A map of the Baltic Sea region, showing the sea in blue and the surrounding landmasses in yellow. The text is overlaid on a semi-transparent white box in the center of the sea.

A strategy for **Ecosystem-Based Fisheries Management** of the Central **Baltic Sea** based on the available knowledge of ecosystem functioning

Ecosystem Approach to Management

„A strategy for the **integrated management of land, water, and living resources** that promotes conservation and sustainable use in an equitable way”, and the ecosystem can be defined as “an interacting complex of living communities and the environment, functioning as a largely self-sustaining unit.” Humans are part of the ecosystem. “

The Convention on Biological Diversity (CBD)

„a comprehensive **integrated management of human activities** based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of the marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity.“

European Marine Strategy

Ecosystem-based (fisheries) management

„**Ecosystem-based management** is an integrated approach to management that **considers the entire ecosystem**, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive, and resilient condition so that it can provide the services human want and need.

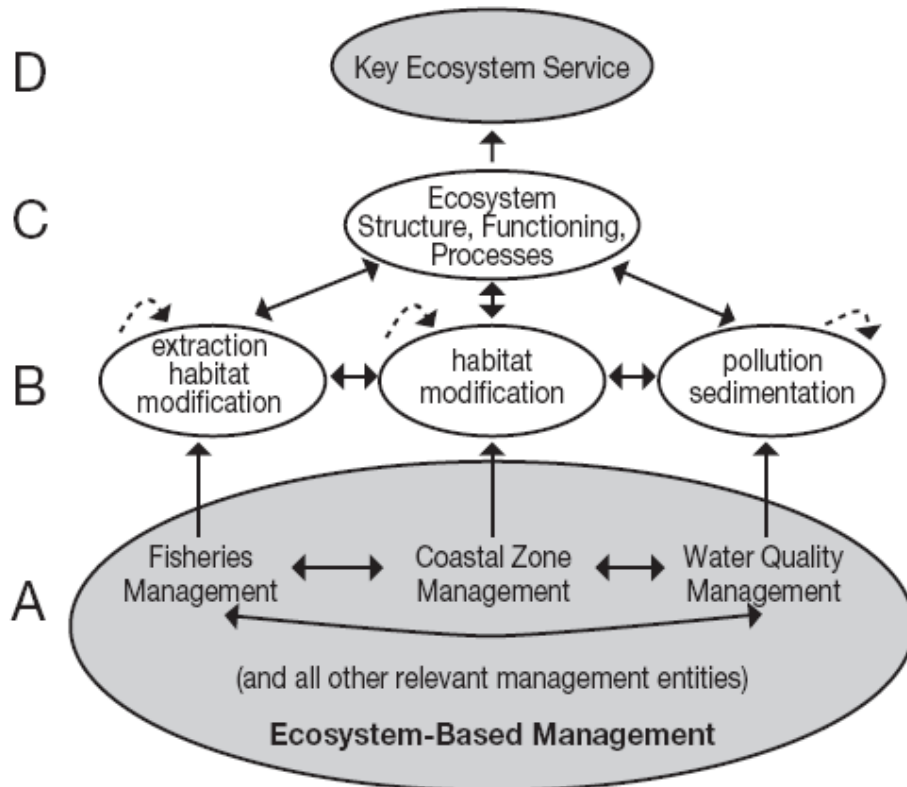
Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it **considers cumulative impacts of different sectors**.“

Scientific Consensus Statement - McLeod et al. 2005

„**EBFM** recognizes the **physical, biological**, economic, and social **interactions among the effected components of the ecosystem** and attempts to manage fisheries to achieve a stipulated spectrum of societal goals, some of which may be in competition.“

Marasco et al. 2007, CJFAS 64

Ecosystem-Approach to Management



Goals is to maintain ecosystem services

Monitoring the effect on ecosystem structure ...

Investigation of interactions of the impacts of individual sectors

Consideration of interactions among policies

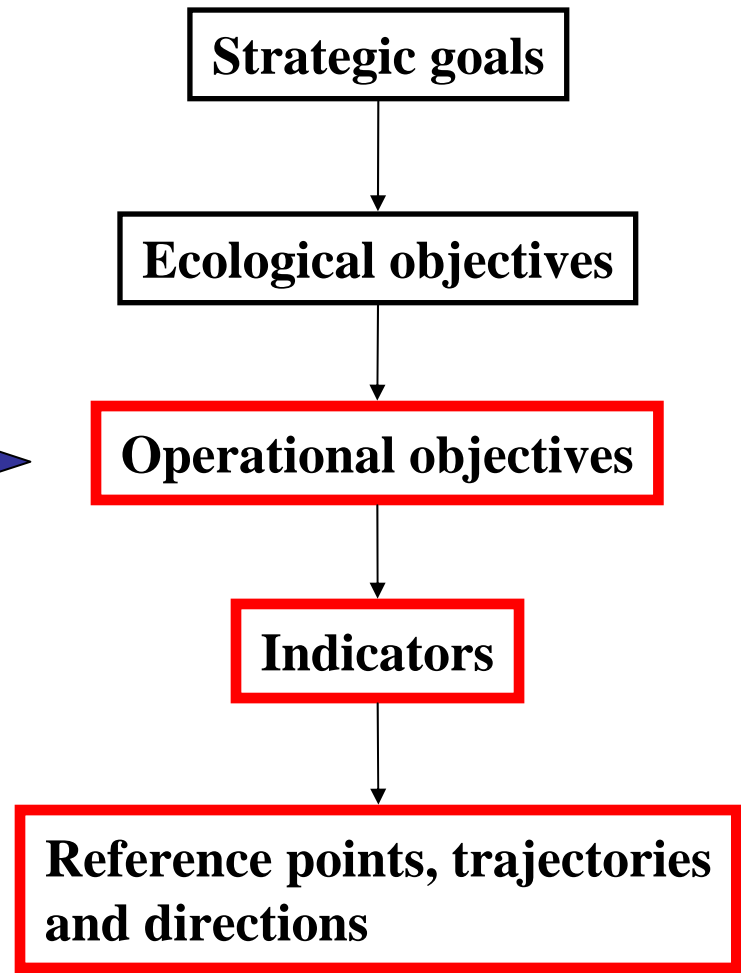
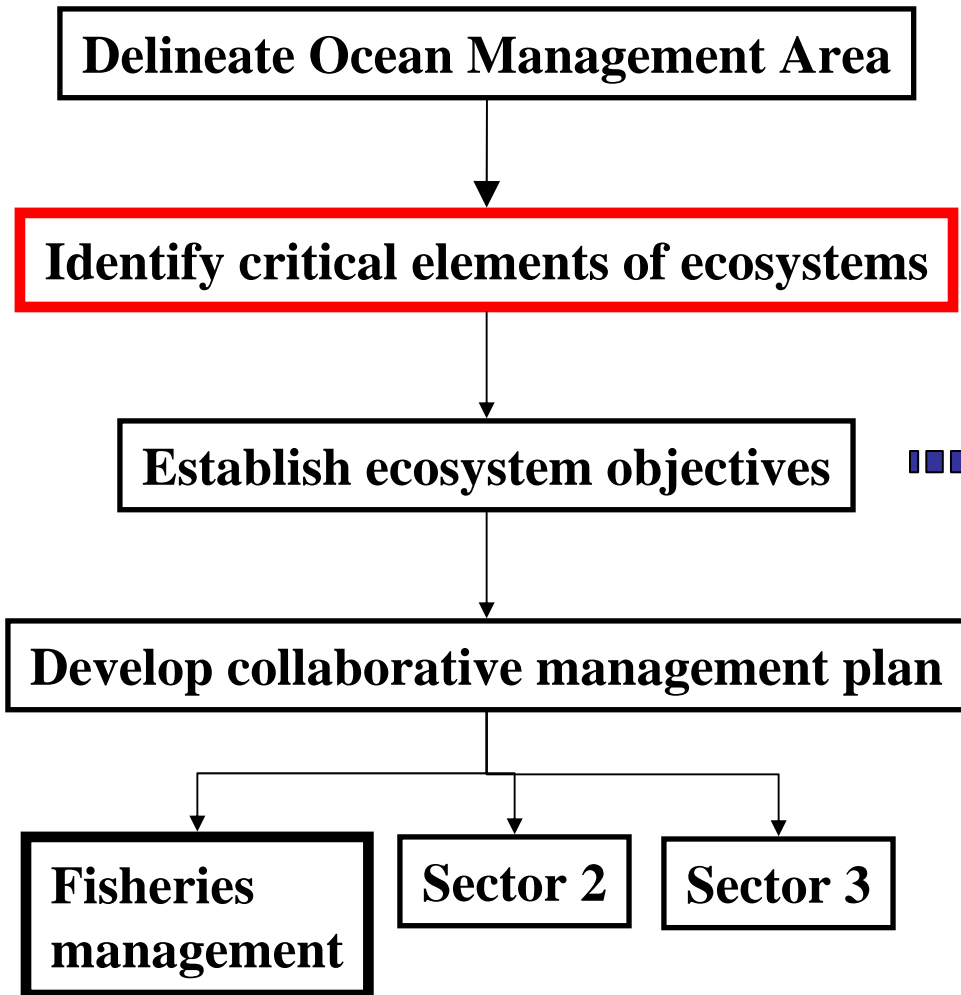
„The 7-step process*“

1. Scoping the current situation
2. Contrasting with the vision
3. Identifying important ecosystem properties and threats
4. Setting ecological objectives
5. Deriving operational objectives with indicators and reference points
6. Ongoing management
7. Periodic updates

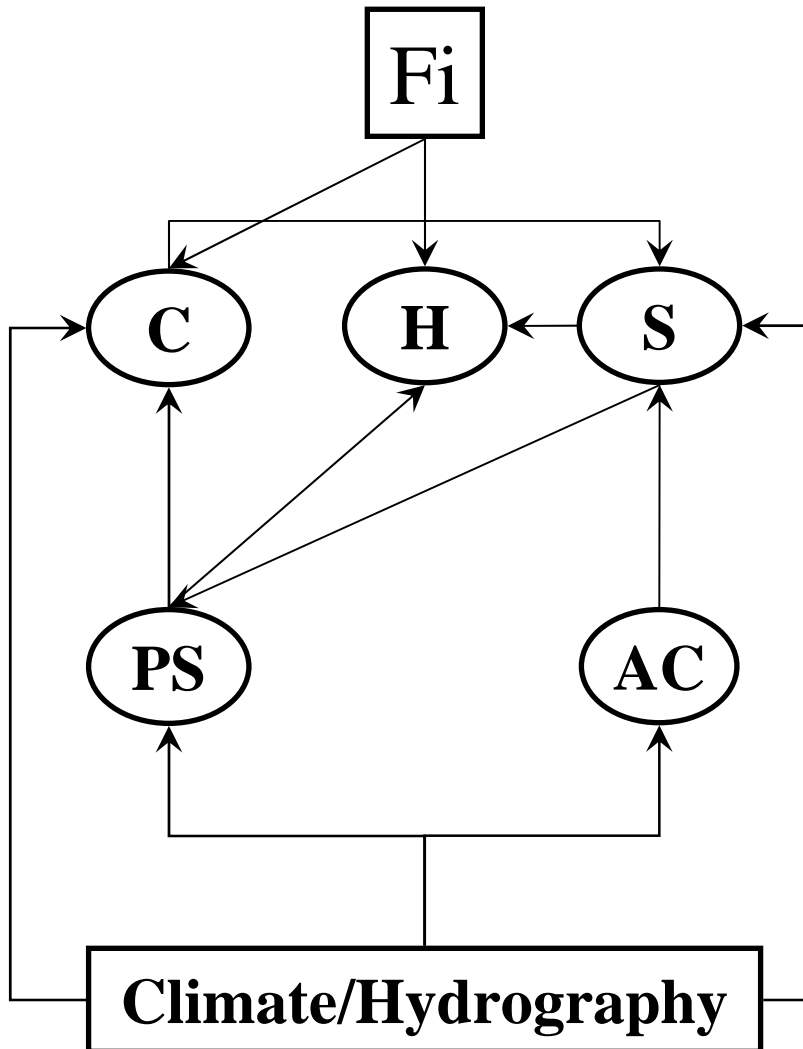
* Rice, Trujillo, Jennings, Hylland, Hagstrom, Astudillo & Jensen. 2005. Guidance to the Application of the Ecosystem Approach to Management of Human Activities in the European Marine Environment. ICES Coop. Res. Rep. 273.

Ecosystem-Based Management

Ecosystem-Based Fisheries Management



Identify critical elements of an ecosystem: a conceptual (upper trophic level) ecosystem model



Fi – Fishery

C – Cod

H – Herring

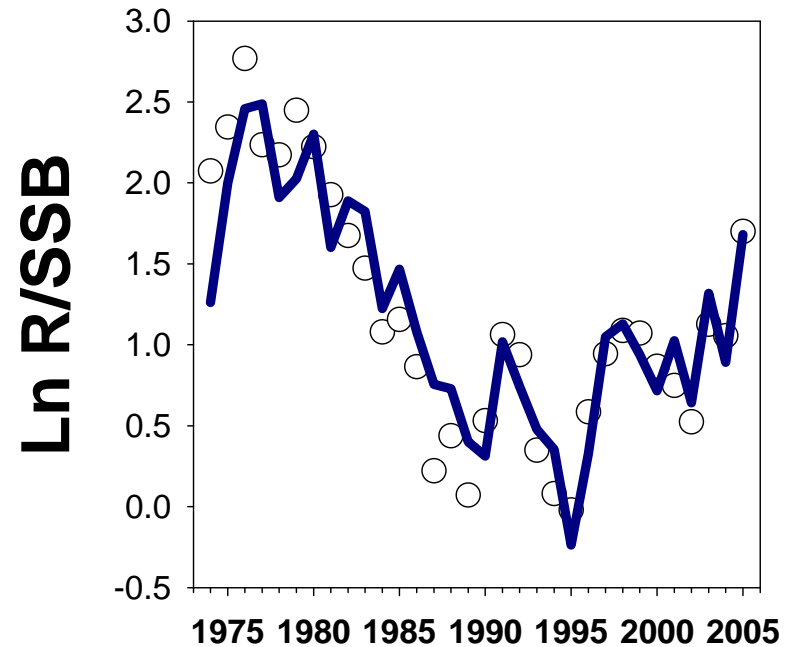
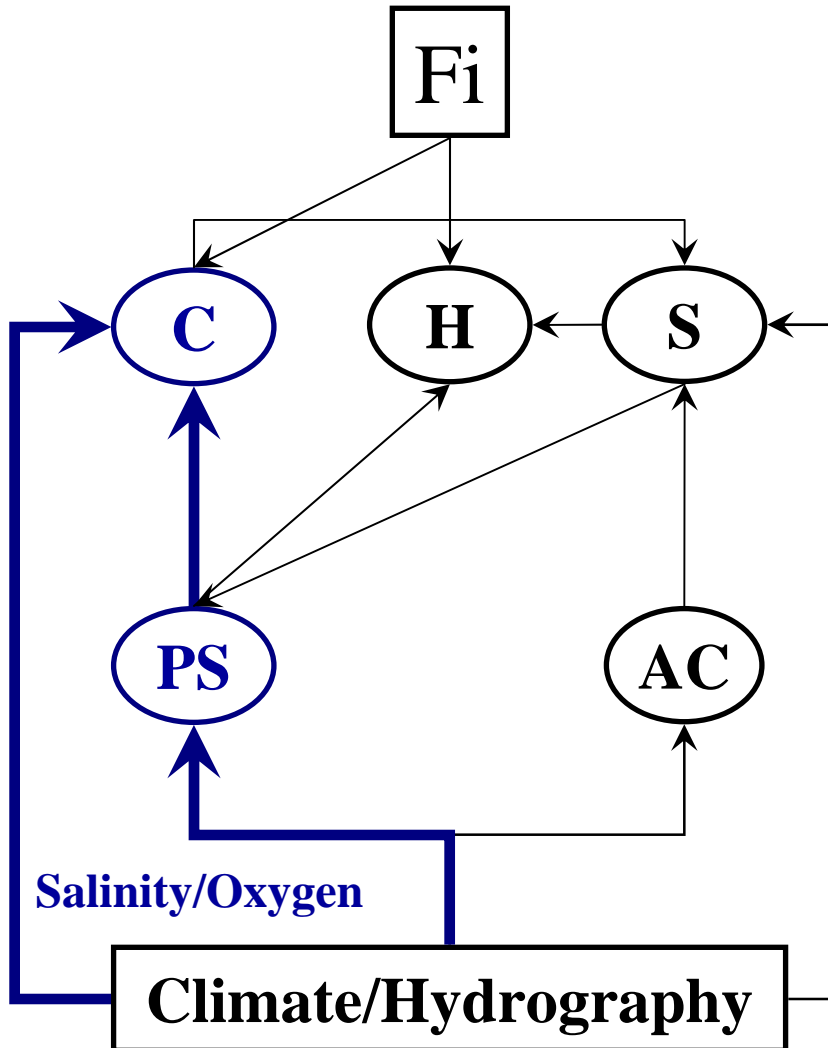
S – Sprat

PS – *Pseudocalanus acuspes*

AC – *Acartia* spp.

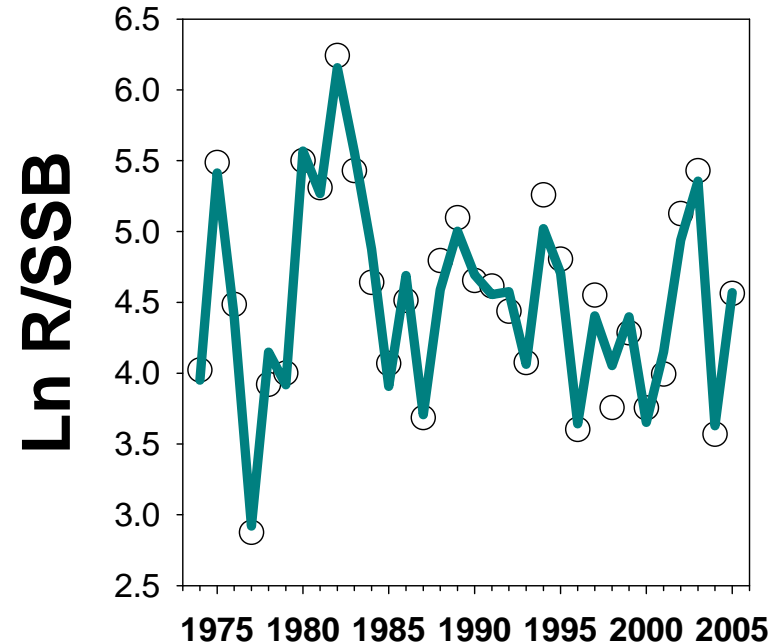
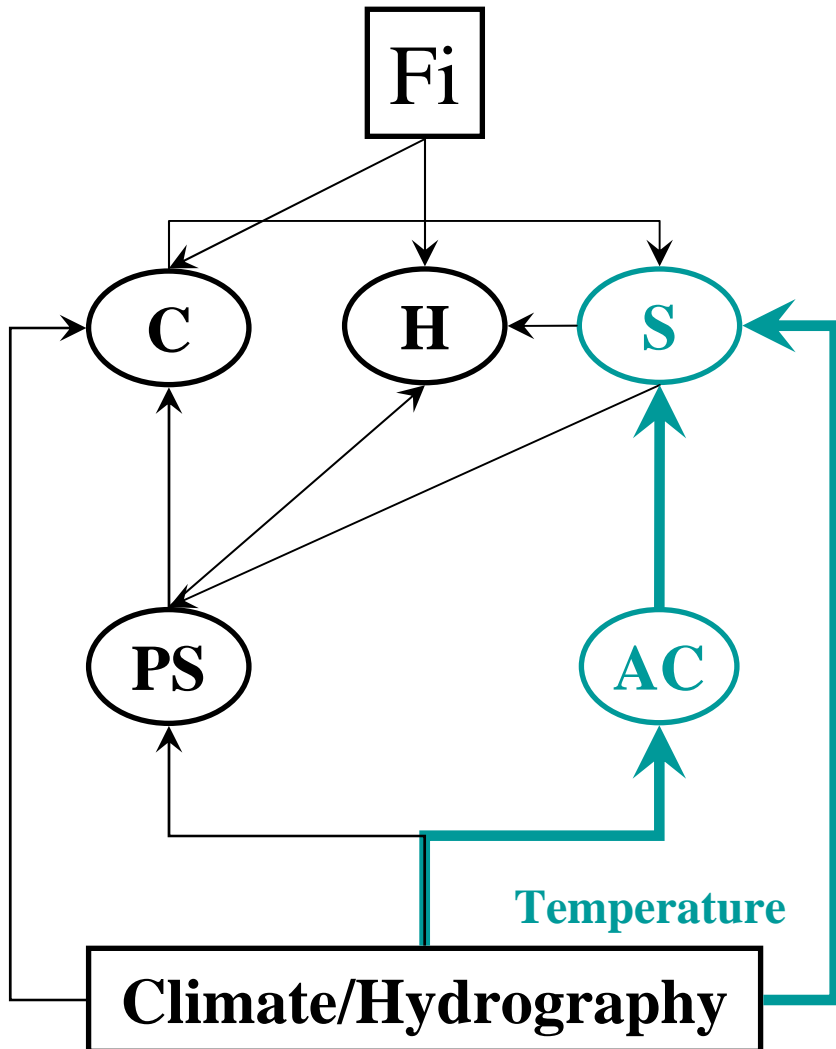
- Key species and interactions !
- Does not mean other species are not important !
- These are limiting interactions we know !
- Period 1974-2005 !

The salinity/oxygen path !



- Generalized Additive Model (GAM)
- Predictors:
 - SSB
 - Reproductive Volume (RV)
 - *Pseudocalanus acuspes* biomass
- R^2 (%) = 85.5

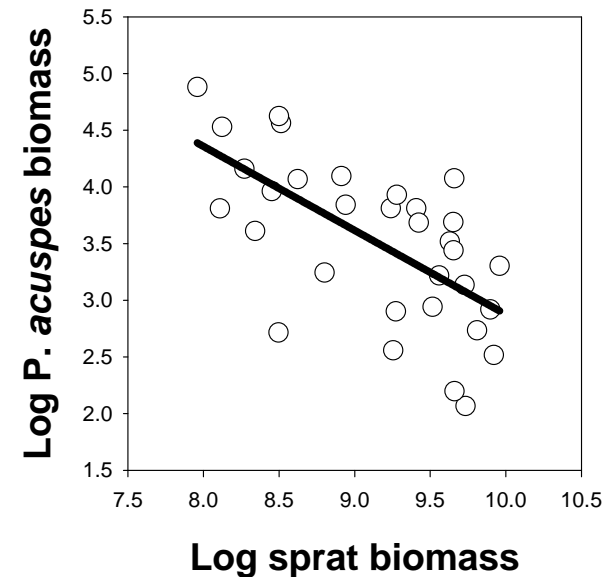
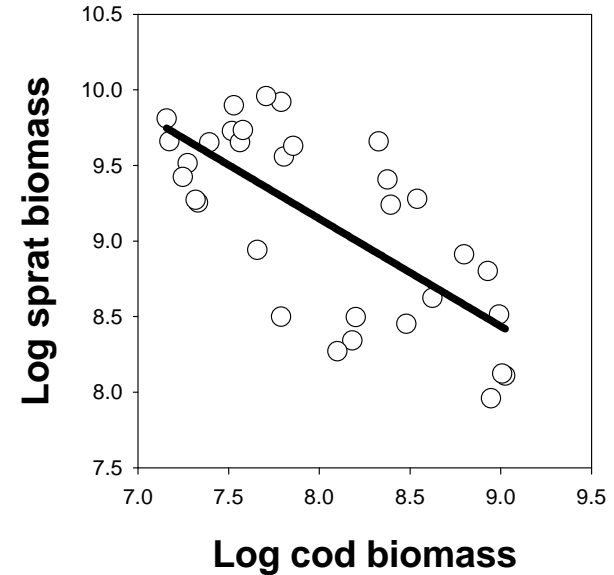
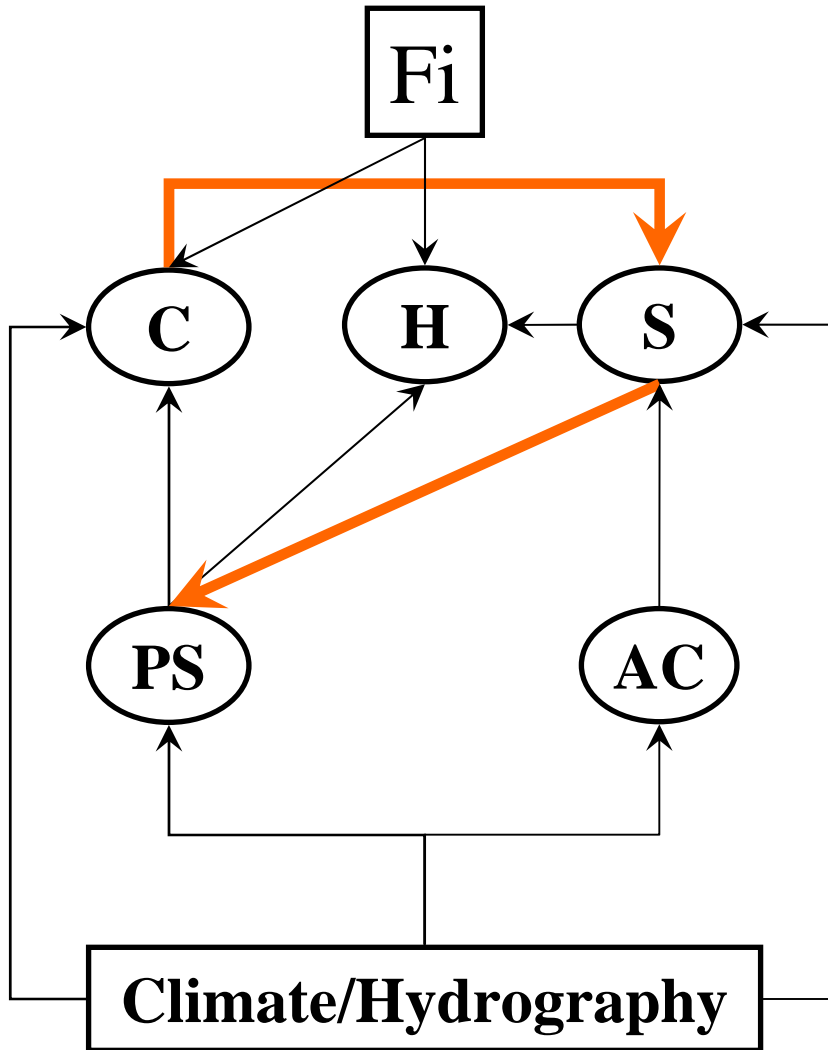
The temperature path !



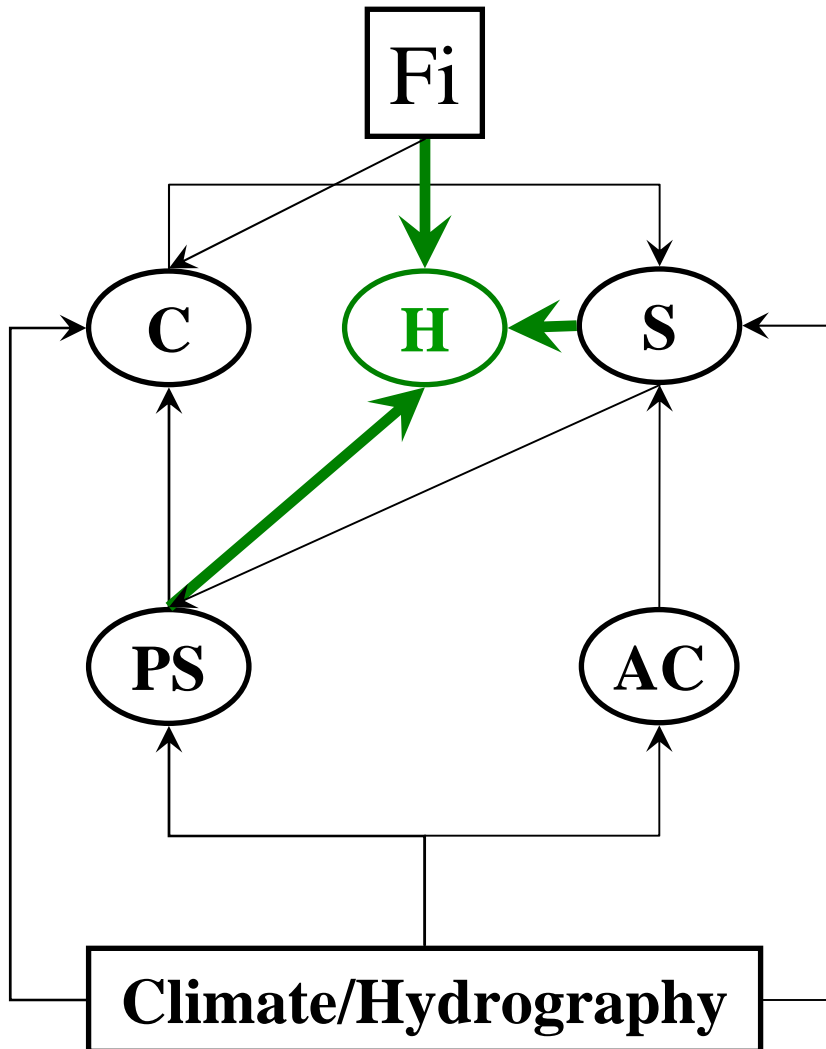
- Generalized Additive Model (GAM)
- Predictors:
 - SSB
 - Temperature
 - *Acartia* spp. biomass
 - NAO
- R^2 (%) = 96.6

(Möllmann et al. 2008)

Trophic interactions: A cascade !

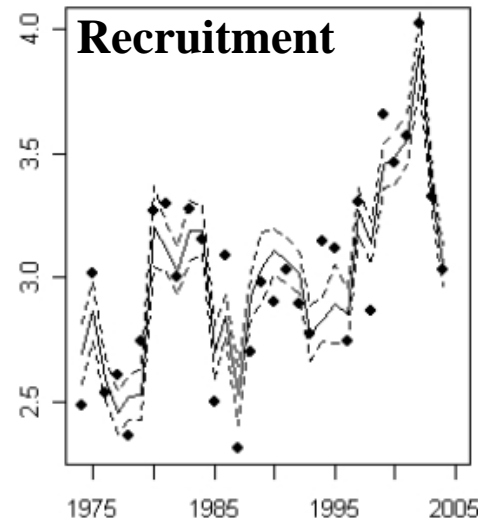


What about the poor herring ?



Growth changes (decline)

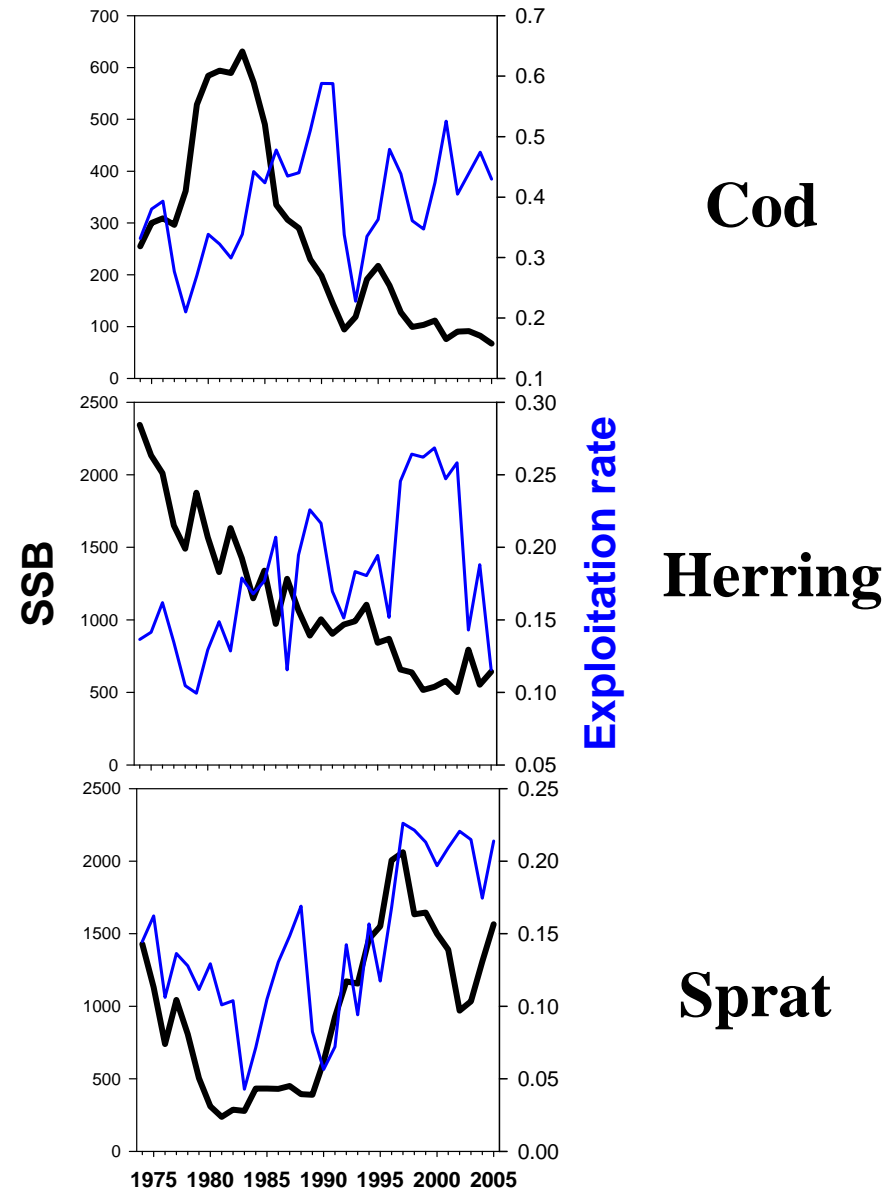
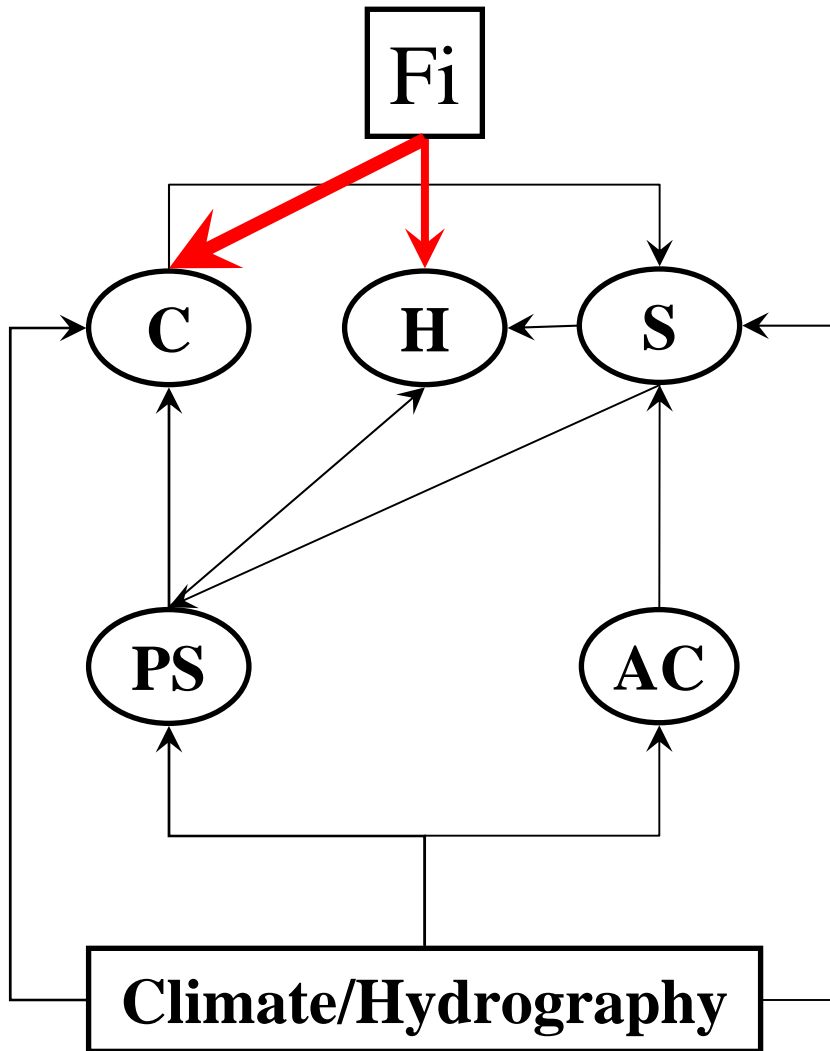
- decrease in *Pseudocalanus acuspes* [Möllmann et al. 2003; Rönkkönen et al. 2004]
- competition with the large sprat stock [Möllmann et al. 2005, Casini et al. 2006]



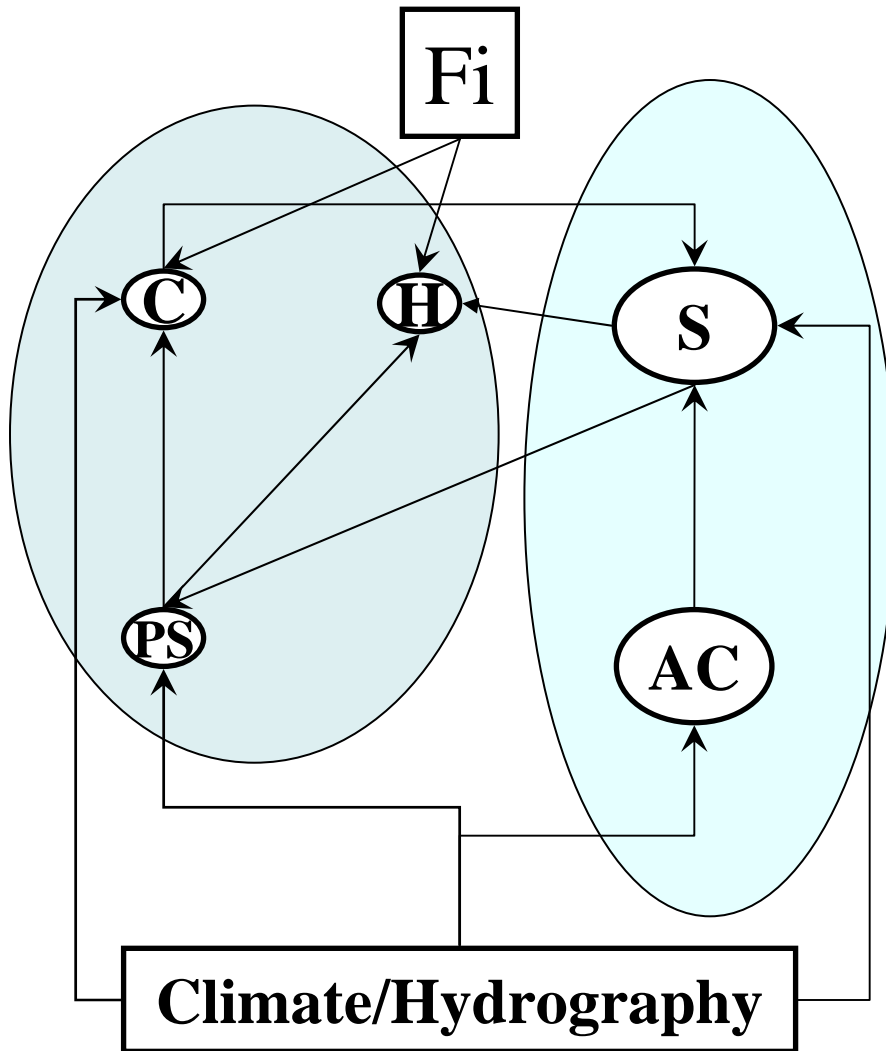
- GAM
- Predictors:
 - SSB
 - WAA
 - *P. acuspes*
 - Temperature
 - BSI
- R^2 (%) = 83.6

Source: ICES/BSRP Workshop on Herring Recruitment Processes in the Baltic Sea (WKHRPB)

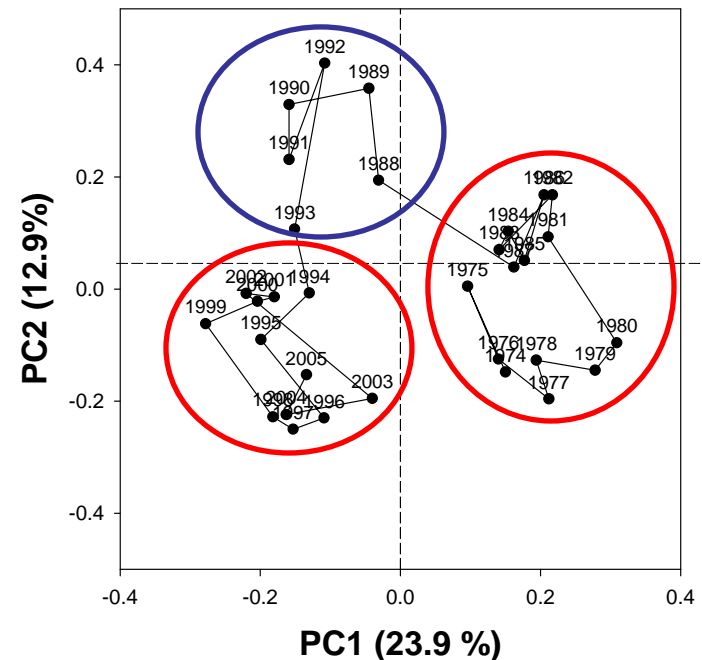
Fishing pressure !



The result: Regimes and Regime shifts !

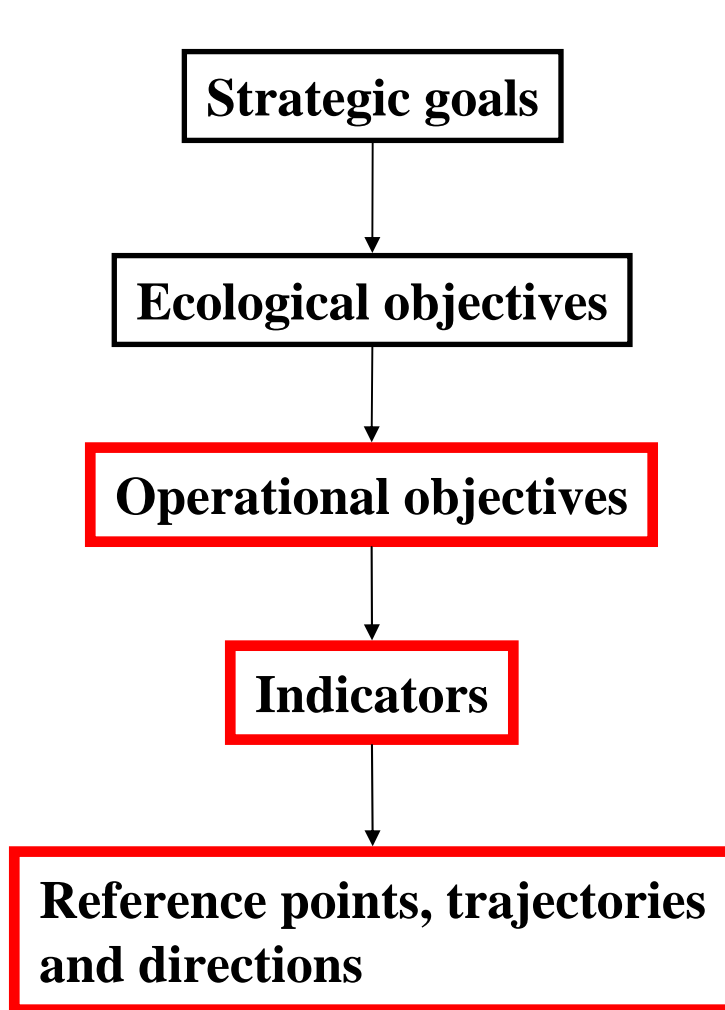


- Temperature path dominates
- Salinity/oxygen/overfished path depressed
- Regime shift ... Community-wide !



(Möllmann et al. 2009)

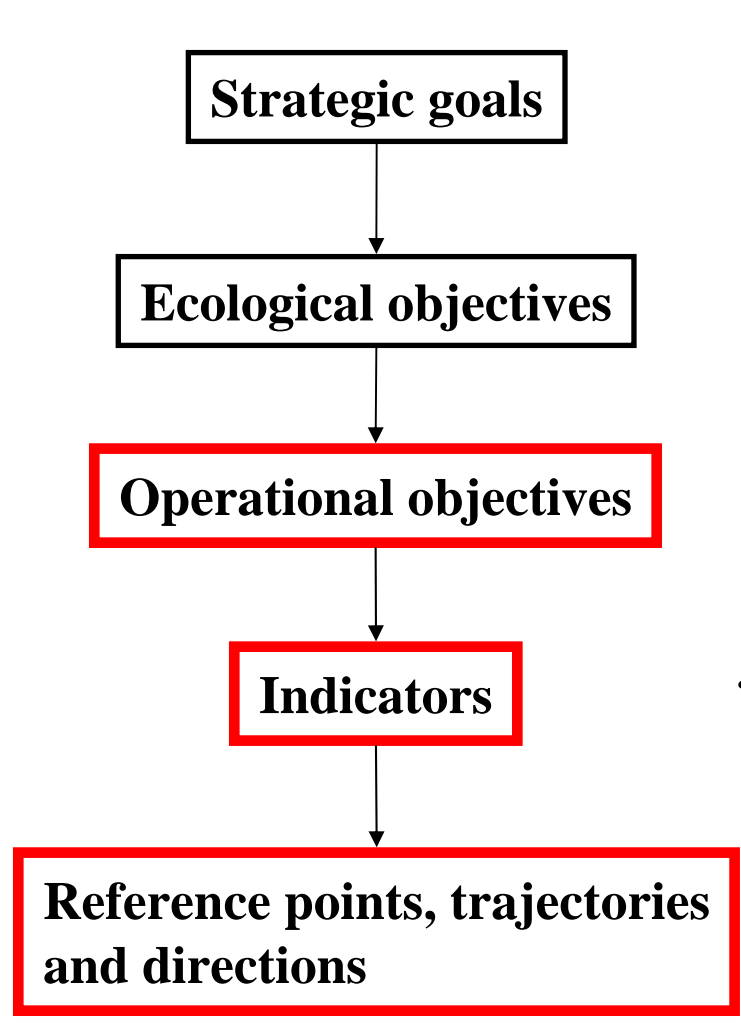
Strategic goals and ecological objectives



- **Largely a matter of agreement within society !**
 - What sort of ecosystem do we want ?
- Most likely at present – **Restore the cod stock !**
 - To what level ?
 - Regime dependent ?
- Perhaps better – **Balance the ecosystem !**
Or: **Maintain ecosystem structure and function !**
- These are Ecological Objectives! For management **Operational Objectives** are needed – with measurable **indicators** and **targets/limits** attached !



Objectives – Indicators – reference limits & targets



- **Should be based on the knowledge we have ?**
- **We know already a lot how the system works !**
 - We know the key species and how they interact !
 - We know how abiotic variables affect the major biotic components !
 - We know that regimes exist and can change and are not necessarily reversible !
- **We can construct a strategy for EBFM !**

Goals & Operational objectives & indicators

1) Prevent overfishing

- **Maintain SSB between 25 and 75 % of the SSBmax**
- **Maintain a „healthy“ age-structure (e.g. 50% of stock > age 5 ...!?)**

2) Prevent unbalancing of ecosystem structure

- **Maintain trophic level of the catch between ...**
- **Maintain a „healthy ratio“ between the 3 key fish species**

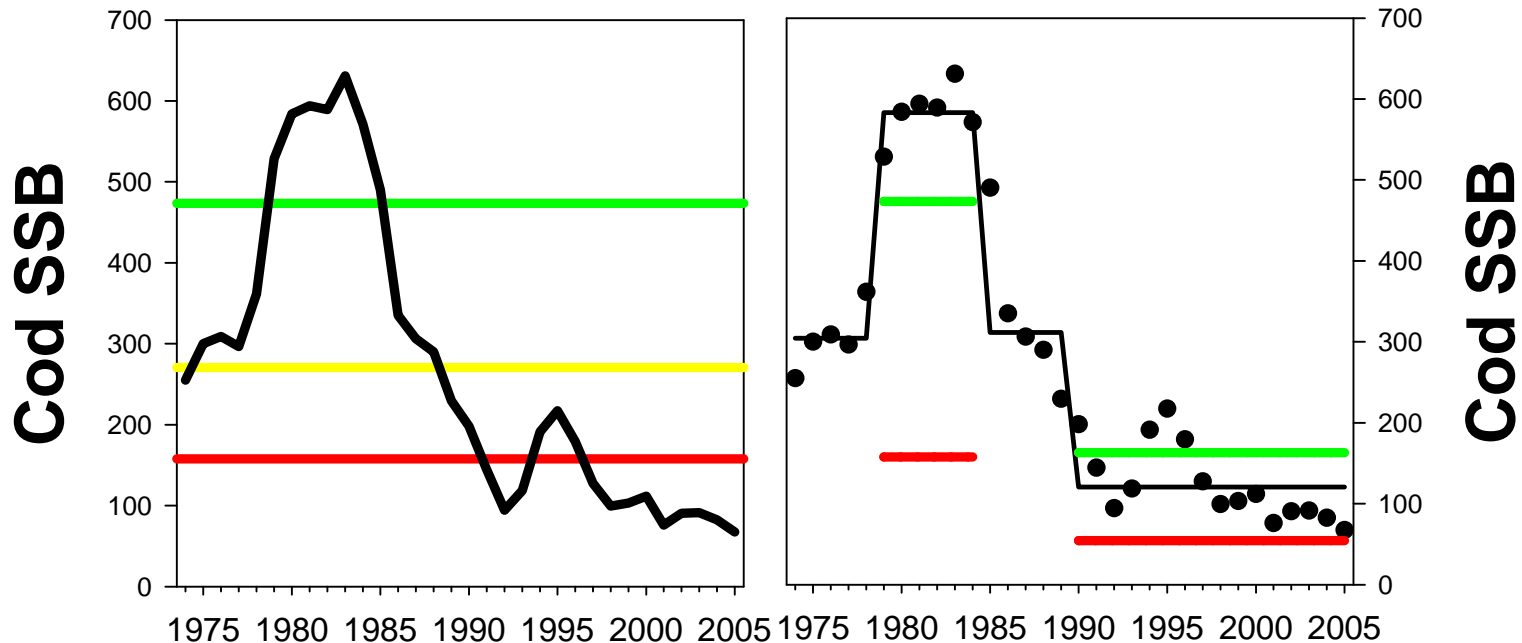
3) Reduce bycatch of non-target species ...

4) Avoid impacts on seabirds and marine mammals

Prevent overfishing

Operational objectives and manageable indicators:
Maintain SSB between 25 and 75 % of the SSB_{max}

Green: 75% of SSB_{max} ; Yellow: Mean; Red: 25% of SSB_{max}



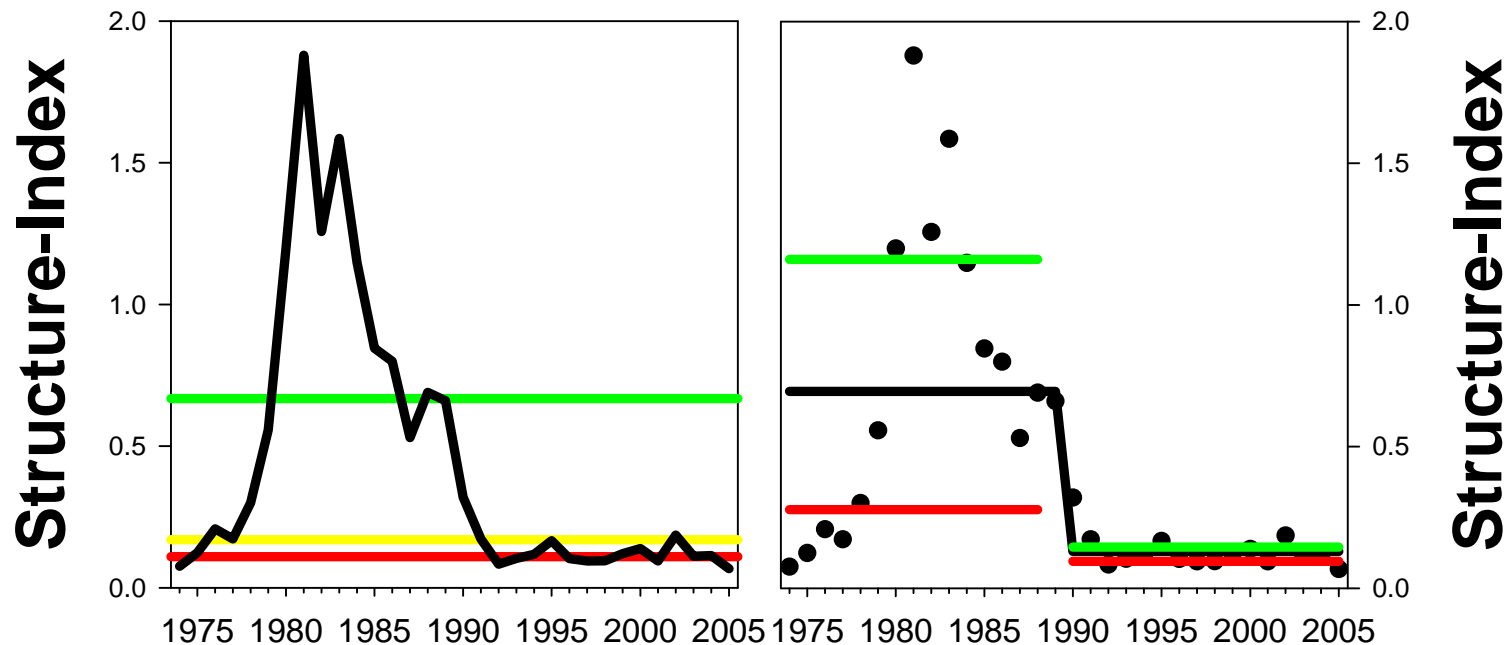
Black lines – Regimes detected by Sequential Regime Shift Detection Method (Rodionov 2004) !

Prevent unbalancing of ecosystem structure

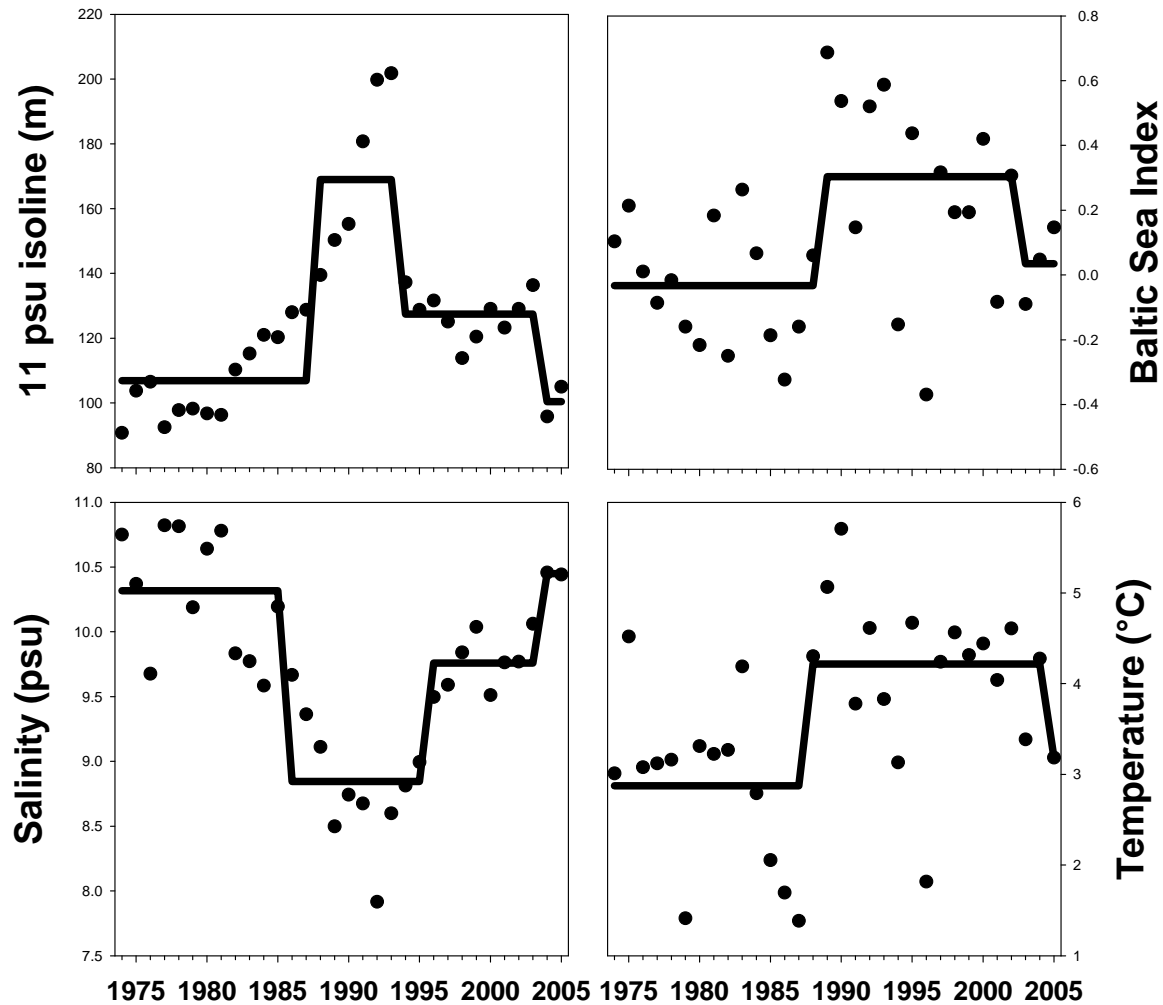
Operational objectives and manageable indicators:

Maintain a „healthy ratio“ between the 3 key fish species

Green: 75%-Quantile; Yellow: Median; Red: : 25%-Quantile
Structure Index (SI) = Ratio C:H:S

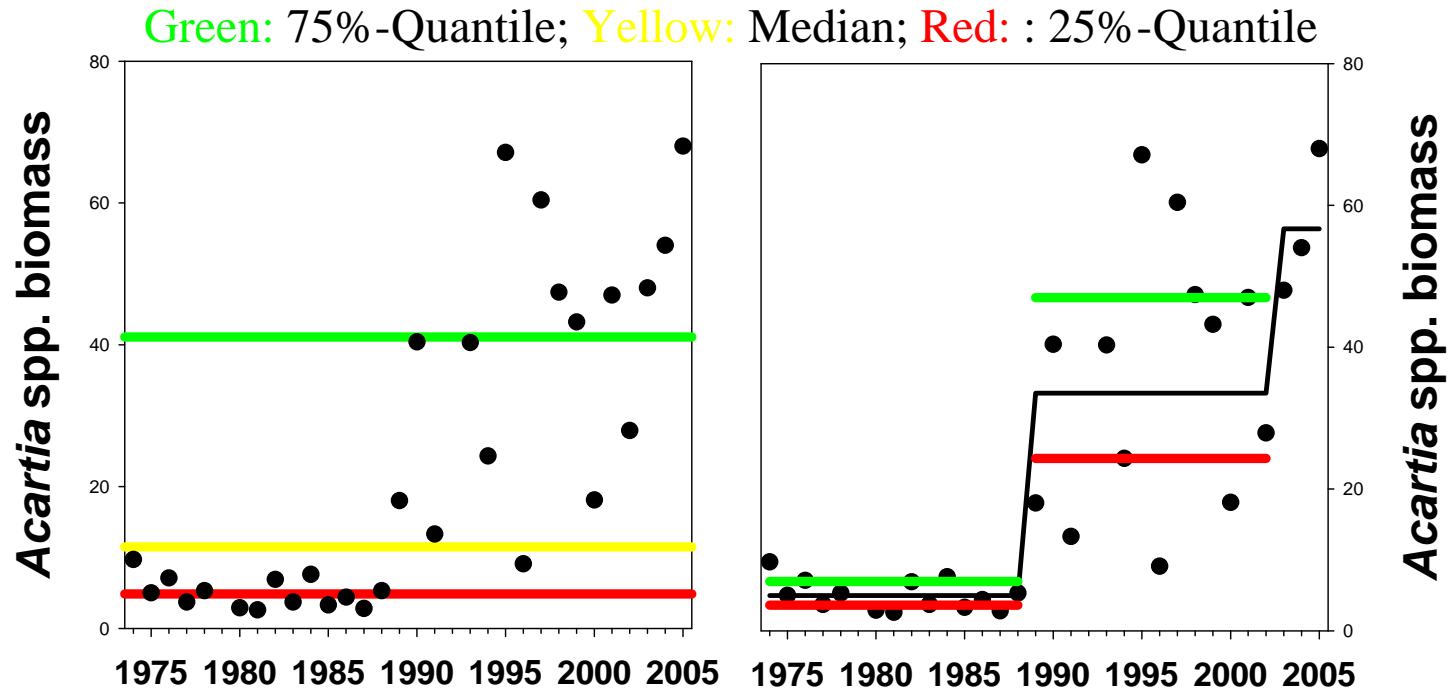


Early warning indicators (abiotic)



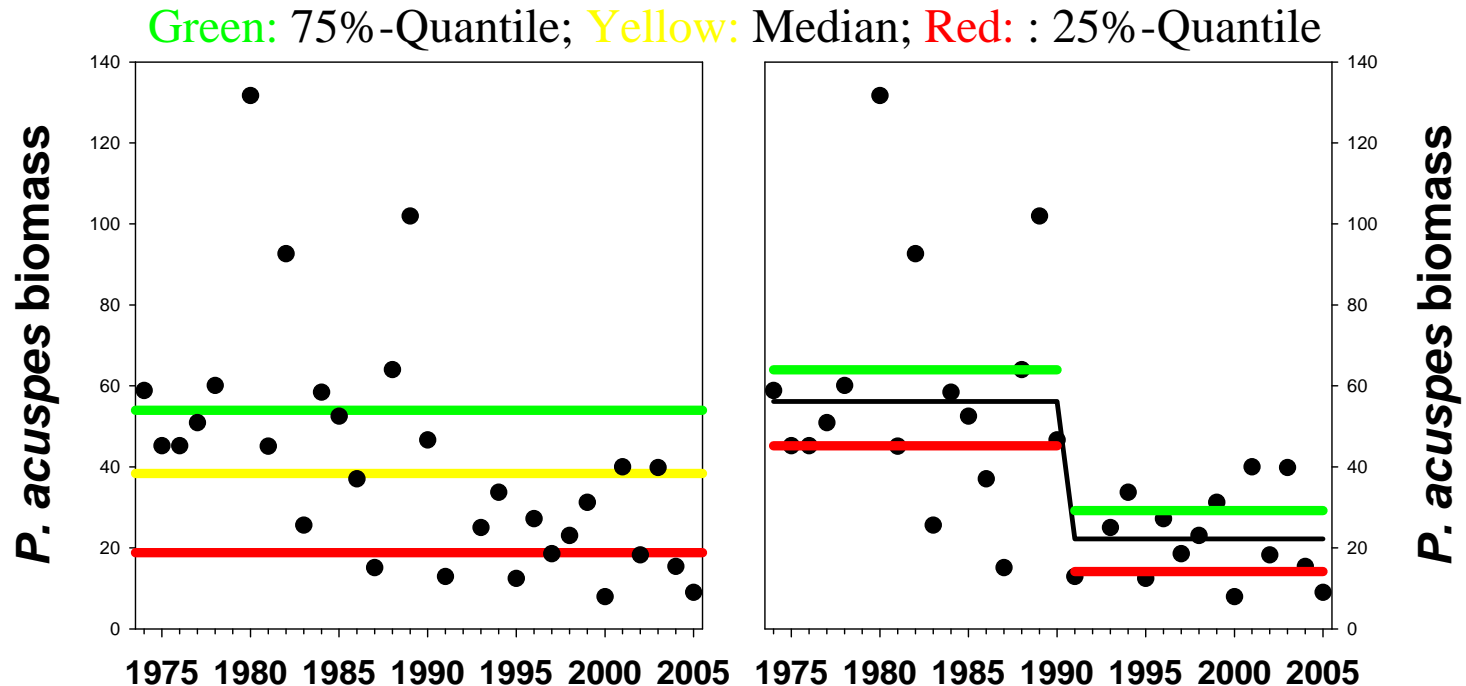
Early warning indicators (biotic)

Secondary environmental (early warning) indicator – *Acartia* spp.

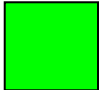
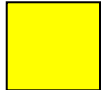
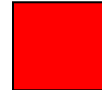
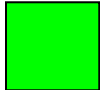
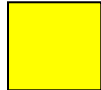



Early warning indicators (biotic)

Secondary environmental (early warning) indicator – *P. acuspes*



EBFM -Strategy

Objective	Indicator	Reference levels	Action
Warning/informing - 1	Baltic Sea Index / NAO, inflows, T	  	  
Warning/informing - 2	Copepods	↓	↓
Warning/informing - 3	Fish R/SSB		
Overfishing	Cod SSB		
	Herring SSB		
	Sprat SSB		
Ecostructure	SI		
...	...	↓	↓

To do in the future !

- Test indicators and decide on the ones to be monitored !
- Early warning indicators need to be monitored !
- Design EBFM monitoring programmes, including physics & e.g. zooplankton !
- Do Risk-Assessments of potential management actions !