UNIVERSITY OF COPENHAGEN

Fisheries impact on the ecosystem – The Baltic Sea fishery

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IIFET Conference 2014, Brisbane, Australia

Why are we doing this?

1. Fishing activities impact the ecosystem in various ways
2. Increasing attention to the subject
3. Is economics able to contribute to enlighten the subject?
4. How can fisheries economics be expanded to address the problem?

What are we doing

1. Address the categorization of Millennium Ecosystem Assessment (MEA) of ecosystem services
2. Address ecosystem models (Ecopaths with Ecosim (EwE) and Atlantis)
3. Ecosystem and economic components of these models are unevenly developed
4. Apply a (dynamic) bioeconomic model (Fishrent)
5. Investigate how the Fishrent model can be expanded to address ecosystem services
6. Combine (i.e. link) Fishrent with EwE and apply it to the Baltic Sea

Method: Link a fishery economic model (Fishrent) and an ecosystem model (Ecopath with Ecosim (EwE)

1. Use Fishrent to compute MEY

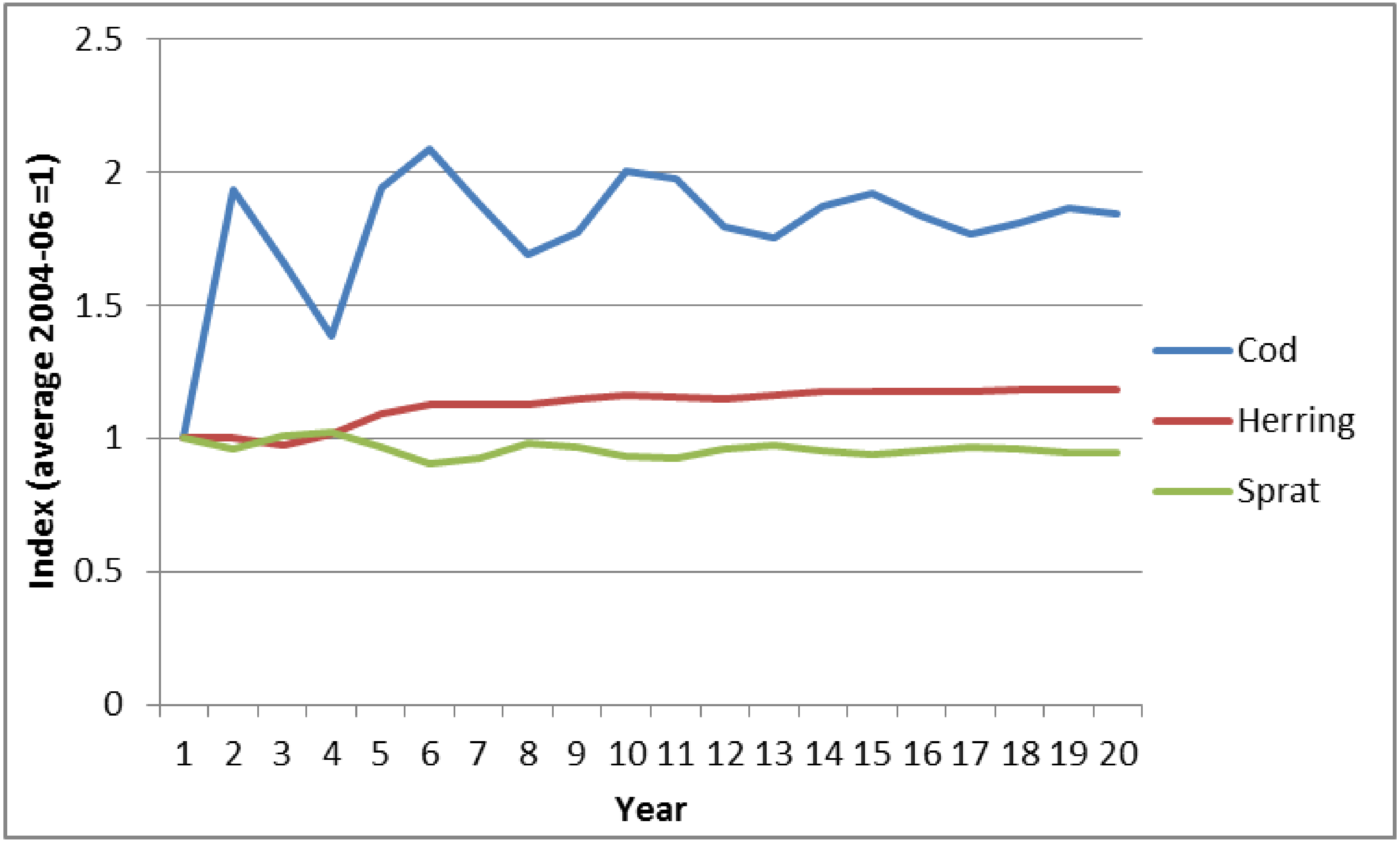
2. Compare current biomass of cod with MEY biomass

3. Increase in biomass app. 1.8 times from app. 150 000 tonnes to 280 000 tonnes

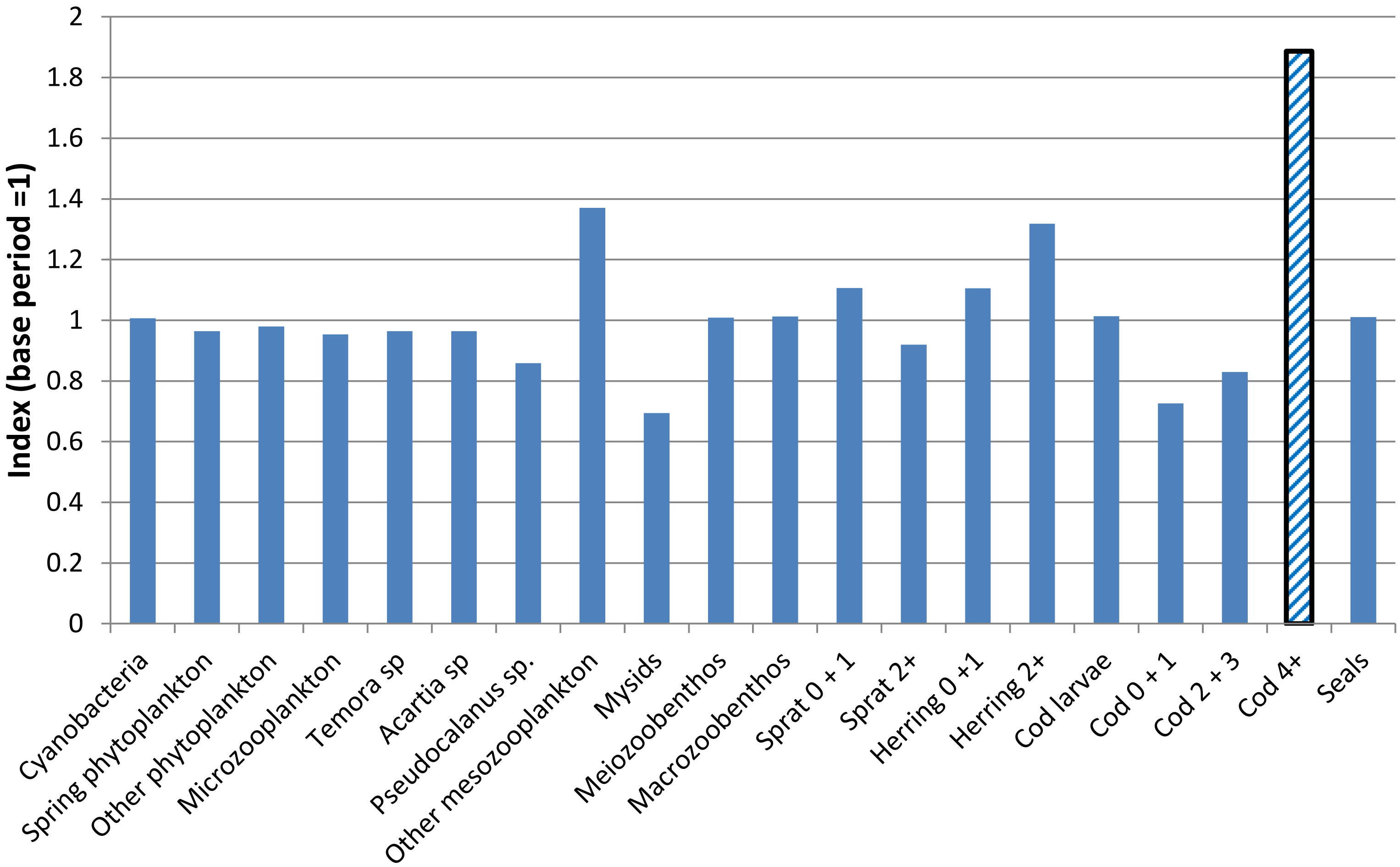
4. Increase biomass in EwE by 1.8

5. Read results

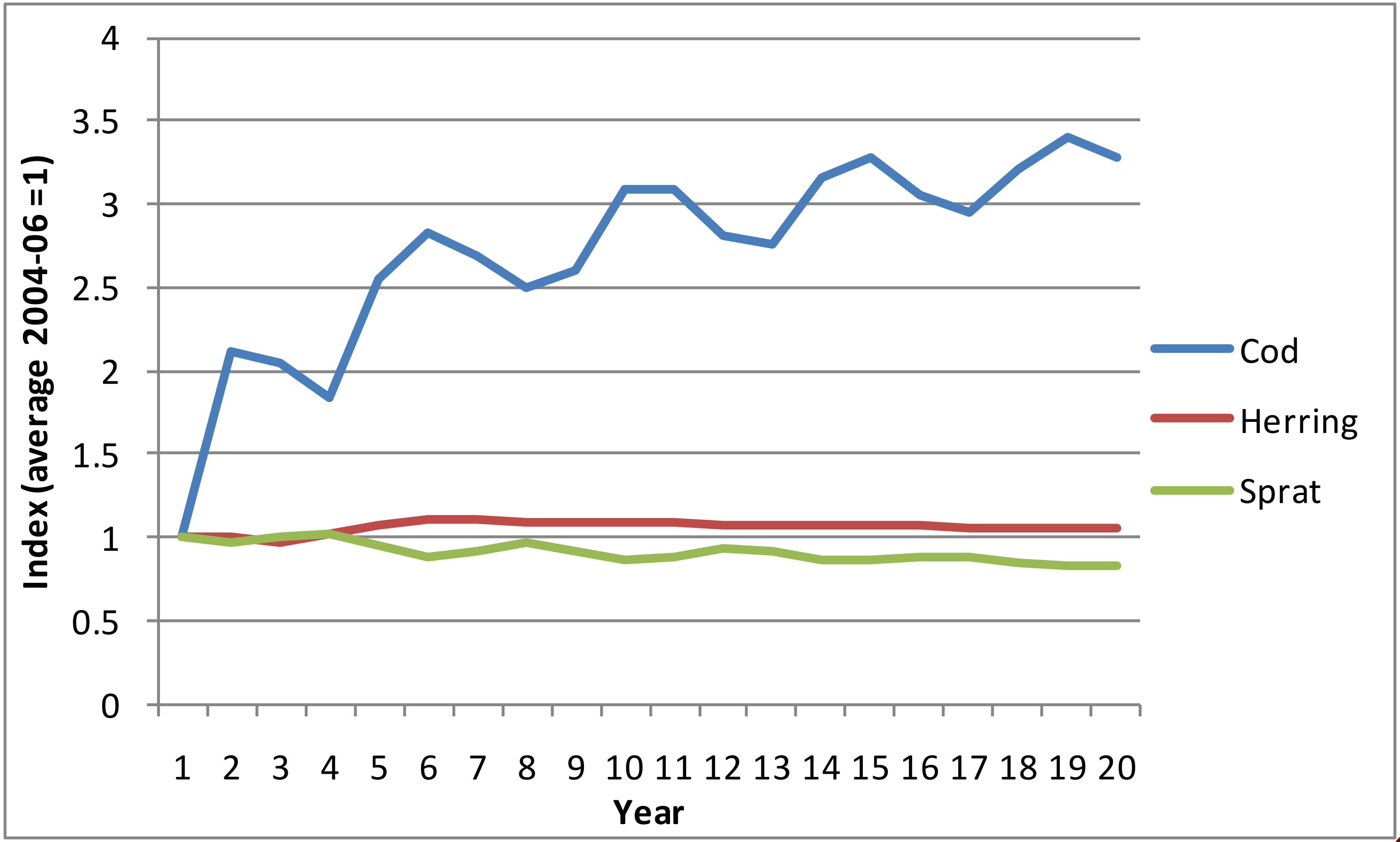
Result 1: EwE. Fishing mortality for cod 4+ reduced in order to increase biomass 1.8 times (specified by MEY in Fishrent)



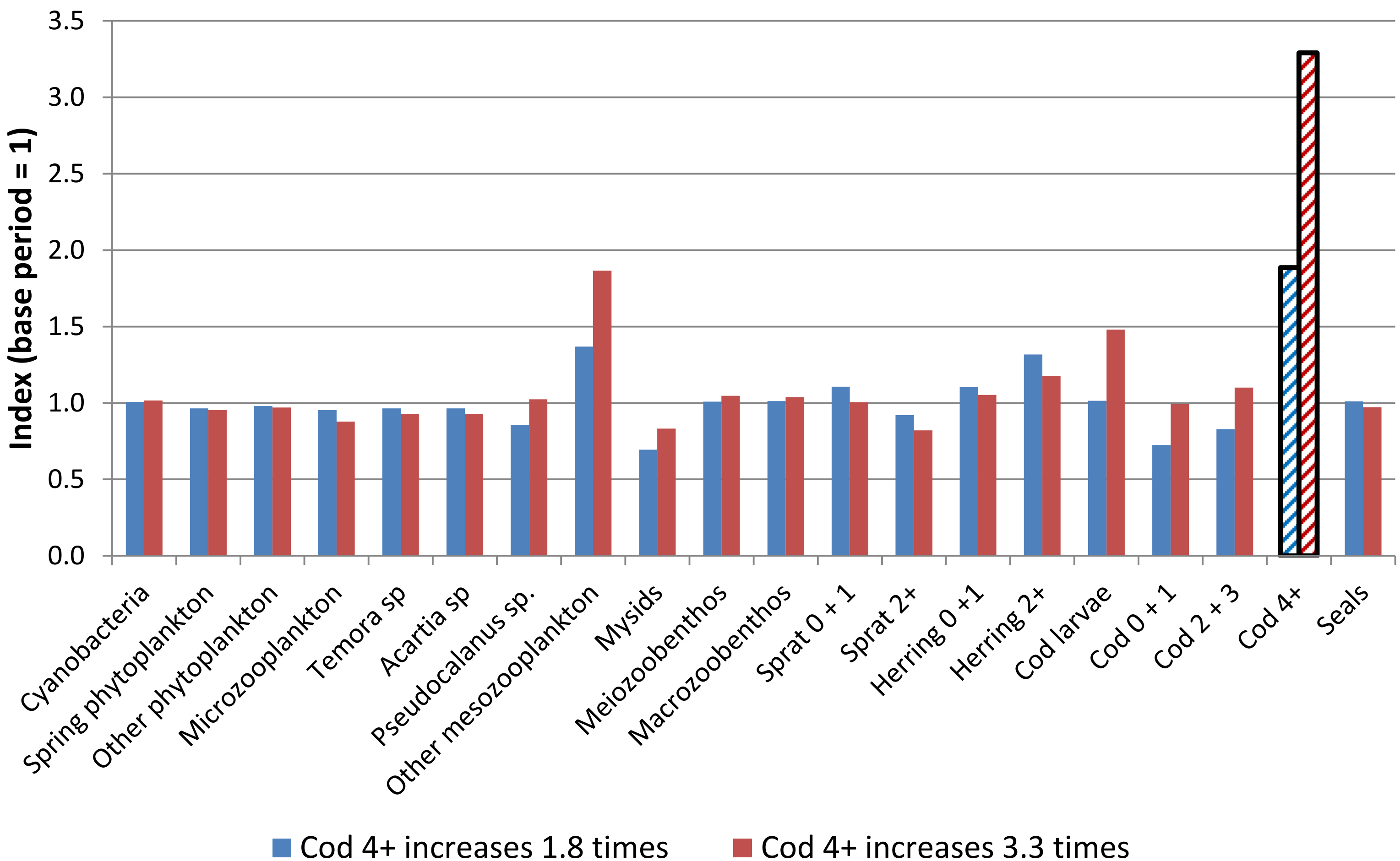
Result 1: Change in ecosystem indicators for the Baltic Sea, at the current situation (year 1) compared to the MEY or management plan situation (after year 15)



Result 2. EwE. Fishing mortality for cod 4+ reduced in order to increase biomass 3.3 times (beyond MEY and app. a closure of the fishery)

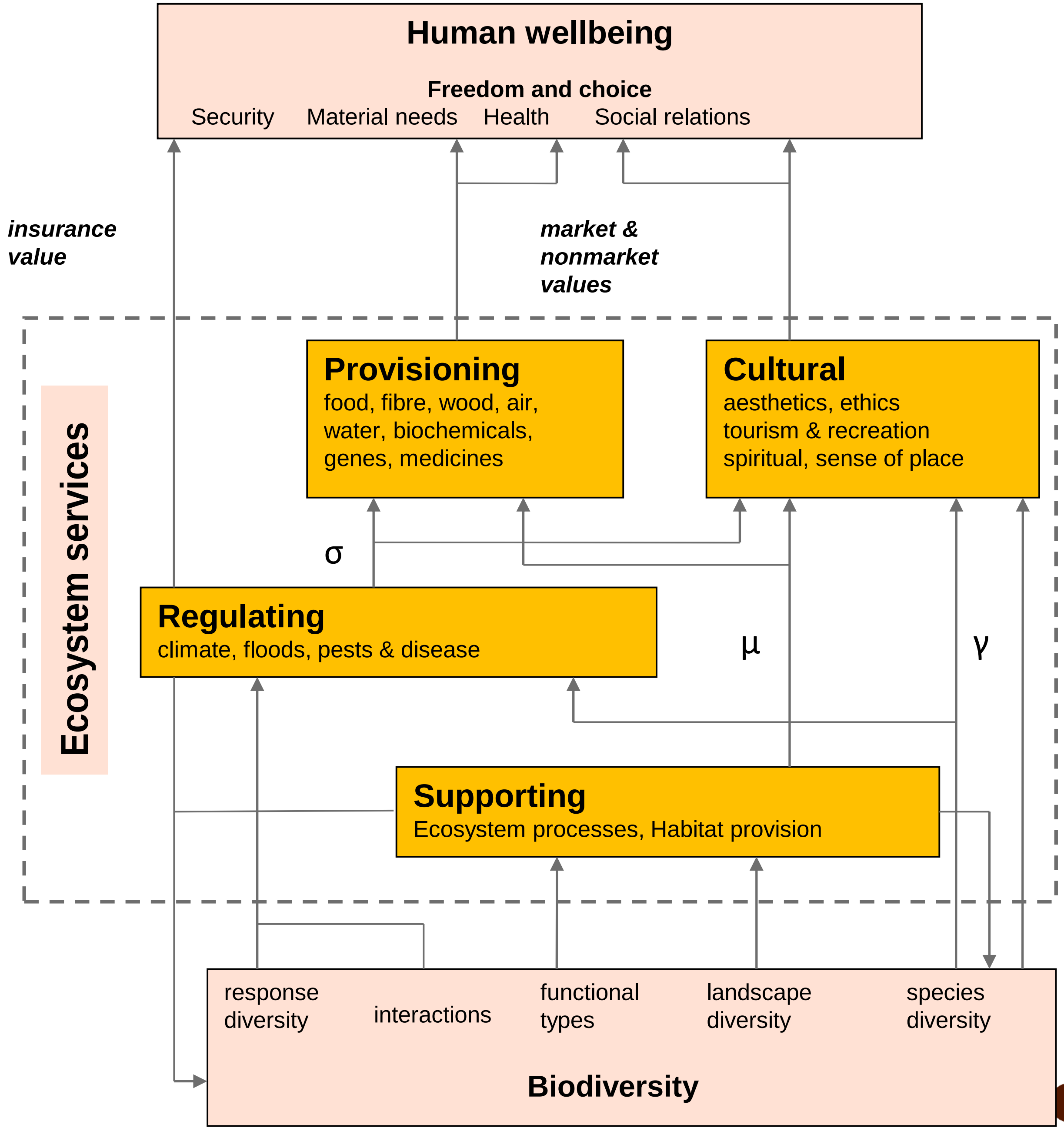


Result 2: Change in ecosystem indicators for the Baltic Sea, at a change in cod 4+ biomass at 1.8 and 3.3 respectively



MA Ecosystem Services Approach

Ocean provide a range of social and economic benefit for humans



MA Ecosystem Services Approach

Impacts of commercial fishing on selected ecosystem services:

Provisioning

- **Food**
- Inedible resources
- Genetic resources
- Chemical resources
- Ornamental resources
- **Energy**
- **Space & waterways**

Regulating

- Atmospheric regulation
- Regulation climate
- Sediment retention
- **Biological regulation**
- Pollution control
- Eutrophication mitigation

Cultural

- **Recreation**
- **Aesthetic value**
- Science & education
- **Cultural heritage**
- Inspiration
- **The legacy of nature**

Supporting

- Biochemical cycling
- Primary production
- **Food web dynamics**
- **Diversity**
- **Habitat**
- **Resilience**

Why Fishrent; model requirements

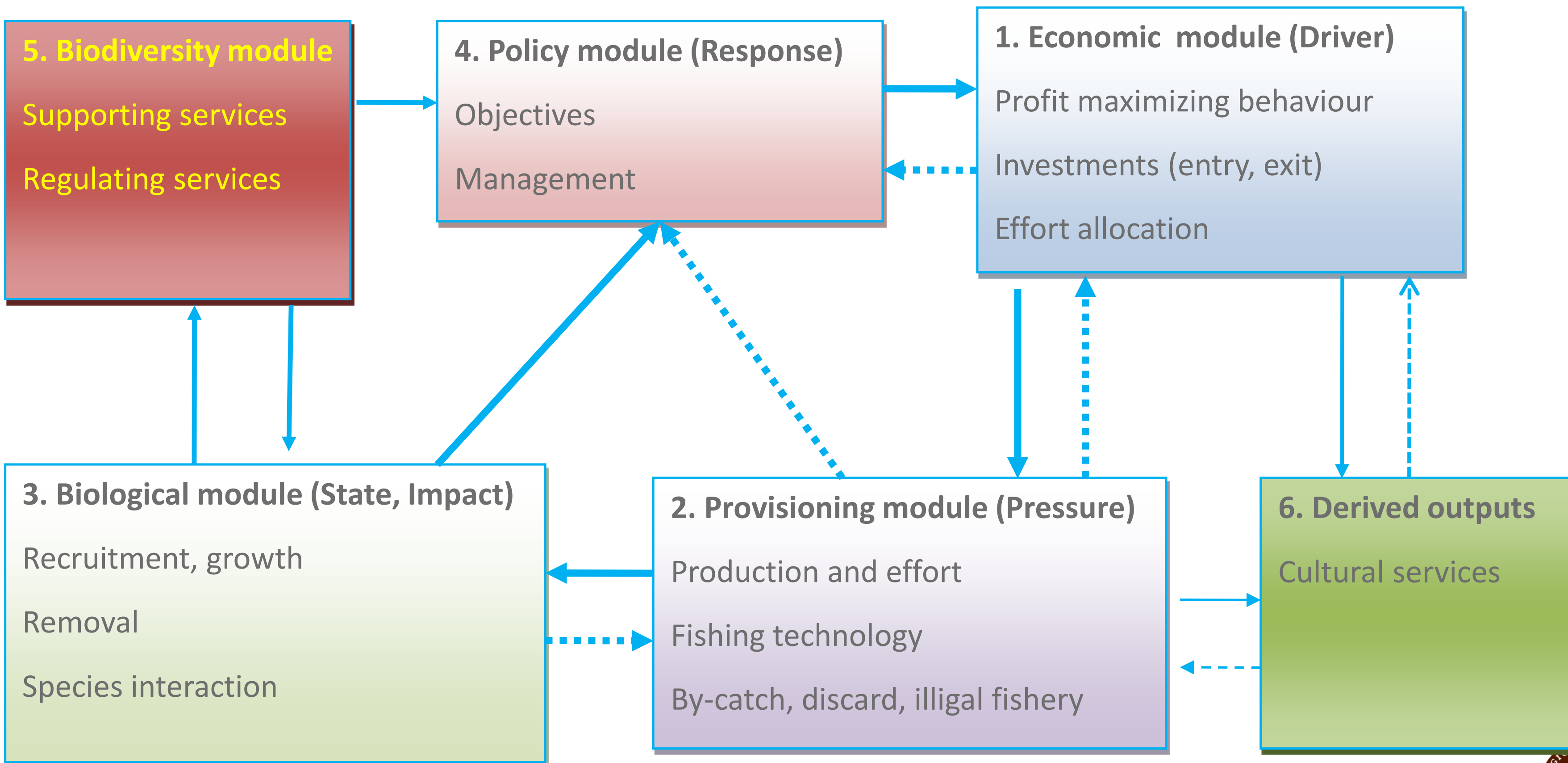
- Integrate simulation and optimization.
- Integrate output (quota)- and input (effort)-driven approaches applied to different situations in the EU, particularly the Atlantic and the Mediterranean/Black Sea areas
- Accommodate multi-species/multi-fleet fisheries, with flexible number of species and segments
- Close link to available economic and biological data (DCF), to allow empirical applications
- Balanced composition between various components: biology, economics, policy.
- Dynamic behaviour over a long period, including stock-growth, investment and effort functions
- Flexibility for applications of various types of relations (e.g. different stock growth functions, approaches to payment for access, etc.).
- Use of a well-known language (Excel) to allow a broad introduction and accessibility to different users.

Fishrent general features

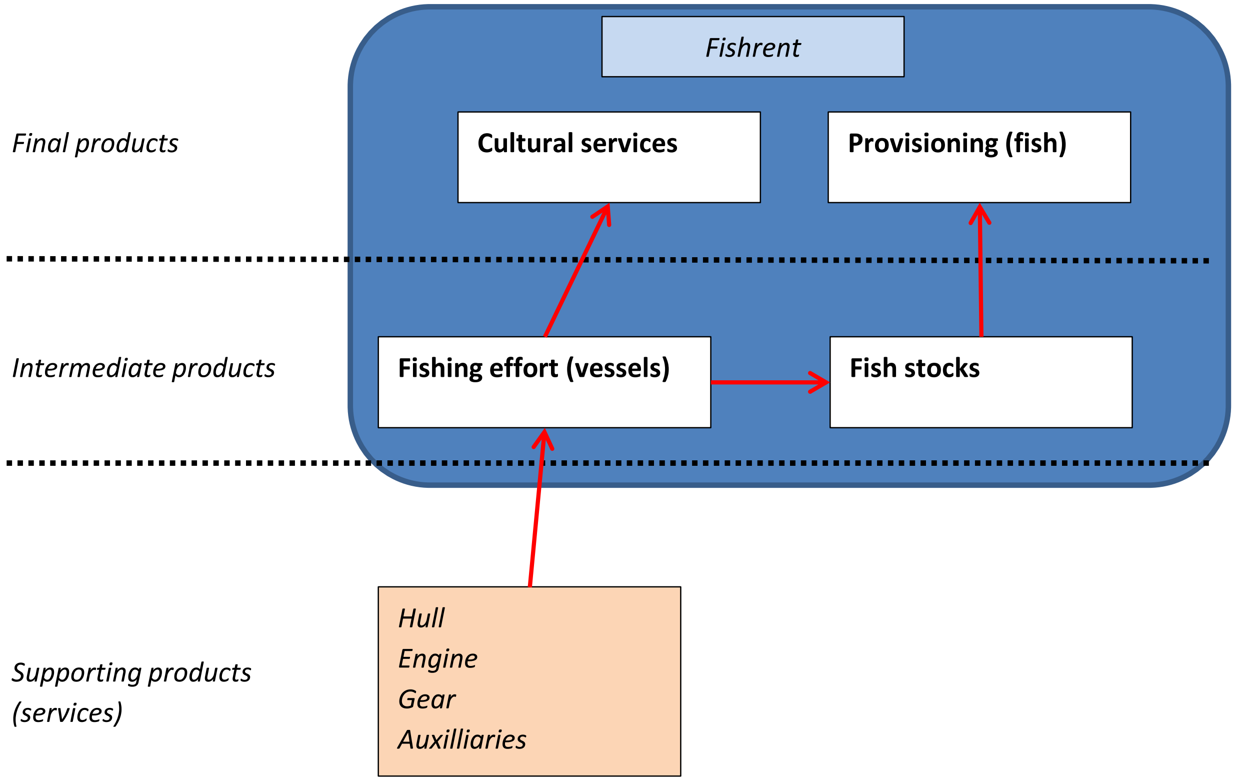
1. **Fish stocks**
   a. Aggregate stock
   b. Recruitment
      - Schaefer
      - Ricker
      - Beverton Holt
      - Stochastic
2. **Model**
   a. A dynamic bioeconomic model which handles both output and input restrictions (control variables) at the same time
   b. Simulates effects for (in our case) 25 years of specific behaviour of the fishermen
   c. Optimize, i. e. maximize resource rent by use of non-linear programming
3. **Policy measures** (control variables)
   a. TAC, effort, ITQ, tax
4. **Results**
   a. Optimization (MEY, MSY)
   b. Net present value for 25 years (in our case)
   c. Develop time paths for a number of variables

Fishrent model

DPSIR method with Ecosystem services included



Link between Fishrent and Ecopath with Ecosim (EwE)



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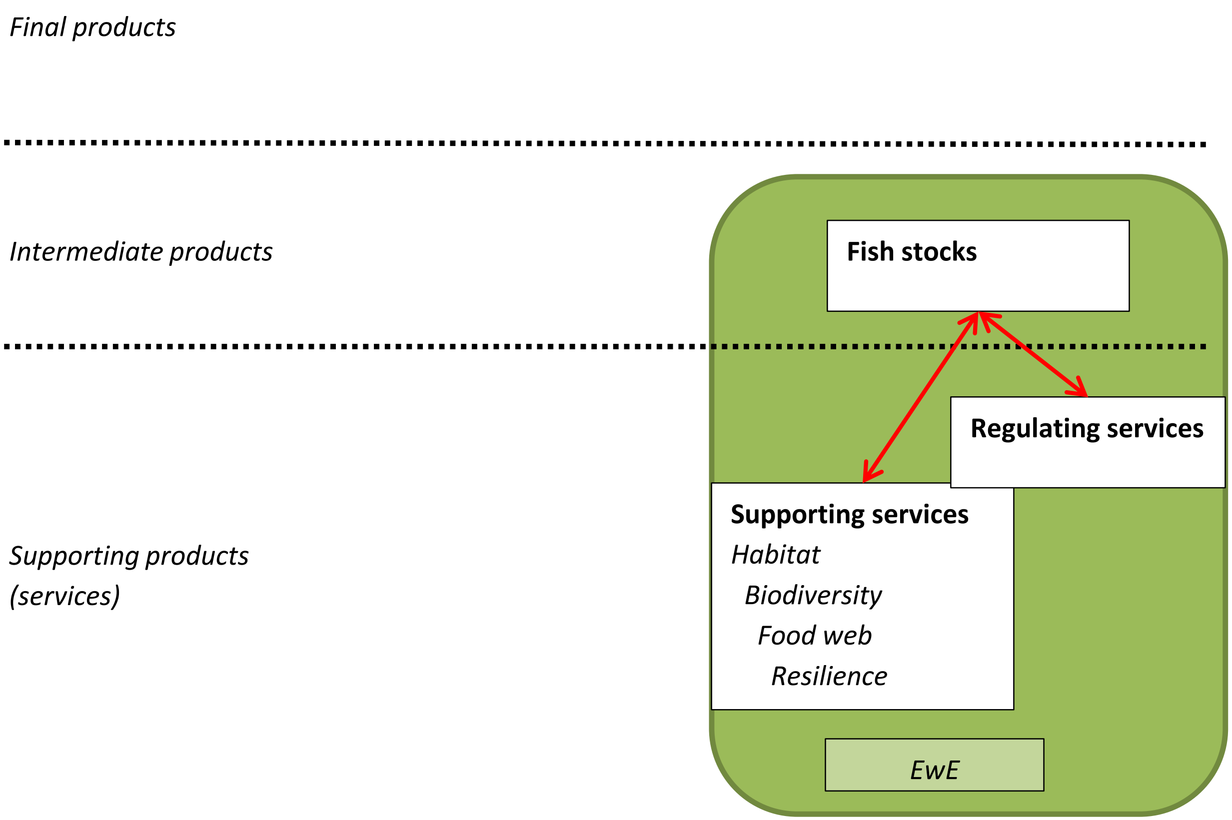

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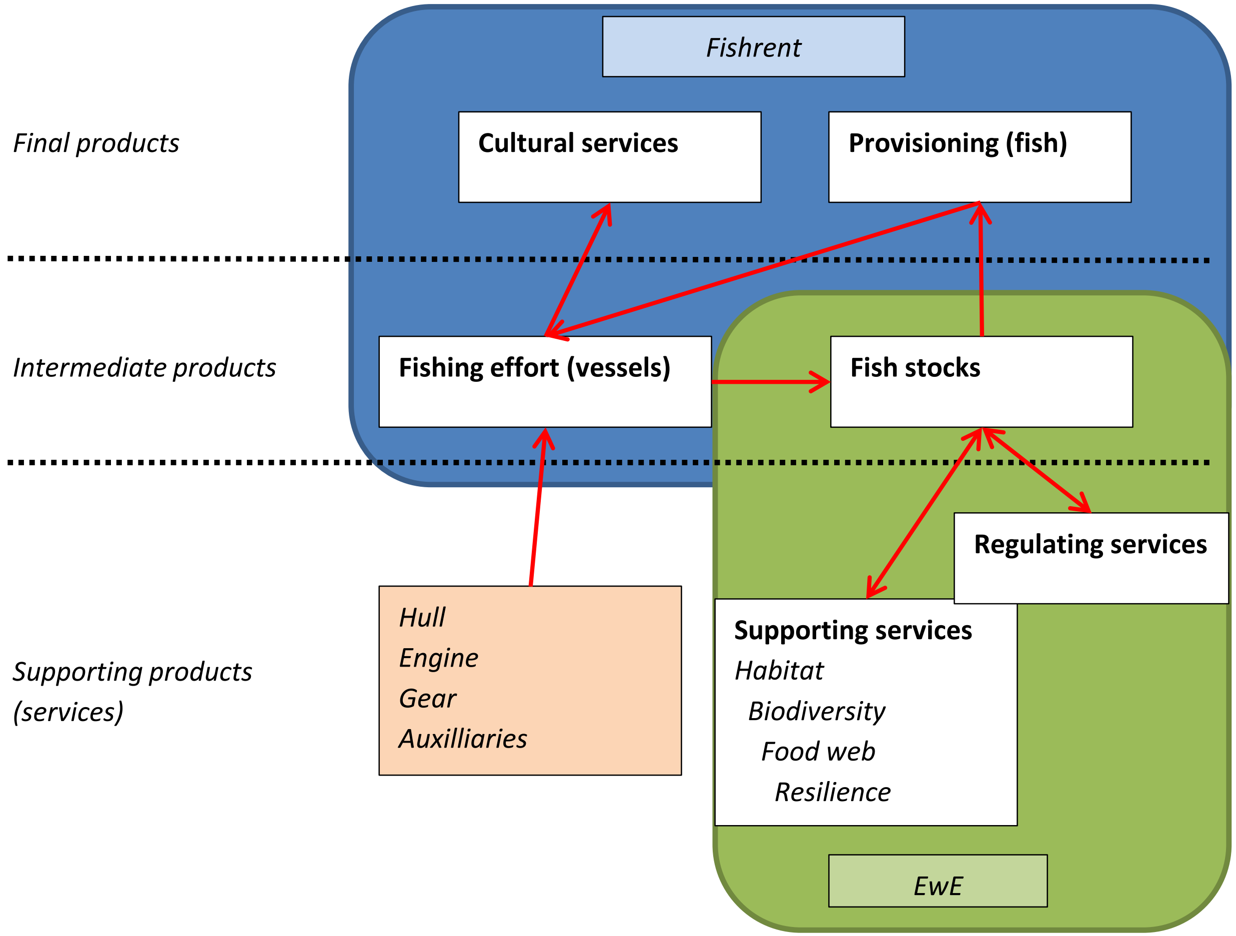


The FISHRENT model contains six modules:

1. Biological module (stock, recruitment)
2. Economic module (costs, earnings, profit)
3. Interface module (production function, technical progress, discard)
4. Market module (price elasticities)
5. Behaviour module (investment)
6. Policy module (harvest control rules)

Main characteristics of FISHRENT (1)

- Accounts for eight species and eight fleet segments (4*4 and 2*2 versions are also available), but can be extended to a larger dimension; a few equation have, because of the model structure, to be elaborated manually.

- The model is a dynamic simulation model, running for a period of 25 years.

- Extension to a longer period is possible.

- By using the Excel Solver tool, the model can be used as an optimization model, which is particularly relevant in relation to the estimation of the potential optimum resource rent.

- The model combines input and output based management, as well as their combinations. This has been achieved by a two stage calculation, in which first the relevant combination of effort and catch is determined and subsequently applied in the actual simulation model.

Main characteristics of FISHRENT (2)

- Contains various options for the collection of rent (payment for access), including fixed fee per unit of capacity (vessel), payment per unit of effort (day-at sea) and tax on revenues or profits.

- Contains a large number of features, including parameter for technological progress, discards of sized and undersized fish, various options for simulation of investments.

- Using Excel implies that all relations are individually specified.

- Consequently,

the specification of any relation can be easily adapted, e.g. each stock may be characterized by a different growth function and each fleet segment by a different investment function.

EwE for the Baltic Sea

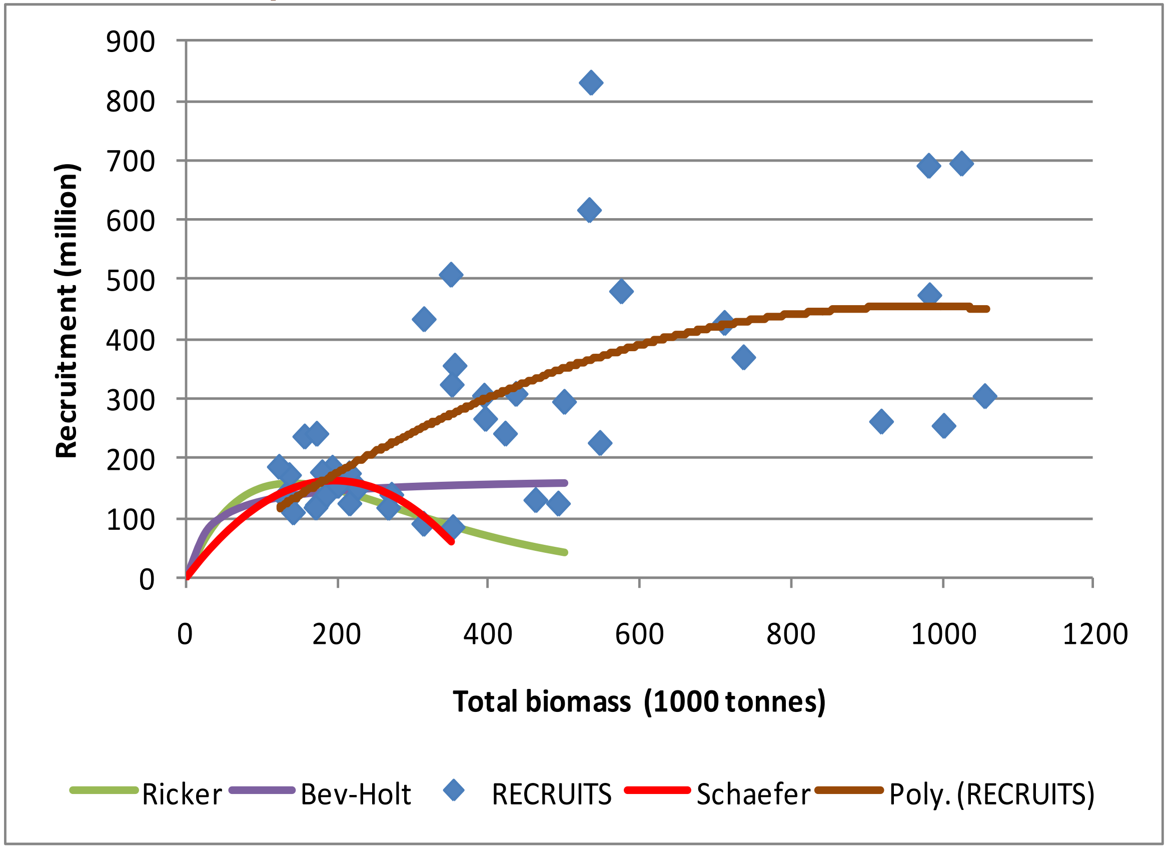
Mass balance model which includes ecosystem indicators

- Cod, herring and sprat divided on juveniles and adults
- Seal
- Phyto- and zooplankton
- Benthos
- Et al.

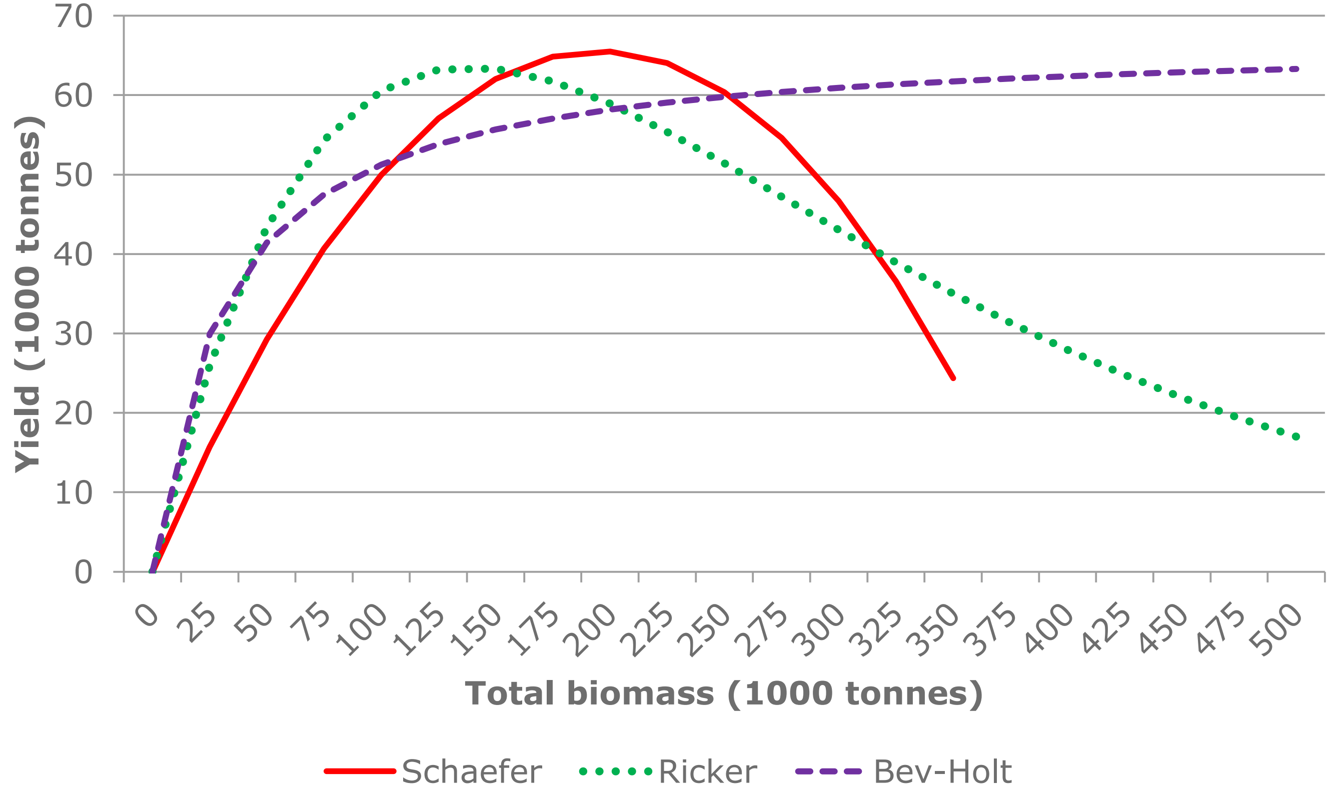
Tomczak et al. (2012) Ecosystem flow dynamics in the Baltic Proper – using a multo-trophic dataset as a base for food web modelling. Ecoligical modelling 230: 123-147

Eastern Baltic cod

Recruitment at age 2 as a function of spawning stock biomass 1966-2008 (Poly. recruits) and 1989-2008 (lower left Ricker, Bev-Holt and Schaefer)



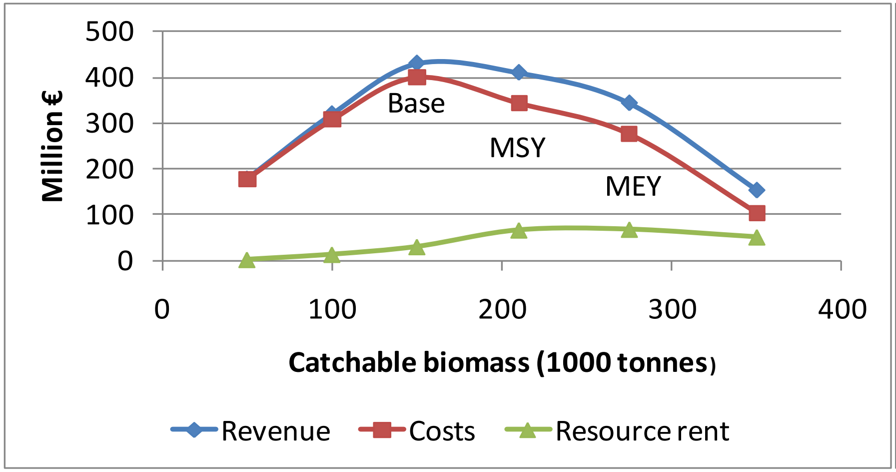
Yield functions for Eastern Baltic cod. The schaefer function is used in FISHRENT

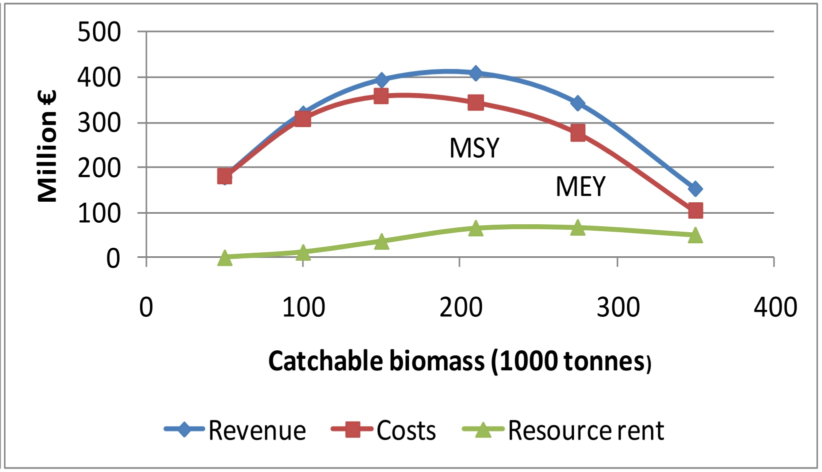


Baltic cod fishery, model parameters

	Trawlers 12-24m	Gill netters 0-12m
Initial no. of vessels	1176	1427
Maximum days at sea per vessel	140	120
Cod price	€ 2.39	€ 2.39
Gross revenue all species base years	€ 305 million	€ 125 million
Value of other species compared to cod value	200%	121%
Fuel cost share of gross revenue	20%	5%
Crew cost share of gross revenue	50% (2.5 crew)	50% (1 crew)
Fixed cost share of vessel value	18%	25%
Capital cost share of vessel value	10%	10%
Discount rate (socio-economic)	3.5%	3.5%
Discard of undersized cod	10%	10%
Catch-effort elasticity (α)	0.6	0.4
Catch-stock elasticity (β)	0.4	0.6
Technical progress per year (τ)	1%	1%
Interest rate (r)	3.5%	3.5%
$\rho_{in} = \rho_{out}$ (1000 €)	234	32
Partial adjustment factor (λ)	0.125	0.125

Maximum sustainable and maximum economic yield from the Eastern Baltic Sea cod stock fishery including catch of other species





Static solution produced as a special case of FISHRENT. "Base" in left diagramme shows the actual 2005-2007 fishery which is unsustainable compared to the right hand diagramme.
None of the static solutions presented above are stable unless the resource rent is extracted.

Investment behaviour is addressed in the dynamic analyses.

Fishrent and EwE linked methodology

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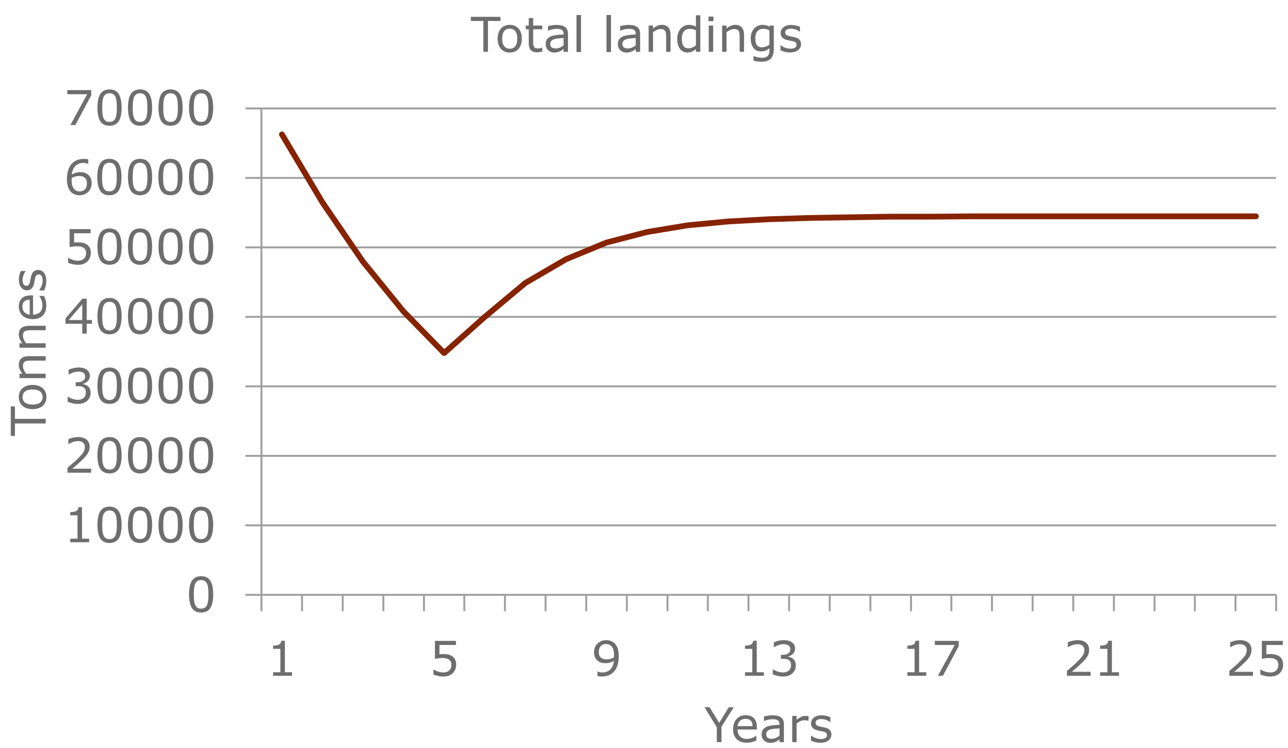
Fishrent and EwE applied according to management plan and time

1. Management plan
   a. Target landings (quota)<= 25% of catchable biomass
   b. Change in landings in T+1 <= 15% of landings in T until target landings are reached
2. Fleet adjustment:
   a. Investment a function of profit (past two years)
   b. The fleets can change only <= 10% up or <= 20% down (arbitrarily set)

Result of the management plan and dynamic adjustment

1. Fishrent
   a. Quotas are reduced in the first years
   b. Profit decreases and vessels leave
   c. Biomass of cod increases
   d. Long run: no. of vessels stabilize (level depends on assumptions about investment (management restrictions)
   e. Profit stabilizes accordingly in the long run
2. EwE
   i. Cod biomass increases
   ii. Other indicators change

Fishrent according to management rule above



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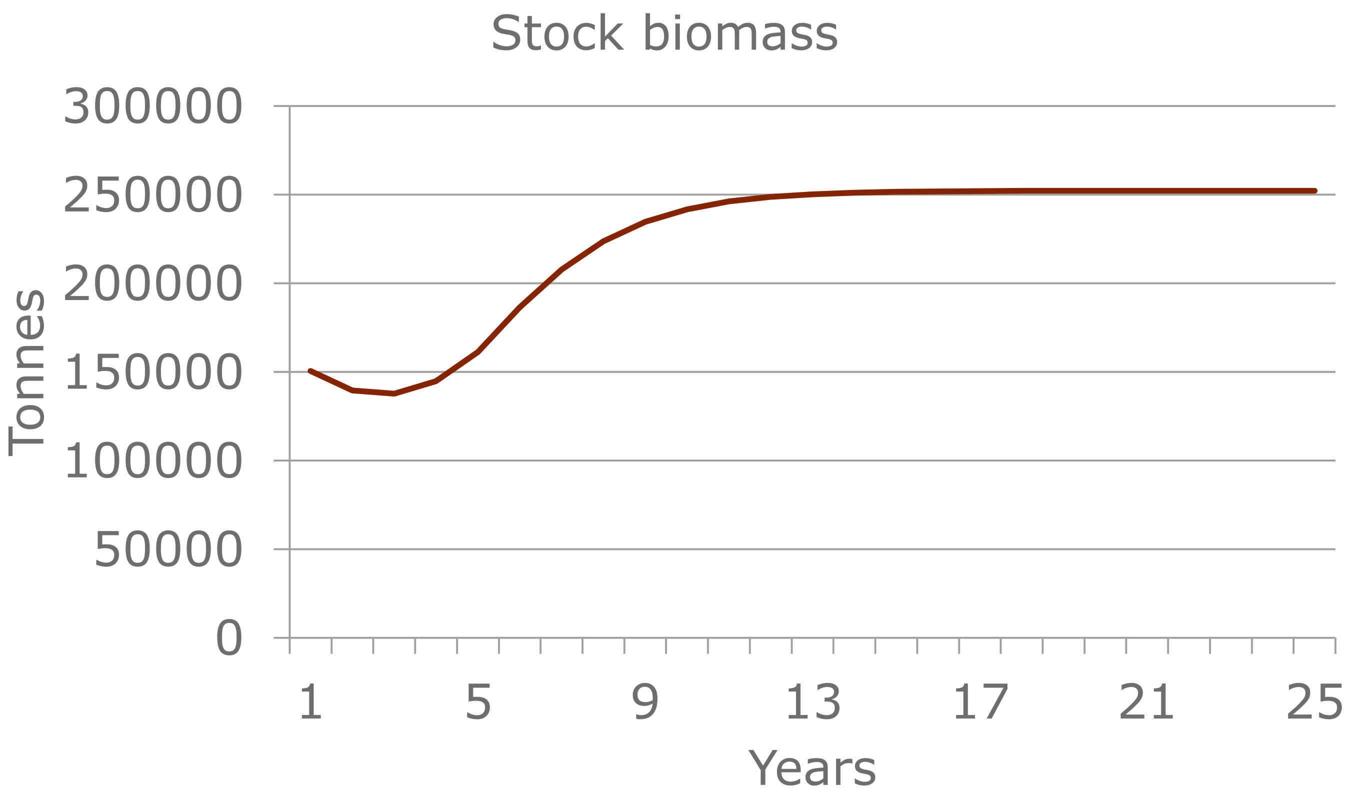

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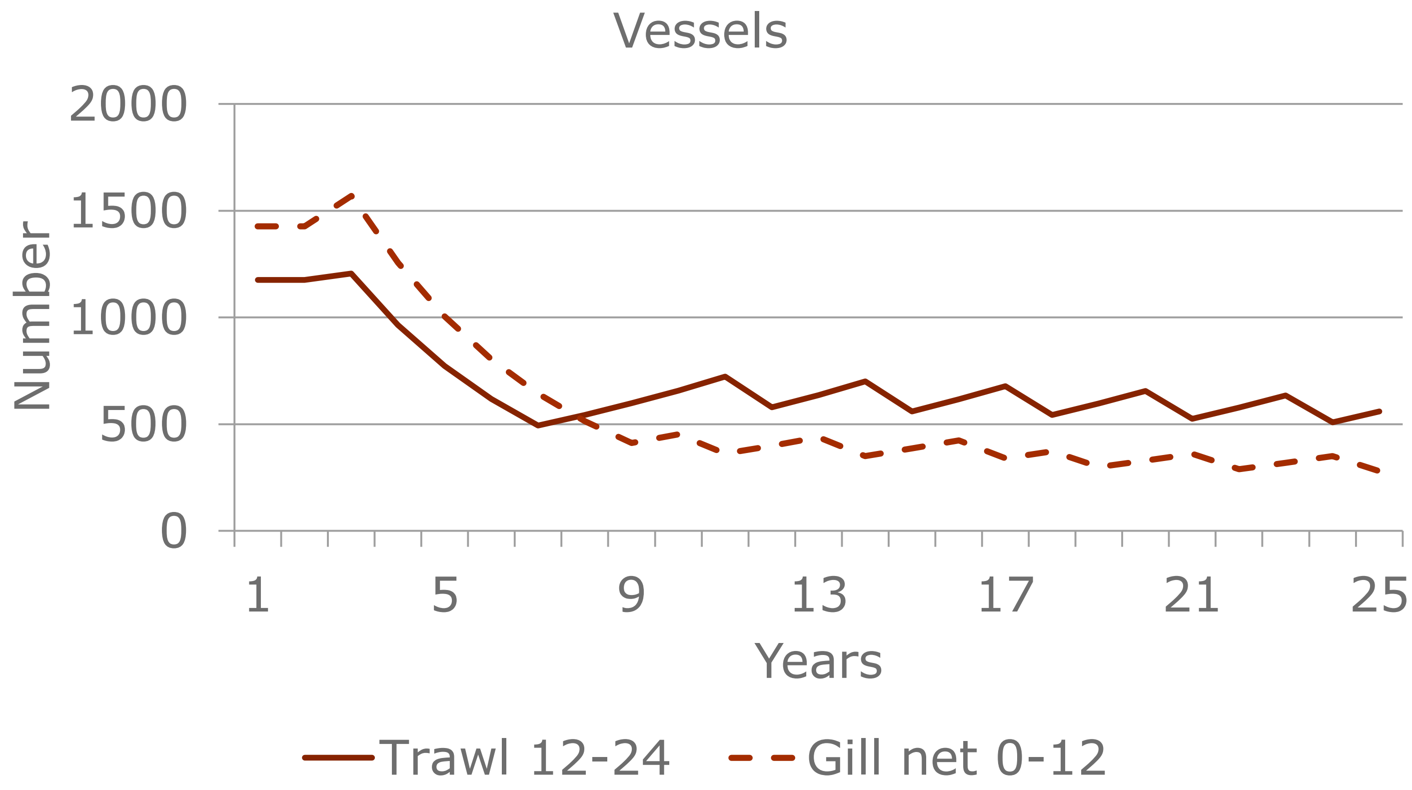

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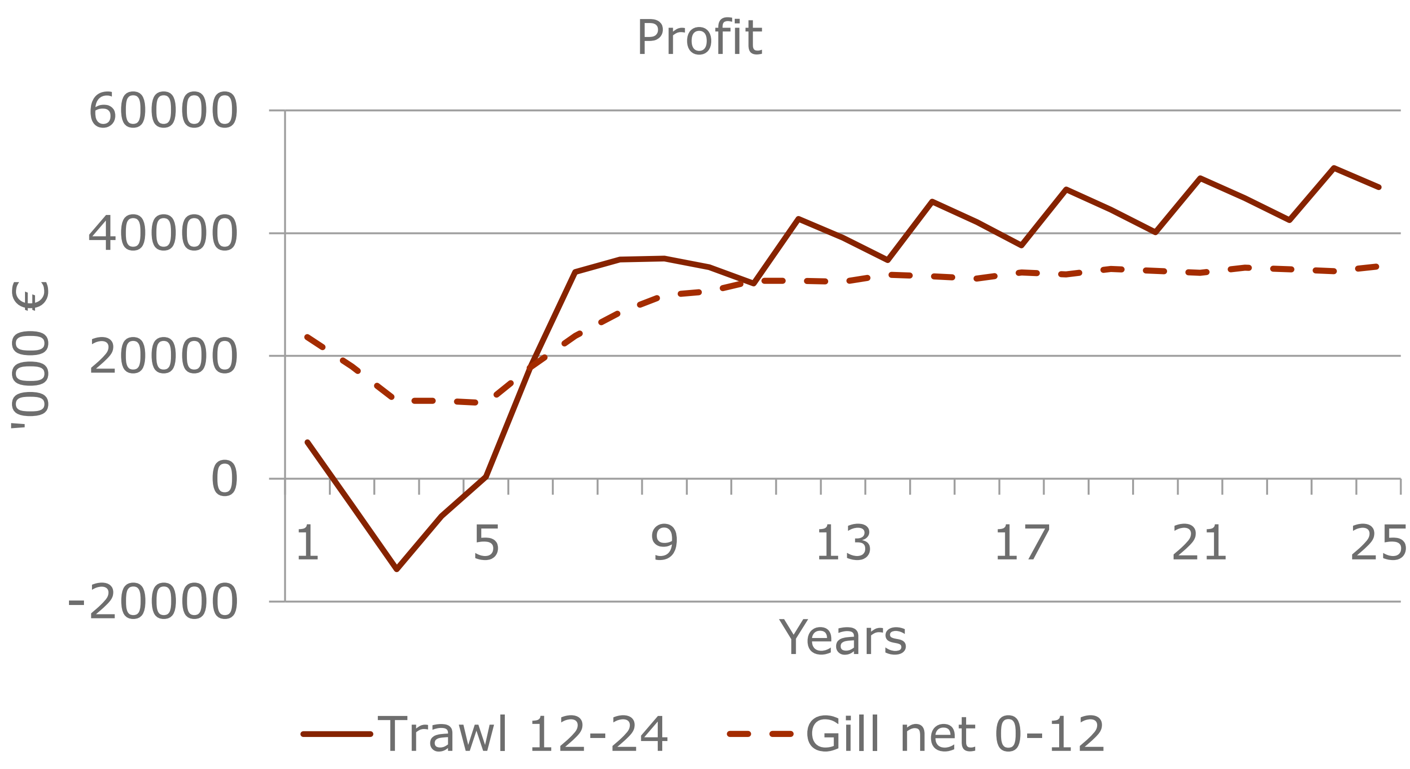

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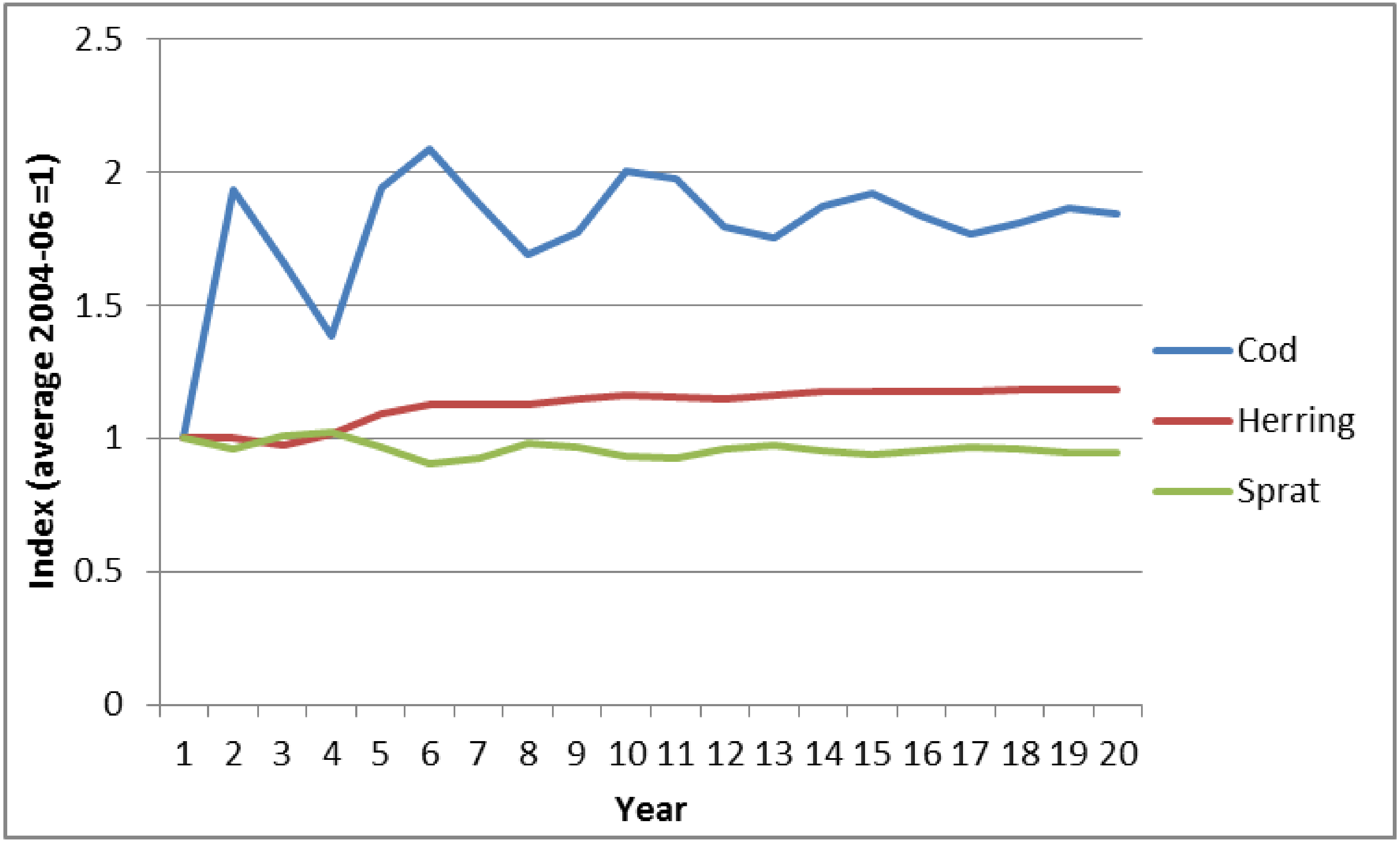

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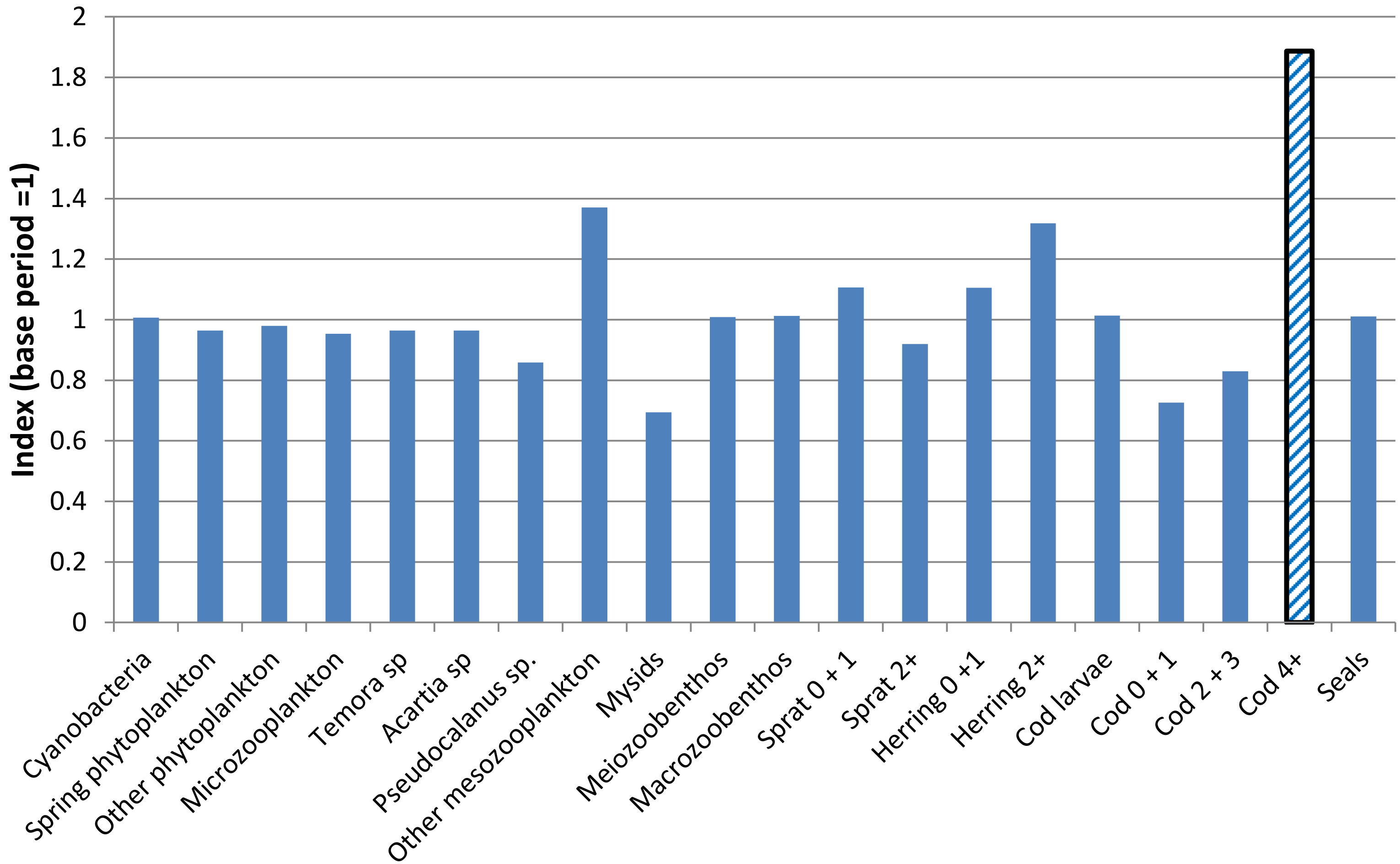

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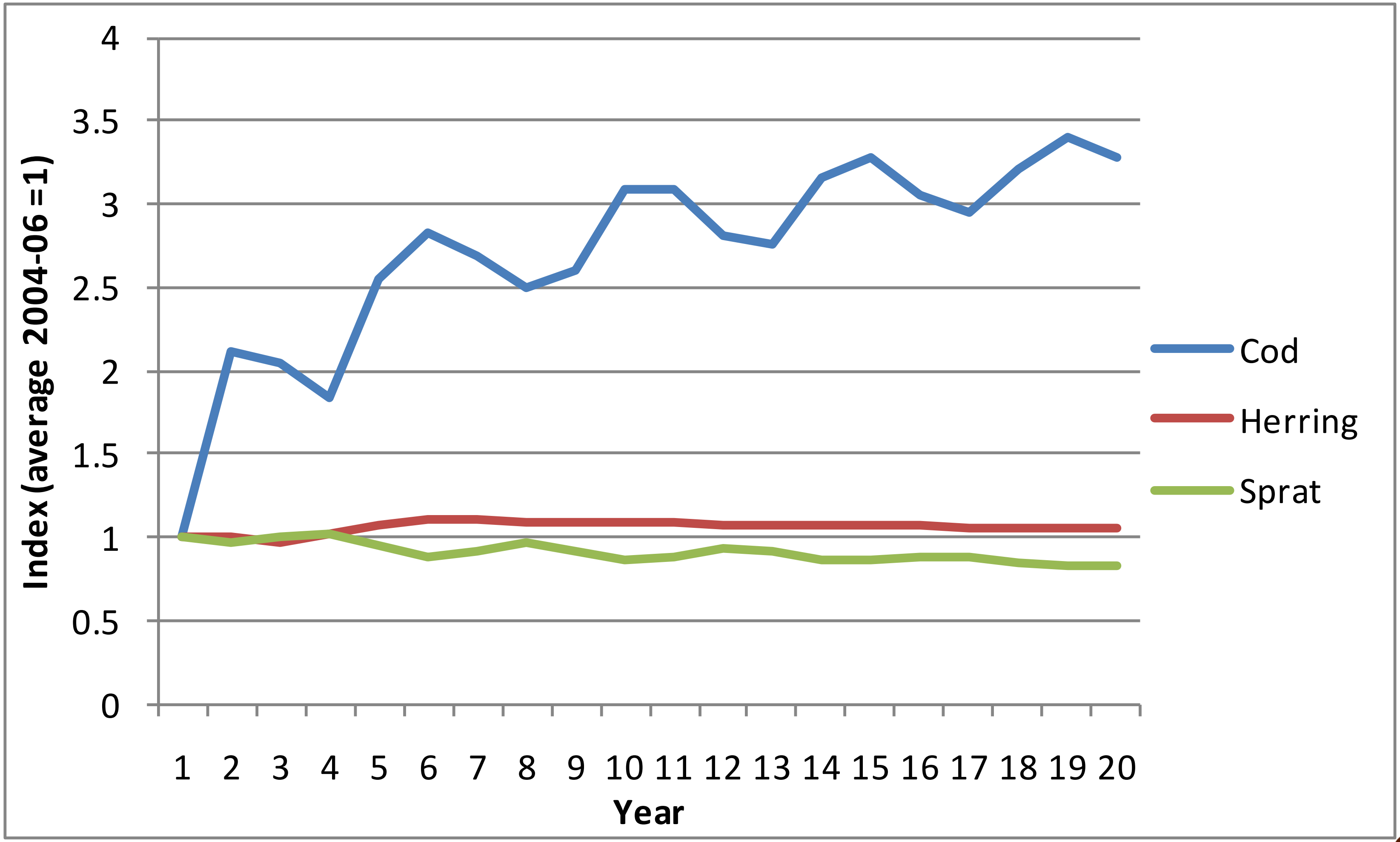

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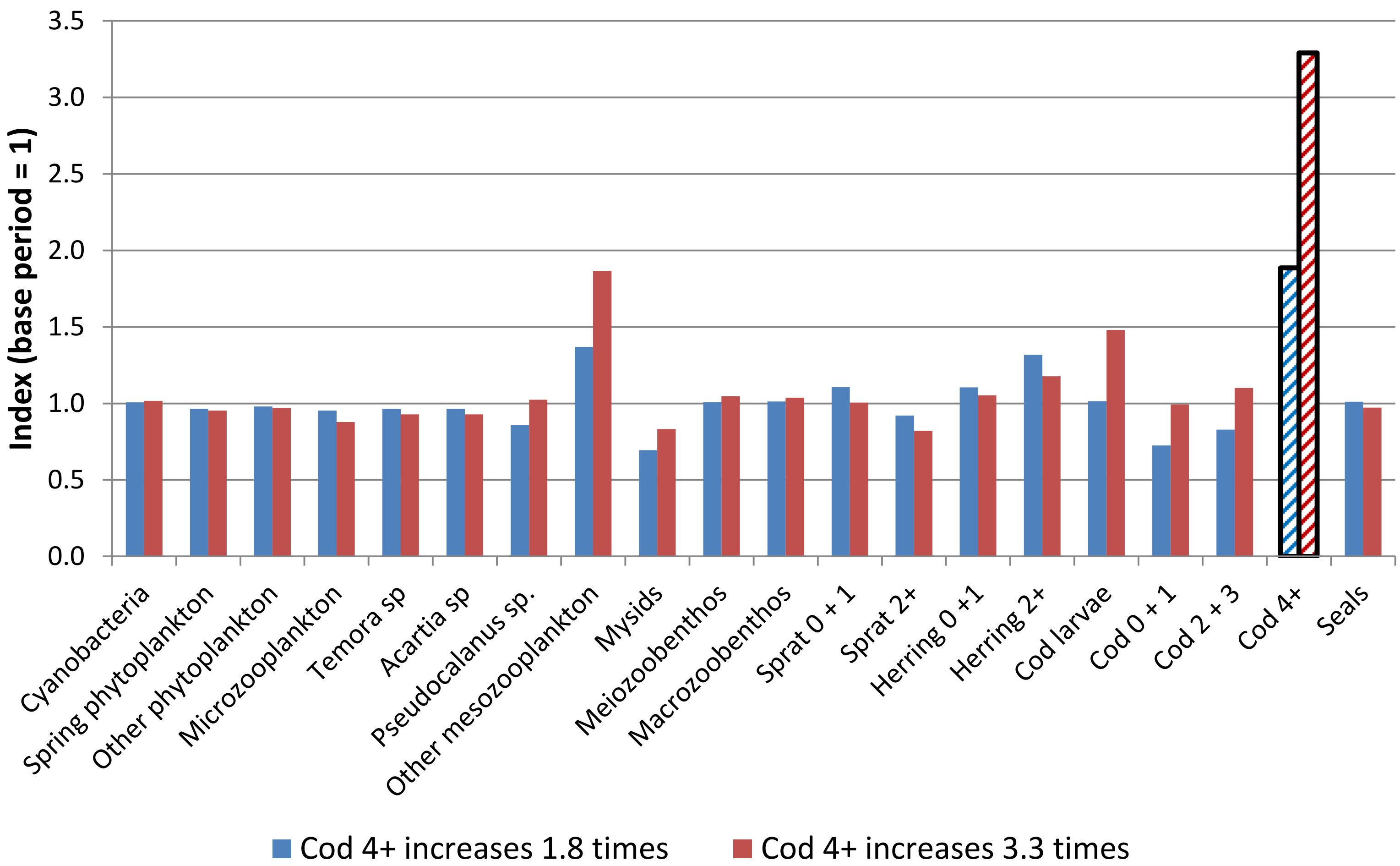

Discussion

1. Models are constructed on theoretical solid ground
2. Linking models seems to be fruitful
3. If a fish stock on high trophical level is managed properly no concern is needed for the underlying system for the Baltic Sea, which changes only slightly
4. Avoidance of double counting and accounting for final, intermidiate and supporting products alleviate the risk of abuse of the ecosystem services if fisheries are managed properly
5. Results are (obviously) dependent on assumptions
6. Uncertainty can be tested by use of sensitivity analyses
7. Fishing activity might not be that important for the environment!!
8. Climate change and land based pollution most likely are the drivers/are more important!!


Thank you for your attention