Climate change promotes risk of hypoxia in coastal zones threatening zoobenthic communities and their function

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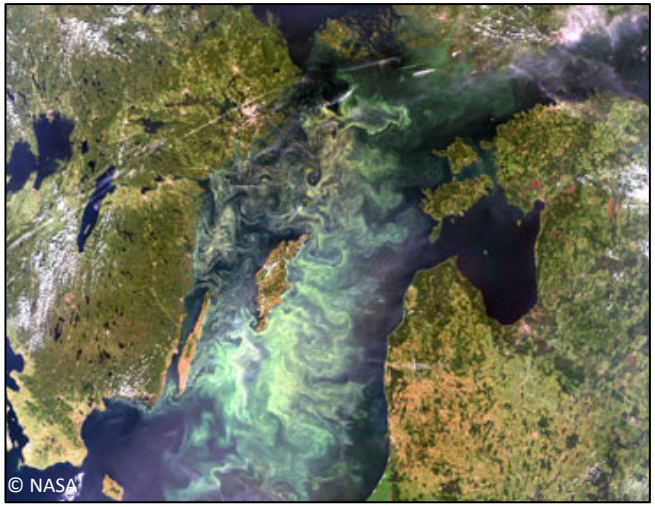
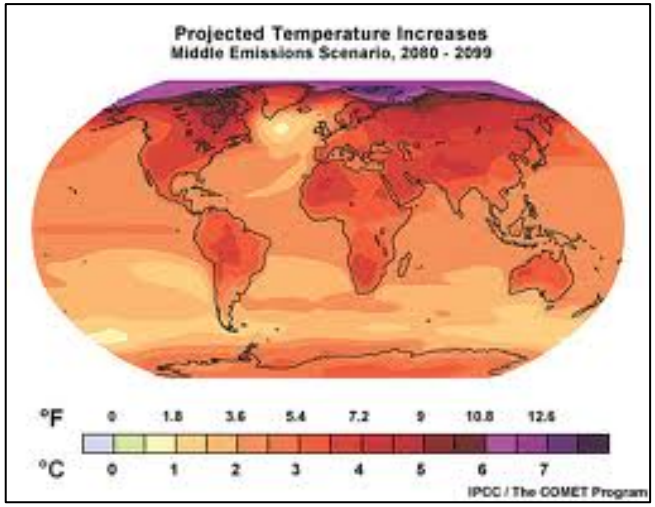
-Low Oxygen Environments In Marine, Estuarine And Fresh Waters-

Liège 5th-9th May, 2014

Major threats to coastal communities

Eutrophication





Climate change

Hypoxia-Anoxia

Habitat degradation

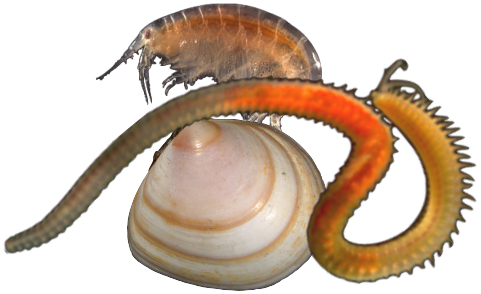
Aim and perspective

Understanding how coastal benthic communities are affected by oxygen depletion over the last decades, regarding…

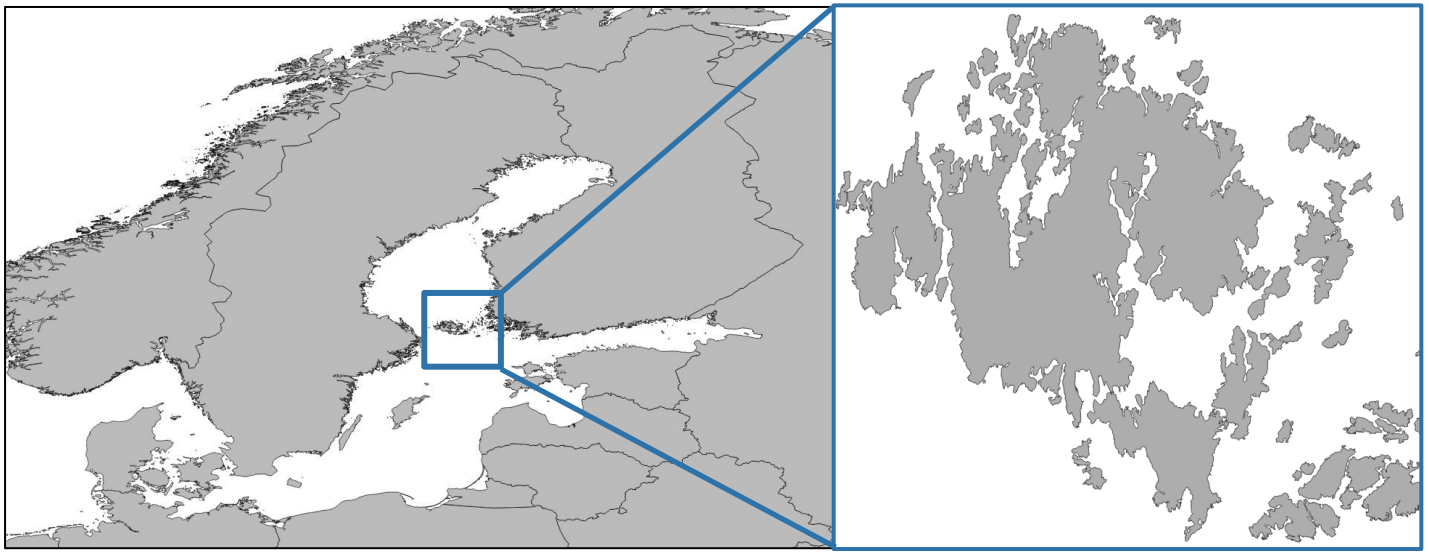
① **Production (biomass)**

② **Food web structure**

③ **Functional traits**

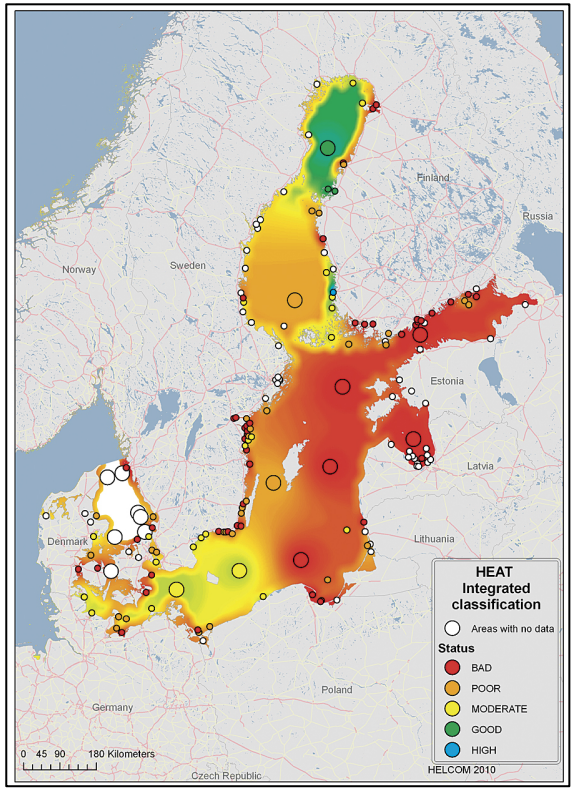


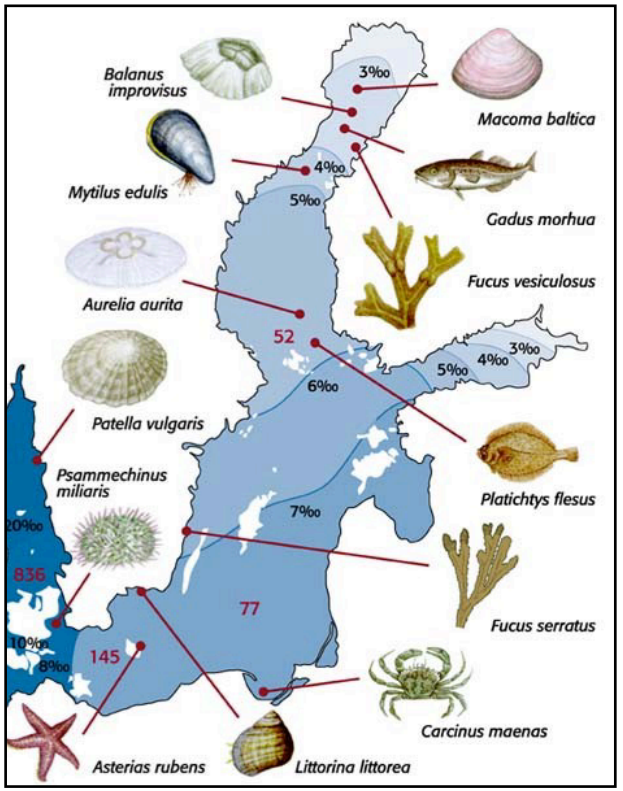
Applying local climate change scenarios to project possible future conditions for benthic communities in coastal zones



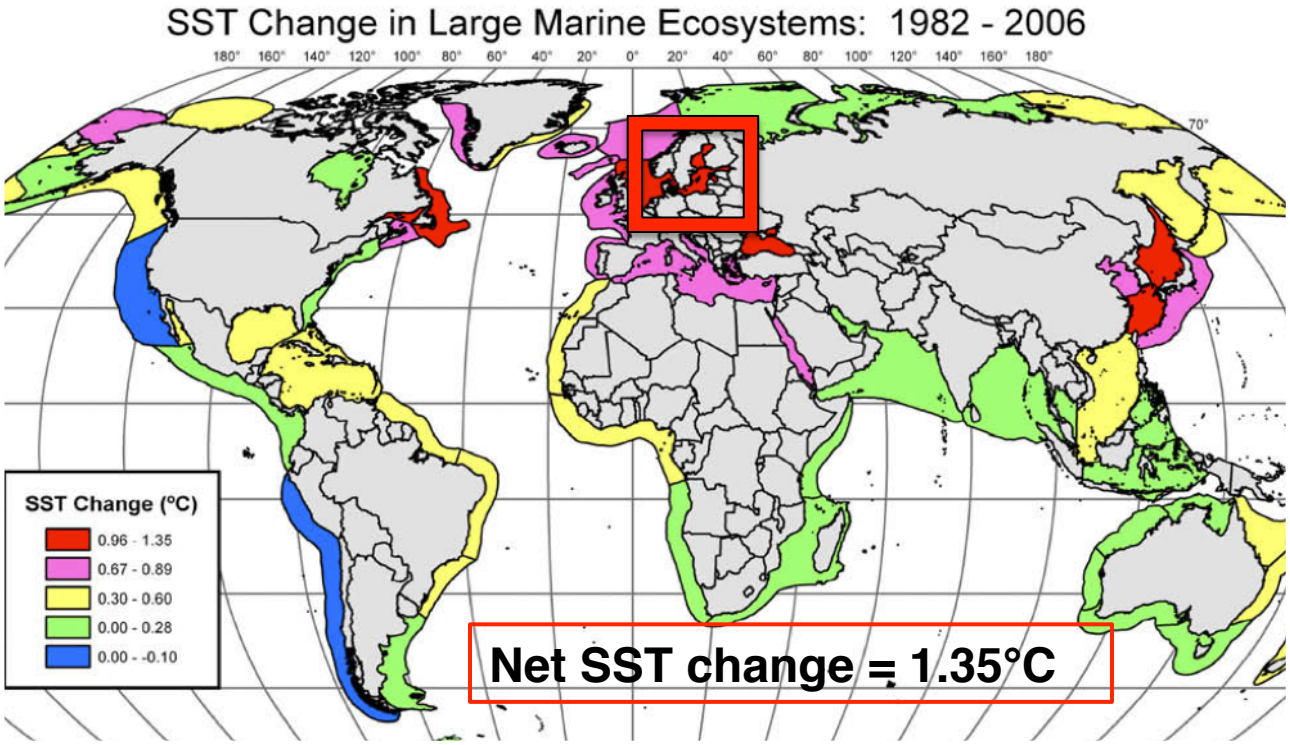
Vulnerability of the Baltic Sea system

- Shallow, land-locked brackish sea
- Limited “marine” inflow/ water exchange
- Steep gradients in environmental variables
- Species living in their physiological distribution limits
- High anthropogenic impact/eutrophication





The Baltic Sea – fastest warming Large Marine Ecosystem



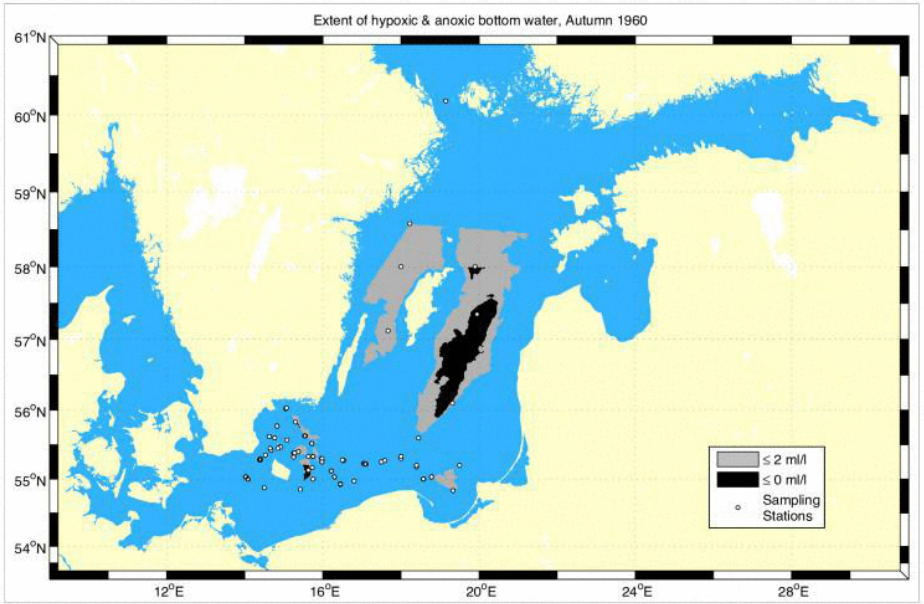
Belkin 2009, *Progress in Oceanography*

- Lowered oxygen saturation concentration
- Link between surface temperature and bottom oxygen

Kabel et al. 2012, Nature Climate Change

SMHI oxygen time series 1960-2013

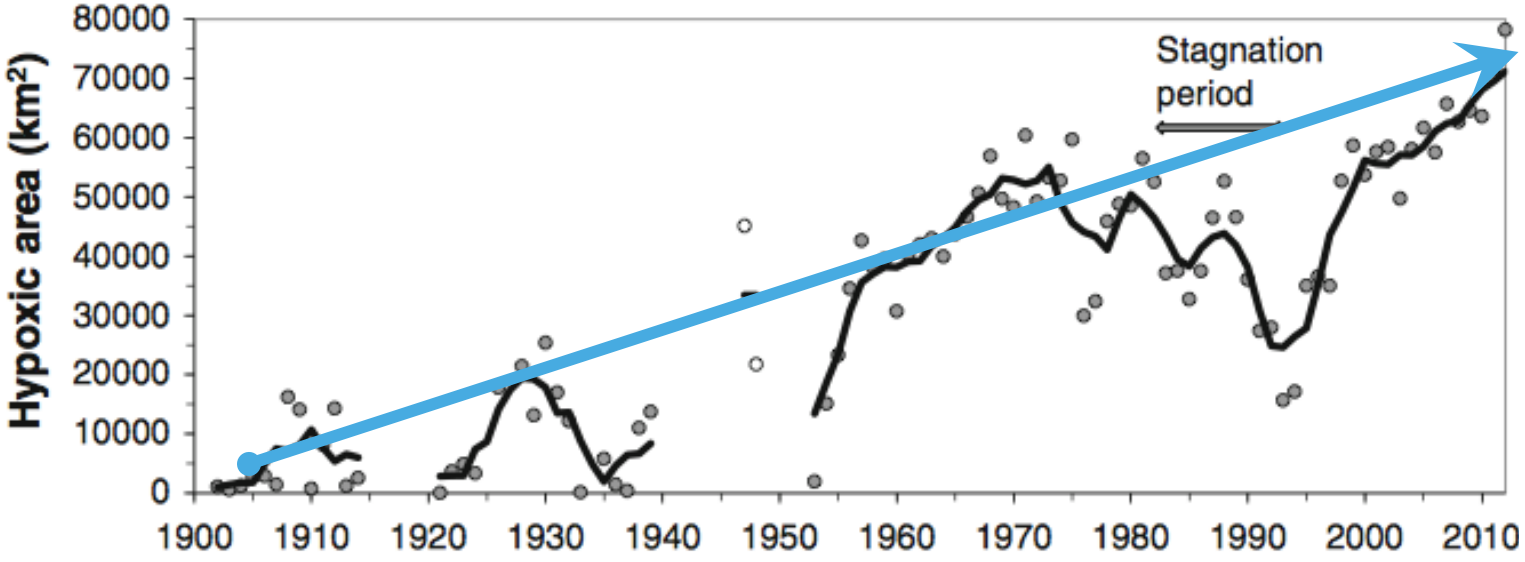
1960 1970 1980 1990 2000 2010



Extent of hypoxic & anoxic bottom water

SMHI Report Oceanography
No. 42, 2011, updated January 2014

Growing trend in hypoxic area in the Baltic Sea

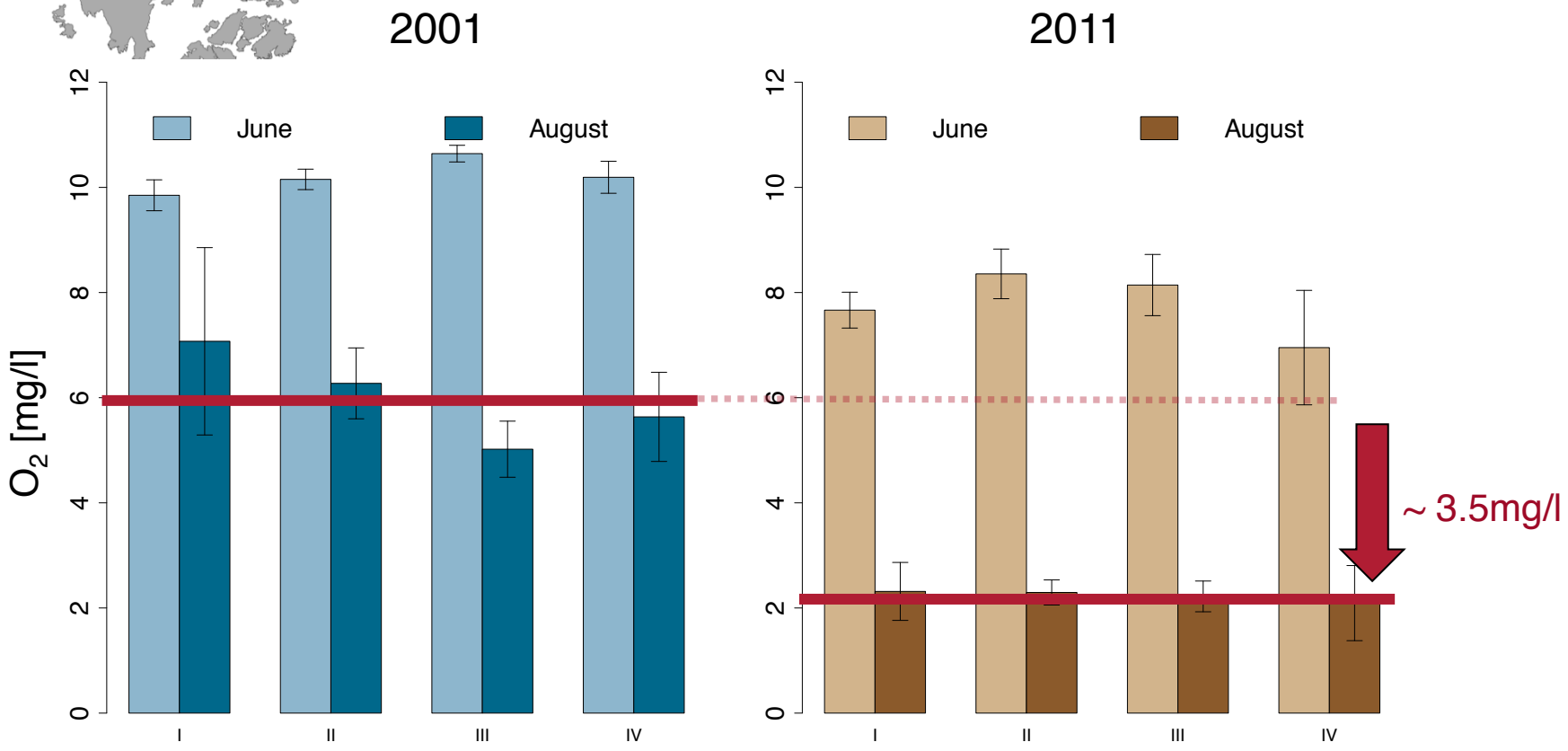


10 fold increase

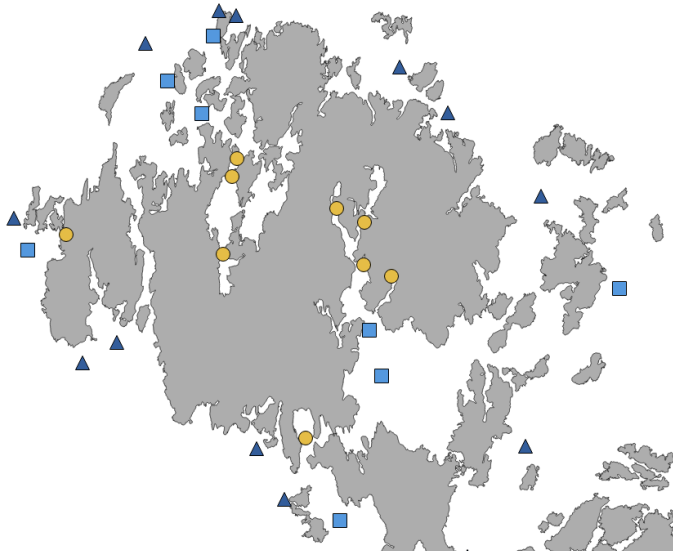
Carstensen et al. 2014, Ambio

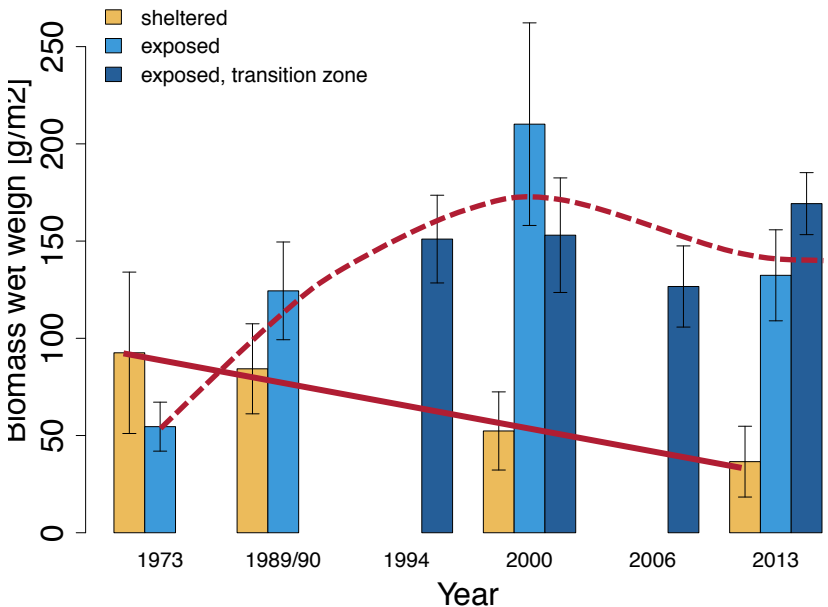
- General elevation in depth
- Pronounced increase in coastal zone (Conley et al. 2011, *Env. Sci. & Tec.*)
- Reduction of available habitat area for aerobic organisms

Small scale temporal development of oxygen climate

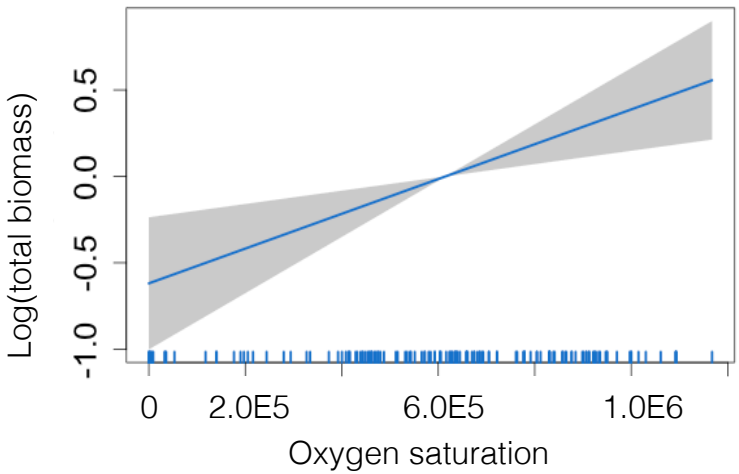


Oxygen as driver of zoobenthic biomass progression





Generalized Additive Model



Log(biomass) ~ s(O_2 sat, k=4) + factor(exposure)

factor (exposure) **< 0.0001*****
s(O_2 sat) **< 0.01****

R-sq.(adj) = **0.328**
Deviance explained = **33.7%**

Anthropogenic induced disturbance gradient and its impact on food web structures

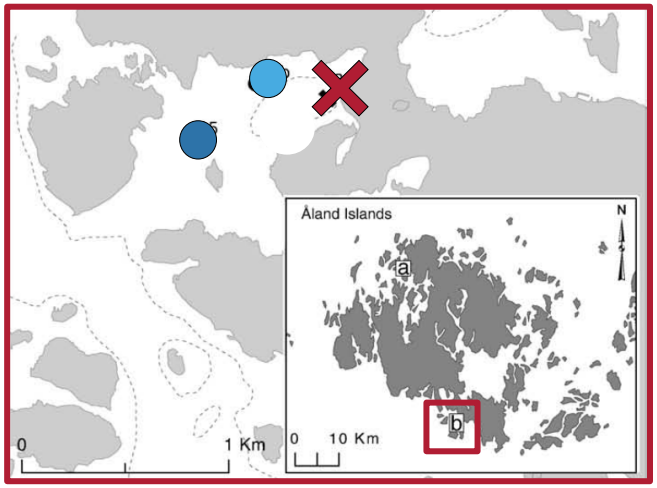
Analyzing

Macrobenthic sub food webs
in multi-decadal snapshot

Comparing

Structures of three sites
along a gradient of organic enrichment

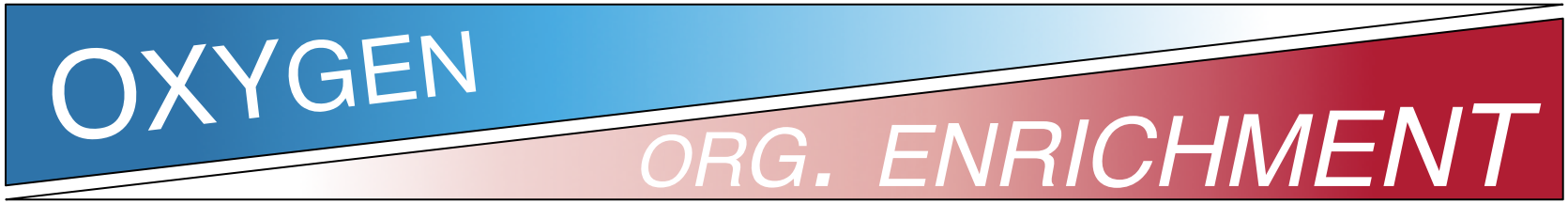
Sensu Pearson & Rosenberg 1978,
Oceanogr. Mar. Biol. Annu. Rev.



Villnäs, Perus, Bonsdorff, 2011, *J Sea Res*

Fish farming as point source for

- **Nutrient enrichment**
- **Organic content load**
- **Hypoxia/ anoxia**



Simplification of web topology with increasing disturbance

Species richness ↓

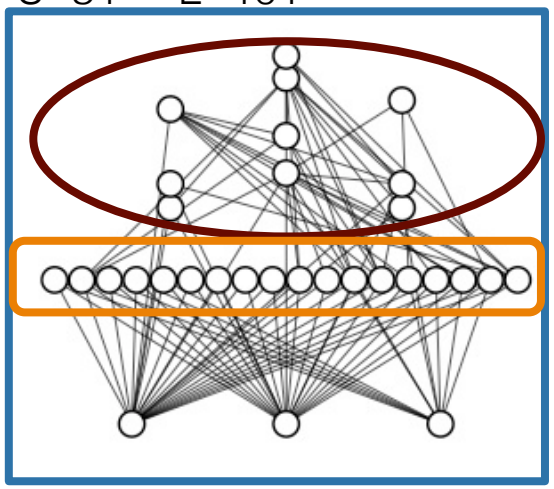
Links ↓

Reduction in top species

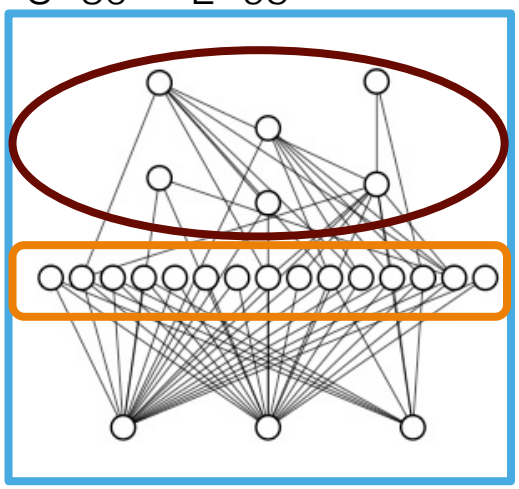
Reduction in intermediate species

Horizontal and vertical loss of complexity

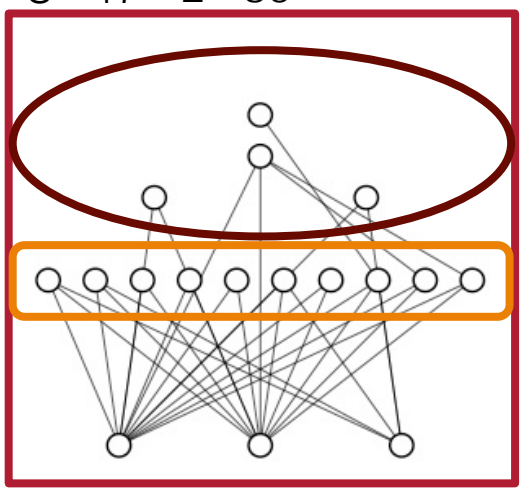
S=31 L=101

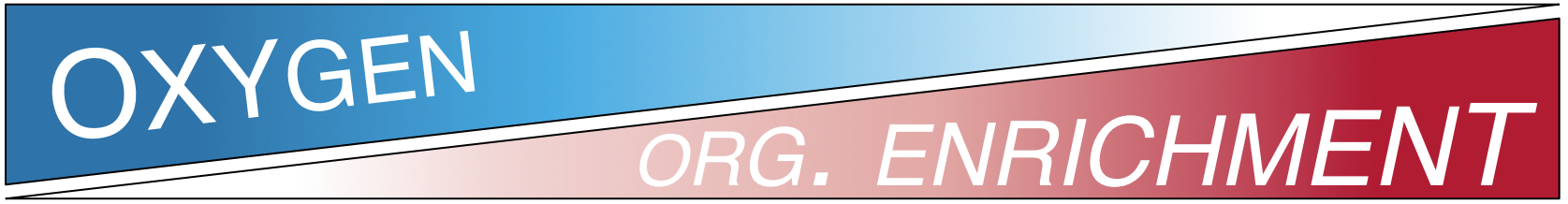


S=30 L=95

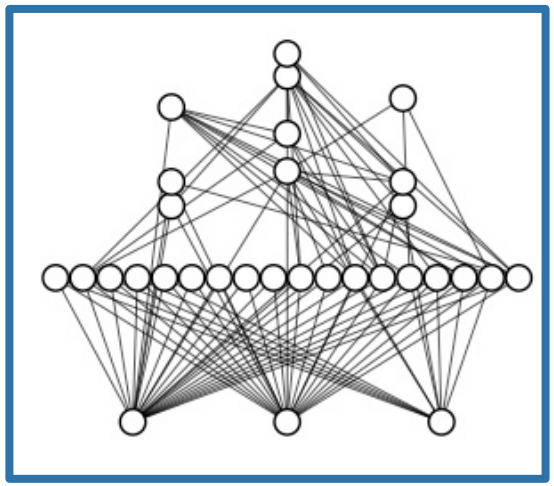
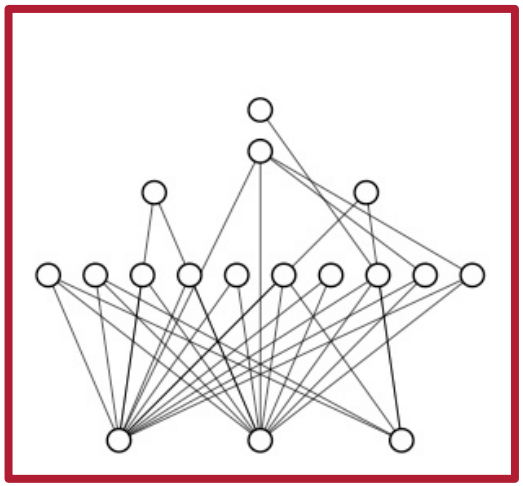


S =17 L =36





Functional trait characteristics

low stress		high stress
	K ⟶ r OXYGEN / ORG. ENRICHMENT	
Small to Large	**Size**	Small to medium
Short to very long	**Longevity**	Short
Planktotrophic	**Larval type**	Direct development
Annual episodic	**Reproductive frequency**	Semelparous
Local to long distance	**Dispersal range**	Local

Climate model scenarios (SMHI)

following Meier et al. 2012, Clim. Dyn.

Baltic Sea model: **RCO-SCOBI** (from SMHI, 3D model, 2 nm res.)

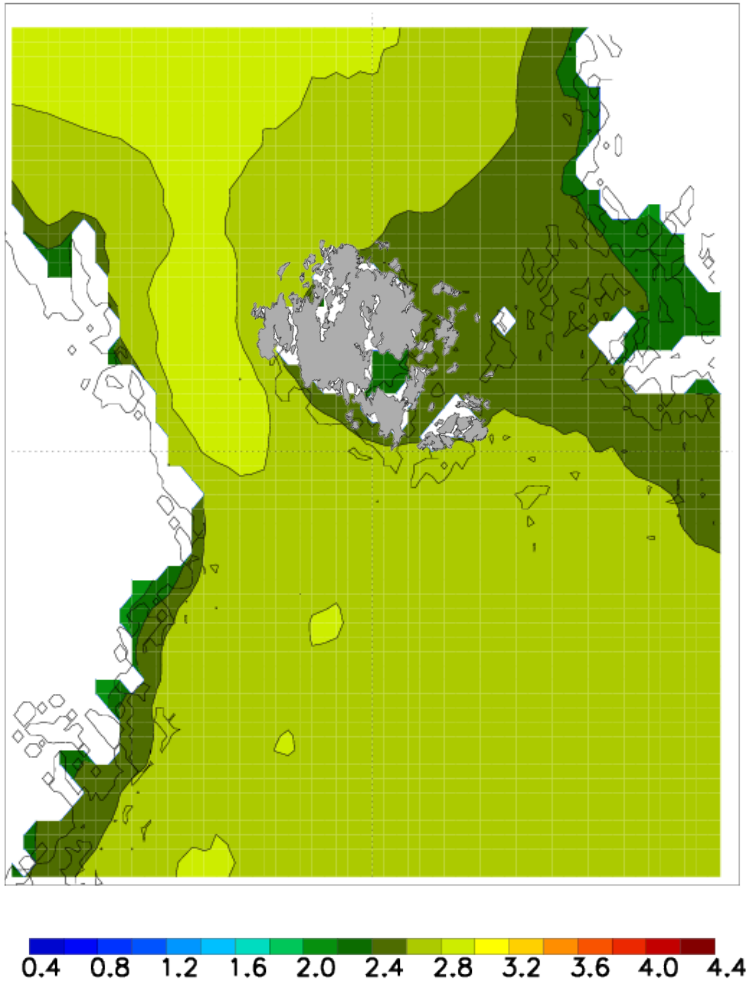
Ensemble mean changes between 2070–2099 and 1978–2007

REF = **Ref**erence conditions
Current nutrient concentrations in rivers and current atmospheric deposition (see Eilola et al. 2009)

BAU = **B**usiness-**A**s-**U**sual
Assuming exponential growth of agriculture in all Baltic Sea countries following HELCOM (2007) and current atmospheric deposition

BSAP = **B**altic **S**ea **A**ction **P**lan
Reduced riverine nutrient concentrations following HELCOM (2007) and 50% reduced atmospheric deposition

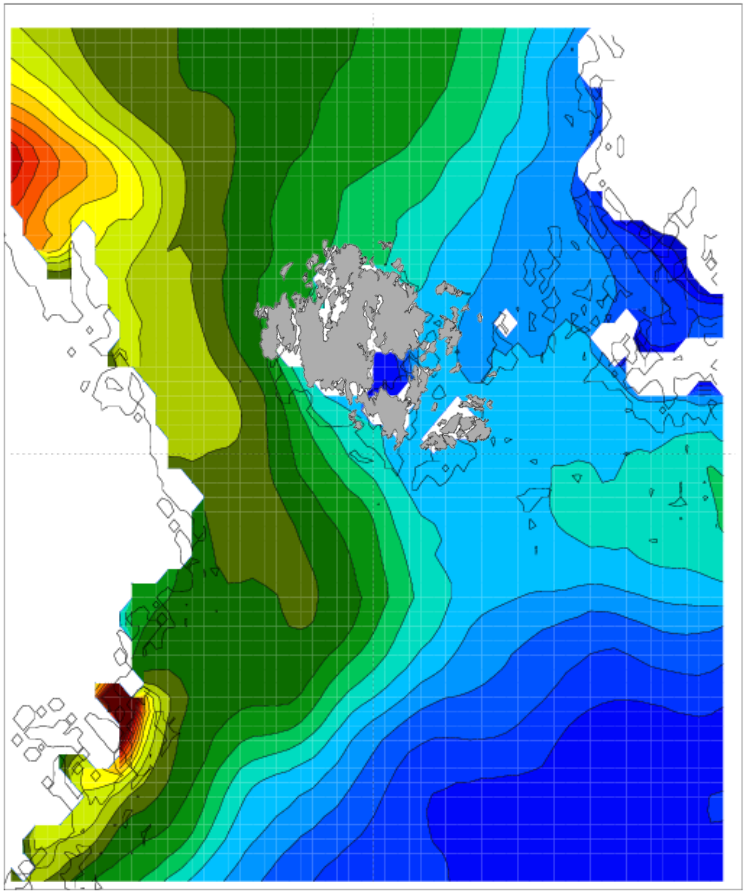
Sea surface temperature



Increase of **2.4 - 2.8°C** in annual mean SST

Ensemble mean changes between 2070–2099 and 1978–2007 of annual mean SST [°C]

Sea surface salinity



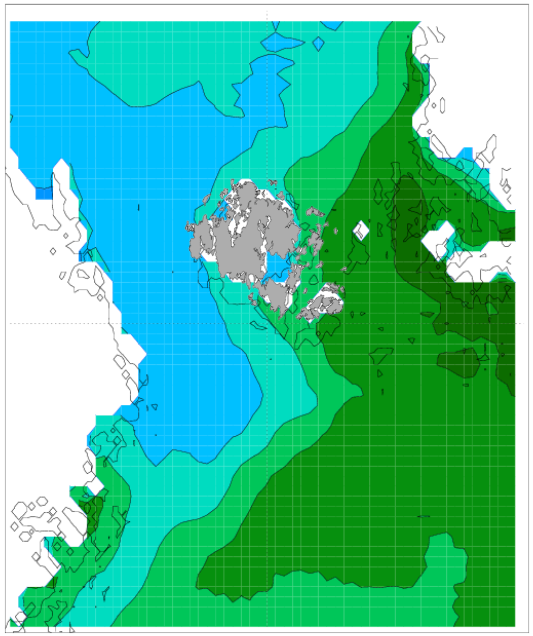
Decrease of **1.5 – 2 psu** in annual mean SSS

Ensemble mean changes between 2070–2099 and 1978–2007 of annual mean SSS [g/kg]

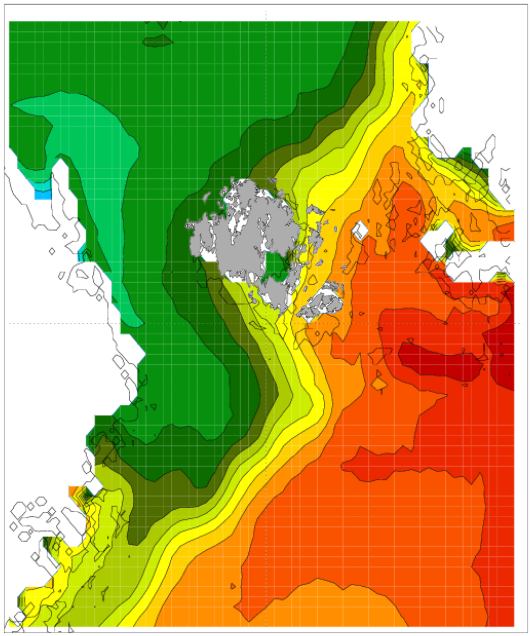
Phytoplankton Chl-a

Spring, upper 10 m

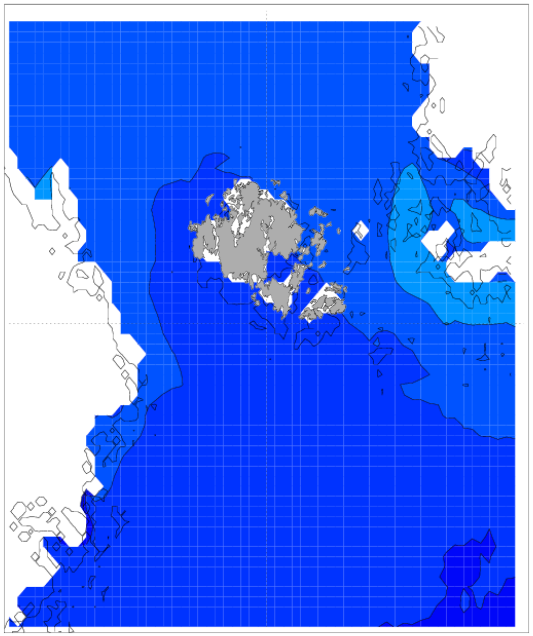
REF

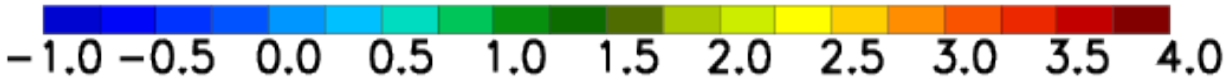


BAU



BSAP

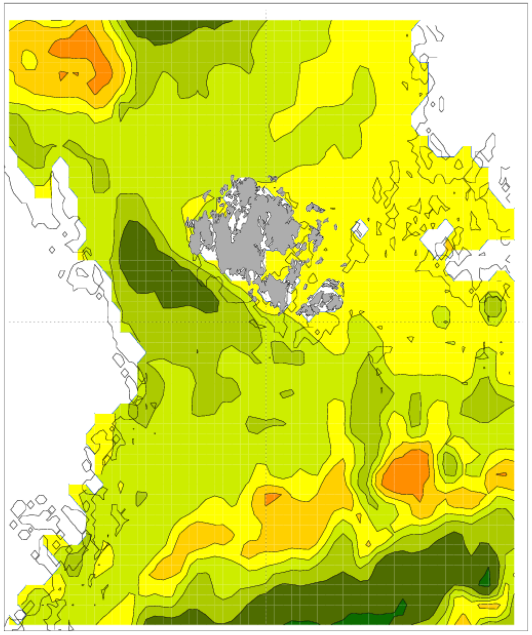




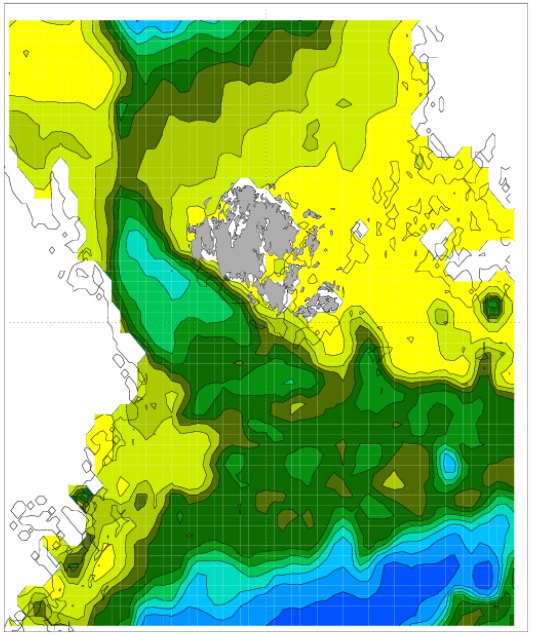
Ensemble mean changes between 2070–2099 and 1978–2007 of spring (March–May) phytoplankton concentration [mgChl-a/m^3], vertically averaged for the upper 10 m

Bottom oxygen conditions

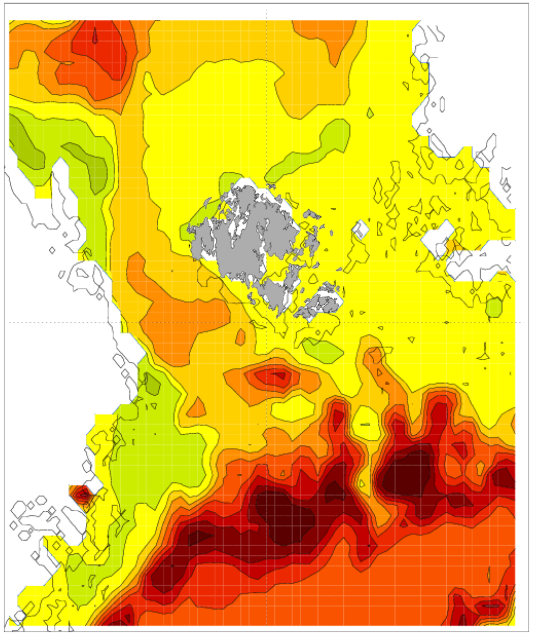
REF



BAU



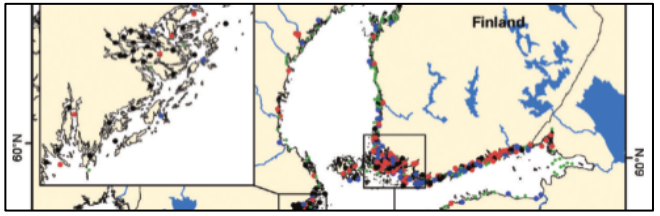
BSAP



Ensemble mean changes between 2070–2099 and 1978–2007 of summer (June–August) concentration [ml/l]

Summary and perspectives

- Increase of hypoxia in coastal zones of the Baltic sea



Conley et al 2011

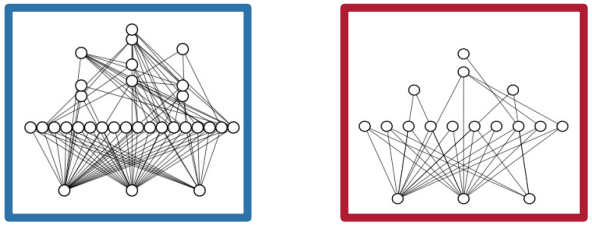
- Pronounced seasonal and long term decline in local oxygen conditions

- High **benthic biomasses** in **deeper** and exposed sites

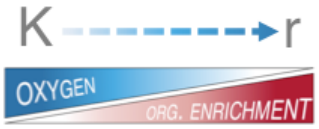
- **Coastal fish** moving into **deeper** water as well
  Snickars et al., *submitted*

Summary and perspectives

- Loss of diversity and complexity in food web structures



- Diverse community becoming more uniform and opportunistic



- High **benthic biomasses** in **deeper** and exposed sites

- Trend in **elevation** of **hypoxic depth**
  (e.g. Hansson & Andersson 2013, SMHI Rep. Ocean. No.49, HELCOM, 2013, Balt. Sea Environ. Proc. No. 133)

Climate change scenarios suggest that these trends will be further amplified in the future

Acknowledgements

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