PICES – ASM - 2016

Ecosystem *Resilience*

What is it and how can we measure it?

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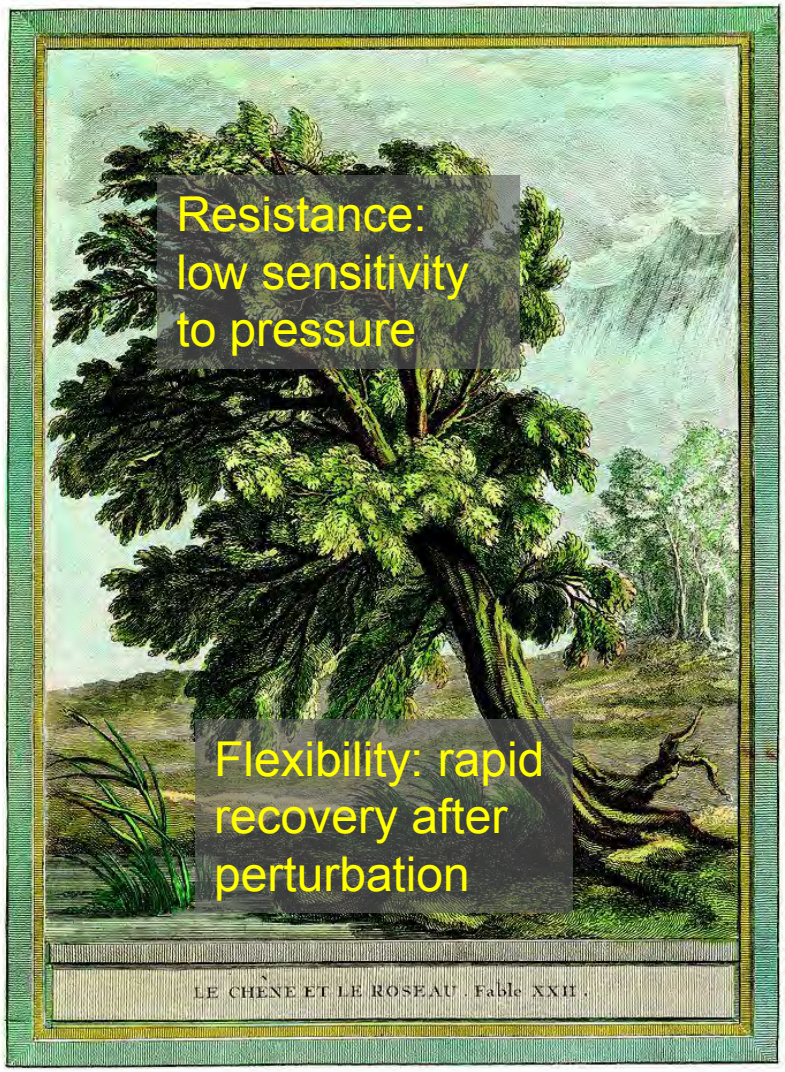
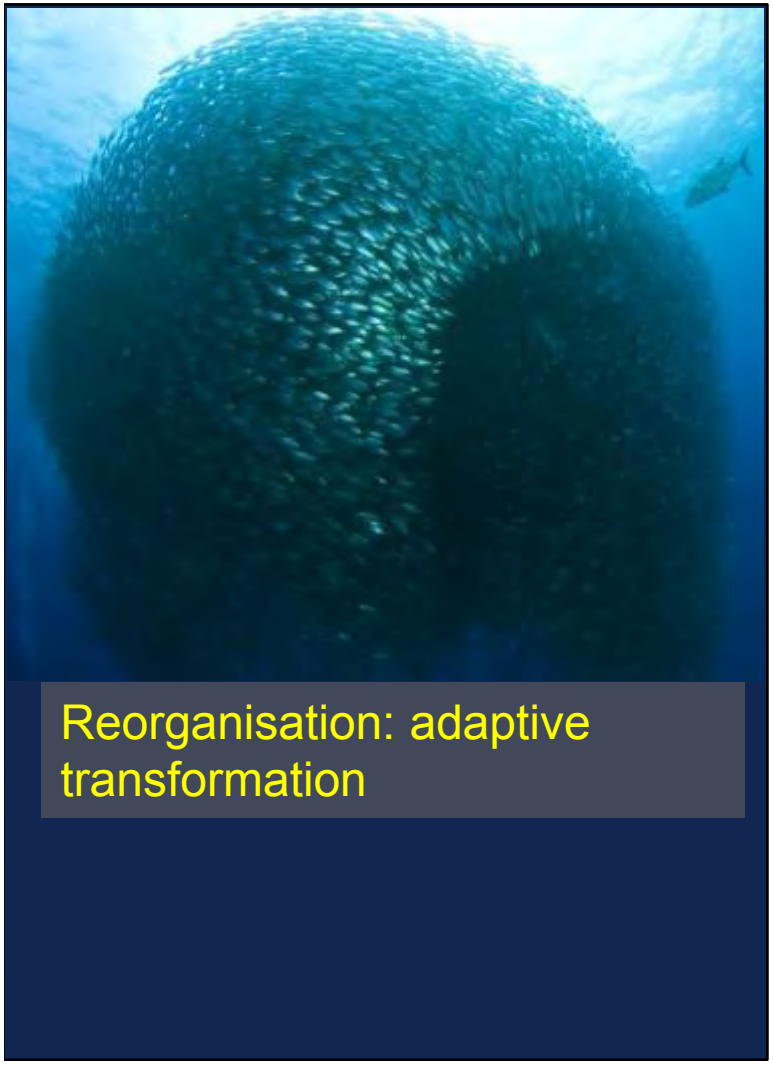
Resilience

the ability of a system to absorb disturbance and maintain structure and function

Resilience: resistance, flexibility, reorganisation





Resilience:

the ability of a system to absorb disturbance and maintain structure and function

Resilience of what to what?

structure & function?

biodiversity
ecosystem level functions
ecosystem services

ecosystems
energy input,
extractive activities
pollution, CC...

demography
genetic diversity
spatial diversity
non-extinction

communities
loss/gain species
phenologies
spatial overlap,...

physical integrity
growth
Reproduction
survival

populations
recruitment,
habitat,
mortality,...

individuals
food supply,
Physical/chemical environment,
predators, parasites, diseases,...

Resilience of what to what?

structure & function?

biodiversity
ecosystem level functions
ecosystem services

ecosystems
energy input,
extractive activities
pollution, CC...

Resilience at ecosystem level does not result from or entail resilience at individual, species or community levels

Resilience: resistance, flexibility, reorganisation

- *Resistance: species composition – and therefore ecosystem functions - remains unaltered by pressures*
- *Flexibility: species composition rapidly returns to original configuration after a perturbation and ecosystem functions are restored*
- *Reorganisation: constant fluctuations in species composition ensure the maintenance of ecosystem functions*

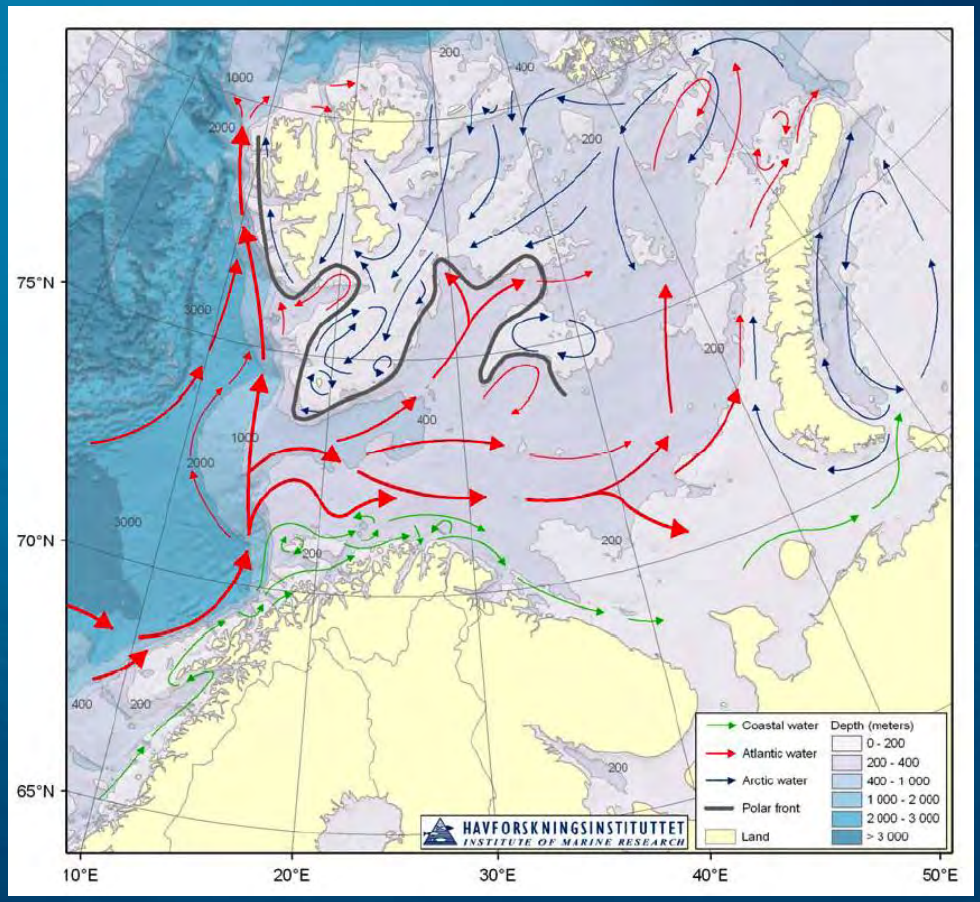
Quantitative measures of ecosystem resilience

Structural properties	*Dynamic properties*
Diversity: specific, functional, phylogenetic, spatial,…	Variability
Redundancy: functional, phylogenetic, spatial,…	Return rates
Modularity: network organisation of species interactions	Tipping points (regime shifts)
	Hysteresis
	Stability
	Synchrony

at the ecosystem level

Levin and Lubchenko (2008)

The Barents Sea



- *1.6 million km²*
- *Norwegian Sea & Arctic influences*
- *PP ~1.6 billion t/y*
- *Total Catch ~ 1.4 million tonnes*
- *Key target species: cod, capelin, saithe, haddock, redfish, red king and snow crabs, shrimps*
- *Large scale ecosystem surveys*

BarEcoRe

Measuring BS ecosystem resilience in practice

Structural analyses

- *species diversity*
- *functional diversity*
- *food web structural properties (modularity)*

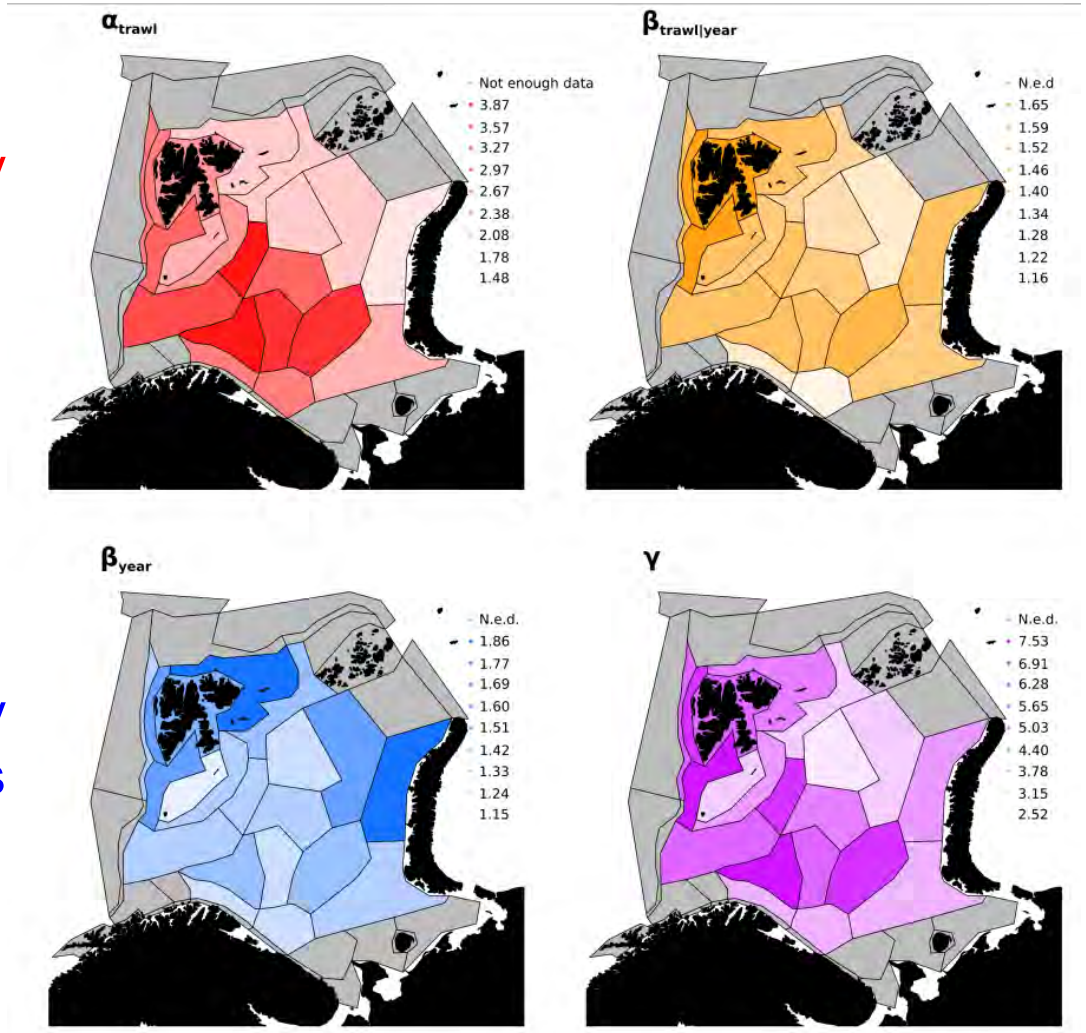
Time-series analyses

- *Regime shifts, trophic oscillations, stability and synchrony*
- *historical reconstructions*
- *'null' ecosystem model*

Regional variations in fish diversity

α-diversity

β-diversity between years

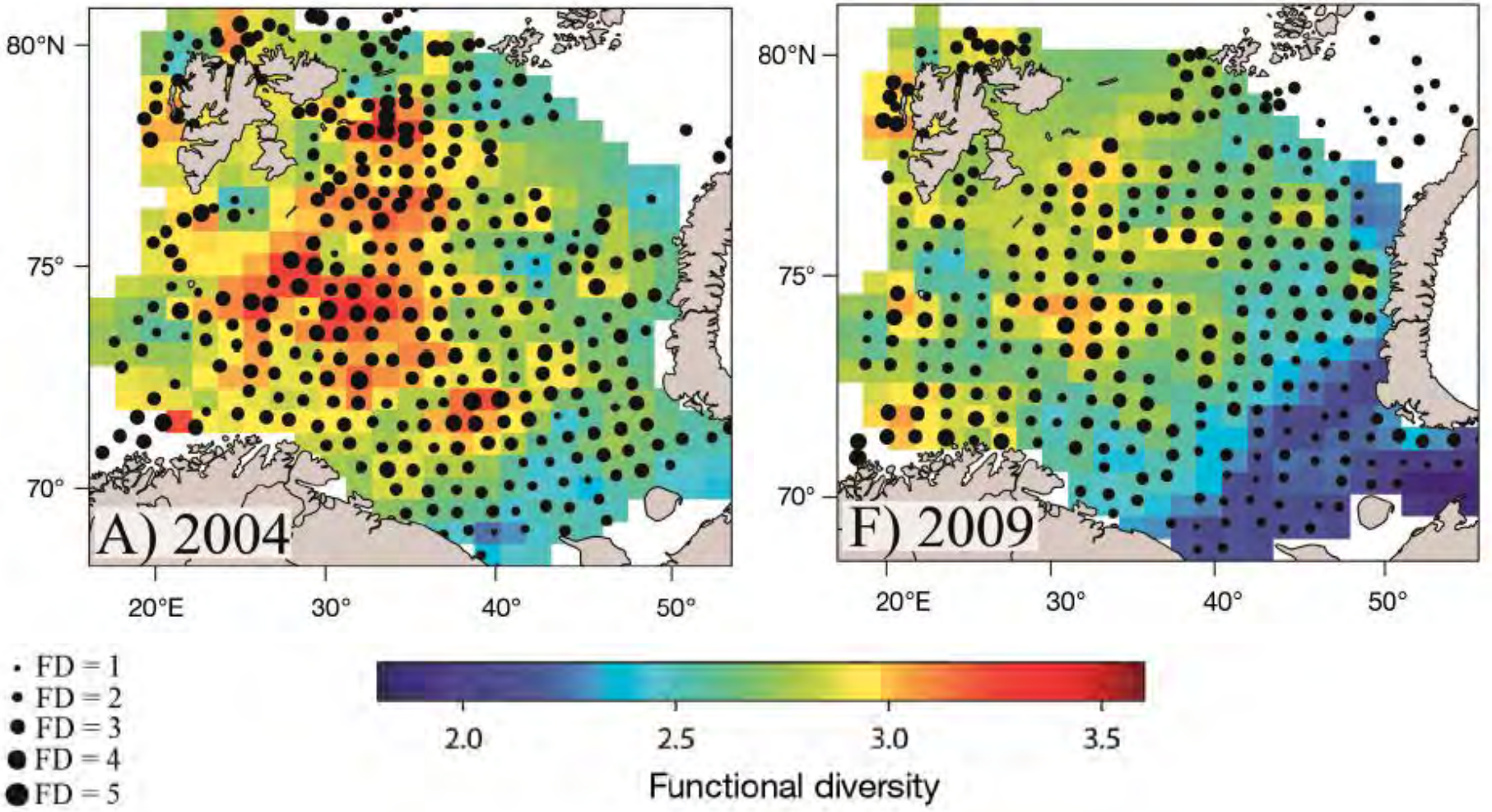


β-diversity within polygons

γ-diversity

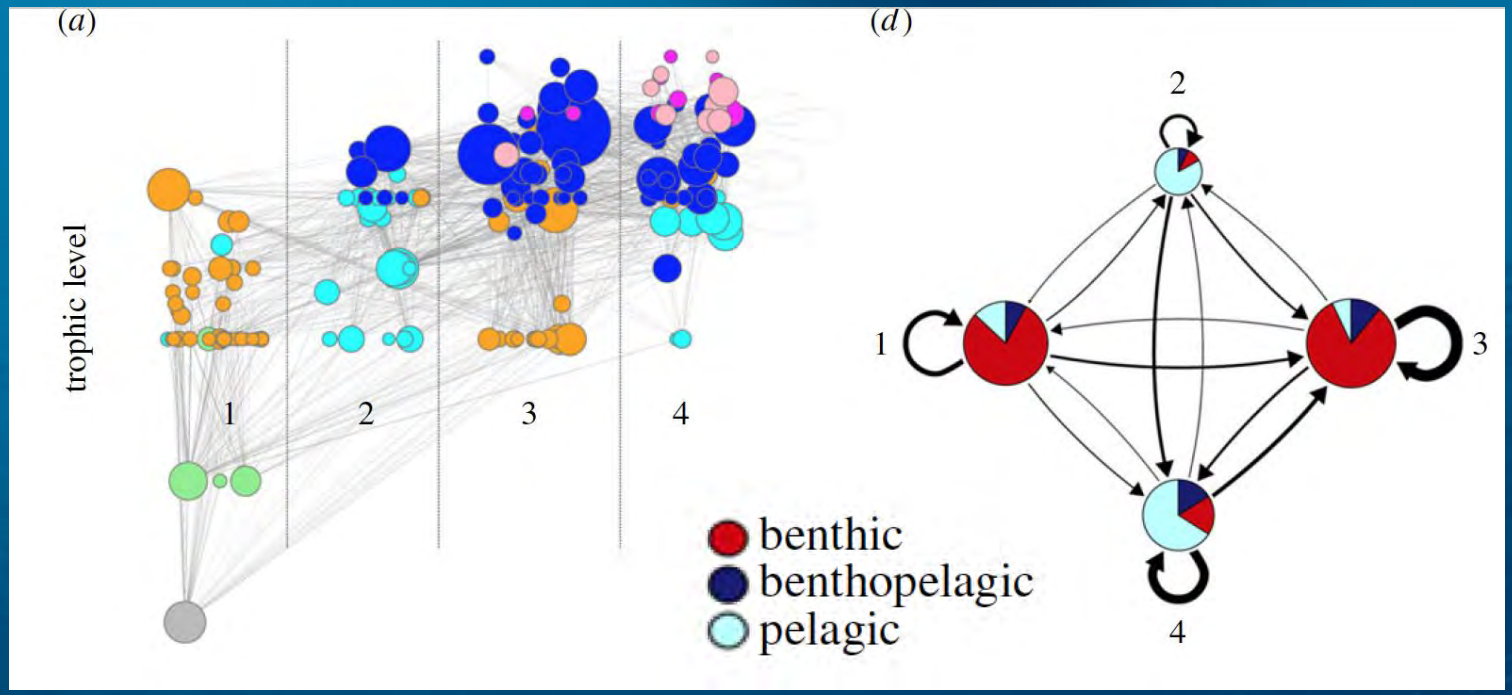
Certain and Planque 2015

Fish functional diversity



Wiedmann et al. 2014

Structural analysis of food webs

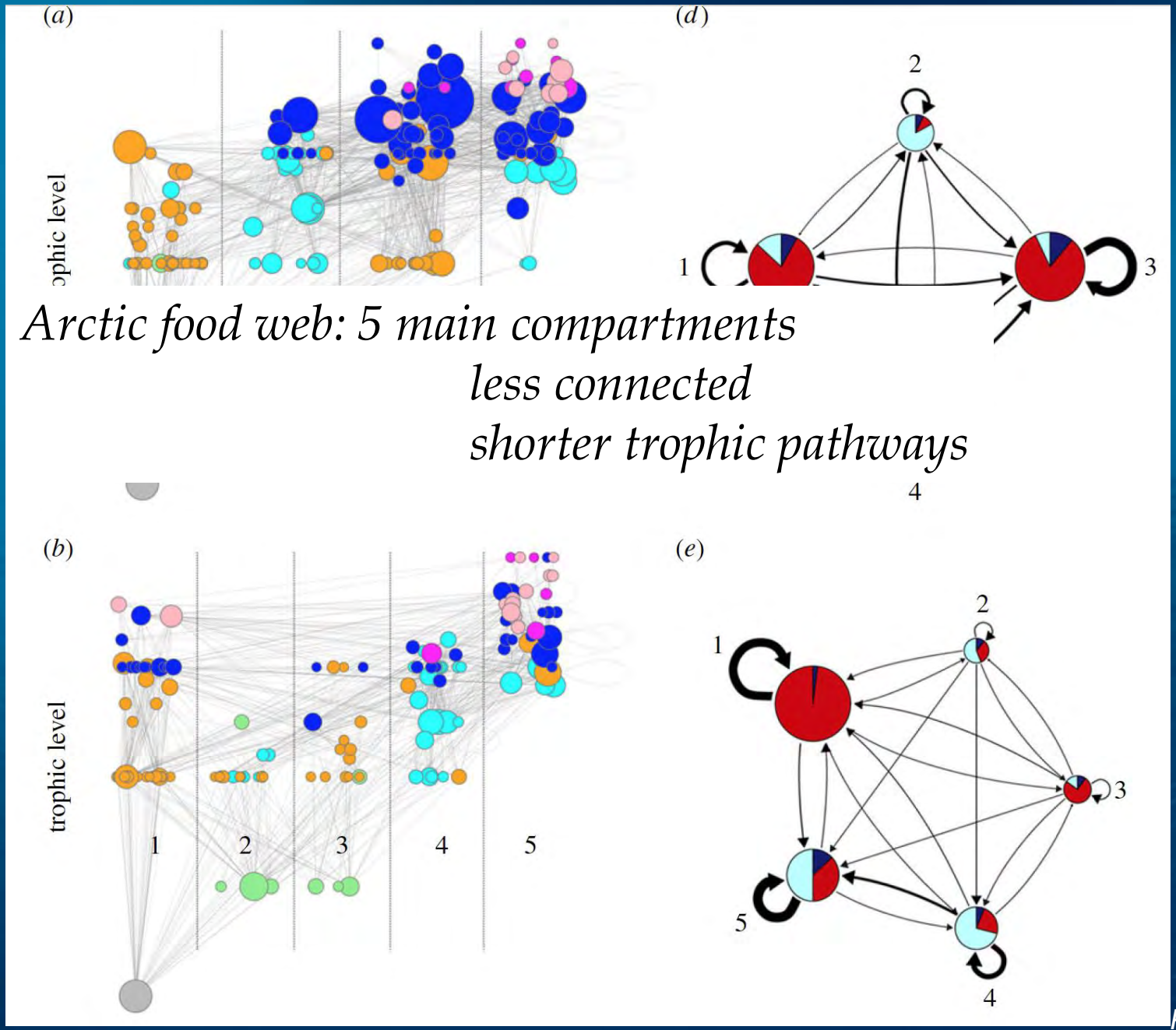


Boreal food web: 4 main compartments

Well connected

Long trophic pathways

Kortsch et al. 2015



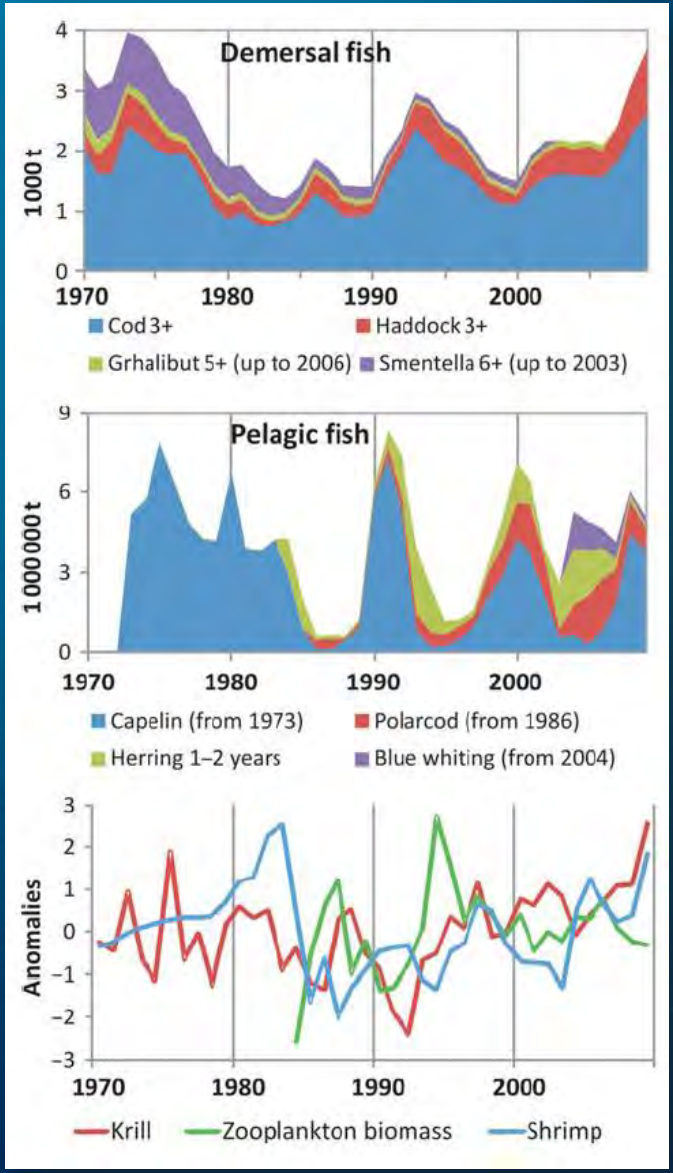
Arctic food web: 5 main compartments

less connected

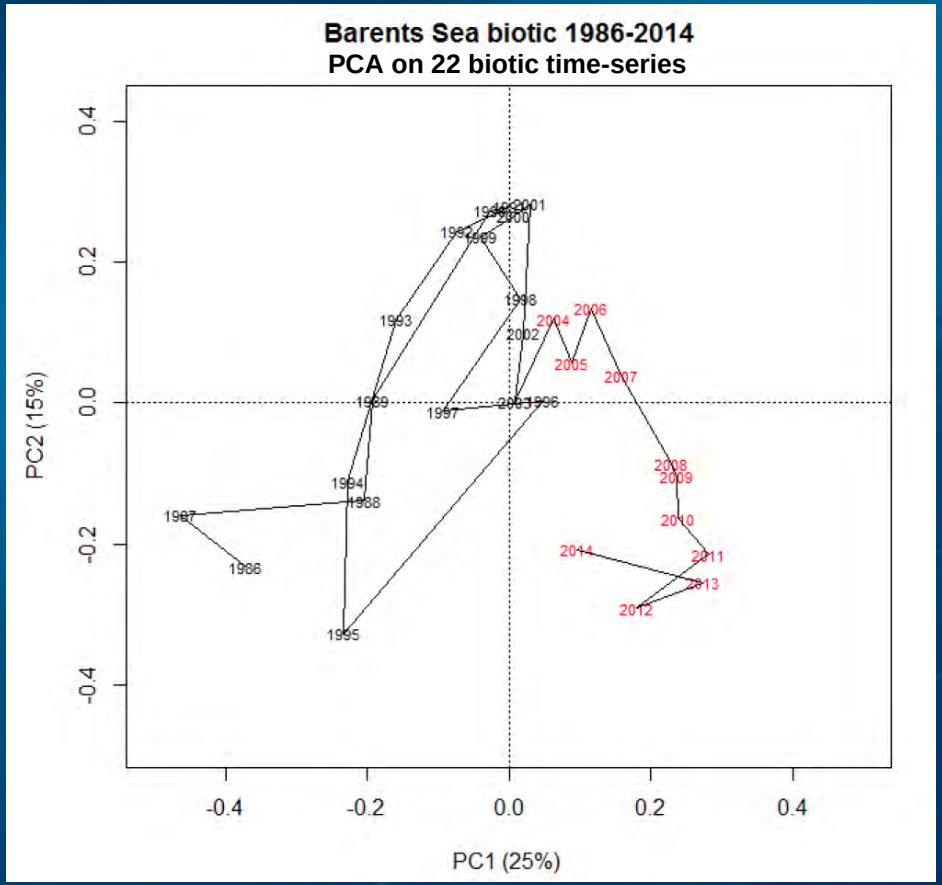
shorter trophic pathways

Kortsch et al. 2015

Historical ecosystem changes



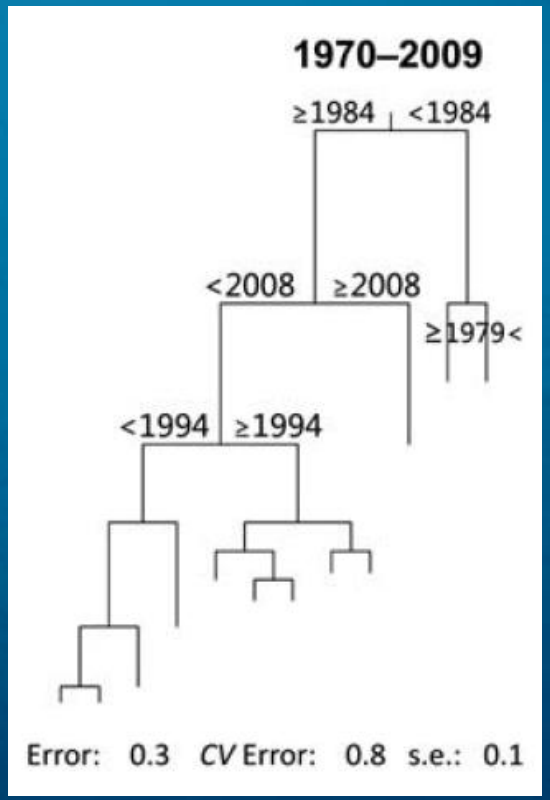
(Johannesen et al., 2012)



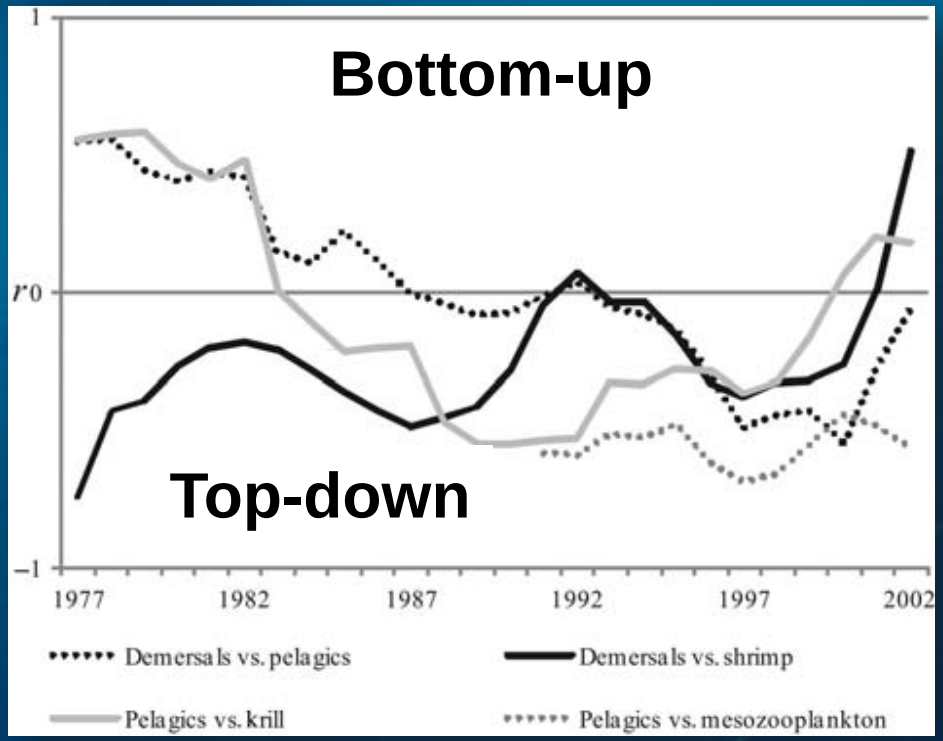
(ICES-WGIBAR 2015)

Historical ecosystem changes

Regime shifts

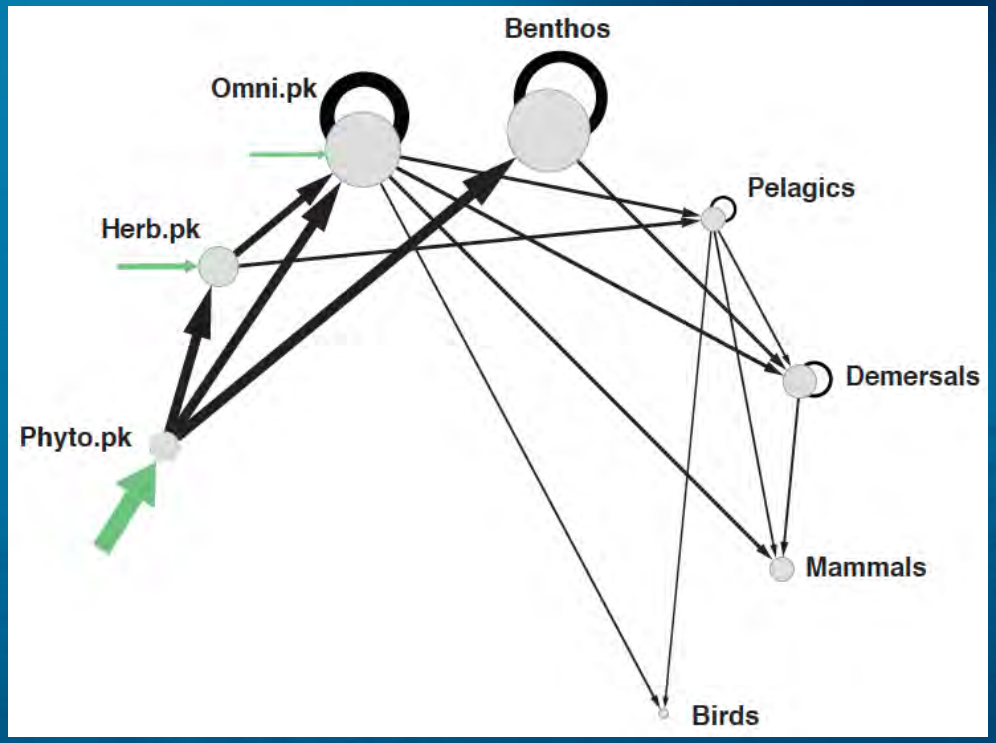


Oscillations in trophic controls



(Johannesen et al., 2012)

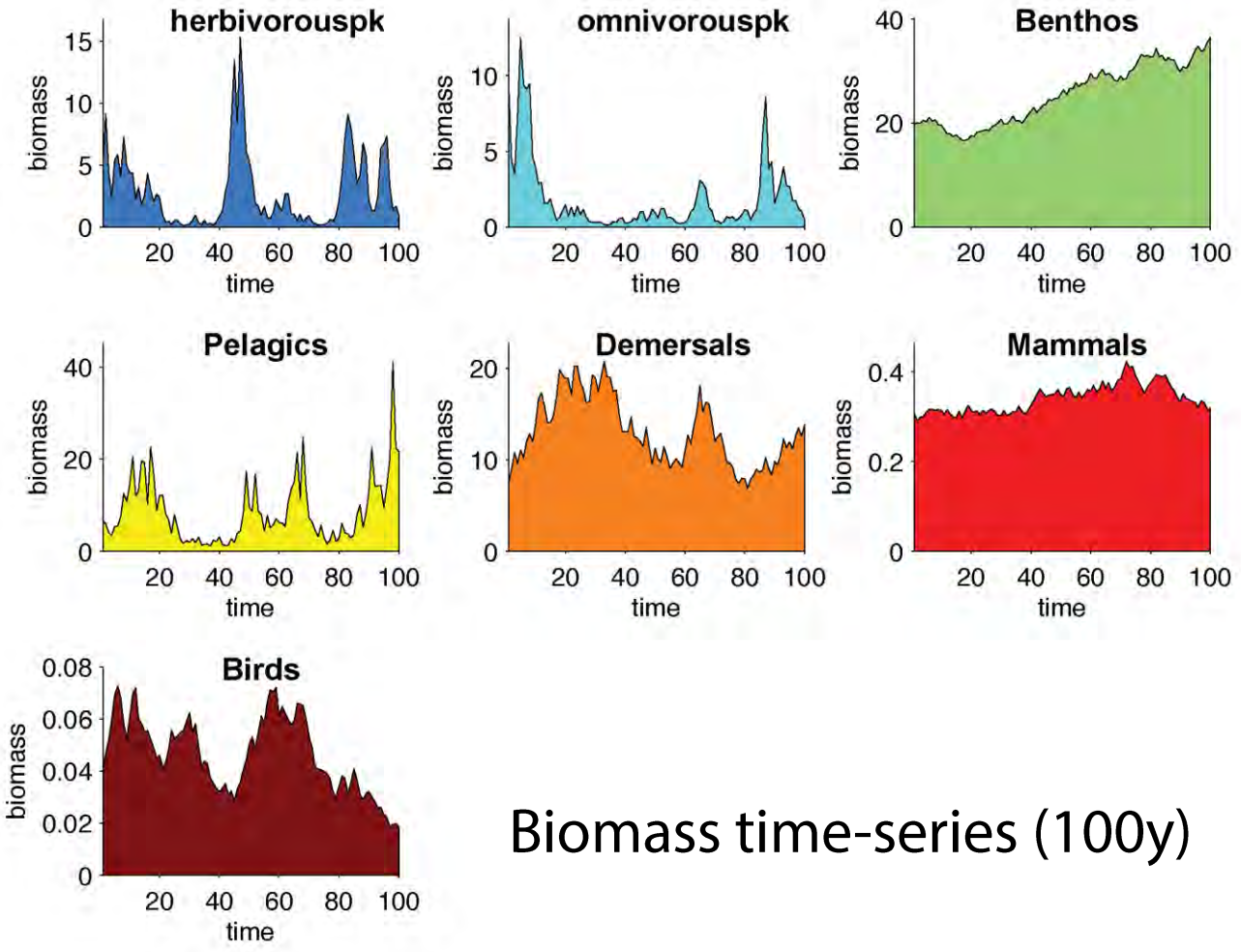
'Null' ecosystem model: Non Deterministic Network Dynamics (NDND)



- *Simple food web*
- *Mass-balanced*
- *Non-deterministic*
- *Constrained by physical and ecological limits*

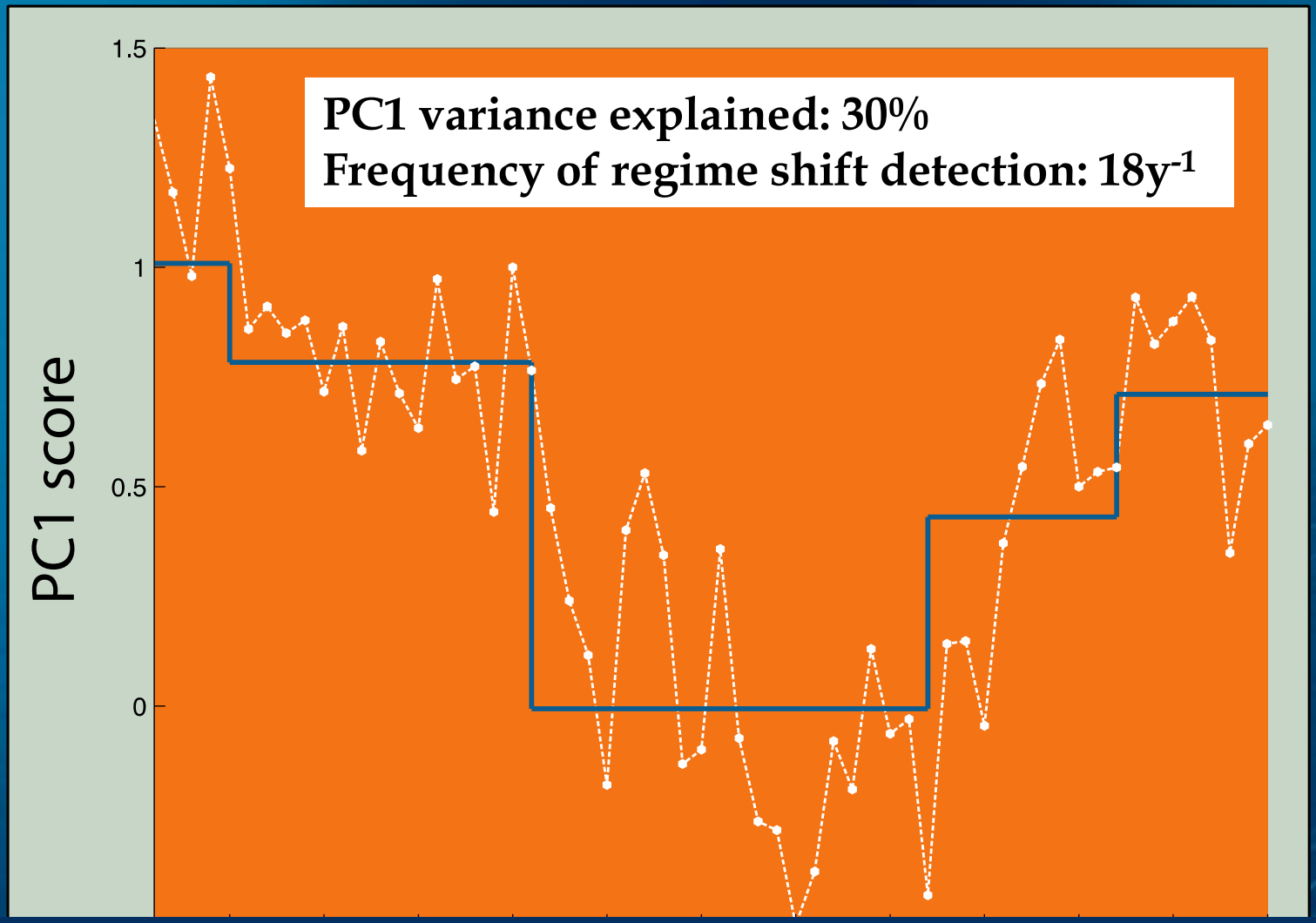
Simulate dynamic changes in structure of the Barents Sea food web

'null model' simulations



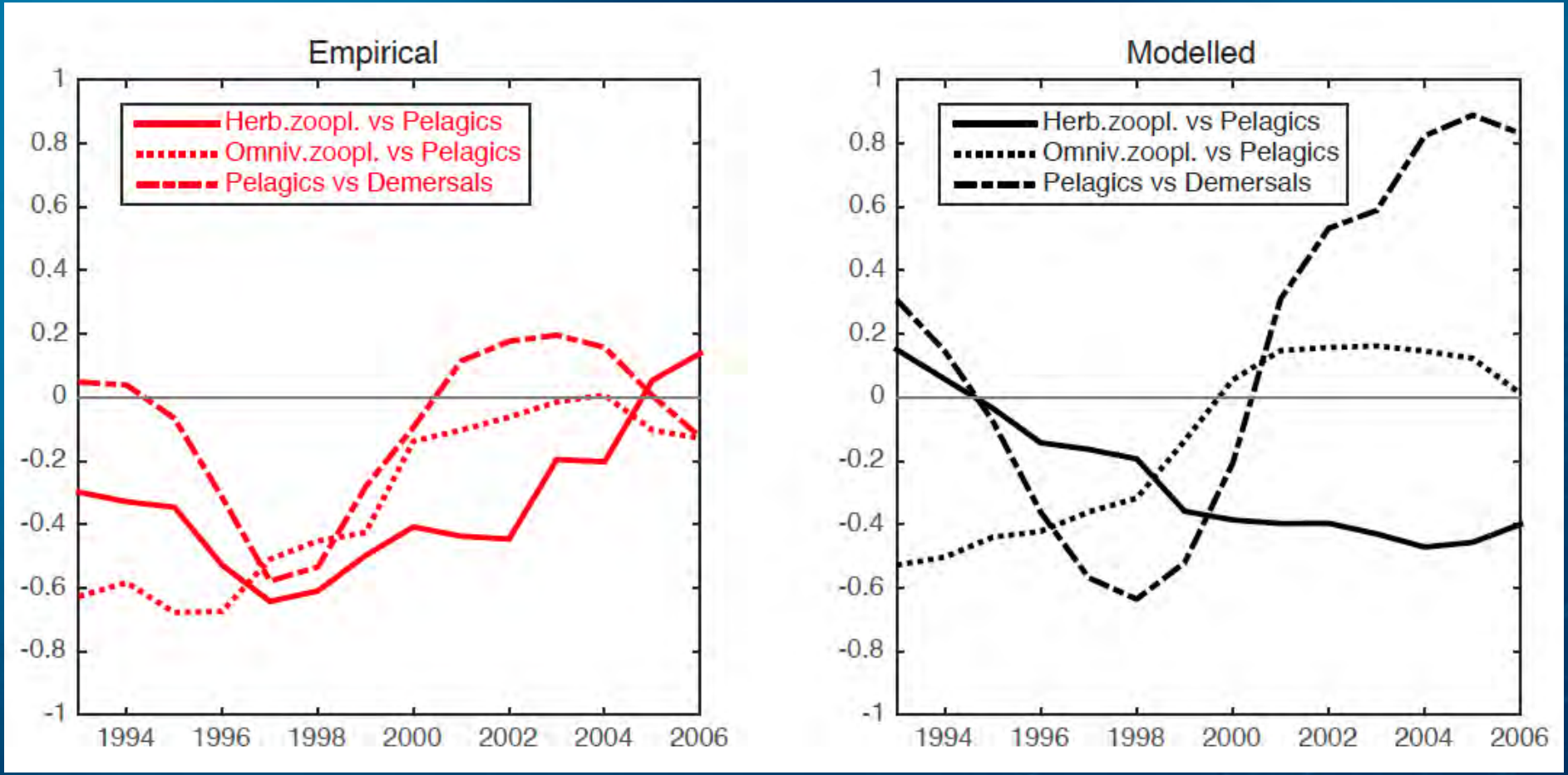
Biomass time-series (100y)

regime shift detection



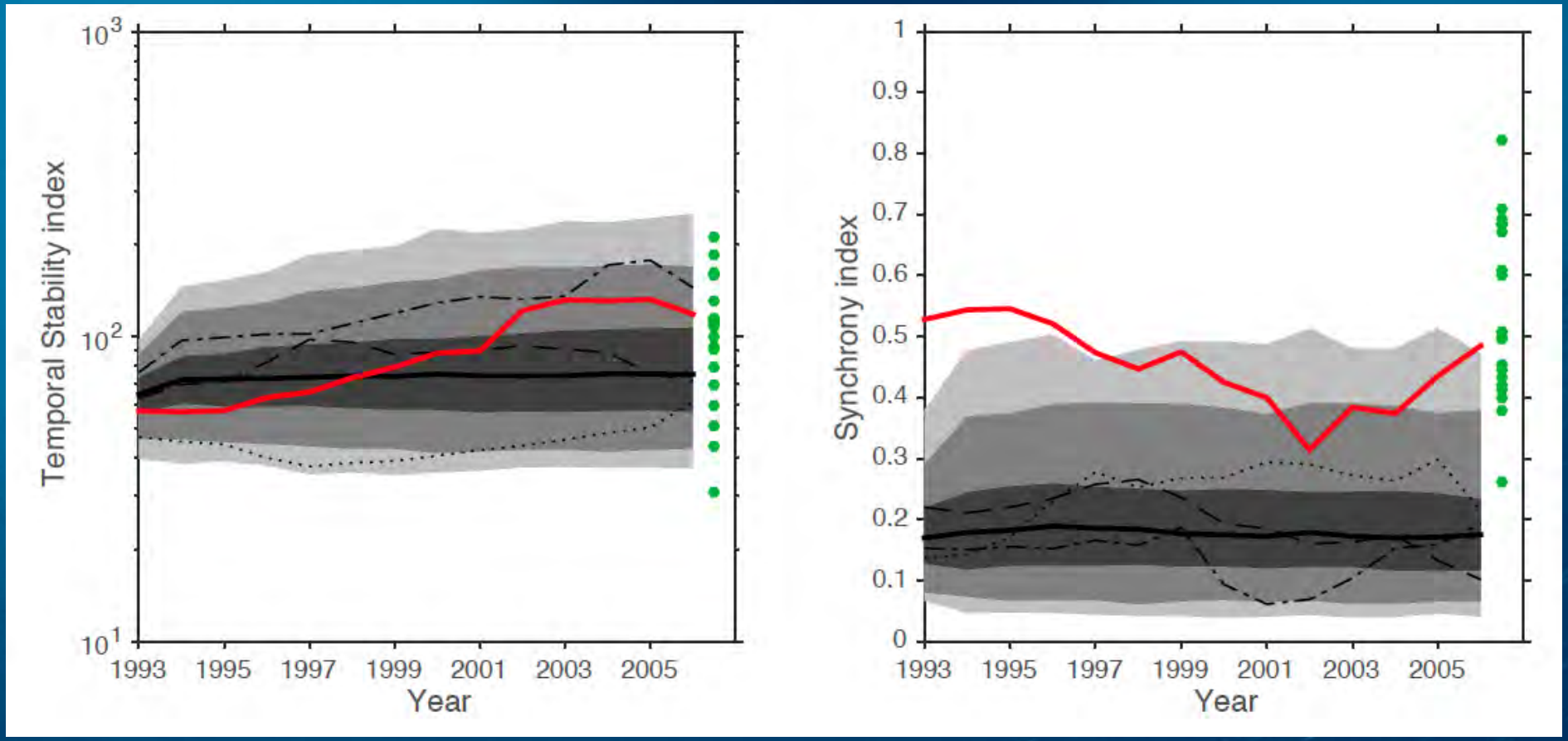
'regime shift like' changes are expected to occur every 18 years under 'null' hypothesis of random trophic interactions

Oscillations in trophic controls



Decadal oscillations in trophic controls are expected under 'null' hypothesis of random variations in trophic interactions

Ecosystem stability and synchrony



Observed stability of ecosystem dynamics is expected, but the synchrony is greater than expected under the 'null' model.

Summary & conclusions

- *Resilience: resistance, flexibility, reorganisation*
- *Ecosystem resilience is not the sum of the resilience of its parts*
- *It is possible to measure some key aspects of resilience at the ecosystem level*
- *Structural aspects of resilience are easier to address than temporal ones*
- *Need for 'reference' of ecosystem states and dynamics*

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