Multi-level oscillating trophodynamic control causes regime shifts in large marine ecosystem

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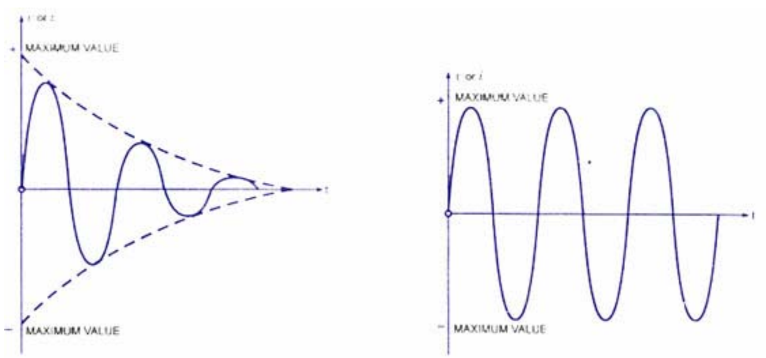
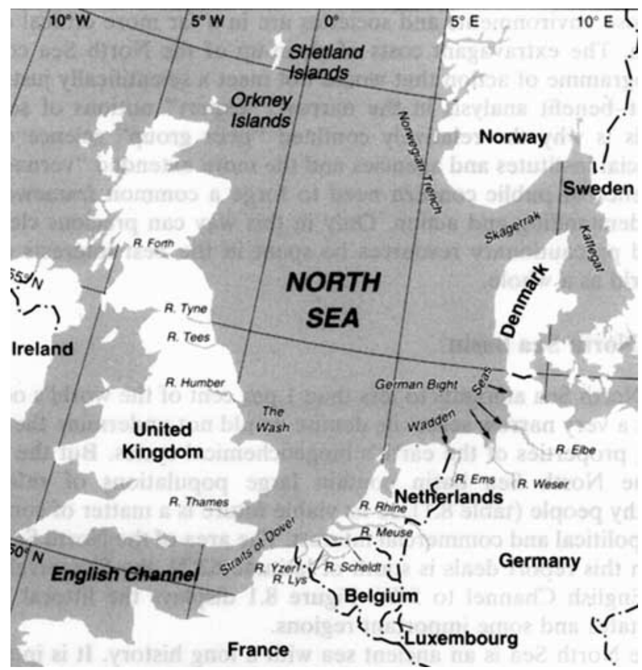


(a) Damped Oscillations (b) Undamped or Sustained Oscillations



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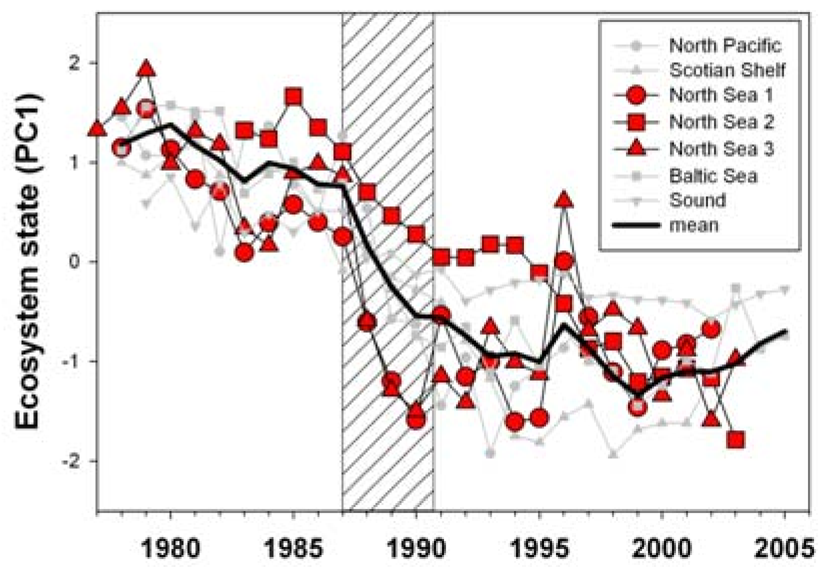
Drivers of Change in the North Sea Ecosystem

Northern Hemisphere Regime Shifts

- Ecosystem regime shift widespread in the Northern Hemisphere (Conversi et al. 2010, Möllmann & Diekmann 2012)

- In the North Sea ecosystem regime shifts reported mainly for the *late 1980s/early 1990s* and to a lesser degree for *late 1970s/early 1980s*

Ecosystem Regime Shift Comparison



Möllmann & Diekmann 2012

North Sea Ecosystem Regime Shifts

- Ecosystem regime shifts observed in the North Sea (mainly in the end of the 1980s/early 1990s)
- mainly attributed to climate **OR** fishing
- „*alternative stable state theory*“ predicts however that „*phase transitions*“ (regime shifts) result from the **interaction between an external and an internal driver**
- external driver can be **climate and/or fishing pressure**, while **trophic control** can be the internal driver (Frank et al. 2007; Litzow & Ciannelli 2008)

Questions ?

- Do changes/oscillations in the control pattern (*bottom-up vs. top-down control*) between trophic levels occur ?
- Do changes/oscillations in the control pattern occur over *multiple trophic levels* ?
- Do changes in the control pattern coincide with the ecosystem regime shifts ?
- What are the *external drivers of change* in the control pattern ?

Data

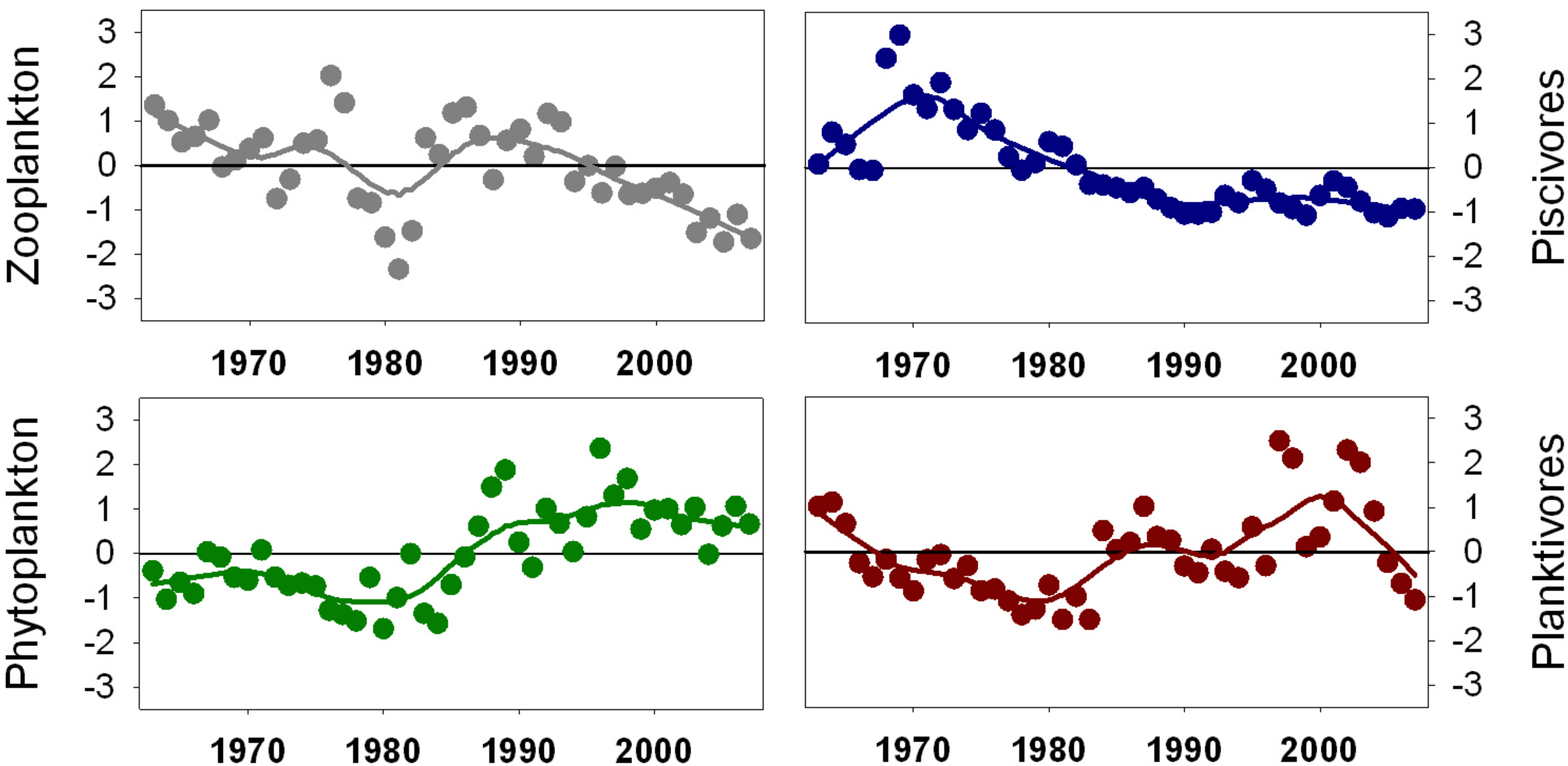
Data (1963- 2007)

- Plankton – Continuous Plankton Recorder (SAHFOS)
- Fish – multispecies fisheries model output (SMS)
  - SSB & fishing mortality

- Trophic Level Indicators
  - Phytoplankton: CPR „phytoplankton colour index“
  - Zooplankton: CPR „total copepods“
  - Planktivores: herring, sandeel, norway pout
  - Piscivores: Cod, haddock, saithe, whiting

- SST (Hadley 3) & Atlantic Multidecadal Oscillation (AMO)

Trophic Level Indicators of the North Sea



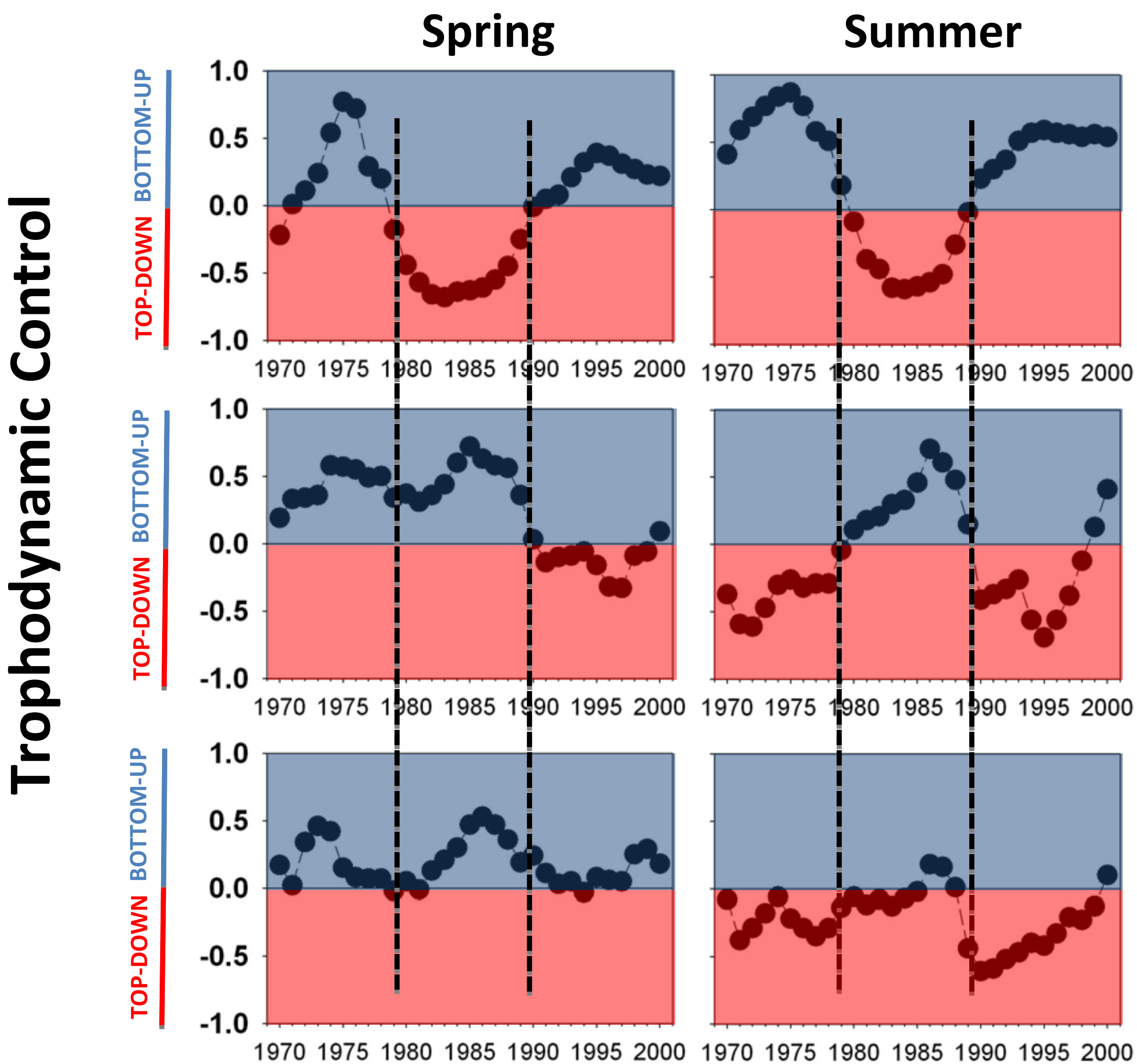
Analyses

- Moving correlation analyses (5-, 10- & *15-year windows*) of adjacent trophic level indicators
  - Positive correlation coefficients indicate BOTTOM-UP CONTROL
  - Negative correlation coefficients indicate TOP-DOWN CONTROL

- Identification of periods when CONTROL changed between BOTTOM-UP and TOP-DOWN

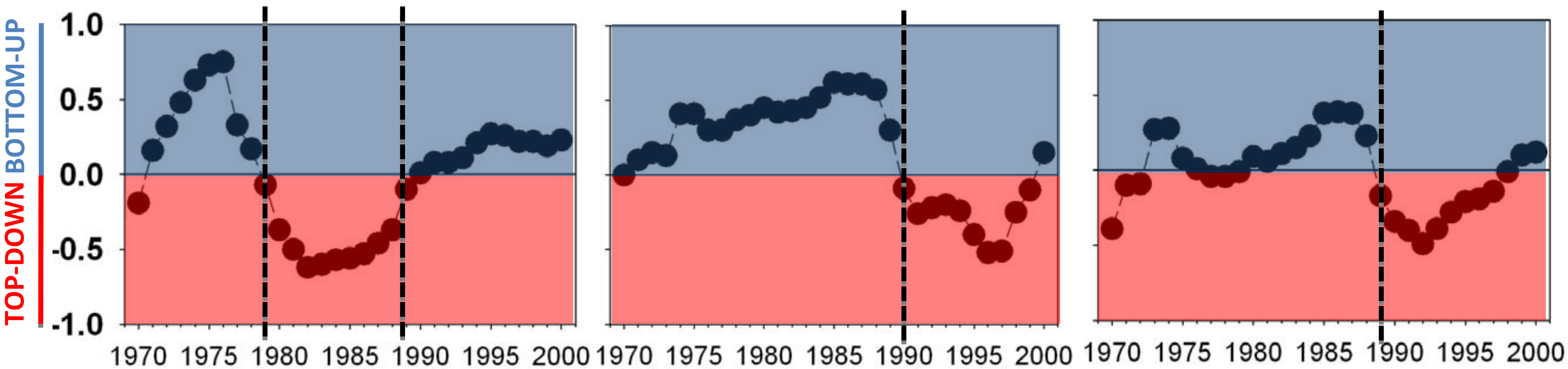
- Test HYDRO-CLIMATE and FISHING PRESSURE as potential DRIVERS of the control change (using Generalized Additive Models – GAMs)

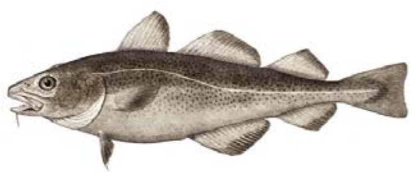
Changes in tropho-dynamic control



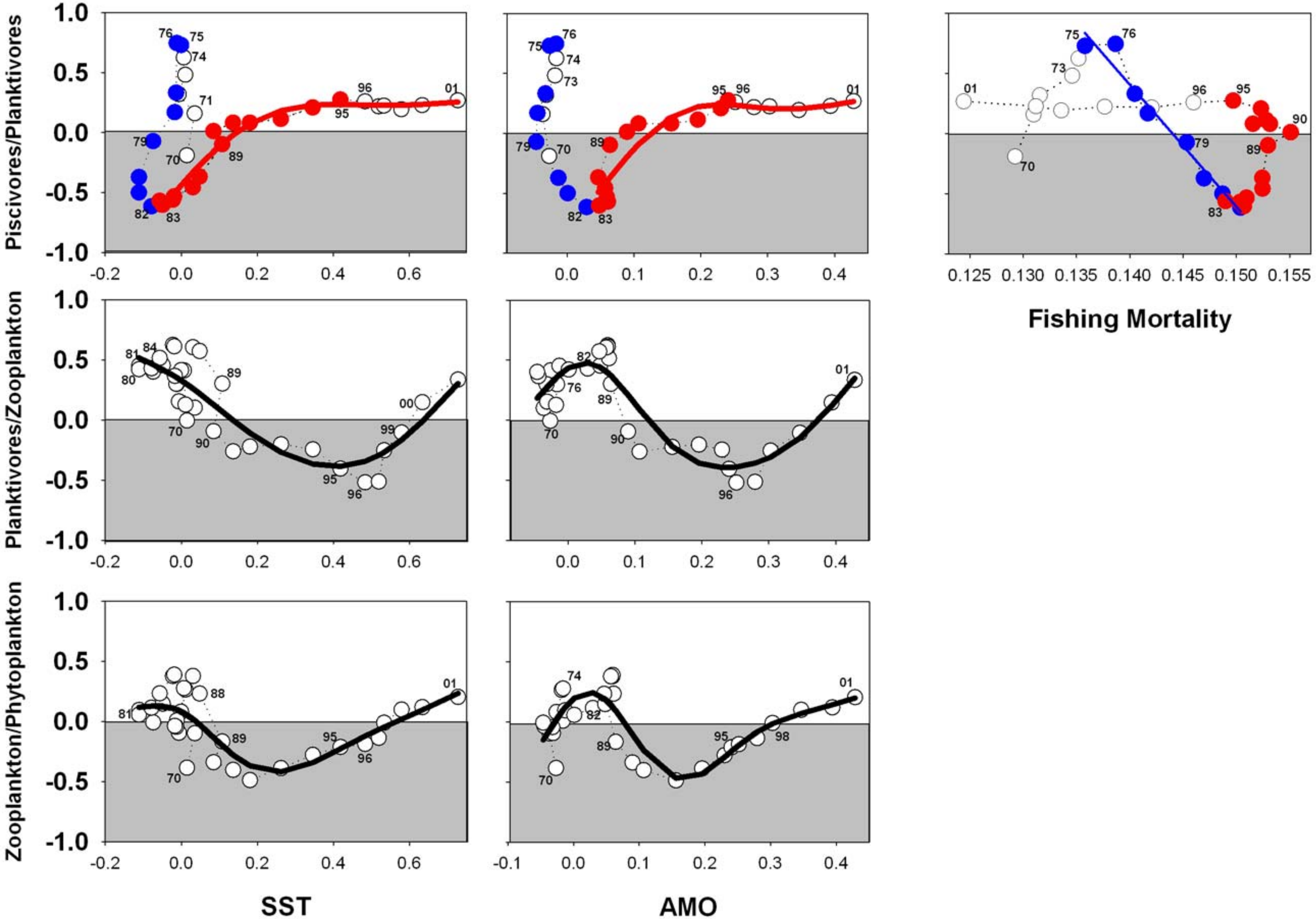
Changes in tropho-dynamic control

<u>Annual averages</u>

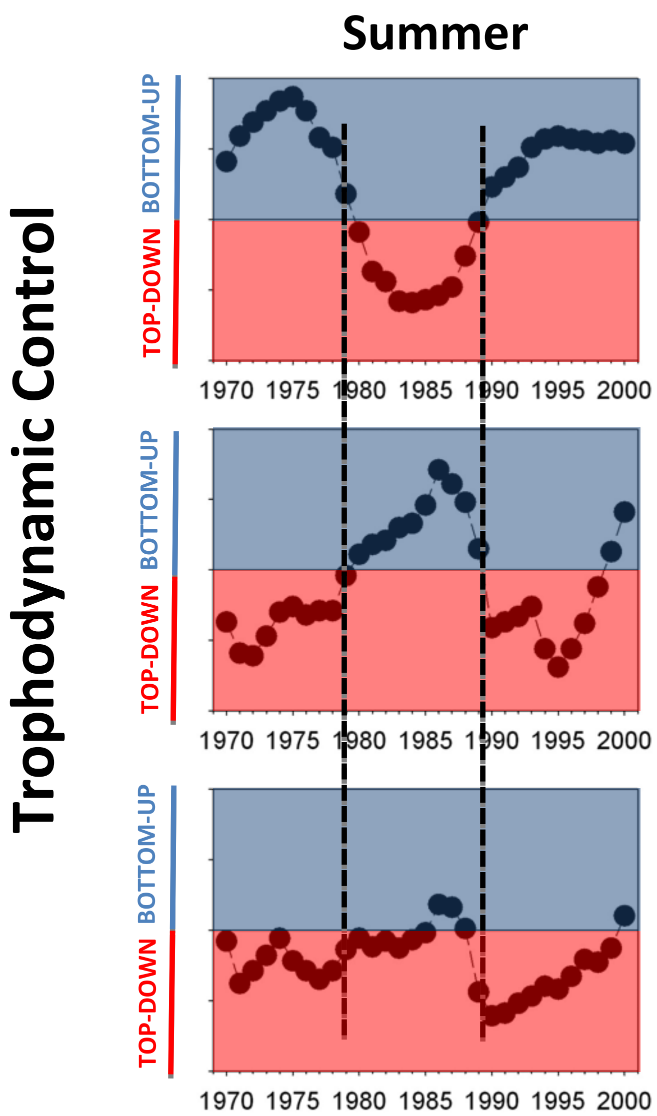




External drivers of changes in tropho-dynamic control



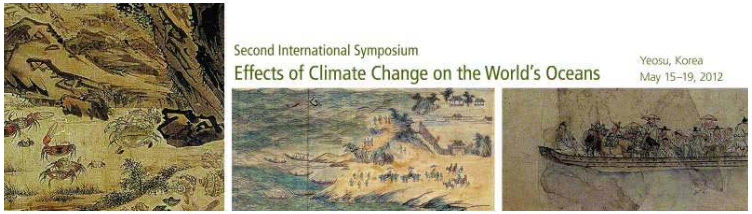
Changes in tropho-dynamic control



- Fishing drives system to top-down control (according to theory – Frank et al. 2007)
- Planktivores profit from both sides – Wasp-Waist-Control
- No multi-level tropic cascade (negative relationships between all trophic levels)
- Warming strengthened consumer control of primary production (according to metabolic theory)

Summary of results – answers to questions

- There are oscillations in the control pattern (*bottom-up vs. top-down control*) between trophic levels occur !
- Oscillations in the control pattern occur over *multiple trophic levels* → ecosystem regime shift !
- Changes in the control pattern coincide with the ecosystem regime shifts !
- Different *external drivers of change* in the control pattern – late 1980s regime shift mainly induced by climate !



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Thanks !

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