Carrying Capacity and Economic Considerations for Shellfish Aquaculture

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Outline

- Ecological effects of shellfish mariculture
- Carrying capacity concepts
- Shellfish farming and nutrient levels in Waquoit Bay, Cape Cod
- Economic approach to social carrying capacity

List of Ecological Effects (1)

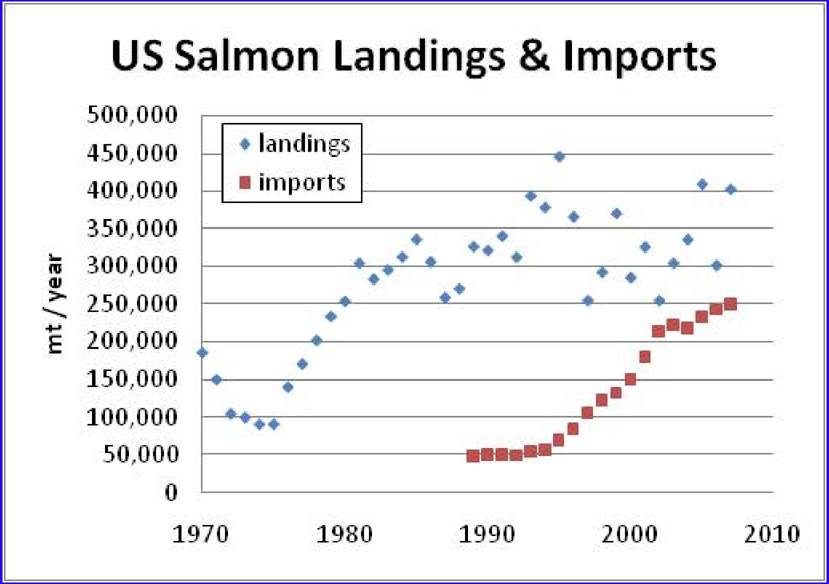
- Nutrient cycling
  - N cycle
  - Removal of nutrients & larvae
- Benthic flora
- Finfish & mobile crustaceans
- Marine mammals, turtles, birds

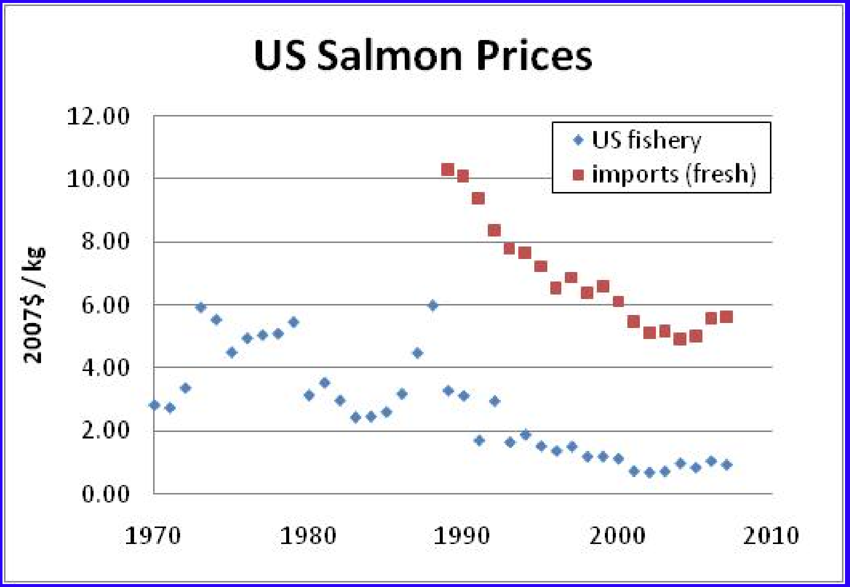
List of Ecological Effects (2)

- Exotic species
- Disease concentration & transmission
- Genetic effects
- Effects on fishing pressure

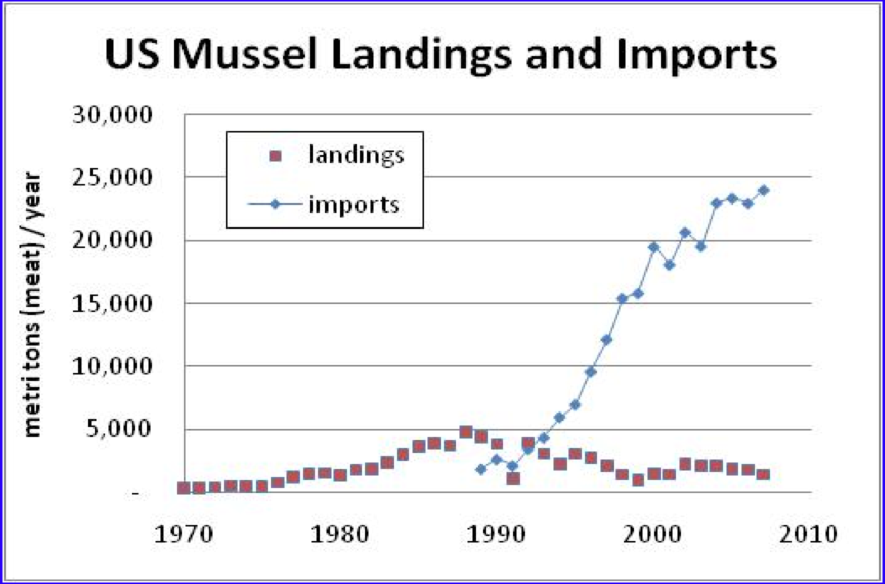
[NRC report now in review]

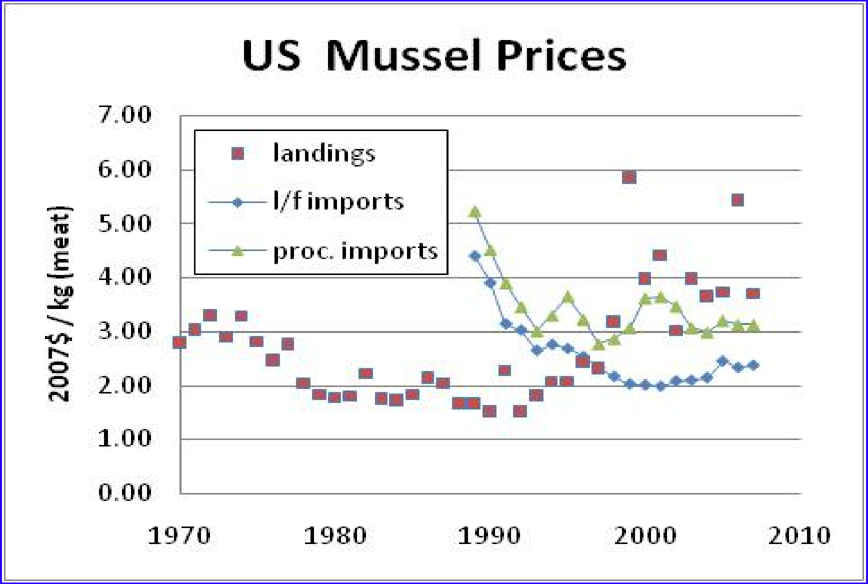
Aquaculture & Wild Fisheries: Salmon

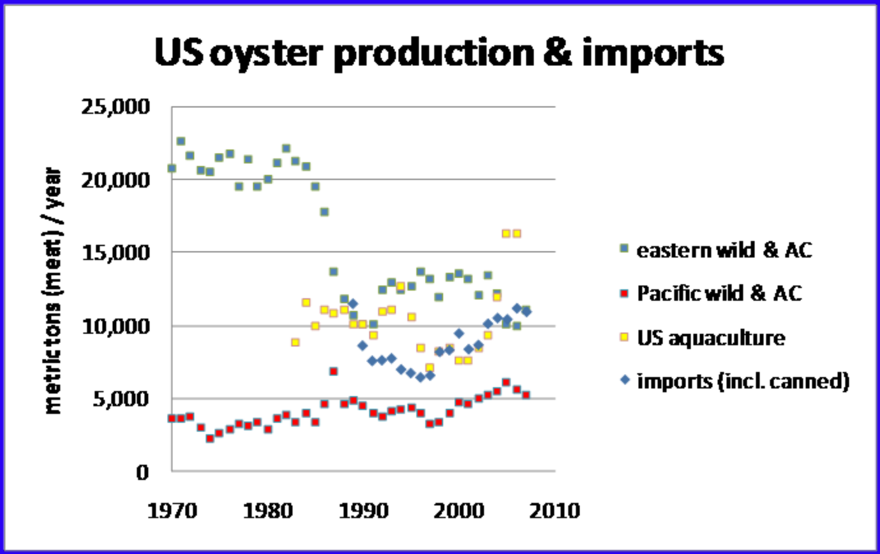


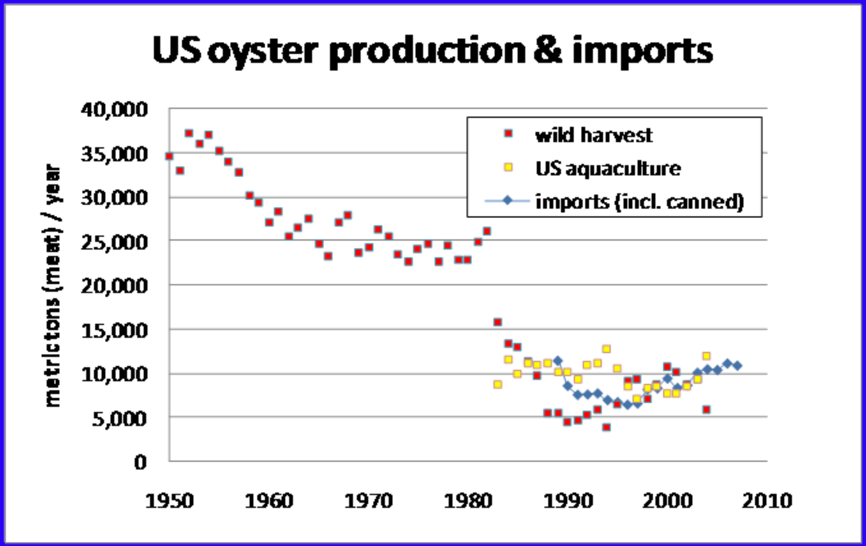


Aquaculture & Wild Fisheries









List of Ecological Effects (2)

- Exotic species
- Disease concentration & transmission
- Genetic effects
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** Carrying Capacity **

Carrying Capacity Concepts

- Physical Carrying Capacity — maximum farming activity in the available physical space (Inglis *et al*. 2000)

- Production Carrying Capacity — the stocking level or density that maximizes production harvests (Kaiser and Beadman 2002)

- Ecological or Ecosystem Carrying Capacity — the stocking level or density above which “unacceptable” ecological impacts arise (McKindsey *et al.* 2006)




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- Ecological or Ecosystem Carrying Capacity — the stocking or density above which unacceptable ecological impacts arise (McKindsey *et al.* 2006)

- Social Carrying Capacity — the maximum extent of farming that avoids unacceptable recreational/aesthetic impacts (Gibbs 2007, 2009)

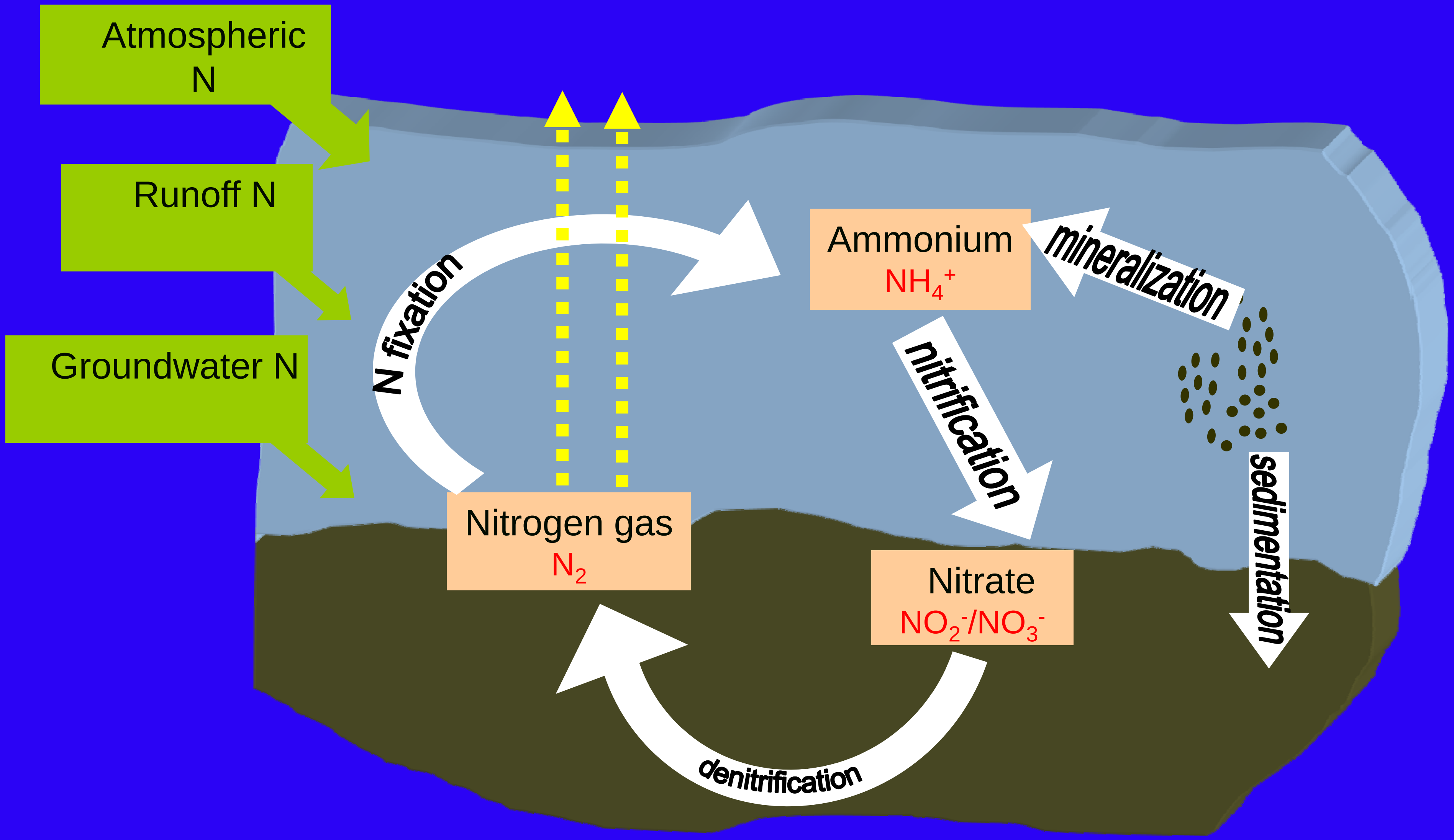
physical CC > production CC > ecological CC > social CC

Waquoit Bay (E. Falmouth)

- N loading has increased with development
- Recurring problems with algal blooms

Oyster & Hard Clam Growout Experiment

Simplified Nitrogen Cycle



Eutrophication

- N loading increase
- Changes in nutrient cycle
  - N is limiting nutrient
  - Algal blooms
- Anoxia, fish kills
- Eelgrass loss

Addressing Eutrophication

- Upstream
  - Land-use regulations
    - Pollutant tax
    - Discharge permit system
  - Alternative septic systems
  - Centralized sewage treatment facility
- Downstream
  - Shellfish aquaculture

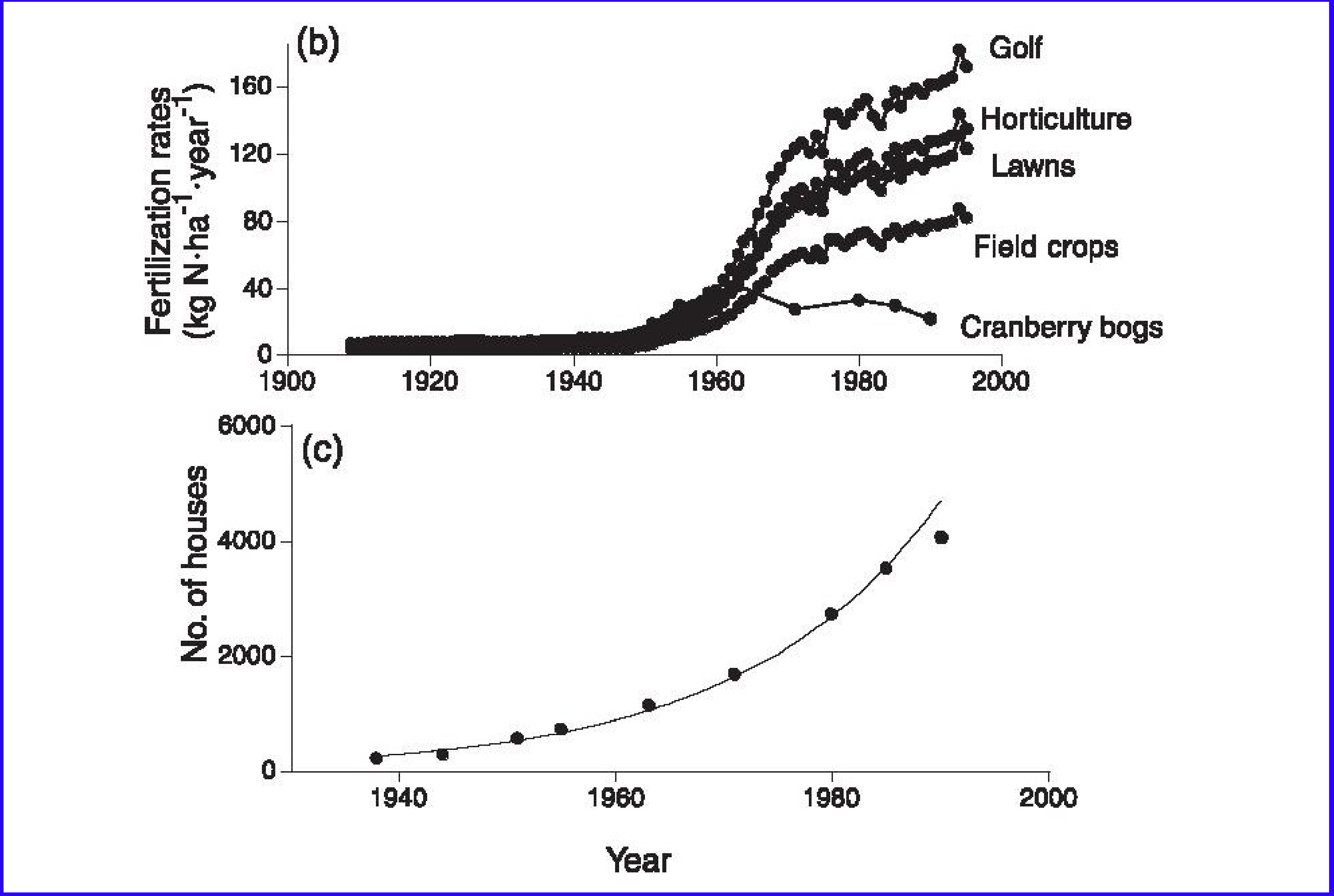
Nitrogen Removal: Oysters

1 square meter tray: 500 oysters

year	1	2	3
incr. denitrif. (kg)	0.01	0.31	0.60
harvesting (kg)	--	--	0.31
	0.01	0.31	0.91

average: 0.41 kg N per m^2 per year

Land Development: Waquoit Bay Watershed



Source: Bowen & Valiela 2001

Nitrogen Loading to Waquoit Bay Watershed (kg/year)

	1990s		1930s	
	N input	% of load	N input	% of load
Atmospheric deposition	95,500	59	91,300	95
Fertilizer	30,500	19	3,200	3
Wastewater	35,700	22	2,100	2
Total	161,700	100	96,600	100

Valiela, I. *et al.* (1997) Ecol. App., 7(2): 358-380

Bowen, J. and Valiela, I. (2001) Can. J. Fish. Aquat. Sci., 58: 1489-1500

Nitrogen Loading to Waquoit Bay Estuary (kg/year)

	1990s		1930s	
	N input	% of load	N input	% of load
Atmospheric deposition	9,100	38	8,400	77
Fertilizer	4,700	19	1,700	16
Wastewater	10,500	43	700	7
Total	24,300	100	10,900	100

Valiela, I. *et al.* (1997) Ecol. App., 7(2): 358-380

Bowen, J. and Valiela, I. (2001) Can. J. Fish. Aquat. Sci., 58: 1489-1500

N Load Reduction

Objective: “eliminate” increased N loading to Waquoit Bay since 1930s: 13,400 kg/yr

Economic efficiency: reduce N using least cost options first.

Management Options

Upstream options:

– Atmospheric deposition: limited scope, esp. short term

– Fertilizer application: possible, but limited scope
  - 50% reduction in application -> 2,700 kg N/yr into estuary, = 20% of target only

– Wastewater treatment: possible, but expensive
  - 2.7 kg N/yr/home into estuary; cost to eliminate is $500/yr/home
  - Onsite denitrifying septic system: 65% effective
  - Neighborhood sewage treatment: 80% effective
  - Large-scale sewage treatment: 90+% effective

Management Options

Downstream option: shellfish farming

- Benefits
  - Removal of N
  - Net value of shellfish production
- Costs:
  - Change in value of real estate
  - Change in value of recreational benefits

- Likely order of alternatives:
  - Shellfish farming
  - Fertilizer application
  - Wastewater treatment

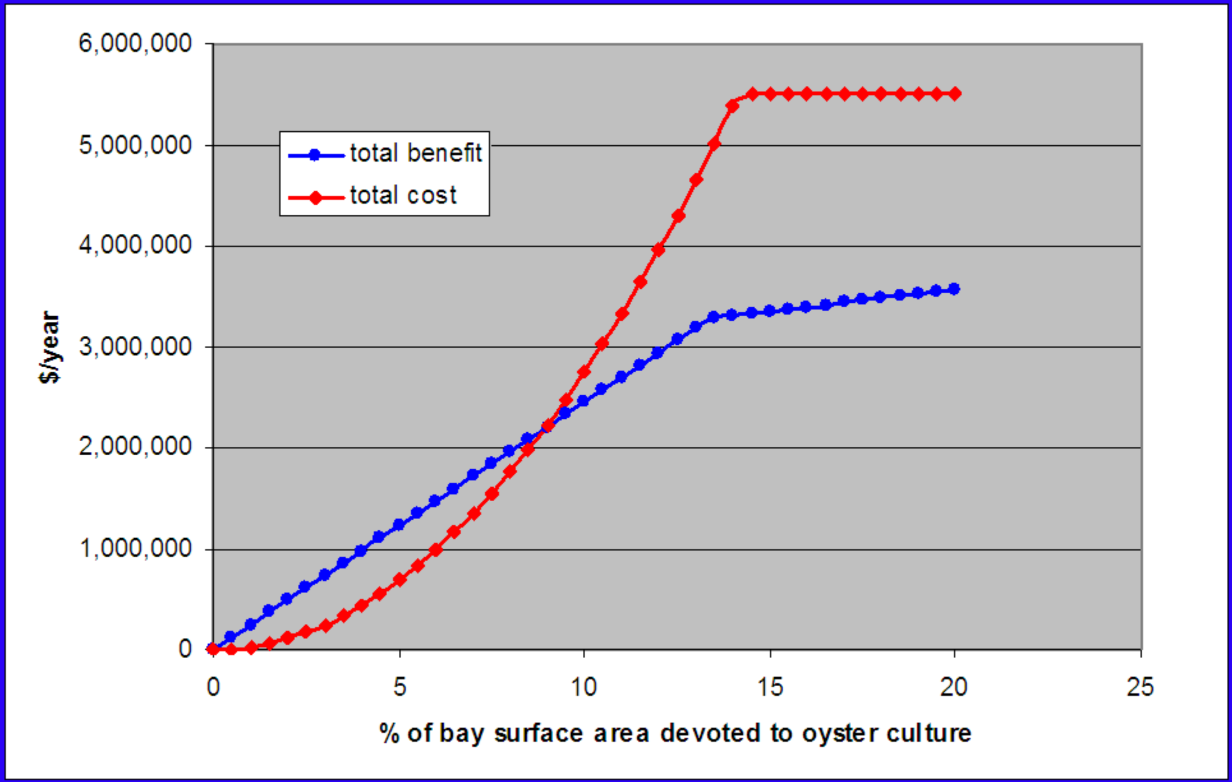
Waquoit Bay N Management

- Objective: “mitigate” increased N loading to Waquoit Bay (13,400 kg/yr)
- Question: what is the potential contribution of oyster farming to this objective?
- Removing 13,400 kg N/yr requires some 90,000 m^2 devoted to oyster farming. Is this feasible?

Economic Model of Social CC

- benefit = avoided cost of upstream control measures + economic surplus of shellfish farm operations
  - avoided cost: $185/kg/yr
  - surplus: 20% of farmgate sales
- cost = loss of real estate value (aesthetic) plus loss of recreational value
  - coastal location premium 30% on mean value of $300,000 for 1,000 homes in WB area
  - recreational value 50,000 person-days/yr at $20

Benefit and Cost of Oyster Farming



- max. net benefit at 4% of WB area
- C > B at 8% of WB area
- 8% could remove 8,000 kg N/yr, or 60% of target

Note: TBD:

- Production C.C.? – probably OK
- Ecological C.C.? – not yet studied

Conclusions (1)

- Shellfish farming can have a wide range of ecological effects
  - Extent of effects depends on scale, nature of farming operations
  - Typically more “benign” than finfish farming
- Shellfish farming can play a significant role in providing protein for growing world population
  - Many coastal regions are underutilized
  - Can be ecologically neutral or beneficial, depending on scale and setting

Conclusions (2)

- Shellfish farming can play a substantial role in managing N levels in coastal waters
  - not a “magic bullet” (setting has to be right)
  - physical/ecological carrying capacity must be adequate
- In the U.S., social carrying capacity is often likely to be a binding constraint
  - socially optimal level of farming depends on local preferences and perceptions
  - community-level aquaculture management plans are a good idea

Closing Thoughts for Shellfish Aquaculture Managers & Growers

- Think in terms of tradeoffs, carrying capacity, acceptable levels of effects
- Invest in community relations (social carrying capacity is negotiable)
- Invite marine scientists along
  - Bio-geo-chemical links
  - Species interactions
  - Bio-economics

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