

*PAME Arctic MPA network and resilience workshop*

# ***Ecosystem Resilience***

*What is it and how can we measure it?*

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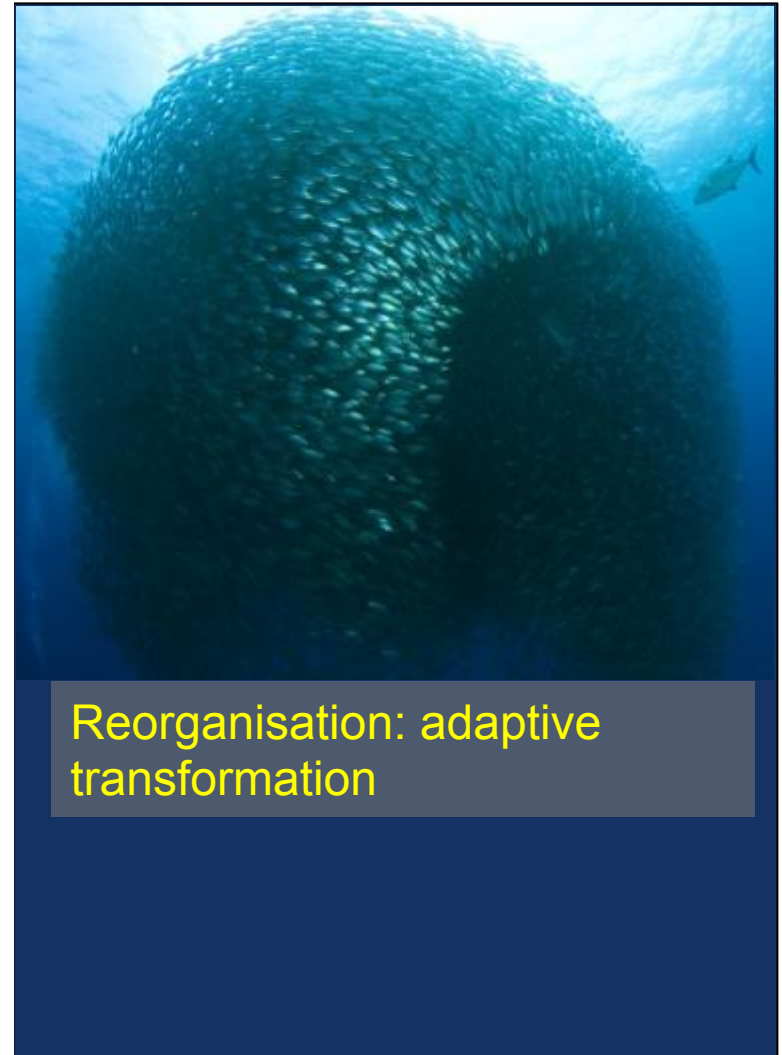


**INSTITUTE OF MARINE RESEARCH**  
**HAVFORSKNINGSINSTITUTTET**

## *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...*

*physical integrity*  
*survival*  
*growth*  
*reproduction*

*demography*  
*genetic diversity*  
*spatial diversity*  
*non-extinction*  
**populations**

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

**individuals**

*recruitment,*  
*habitat,*  
*mortality,...*

*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

<i>Structural properties</i>	<i>Dynamic properties</i>	
<b>Diversity:</b> specific, functional, phylogenetic, spatial,...	Variability	at the ecosystem level
<b>Redundancy:</b> functional, phylogenetic, spatial,...	Return rates	
<b>Modularity:</b> network organisation of species interactions	Tipping points (regime shifts)	
	Hysteresis	
	Stability	
	Synchrony	

*Levin and Lubchenko (2008)*





# *Measuring Barents Sea ecosystem resilience in practice*

## *Structural analyses*

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

## *Time-series analyses*

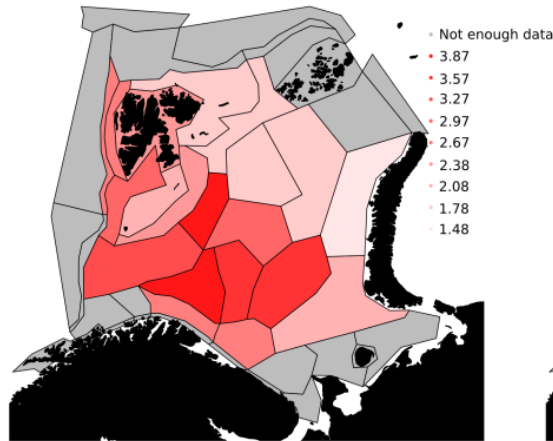
- *Regime shifts, trophic oscillations, stability and synchrony*
- *historical reconstructions*
- *'null' ecosystem model*



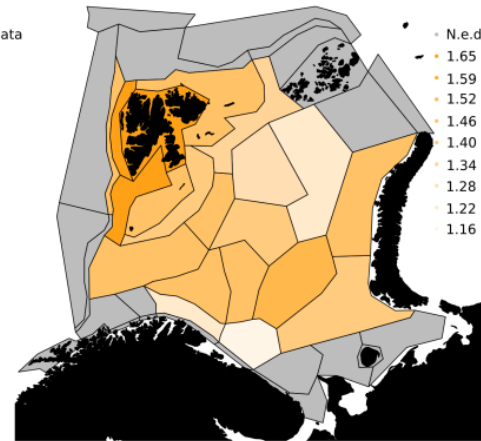
# Regional variations in fish diversity

$\alpha$ -diversity

$\alpha_{\text{trawl}}$



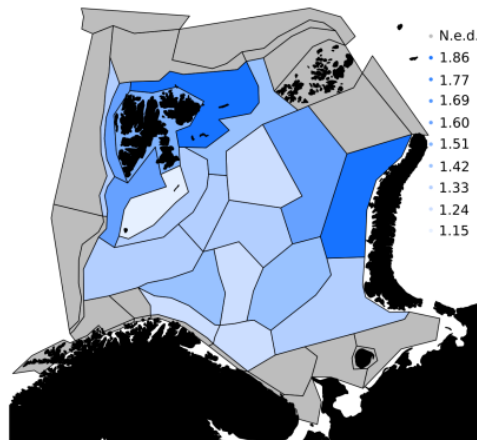
$\beta_{\text{trawl/year}}$



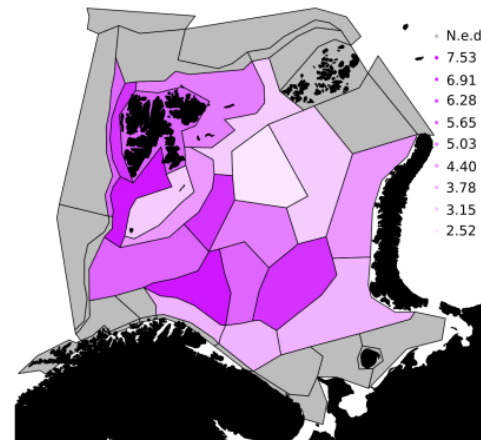
$\beta$ -diversity  
within polygons

$\beta$ -diversity  
between years

$\beta_{\text{year}}$

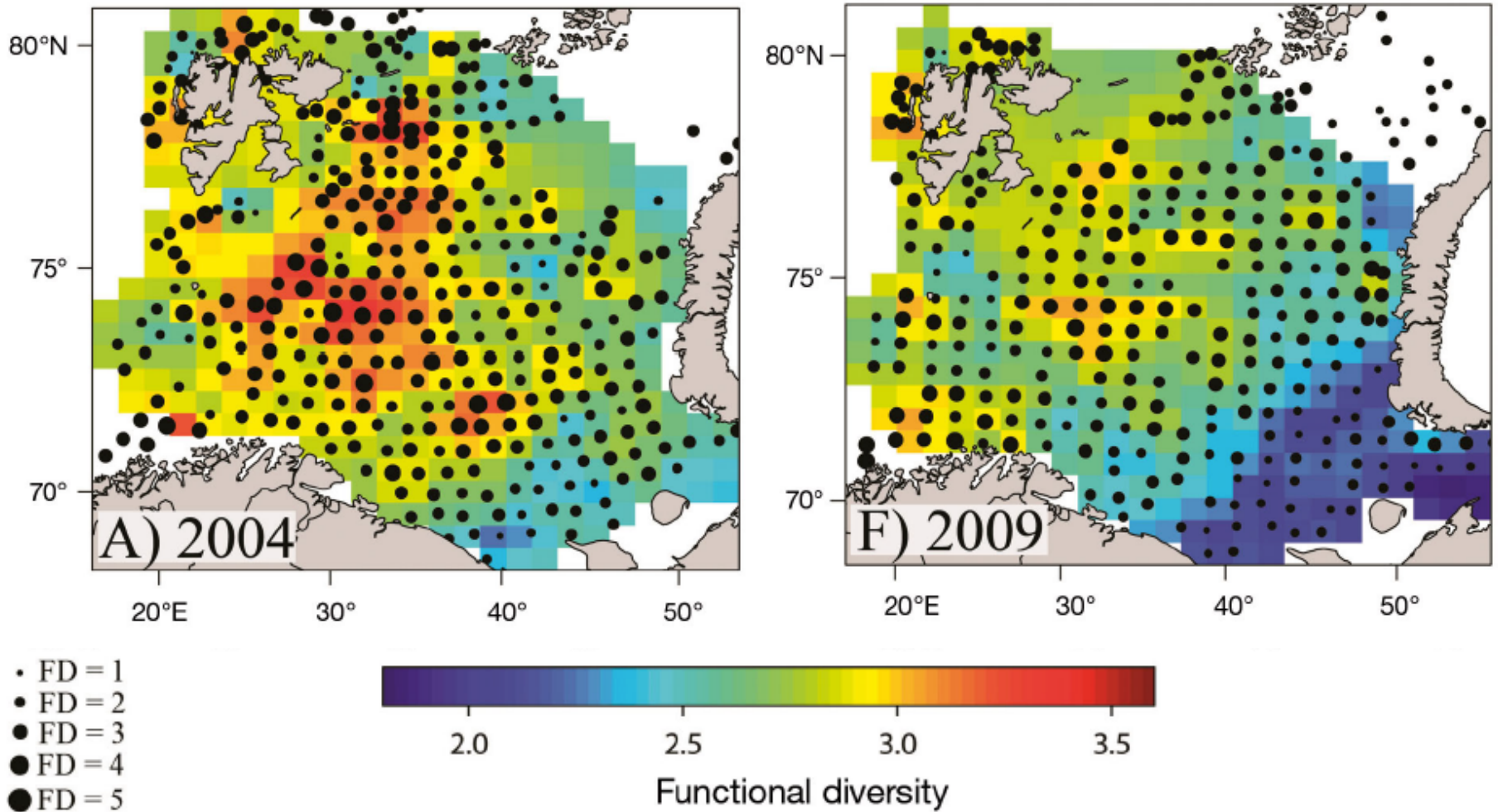


$\gamma$

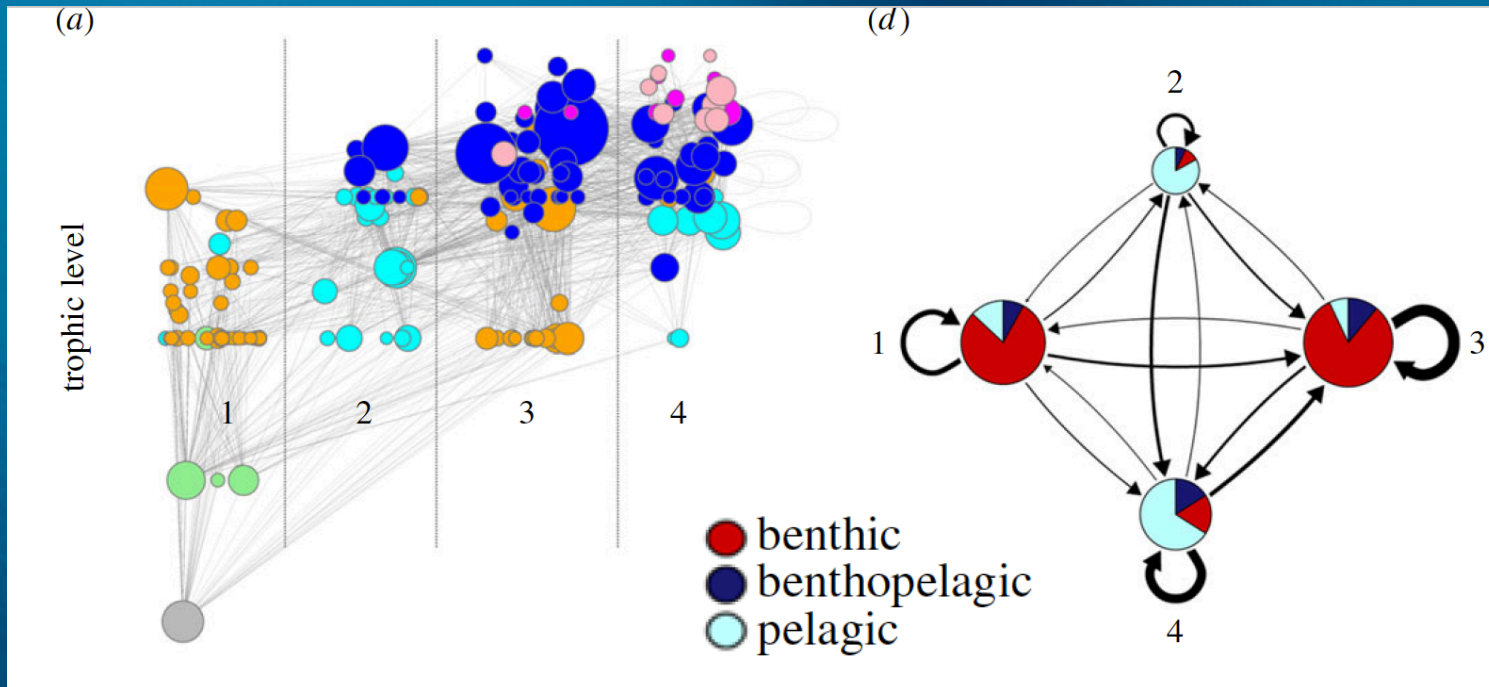


$\gamma$ -diversity

# Functional diversity



# Structural analysis of food webs

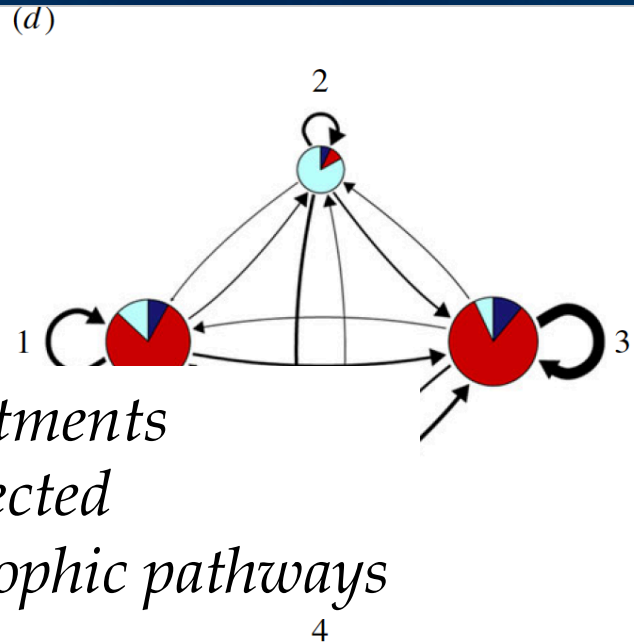
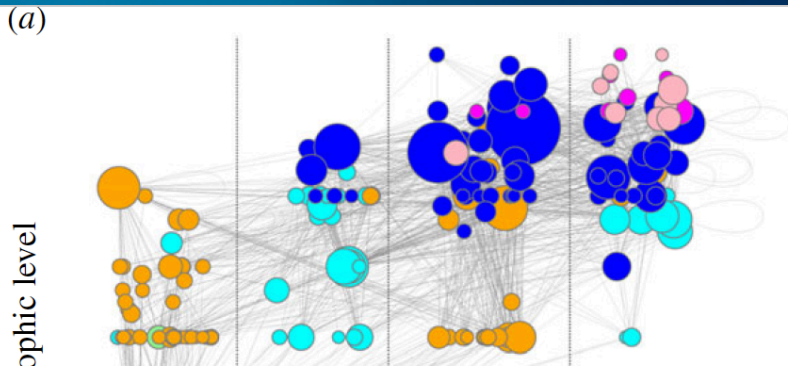


*Boreal food web: 4 main compartments*

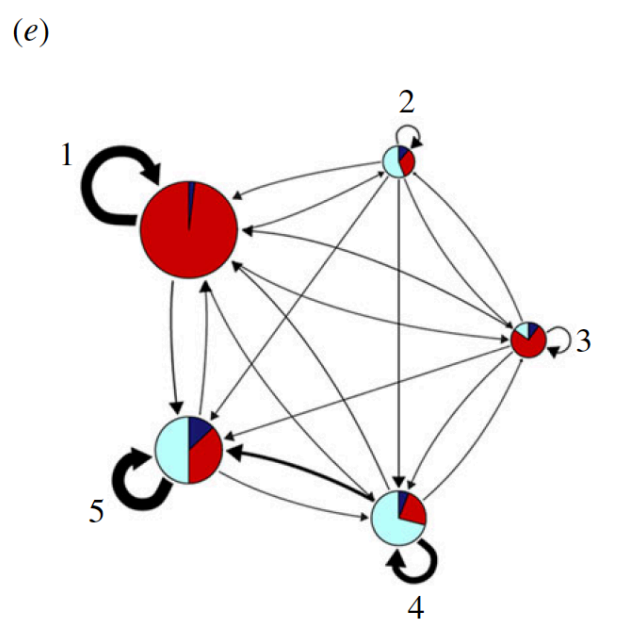
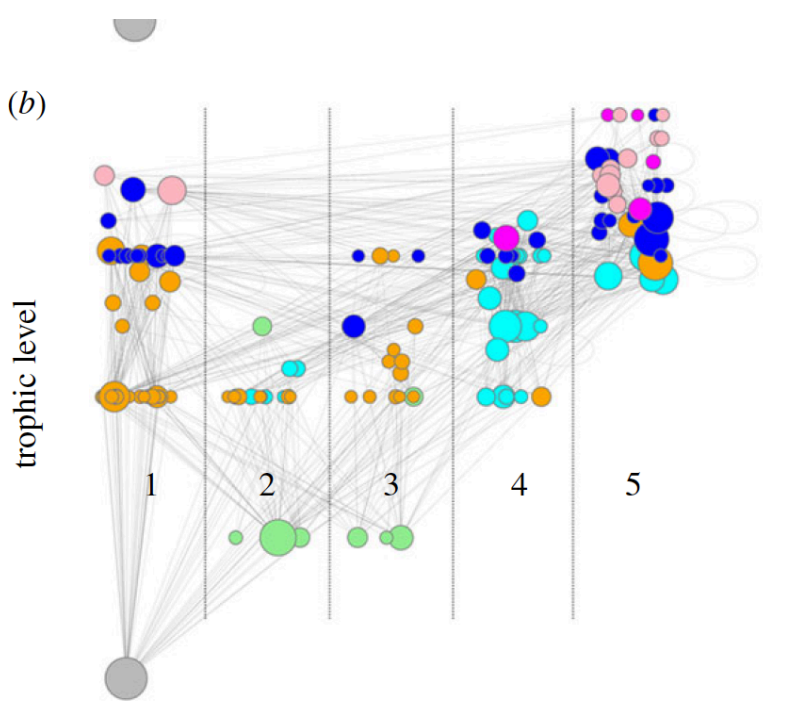
*Well connected*

*Long trophic pathways*





*Arctic food web: 5 main compartments  
less connected  
shorter trophic pathways*



## *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*



## *Implications for MPA network design*

- *Clarify what level of biological organisation are the objective of the MPA network (populations, communities, ecosystems)*
- *Consider diversity, redundancy, (modularity) of habitats*
- *Consider the specific aspect of spatial scale and connectivity*
- *Accompany MPA development with dedicated monitoring of resilience components*

