SPICOSA

Science and Policy Integration for COastal System Assessment

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SSA5 Limfordren, Denmark.

Interaction between eutrophication and mussel production

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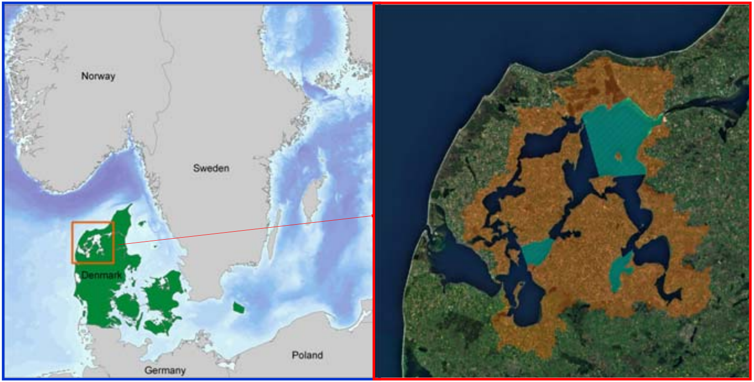

Norway
Sweden
Denmark
Poland
Germany

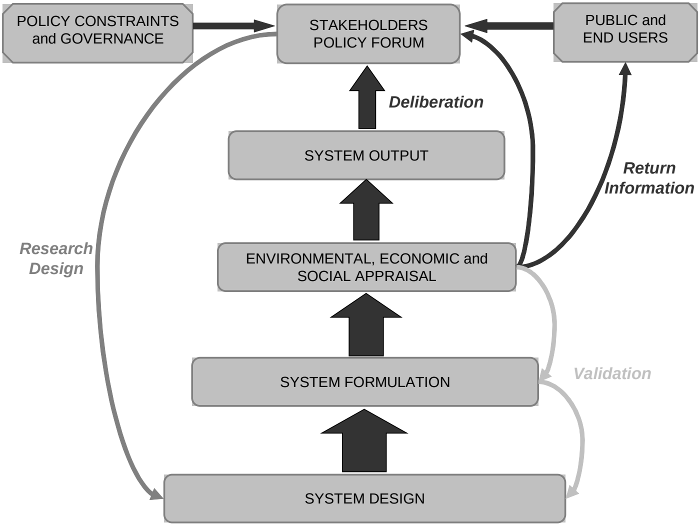
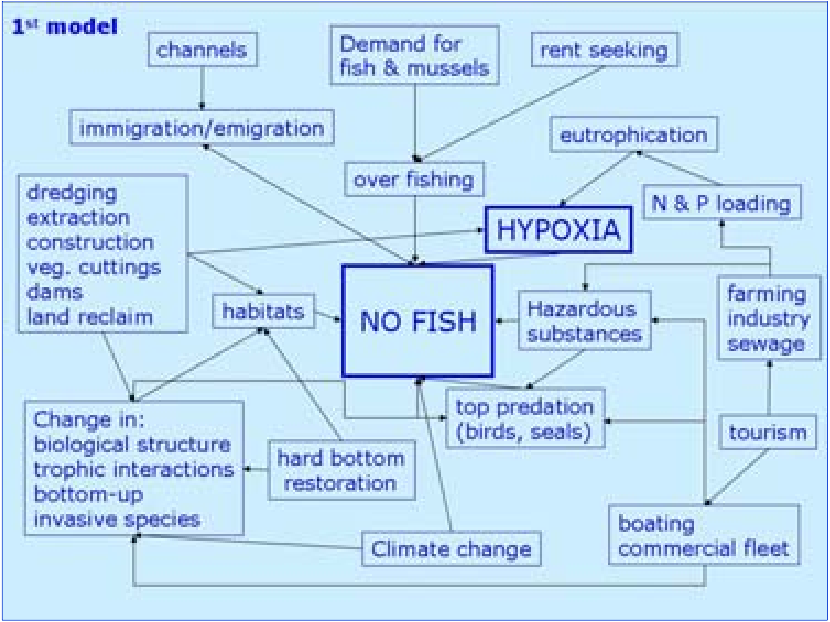


Fig. 2: Schematic of System Approach components for an ICZM Policy Issue.

Stakeholder meting

- Fisher
- Nature conversation
- Recreational fisher
- Shell fish aqua-culture
- Mussel Fisher
- Tourist
- ...
- Hypoxia and no fish
- HAB and closure


1st model
channels
Demand for fish & mussels
rent seeking
immigration/emigration
eutrophication
over fishing
dredging
extraction
construction
veg. cuttings
dams
land reclaim
HYPOXIA
N & P loading
habitats
NO FISH
Hazardous substances
farming
industry
sewage
Change in:
biological structure
trophic interactions
bottom-up
invasive species
top predation (birds, seals)
hard bottom restoration
tourism
Climate change
boating
commercial fleet

Limfjorden

- Shallow estuary
- Nutrient loadings have increased tremendously over the last 100 years, particularly from the 1950's and onwards,
- e.g. have nitrogen loadings increased by a factor of five from the early 1900 to the mid 1980's
- Changes in the ecosystem
  - reduced water clarity,
  - wide spread anoxia and
  - severe reductions in the distribution of eelgrass (Zostera marina L.)
  - Fish stocks declined since the mid 1950's,
  - in 1992 the landings reached such a low level that a commercial fishery of demersal species was no longer sustainable
  - During the same period mussel dredging was increased and is now the main commercial production activity
  - In the 1980's, in the mid 1990's and again recently the mussel fishery has suffered from declining stock because of increased mortality from hypoxia event and failing stock recruitment.

Limfjorden

- The shift in fishery from fish to mussels reflects a change in the ecosystem structure
- Shift in primary producers from benthic macro-vegetation to primarily pelagic phytoplankton
- Shift toward benthic filtrators, which are less suited as food for fish.
- Widespread loss of habitats associated with a major death of eelgrass,

Interactions between nutrient loadings and the mussel

1. Positive interaction: nutrients stimulated phytoplankton growth and increased food concentration and the growth rate for blue mussel.
2. Negative interaction: anoxia is killing blue mussels and thereby lowering the harvest. We assume that anoxia is directly related to nutrient loadings.
3. Interaction in opposite direction: When mussels are harvested both nitrogen and phosphorous are removed simultaneously.

Scope of model

- Eutrification and mussel production
- EU Water Framework Directive and Natura 2000 –> Reduction in phosphorous and nitrogen loads
- Mussel growth already limited by nutrition loads
- Increasing return to scale in farming
- Multiple, prolong oxygen depletion and harmful algal bloomes

The model

1. Primary production.
   - Driving factor are annual loads of phosphorous and nitrogen.
   - Wind speed
   - Salinity
   - NAO-index
   - Surface radiation

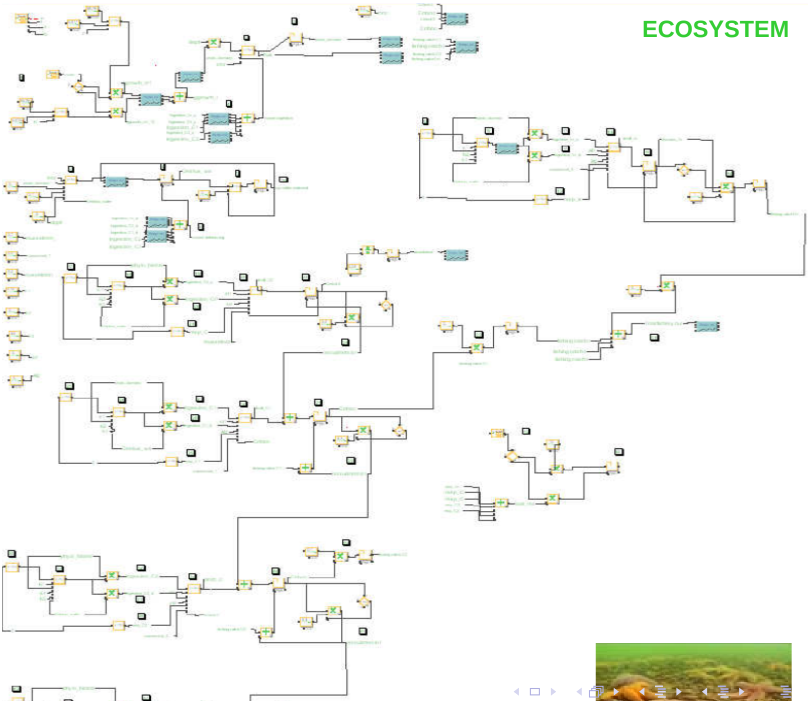
The model

2. Mussel production
    - Three size-classes of mussels below 2 meters
    - one common class of mussels above 2 meter
    - one living on lines associated with aquaculture.
    - Mussel growth is limited by the phytoplankton biomass and depends on temperature.
    - Fisher make decision on effort based on
        - Expected catch
        - Variable costs, price
        - Open or closed
        - Daily and weekly quot

The model

3. Hypoxia either with a constant occurrence in June, July and August, or as a stochastic event in the same months.
4. Originally, the idea was to make an empirical link to loadings, but at present, hypoxia occurrence is not significantly linked to nutrient loadings.

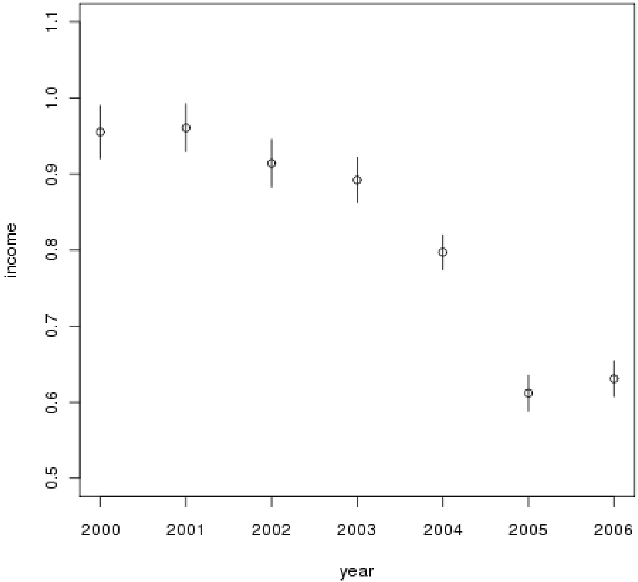
ECOSYSTEM

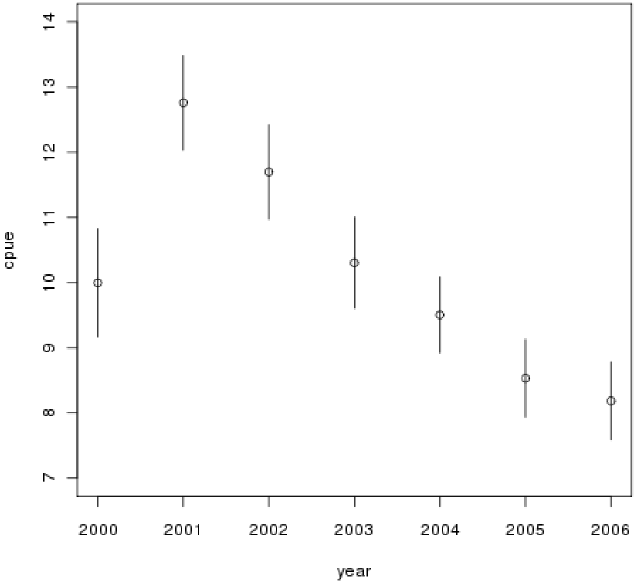


Economic model

Fishing

- Accounting statistics 2000–2006
- Variable cost, fixed cost, CPUE, prise
- License limited to 51 boats
- Self regulation, closed periods, daily quotas 25t, weekly quota 85t –> 45t


income
year
0.5
0.6
0.7
0.8
0.9
1.0
1.1
2000
2001
2002
2003
2004
2005
2006

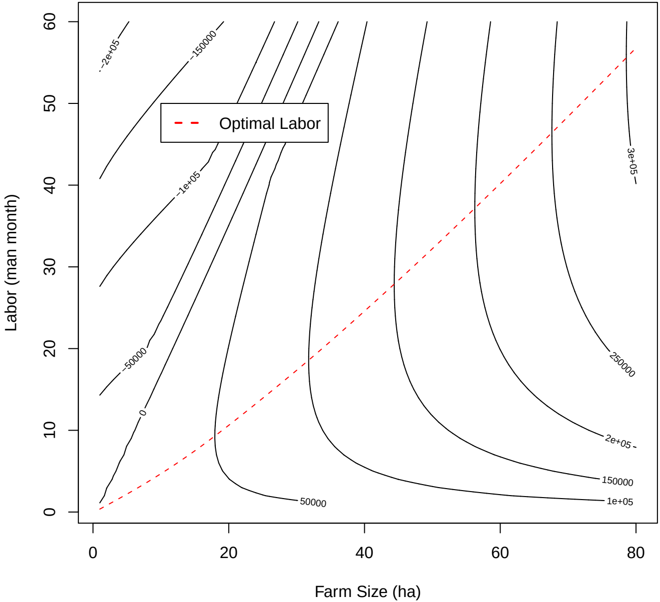

cpue
14
13
12
11
10
9
8
7
2000
2001
2002
2003
2004
2005
2006
year

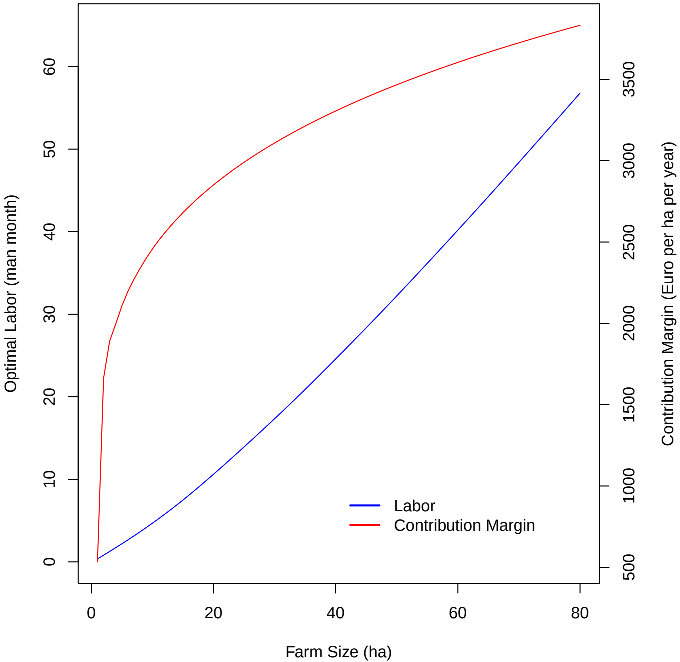
Economic model

Shell Fish Farming

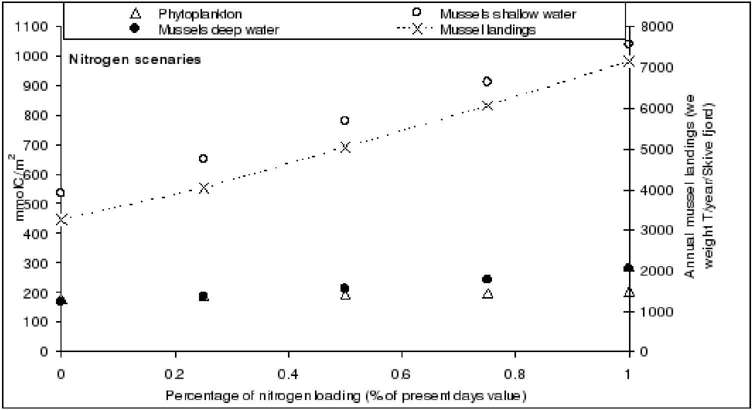
- New enterprises, few accounting data
- Interview, expectations
- Increasing return to scale: area and labour
- Husbandry function
- Problem: Harvest closure and restricted area
- Intention: A model where the farmer optimize the harvest time + risk of closure

Contribution Margin

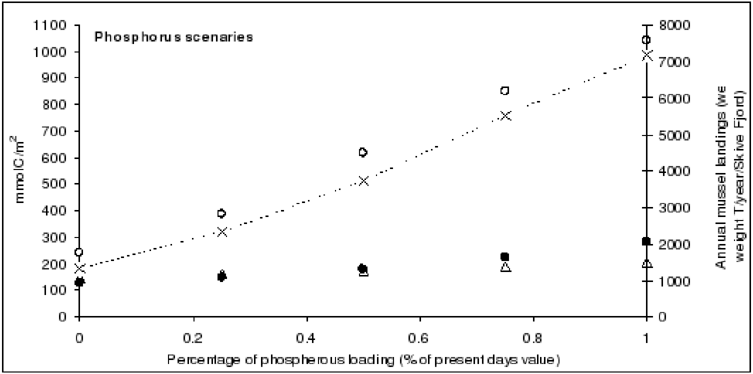




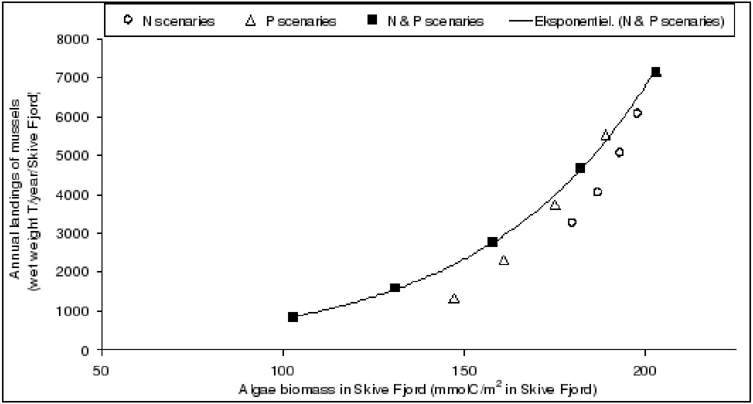
Optimal Labor (man month)
0
10
20
30
40
50
60
Contribution Margin (Euro per ha per year)
500
1000
1500
2000
2500
3000
3500
Farm Size (ha)
0
20
40
60
80
Labor
Contribution Margin

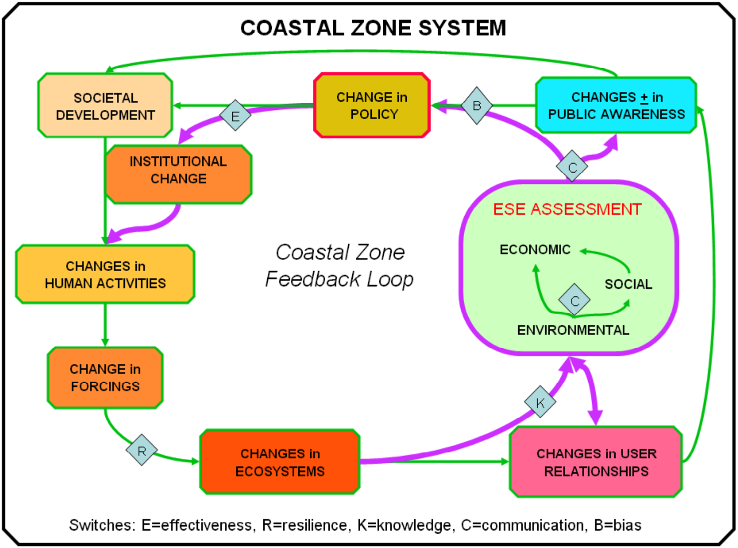


Phytoplankton
Mussels deep water
Mussels shallow water
Mussel landings
Nitrogen scenarios
mmol C/m^2
Annual mussel landings (we weight T/year/Skive fjord)
Percentage of nitrogen loading (% of present days value)
0
100
200
300
400
500
600
700
800
900
1000
1100
1000
2000
3000
4000
5000
6000
7000
8000
0.2
0.4
0.6
0.8
1



Phosphorus scenaries
mmolC/m2
Annual mussel landings (we weight T/year/Skive Fjord)
Percentage of phospherous loading (% of present days value)
1100
1000
900
800
700
600
500
400
300
200
100
0
8000
7000
6000
5000
4000
3000
2000
1000
0
0.2
0.4
0.6
0.8
1


N scenaries
P scenaries
N & P scenaries
Eksponentiel. (N & P scenaries)
Annual landings of mussels (wet weight T/year/Skive Fjord)
8000
7000
6000
5000
4000
3000
2000
1000
0
50
100
150
200
Algae biomass in Skive Fjord (mmolC/m^2 in Skive Fjord)


COASTAL ZONE SYSTEM
SOCIETAL DEVELOPMENT
CHANGE in POLICY
CHANGES ± in PUBLIC AWARENESS
E
B
C
INSTITUTIONAL CHANGE
ESE ASSESSMENT
ECONOMIC
SOCIAL
C
ENVIRONMENTAL
CHANGES in HUMAN ACTIVITIES
Coastal Zone Feedback Loop
CHANGE in FORCINGS
K
R
CHANGES in ECOSYSTEMS
CHANGES in USER RELATIONSHIPS
Switches: E=effectiveness, R=resilience, K=knowledge, C=communication, B=bias

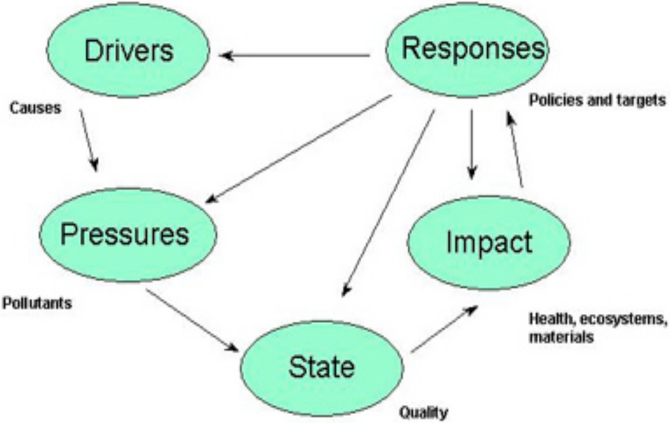
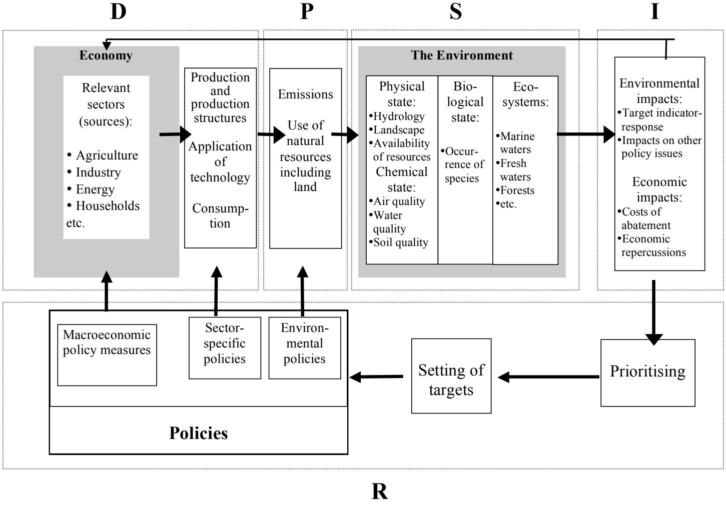


Figure 1. The DPSIR assessment framework

Figure 2: Integrated Environmental Assessment in a DPSIR framework. From NERI



DPSIR

Driver	Increase in N & P (multiple causes)
Pressure	Nutrient load
State	Change from fish to mussels, change of macro vegetation to phytoplankton (regime shifts)
Impact	Hypoxia, water quality/clarity
Response	Water Framework Directive targets of reducing nutrient loads to the fjord system.