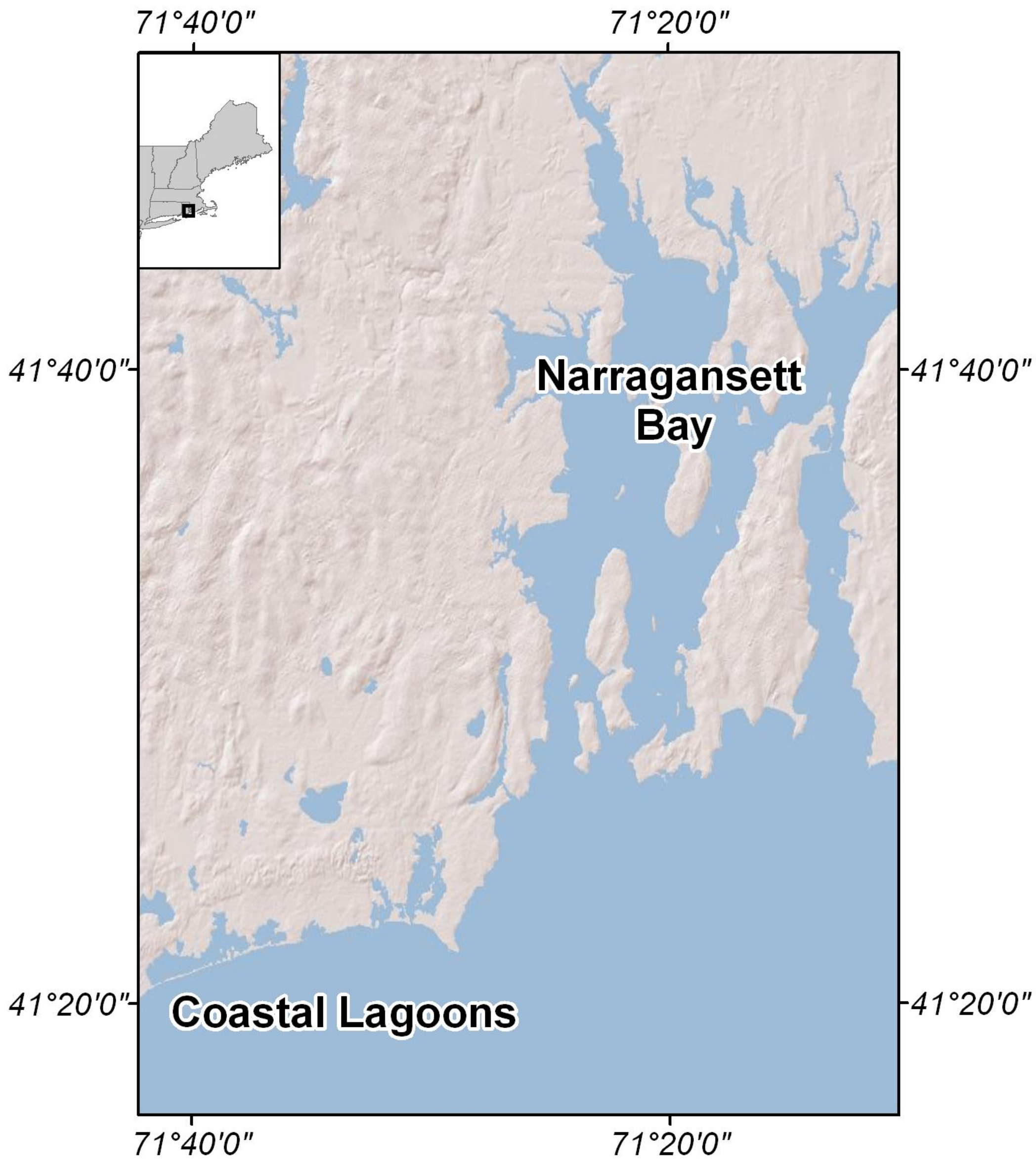
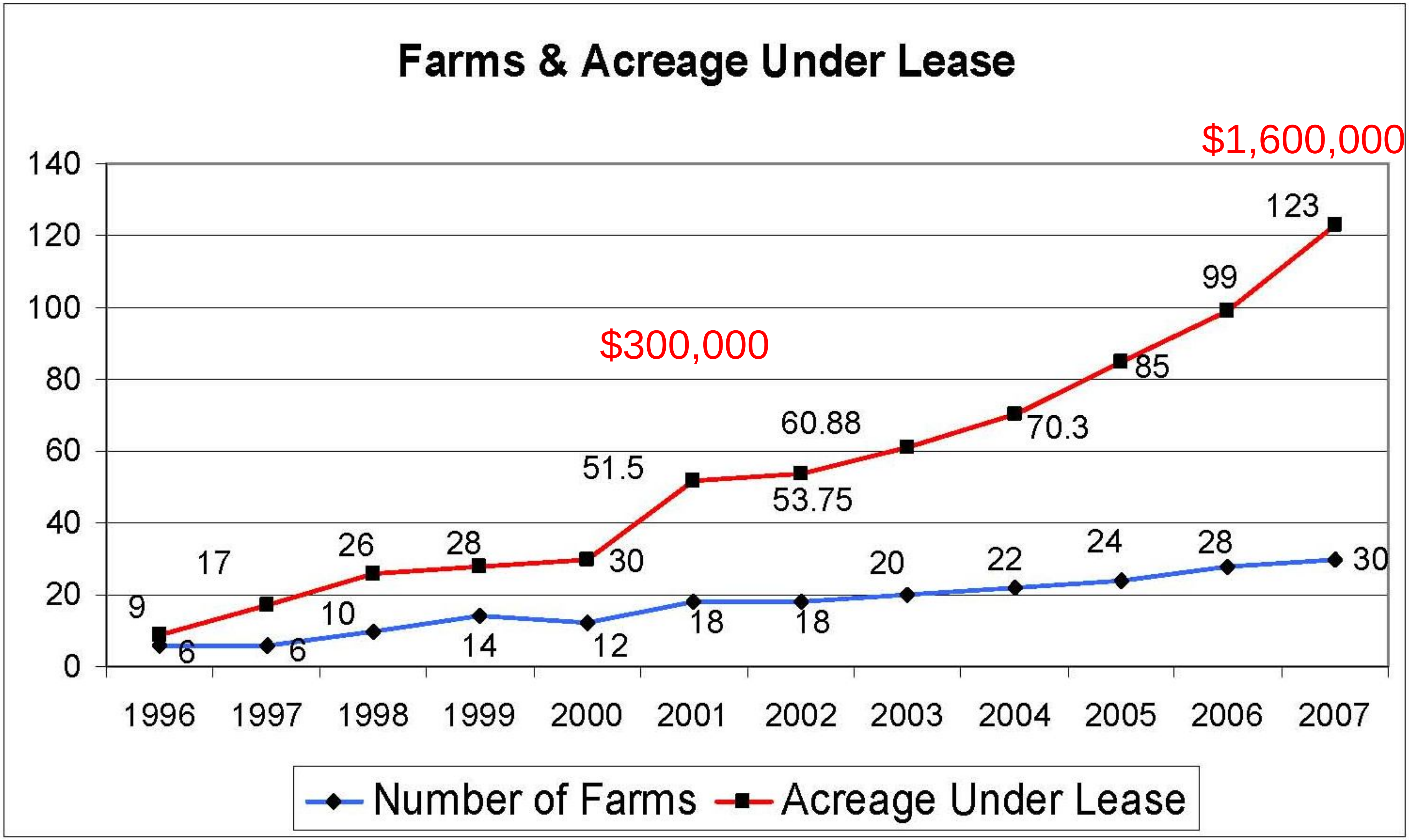
The University of Rhode Island

THINK BIG WE DO



Map data from RIGIS & Esri, Inc.. Created by P. August


Oyster
Aquaculture



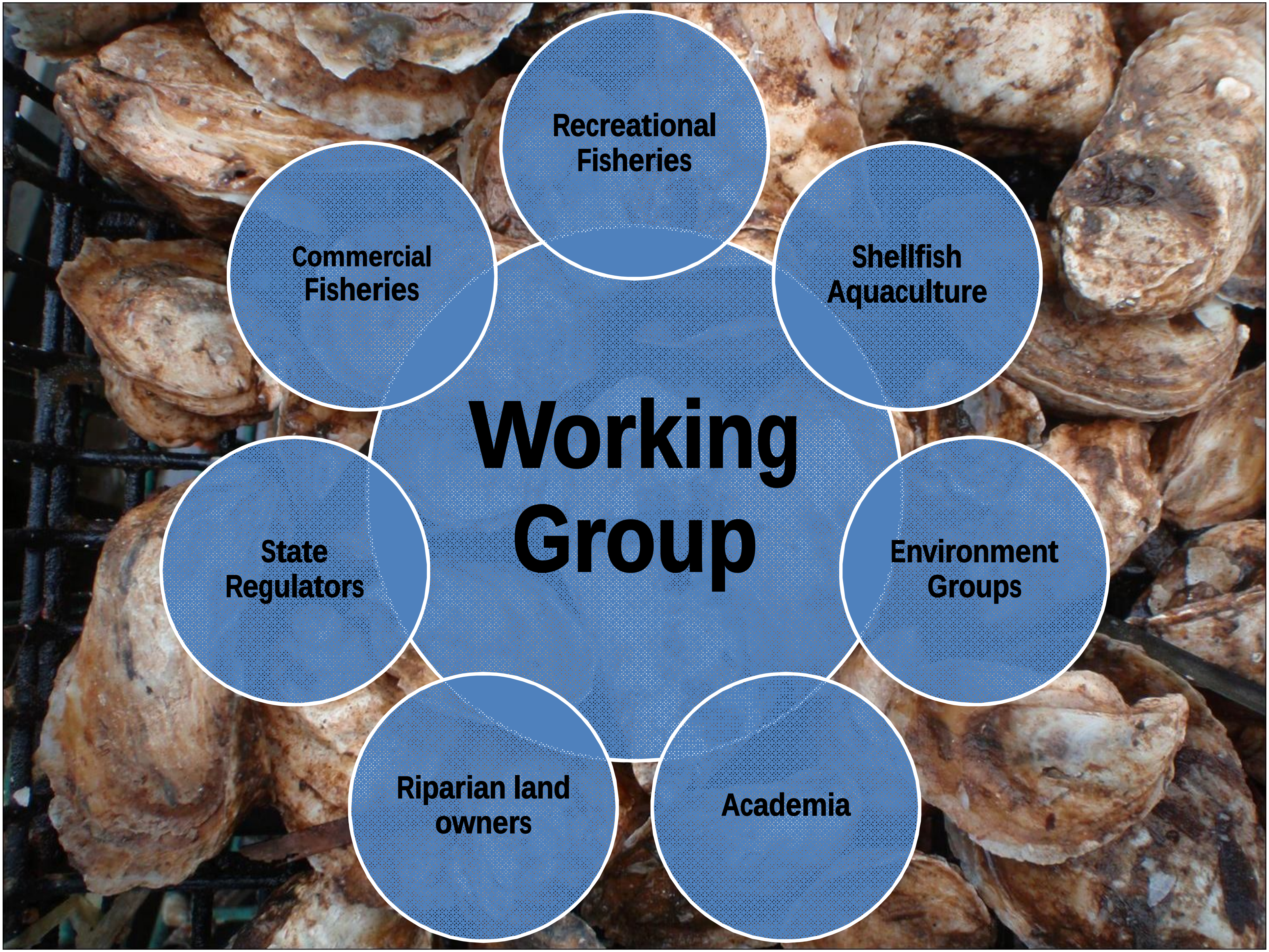
Taken from Alves 2007

CRMC

Coastal Resources Management Council

Working Group on Aquaculture Regulations

http://www.crmc.ri.gov/index.html


Recreational Fisheries
Commercial Fisheries
Shellfish Aquaculture
Working Group
State Regulators
Environment Groups
Riparian land owners
Academia


What is the **carrying capacity** for **oyster aquaculture** in Narragansett Bay and RI’s coastal ponds?
Providence Journal
Sunday, March 2, 2008

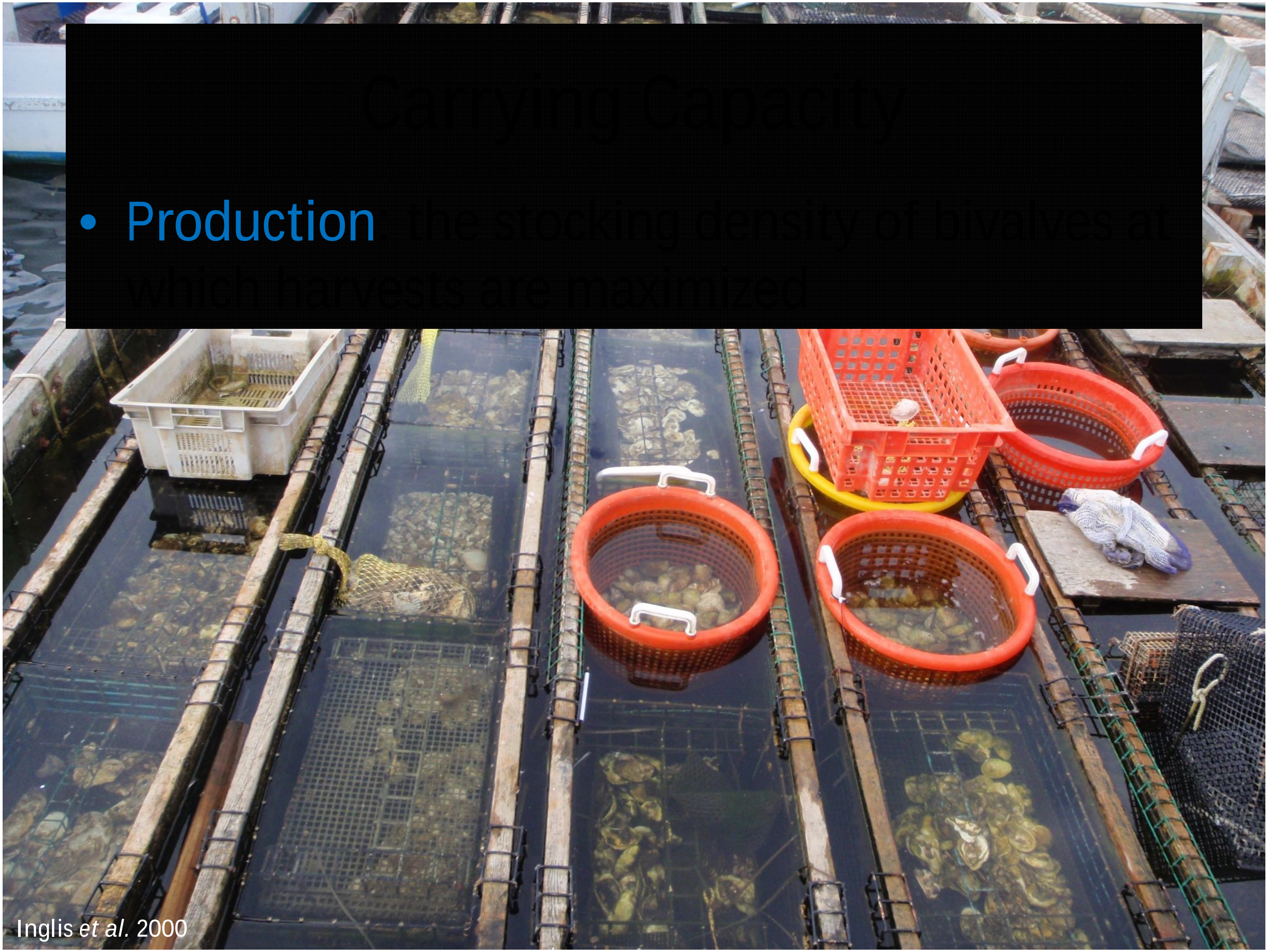
Carrying Capacity

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

Inglis *et al.* 2000, photo credit SPEAR

[redacted]

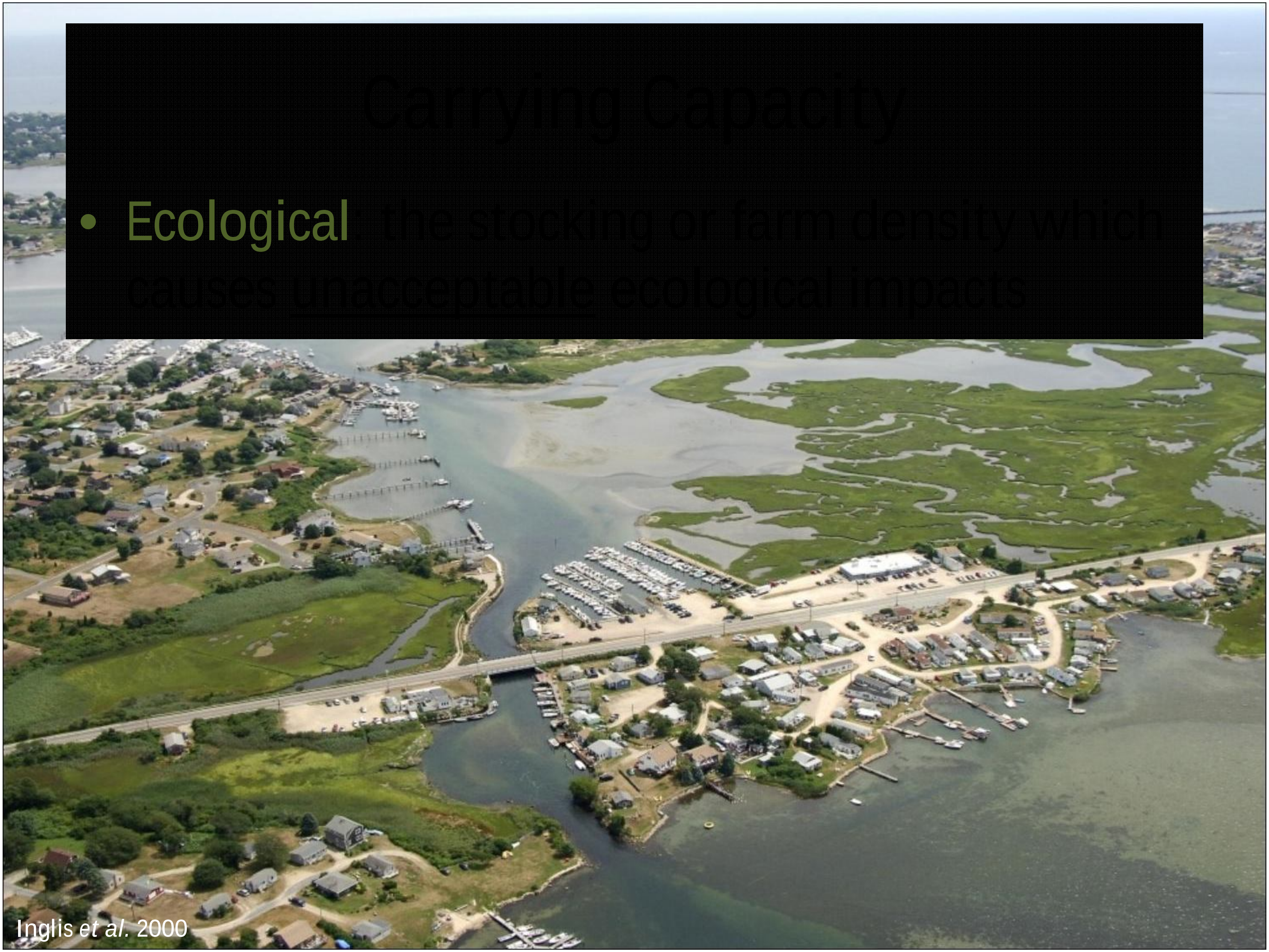
- Production [redacted]



Inglis *et al.* 2000

[redacted]

- Ecological [redacted]

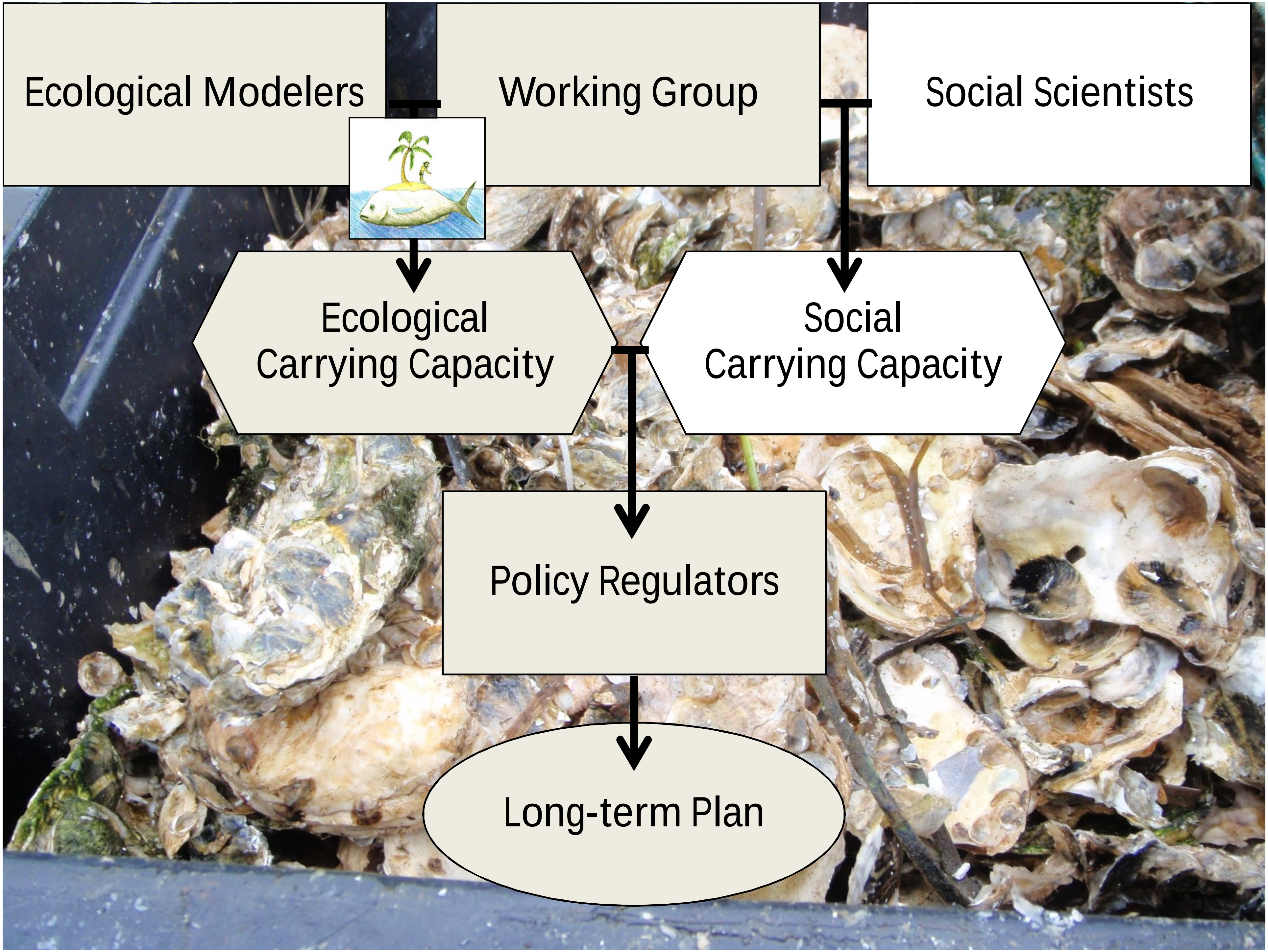


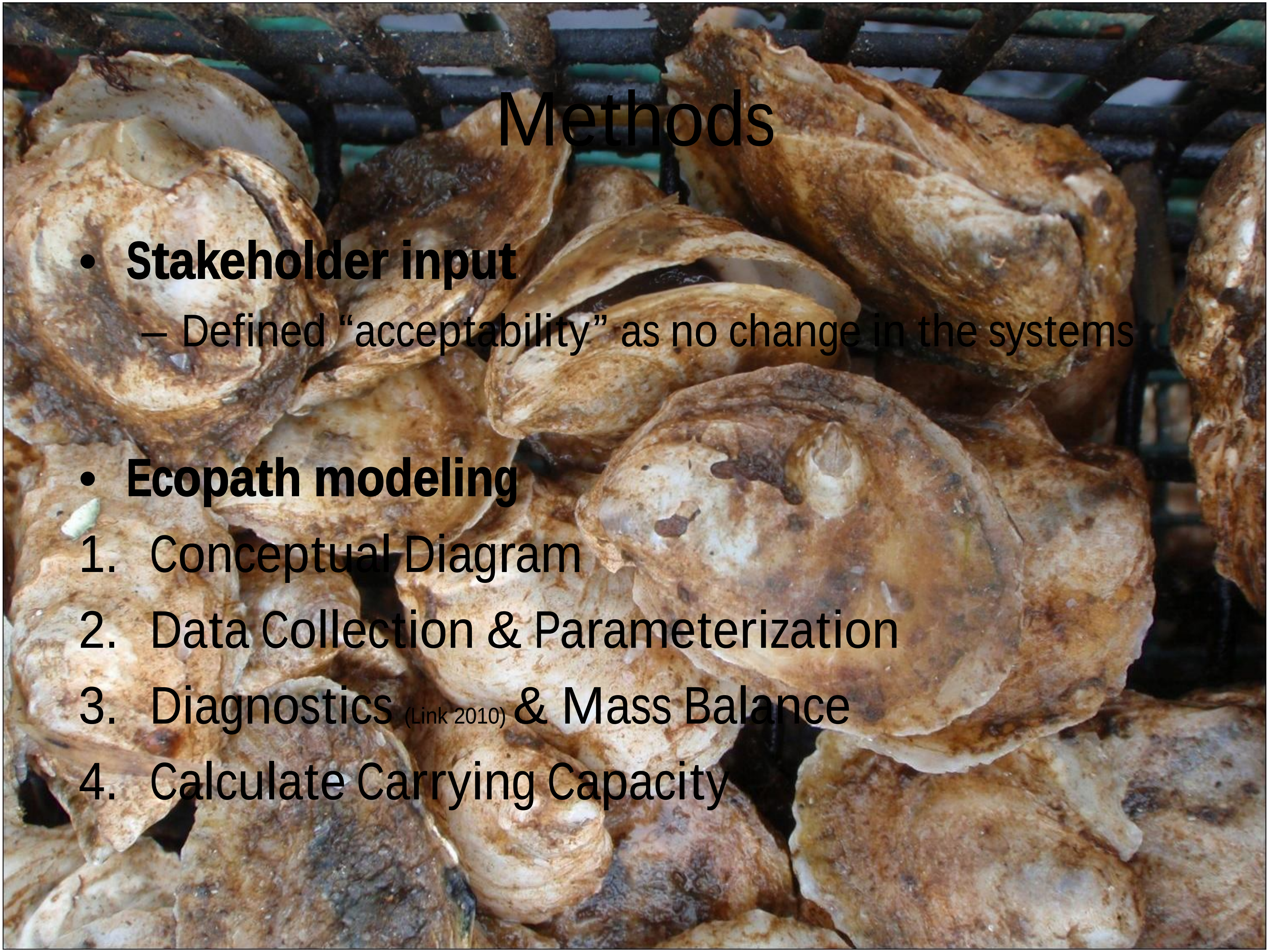
Inglis *et al.* 2000

Carrying Capacity

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

Inglis *et al.* 2000


Ecological Modelers
Working Group
Social Scientists
Ecological
Carrying Capacity
Social
Carrying Capacity
Policy Regulators
Long-term Plan



Methods

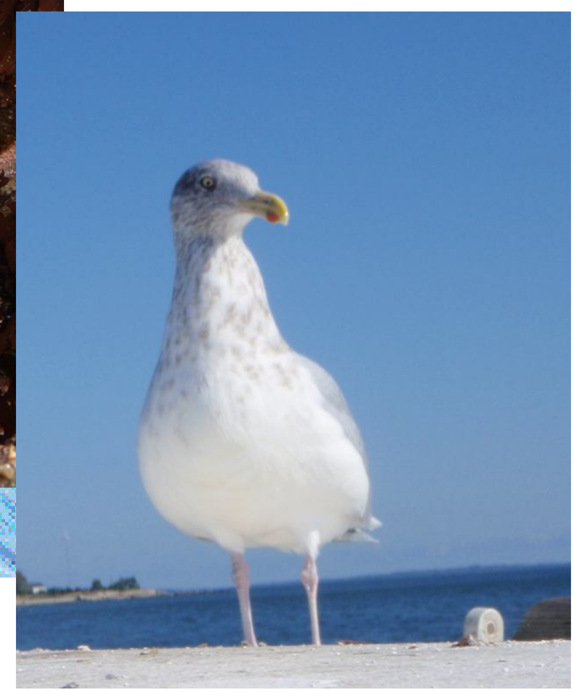
- **Stakeholder input**
  - Defined “acceptability” as no change in the systems

- **Ecopath modeling**

1. Conceptual Diagram
2. Data Collection & Parameterization
3. Diagnostics (Link 2010) & Mass Balance
4. Calculate Carrying Capacity

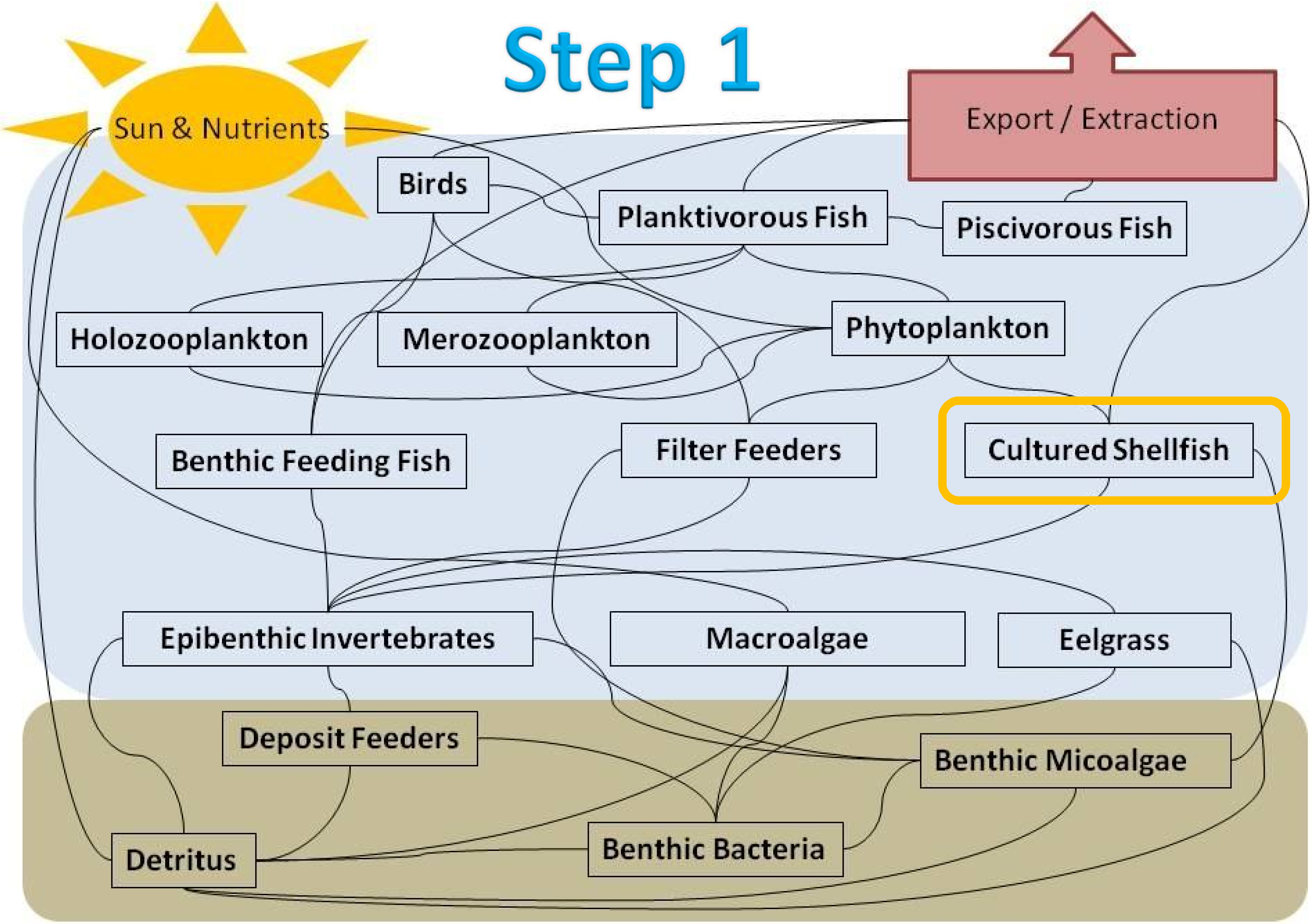
Ecopath

"All living organisms are linked together"



http://www.ecopath.org/

Step 1


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

Narragansett Bay

Monaco & Ulanowicz 1997

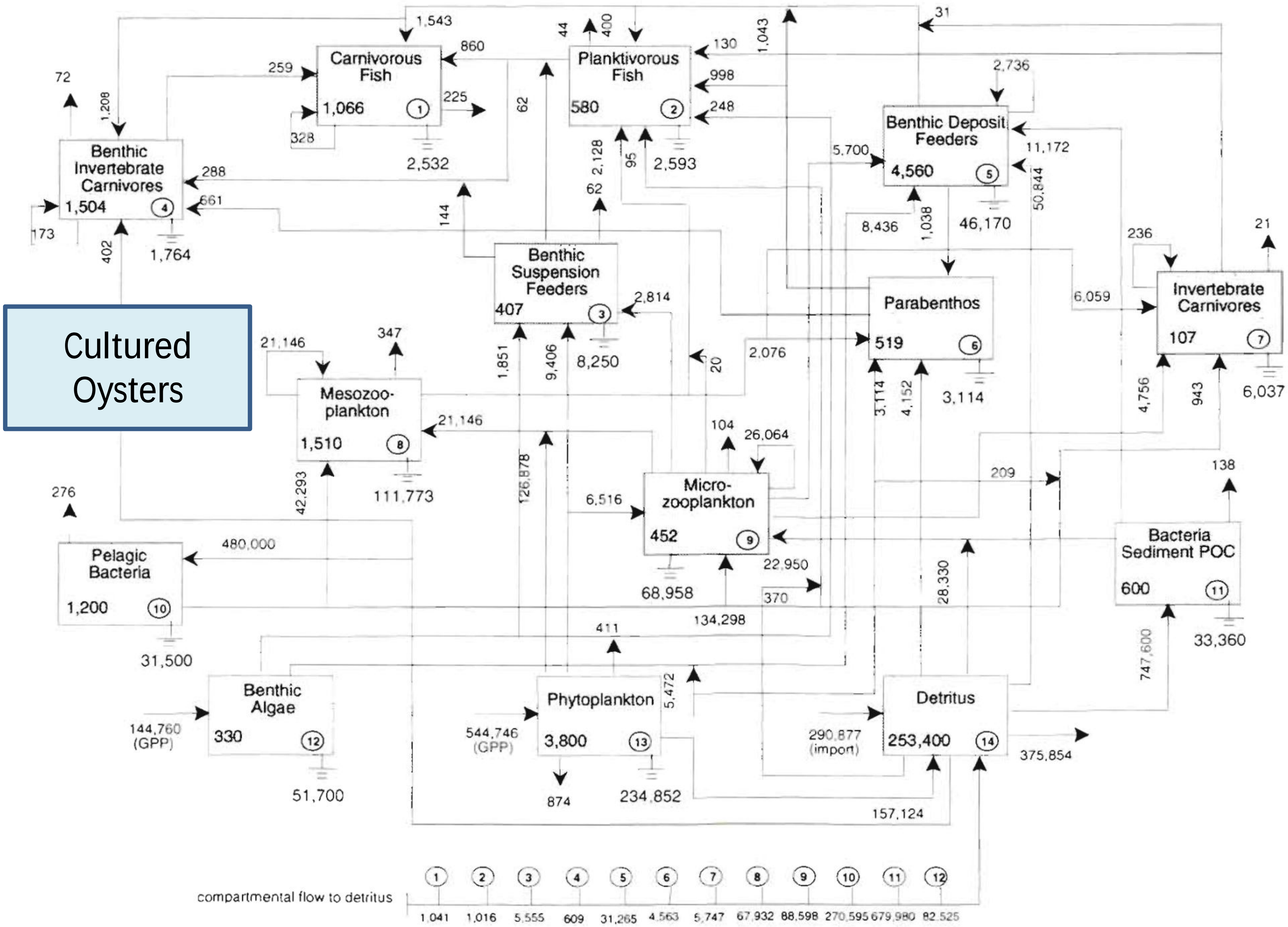


Fig. 2. Average annual energy flow (mg C m^{-2} yr^{-1}) and compartmental biomass (mg C m^{-2}) in Narragansett Bay

Step 2

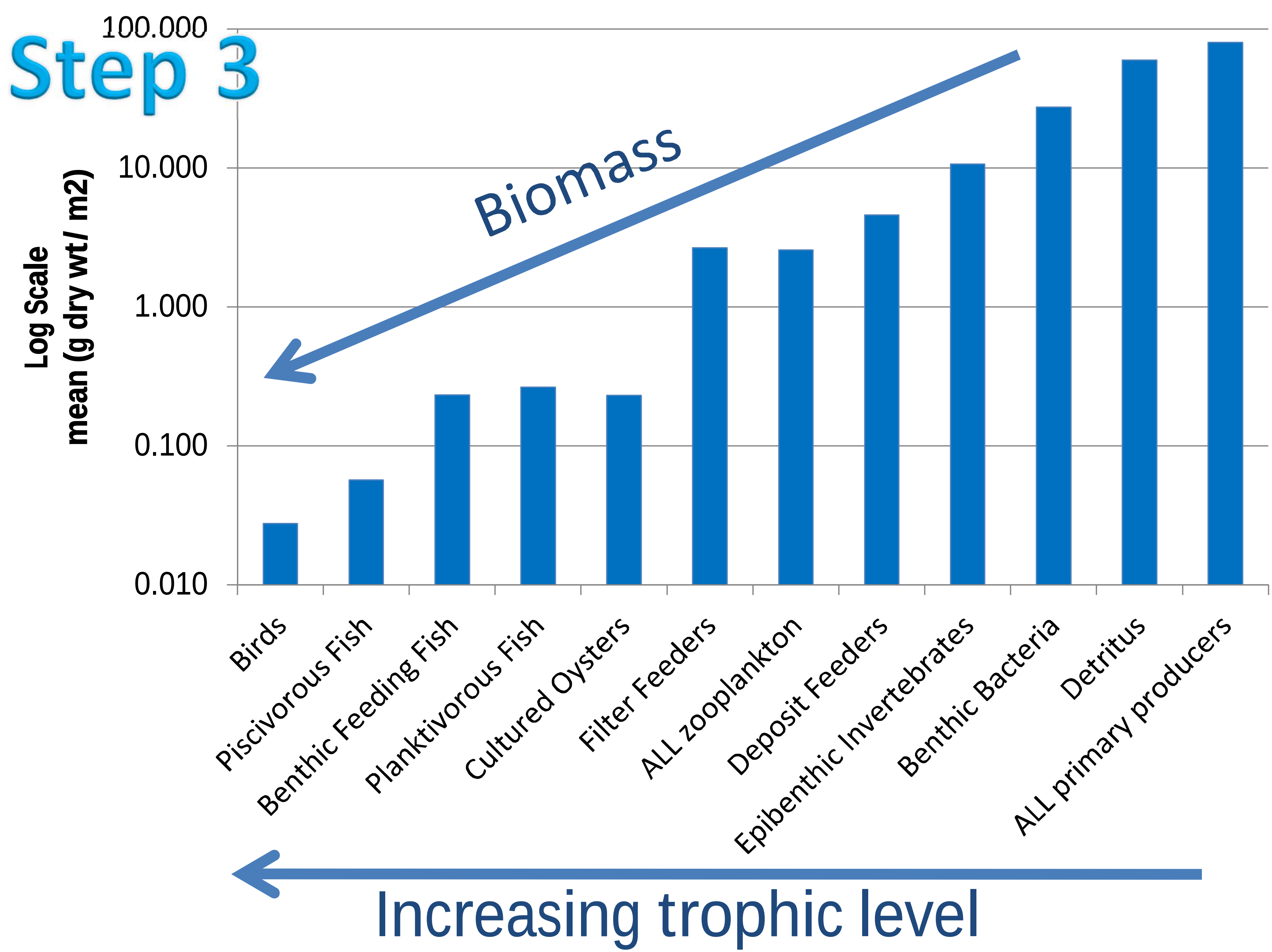
Salt Ponds Coalition

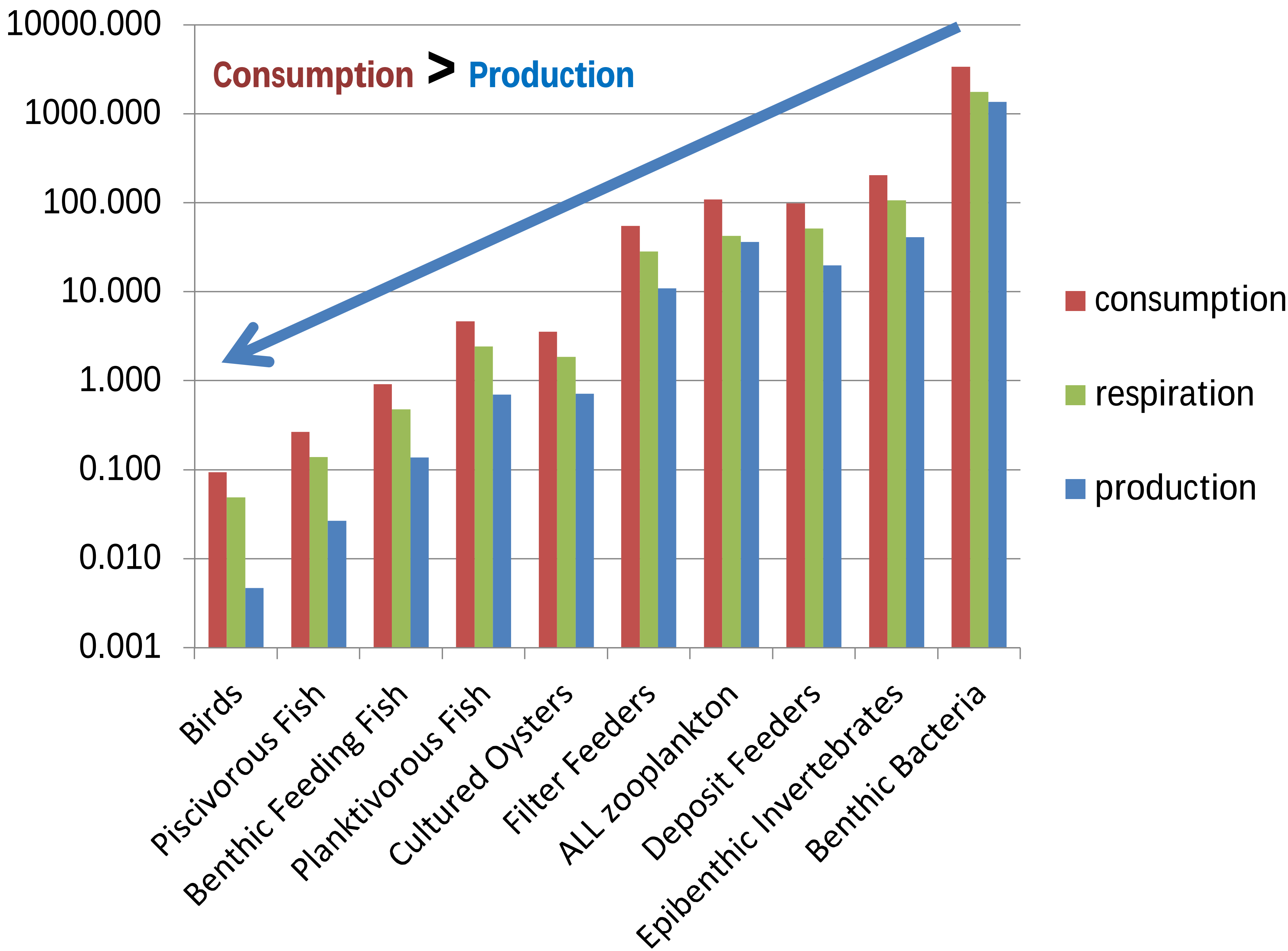
University of Rhode Island GSO Graduate School of Oceanography

NOAA

State of Rhode Island Department of Environmental Management

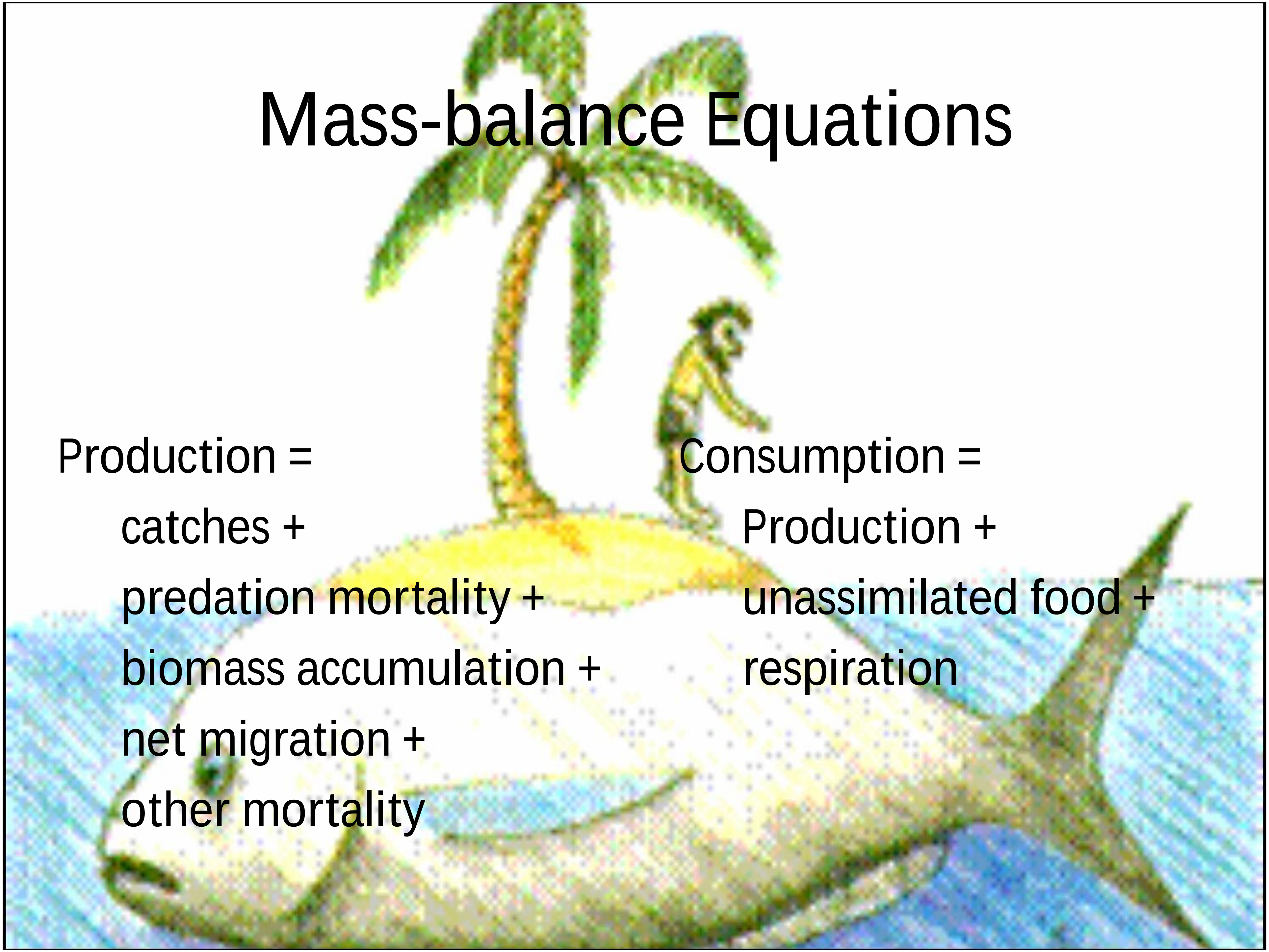
- Biomass
- Production
- Consumption
- Diet Composition
- Fisheries Catch


Step 3
Log Scale
mean (g dry wt/ m2)
100.000
10.000
1.000
0.100
0.010
Biomass
Birds
Piscivorous Fish
Benthic Feeding Fish
Planktivorous Fish
Cultured Oysters
Filter Feeders
ALL zooplankton
Deposit Feeders
Epibenthic Invertebrates
Benthic Bacteria
Detritus
ALL primary producers
Increasing trophic level



Consumption > Production
10000.000
1000.000
100.000
10.000
1.000
0.100
0.010
0.001
consumption
respiration
production
Birds
Piscivorous Fish
Benthic Feeding Fish
Planktivorous Fish
Cultured Oysters
Filter Feeders
ALL zooplankton
Deposit Feeders
Epibenthic Invertebrates
Benthic Bacteria

Mass-balance Equations



Production =
- catches +
- predation mortality +
- biomass accumulation +
- net migration +
- other mortality

Consumption =
- Production +
- unassimilated food +
- respiration

Throughput of Flows

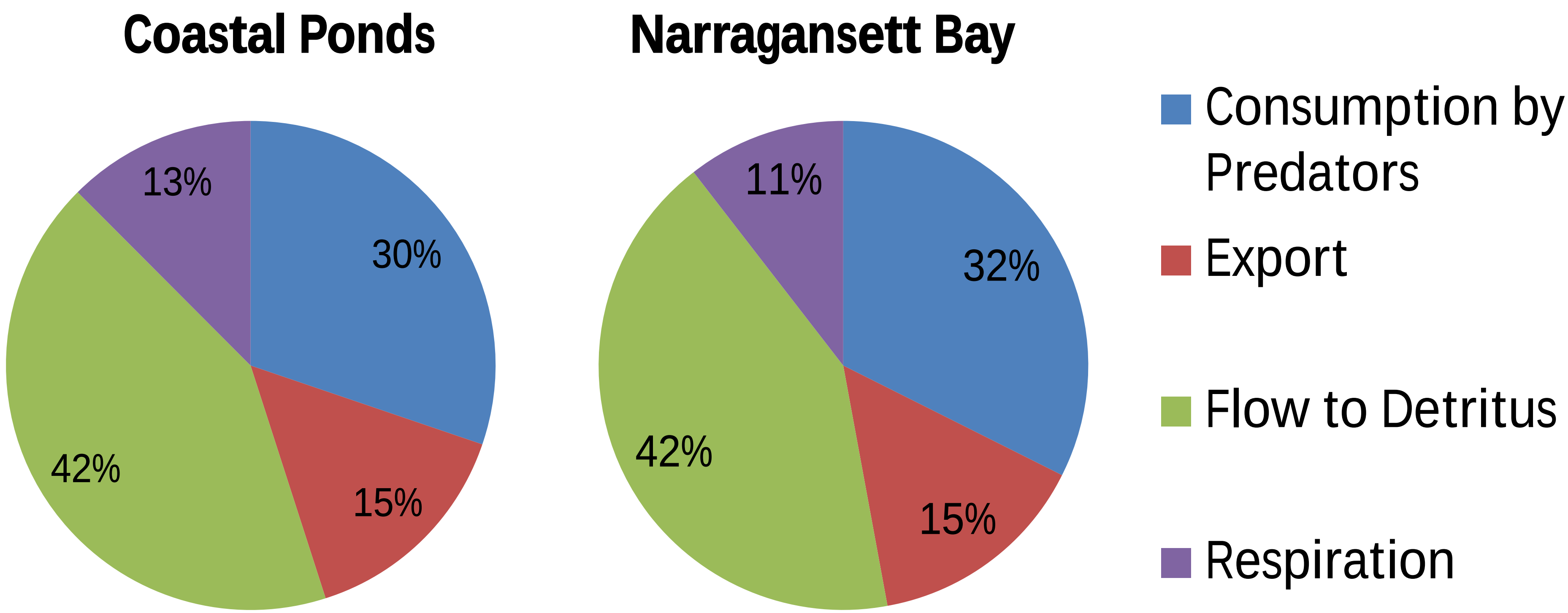
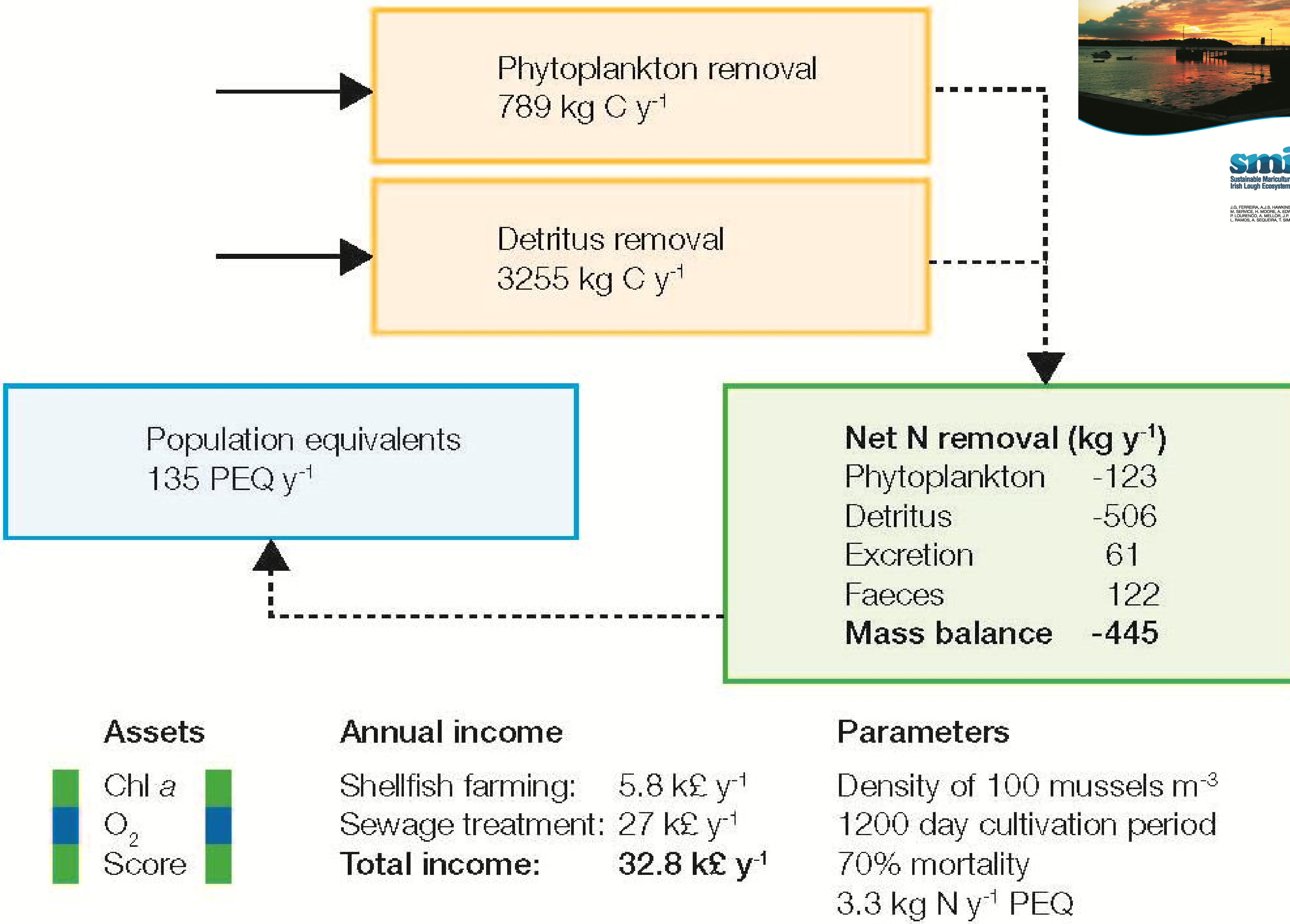
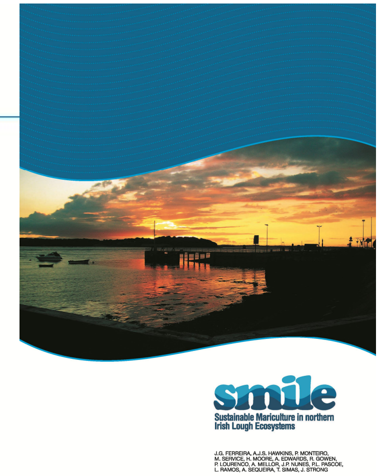


Figure 72. Mass balance for a 6000 m² mussel bottom lease in Carlingford Lough.

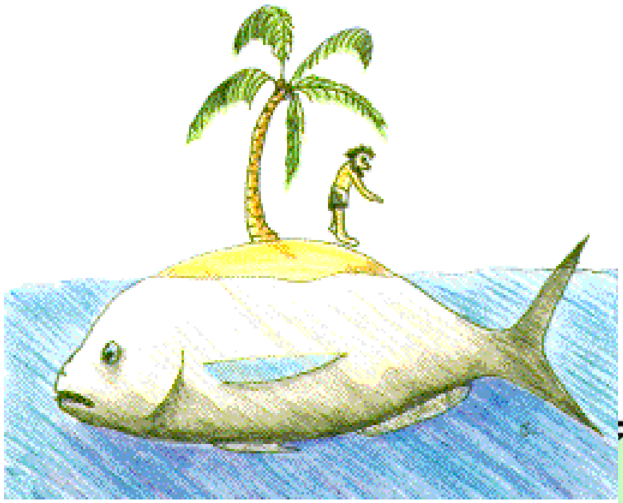




taken from Ferreira et al 2007 SMILE book

W. Jiang, M.T. Gibbs / Aquaculture 244 (2005) 171–185

Step 4



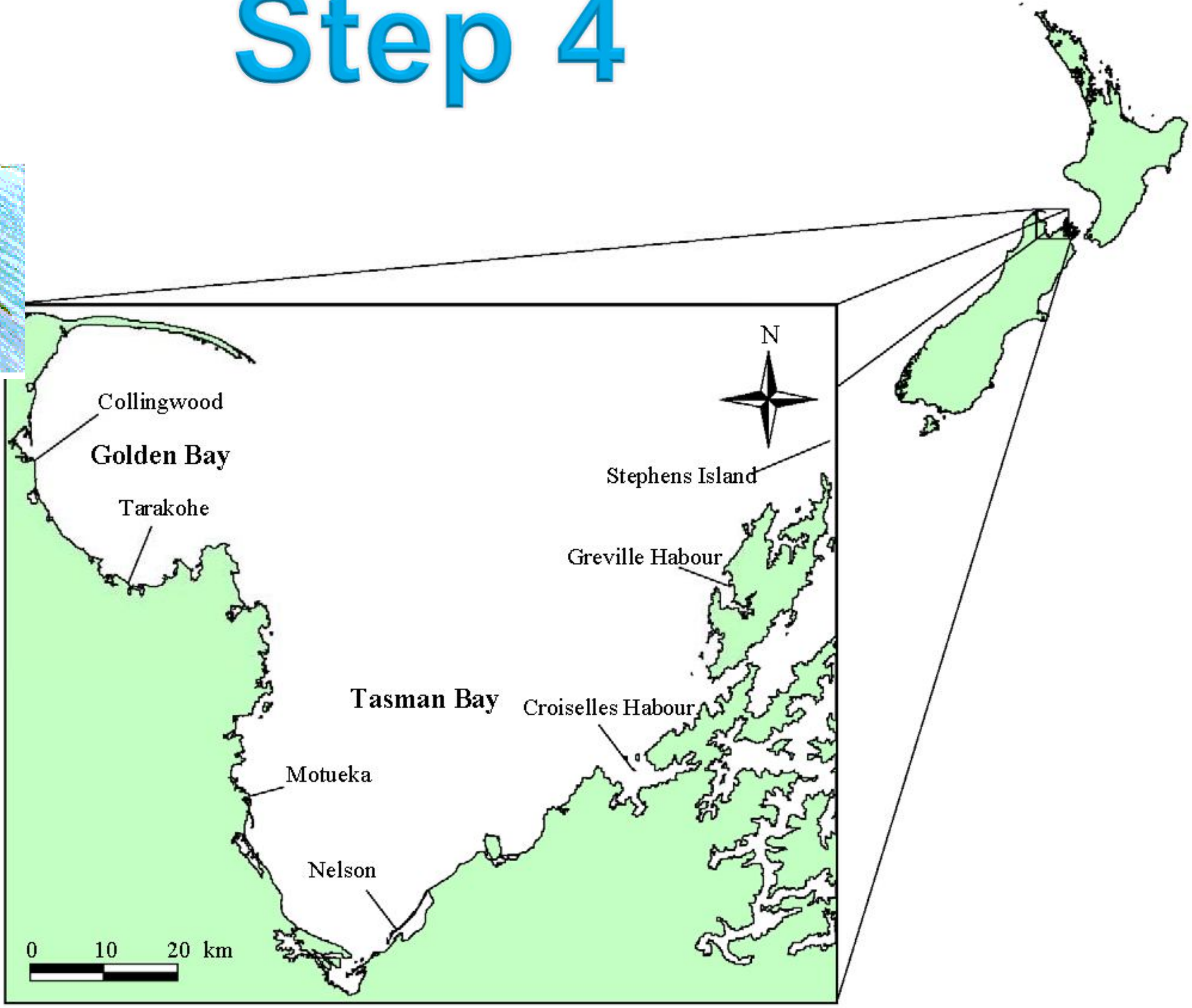
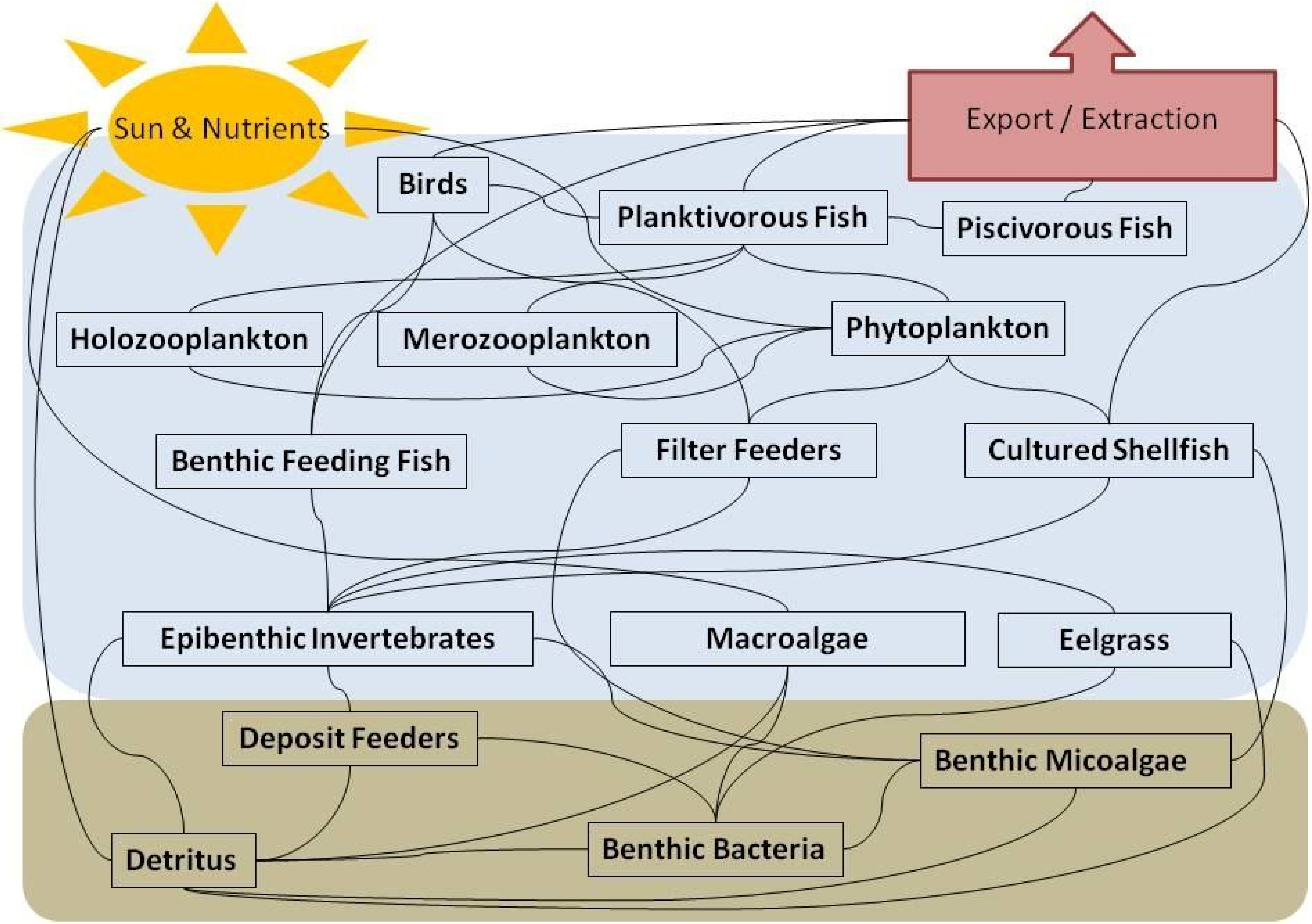


Fig. 1. Map showing Golden and Tasman Bays, northern end of the South Island of New Zealand.



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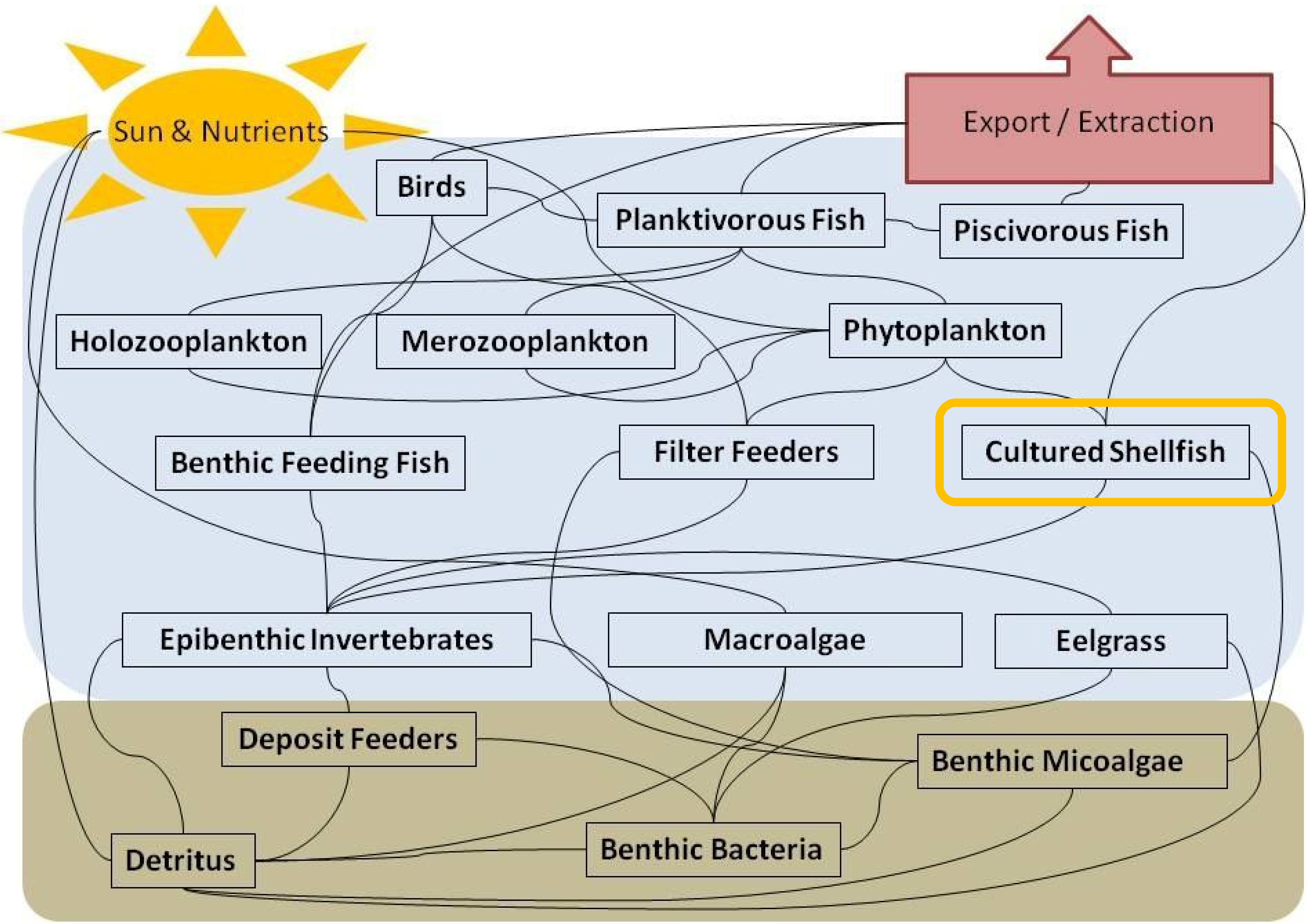
Detritus
Benthic Bacteria



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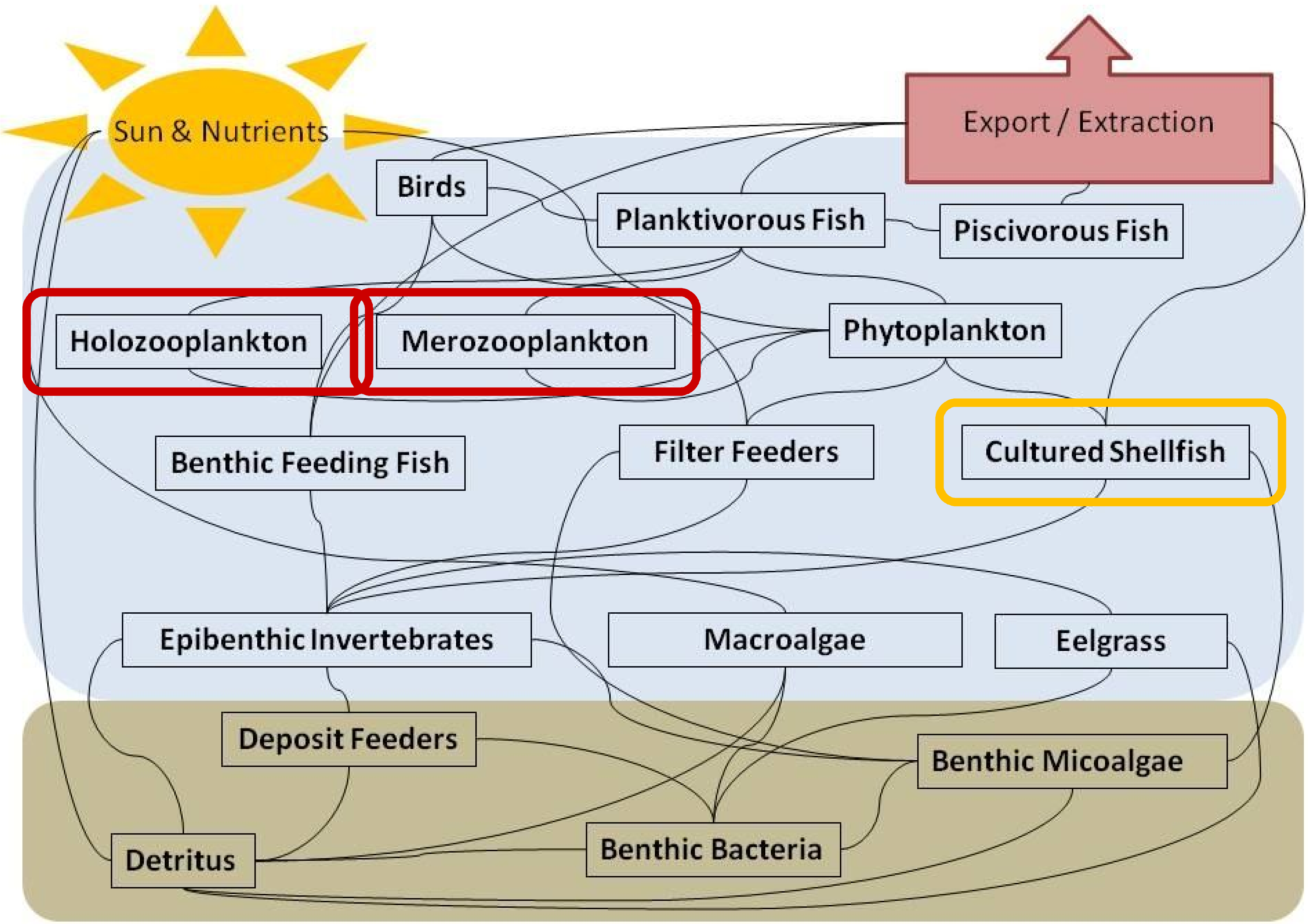
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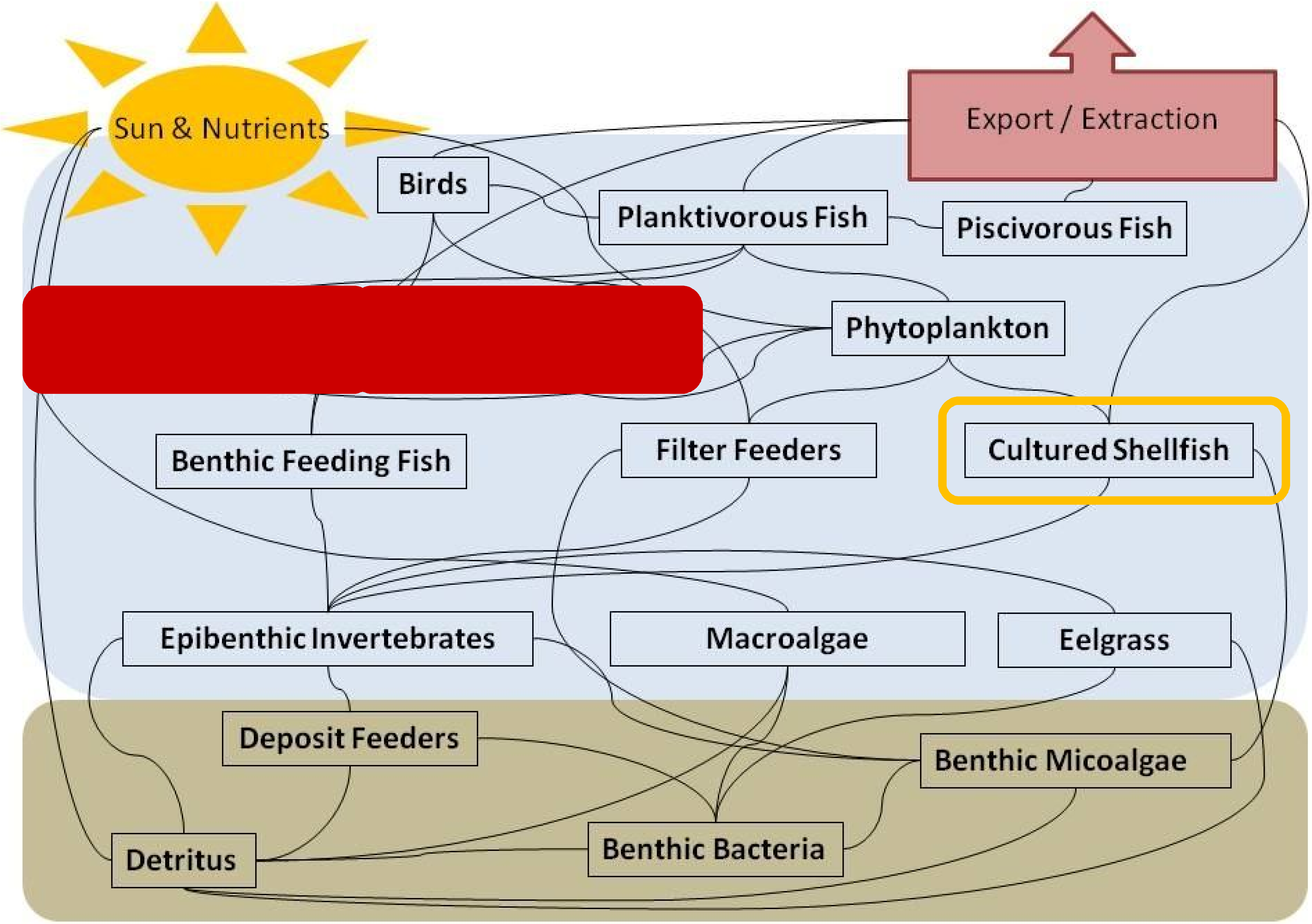

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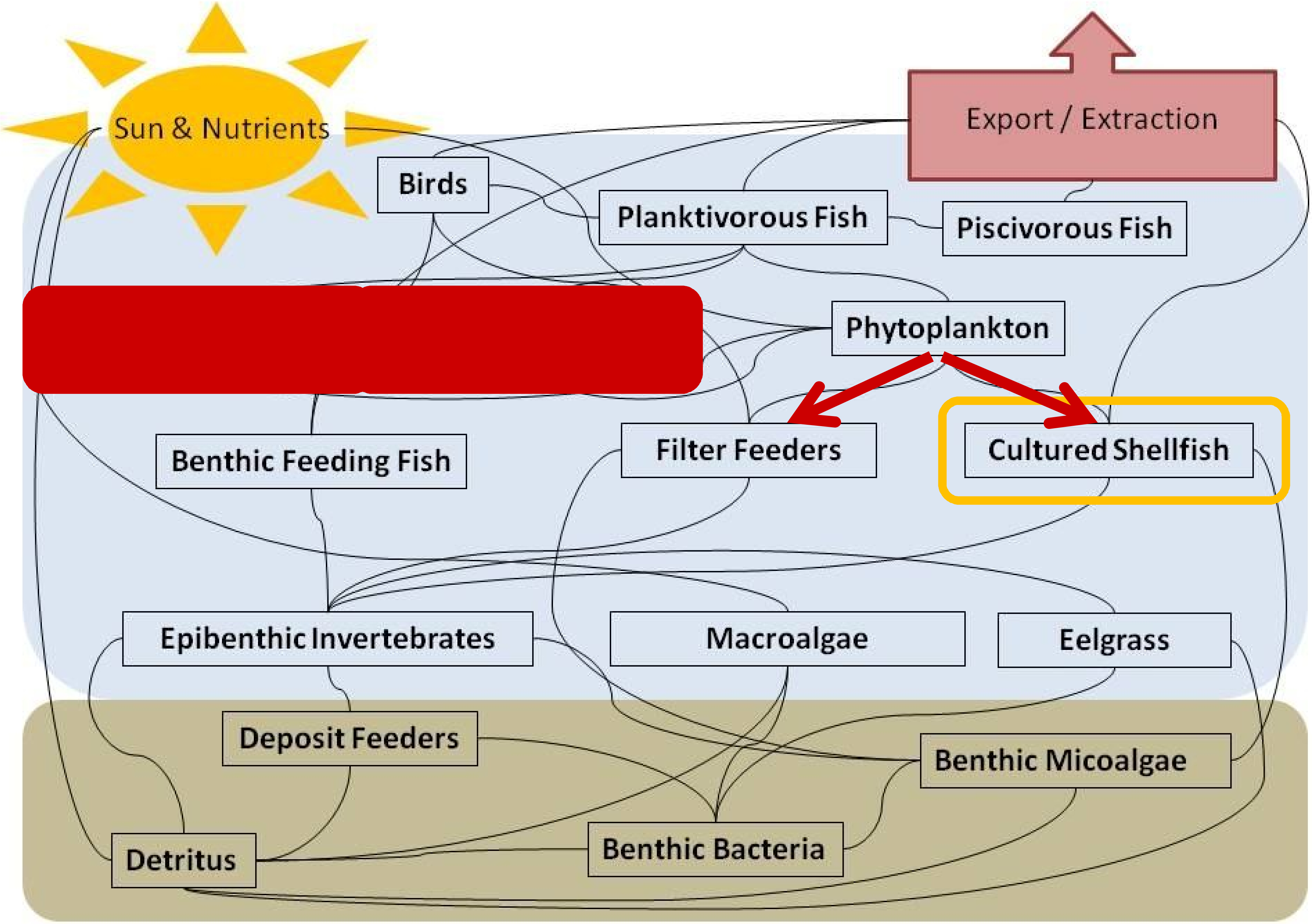

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Narragansett Bay

Monaco & Ulanowicz 1997

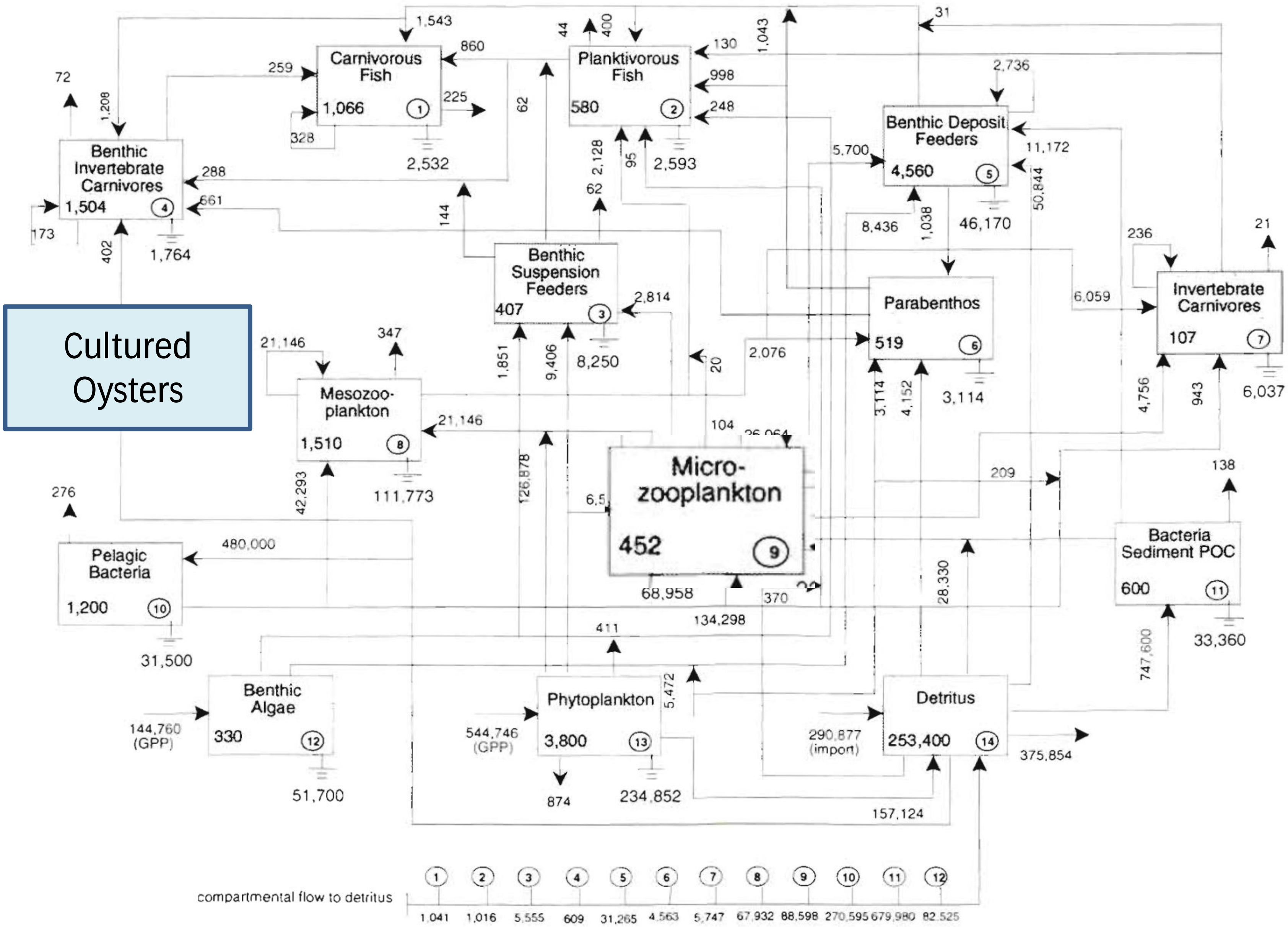
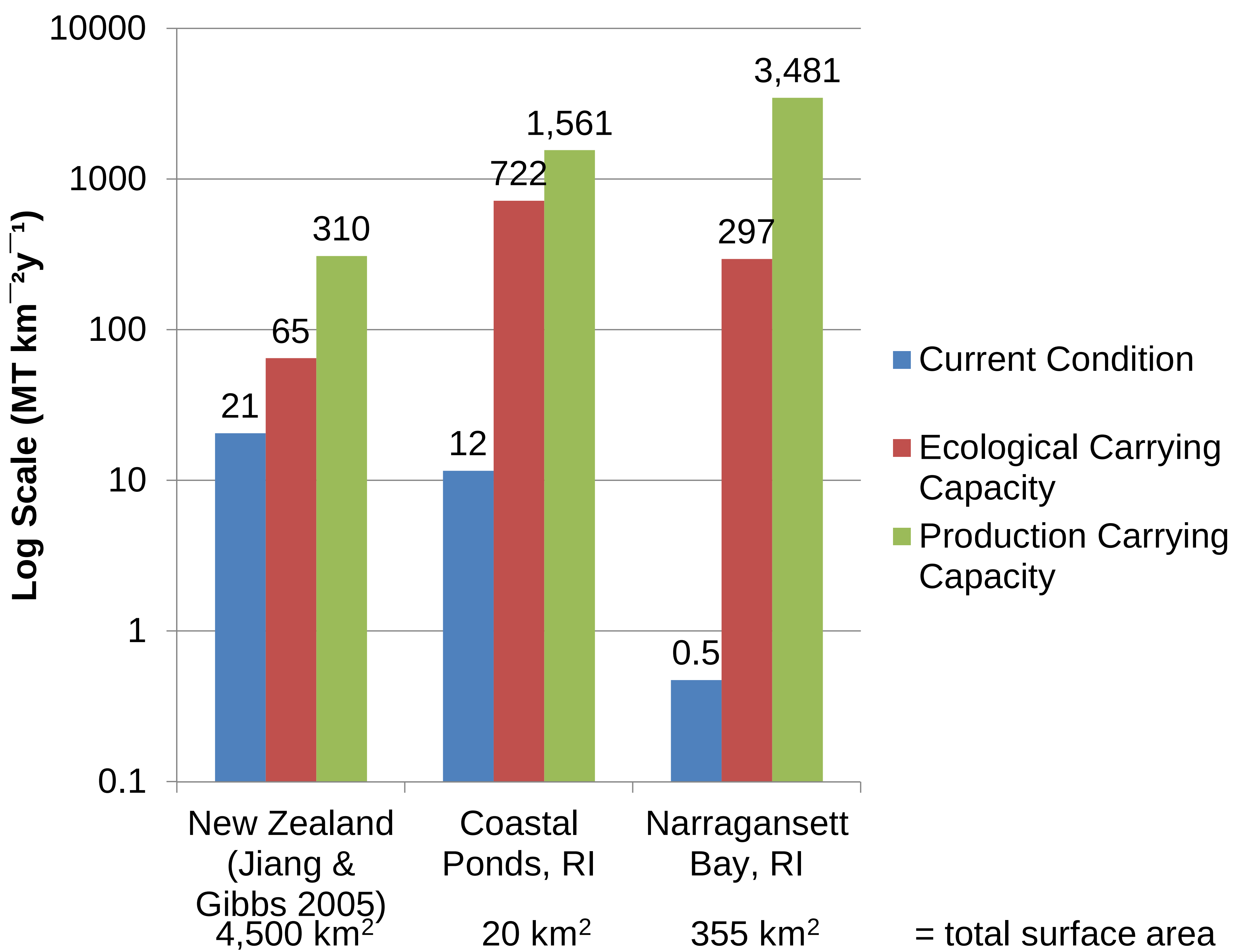
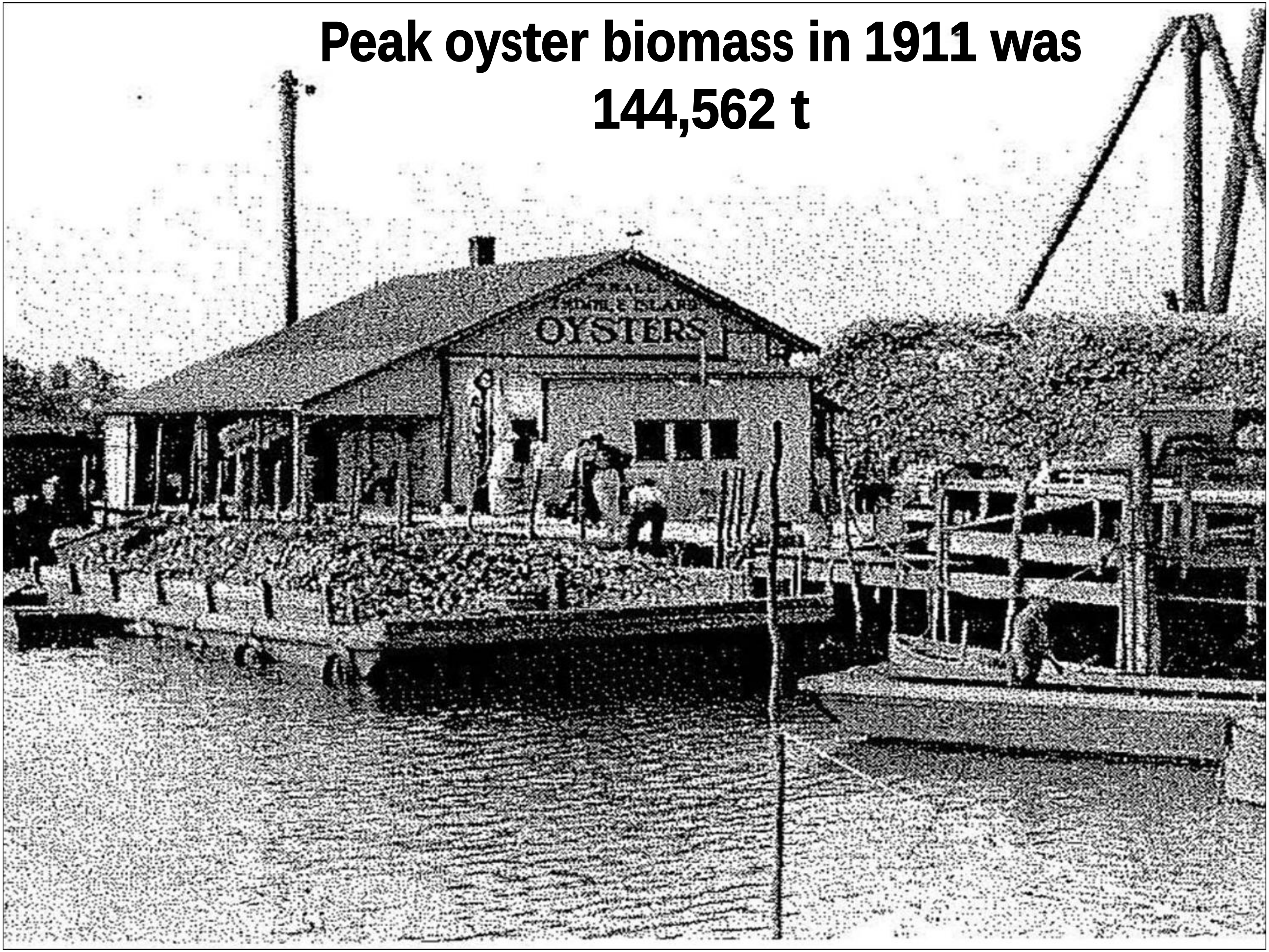


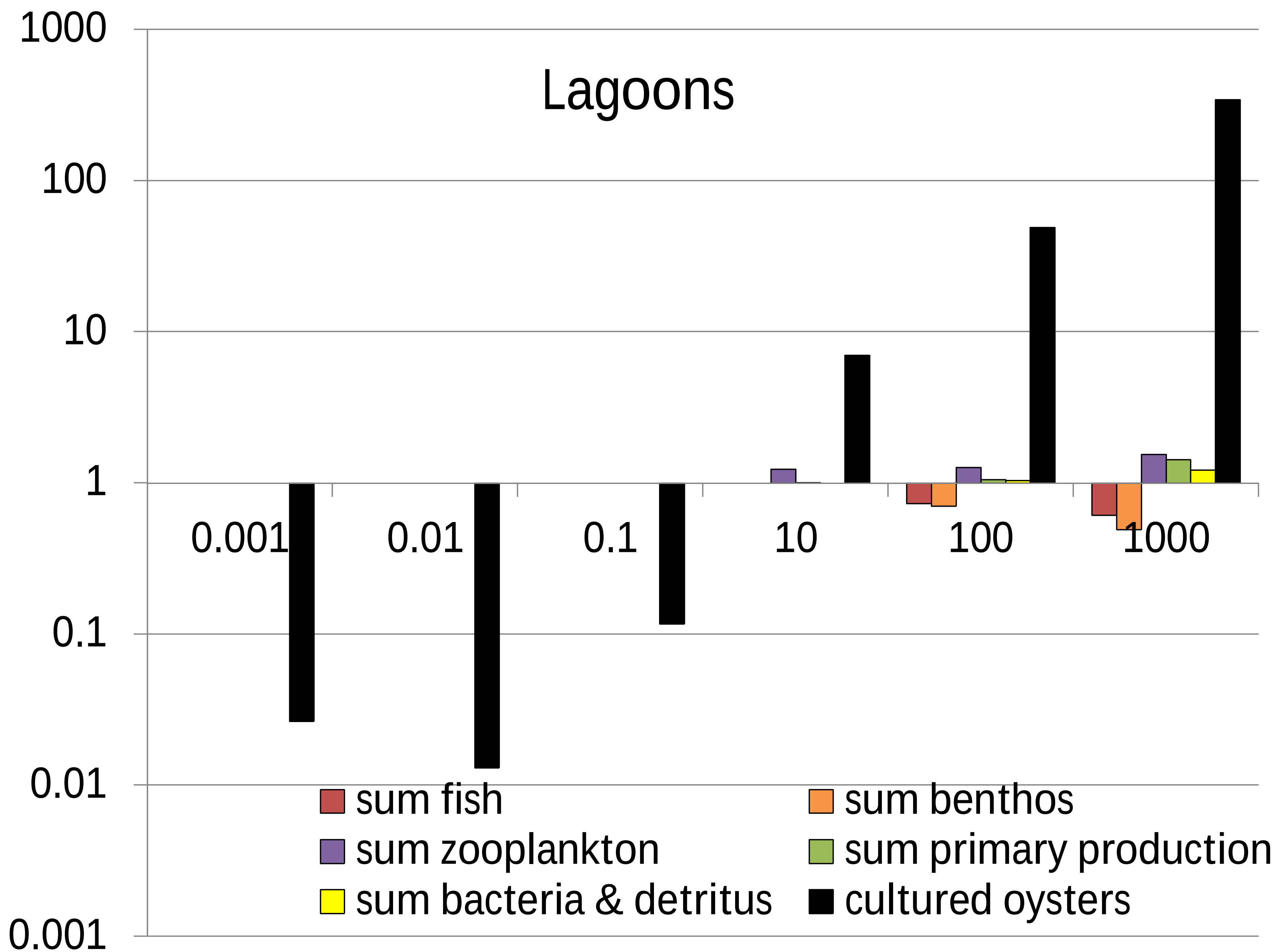
Fig. 2. Average annual energy flow (mg C m^{-2} yr^{-1}) and compartmental biomass (mg C m^{-2}) in Narragansett Bay


Log Scale (MT km⁻²y⁻¹)
10000
1000
100
10
1
0.1
21
65
310
12
722
1,561
0.5
297
3,481
Current Condition
Ecological Carrying Capacity
Production Carrying Capacity
New Zealand (Jiang & Gibbs 2005)
Coastal Ponds, RI
Narragansett Bay, RI
4,500 km2
20 km2
355 km2
= total surface area

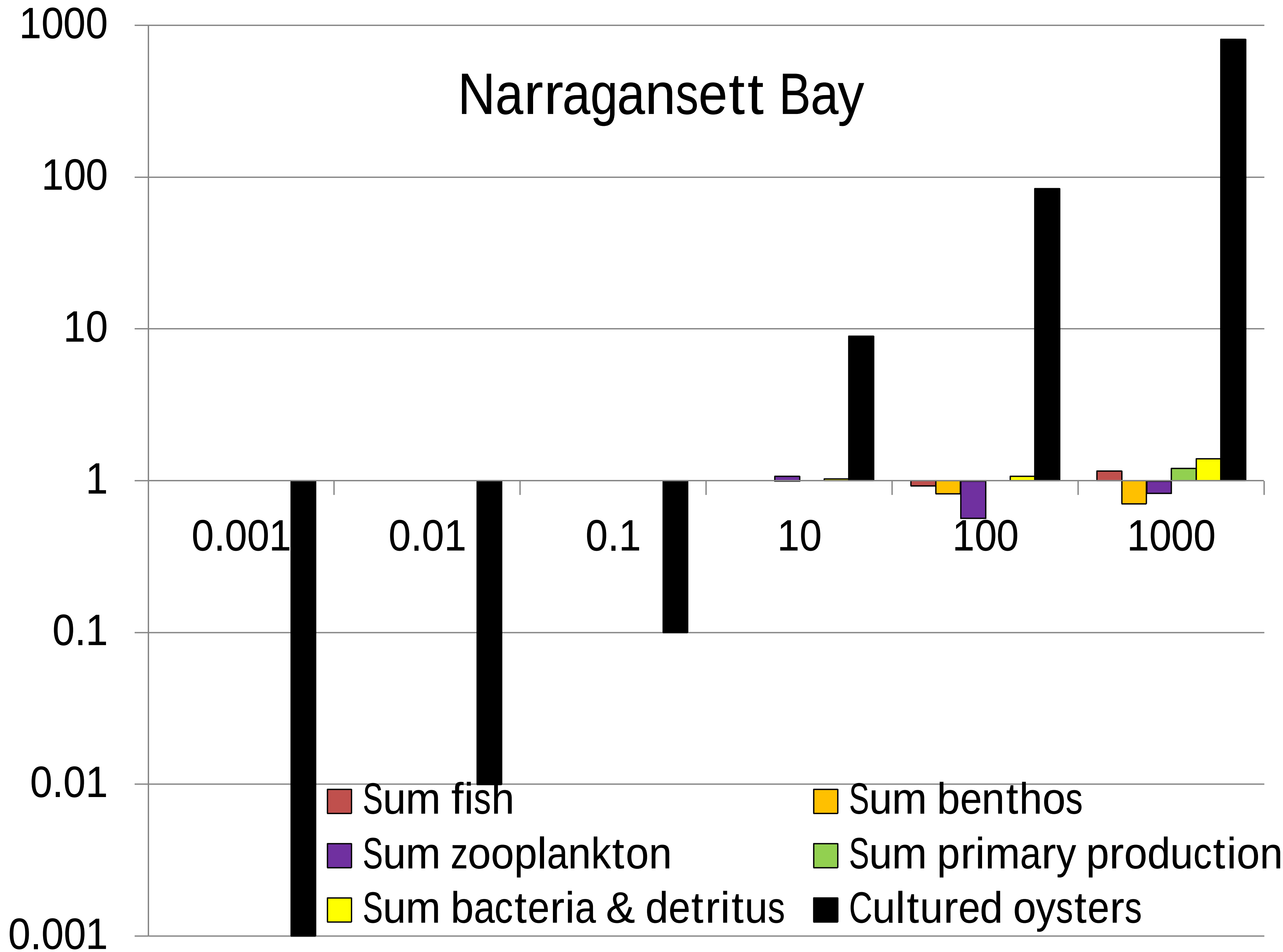
Water Body	Surface Area (Km^2)	Total biomass (t)	Harvest biomass (t)
Narragansett Bay	355	105,435	39,011
Point Judith	6.37	4,601	1,288
Potter	1.33	962	269
Ninigret	6.92	5,001	1,400
Quononchontaug	2.93	2,133	592
Winnipaug	1.89	1,304	365
Total RI waters	**374.44**	**119,436**	**42,925**

Peak oyster biomass in 1911 was 144,562 t





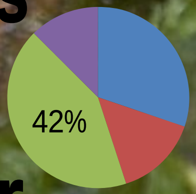
Lagoons
1000
100
10
1
0.1
0.01
0.001
0.001
0.01
0.1
10
100
1000
sum fish
sum benthos
sum zooplankton
sum primary production
sum bacteria & detritus
cultured oysters



Narragansett Bay
1000
100
10
1
0.1
0.01
0.001
0.001
0.01
0.1
10
100
1000
Sum fish
Sum benthos
Sum zooplankton
Sum primary production
Sum bacteria & detritus
Cultured oysters

Conclusion

- **Potential for continued aquaculture growth**
- **Current policy of 5% well within ecological limitations of the modeled systems**
- **Oysters are not food limited - Large detritus pool available**
- **Cultured oysters have little impact on other species – currently and at carrying capacity**
- **Low trophic levels (plankton groups) most affected if surpass ecological carrying capacity**



Conclusion

- **Methods transferable to other densely populated systems with user conflict issues**
- **Carrying capacity approach supports an Ecological Approach to Aquaculture**
- **Timely & Needed - National Policy**


Thank you
NOAA National Marine Aquaculture Initiative (NA08OAR4170838)
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RINHS – Wald Grant
Dissertation Committee:
B. Costa Pierce, D. Bengtson, J. Link, G. Forrester, M. Rice
Dr. Mark Monaco
GSO: Oviatt and Collie labs
RI Department of Environmental Management
NOAA Narragansett Bay & Woods Hole Labs
RI Salt Pond Coalition

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Byron C, Bengtson D, Costa-Pierce B, Calanni J (2011) Integrating Science into Management: Ecological Carrying Capacity of Bivalve Shellfish Aquaculture. Marine Policy 35:363-370

Byron C, Link J, Bengtson D, Costa-Pierce B (submitted) Calculating Carrying Capacity of Shellfish Aquaculture Using Mass-Balance Modeling: Narragansett Bay, Rhode Island.

Byron C, Link J, Costa-Pierce B, Bengtson D (submitted) Modeling Ecological Carrying Capacity of Shellfish Aquaculture in Highly Flushed Temperate Lagoons.


RIDEM


GRUNDENS


OYSTER FARM...PLEASE...NO WAKE