Modeling and governing feed-backs between ecological and economic dynamics

Martin F. Quaas

Department of Economics
Christian-Albrechts-Universität zu Kiel

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Environmental and Resource Economics; Ecological Economics

Sustainability economics

1. Subject focus: relationships between humans and nature.
2. Orientation towards (uncertain) future.
3. Normative foundation of sustainability: justice in the relationships between
   - presently living humans (intragenerational justice)
   - future generations of humans (intergenerational justice)
   - non-human nature
4. Concern for efficiency: non-wastefulness

Baumgärtner and Quaas (2010). What is sustainability economics? *Ecological Economics* 69:445–450.

Environmental- and Resource Economics; Ecological Economics

General Approach

1. Descriptive model: Ecological and economic dynamics
2. Normative criteria to evaluate outcomes
3. Policy recommendations: Which institutions and instruments achieve the desired outcome?

Baumgärtner/Becker/Frank/Müller/Quaas (2008). Relating the Philosophy and Practice of Ecological Economics. The Role of Concepts, Models and Case Studies in Inter- and Transdisciplinary Sustainability Research. *Ecological Economics*, 67(3):384–393.

Questions and Issues

- Improve models: Take into account
  - uncertainties
  - feed-backs between ecological and economic dynamics
    (example: demand-side interactions in fisheries)
- How to meet multiple objectives?
  (example: stochastic viability analysis)
- Identifying trade-offs: Who gains, who loses?
  (example: workers in fishing industry)
- Develop innovative policy recommendations
  (example: fishing quotas in terms of numbers vs. biomass)

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Viability

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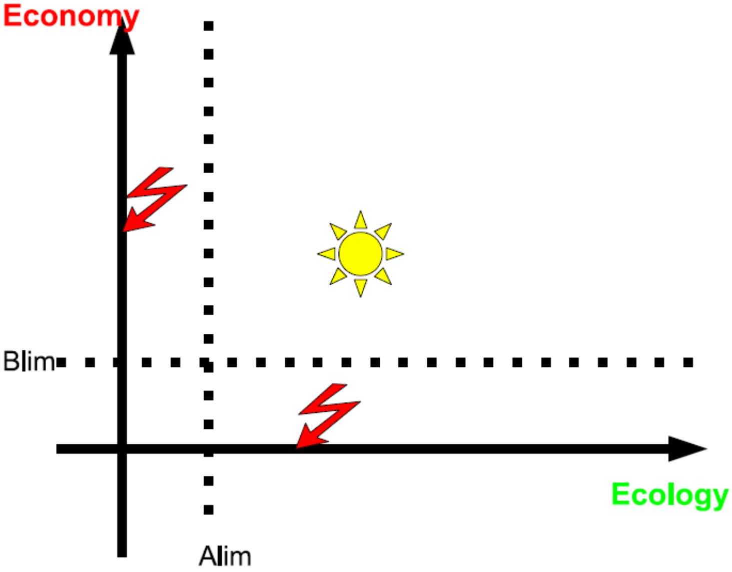

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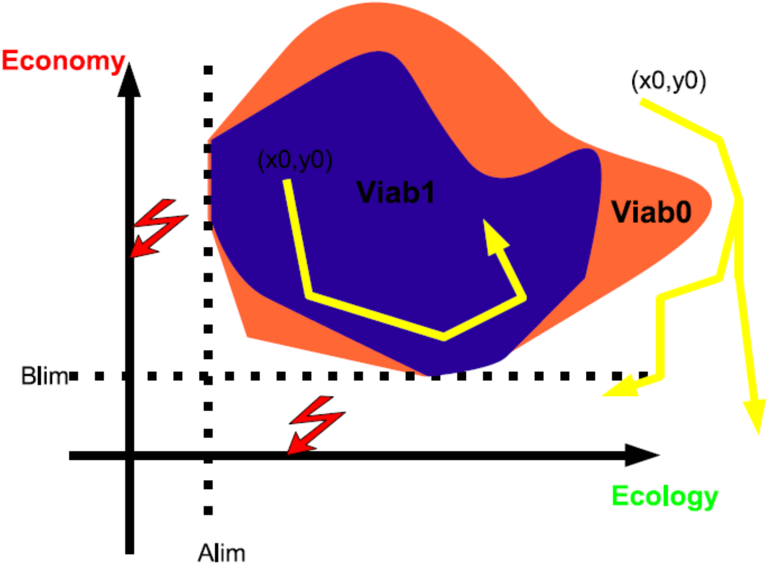
Viability analysis



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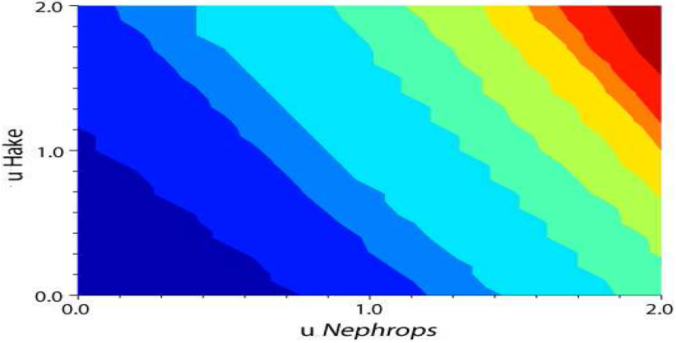
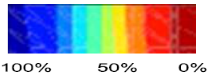
Stochastic Viability: Multi-Species Fisheries

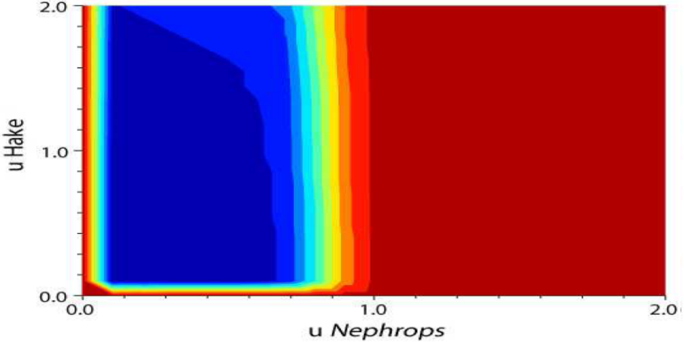


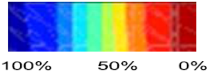


probability of ecological viability

Doyen/Thébaud/Béné/Martinet/Gourguet/Bertignac/Fifas (2012). A stochastic viability approach to ecosystem-based fisheries management, *Ecological Economics* 75:32–42.

Stochastic Viability: Multi-Species Fisheries





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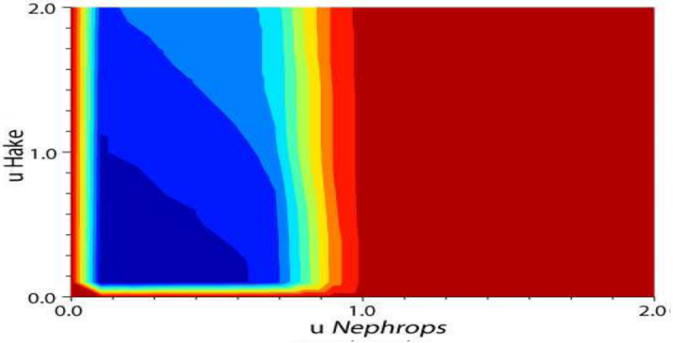
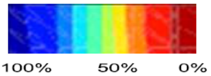
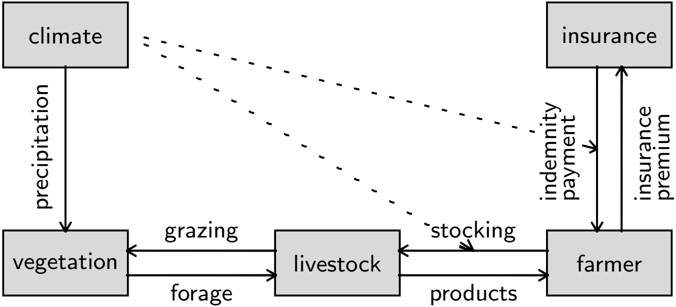




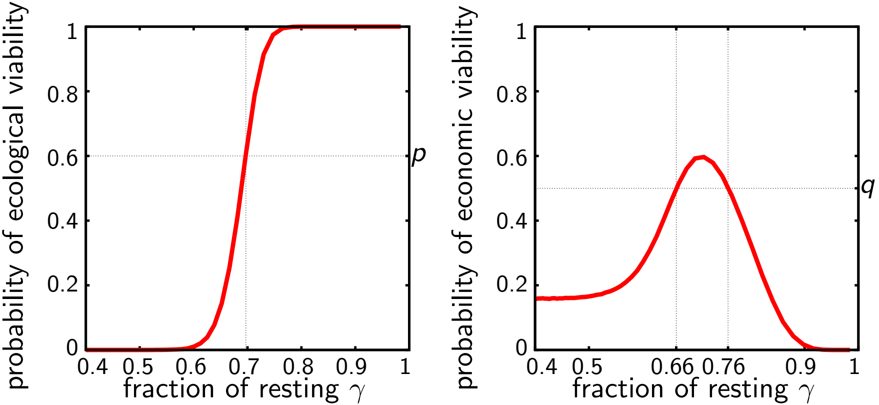
probability of ecological and economic co-viability


Source: Nguni Cattle Breeders Association of Namibia

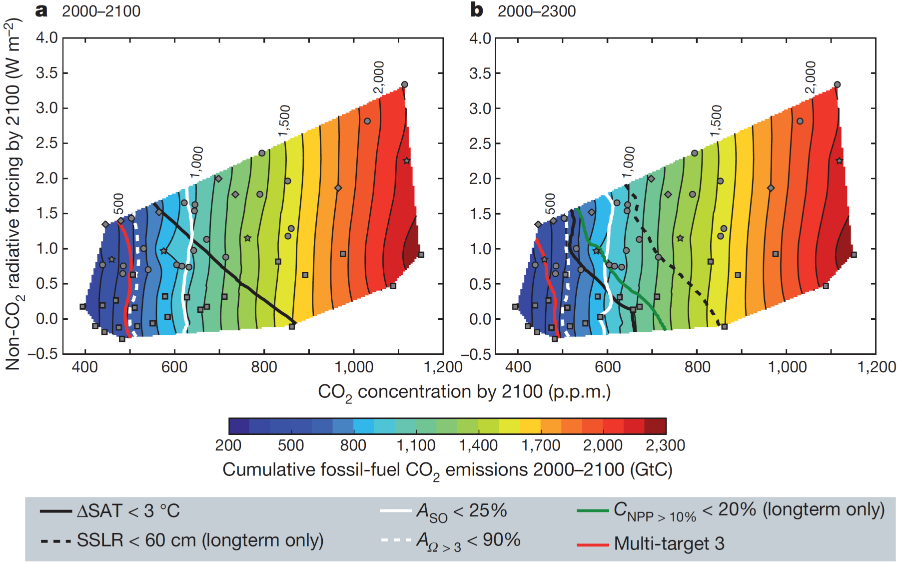

Source: Wikipedia, 2010


climate
insurance
precipitation
indemnity payment
insurance premium
vegetation
grazing
forage
livestock
stocking
products
farmer

Stochastic Viability: Rangelands



Stochastic Viability: Global Climate



Contour lines: 66% Chance of complying with viability constraints.

Steinacher/Joos/Stocker (2013). Allowable carbon emissions lowered by multiple climate targets, *Nature* 499:197–201.

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Maximizing expected present value of utility

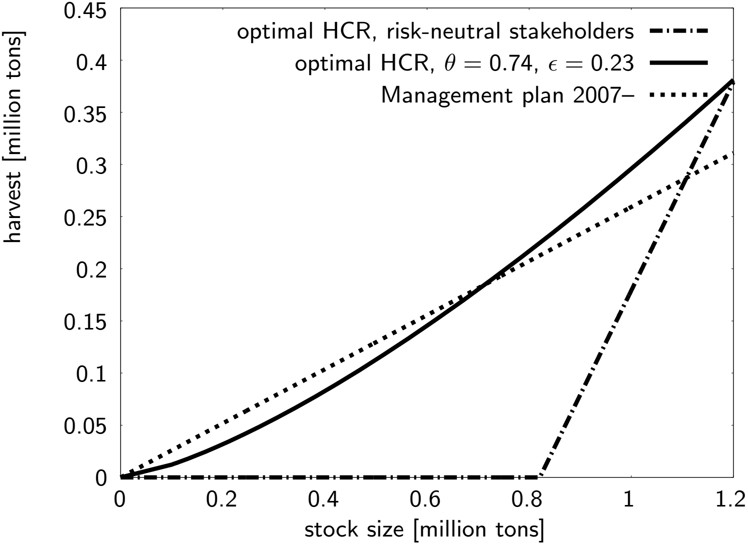
$$\max_{\{x_t\}} E \sum_{t=0}^{\infty} \delta^t \, U(\pi(s_t, x_t))$$

- s_t: stock size; x_t: harvest
- $\delta < 1$: discount factor
- method: stochastic dynamic programming
- solution: optimal feedback policy
  (in fisheries often termed harvest-control rule; HCR)

McGough/Plantinga/Costello (2009). Optimally Managing a Stochastic Renewable Resource under General Economic Conditions, *B.E. J Econ Analysis & Policy*, 9(1), 56.
van Dijk/Haijema/Hendrix/Groeneveld/van Ierland (2013). Fluctuating quota and management costs under multiannual adjustment of fish quota. *Ecol Modelling* 265:230–238.

Maximizing expected present value of utility

Example: Eastern Baltic cod fishery



Kapaun/Quaas (2013). Does the optimal size of a fish stock increase with environmental uncertainties? *Environmental and Resource Economics* 54(2):293–310.

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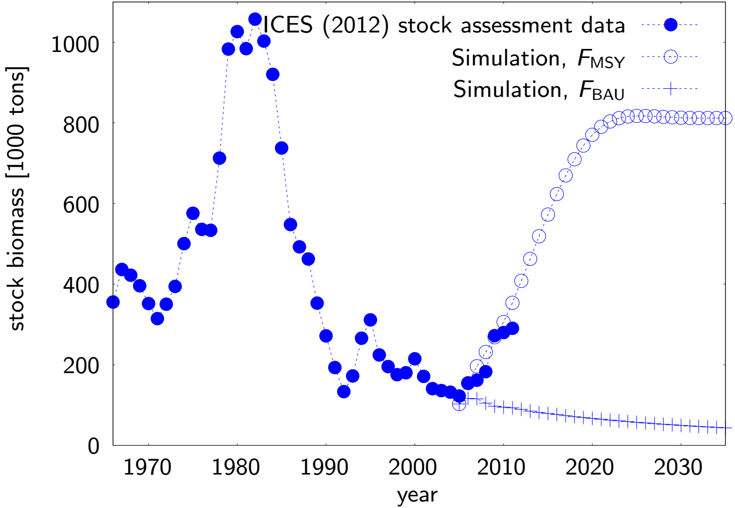
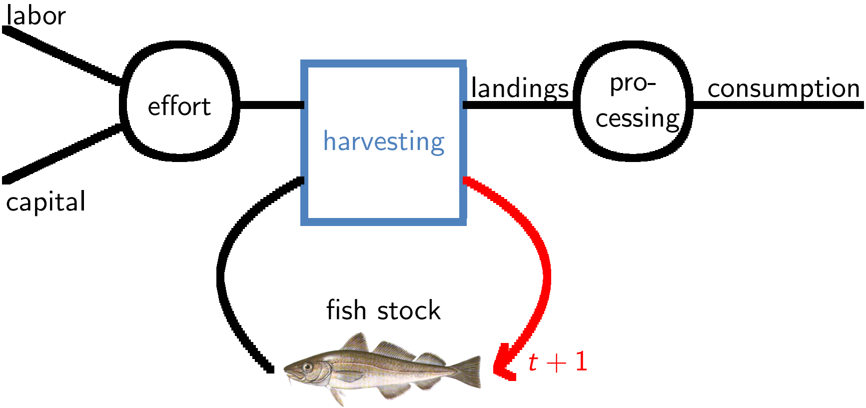
Eastern Baltic cod fishery

maximum sustainable yield (MSY) management vs. business as usual (BAU)

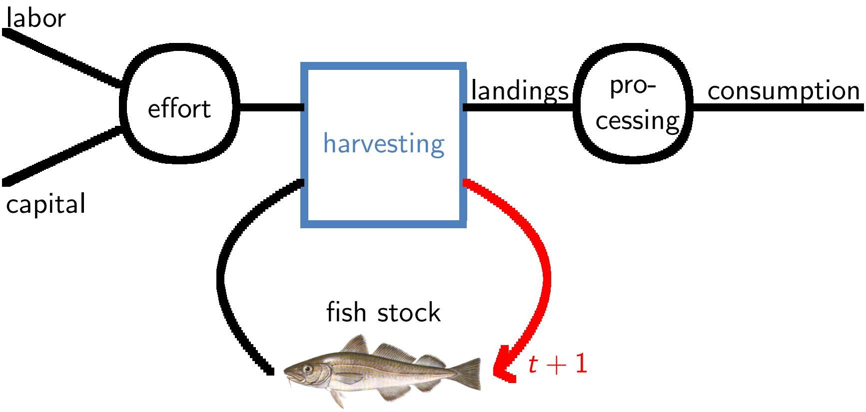


Quaas/Stoeven (submitted). Public and private management of renewable resources: Who gains, who loses?

Sustainable fishery management: Who gains, who loses?



Sustainable fishery management: Who gains, who loses?



fishermen surplus FS

resource rent RR

user surplus US

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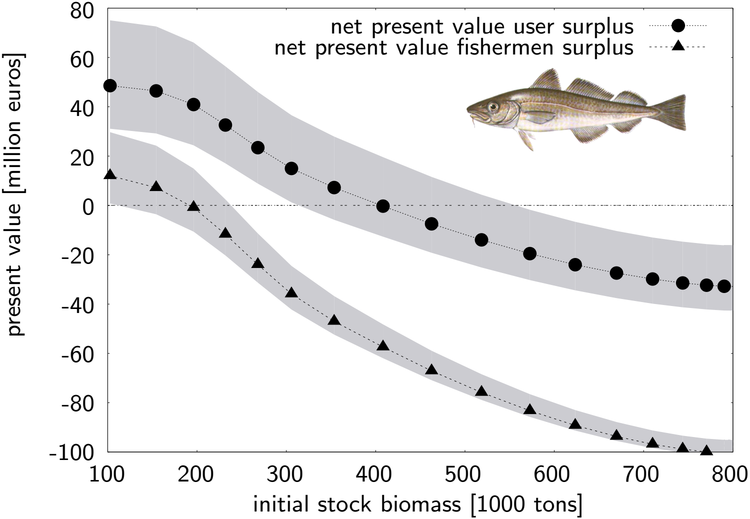
Sustainable fishery management: Who gains, who loses?

Comparing present value of benefits under maximum sustainable yield (MSY) management vs. business as usual (BAU)



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Interactions in multi-species fisheries

- ecological interactions: predator-prey, competition, symbiosis

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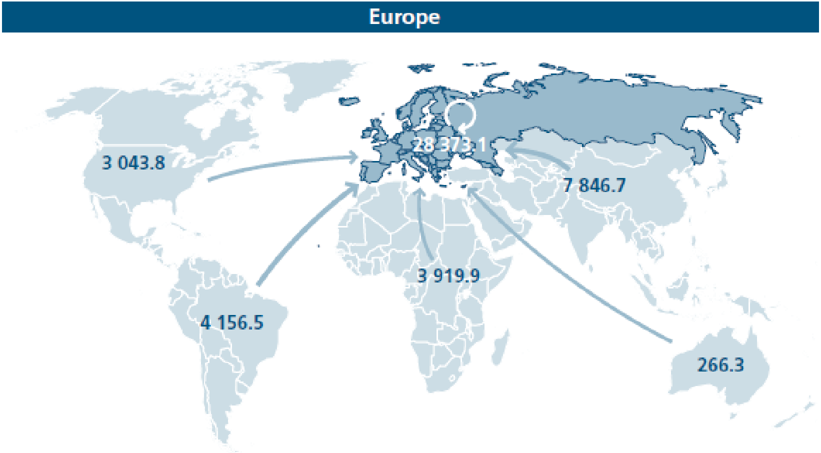
- economic interactions: technical (bycatch),

Quaas/Requate (2013). Sushi or fish fingers? Seafood diversity, collapsing fish stocks, and multi-species fishery management, *Scandinavian Journal of Economics* 115(2):381–422.

Interactions in multi-species fisheries

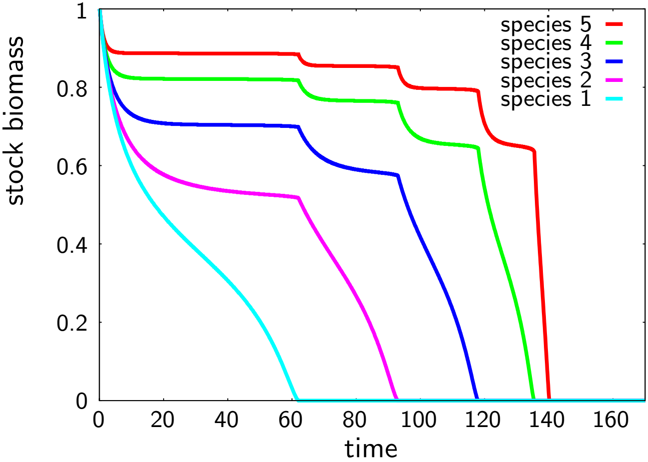
- ecological interactions: predator-prey, competition, symbiosis
- economic interactions: technical (bycatch), demand-side



trade in fishery products, million US $, FAO SOFIA 2012

Quaas/Requate (2013). Sushi or fish fingers? Seafood diversity, collapsing fish stocks, and multi-species fishery management, *Scandinavian Journal of Economics* 115(2):381–422.

Demand-side interactions between fisheries



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TWO ASPECTS OF OVERFISHING

consumer value seafood diversity: 'love of variety'

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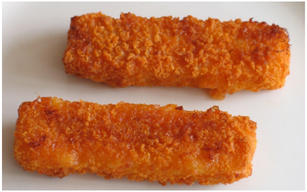

- collapse of fish stocks is economic problem on top of inefficiently low stocks and yields

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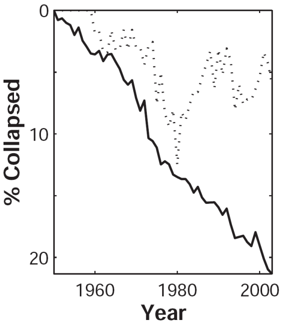
TWO ASPECTS OF OVERFISHING

1. inefficiently low stocks and yields
   - extensively studied
   - fundamental principles well understood

e.g. Clark (1990)

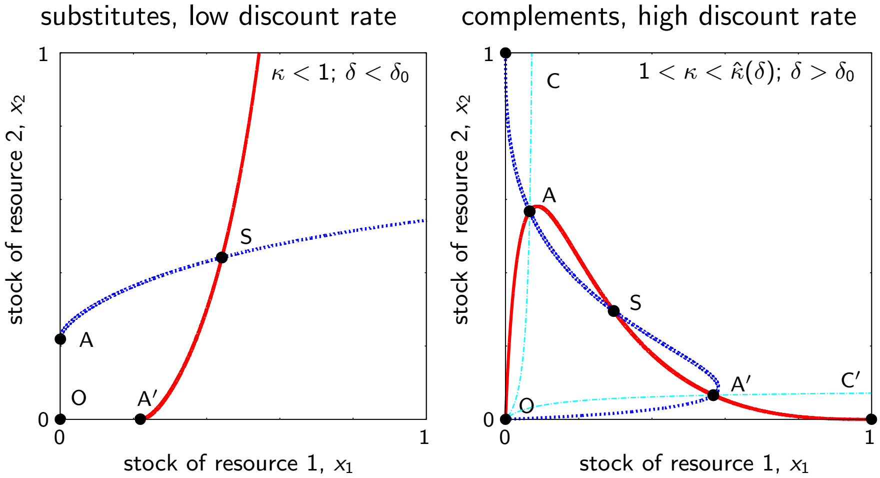
2. collapse of stocks at world-wide scale
   - recognized more recently
   - has become focus of scientific interest and public concern in the last years

Costello et al. (Science, 2008)
Heal and Schlenker (Nature, 2008)
Worm et al. ((Science, 2006)



Costello et al. (2008)

Coupled ecological-economic system may have multiple equilibria even if the natural system has not



Quaas/van Soest/Baumgärtner (2013). Complementarity, impatience, and the resilience of natural-resource-dependent economies. *J Env Econ Management* 66(1):15–32.

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GROWTH OVERFISHING: EXAMPLE OF BALTIC COD

Baltic Sea, early 1980s

GROWTH OVERFISHING: EXAMPLE OF BALTIC COD

Baltic Sea 2007

Fishing Quotas in Terms of Numbers vs. Biomass

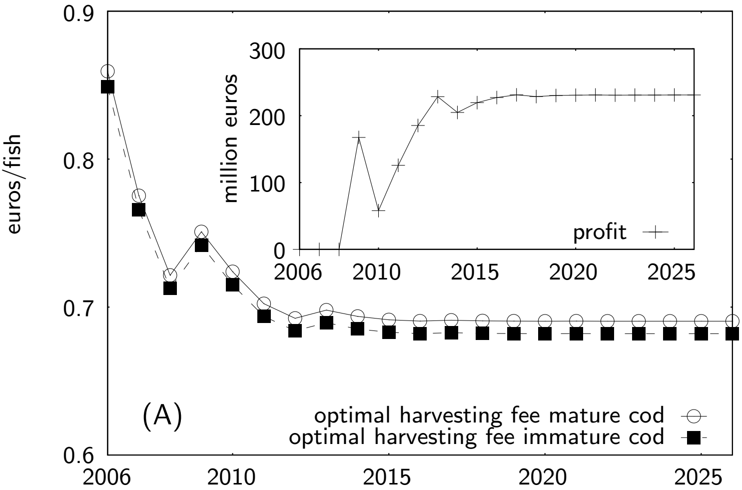
Proposal for new design of regulation

- Total allowable catch (TAC) in number of individual fish
- System of tradable quotas (TQ) in numbers of individual fish and appropriate exchange rates

Conventional biomass management	New individual-based management
TAC in tons of biomass	TAC in number of individual fish
TQs in tons of biomass save fishing cost but have no positive effect on stock	TQs in numbers save fishing cost and set incentives that prevent growth overfishing
Gear restrictions are necessary to prevent growth overfishing	Fisherman decides on fishing gear

Quaas/Requate/Ruckes/Skonhoft/Vestergaard/Voss (2013). Incentives for Optimal Management of Age-Structured Fish Populations. *Res Energy Econ* 35(2):113–134.
Diekert (2012). Growth Overfishing: The Race to Fish Extends to the Dimension of Size, Environ Resource Econ DOI 10.1007/s10640-012-9542-

Fishing Quotas in Terms of Numbers vs. Biomass



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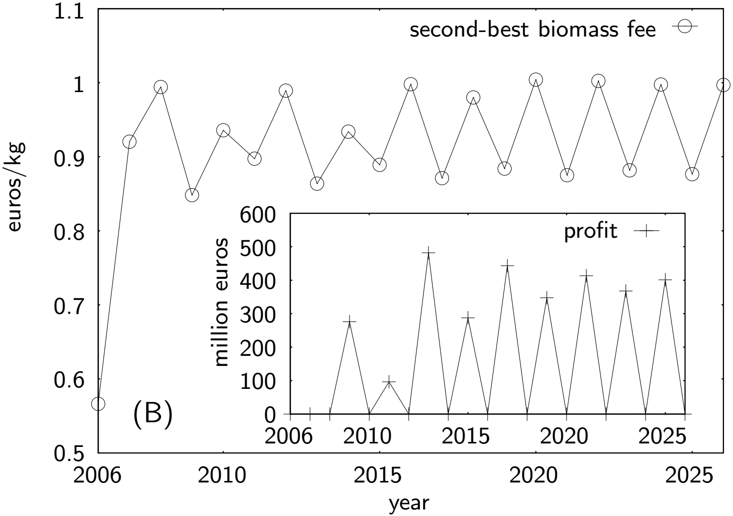

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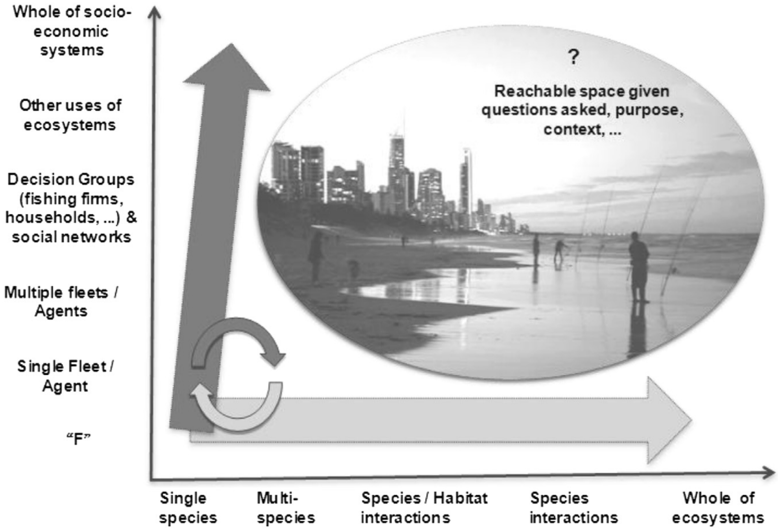
Ecological-economic models: Scale and Scope



Thébaud/Doyen/Innes/Lample/Macher/Mahévas/Mullon/Planque/Quaas/Smith/Vermard (2014). Building ecological-economic models and scenarios of marine resource systems: Workshop report. *Marine Policy* 43:382–386.