Empirical & dynamic models to predict changes in coastal ecosystems due to global warming

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WATER • ENVIRONMENT • HEALTH

Empirical & dynamic models to predict changes in coastal ecosystems due to global warming

Overall climate changes that have either direct or indirect impacts on the coastal marine ecosystems include:

1. Increased air temperature
2. Changed wind patterns
3. Higher water levels
4. Increased run-off due to increased precipitation
5. Enhanced nutrient loads from land to sea (short term)

METHODS

Empirical

- Temporal trends
- Linking past met condition to Biological structure & processes

Numerical (dynamic)

- Extrapolate outside area of observations
- Interpolate intelligently between observations

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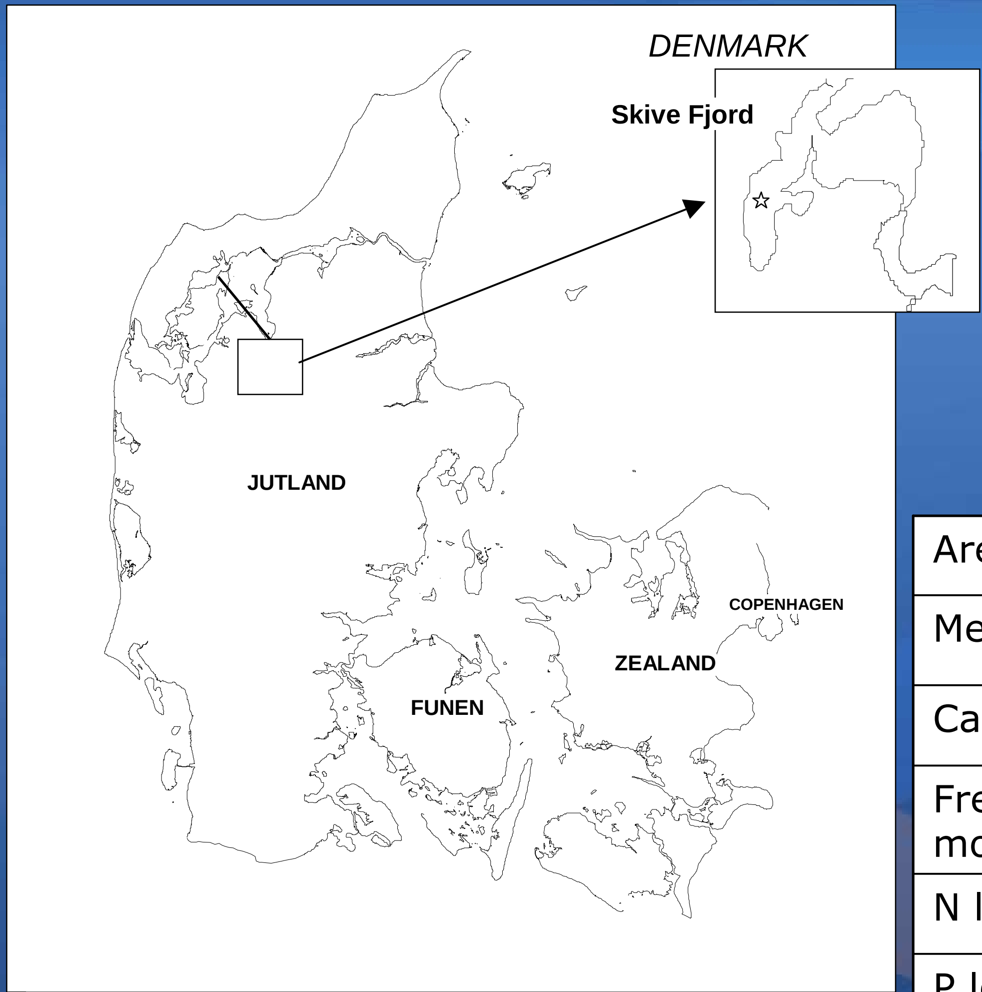

Skive Fjord estuary is one of the most eutrophic and freshwater influenced tributaries of the Limfjord Belt (that connects the North Sea in the west and the Kattegat in the east).

Area (km^2)	101
Mean depth/Station depth (m)	5.1/5.2
Catchment area (km^2)	2200
Freshwater discharge (10^6 m^3 mo^{-1})	81 ± 20
N load (ton mo^{-1})	302 ± 104
P load (ton mo^{-1})	13.5 ± 8

Regular monitoring began in 1982 with monthly samplings

During the period analysed

1984-1988: monthly sampling
1989-1994: 20-25 samplings/year
1995-present: 30-45 samplings/year

Water quality is affected by a combination of:

- *Meteorological forcings (wind, temperature, insolation)*
- *Human impacts (primarily nutrient load)*
- *Temporal variation in benthic grazing capacity (blue mussels)*

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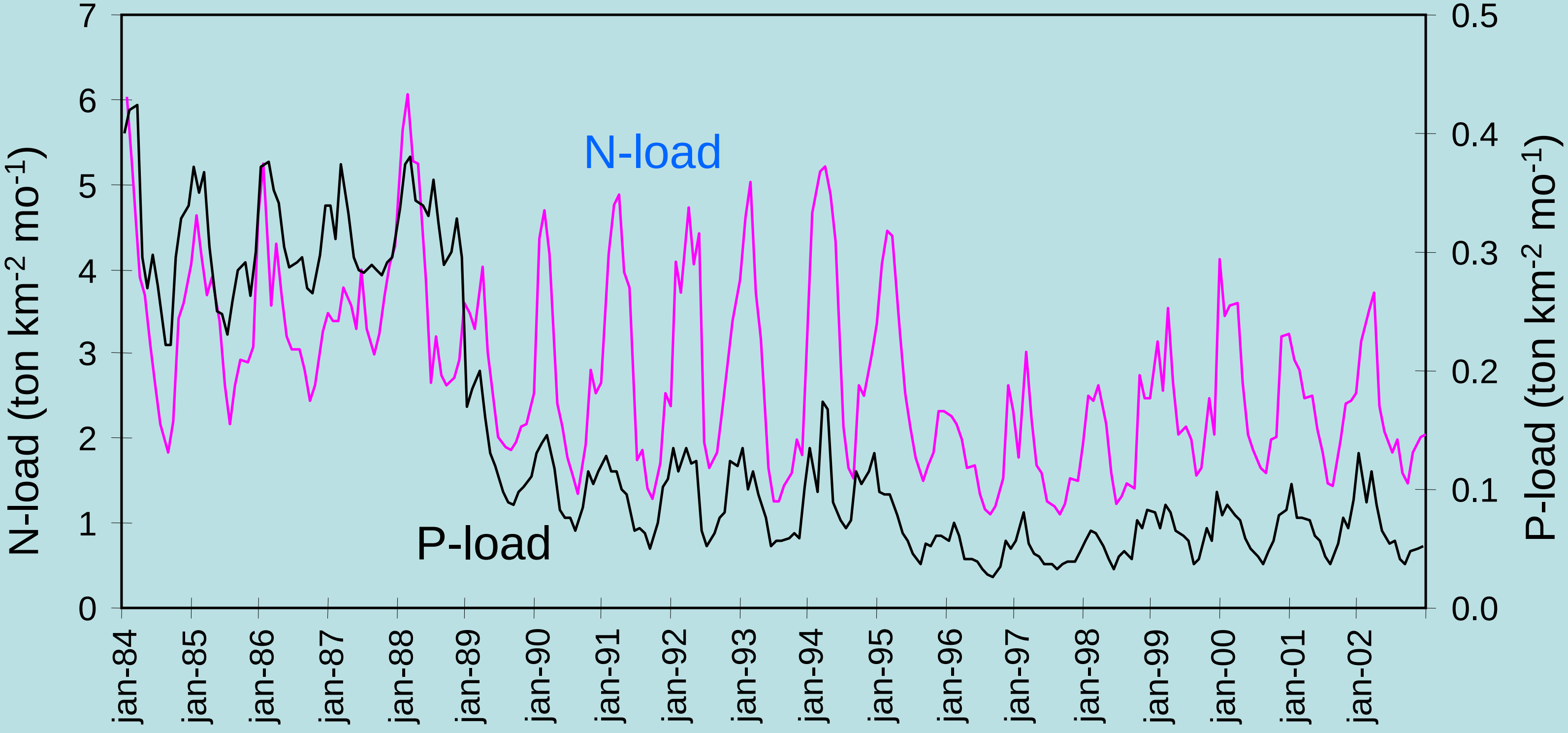
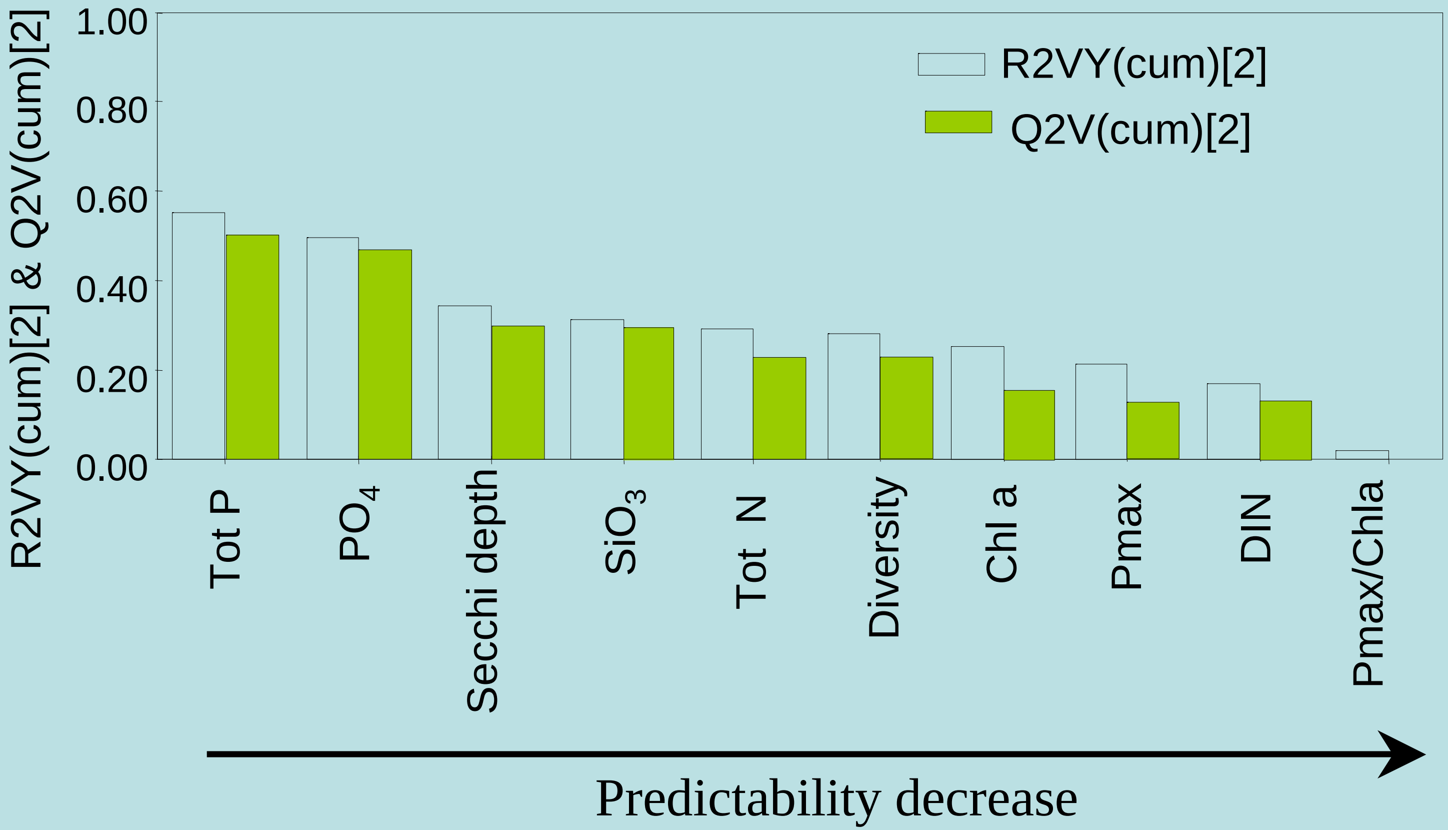
- N-load is dominated by diffuse sources (agriculture) and scales to run-off

- Point sources (sewer treatment) was reduced in 1988 and since 1990 diffuse sources also dominate P-load.



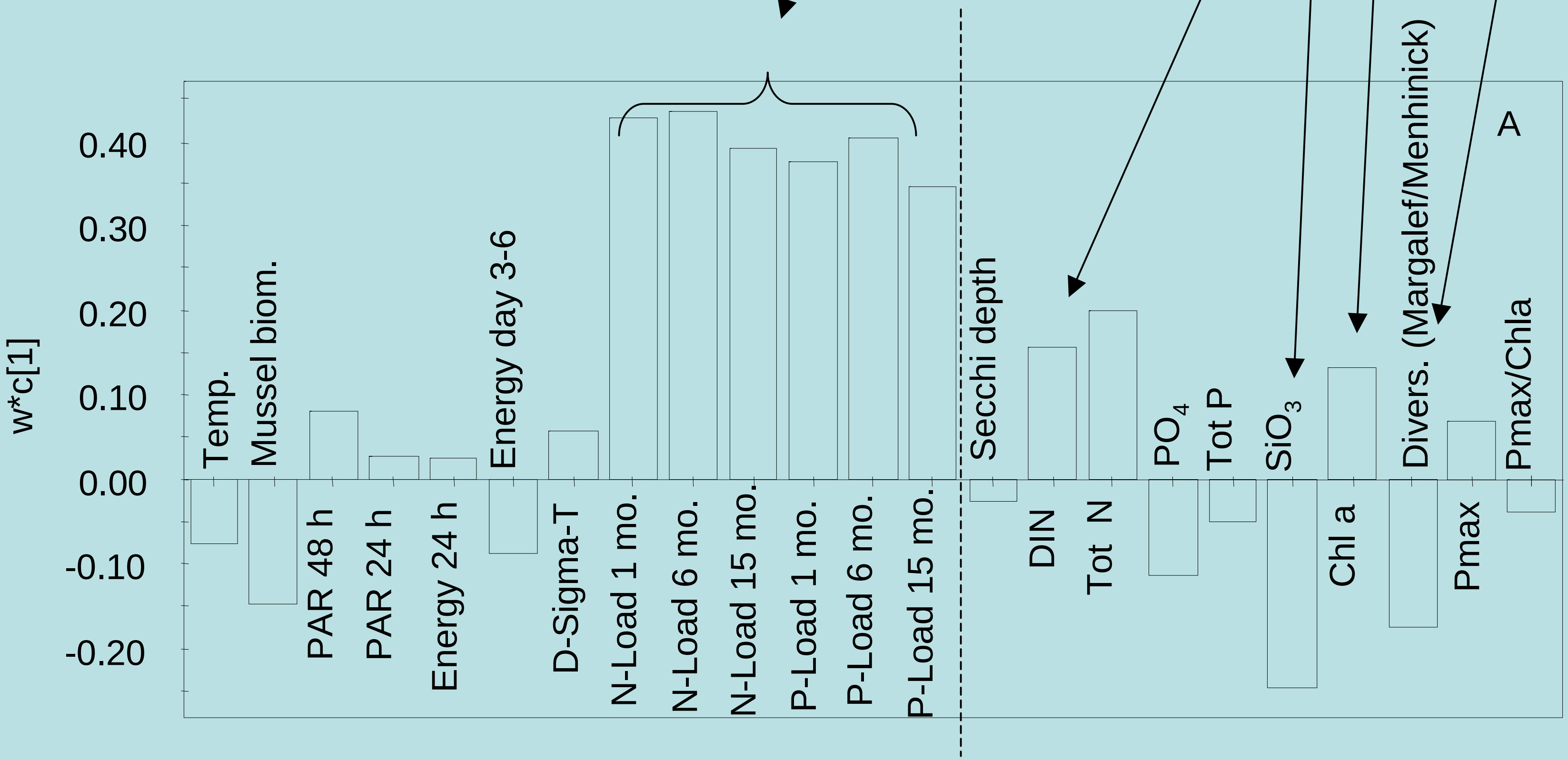
Multivariate statistics:

Predictability of water quality variables was highest for phosphorus and lowest for Chla specific primary production



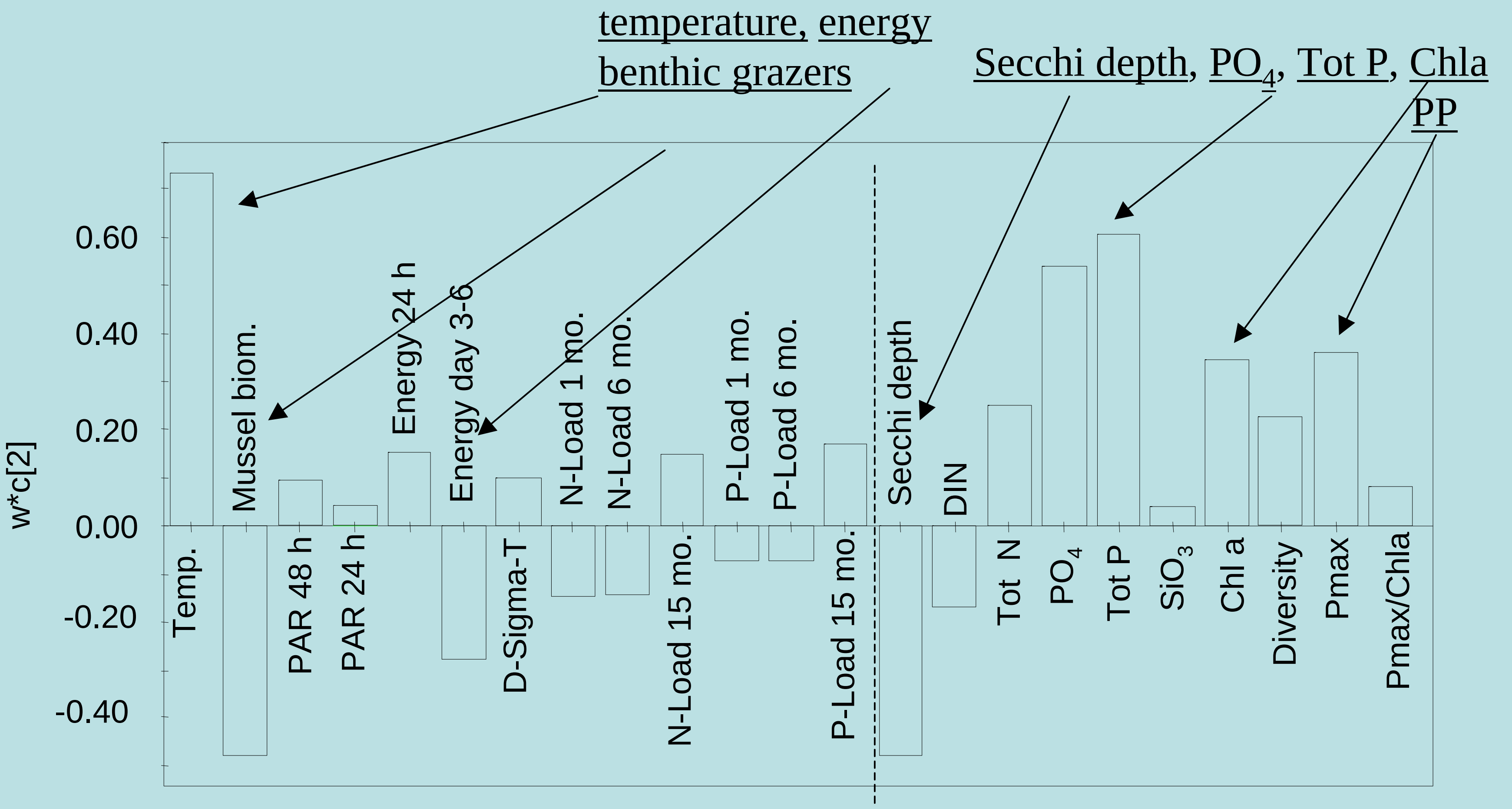
Multivariate statistics:

The 1. PLS component was dominated by nutrient loads that affected DIN, Tot N, SiO_3, Chla and plankton diversity



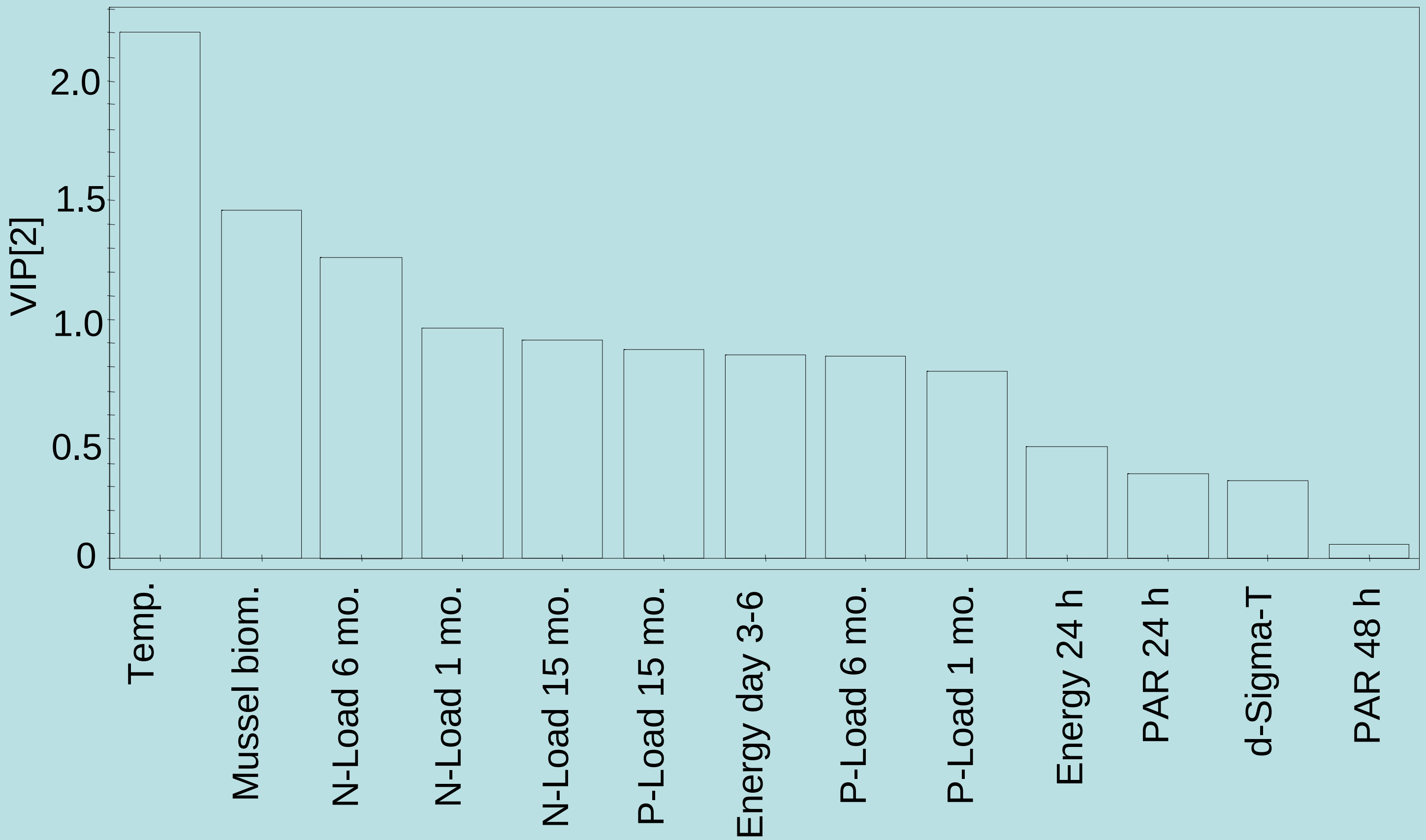
Multivariate statistics:

The 2. PLS component was dominated by



Multivariate statistics:

Overall: **Temperature**, benthic grazers and N-load were the most influential pressures for water quality parameters during summer.



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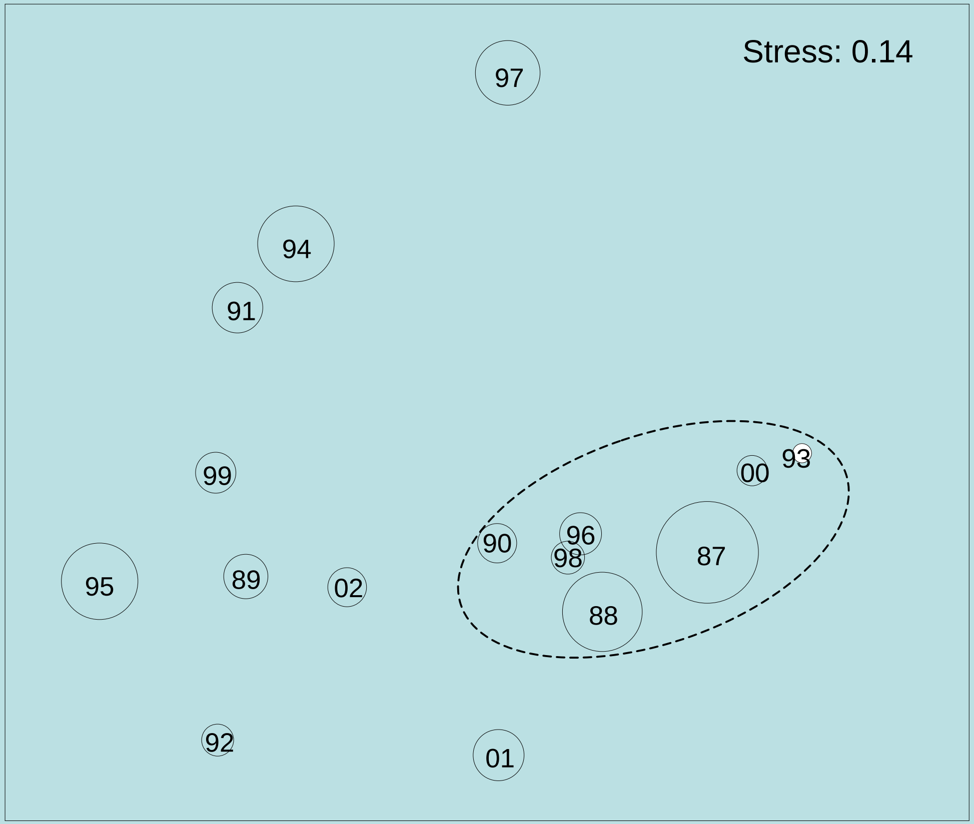
The MDS analysis of summer phytoplankton communities showed one distinct group consisting of 7 years (1987-88, 1990, 1993, 1996, 1998, 2000). These years were characterized by water temperatures below average (17.0 oC), wind energy higher than average and the community consistently was dominated by the diatom *Skeletonema costatum* that on average constituted 65% of the total biomass.



S. costatum on average contributed with 14% in the other years. In the years with summer temperature above long-term average the community was dominated by the dinoflagellates *Gymnodinium sanguineum* (1989), *Prorocentrum minimum* (1992), *G. sanguineum / P. minimum* (1995), the diatoms *Cerataulina pelagica* (1991, 1994, 1997) and *Rhizosolenia fragilissima* (2002).

The community composition was unrelated to phytoplankton biomass and nutrient load!!

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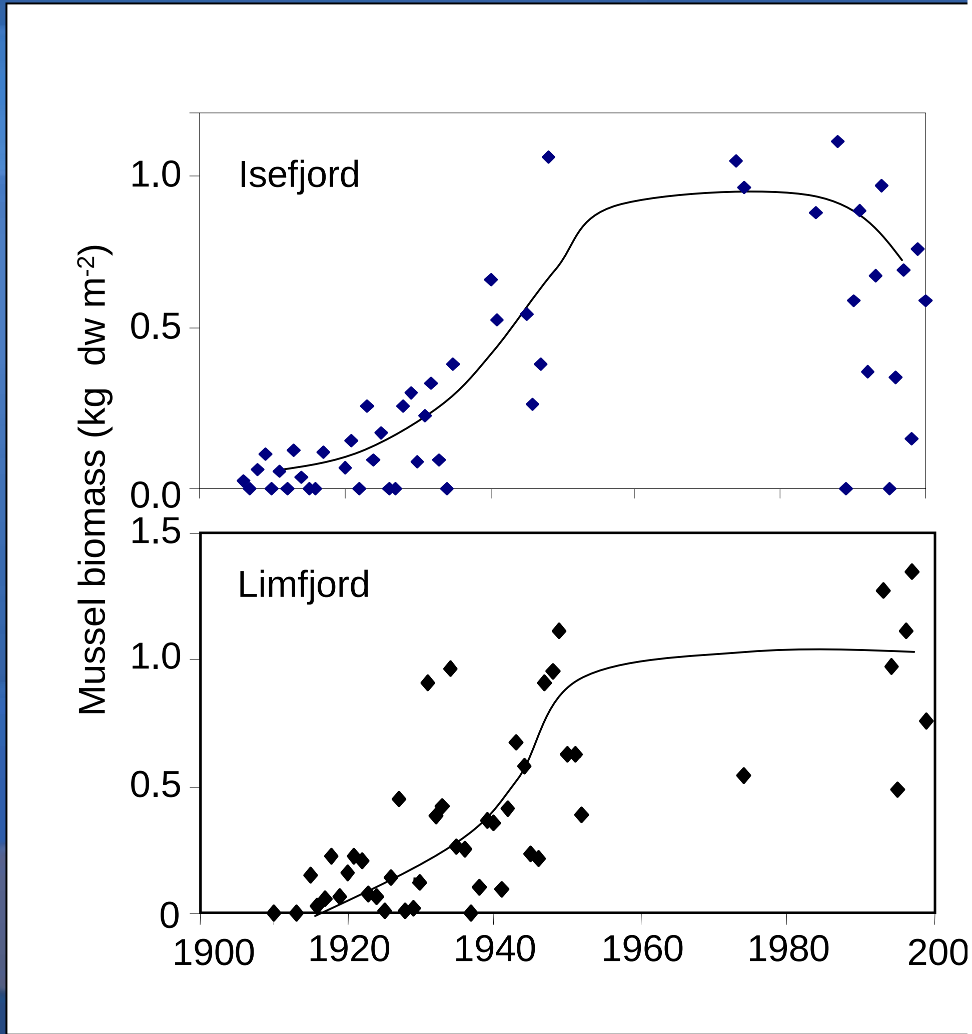
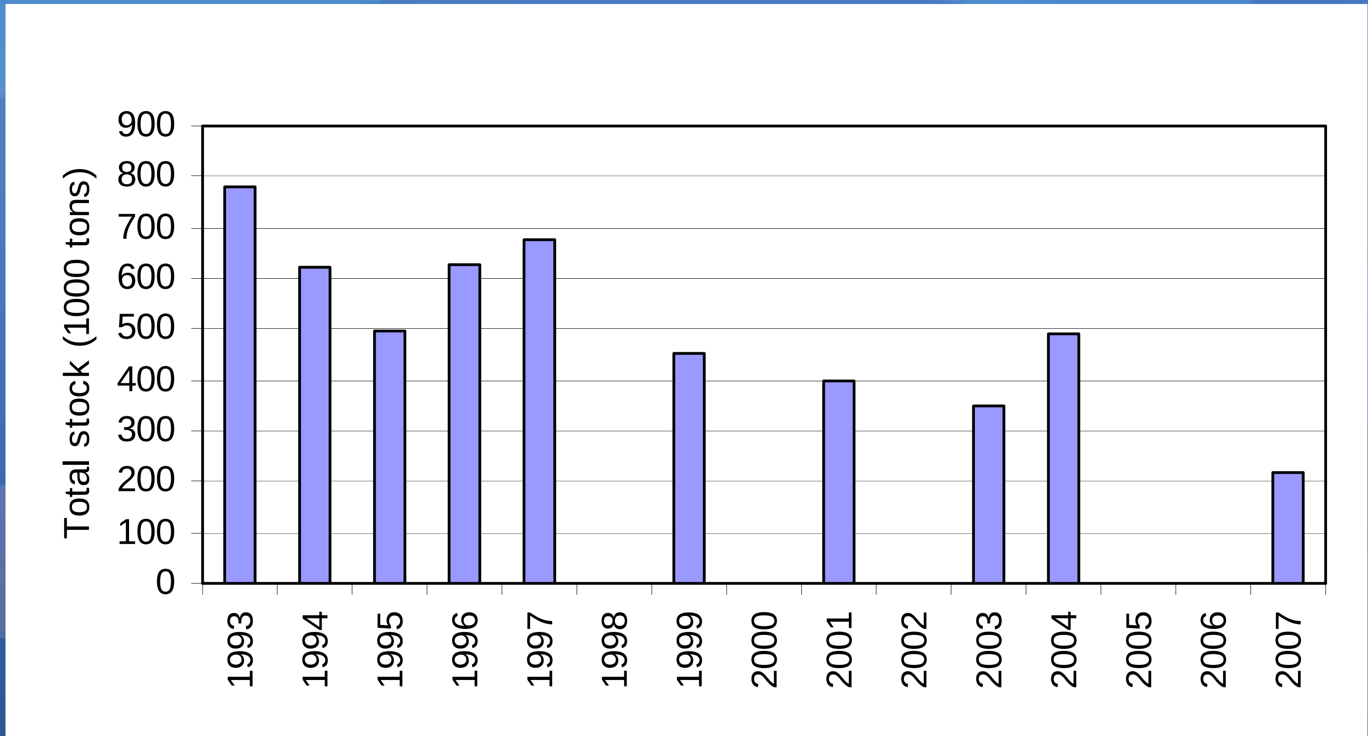
During the past 100 years mussel biomass has increased 20-fold in Danish estuaries as result of eutrophication –

But this trend has reversed but uncoupled to change in eutrophication



The total stock of mussels in the Limfjord has decreased steadily during the past 15 years



Due to a combination of increased stratification during summer and higher winter temperatures

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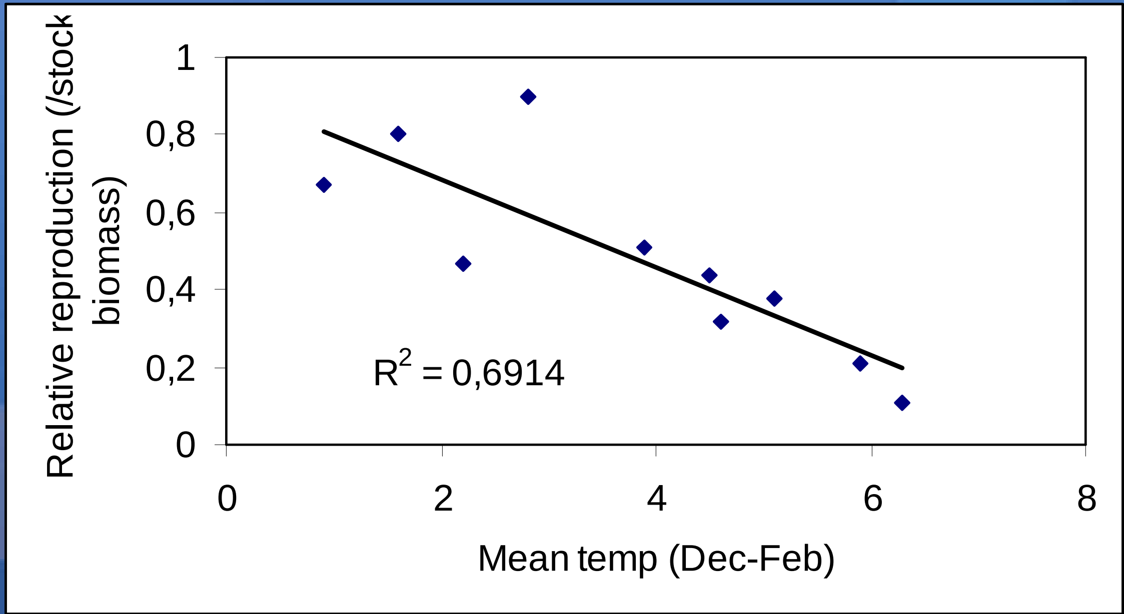
In warm winters accumulated storage in mussels is used for maintenance on expence of reproductive output



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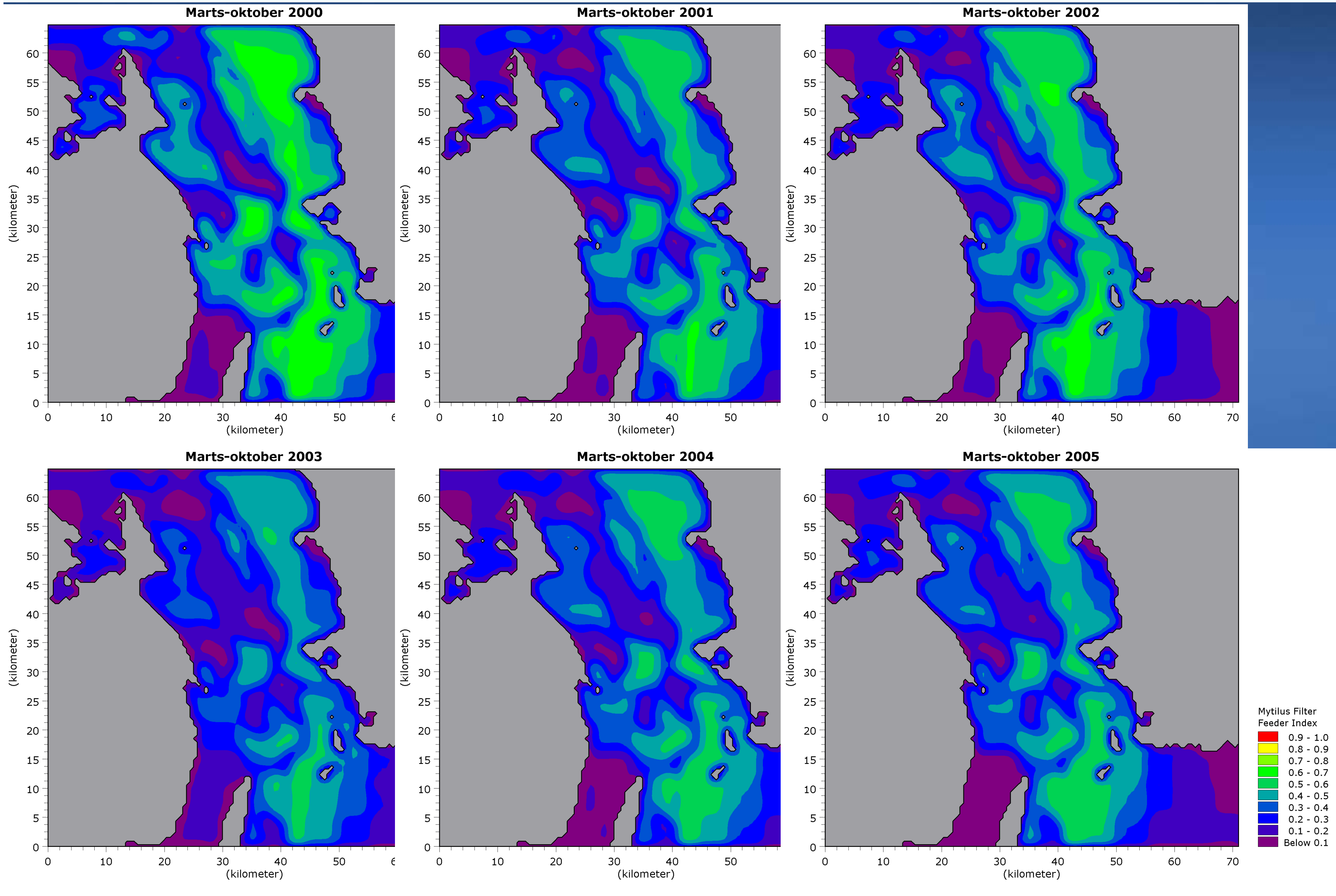
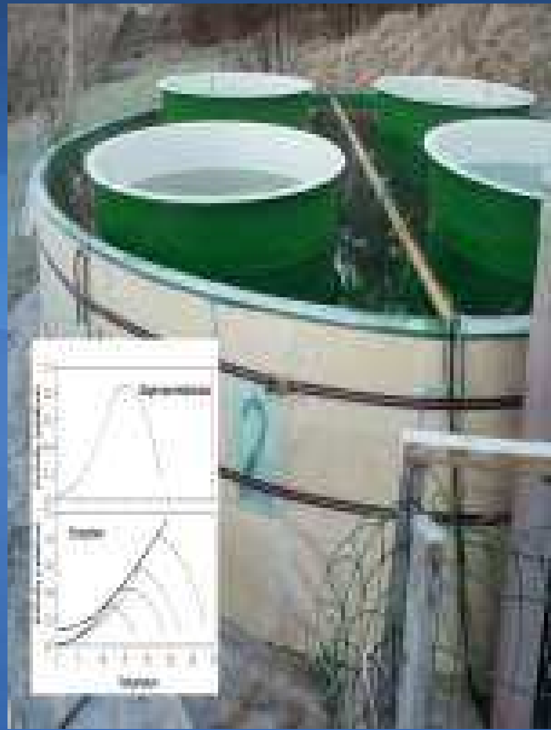


Food availability to benthic filter-feeders vary between years due to strength of stratification (warm summers)

Experimental work

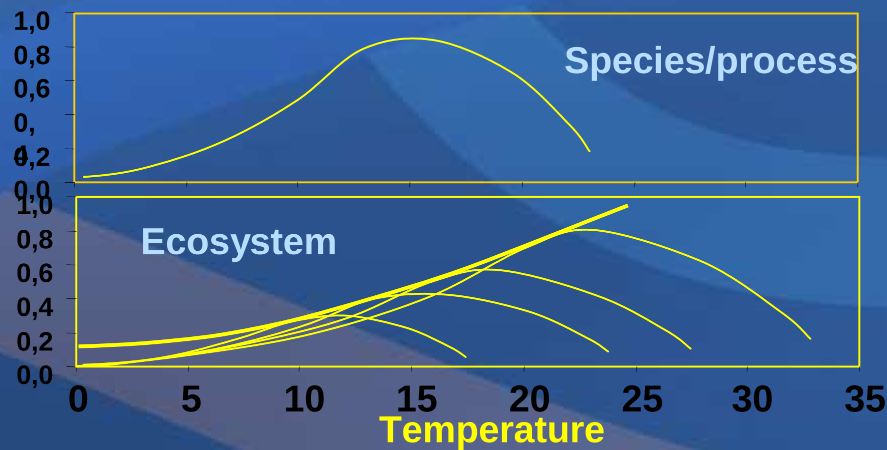
Experimental work for improving biological model description

Early spring mesocosms experiments in Bergen



Aim:

To quantify the importance of temperature on the structural and functional interaction between heterotrophic and autotrophic pelagic during spring bloom



Modelling Approach

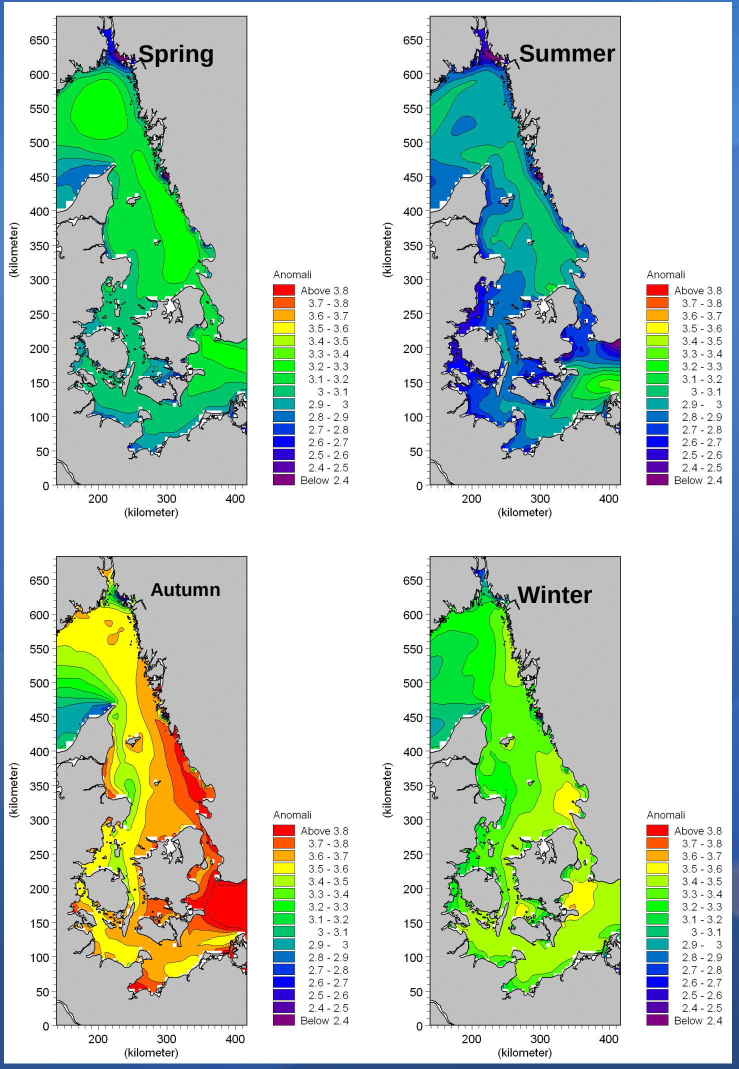
Large Scale modelleling

Detail modelling

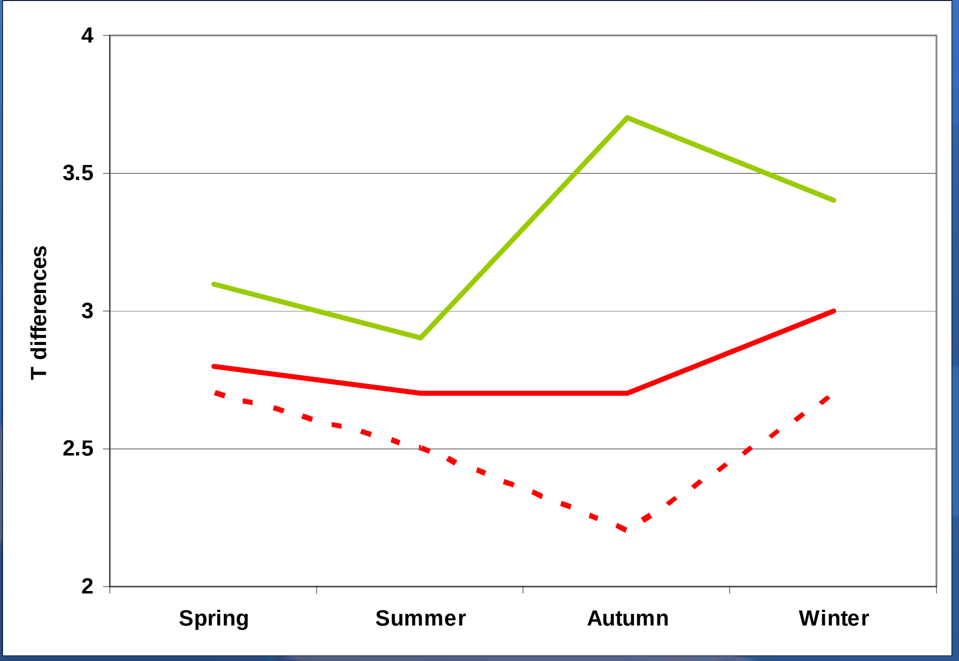
Ecological Effects due to Climate Changes

Temperature changes

Changes in surface temperature
Scenario – reference condition

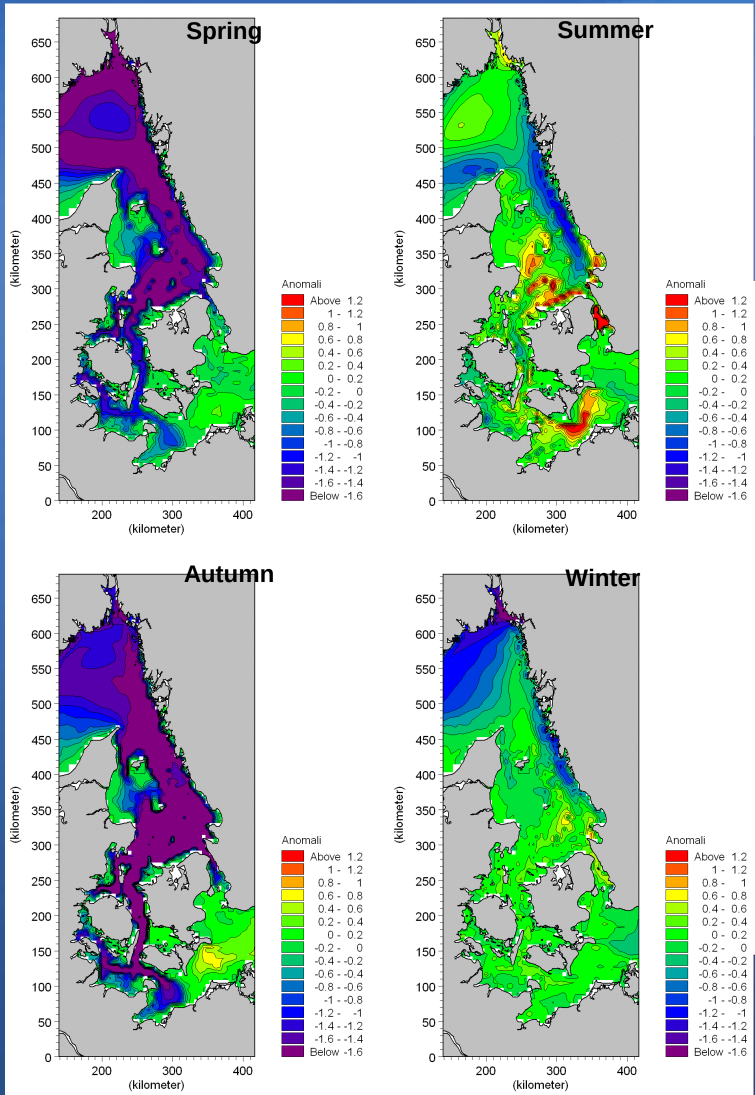


The temperature in surface and bottom water increases, but not equally

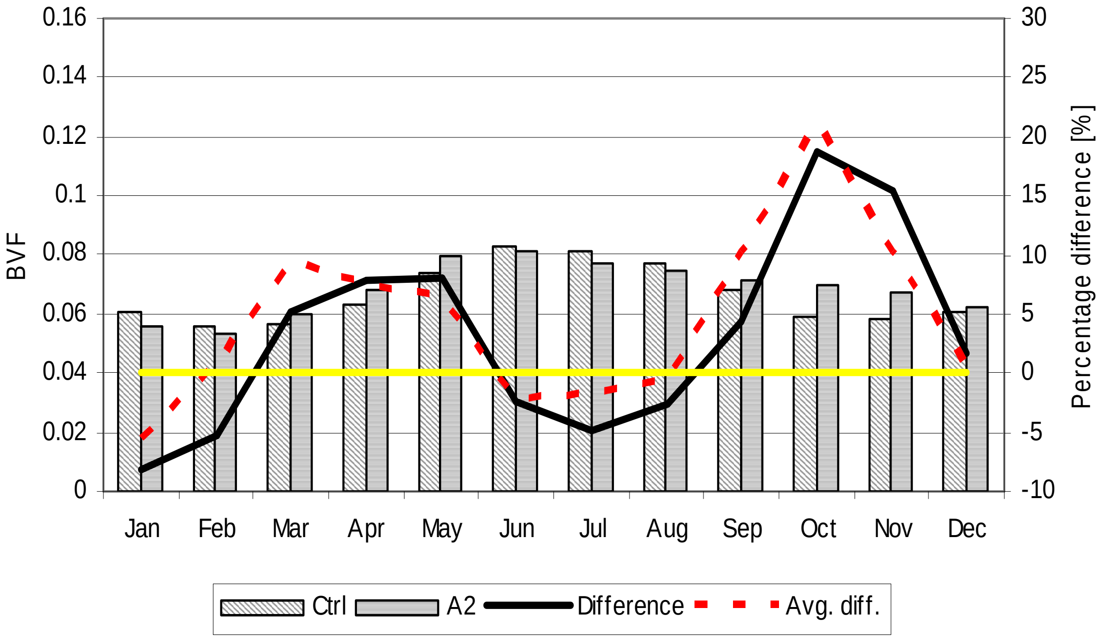


Salinity changes

Changes in salinity difference between surface and bottom water



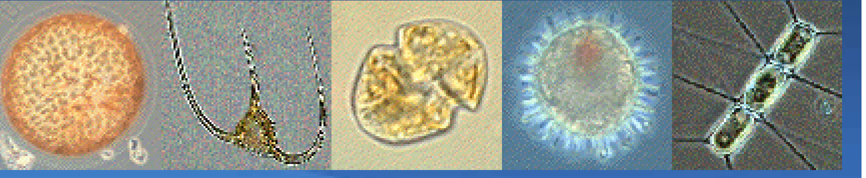
If the values are below zero (blue/purple) the salinity difference is larger in the future climate than seen today



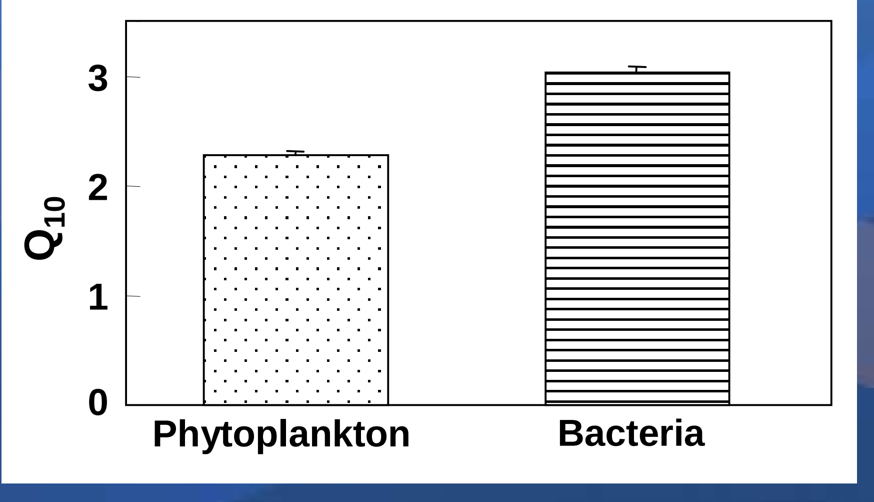
More pronounced stratification in spring and autumn

Temperature and the Microbial Ecosystem

Impact of enhanced temperature on the microbial ecosystem



Results from mesocosm experiments verify that heterotrophic organisms (bacteria and zooplankton) responds to a higher degree than phytoplankton



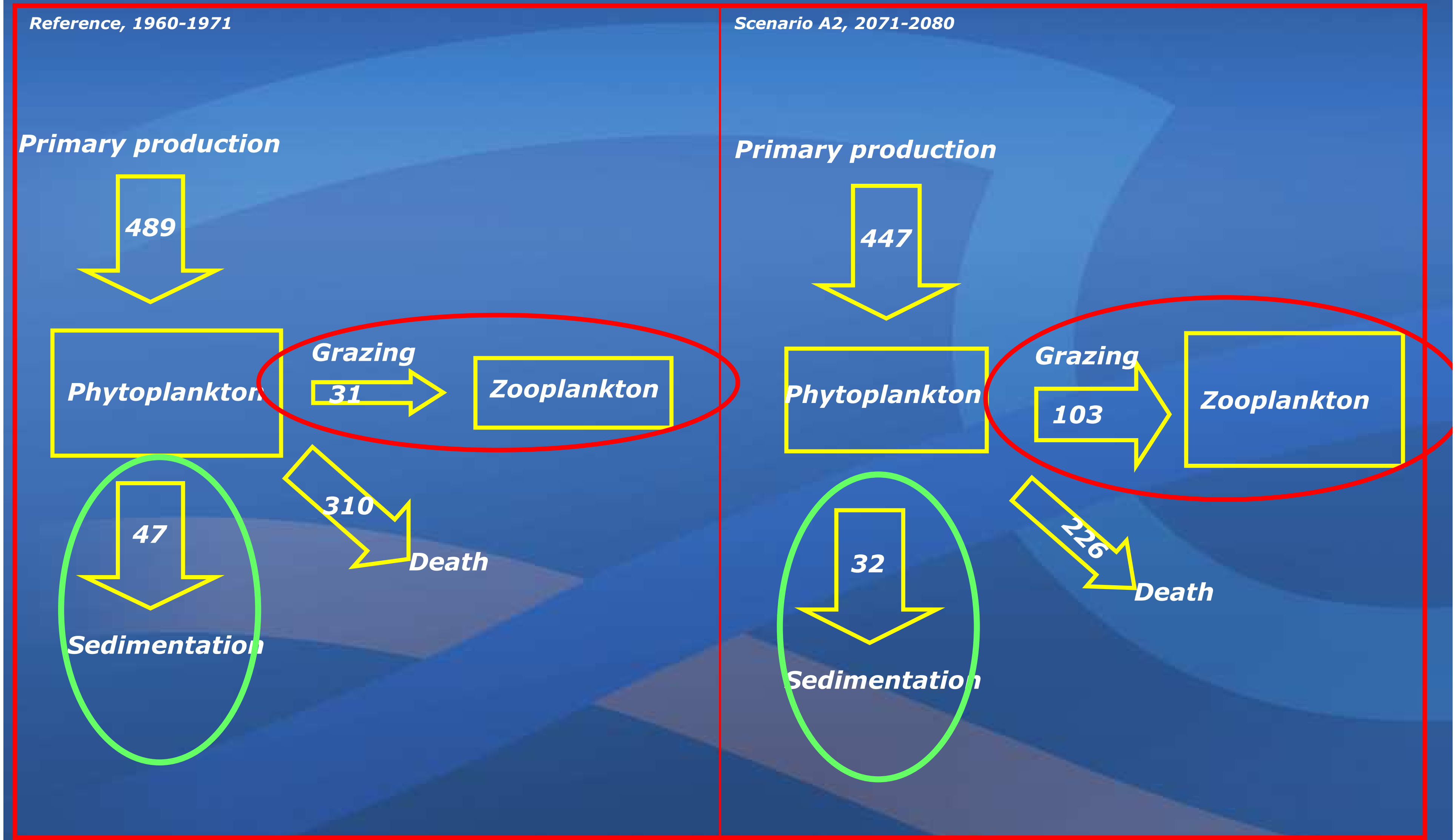
Model Forcings

Differences in metrological condition between the reference and the future scenario

	Reference 1961-90			Scenario A2 2071-2100		
	Min.	Avg.	Max.	Min.	Avg.	Max.
Air temperature [°C]	0.9	2.7	4.3	3.5	5.3	7.3
Net precipitation [mm/day]	0	0.09	0.49	0	0.10	0.56
Solar radiation [mmol/day]	3.7	12.6	24.2	3.5	11.1	21.6
Wind direction [Degree]	-	209	-	-	209	-
Wind speed [m/s]	0.3	7.7	16.5	0.4	8.0	17.1

Modelled Spring Bloom Results

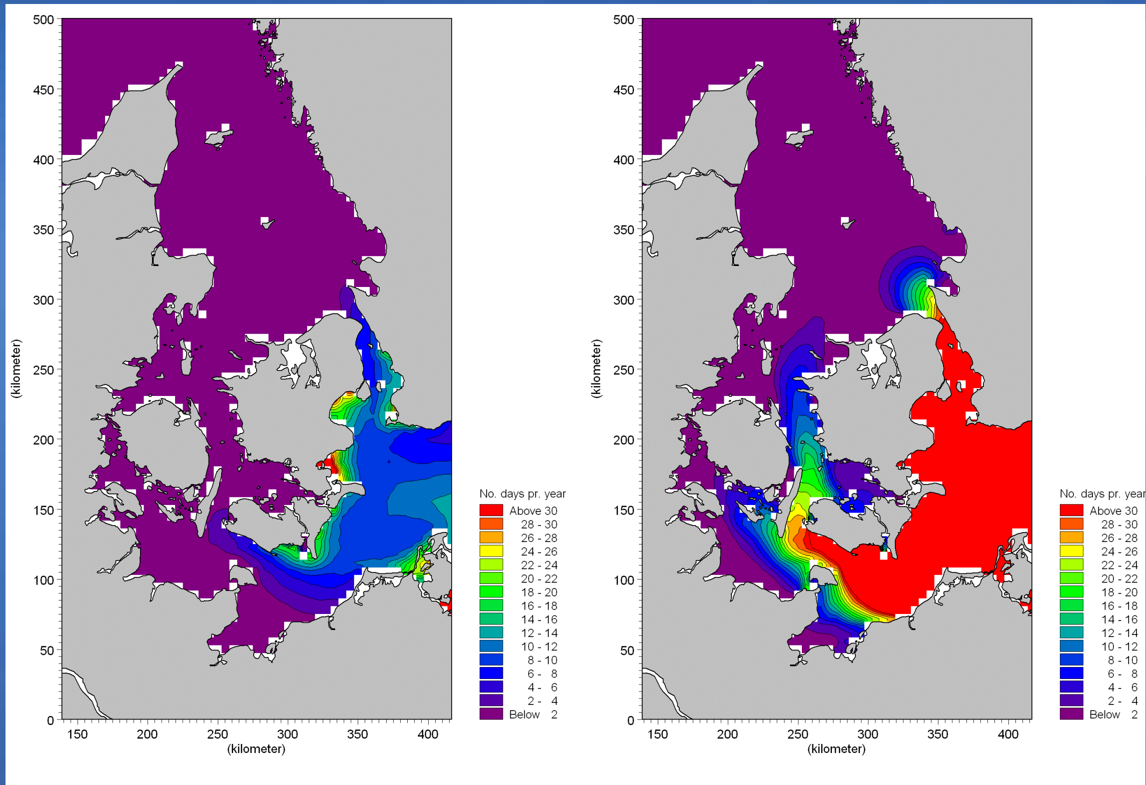
Spring bloom, February - March



Cyano Bacteria

Reference, 1961-90

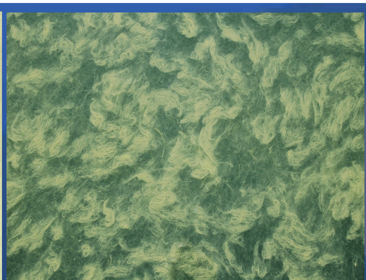
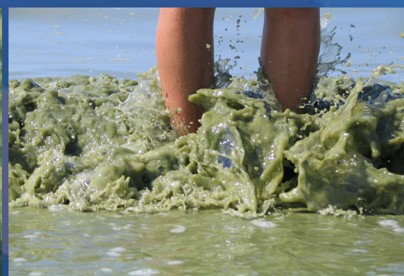
Scenario A2,2071-2100



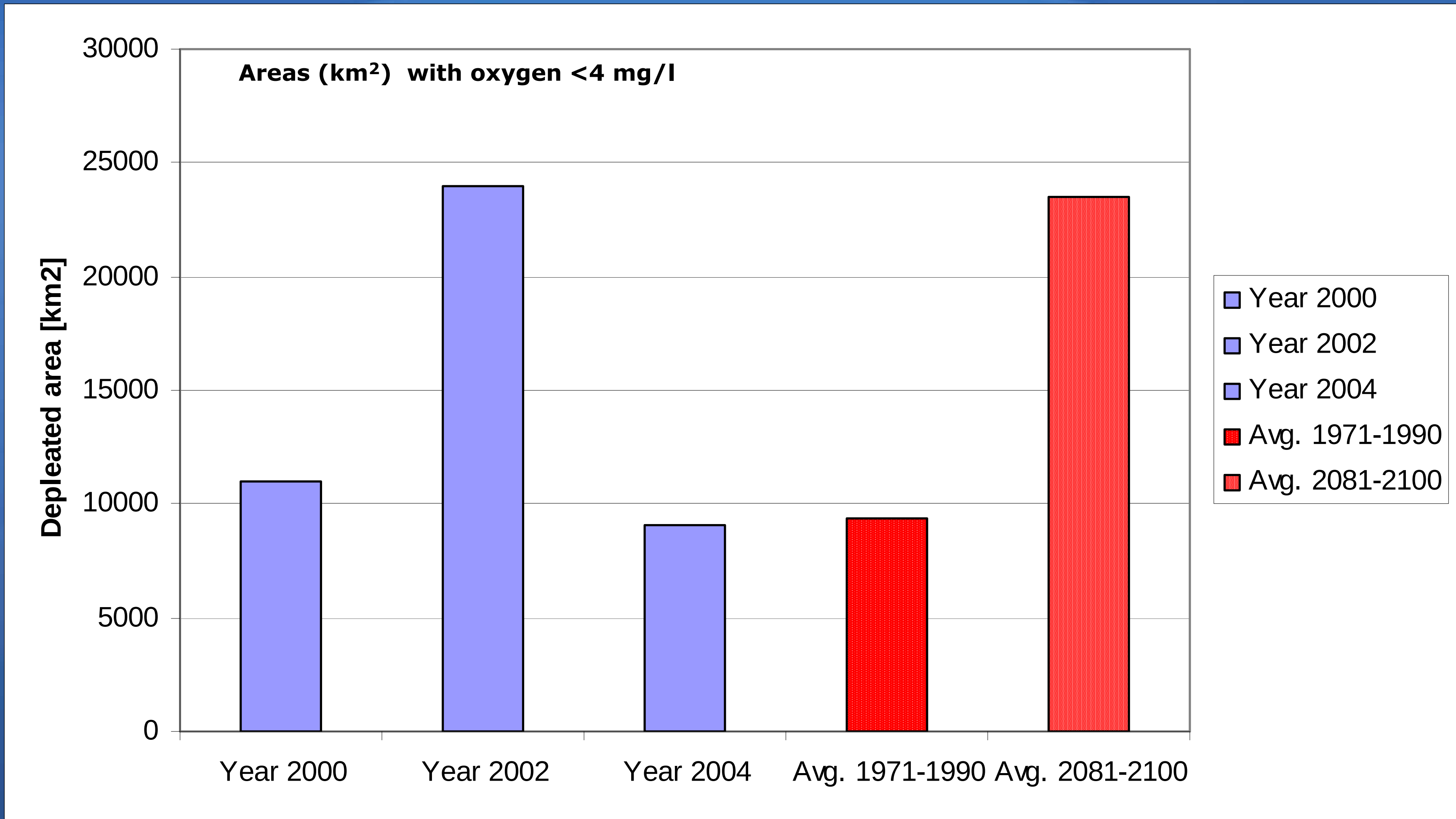
Higher temperature and enhanced freshwater run-off result in good conditions for cyanobacterial growth

More days with high risk of cyanobacteria



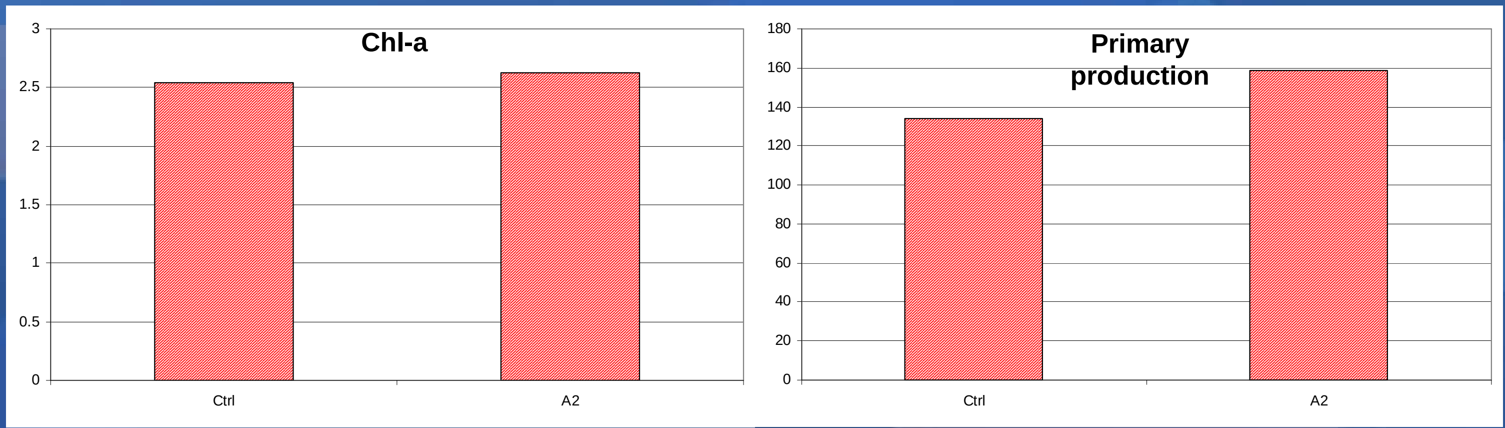

Oxygen conditions



Conclusions

1. Higher coupling between autotrophs and heterotrophs
2. Higher re-mineralization in the water column
3. Less spring bloom but higher primary production throughout the year
4. No major chances in amount of sedimentation over the year, but the organic matter in general is less nutrient rich
5. Lower food quality to the benthic food web

Average chl-a and primary production throughout the year



Ecological Effects due to Climate Changes

Thank you for your attention …