World Aquaculture Society

Aquaculture America 2008

9 – 12 February 2008. Florida, USA.

A dynamic ecological-economic modeling approach for management of shellfish aquaculture

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Presentation layout

	No. slides
➢ Rationale and objectives	2
➢ Model description	2
➢ Simulation results	1
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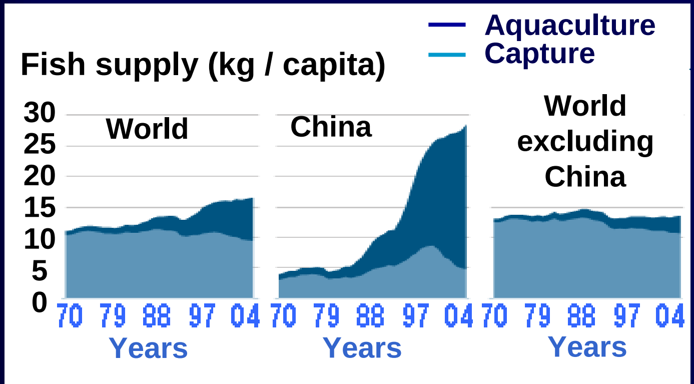
Rationale



Data source: FAO

Aquaculture is increasing, and is expected to continue to increase as a result of:

- Declining of wild stocks
- Increase in demand

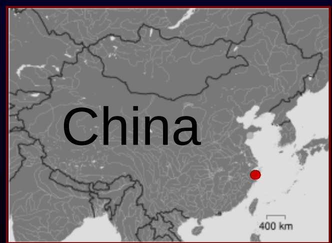
- Mariculture represents 73% of total production
- However estuarine and coastal ecosystem have a limited carrying capacity, beyond which aquaculture became less efficient
  - •Aquaculture waste discharge
  - •Availability of food resources
  - •Space limitations
- Economic production limits: Law of diminishing returns

Understanding those limits is of crucial importance both for the environmental and economic systems

Objectives

- To conceptualize ecological and economic interactions in mariculture
- To implement a dynamic ecological-economic model in order to:
  - Simulate the socio-economics of aquaculture production
  - Simulate its effects on the estuarine and coastal ecosystems
  - Simulate the feedbacks of the environmental system on the socio-economics
- Apply to a case study:

Currency:
China Renminbi (Yuan)
Exchange rate:
1USD ≈ 7.2 RMB



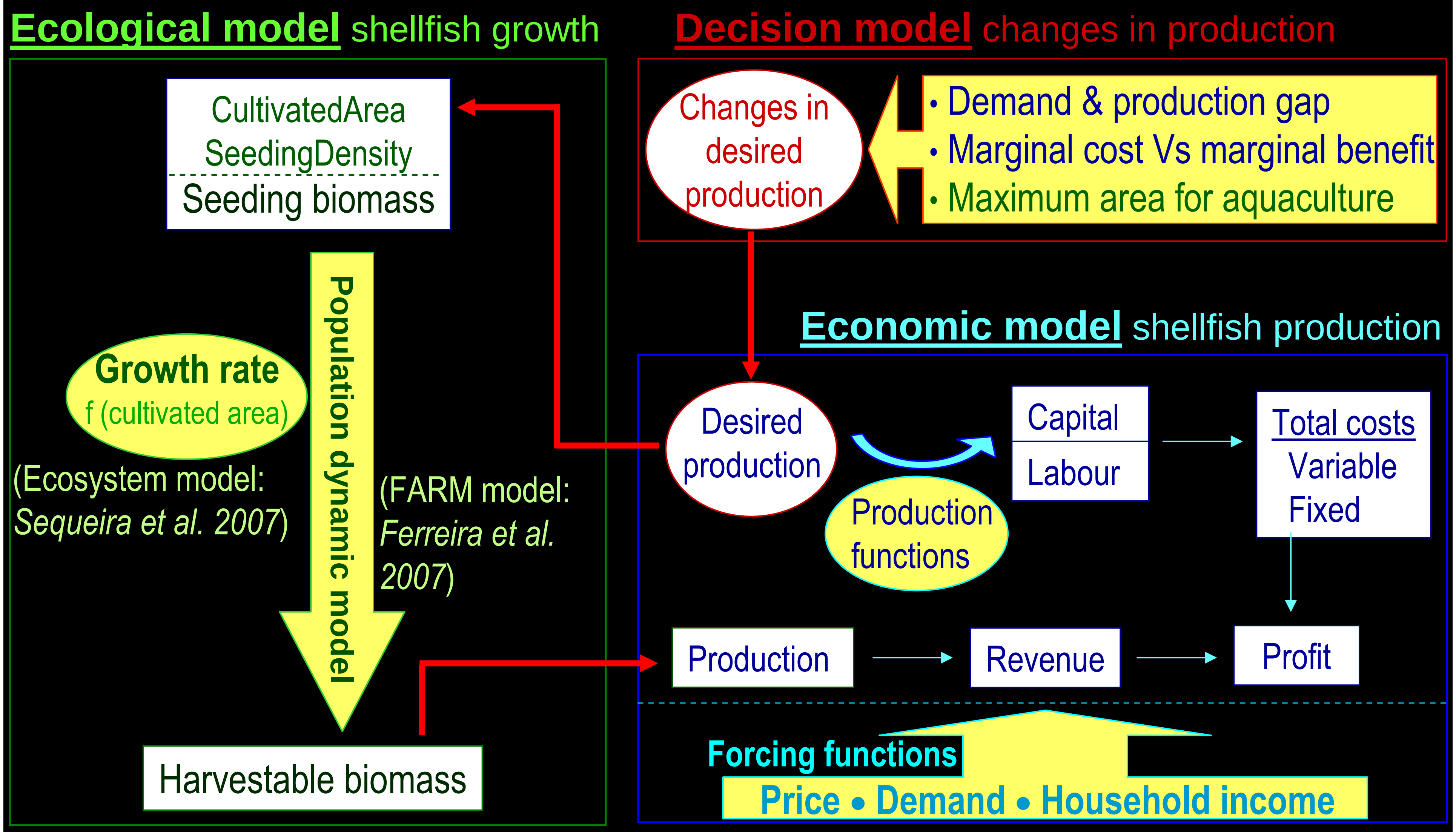
Xiangshan Gang

Volume: 3 803 10^6 m^3
Area: 365 km^2

Shellfish production:
38 300 ton yr^{-1}
6 600 10^3 euros

Conceptual model – MARKET

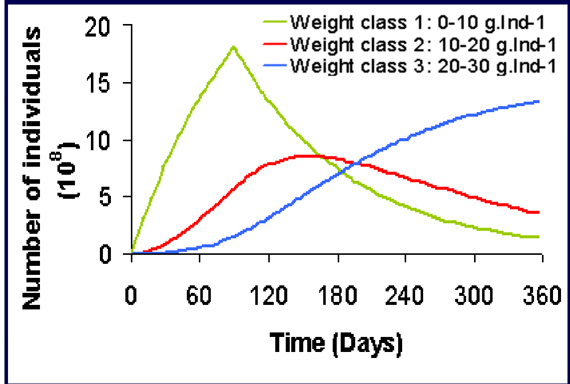
Modeling Approach to Resource economics decision-maKing in EcoaquaculTure



Model integration and assumptions

Ecological model

Timestep 0.01 yr



Seeding biomass

↓

Available biomass for harvest

↓

Harvested shellfish yield

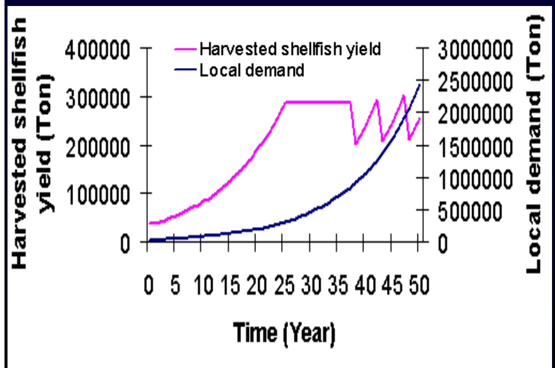
Integration

Changes in desired production

↓

Desired production

Production



Economic model

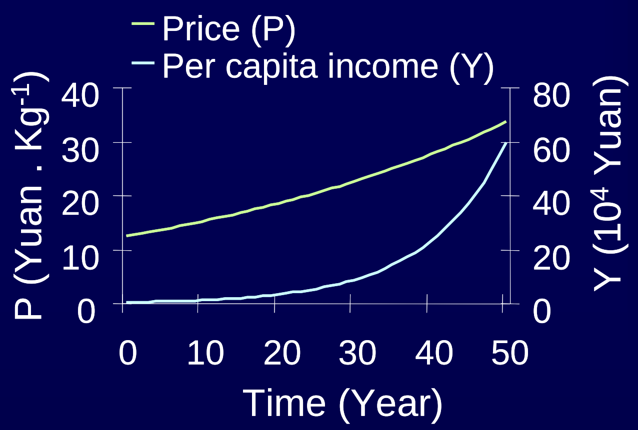
Timestep 1 yr

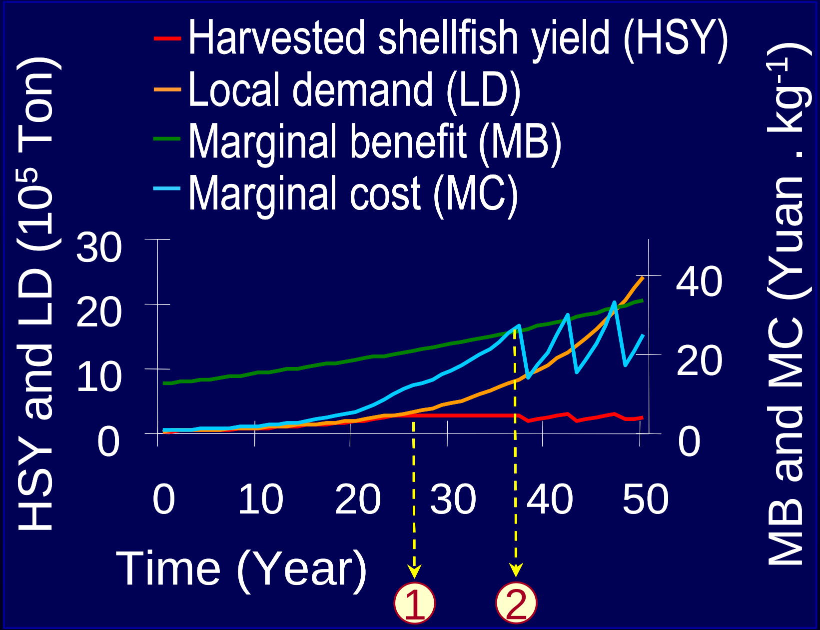
Assumptions

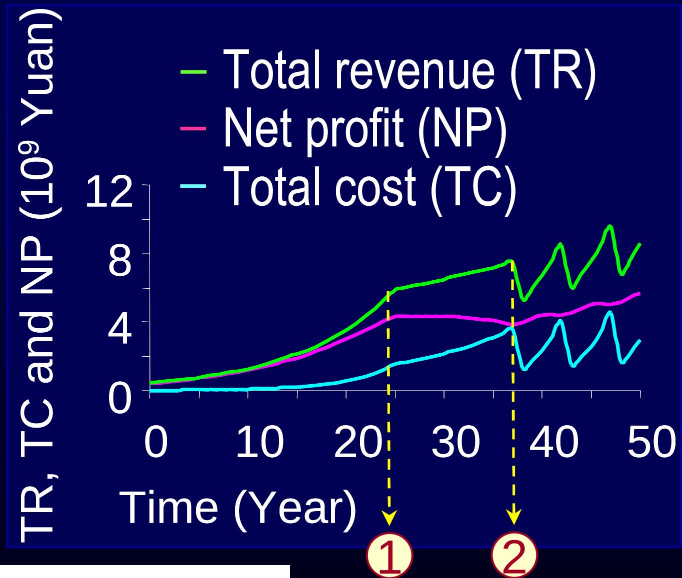
- The local system is forced by the global market, i.e.:
  - Price
  - Demand
  - Income
- Farmers are price takers
- Individual profit maximization
- Perfect rationality
- No government intervention
- Optimal production:
  - Seed density
  - Economic Input/output
- Changes in desired production (ton . yr^{-1}) are implemented through changes in cultivated area
- Growth rate is function of cultivated area (from ecosystem model EcoWin2000)

Simulation results

Standard model assumption values
Price annual growth: 2%
Per capita income annual growth: 10 %
Max. cultivation area (% of total bay): 83%



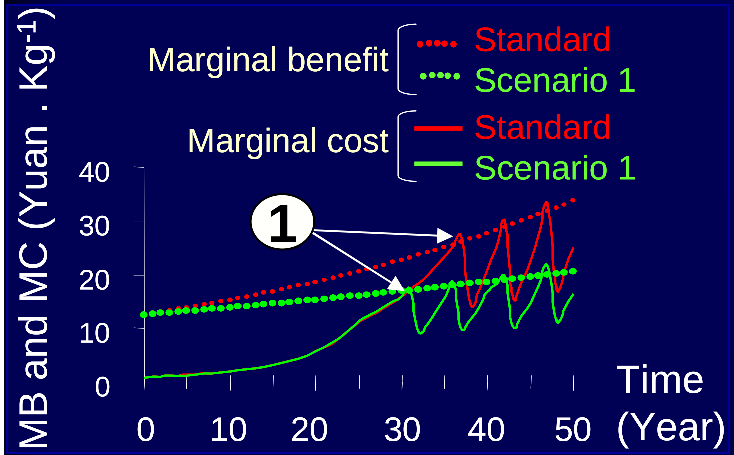


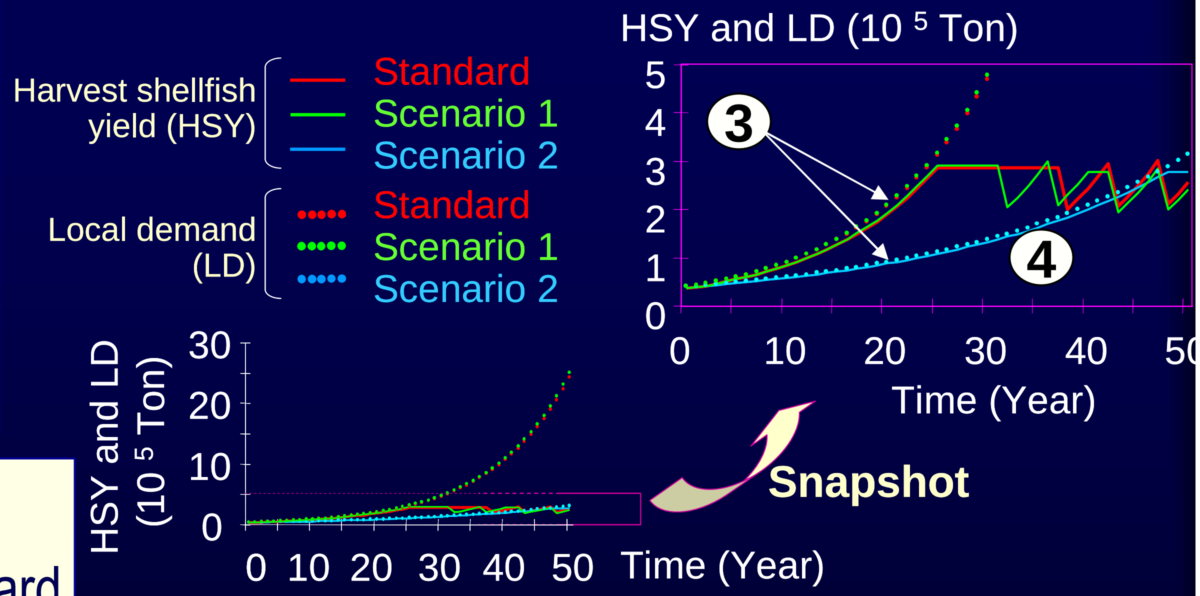


① Maximum cultivated area limits production
② Economic profitability limits production: MarginalCost (MC) > MarginalBenefit (MB)

Scenarios / sensitivity analysis

Scenario1: half of price annual growth rate (1%) **Scenario 2:** half of income yearly increase (5%)

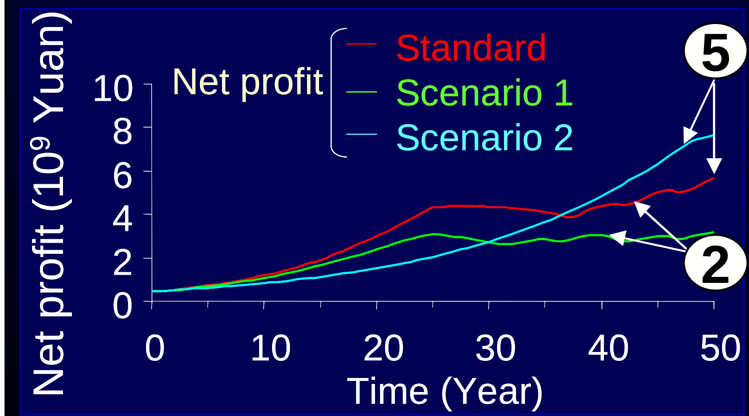




Scenario 1

1 MC = MB sooner than in standard

2 Net profit decreases



Scenario 2

3 Exploitation at slower rate (lower demand)

4 Less ecological pressure (slower harvest growth)

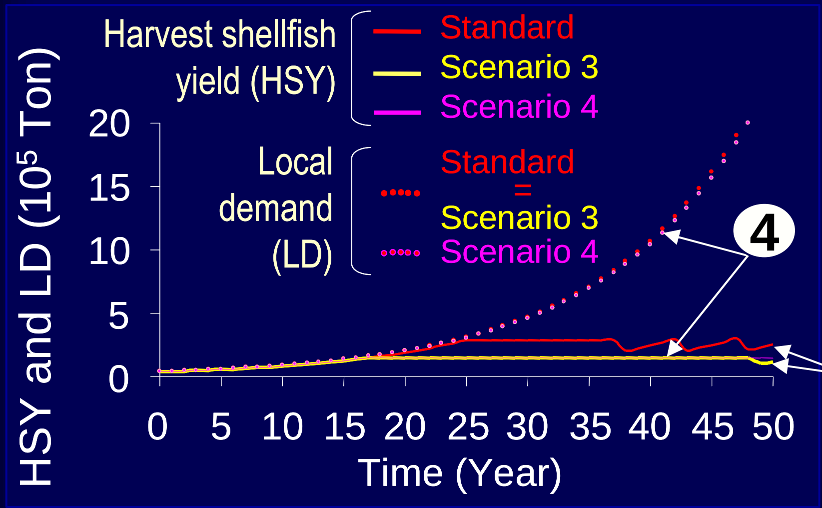
MC less MB (entire simulation time)

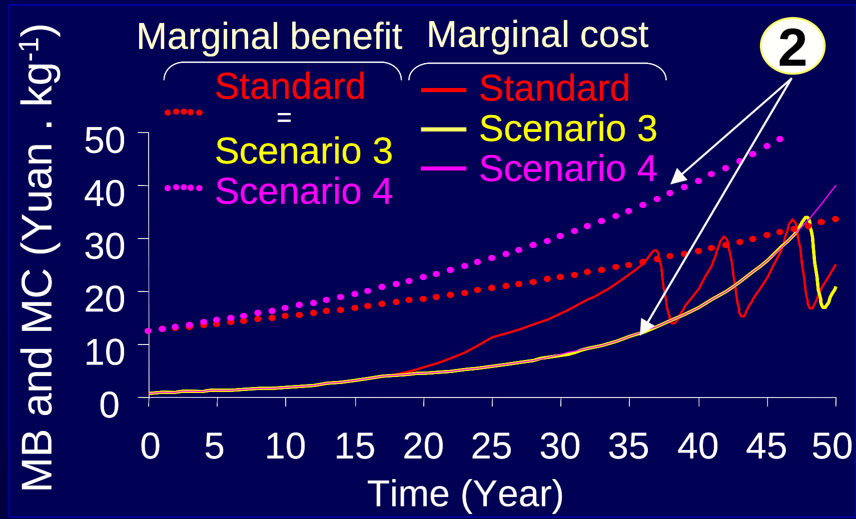
5 More profitable, in the long term

Scenarios / sensitivity analysis

Scenario3: half the maximum cultivated area (20 800 ha)

Scenario 4: half maximum cultivated area; increase price annual growth (3%)





<u>Maximum cultivated area reduction</u> (Scn 3):

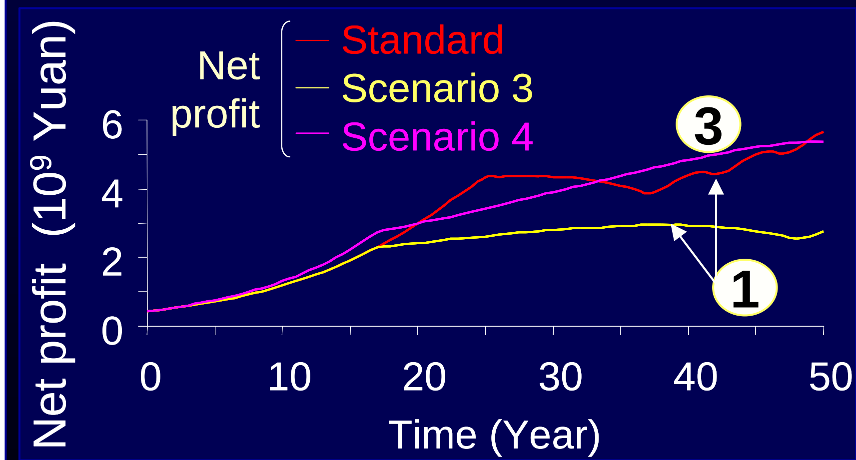
① Reduces production and net profit

<u>Together with an increase in price</u> (Scn 4):

② MC less MB (entire simulation time)

③ Profits sustainable in the long term

④ But demand not achieved



Discussion and conclusions

- The MARKET model addresses broad scale trends of ecological-economic feedbacks in aquaculture:
  - Profit is ensured in all the scenarios
  - Ecosystem carrying capacity is the first limiting factor in all scenarios
  - For this case study, where we simulated only shellfish production, the carrying capacity limit was mainly related with space. There was no disruption on the ecological functions of the ecosystem
  - However if simulating other aquaculture products, such as fish, is expectable that the carrying capacity limit is related with the generated wastes

Future developments and research

- The MARKET version presented is a proof of concept. Further developments must include:
  - Integrate the model in a detailed ecosystem model
  - Develop the model for other aquaculture species and practices, specially those that typically have negative ecosystem impacts

From this case study the following question raises:

If we analyze together
- **Forecast of the global demand for mariculture**
- **Economic production limiting factors**
- **Carrying capacity of estuaries and bays worldwide**

What is going to be the limiting factor?

Thank you for the attention

Acknowledgments

SPEAR project (EU INCO-DEV Contract Nº INCO-CT-2004-510706)

FCT (Portuguese Foundation for Science and Technology)

Key references

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