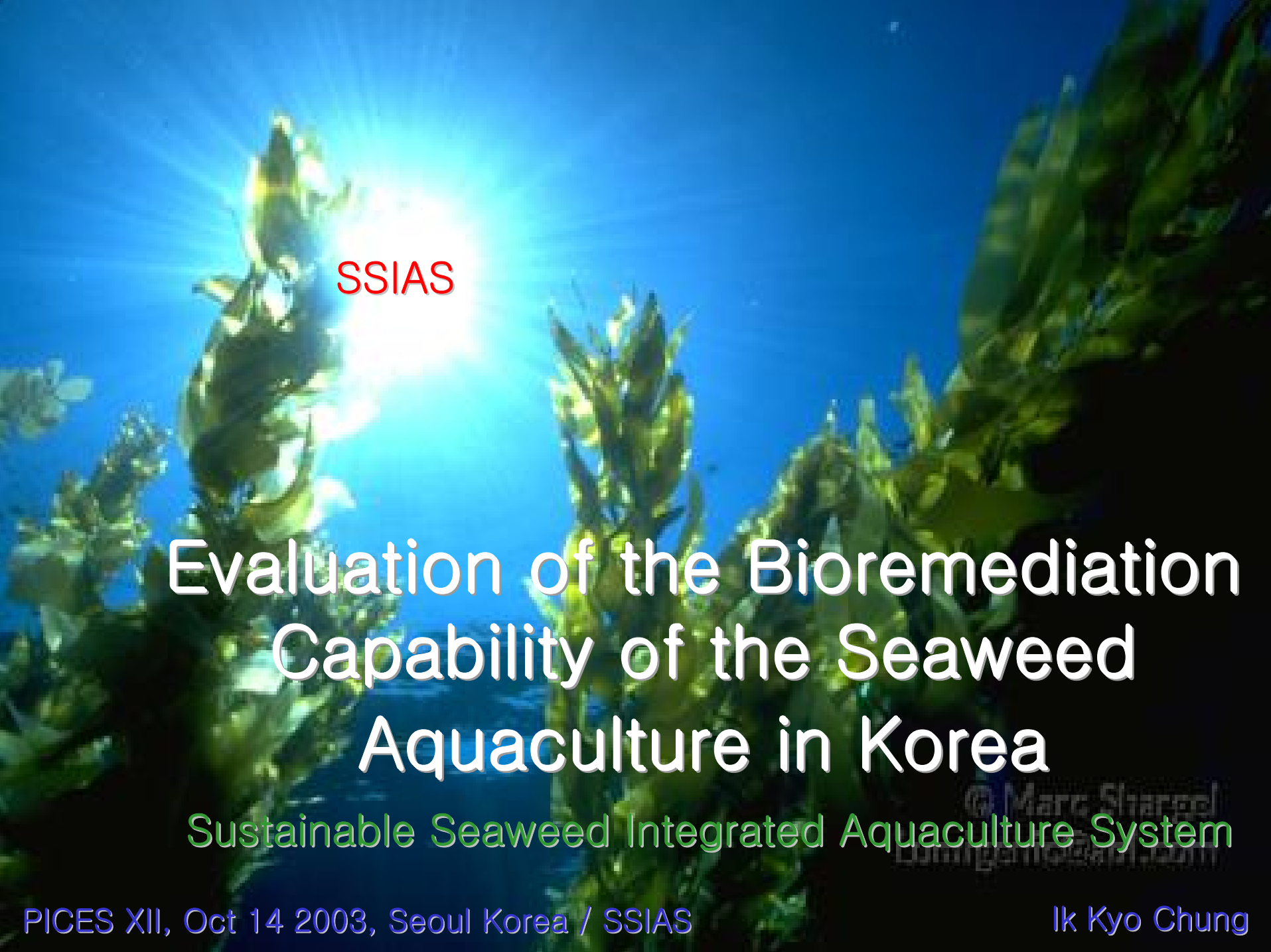


SSIAS

Evaluation of the Bioremediation Capability of the Seaweed Aquaculture in Korea

Sustainable Seaweed Integrated Aquaculture System

PICES XII, Oct 14 2003, Seoul Korea / SSIAS

Ik Kyo Chung

Team Work

Ik Kyo Chung, S.J. Ryu and Y.H. Kang

Dept. of Marine Science, Pusan National University

J.A. Lee

School of Environmental Science and Engineering, Inje University

T.-H. Seo and J.-A. Shin

Division of Aquatic Science, Yosu National University

C. Yarish

Dept. of Ecology and Evolutionary Biology, University of Connecticut, USA

Y.-F. Yang

Institute of Hydrobiology, Jinan University, China

Bilateral Project

- China

  "Bioremediation effects of cultivation of large-sized seaweeds in the eutrophic mariculture areas"

  - P.I. Dr. Yu-Feng Yang

- Korea

  "The development of environmentally sound integrated polyculture system"

  - P.I. Ik Kyo Chung

Interactions between Aquaculture and Environment

- Modification to the environment
- Waste products – eutrophication
- Interactions with wildlife
- Use of resources

Example

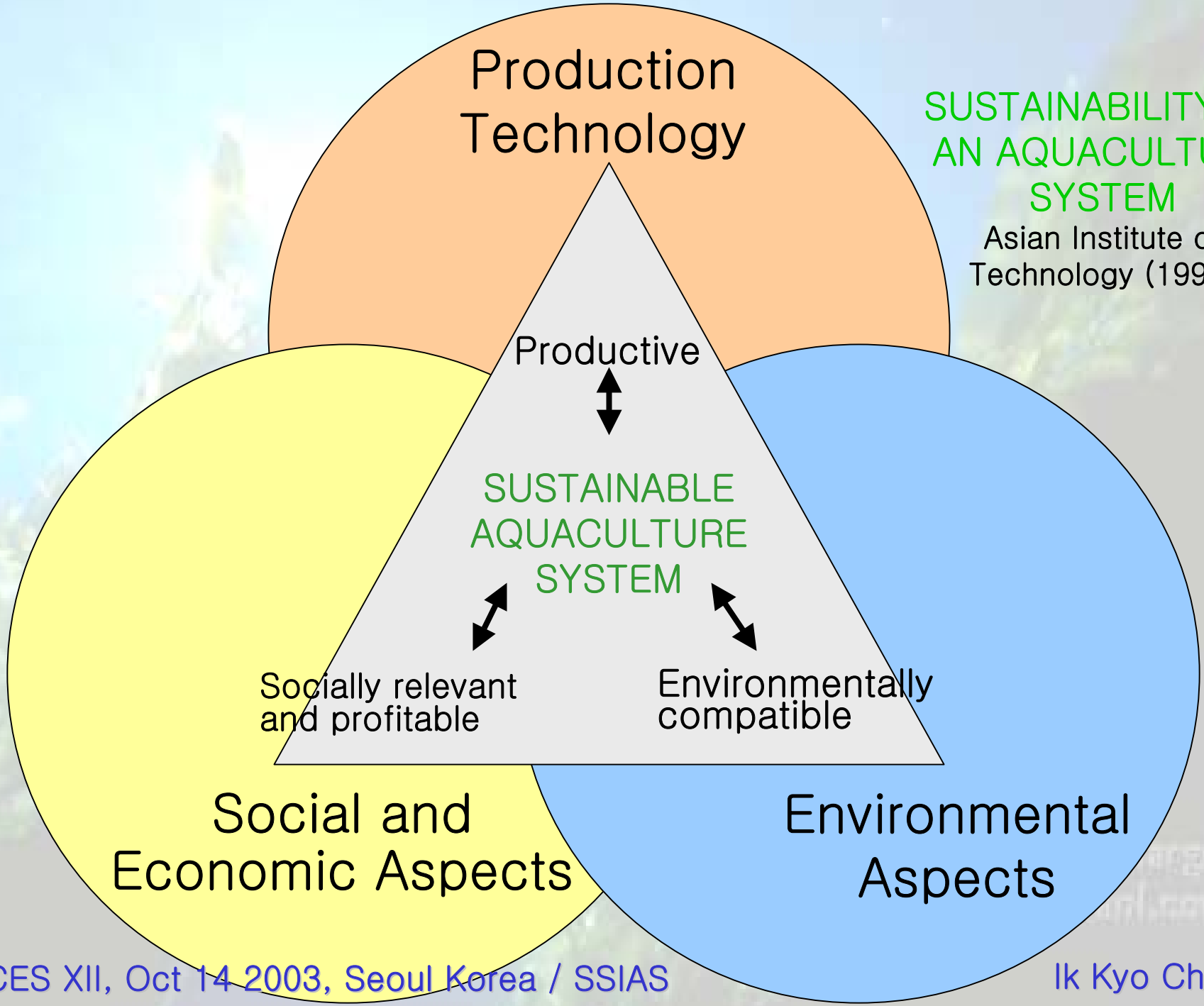
- Caged salmon farming
  - Water movement and quality
  - Sedimentation and benthic enrichment
  - Introduction of exotic species

Priority Areas for Further Research (FAO)

- the adoption of aquaculture by poor rural households;
- technologies for sustainable stock enhancement, ranching programmes and open ocean aquaculture;
- the use of aquatic plants and animals for nutrient stripping;
- integrated systems to improve environmental performance;
- managing the health of aquatic animals;
- nutrition in aquaculture;
- the quality and safety of aquaculture products;
- emerging technologies, including recirculating systems, offshore cage culture, integrated water use, artificial upwelling and ecosystem food web management, domestication and selective breeding and genetic improvement.

Old Wisdom : Ultimate Solution

- Can **seaweed aquaculture** reduce the environmental impact of cultural eutrophication in the coastal environment?
- Can **the integration of seaweed aquaculture** with fed aquaculture be the solution of bioremediation of eutrophication caused by nutrient rich effluents from finfish and other forms of fed aquaculture in the coastal ecosystem?
- Why do we consider the Sustainable Seaweed Integrated Aquaculture System (SSIAS)?


Production Technology
SUSTAINABILITY OF AN AQUACULTURE SYSTEM
Asian Institute of Technology (1994)
Productive
SUSTAINABLE AQUACULTURE SYSTEM
Socially relevant and profitable
Environmentally compatible
Social and Economic Aspects
Environmental Aspects

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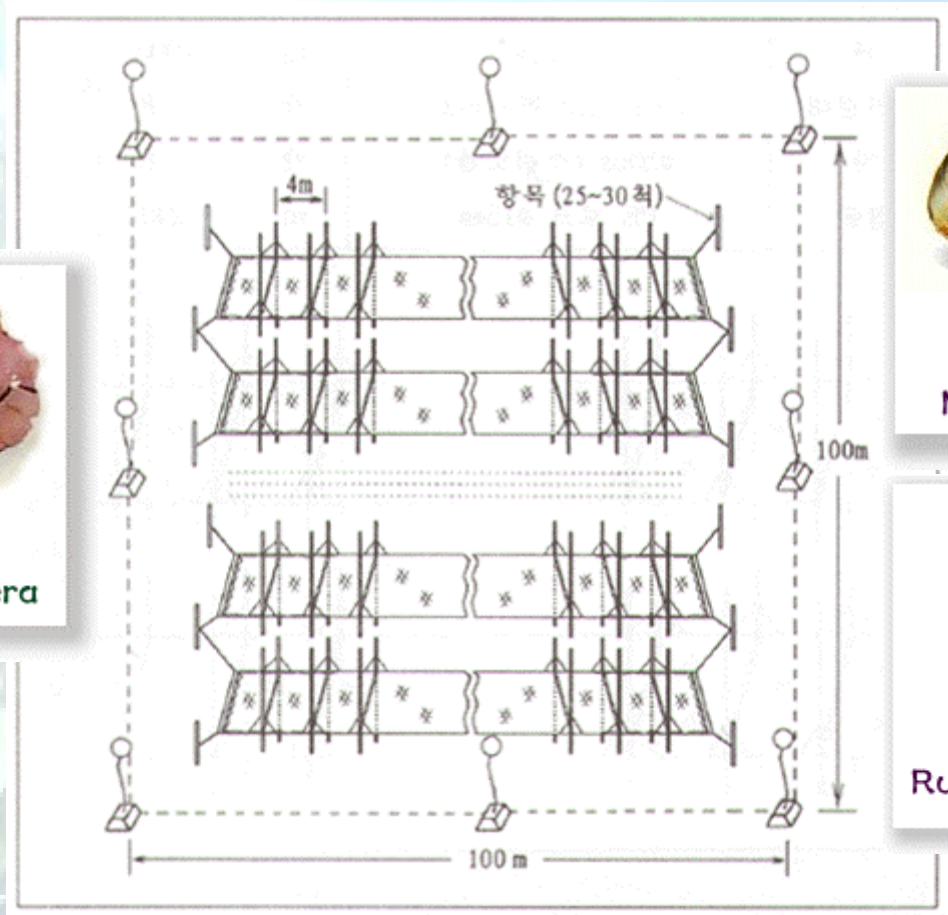
Integrated Culture Examples

- Israel: Sea bream + *Ulva*; abalone + fish + *Ulva*; abalone + fish + mollusc + *Ulva*
- China: Shrimp + crab + seaweeds; mussel + scallop + *Laminaria*/*Undaria*
- Japan: shrimp + *Ulva*
- European estuary: integrated polyculture system
- Norway: salmon + mussel + seaweed
- Canada (northwest): salmon + *Porphyra*
- Hawaii: shrimp + *Gracilaria*
- Chile: seaweed biofilter – *Gracilaria* + salmon
- Philippine (with Norway): sea urchin/sea cucumber + *Eucheuma*/*Gracilaria*
- France: sewage treatment system–*Ulva*
- South Africa: finfish aquaculture effluent + *Gracilaria*
- Southeast Asia: shrimp + seaweeds
- Australia: shrimp + oyster + *Gracilaria*, *Saccostrea*

Polyculture Experiences in Korea

- Studies on the development of polyculture system in the coastal waters of Korea
- Background
  - Decreased aquaculture productivity
    - Over-stocking, loss of culture grounds, increase in land-fills, pollution - *i.e.* cultural eutrophication, industrial contamination, etc.
    - Sustainability
- Objectives
  - To do feasibility study and analyses of polyculture
  - To develop practical guidelines for polyculture
- National Fisheries Research Institute
- Period: 1990-1994

Polyculture

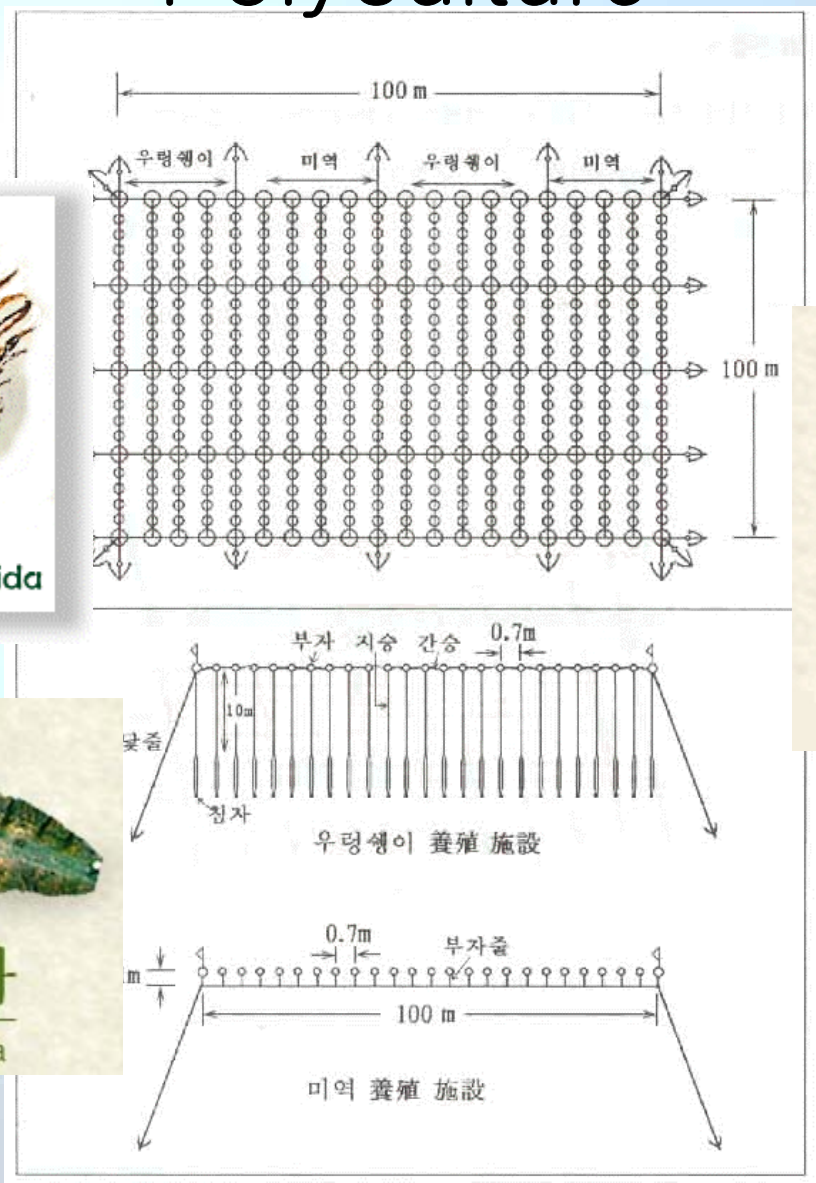


김
Porphyra tenera

동 죽
Mactra veneriformis

바지락
Ruditapes philippinarum

Polyculture



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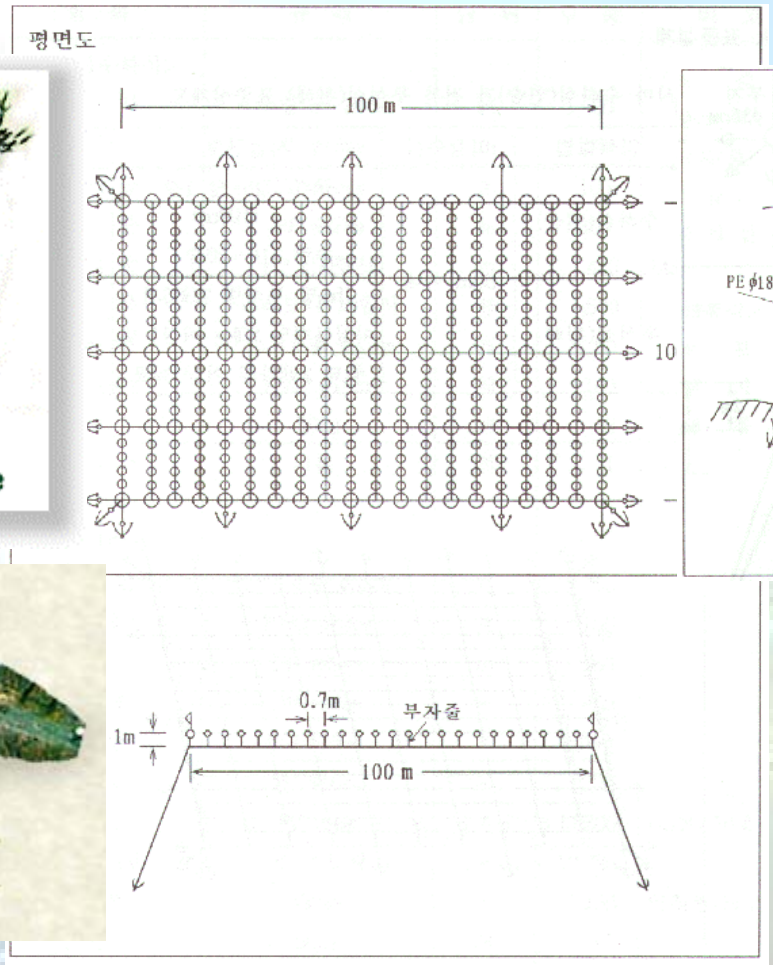
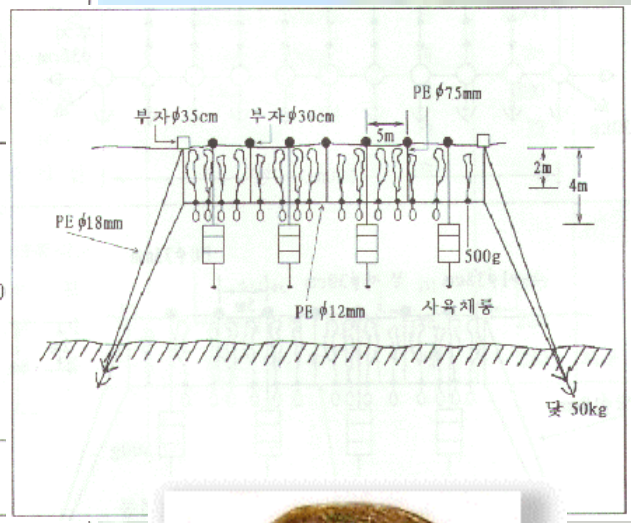
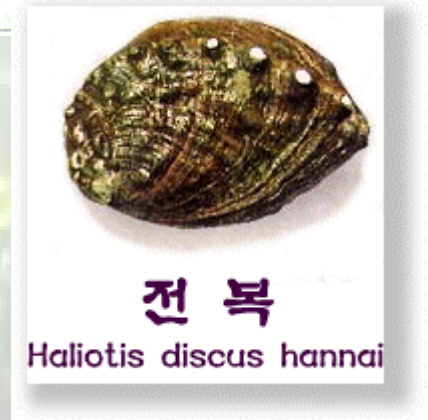
Polyculture



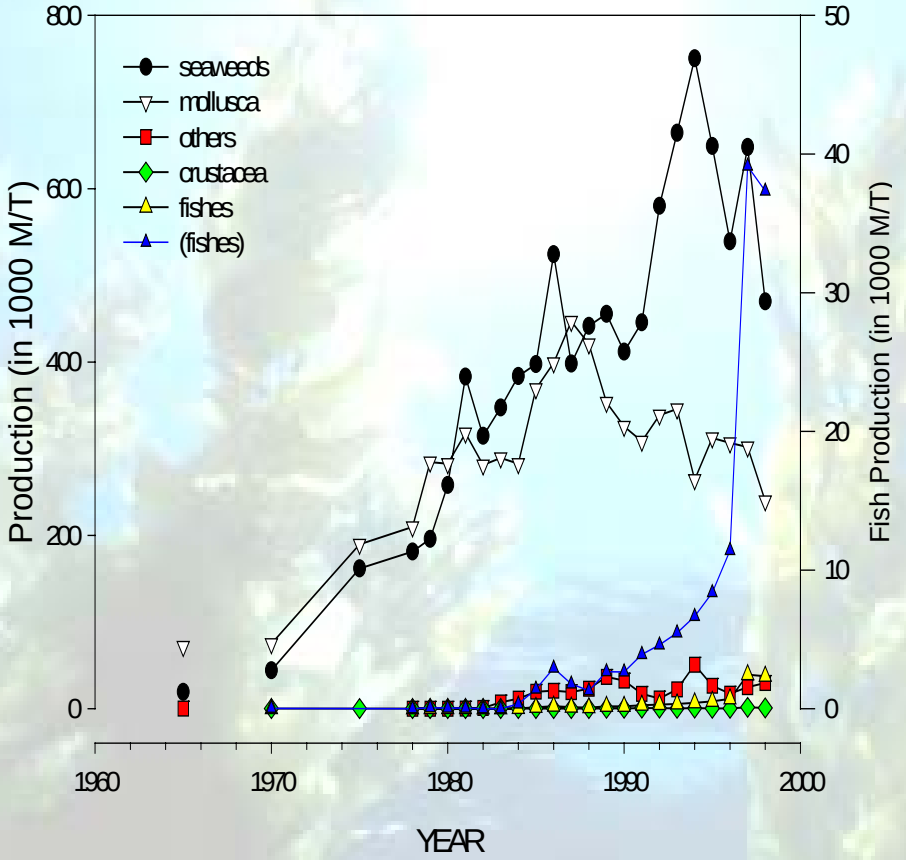


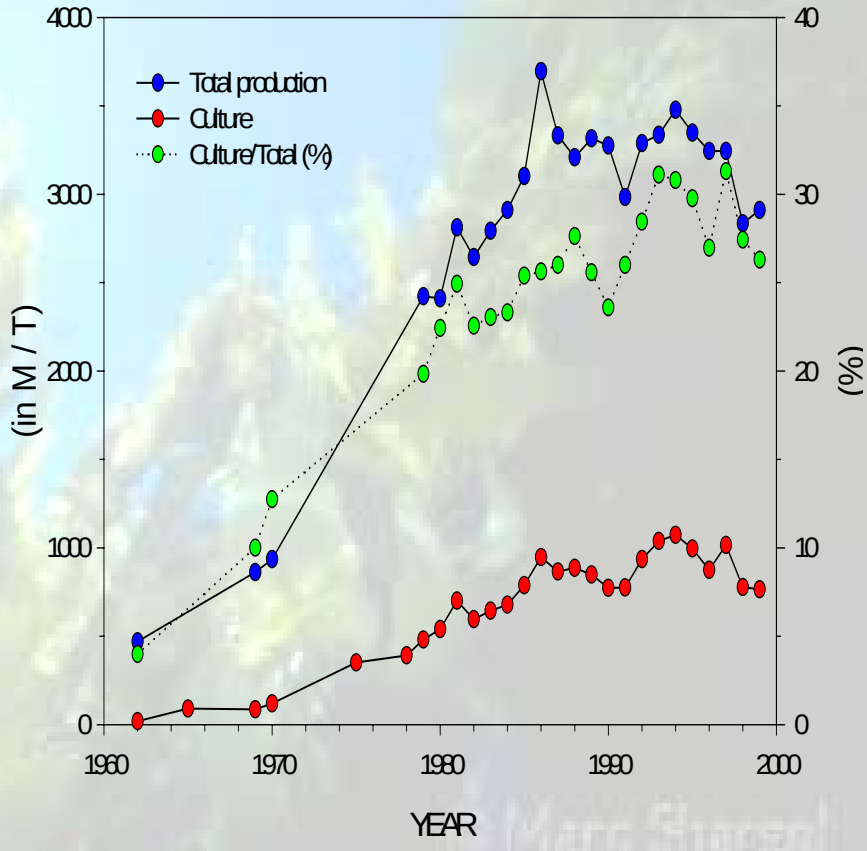


Study Areas and Aqucultured Species

- Southeastern coastal area
  - Sea squirts (*Halocynthia roretzi*)
  - Seaweeds (*Undaria pinnatifida*, *Laminaria japonica*)
- Mid-western coastal area
  - Abalone (*Haliotis discus hannai*)
  - Seaweeds (*Laminaria japonica*, *Hizikia fusiformis*)
- Southwestern coastal area
  - Short necked clams (*Ruditapes philippinarum*)
  - Surf clams (*Macta veneriformis*)
  - Seaweed (*Porphyra tenera*)
- Southern coastal area
  - Oyster (*Crassostrea gigas*), sea squirts (*Halocynthia roretzi*), blue mussel (*Mytilus edulis*)

Aquaculture Production in Korea





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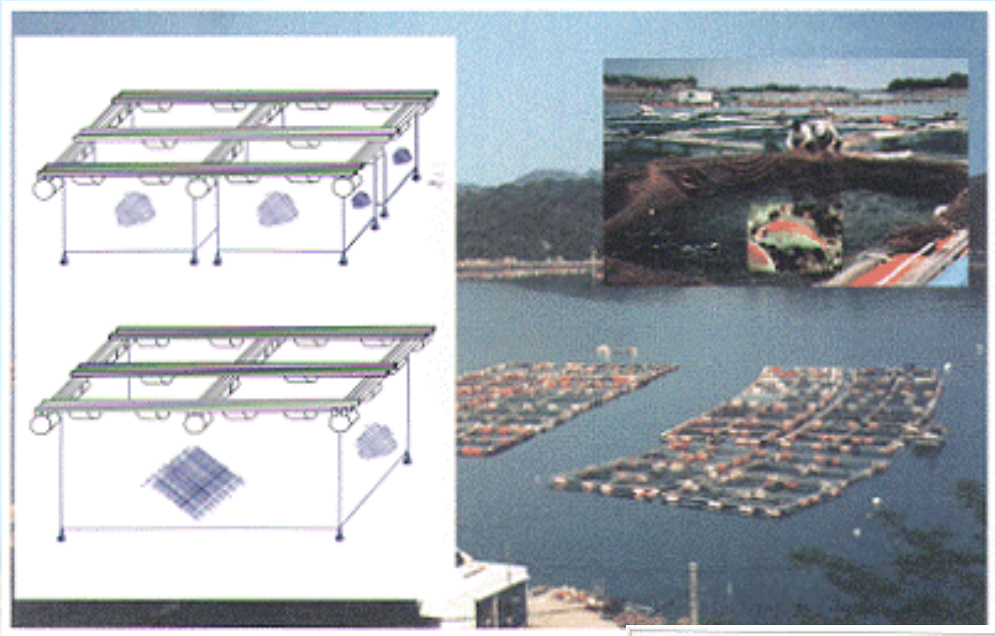
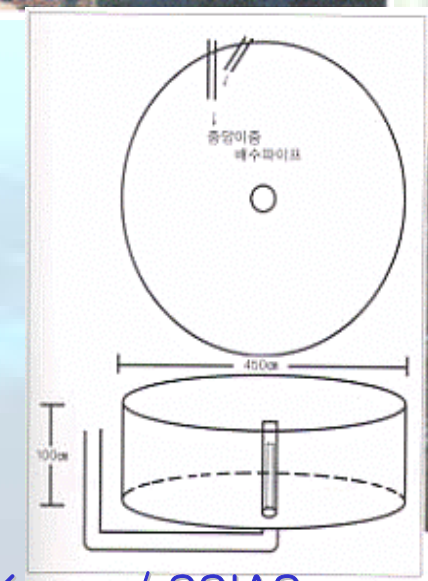
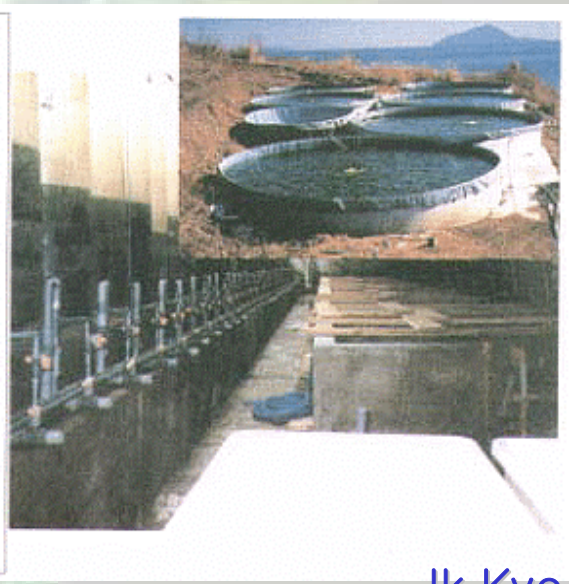
Aquaculture of Fish



Net cage





Tanks or pond

SSIAS Project Overview

- Concept: Integrate and balance extractive and fed aquaculture
  - Sustainability
    - Fed and extractive culture system
    - Seaweeds & shellfish
  - Environmentally soundness
    - Biofilter/production system : Seaweeds
  - Socio-economically viability
- Species
  - Temperature, light intensity, photoperiod, etc.
  - Cultivars
  - Wild species

First Step : Selection of Species Lab Experiments and Field Survey

- Cultivars and wild species
  - *Porphyra*, *Undaria*, *Laminaria*, *Enteromorpha* etc.
  - Field survey (all seasons)
  - Ecophysiological studies (biofiltration capabilities)
- Physiology under high ammonia concentration
  - Photosynthetic rates
  - Nutrient (ammonium) uptake rates
  - Growth rates
  - Environmental factors
- Seed stock
- Simple uptake and growth model
  - Simulation

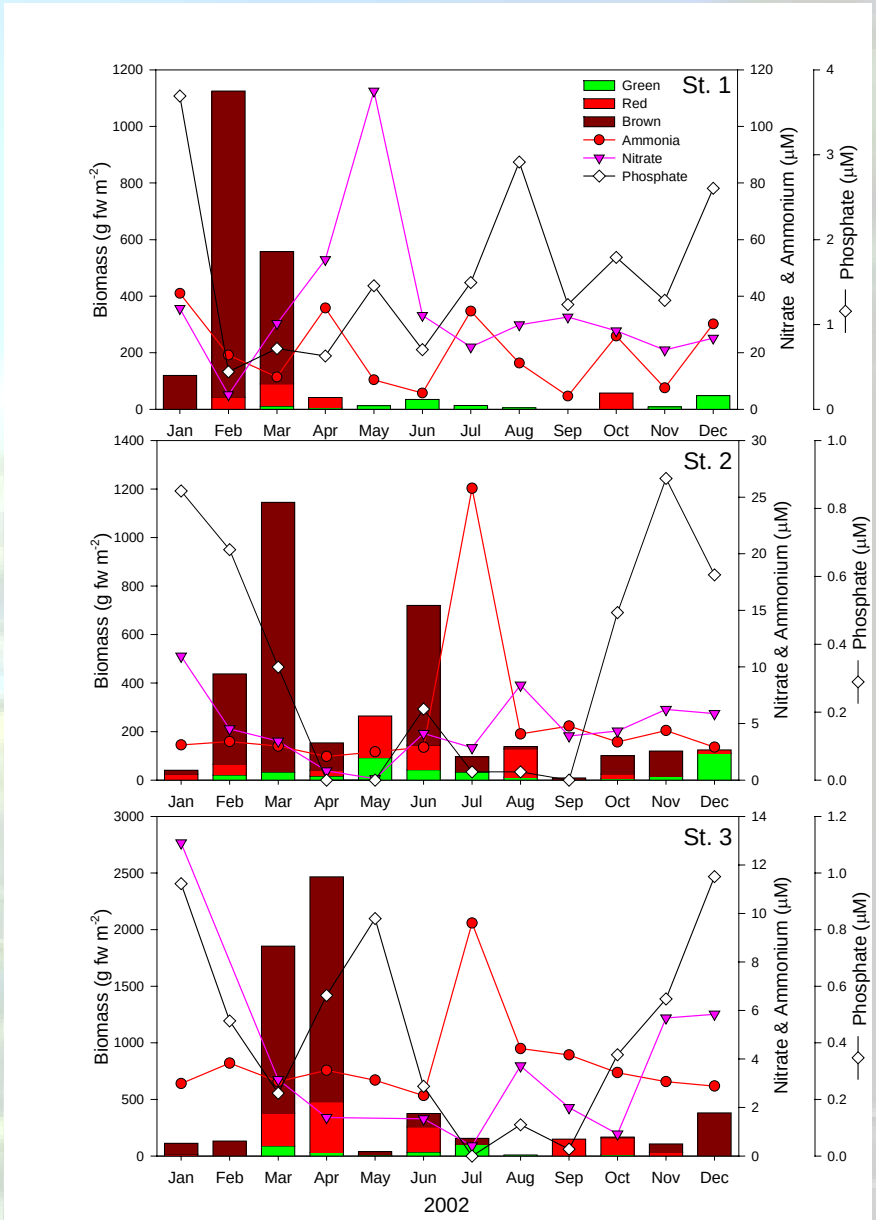
Lab scale experiments

Short - term Long - term

Field Survey

Pilot tank culture study

Field Survey



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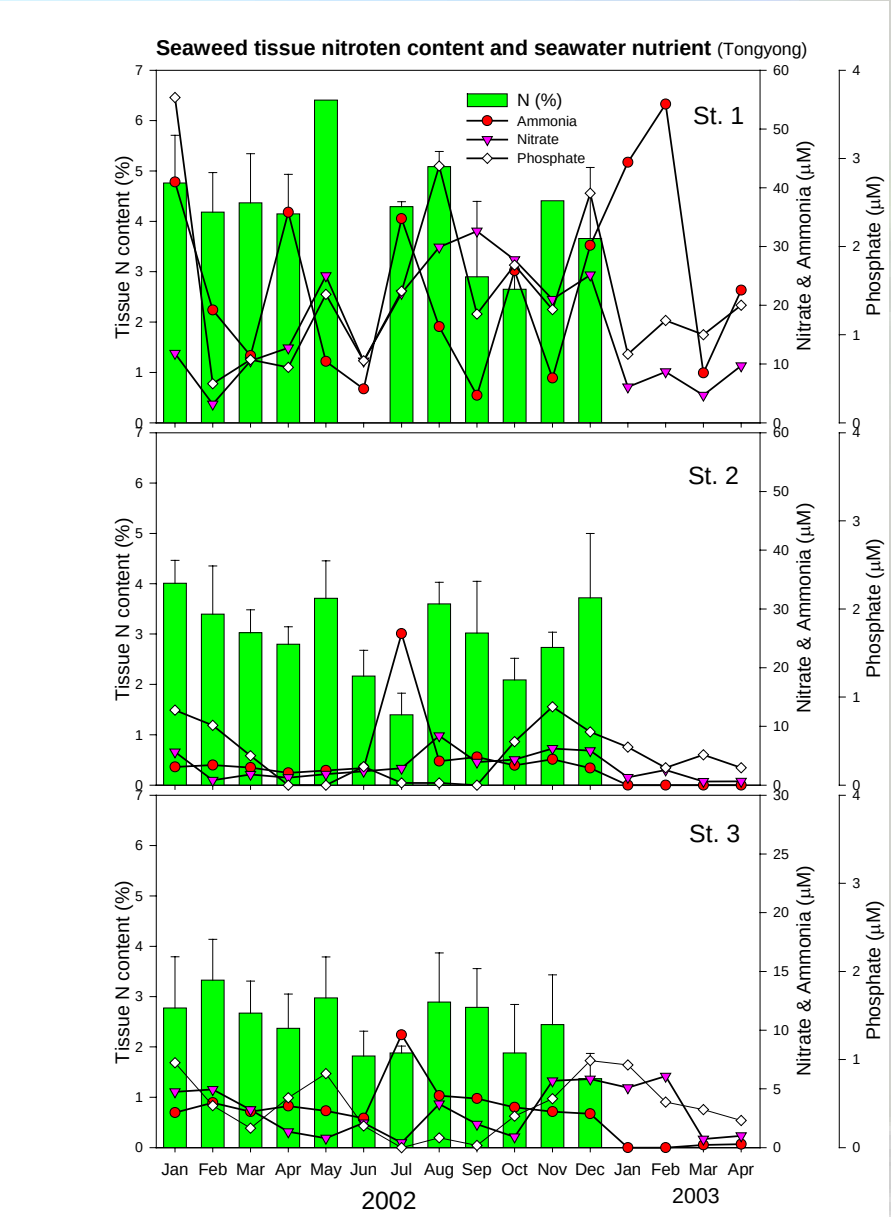
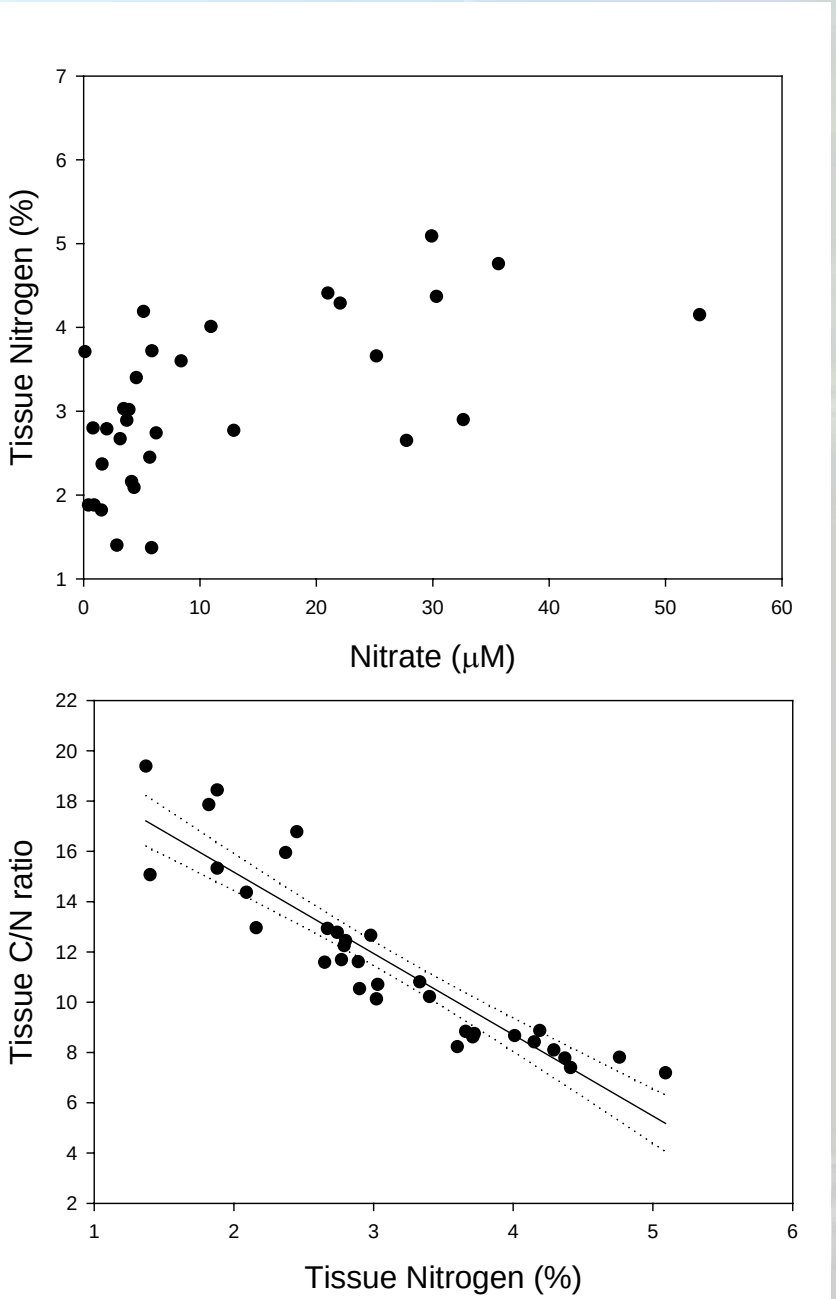
Field Survey



Field Survey



Rates of ammonium uptake

	Porphyra yezoensis		*Enteromorpha sp.*	
	NH_4^+ (μM)	Uptake rate (μmol · g^{-1}dw · min^{-1})	NH_4^+ (μM)	Uptake rate (μmol · g^{-1}dw · min^{-1})
V_{0-20}	40	0.160±0.117	40	0.394±0.044
	75	0.245±0.031	75	0.570±0.103
	150	0.885±0.187	150	1.673±0.115
	250	1.449±0.008		
V_{60-120}	40	0.105±0.081	40	0.116±0.079
	75	0.211±0.077	75	0.057±0.005
	150	0.506±0.198	150	0.125±0.066
	250	0.775±0.173		

Laminaria japonica (tank)

$V_{0-.5}$ 1.776 – 2.520

V_{2-11} 0.086 – 0.090

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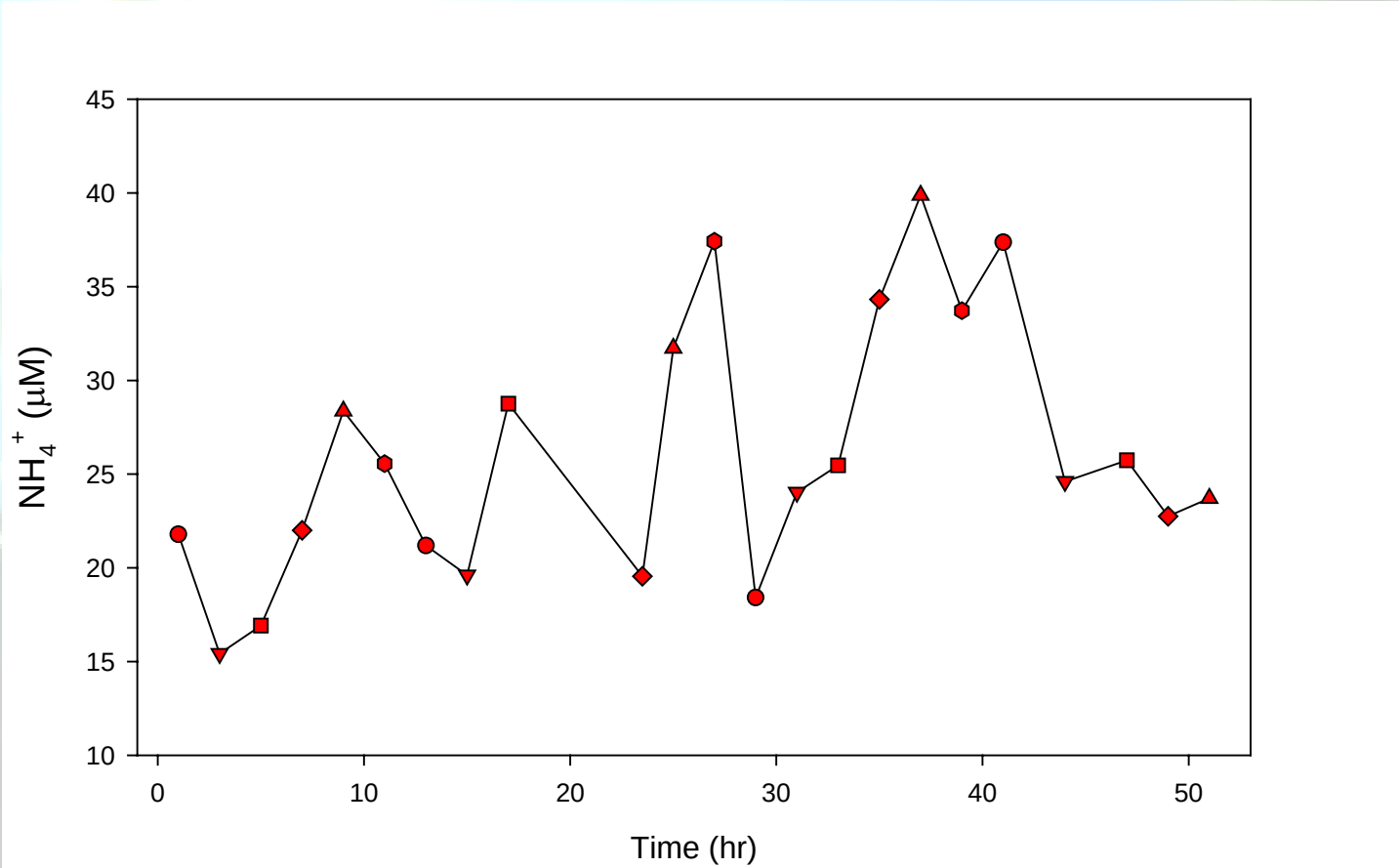
Second Step: Mid-Sized Pilot System

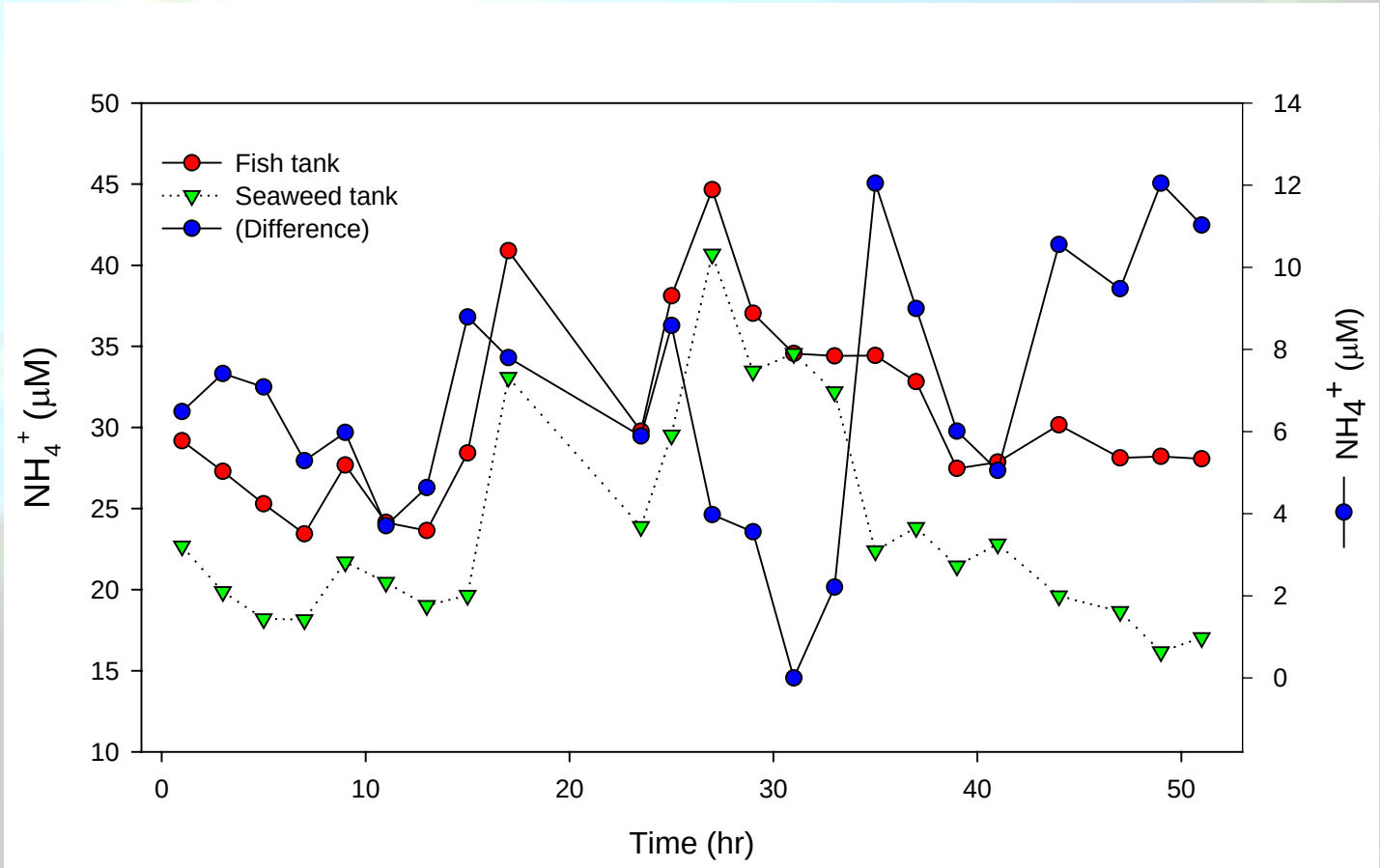
- Scaled-up system
- Large tank systems (>4m^3)
- Population level parameters
  - Biofilter
  - Growth, production and harvesting
  - Physical set-ups
    - Closed, flow-through
    - Flushing rate, flow rate, mixing (aeration)
    - Stocking density
- Simple model for biofilter/production efficiency
  - Nutrient cycle and budget (nitrogen, phosphorus)
  - Nutrient removal efficiency

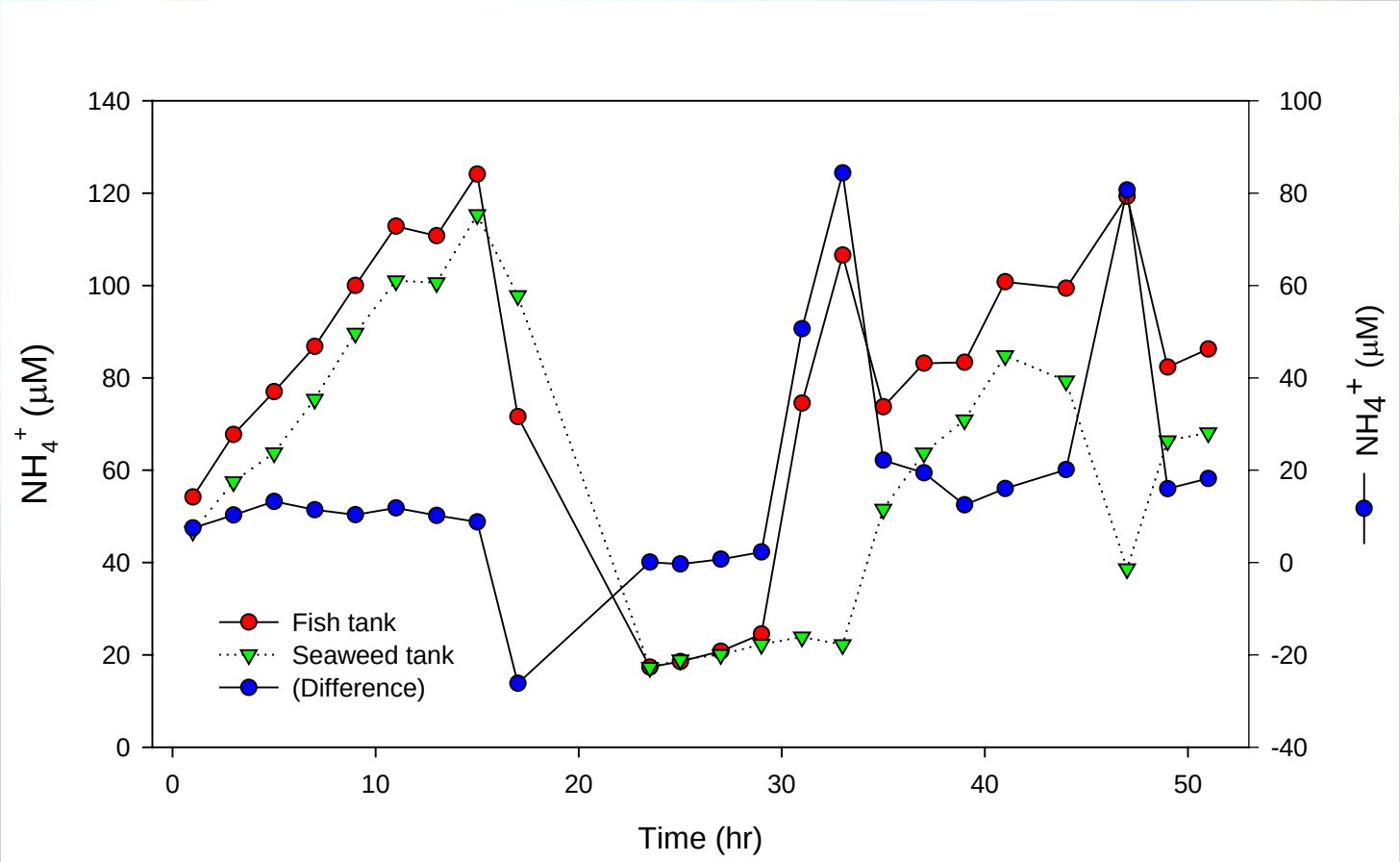
Pilot Tank Culture Study
(Finfish – Seaweed)

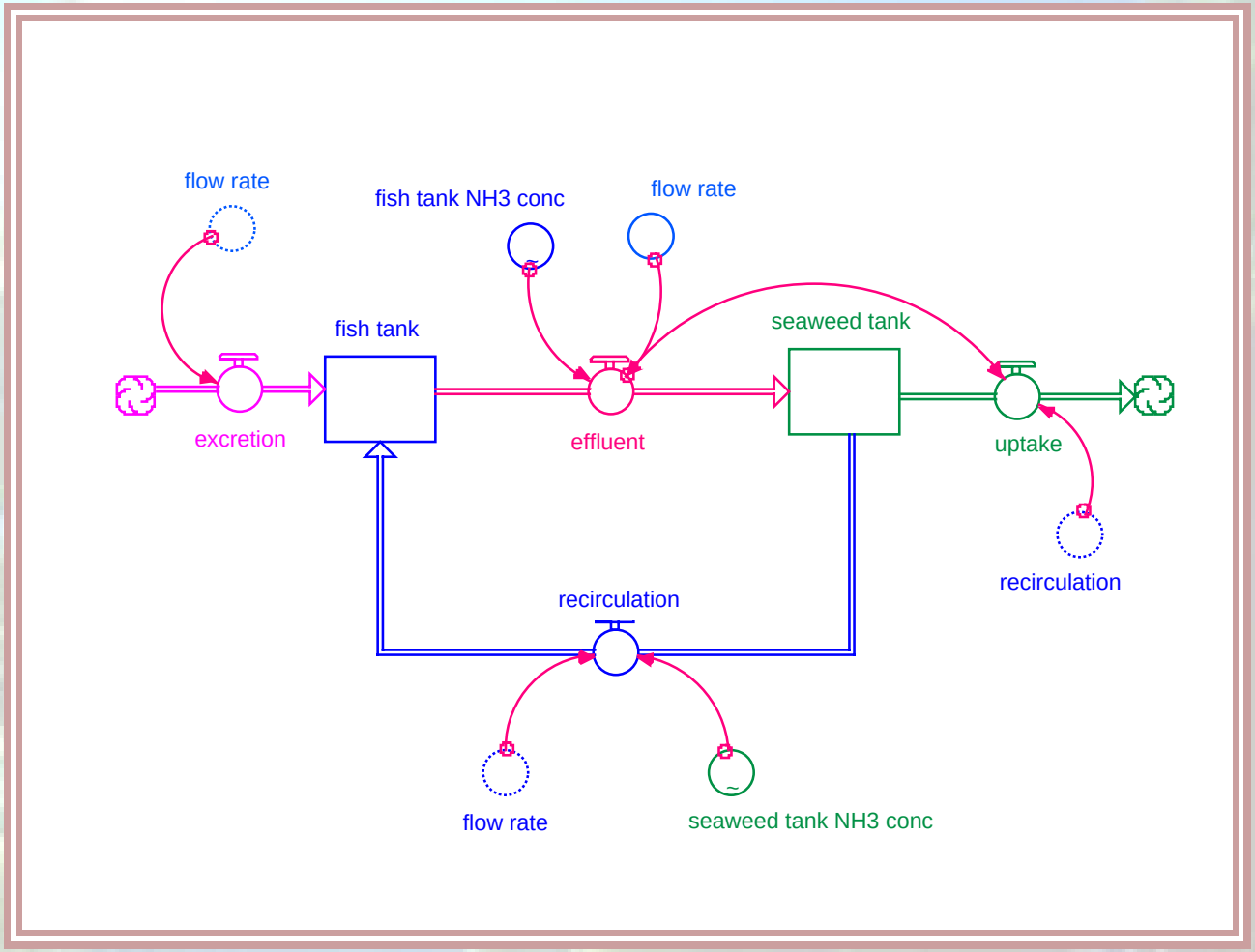
Acanthopagrus schlegeli (Bleeker)

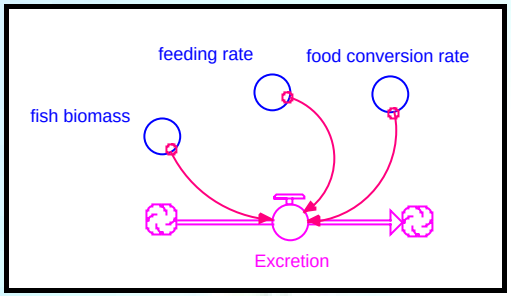
Ulva pertusa Kjellmann

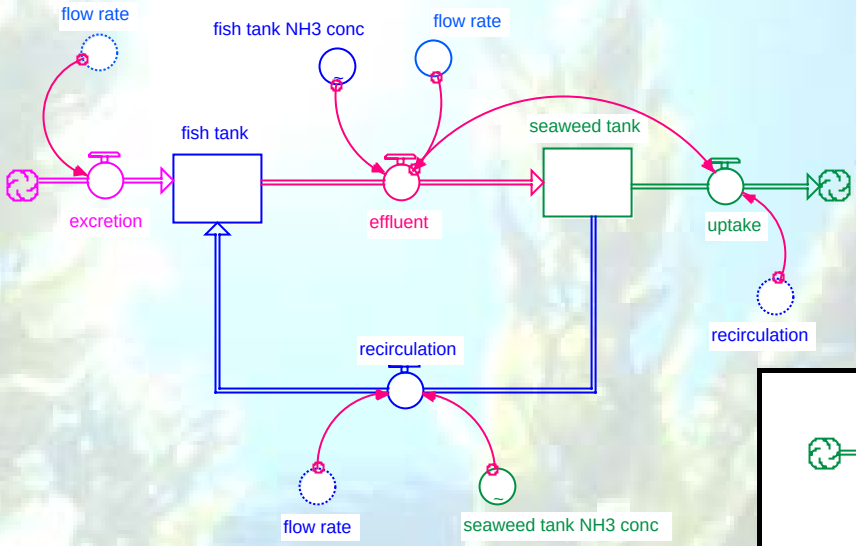

45
40
35
30
25
20
15
10
0
10
20
30
40
50
NH_4^+ (μM)
Time (hr)

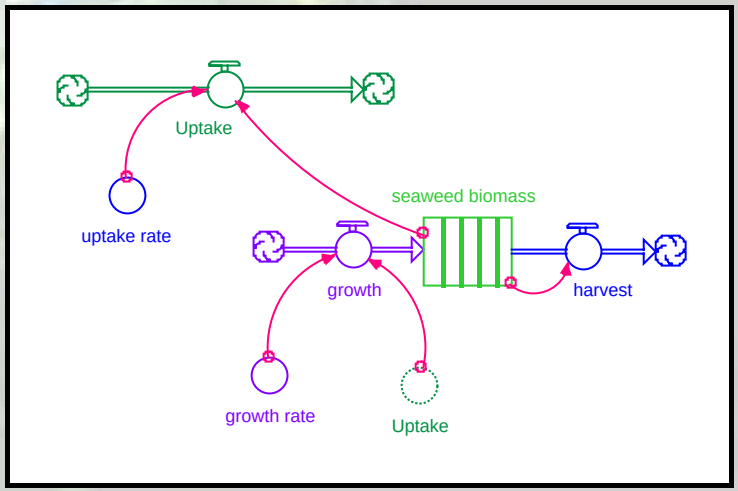

Fish tank
Seaweed tank
(Difference)
NH_4^+ (μM)
NH_4^+ (μM)
Time (hr)
50
45
40
35
30
25
20
15
10
14
12
10
8
6
4
2
0
0
10
20
30
40
50


140
120
100
80
60
40
20
0
100
80
60
40
20
0
-20
-40
0
10
20
30
40
50
Time (hr)
NH4+ (μM)
NH4+ (μM)
Fish tank
Seaweed tank
(Difference)


flow rate
fish tank NH3 conc
flow rate
fish tank
seaweed tank
excretion
effluent
uptake
recirculation
recirculation
flow rate
seaweed tank NH3 conc


feeding rate
food conversion rate
fish biomass
Excretion


flow rate
fish tank NH3 conc
flow rate
fish tank
seaweed tank
excretion
effluent
uptake
recirculation
recirculation
flow rate
seaweed tank NH3 conc


Uptake
uptake rate
seaweed biomass
growth
harvest
growth rate
Uptake

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Final step: Field application and operation

- Earthen ponds, tanks and raceways
  - with aeration and pH controls
- Floating net cage with long-lines and rafts
- Ecosystem and carrying capacity models
  - Odum (1993)
    - Inputs from outside the system; Processing functions; Outputs to the external environment
  - Rawson *et al*. (2002)
    - Understanding the carrying capacity of coastal waters for aquaculture
    - 3-D physical, chemical, and biological simulation
    - Jailhouse Bay and Incan Bay (Sino-US Living Marine Resources Panel)

Conclusion

- The amount of nitrogen removed by seaweeds aquaculture should not be underestimated
- The best practices for the SSIAS should be applied immediately.

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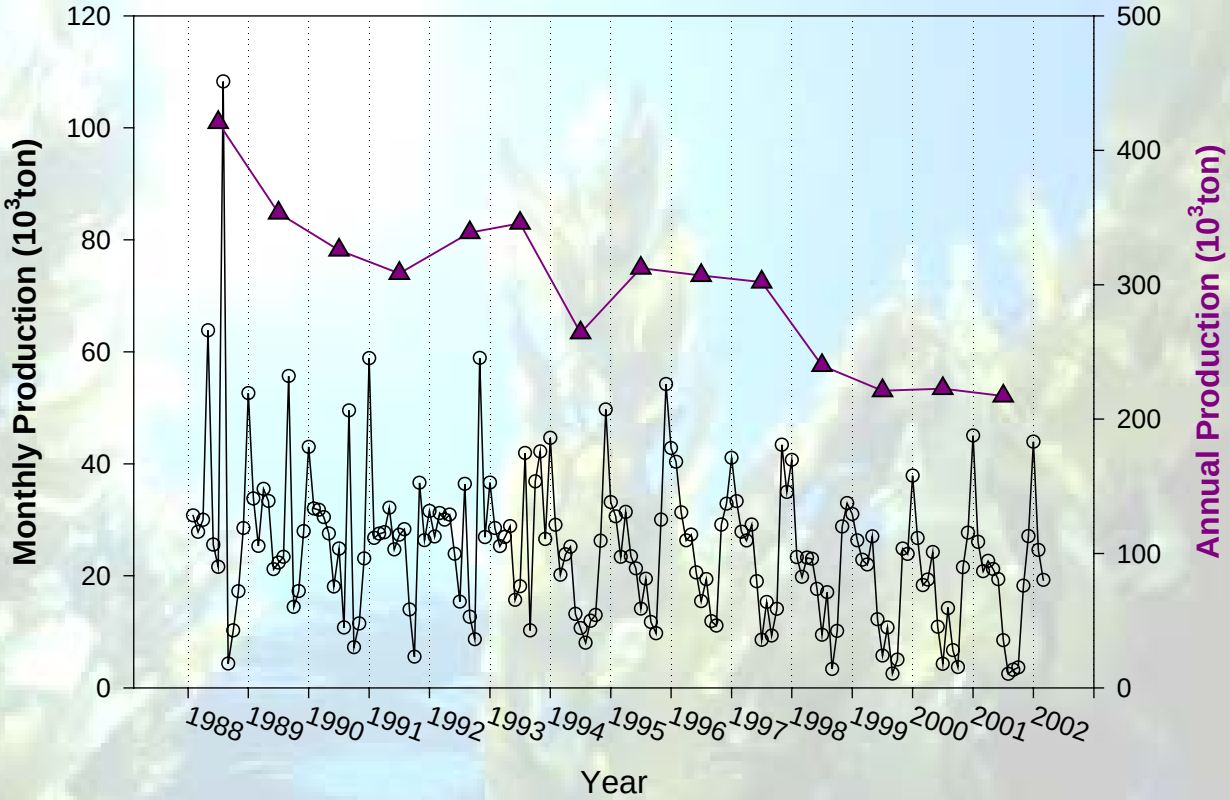
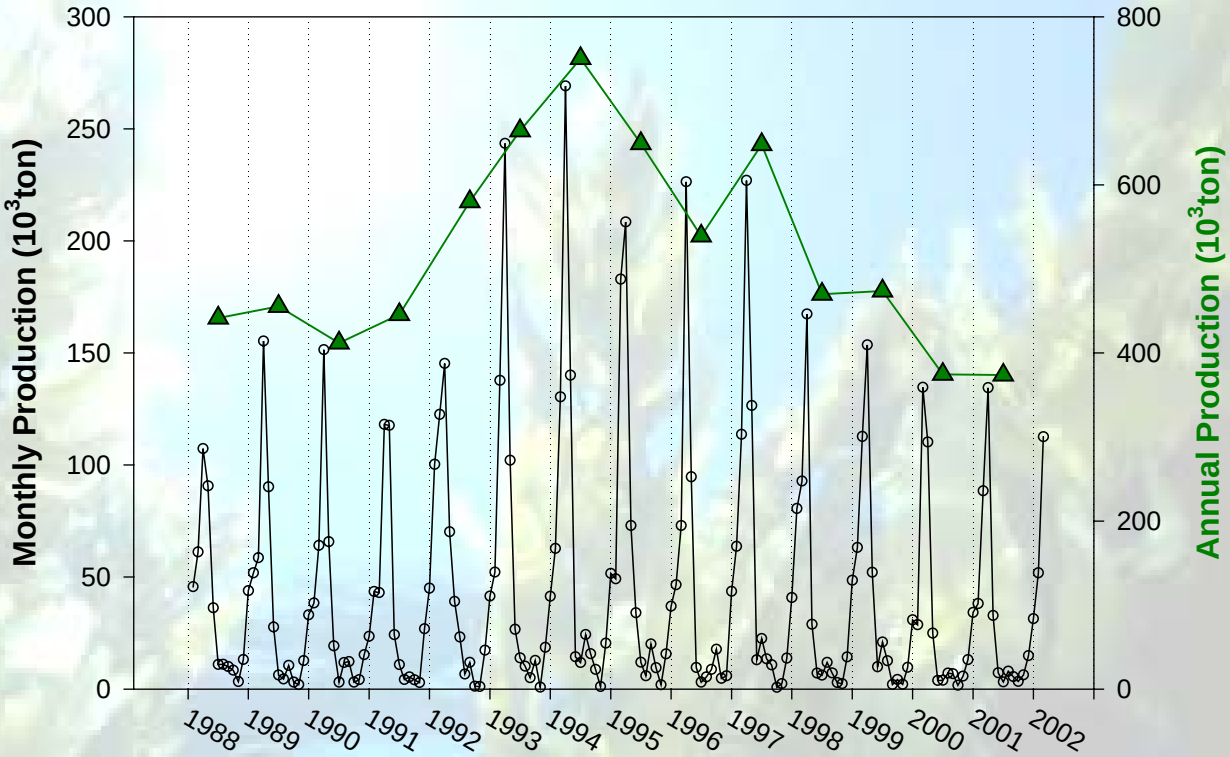
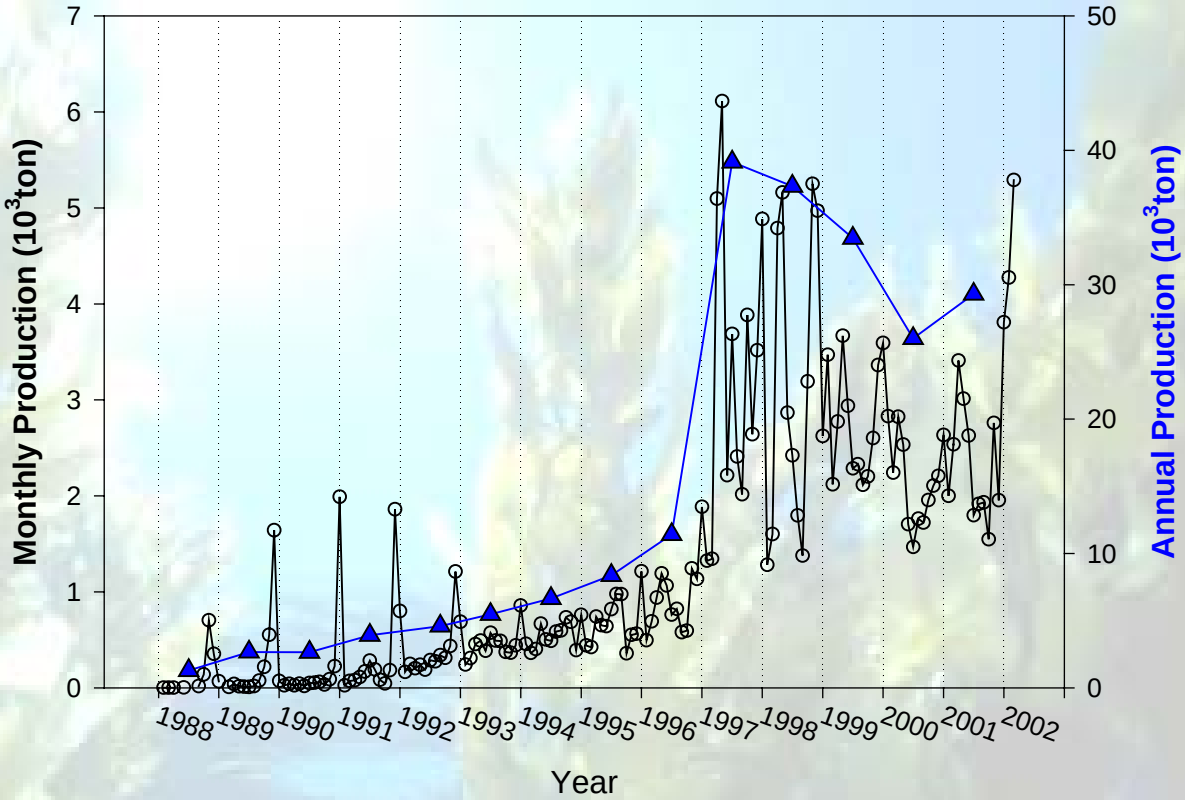
Shellfish Production



Seaweeds Production



Finfish Production



Crustacean Production