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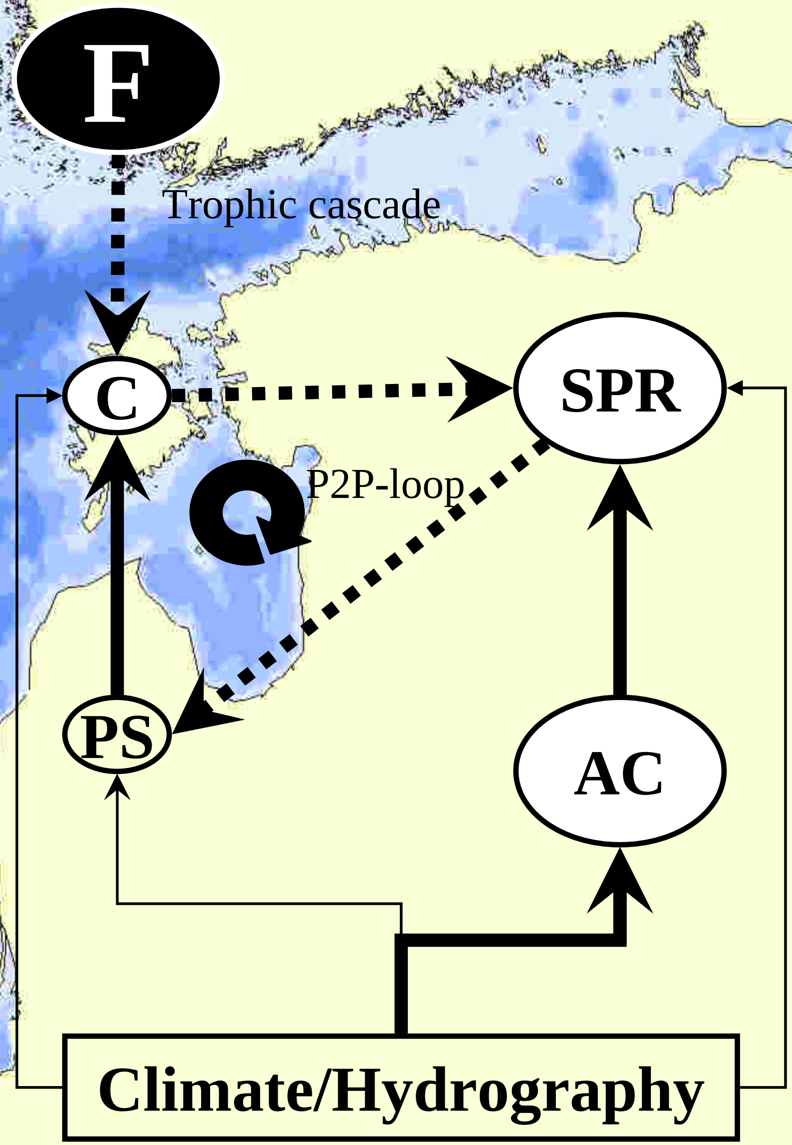
Indirect effects of climate- and overfishing-induced zooplankton changes on ecosystem structure – regime shifts, trophic cascades and feedback loops in a simple ecosystem



UH
University of Hamburg

Latvian Fish Resources Agency

The Baltic Sea

Characteristics

- large semi-enclosed brackish water body
- stratified water-column with a permanent halocline
- low diversity
- high productivity
- eutrophication
- pronounced climate influence through variability in temperature & salinity
- high fishing pressure

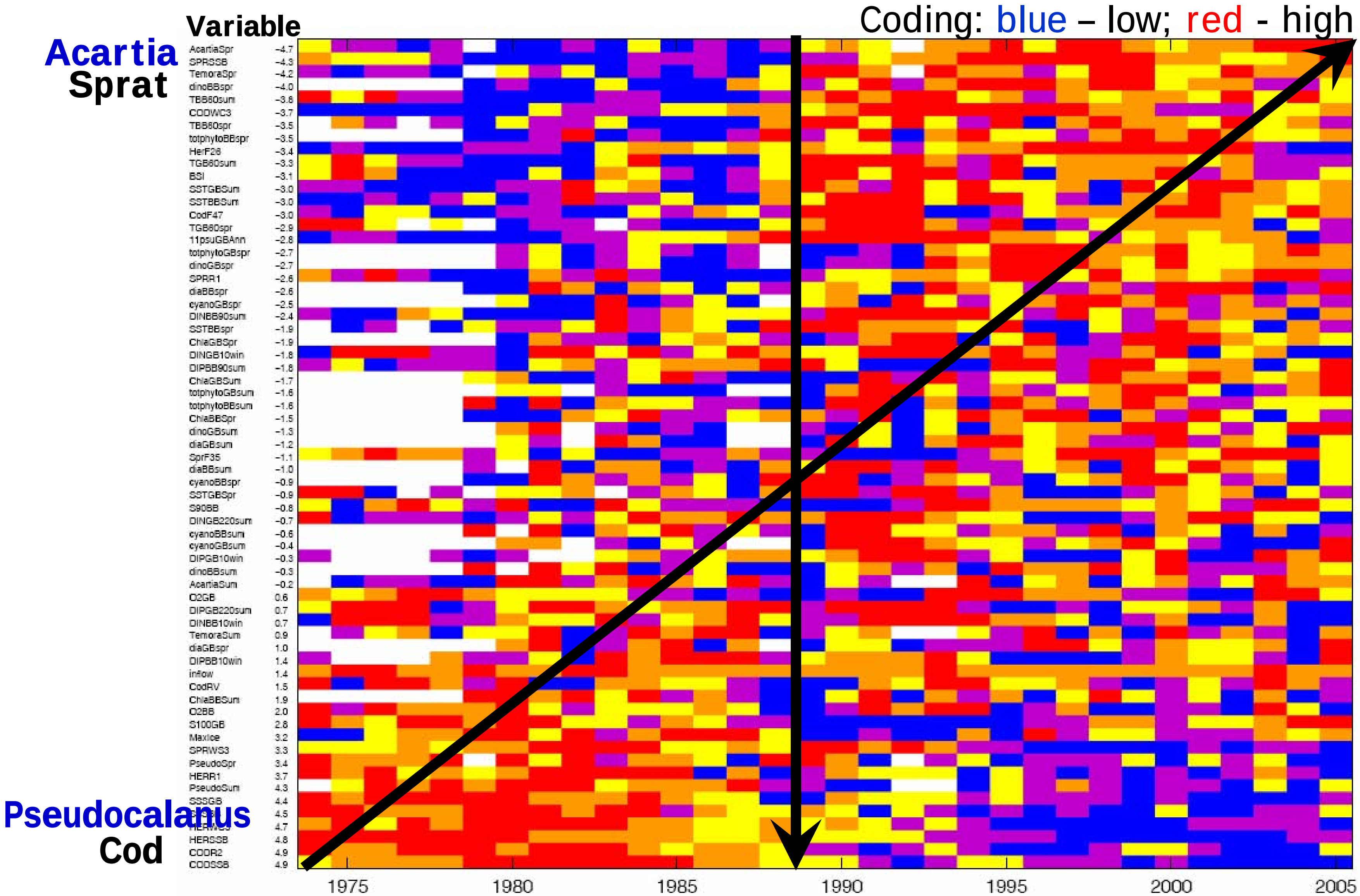
Central Baltic Sea

”Ecosystem Assessment”– Data & Methods”

- Time series from 1974-2005
- 65 variables (12 fish-related, 6 zooplankton, 20 phytoplankton-related, 8 nutrient, 19 physical datasets)
- **P**rincipal **C**omponent **A**nalysis
- Traffic-light plot

Source: ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea [WGIAB]

Ecosystem Regime Shift – "Traffic lights"



Aims

- Demonstrate the influence of **climate and human forcing** on the pelagic Baltic ecosystem
- Central **importance of zooplankton** (2 dominant copepod species) for the ecosystem

1) Climate effects on *Pseudocalanus acuspes* and *Acartia* spp.
2) Zooplankton effects on cod and sprat recruitment
3) A trophic cascade & feedback-loops

Data & Methods

Data:

Zooplankton

- Latvian Fish Resources Agency
- Spring
- Judai-Net (160µm)

Phytoplankton

- Biomass
- ICES Database

Hydrography

- Temperature, salinity, cod reproductive volume (RV)
- ICES Database

Fish

- Biomass and recruitment (age 0)
- Multispecies Virtual Population Analysis (MSVPA)
- ICES Study Group on Multispecies Assessments of the Baltic Sea

Methods:

Regime shift analysis

- Sequential Regime Shift Detection Method (Rodionov 2004)

Statistical modelling

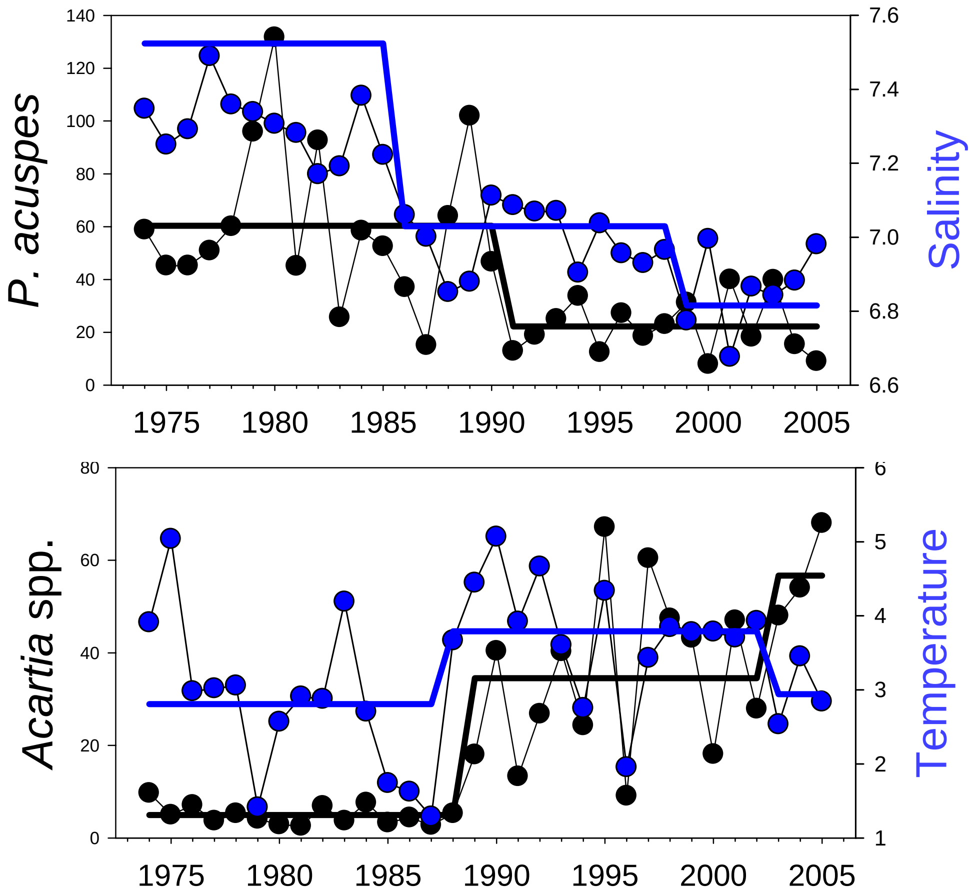
- Linear Models
- Generalized Additive Models (GAMs)

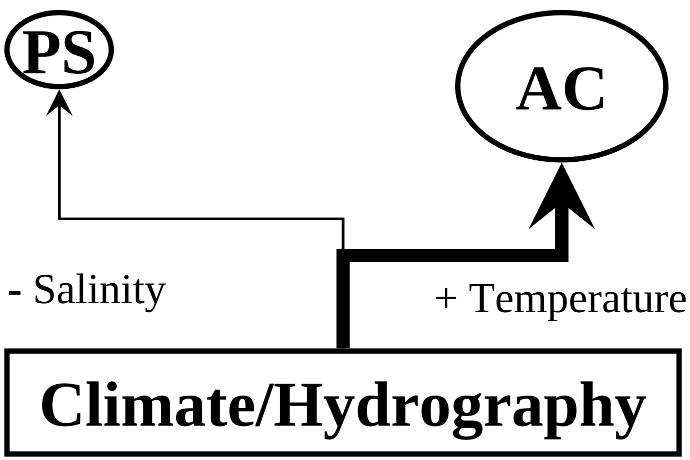
Model selection

- Linear Models: AIC (**A**kaike **I**nformation **C**riterion)
- GAMs : GCV (**G**eneralized **C**ross
- **V**alidation criterion)

”Regime-shift” between key-species

Regime Shifts detected by
Sequential Regime Shift Analysis
(Rodionov 2004)





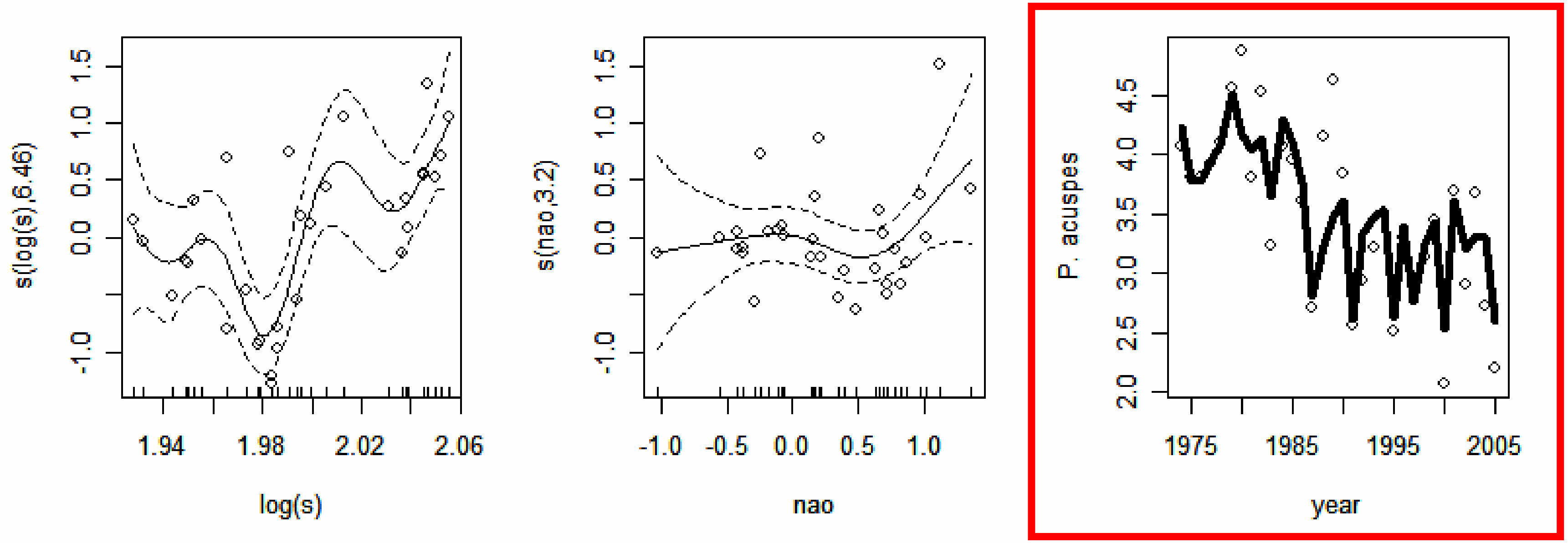
PS – *Pseudocalanus acuspes*, AC – *Acartia* spp.

Pseudocalanus acuspes & Hydro-Climate

Results of GA-Modelling

*** p < 0.001

Predictors	GCV	R^2 (%)
Salinity***	0.313	63.0
Salinity***, NAO	0.311	72.0



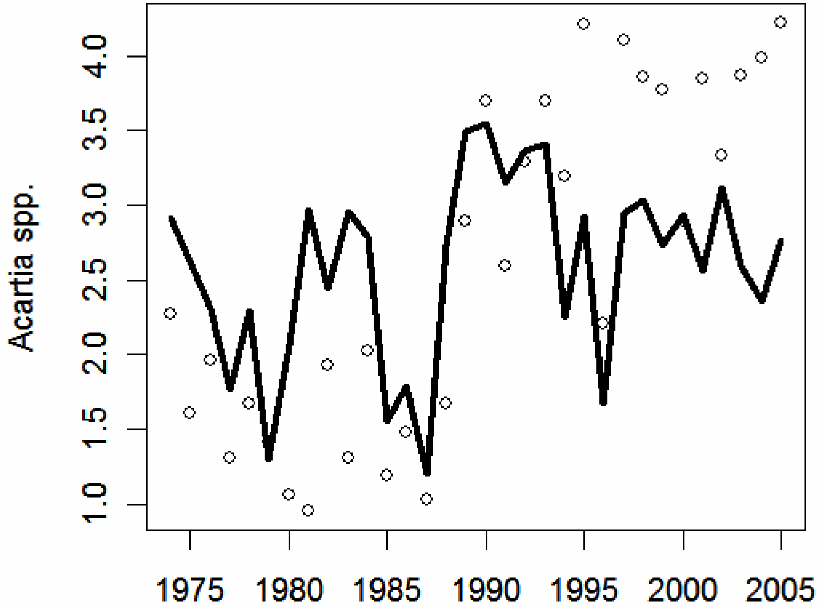
GCV – measure of model quality (the lower the better)

Acartia spp. & Hydro-climate

Results of Linear-Modelling

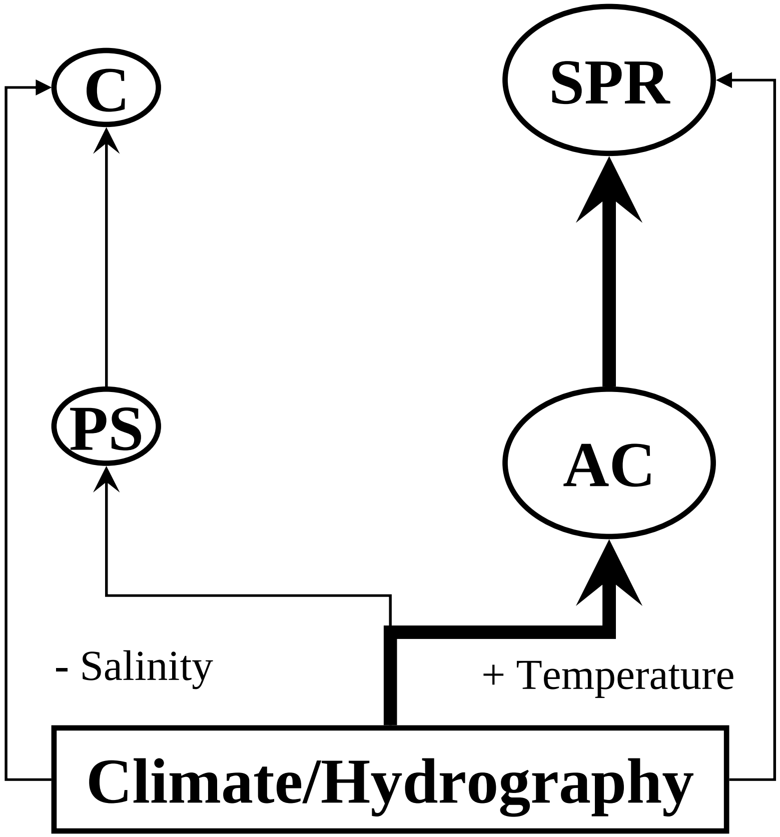
** $p < 0.01$

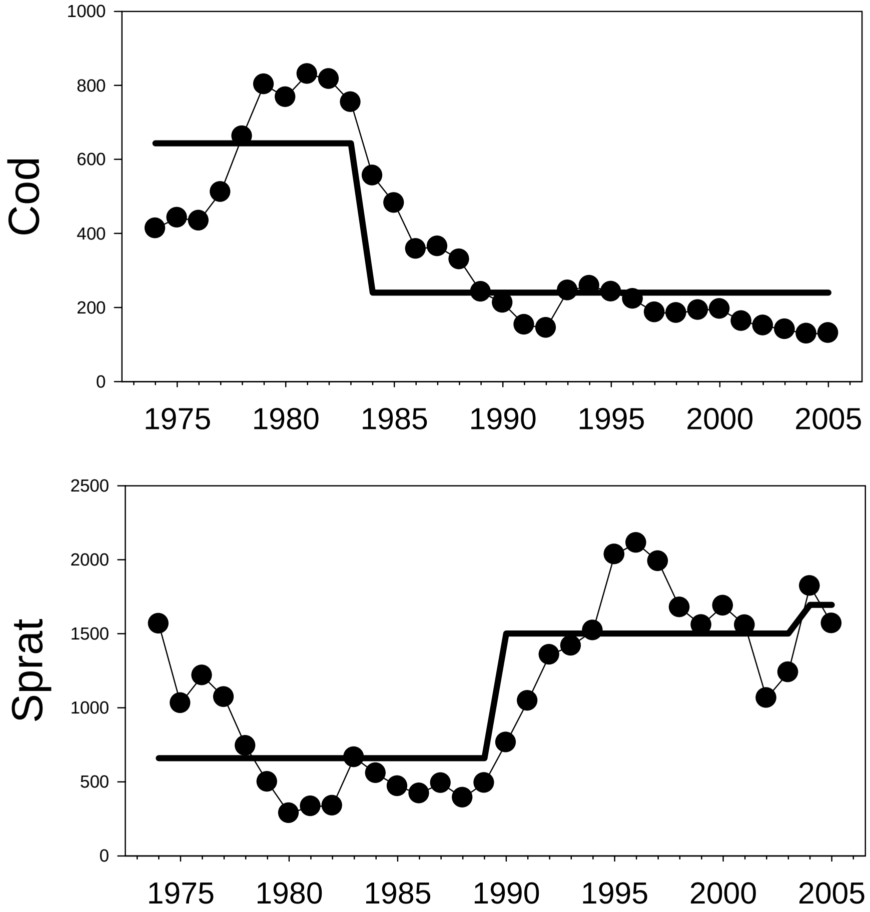
Predictors	AIC	R^2 (%)
Temperature**	94.73	23.3
Temperature, NAO	93.35	31.0



AIC – the lower the better ... !

”Regime-shift” between key-species





PS – *Pseudocalanus acuspes*, AC – *Acartia* spp., C – Cod, SPR - Sprat

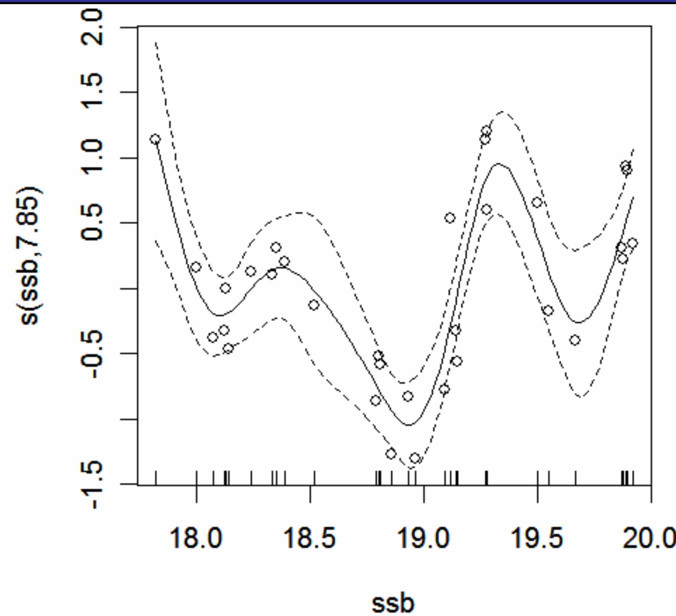
Cod recruitment & Hydro-Climate & *P. acuspes*

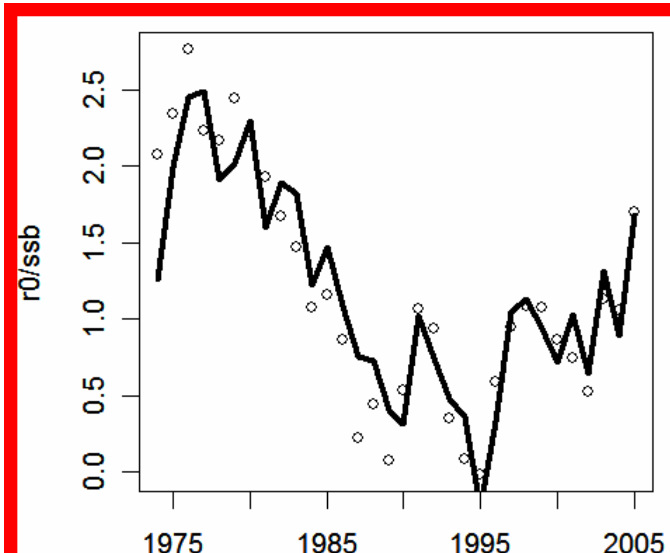
Response – ln(R/SSB) -> Recruitment success

Results of GA-Modelling

Predictors	GCV	R^2 (%)
SSB***	0.255	76.2
SSB***, Reproductive Volume	0.242	79.4
SSB***, Reproductive Volume*, *P. acuspes***	0.187	85.8
SSB***, Reproductive Volume*, *P. acuspes***, NAO	0.205	85.8

***p < 0.001
** p < 0.01
* P < 0.05





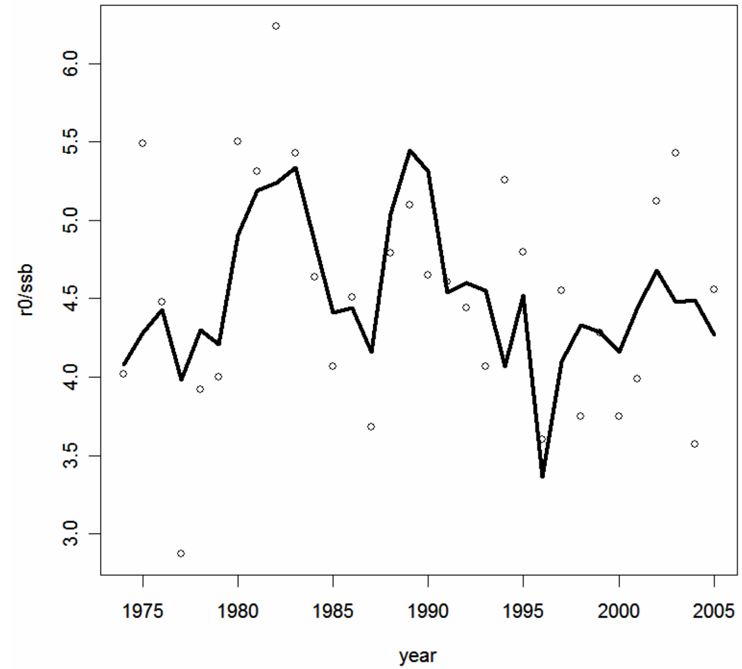
Sprat recruitment & Hydro-Climate & *Acartia* spp.

Response – ln(R/SSB) -> Recruitment success

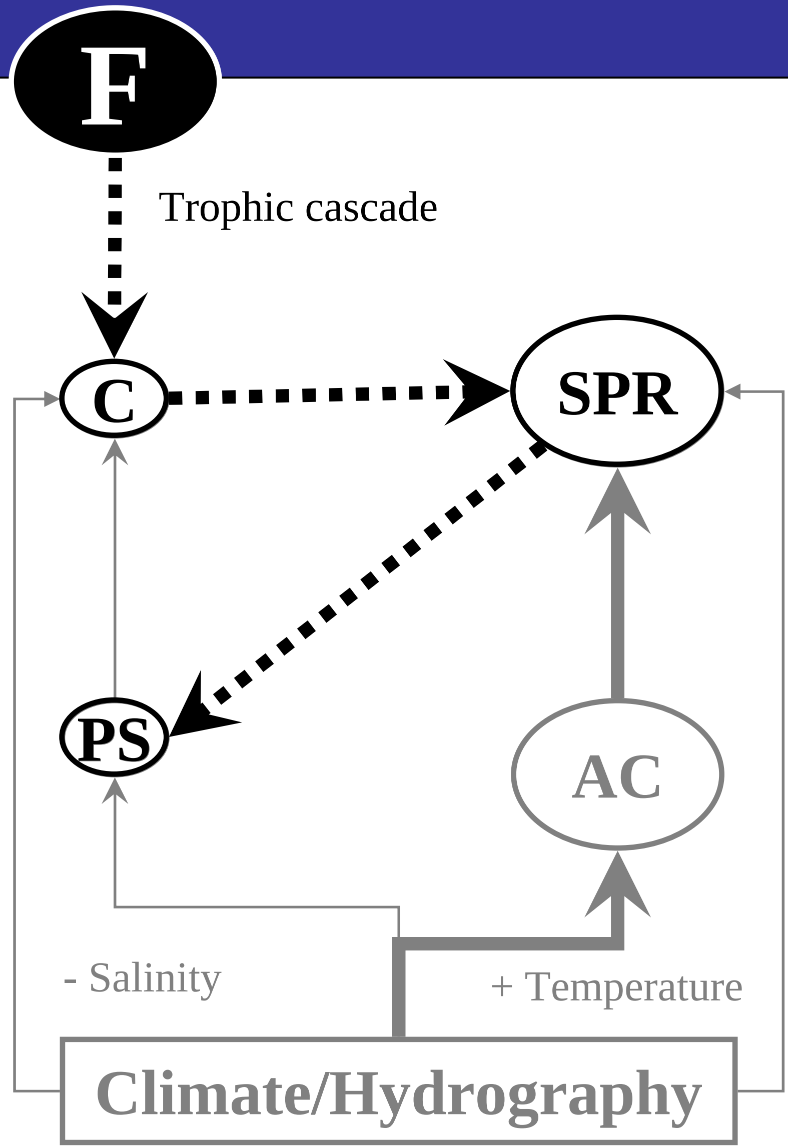
Results of Linear-Modelling

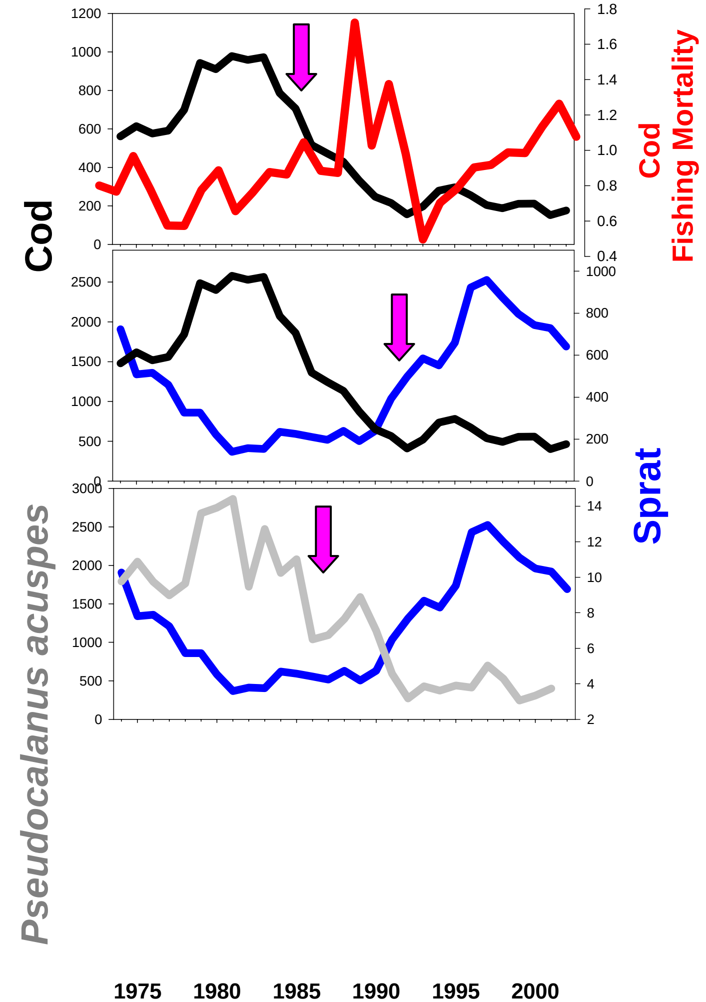
Predictors	AIC	R^2 (%)
SSB**	68.46	20.0
SSB**, Temperature*	64.34	40.2
SSB***, Temperature*, *Acartia* spp.*	63.66	49.52
SSB***, NAO*, *Acartia* spp.*,	76.34	87.6

***p < 0.001
** p < 0.01
* P < 0.05



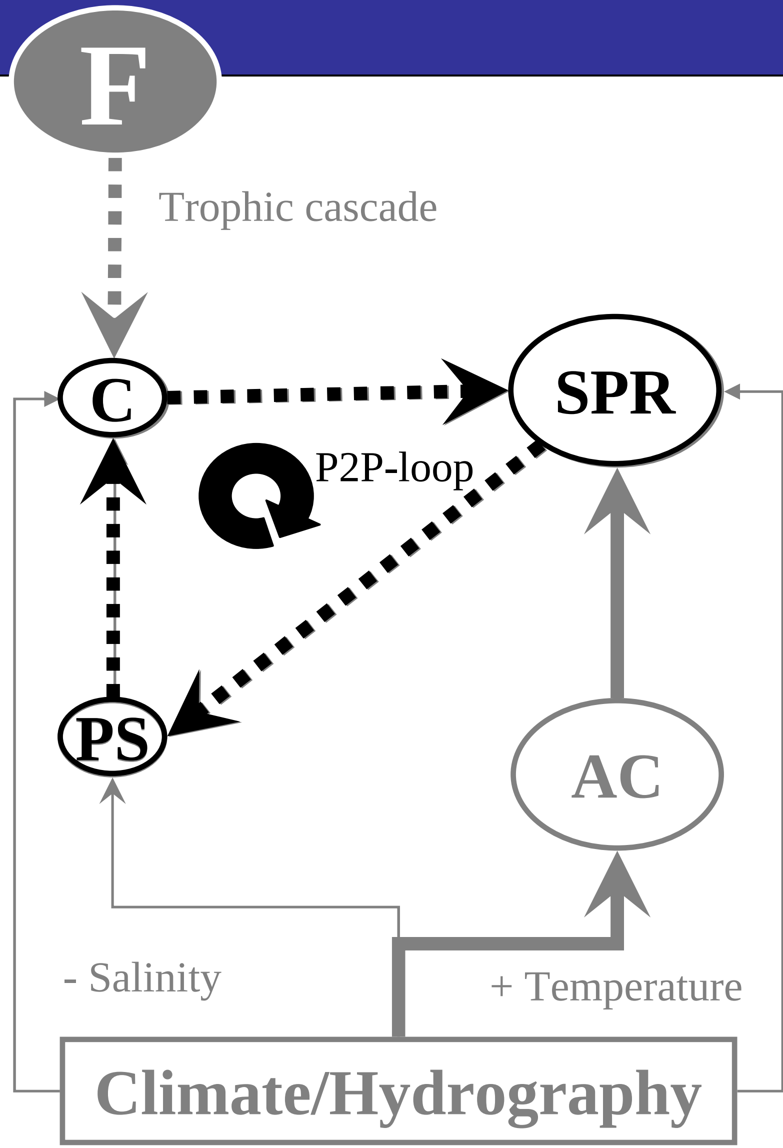
Species-level Trophic Cascade

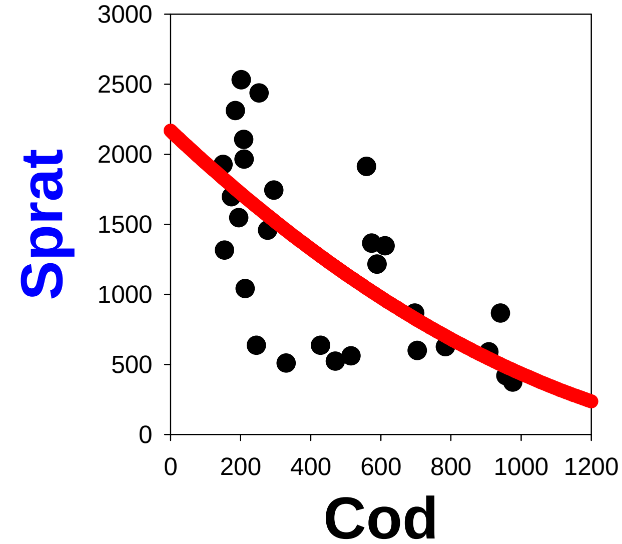


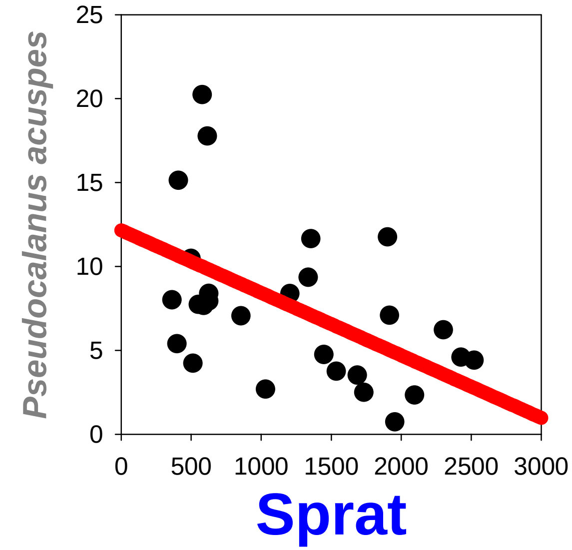


PS – *Pseudocalanus acuspes*, AC – *Acartia* spp., C – Cod, SPR – Sprat, F – Fishery

”Limiting” Predator –2- Prey LOOP







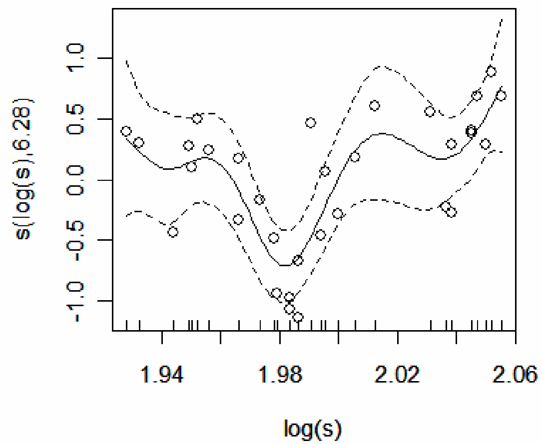
P2P-loop after Bakun (2007)

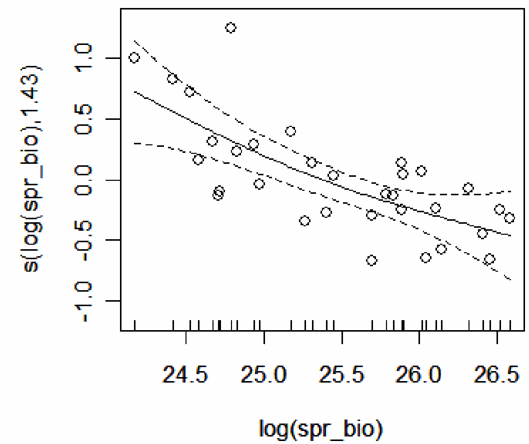
Pseudocalanus acuspes & Hydro-Climate & Top-down control

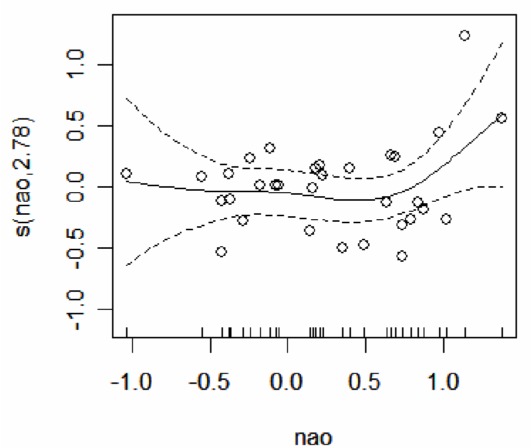
Results of GA-Modelling

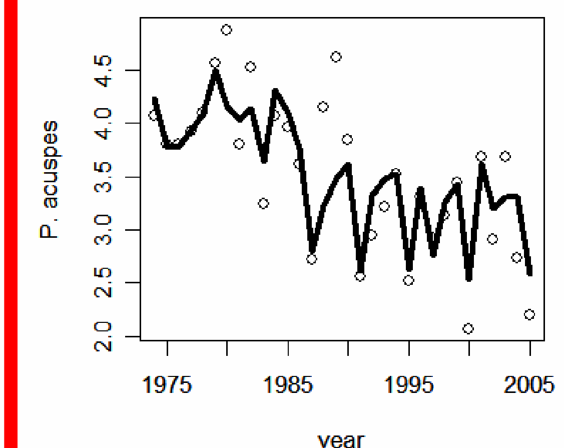
Predictors	GCV	R^2 (%)
Salinity***	0.313	63.0
Salinity***, NAO	0.311	72.0
Salinity**, NAO, Sprat biomass**	0.230	80.8

***p < 0.001
** p < 0.01

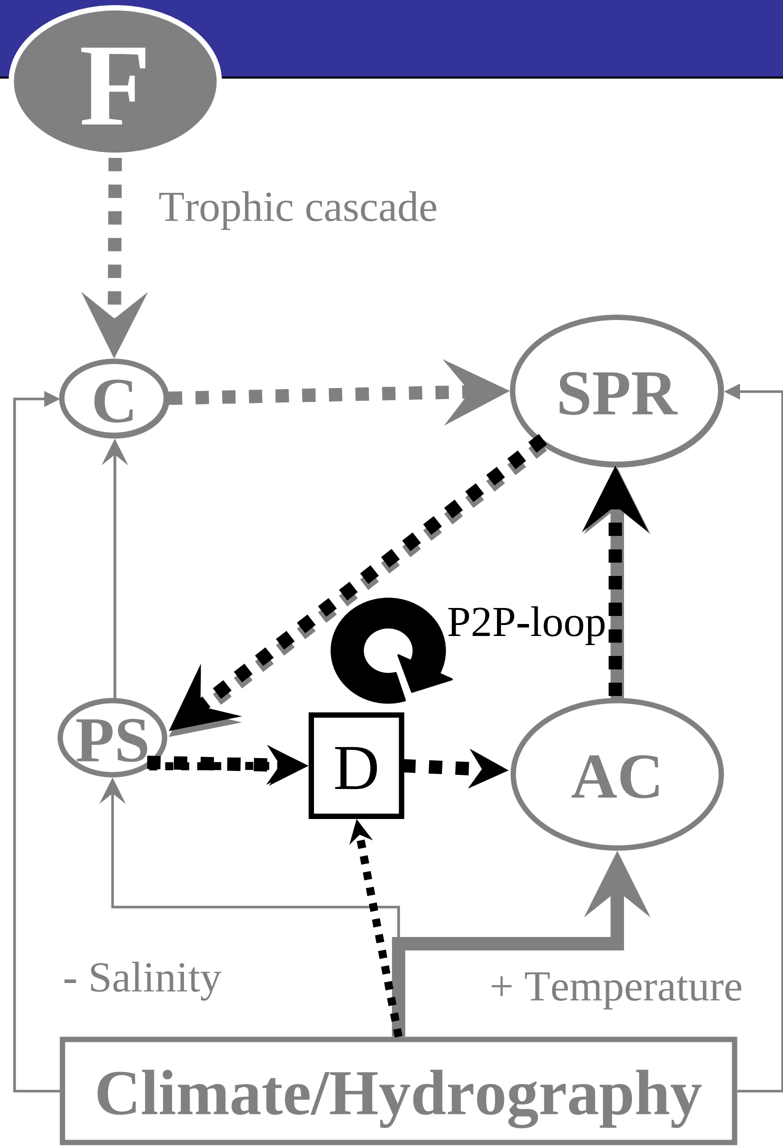


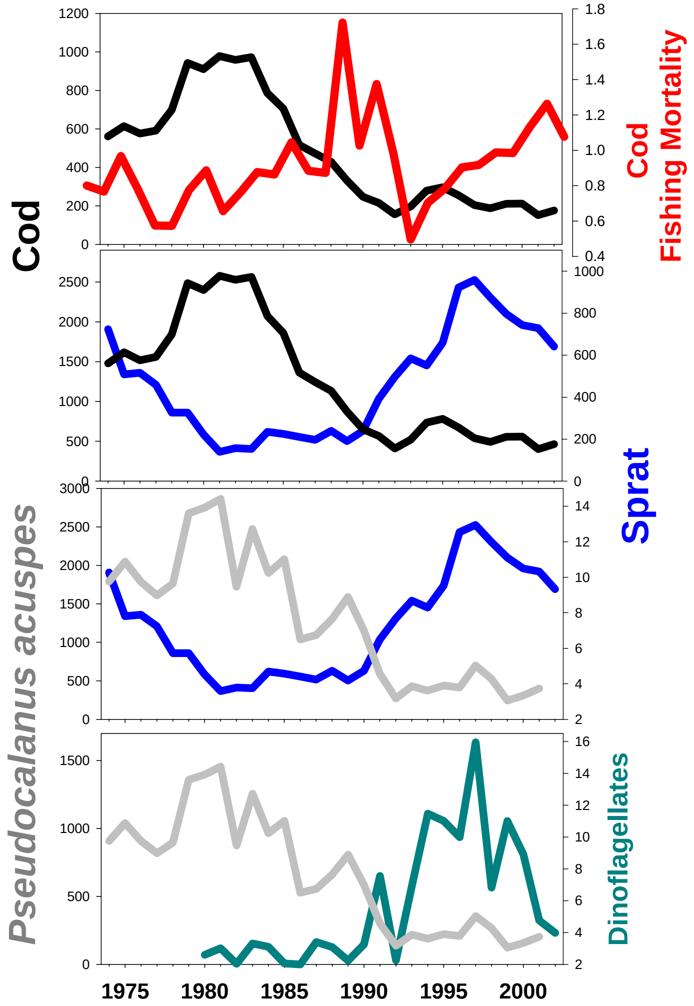






”Promoting” Predator –2- Prey LOOP ?





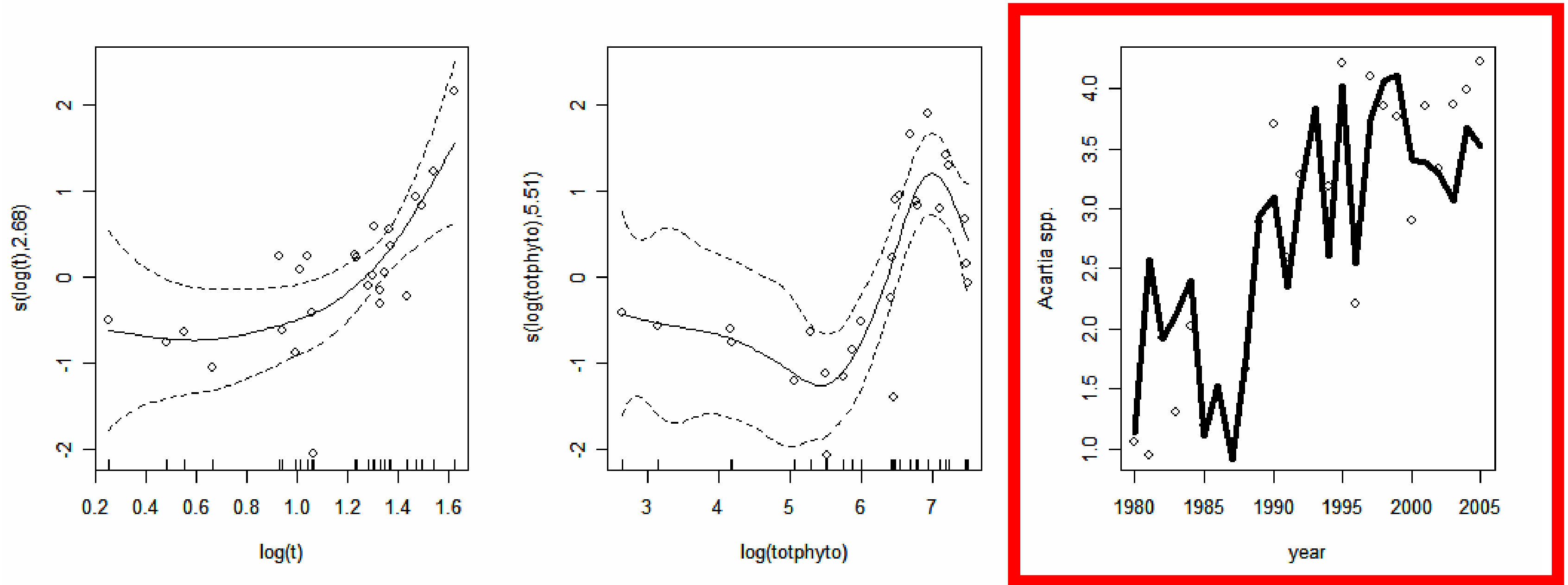
PS – *Pseudocalanus acuspes*, AC – *Acartia* spp., C – Cod, SPR – Sprat, F – Fishery, D - Dinoflagellates

Acartia spp. & Hydro-Climate & Bottom-up control

** p < 0.01
* P < 0.05

Results of GA-Modelling

Predictors	GCV	R^2 (%)
Temperature*, Dinoflagellates**	0.592	80.4
Temperature, Dinoflagellates, NAO	0.614	83.9



Summary

- Climate-induced changes in salinity and temperature have caused a *Regime-shift* in the pelagic Baltic ecosystem on all trophic levels
- *Regime-shift* from salinity-controlled (*P. acuspes*/cod) to temperature-controlled (*Acartia* spp./sprat) species
- <u>*P. acuspes* and *Acartia* spp. are key ecosystem components</u>, mediating the climate effect to the important fish stocks
- Overfishing of cod cascades down to *P. acuspes* (and potentially to dinoflagellates ?), stabilizing the new regime through P2P-loops