Ecological network indicators of ecosystem status and change in the Baltic Sea

Maciej T. Tomczak(1), Johanna J. Heymans (2), Johanna Yletyinen (3,4), Susa Niiranen (4), Saskia A. Otto (4) and Thorsten Blenckner (4)

1) Baltic Sea Centre, Stockholm University, Sweden
2) Scottish Association for Marine Science, Scottish Marine Institute, Dunbeg, Oban, United Kingdom
3) Nordic Centre for Research on Marine Ecosystems and Resources under Climate Change (NorMER), Stockholm Resilience Centre, Stockholm, Sweden
4) Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden

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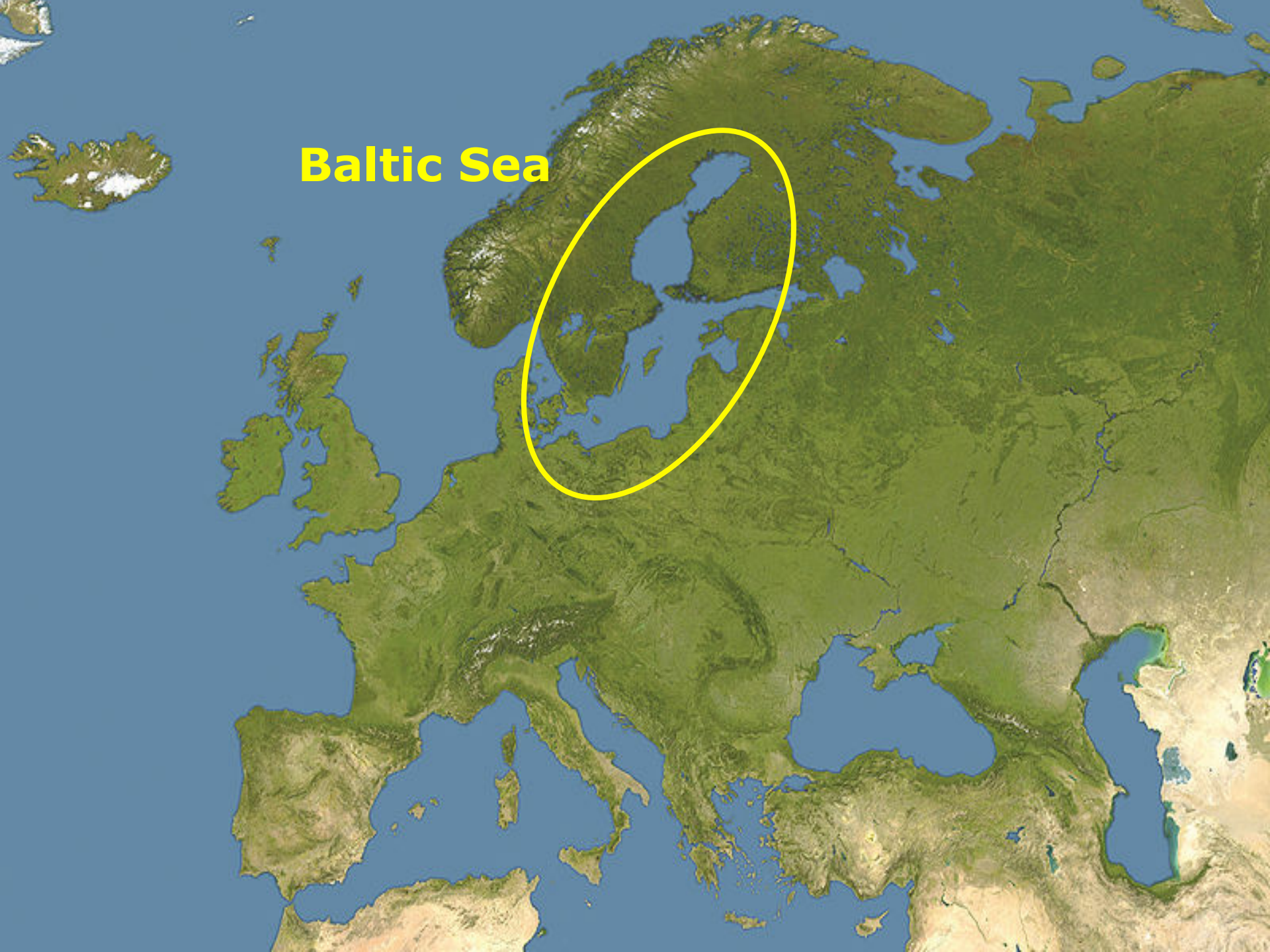
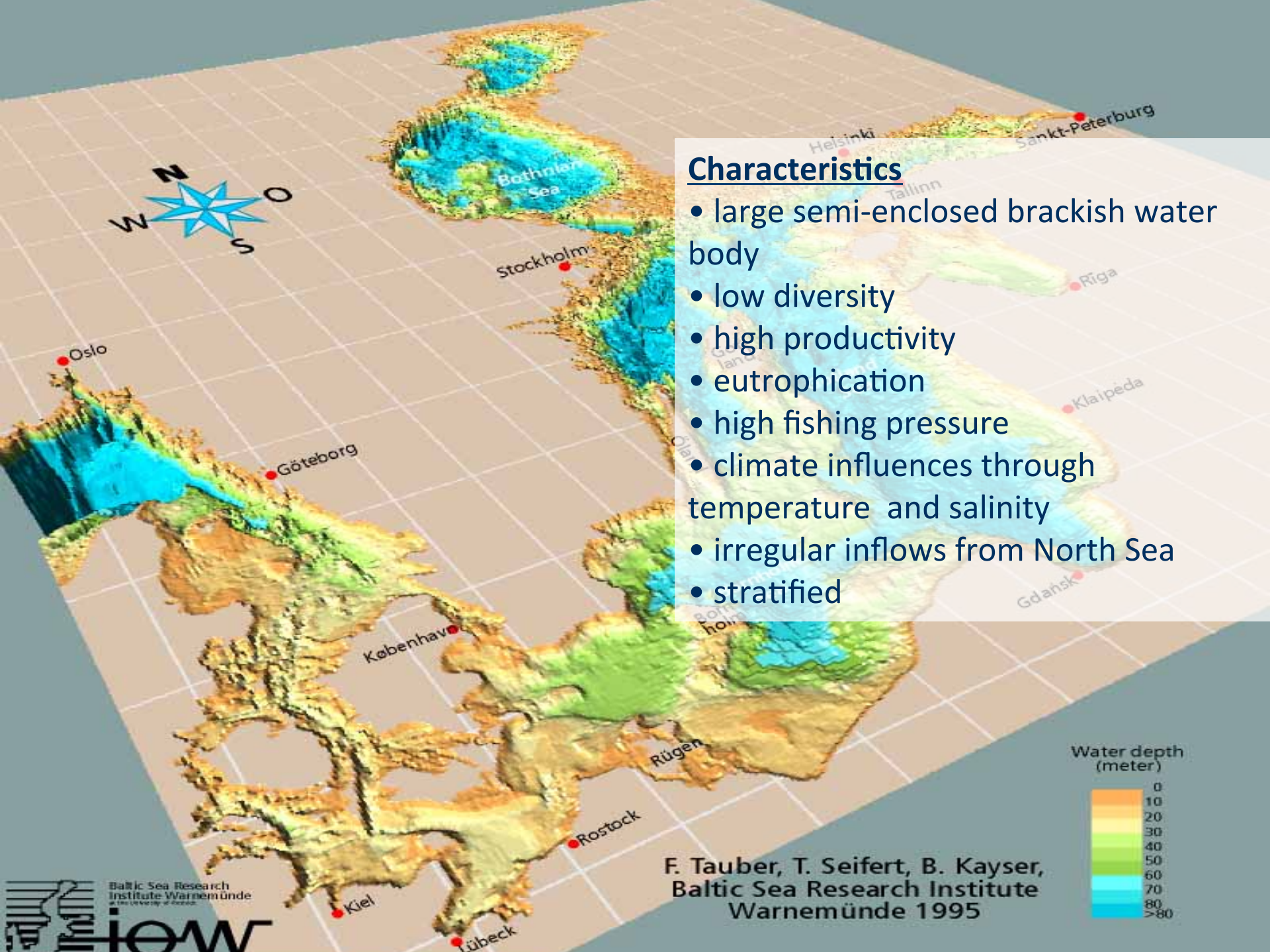

Baltic Sea

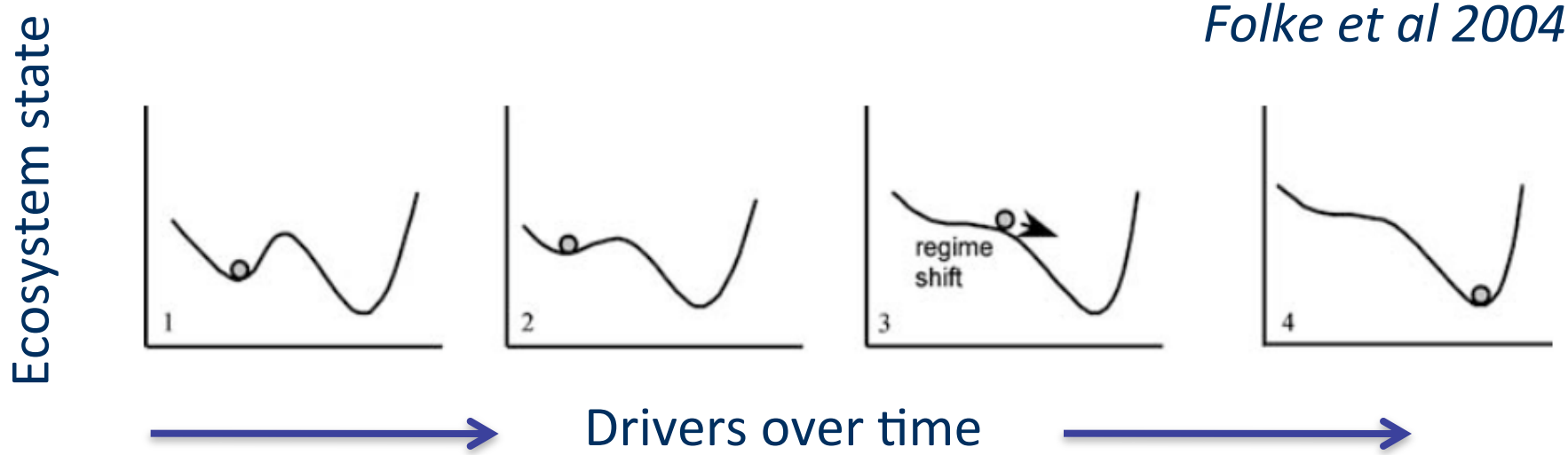


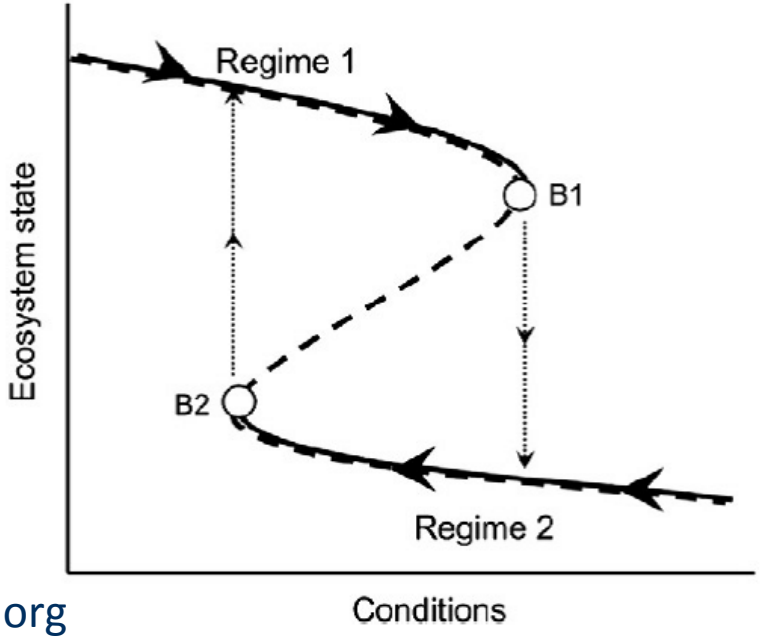
Characteristics

- large semi-enclosed brackish water body
- low diversity
- high productivity
- eutrophication
- high fishing pressure
- climate influences through temperature and salinity
- irregular inflows from North Sea
- stratified

Concept: Regime Shifts

Folke et al 2004





http://oceantippingpoints.org

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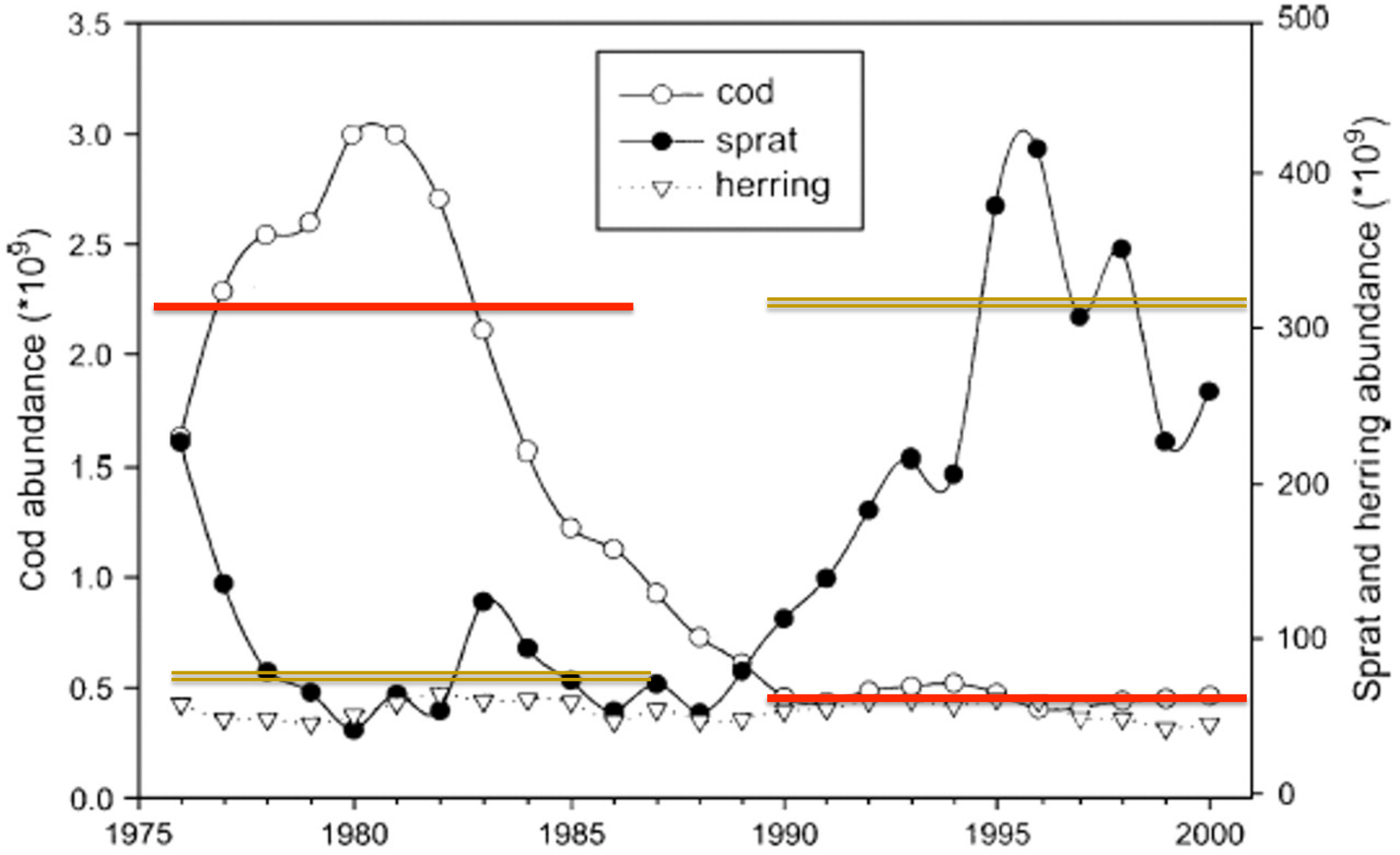
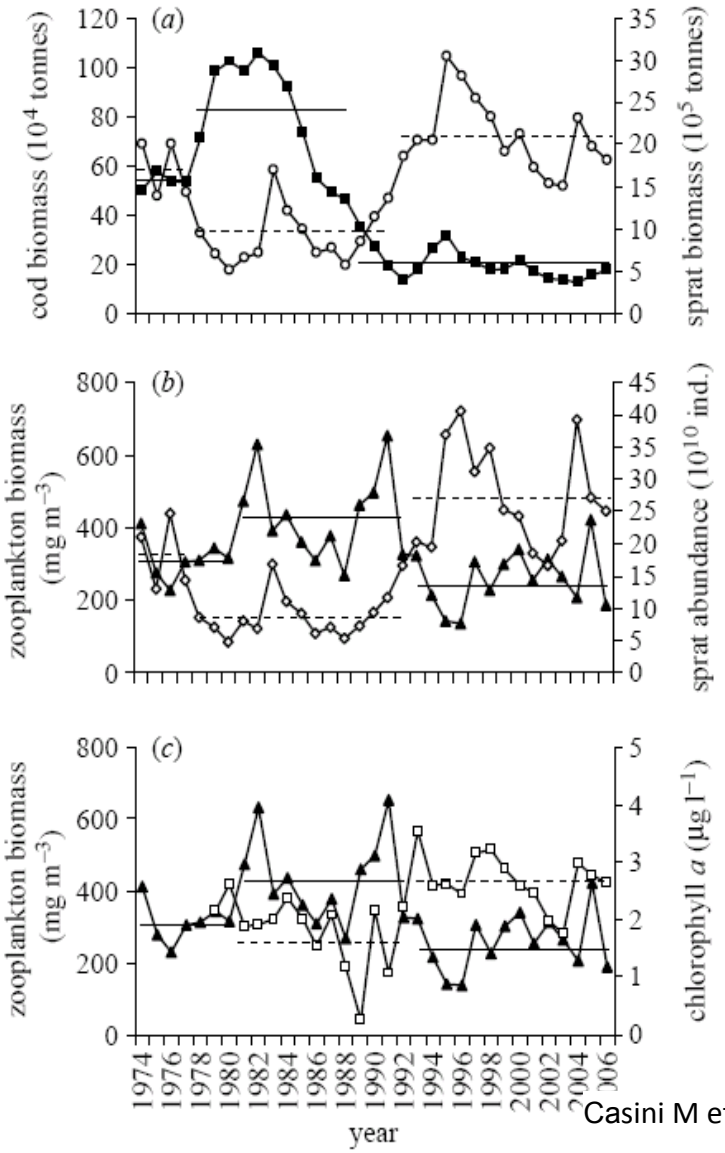
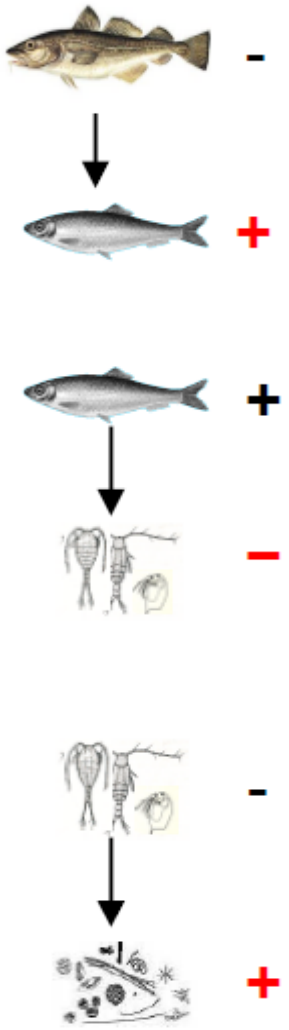
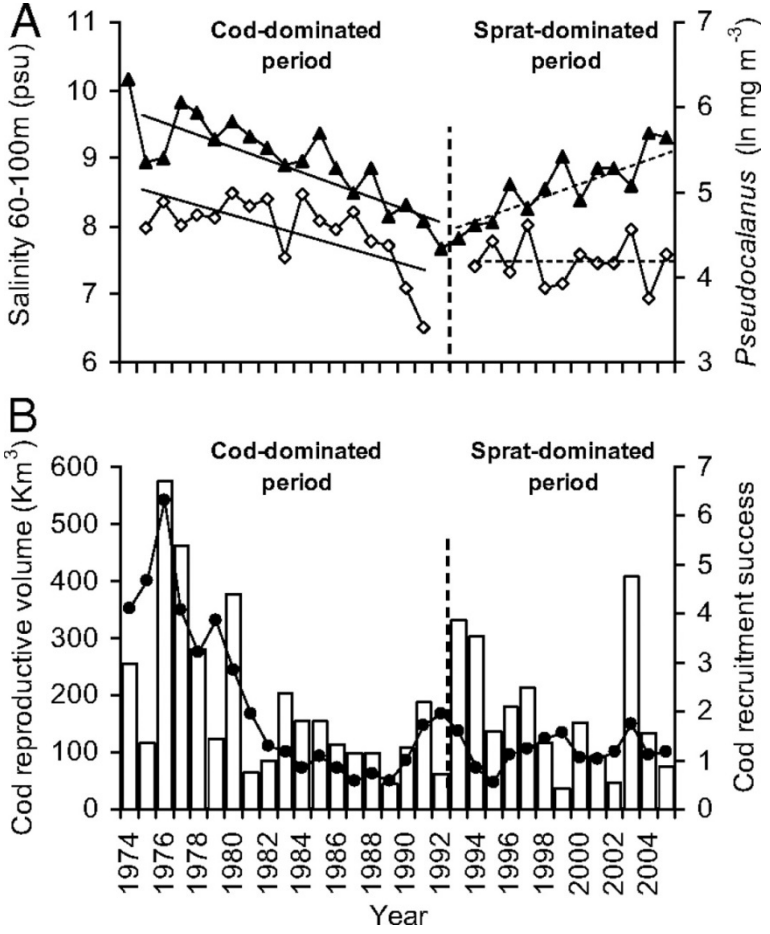
Ecosystem dynamics – regime shift 1974-2006
Food-web reorganisation









Casini M et al. PNAS 2009;106:197-202

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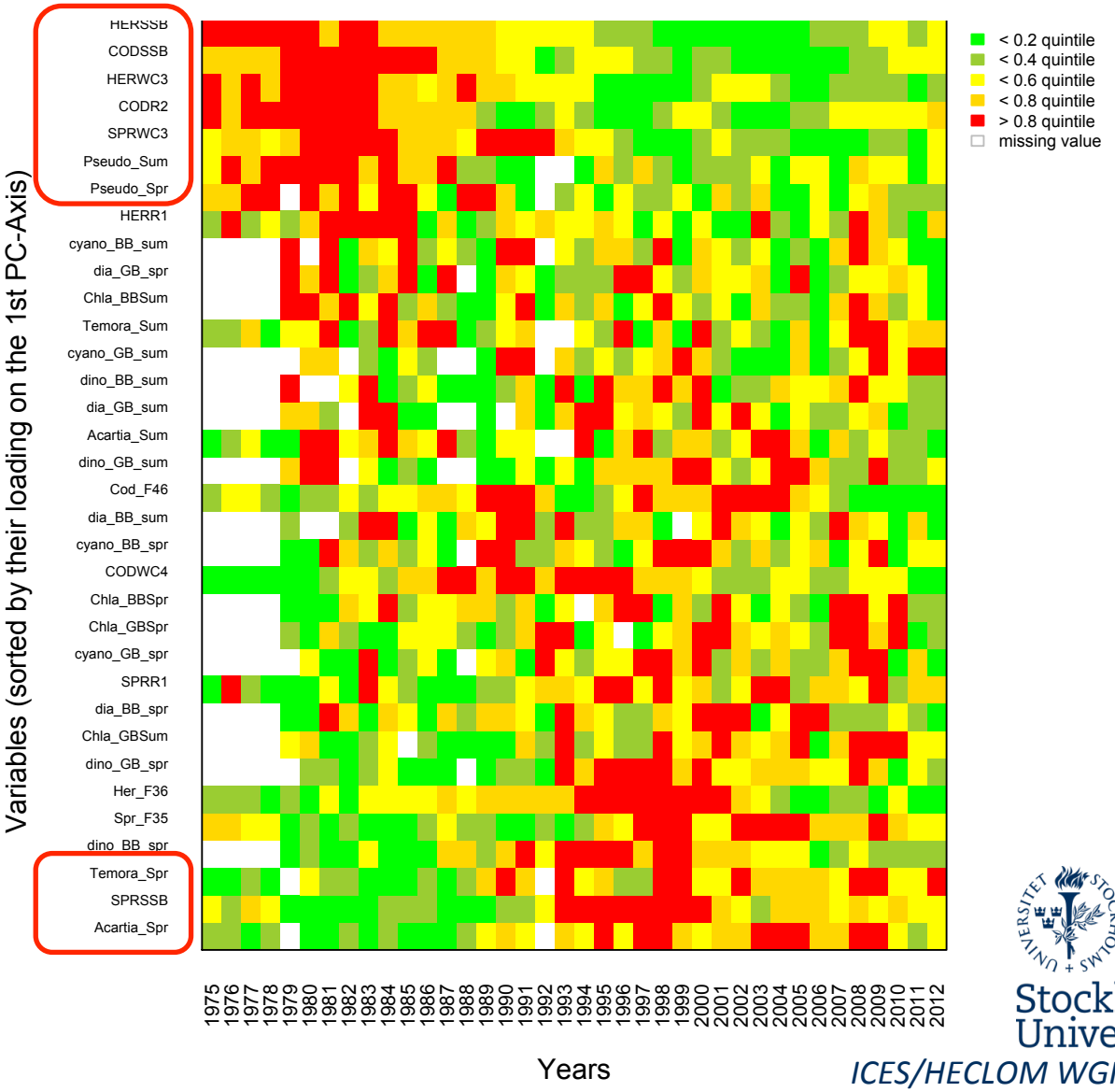
Regime Shift at the Baltic Sea

Cod
Herring
Pseudocalanus sp.
Sprat mean weight

Acartia sp.
Temora sp.
Sprat



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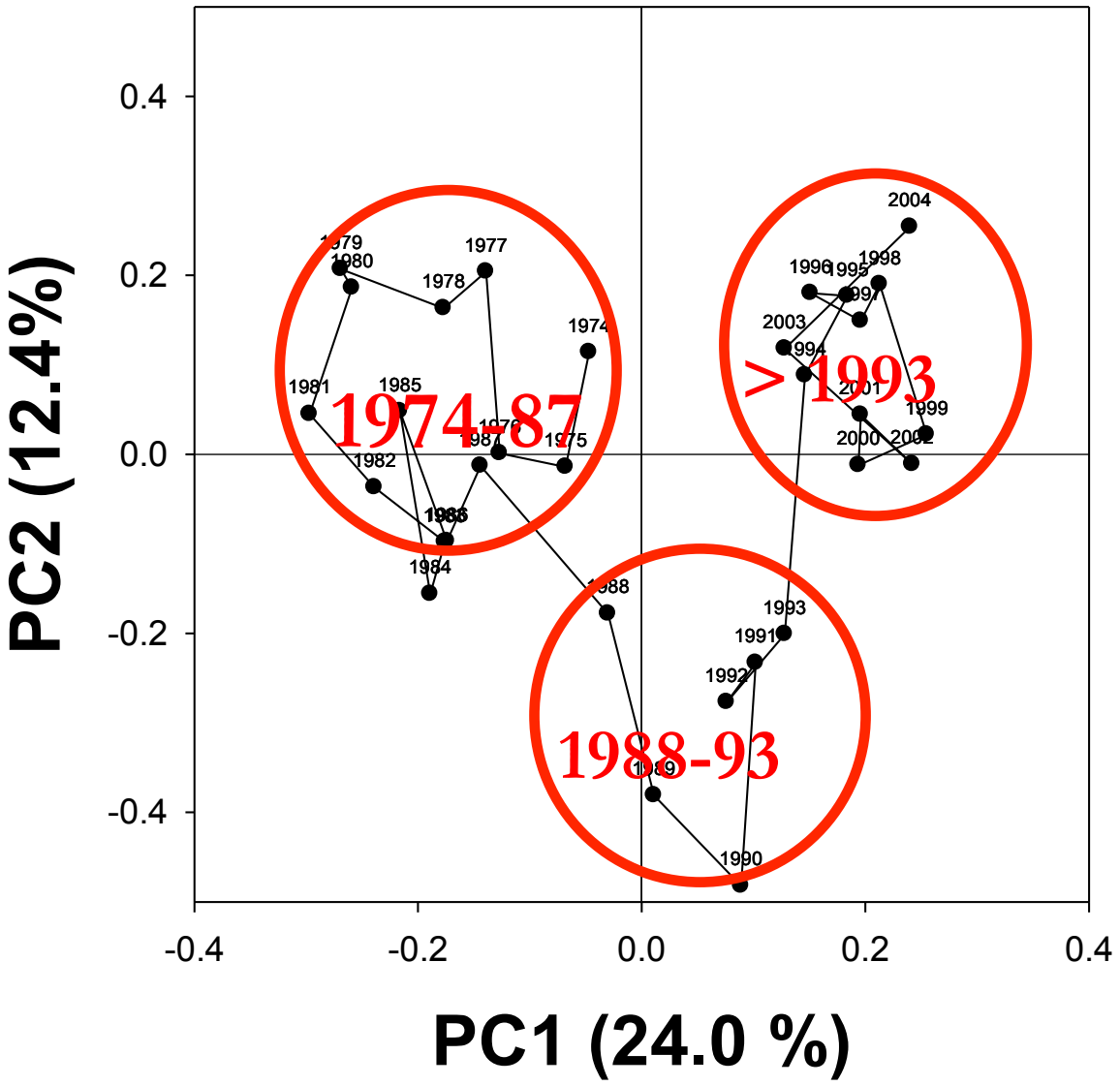
Ecological regime shifts in the Baltic Sea - due to overexploitation and climate change



Möllmann et al. 2009

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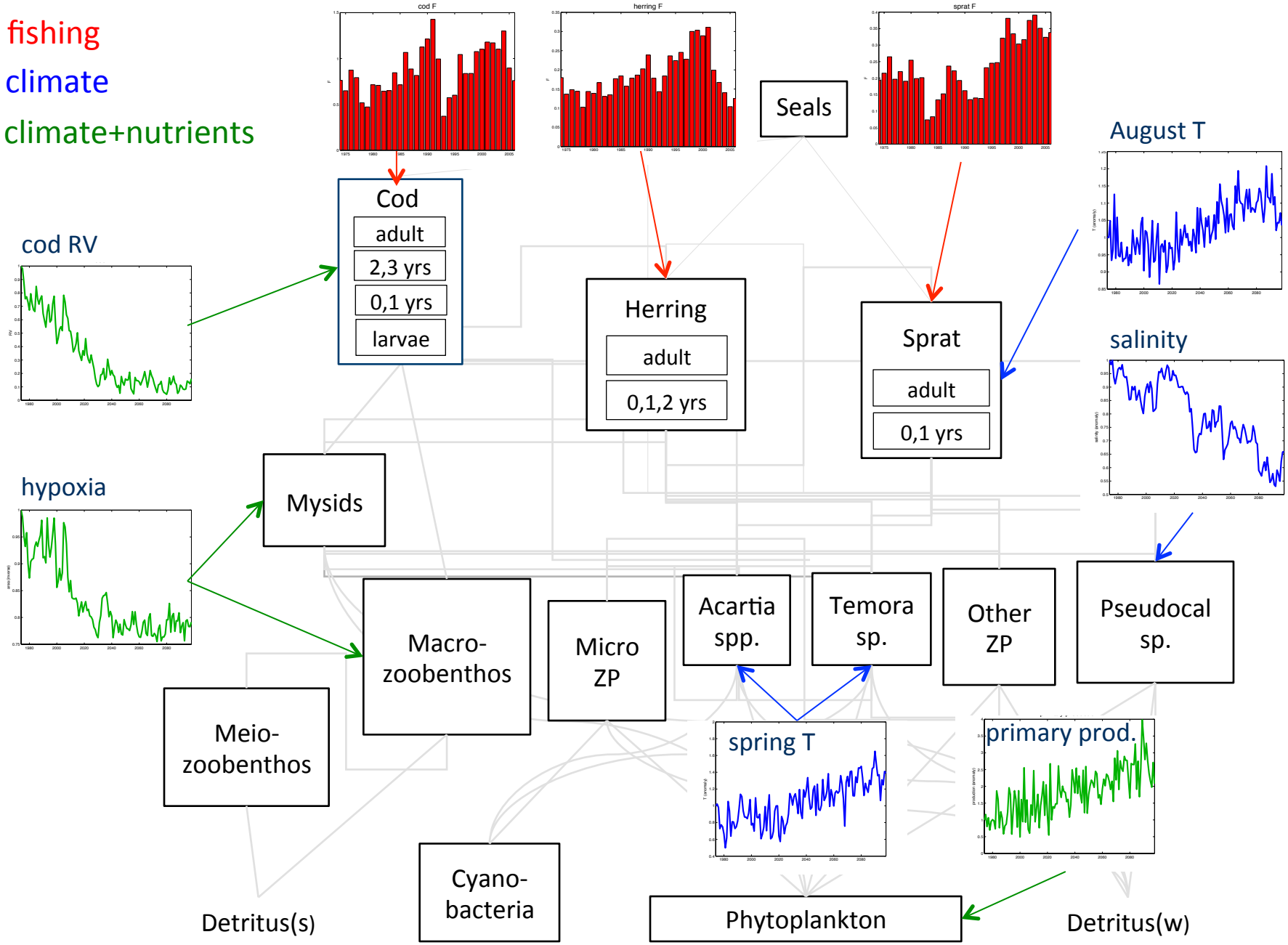
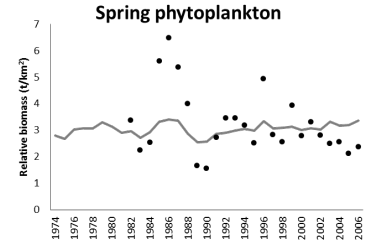
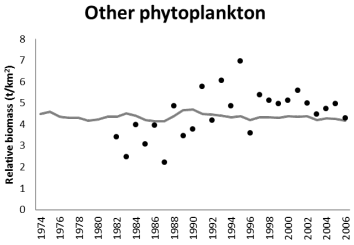
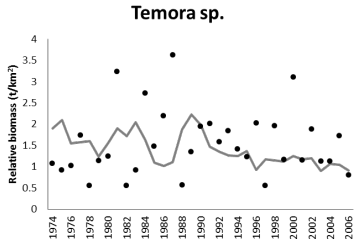
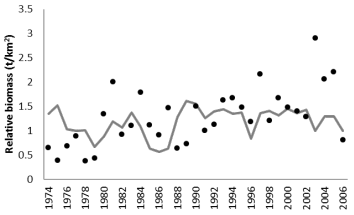


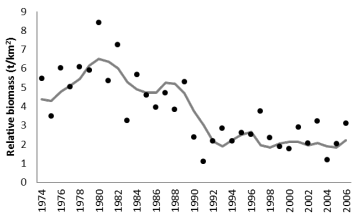
Tomczak et al. 2012

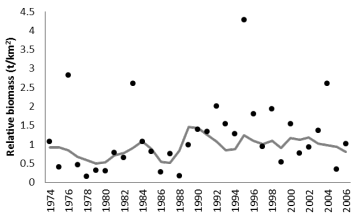


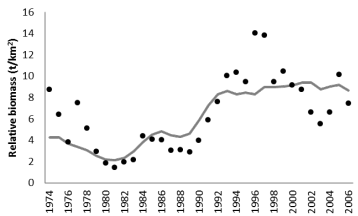


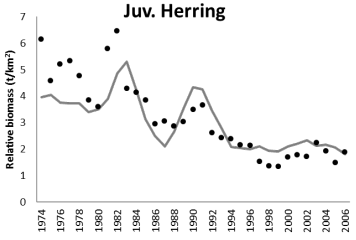


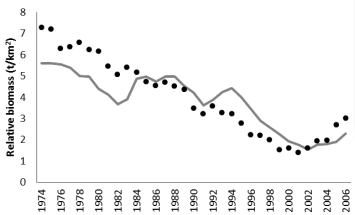


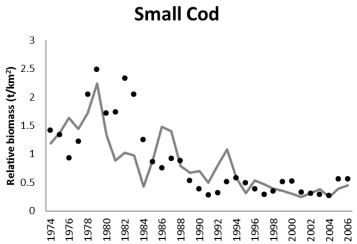


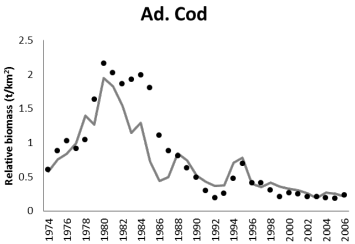


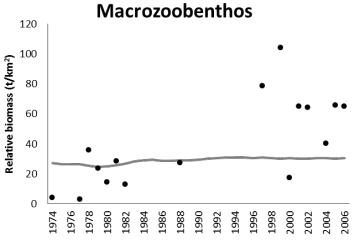


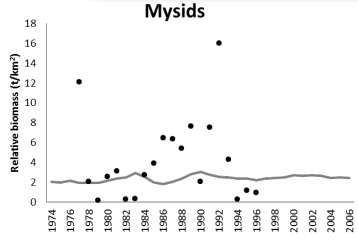


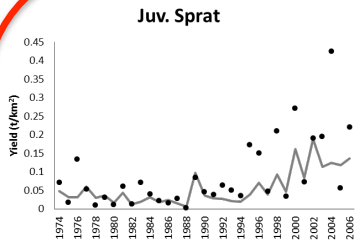


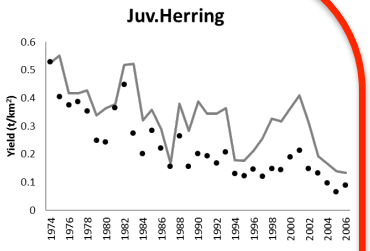


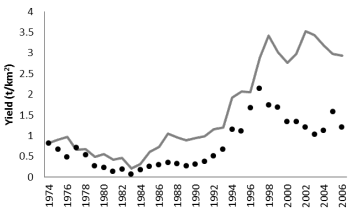


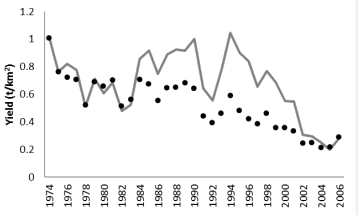


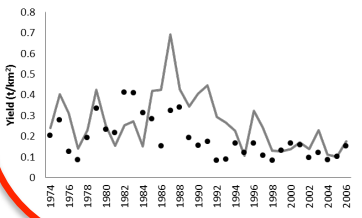


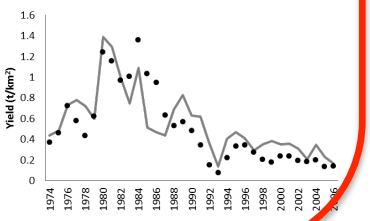












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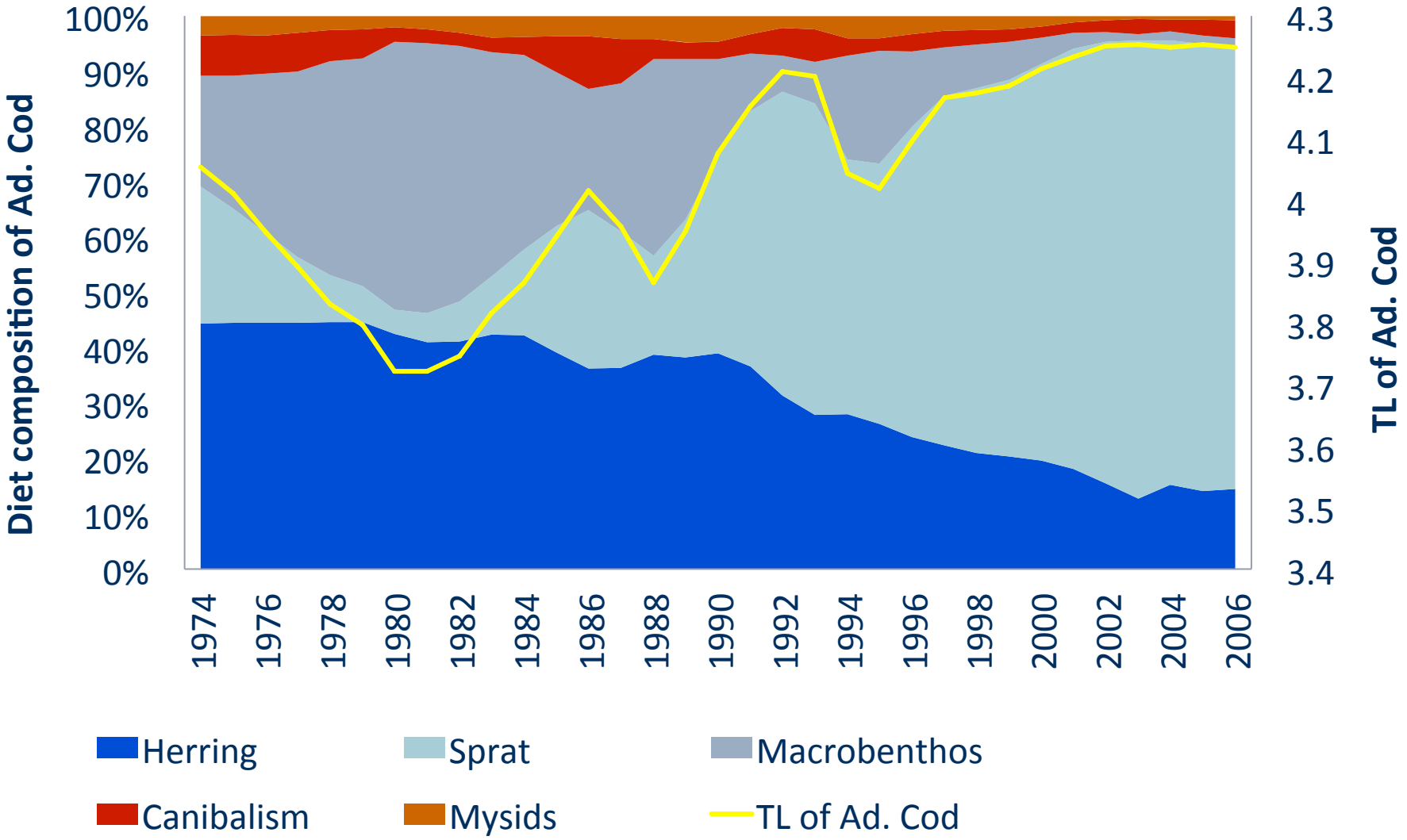
Adult cod - diet composition changes (model)



Indices and ENA (1974-2006)

1. Total System Throupout **(TST)** 2. Relative Ascendance **(A/C)** 3. Average Mutual Information **(AMI)** 4. Entropy **(H)**	Network Indices
5. Finn Cycling Index ***(FCI)*** 6. Predatory Cycling Index ***(PCI)*** 7. Mean Path Length ***(MPL)*** *8. Proportional Flow to Detritus* ***(PFD)*** 9. Total biomass per Total Production ratio ***(ToTB/ToTP)*** 10. The Total Production per Total respiration ratio ***(ToTP/ ToTR)***	Recycle and Structure
11. Total catches ***(TC)*** 12. Primary Production Required per PP ***(PPR/PP)*** 13. Mean Trophic Level of Catch ***(mTLc)*** *14. Kempston* ***Q***	Fisheries effect

Ecological Network Analysis

- The overhead (Ø) is the fraction of a system's capacity and it indicates the system's energy in reserve (Monaco and Ulanowicz, 1997)
- Proposed Redundancy (R=internal Ø) as an index of system resilience

$$R = -\sum_{i=1}^{n}\sum_{j=1}^{n}(T_{ij})\cdot\log\left(\frac{T_{ij}^{2}}{\sum_{j=1}^{n}T_{ij}\cdot\sum_{i=1}^{n}T_{ij}}\right)$$

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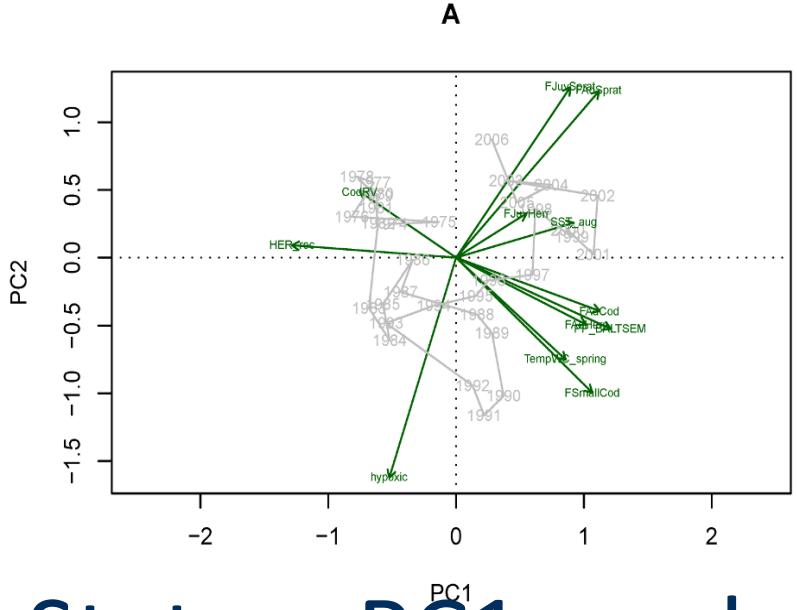
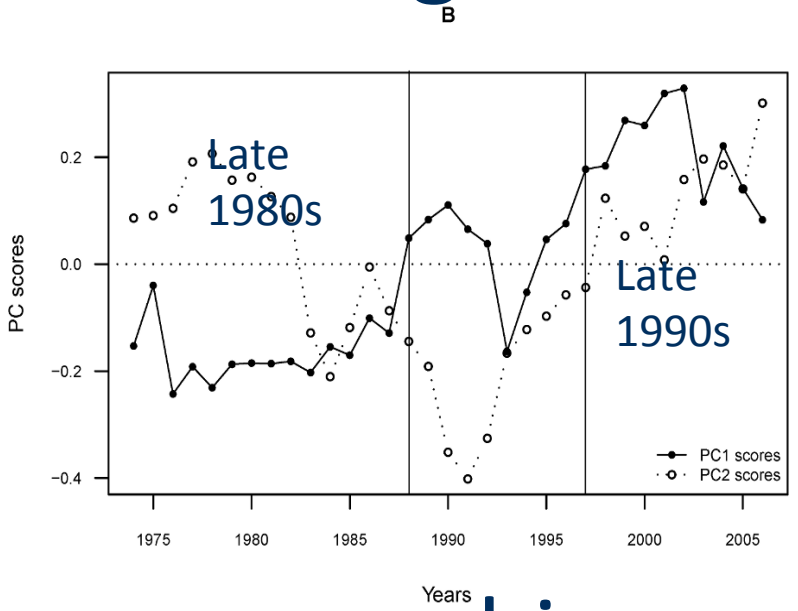
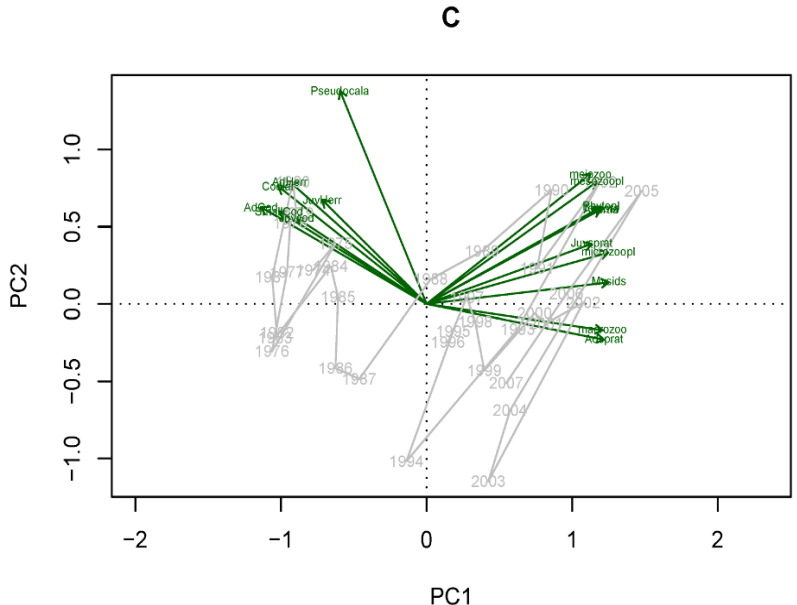
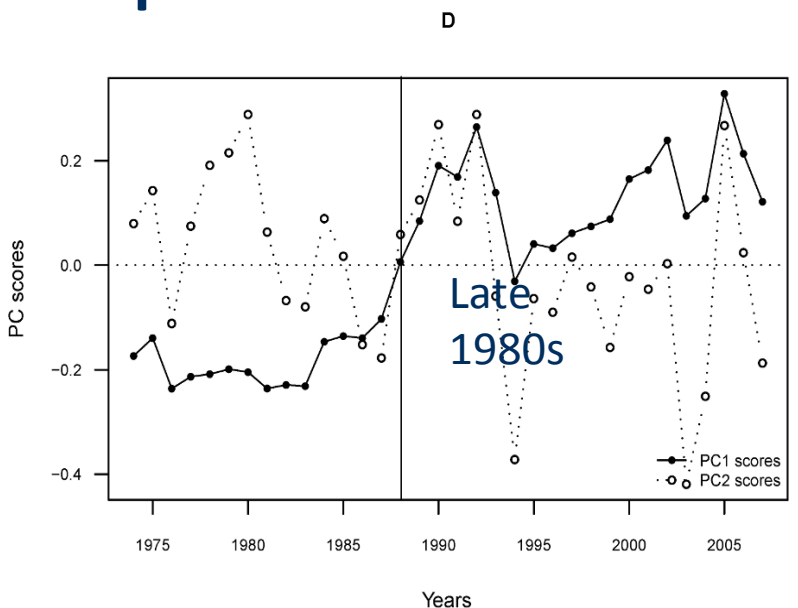
Pressures - PC1 model forcing





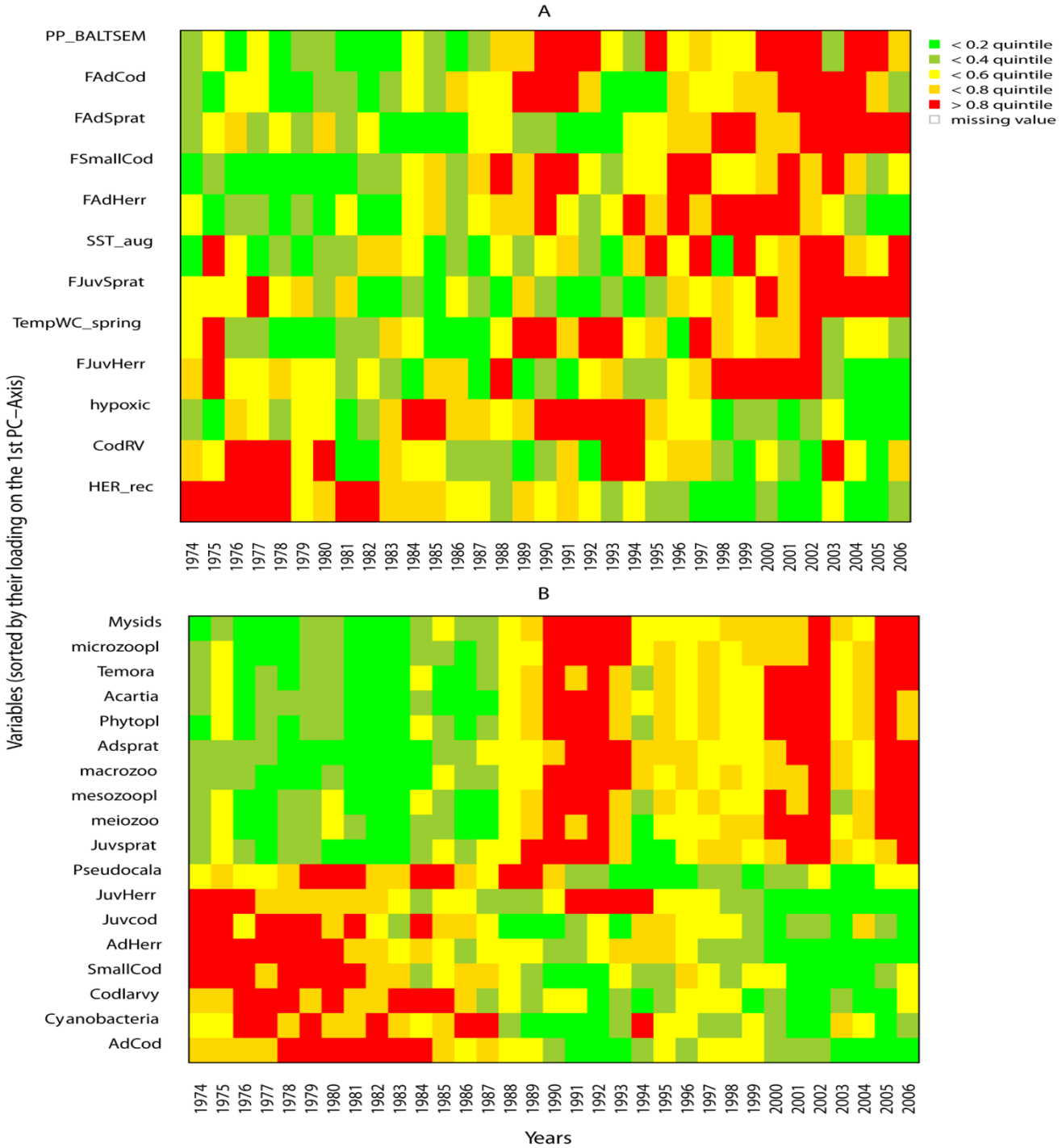
State - PC1 model responce - biomass





Pressures

Biomass



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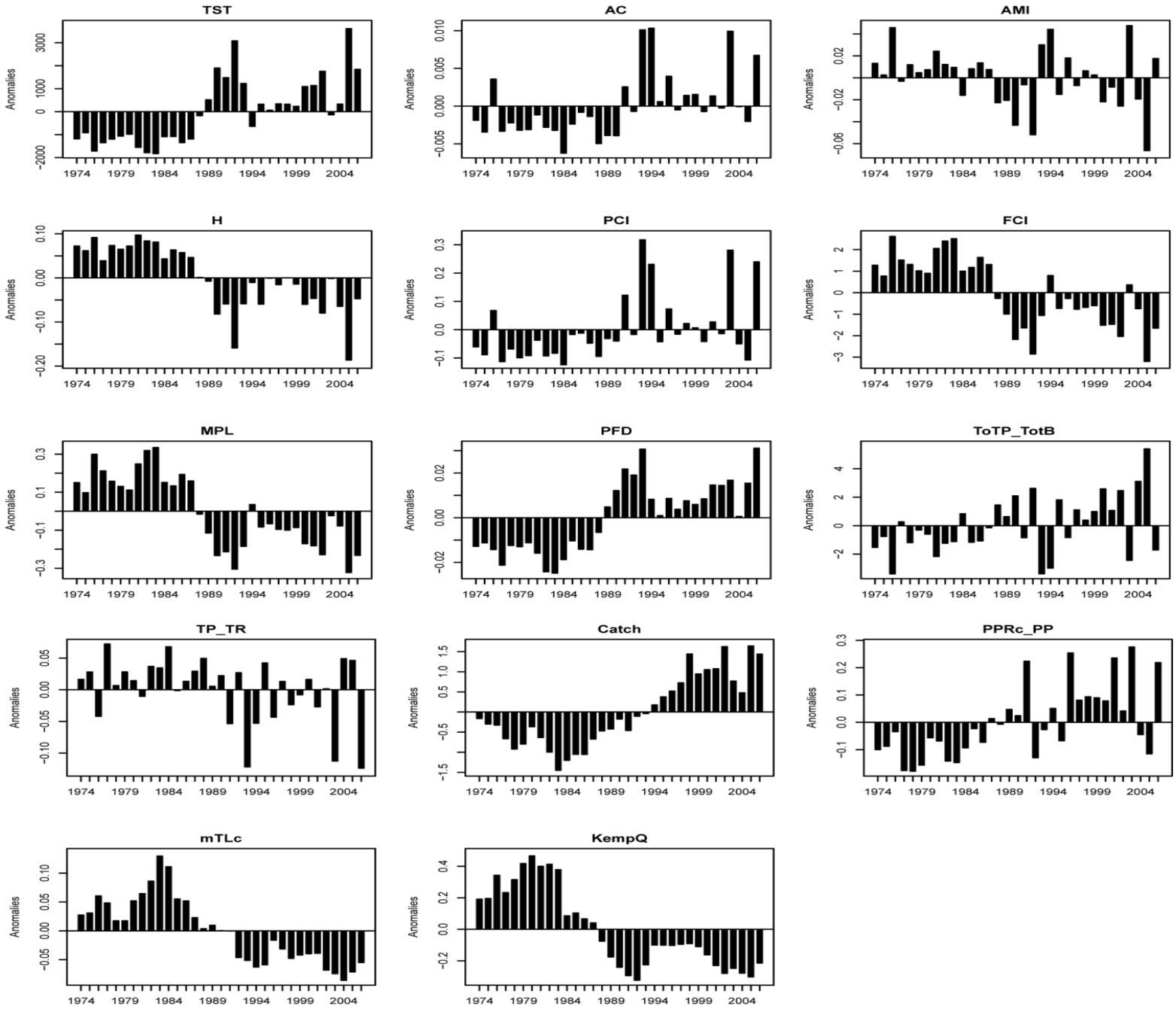

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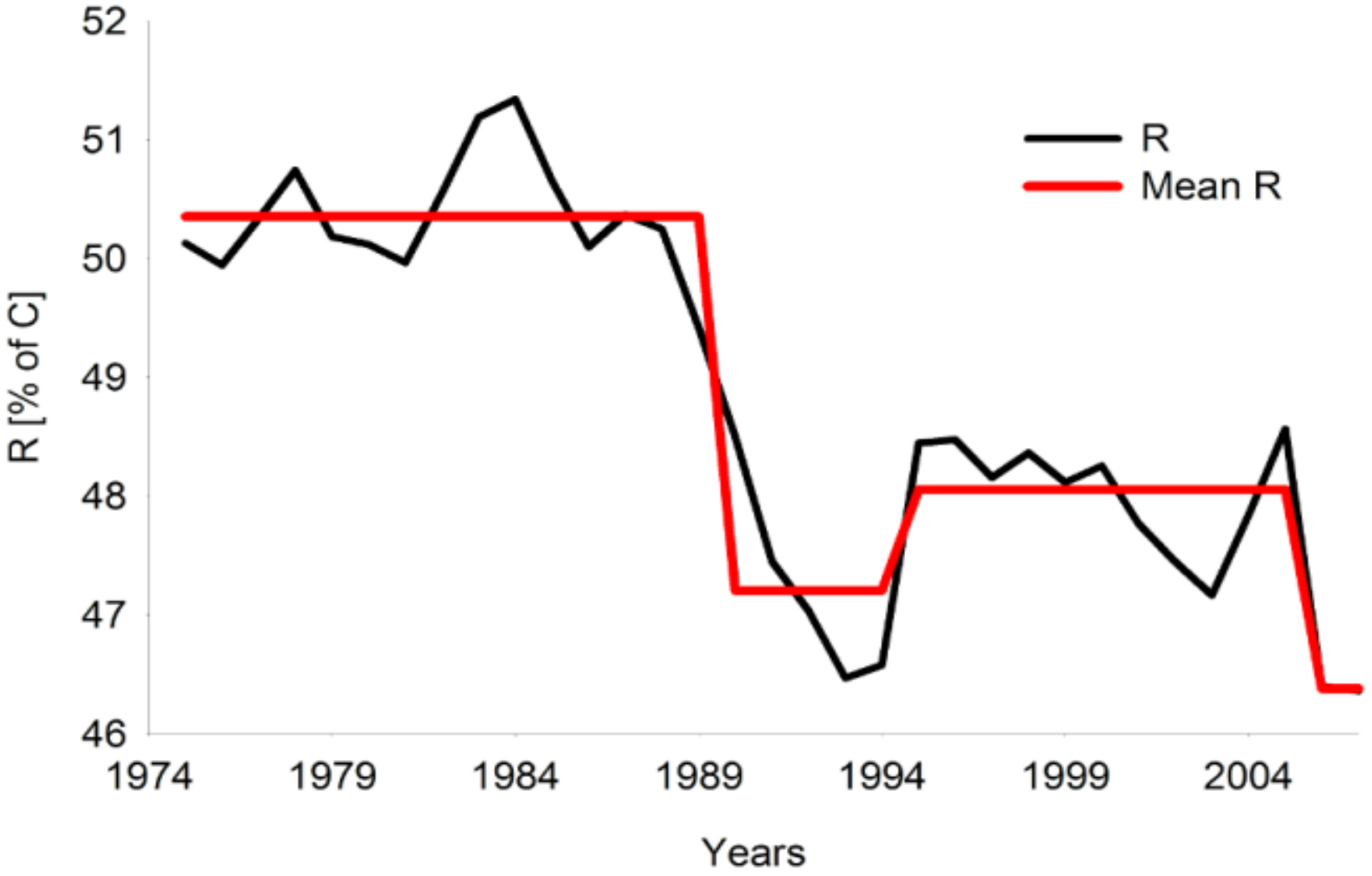
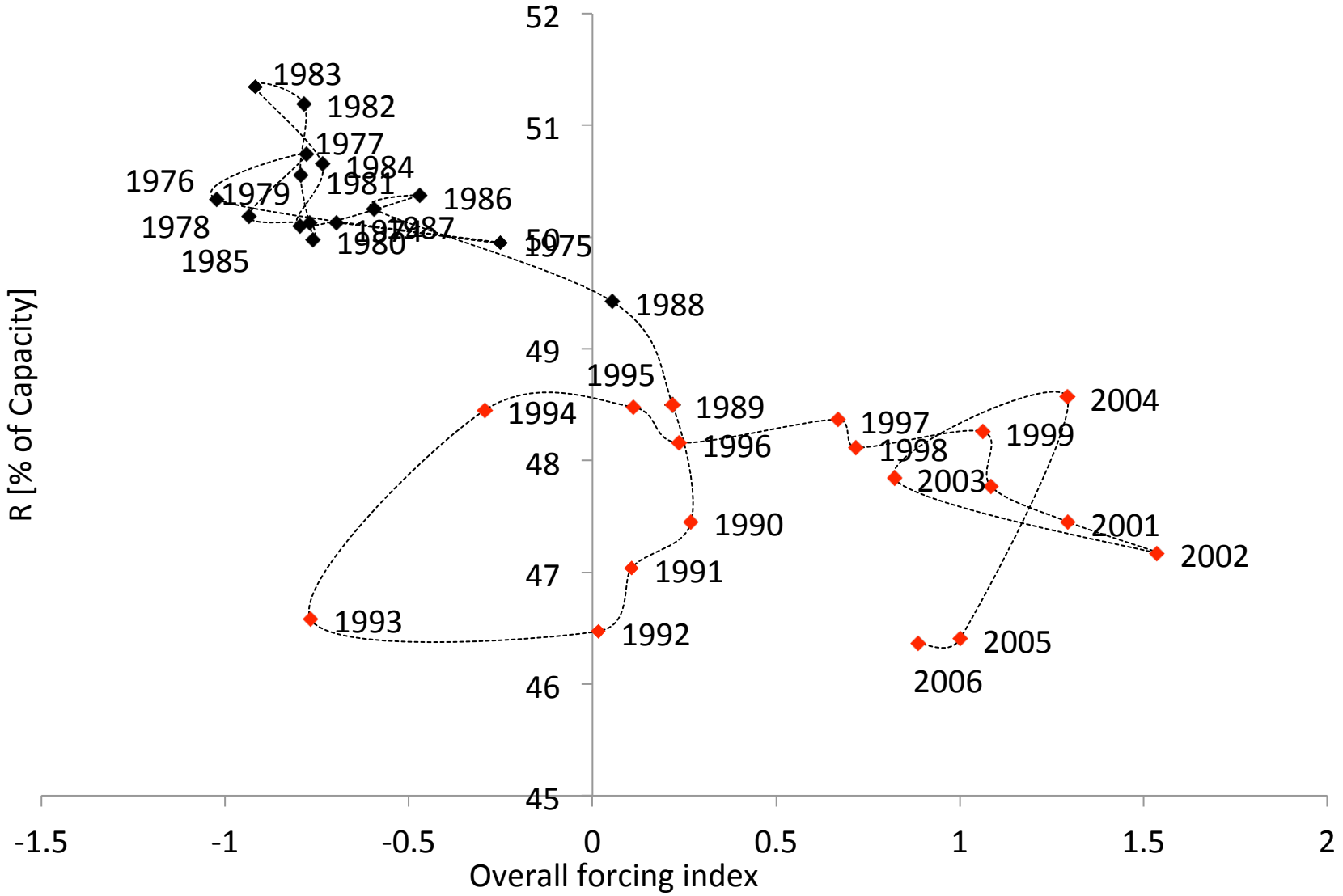
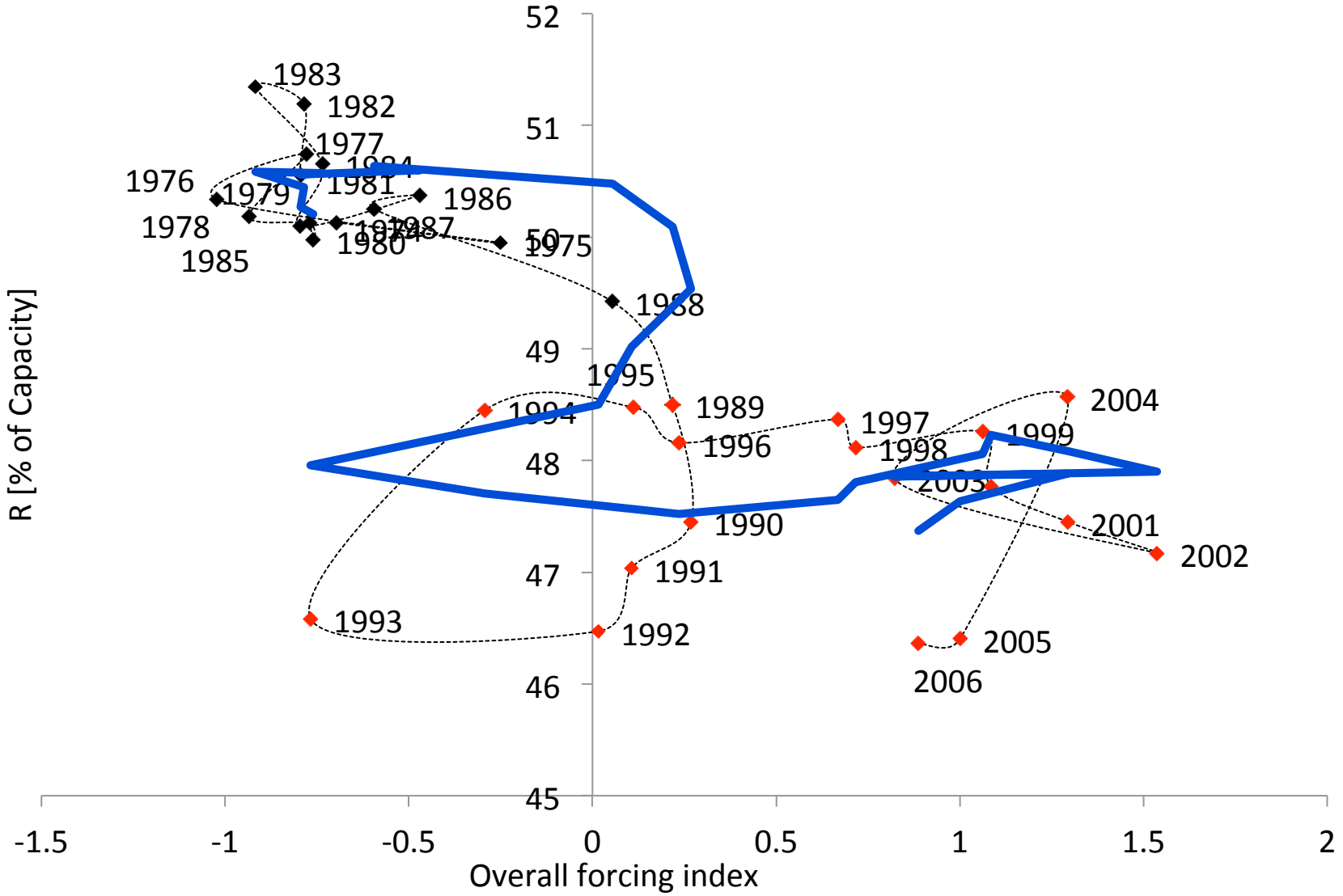
Regime shift – Resilience



Regime shift – Resilience and presures



Regime shift – Resilience and presures



Conclusios

- Adrupt changes at system (Low resilience)
- Food-web reorganization and redirection of energy flow pathways
- Ecosystem topology also changed from a web-like structure to a linearized food-web

- ENA indices - very informative but:
  - not operational indicators
  - model dependent reference points

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Abstract

Several marine ecosystems under anthropogenic pressure have experienced shifts from one ecological state to another. In the central Baltic Sea, the regime shift of the 1980s has been associated with food-web reorganization and redirection of energy flow pathways. These long-term dynamics from 1974 to 2006 have been simulated here using a food-web model forced by climate and fishing. Ecological network analysis was performed to calculate indices of ecosystem change. The model replicated the regime shift. The analyses of indicators suggested that the system's resilience was higher prior to 1988 and lower thereafter. The ecosystem topology also changed from a web-like structure to a linearized food-web.

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Thank you

Thank you for prof Christian Möllmann and ICES/HELCOM Working Group on Integrated Ecosystem Assessment of the Baltic Sea

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