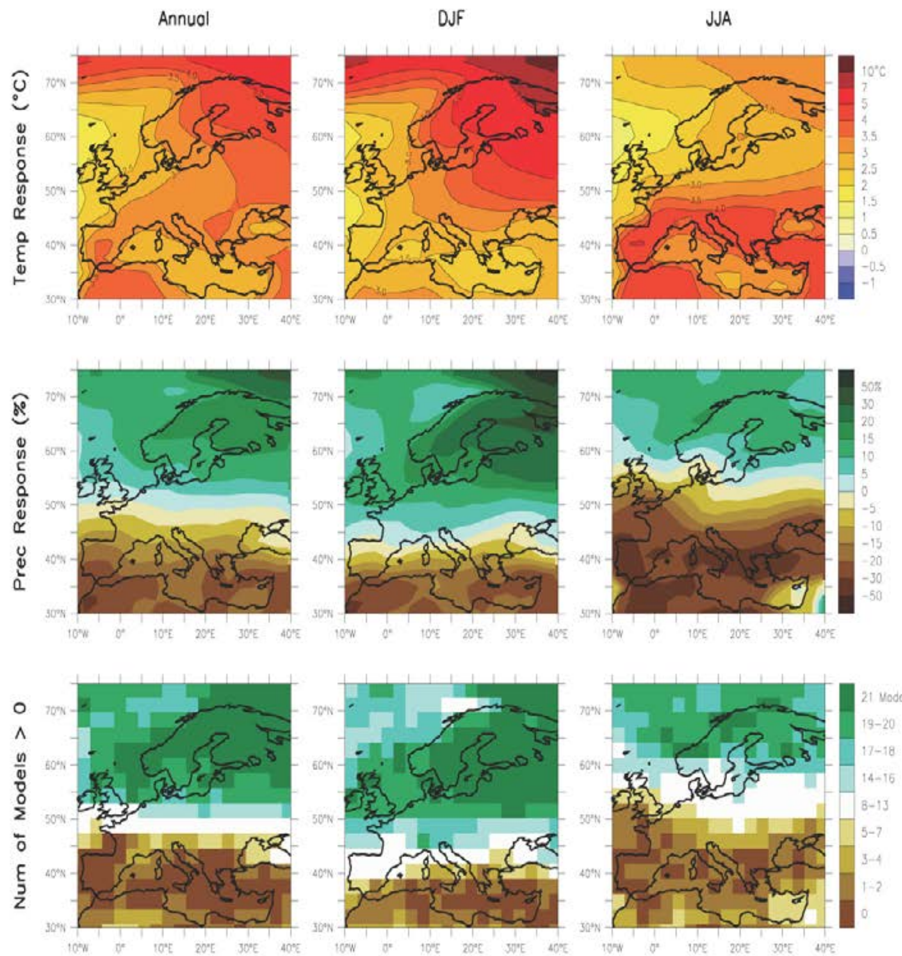
Projected future climate change and ecosystem changes in the Gulf of Bothnia

Agneta Andersson

Umeå University

ECOCHANGE.

Projected climate-induced changes in temperature and precipitation in Europe during 100 years, using assembly analysis of 21 models (Cubasch et al. 2001, HELCOM 2007).



Freshwater will bring allochthonous terrestrial organic matter (AOM) to the sea:

Humic substances
Dissolved organic carbon (DOC)
Colored dissolved organic matter (CDOM).

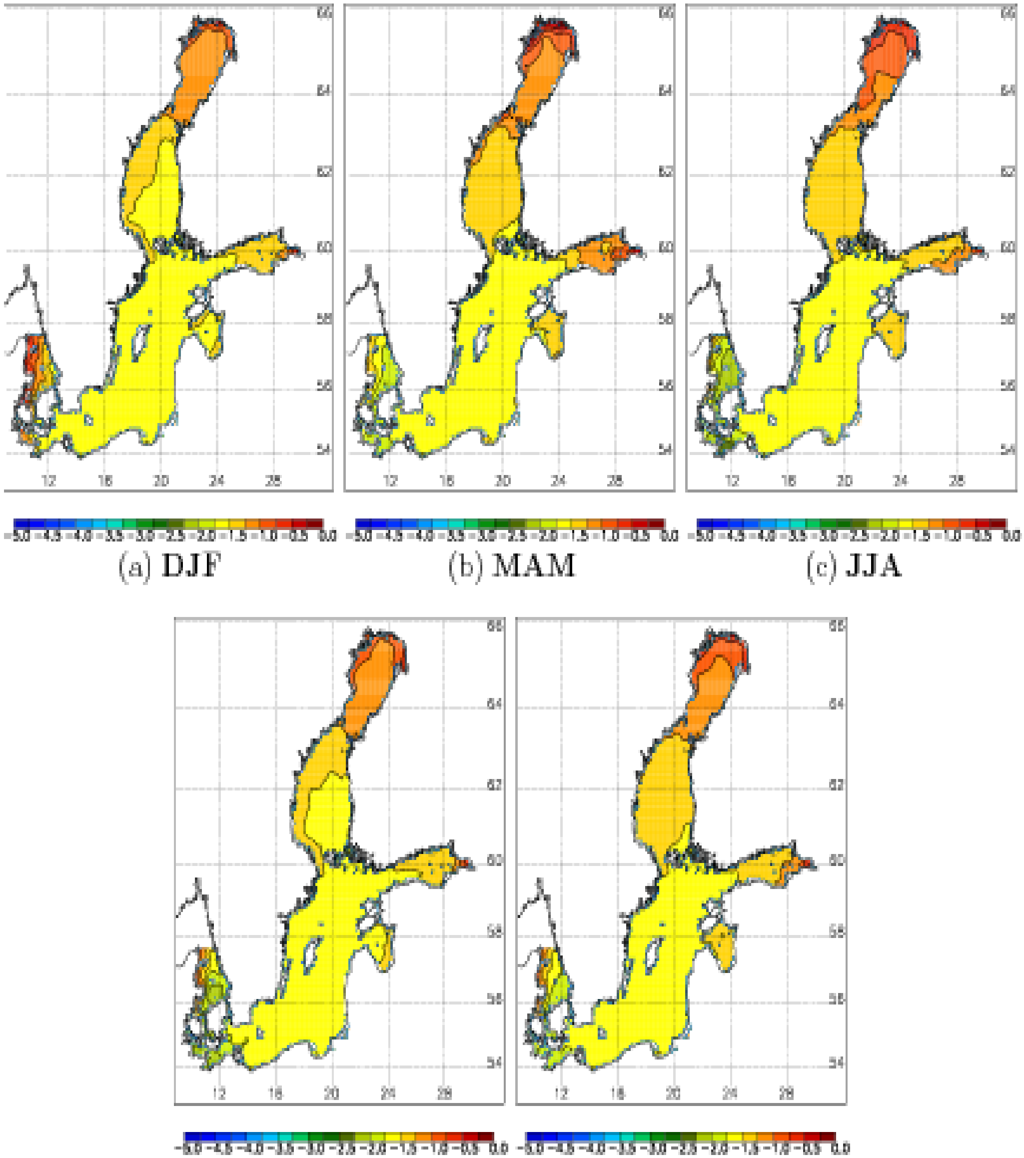
Increased precipitation and land run-off

Change; Salinity

Lower salinity in the sea.

Bothnian Bay	
Today	3
In 100 years	2
Bothnian Sea	
Today	4
In 100 years	2,5
Baltic proper	
Today	7
In 100 years	5

Less salinity – Higher AOM



(a) DJF (b) MAM (c) JJA (d) SON (e) Annual

Meier et al. Ambio 2012

Our hypothesis

Classical Food Web:

Present

Basal trophic level:

Phytoplankton/algae

Primary production

Carbon source: Inorganic carbon DIC, sun light

Microbial Food Web

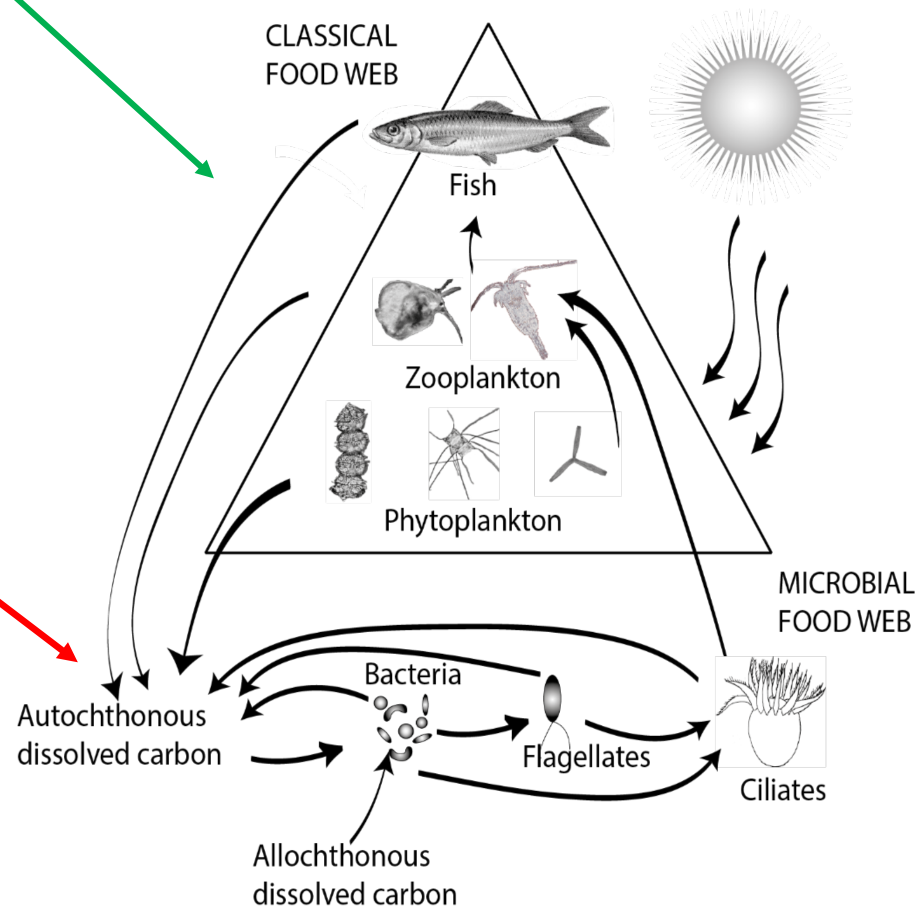
Future, Climate Altered

Basal trophic level:

Bacteria

Bacterial production

Carbon source: Dissolved organic carbon (DOC, humic substances) . E.g. Terrestrial C, algal exudate.



By: Kristina Viklund
Umeå Marina Forskningscentrum

Present situation:

Primary production 10x higher in the Baltic proper than in the Bothnian Bay.

Bacterial production similar in the gradient.

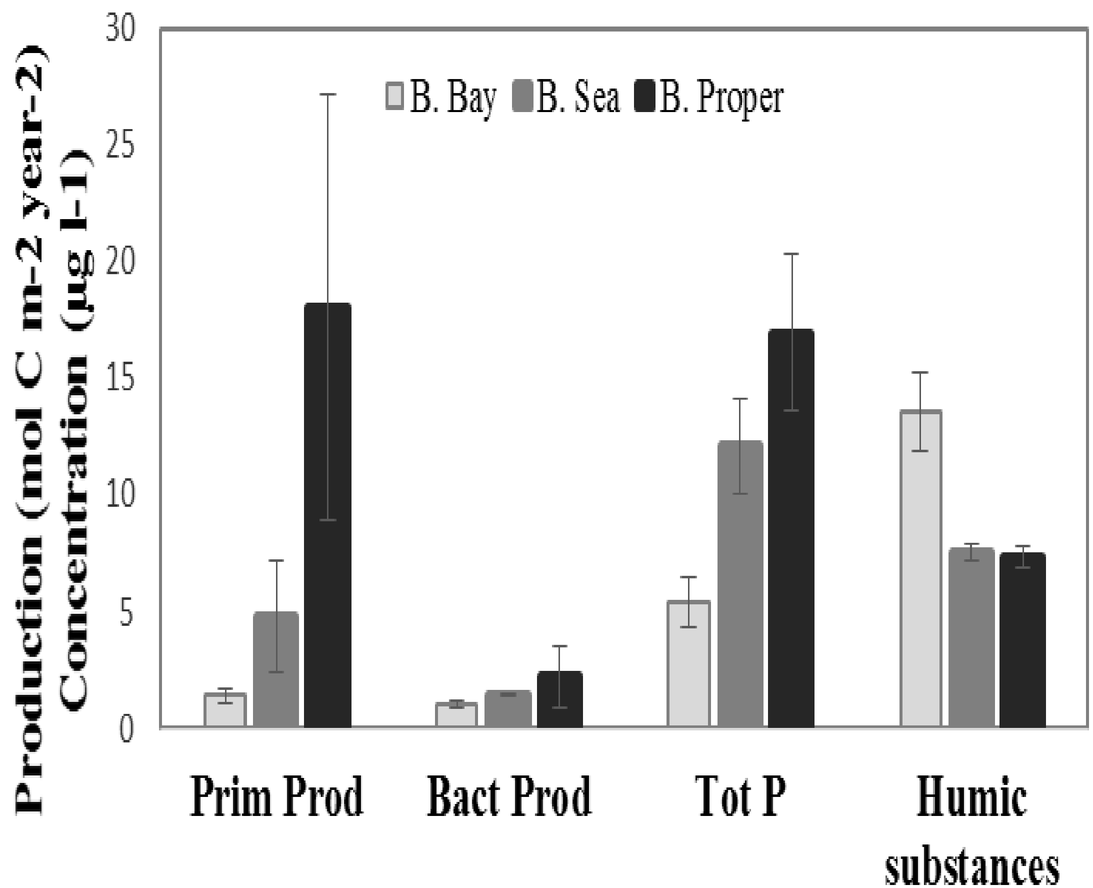
Phosphorous 3 x higher in the south than in the north.

Humic substances twice as high in the north.

Freshwater bring (AOM) allochthonous organic matter to the sea:

Humic substances
DOC
CDOM (colored dissolved organic matter)

Off-shore yearly production



North-south gradient – a mirror of future changes?

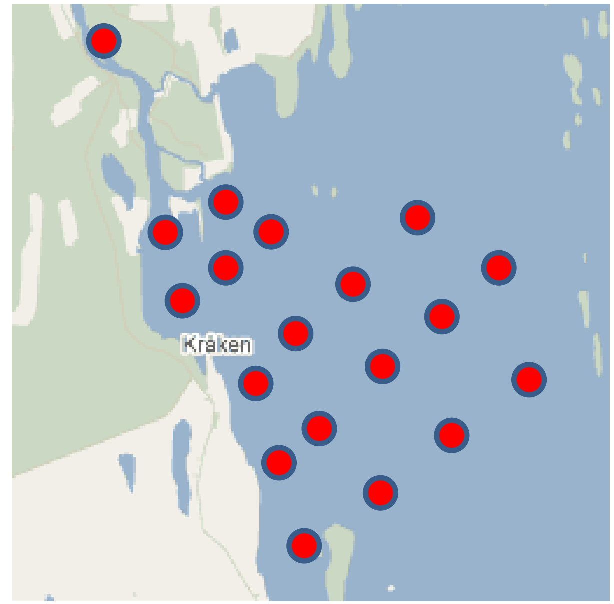
Andersson et al. Ambio 2015

How does river inflow affect production in coastal areas?

Råne estaury, Bothnian Bay
Öre estaury, Bothnian Sea
Emån estuary, southern Baltic Sea

Råne estuary Bothnian Bay

Öre estuary Bothnian Sea



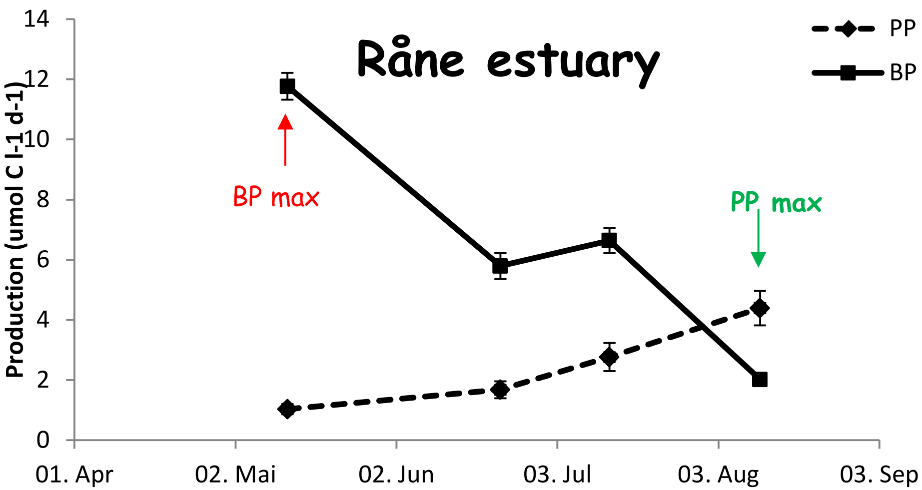
Emån estuary, Baltic proper

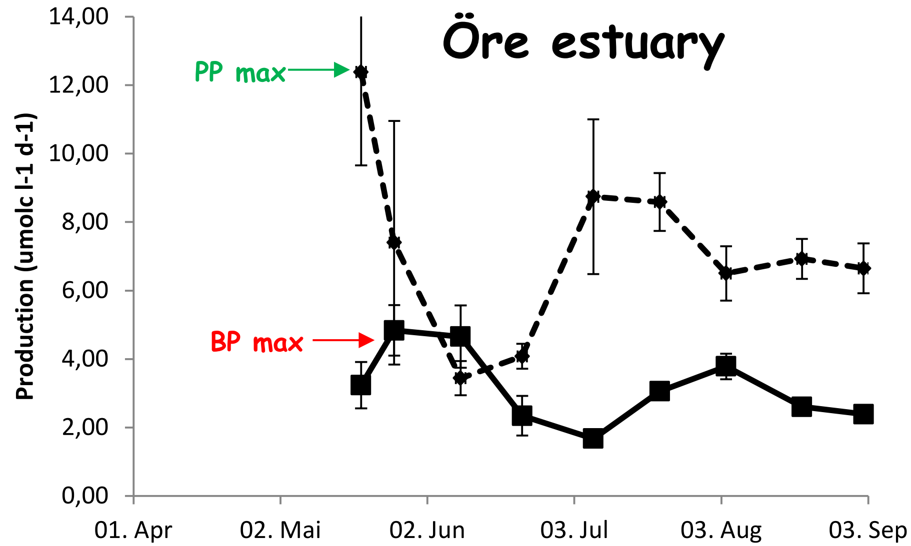
Sampling during the productive season

Primary production
Bacterial production

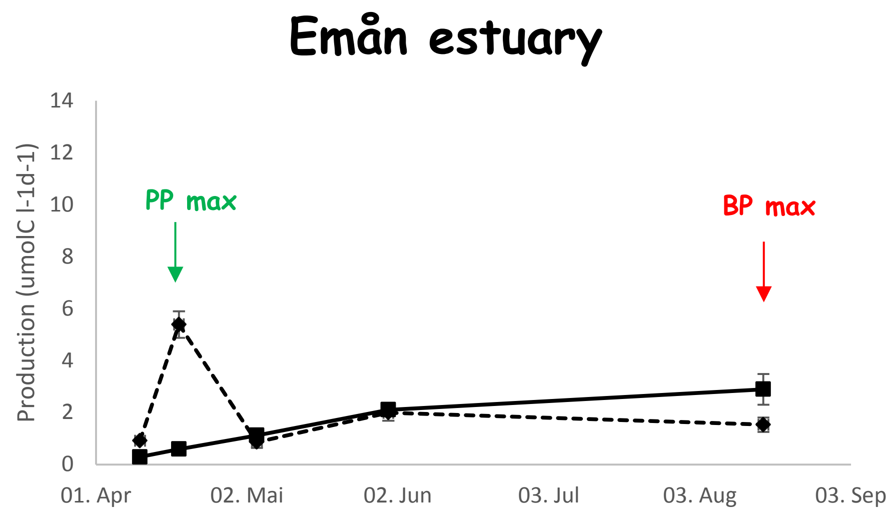
Explanatory variables

Shifts in the timing of primary and bacterial production from north to south in the Baltic Sea





Different succession order of the basal producers in the north compared to the south

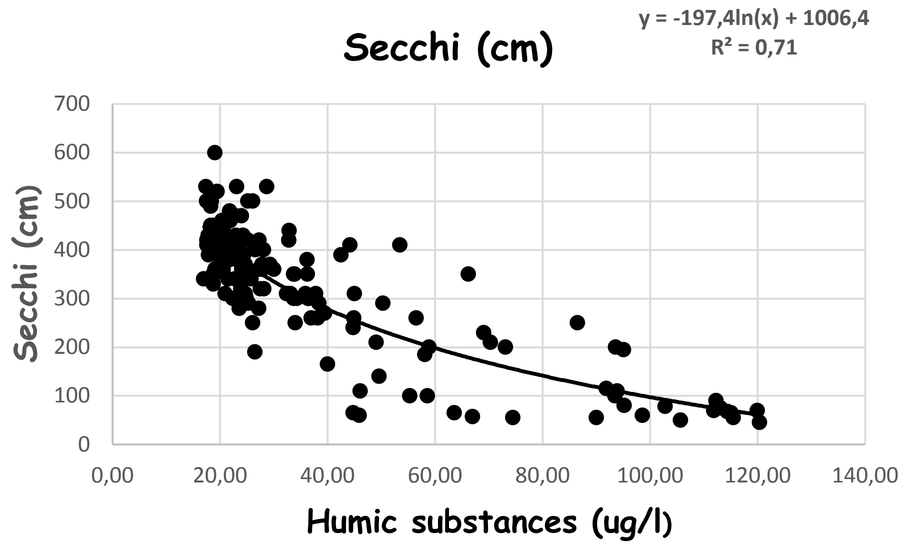


Gulf of Bothnia

High Humics –

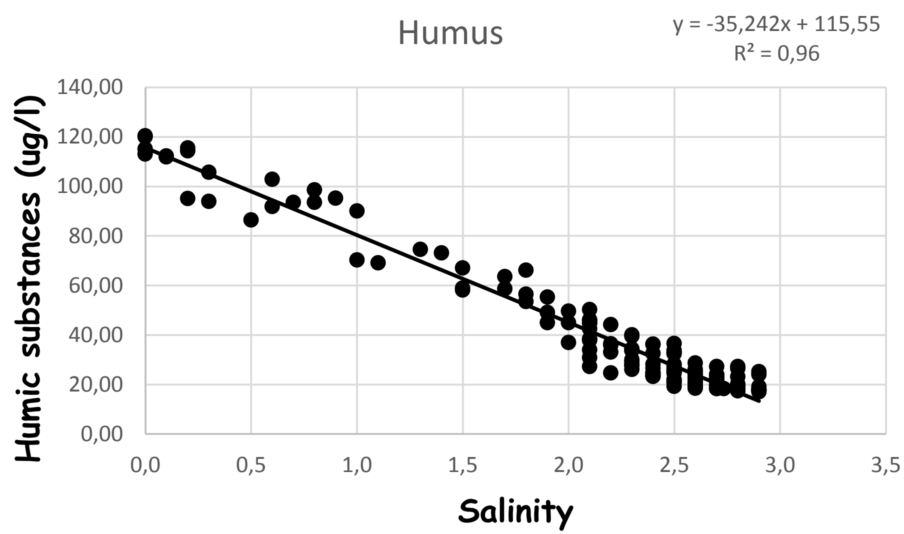
Low Secchi –

Poor Light Climate



High Humics –

Low Salinity



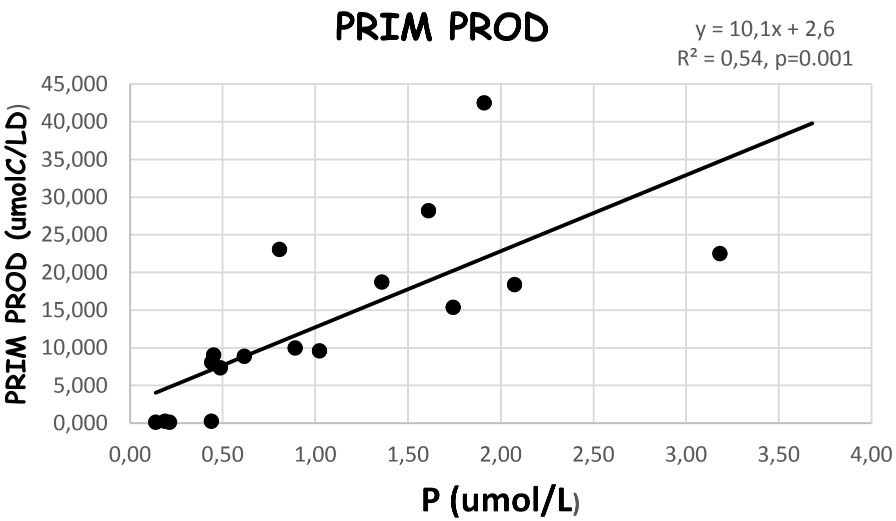
Gulf of Bothnia, Spring

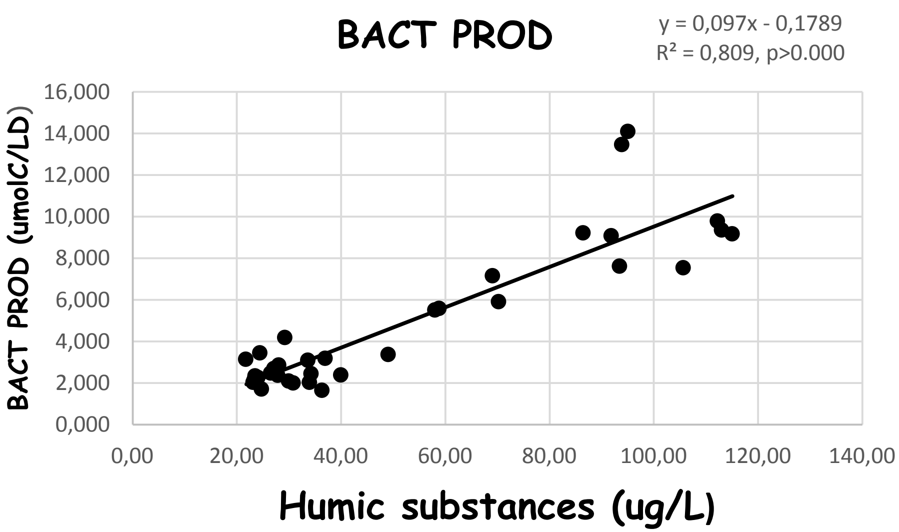
Primary Production:

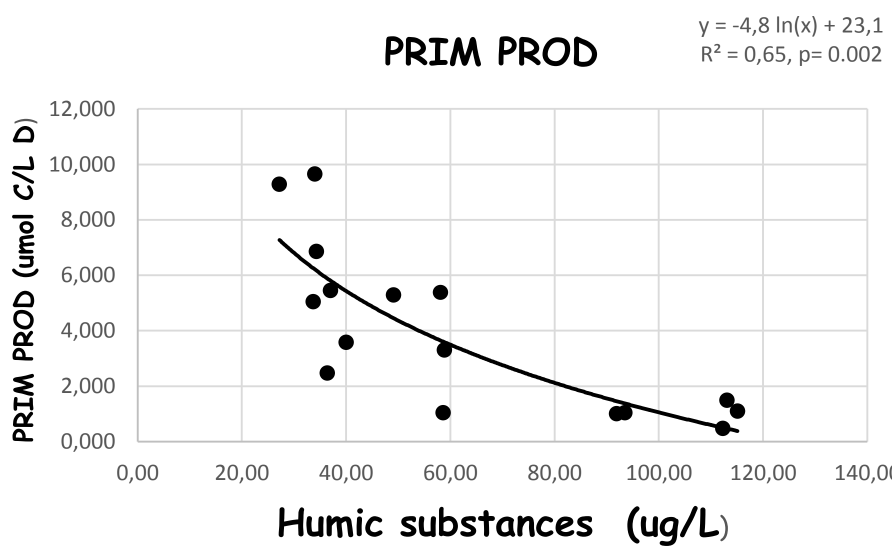
Positively related to P
Negatively related to Humics

Bacterial Production:

Positively related to Humics



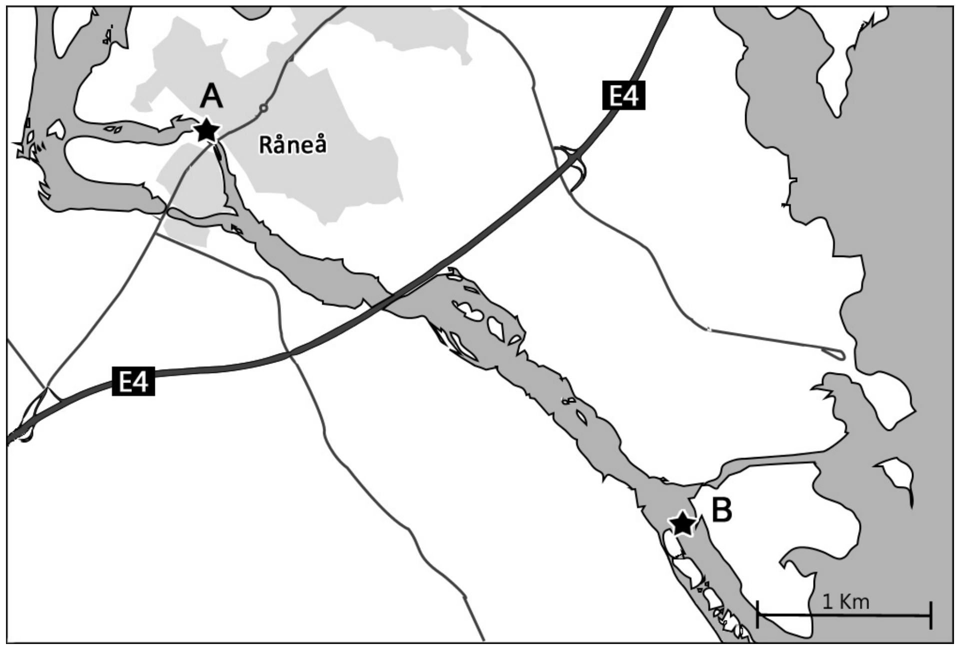




Stepwise Multipl. Regr.	Estuary	Test Variable	Model r^2	Model Sign.	Predict.	Slope	Predict. Sign.
Bothnian Bay	**Råne**	Prim Prod	-				
		Bact Prod	0.68	<0.001	**Humics**	**+0.83**	<0.001
Bothnian Sea	**Öre**	**Prim Prod**	0.60	<0.001	**P**	**+0.70**	<0.001
					SPM	**-0.27**	<0.001
					Humics	**-0.26**	0.044
		Bact Prod	0.50	<0.001	**Temp**	**+0.65**	<0.001
					DOC	**+0.28**	0.010
Baltic proper	**Emån**	**Prim Prod**	0.61	<0.001	**P**	**-1.20**	<0.001
					Temp	**-0.78**	0.001
		Bact Prod	0.62	<0.001	**Temp**	**+0.79**	<0.001

Andersson et al. Ambio 2015

Regulation of bacterial production in the Råne estuary, northern Baltic Sea

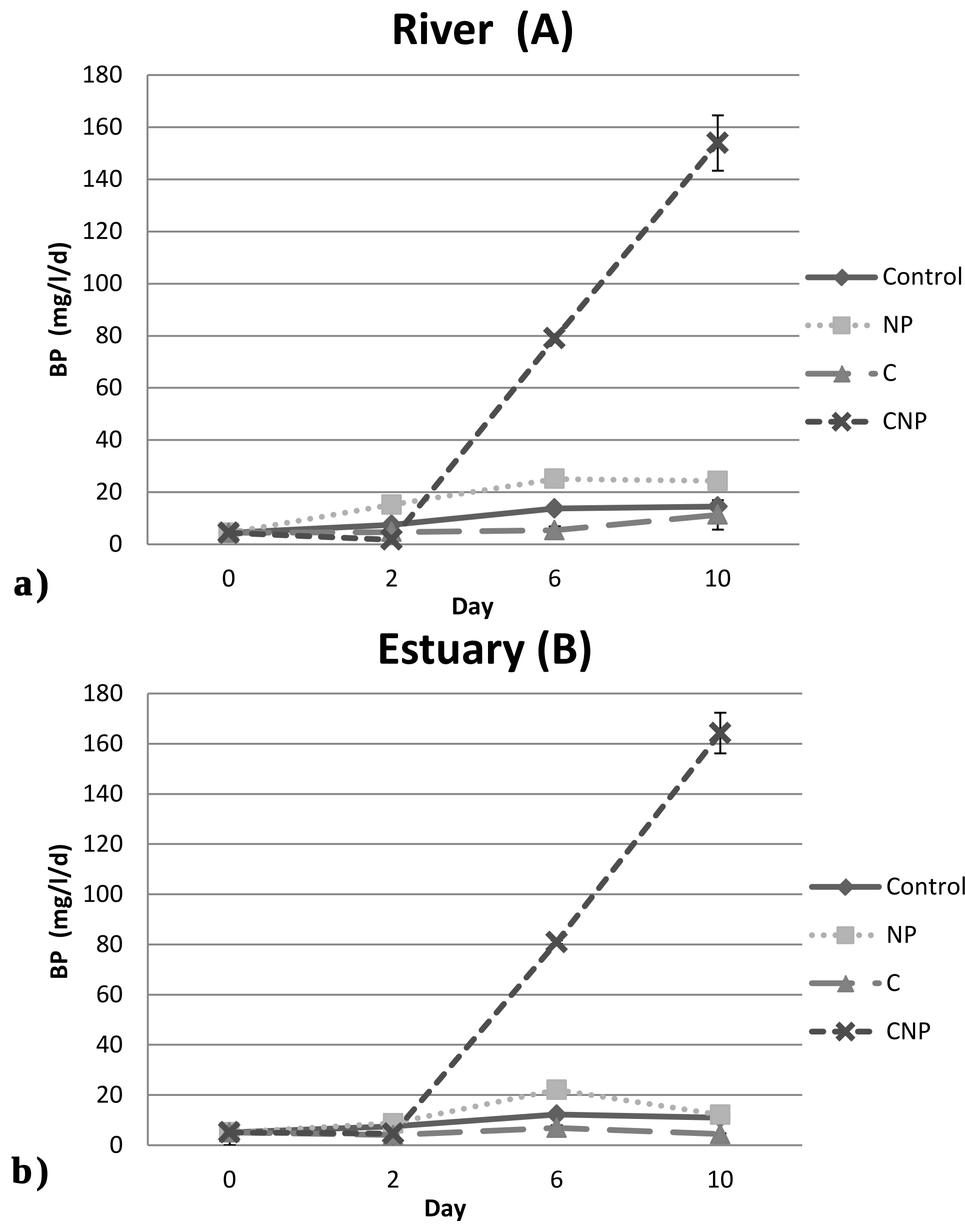


Spring sampling: May 2015

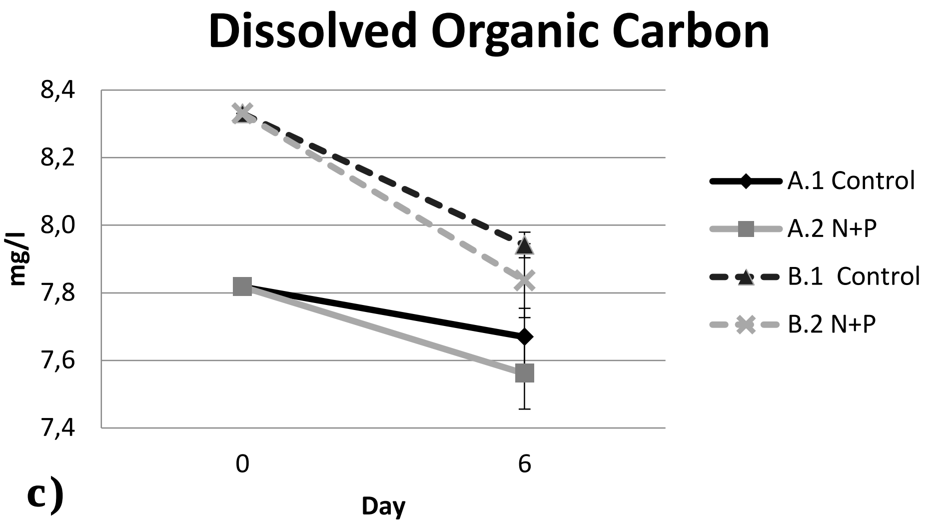
Is carbon a limiting substance for bacterial production?
Are there differences in the river and in the estuary?

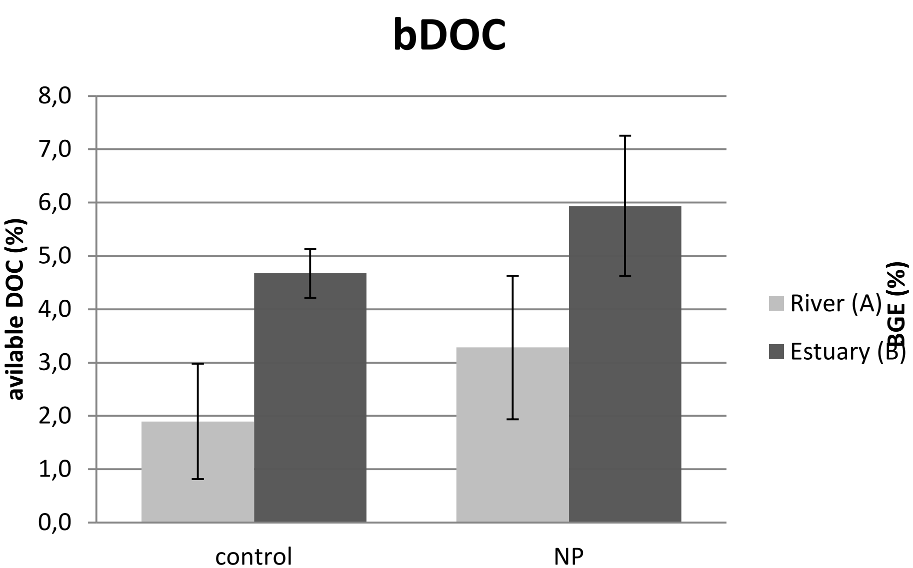
Enrichment experiment:

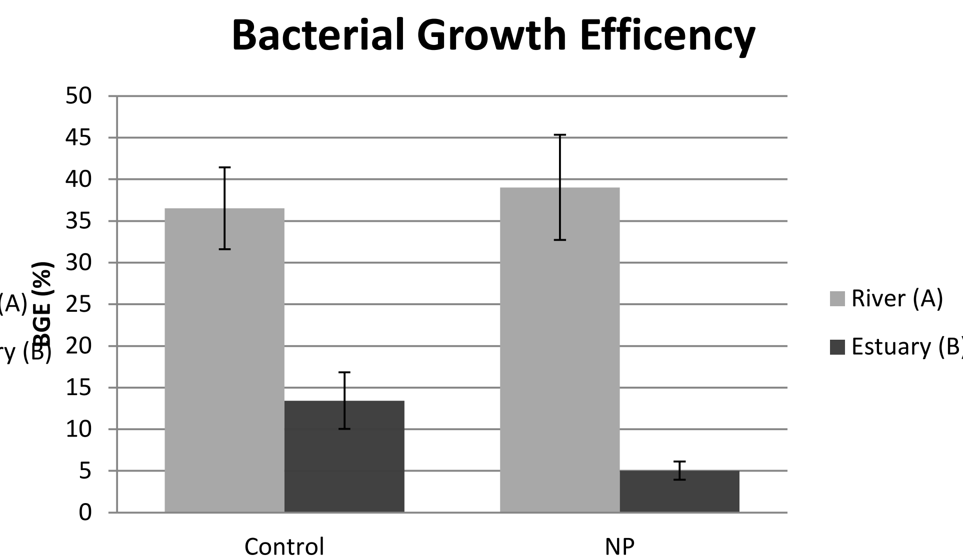
Control
NP enrichment
C enrichment
NPC enrichment



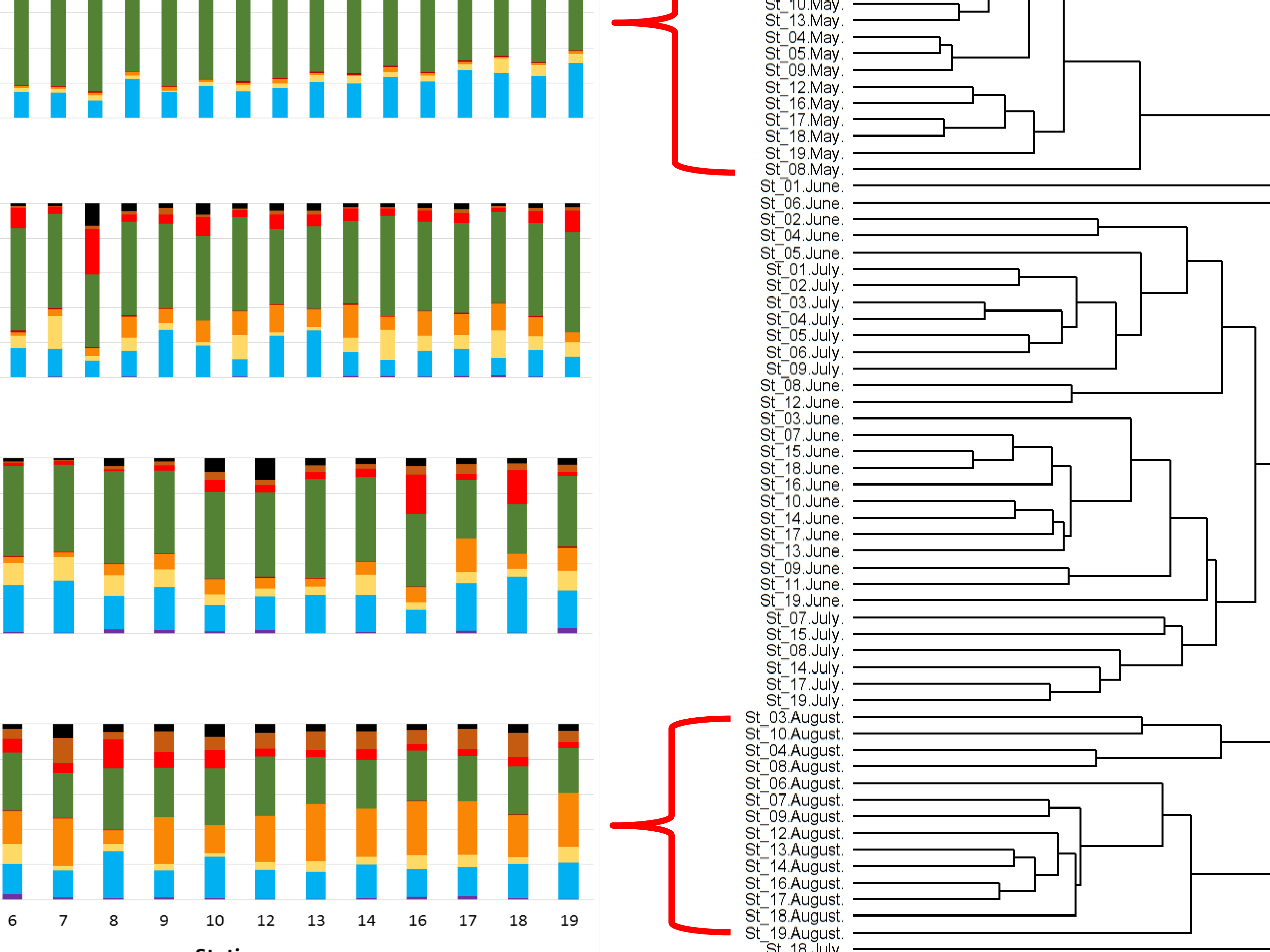
Bacterial production limited by N-P and not by C at both sites







Available carbon higher in the river-mouth.
Bacterial growth efficiency lower in the river mouth. Bacterial metabolism differ: Respiration may be higher in the estuary.



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St_10.May.
St_13.May.
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St_09.May.
St_12.May.
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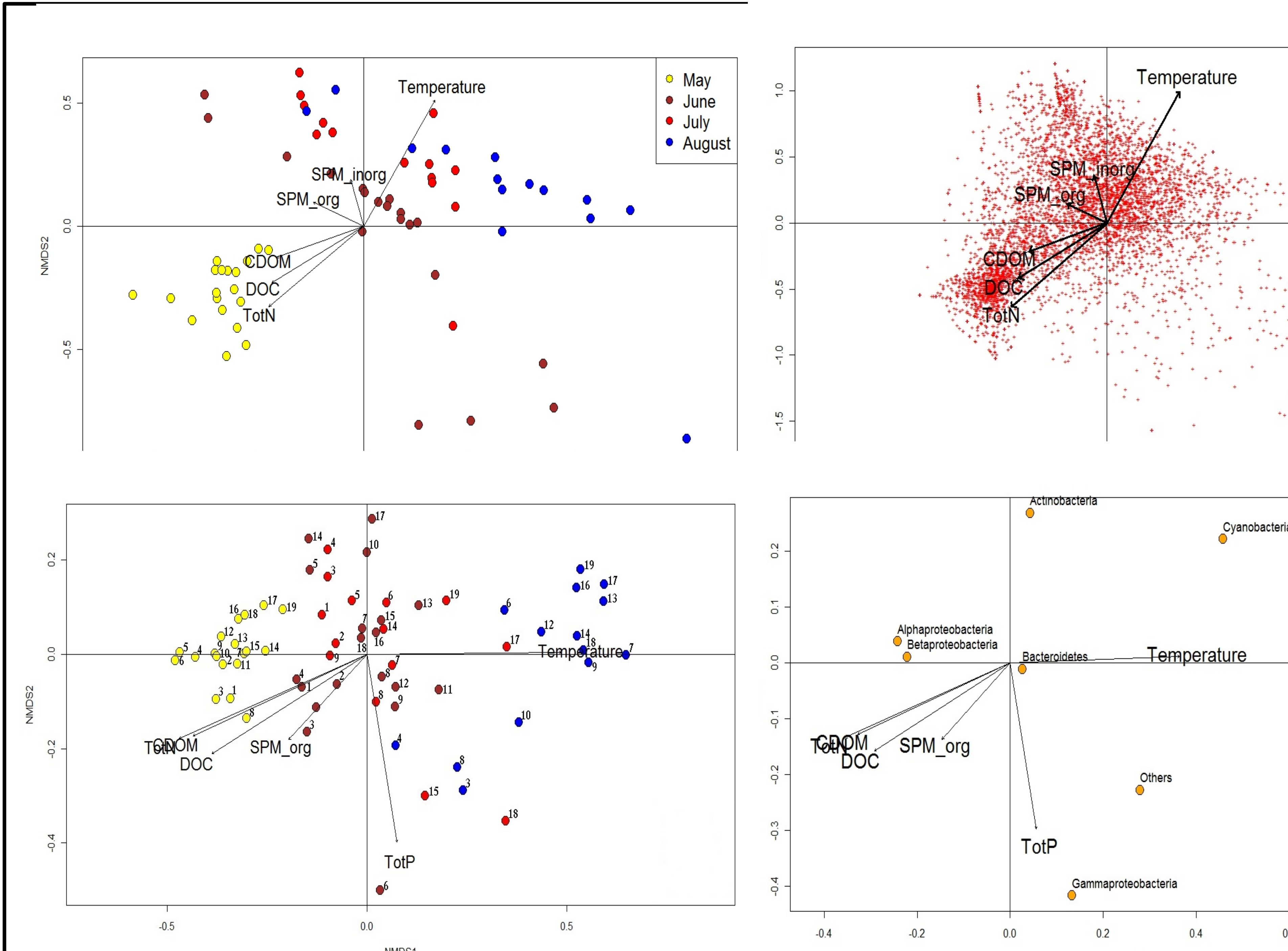
St_18.July



May
June
July
August
Temperature
SPM_inorg
SPM_org
CDOM
DOC
TotN
TotP
NMDS1
NMDS2
Actinobacteria
Cyanobacteria
Alphaproteobacteria
Betaproteobacteria
Bacteroidetes
Others
Gammaproteobacteria

How does increased AOM inputs affect the food web structure, trophic balance and food web efficiency?

Food web structure: E.g. changes at the base: Dominance of bacterial production or primary production. Changes at intermediate tropic levels, e.g. ciliates.

Trophic balance: Prim prod – Bact prod.
Positive values = Autotrophy, Negative values= Heterotrophy

Food web efficiency (FWE) = Top level production / (Prim prod + Bact Prod)

Basal production = Prim prod + Bact prod

Approach:

Mesocosm experiments
Modelling studies
Time series analyses of ecological data

Mesocosm experiments, Pelagic systems:

1. A conceptual study. Effects of food web length (+- fish) and AOM addition (glucose). Tested FWE

2. A climate change scenario: Effects of natural AOM and higher temperature on FWE.

3. A climate change scenario: Effects of natural AOM and higher temperature on intermediate trophic level, Ciliates.

Indoor mesocosm facility (5 m high)at Umeå Marine Sciences Centre. Photo K.Viklund.

Food web interactions determine energy transfer efficiency and top consumer responses to increased allochthonous carbon input.

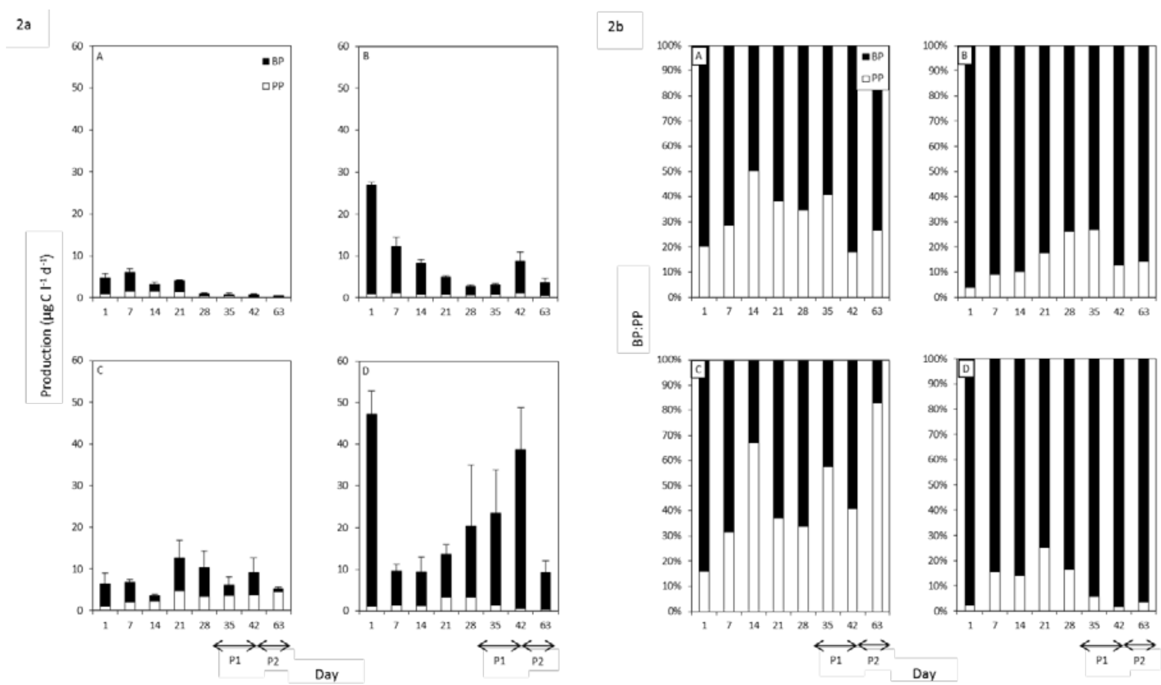
Degerman et al. manuscript

Effects of food web length (+- fish) and AOM addition (glucose)

NP CNP NP CNP

Zooplankton

Fish

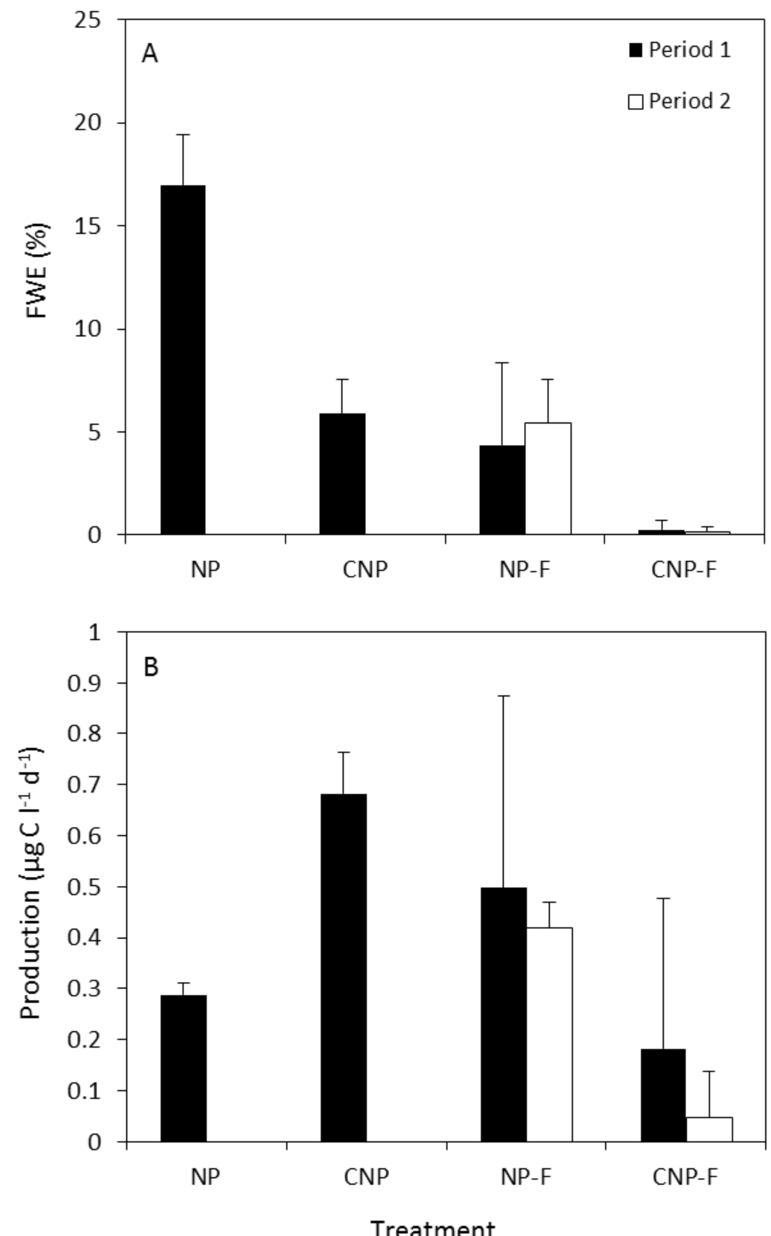


Carbon addition caused lower FWE where Zooplankton was highest level.

Carbon addition caused lower FWE where fish was highest level.

Carbon addition induced higher Zooplankton production.

Carbon addition induced lower fish production



Zooplankton Fish

Conclusions:

Transparent labile AOM can induce higher zooplankton production if energy is significantly channeled both from phytoplankton and bacteria. Primary production is not reduced.

Planktivore fish seems to "reduce" its own production via cascade effects, selectively promoting bacteria, which induce a longer food web. A longer internal food web means more respiratory losses etc.

Impacts of elevated terrestrial nutrient loads and temperature on pelagic food-web efficiency and fish production

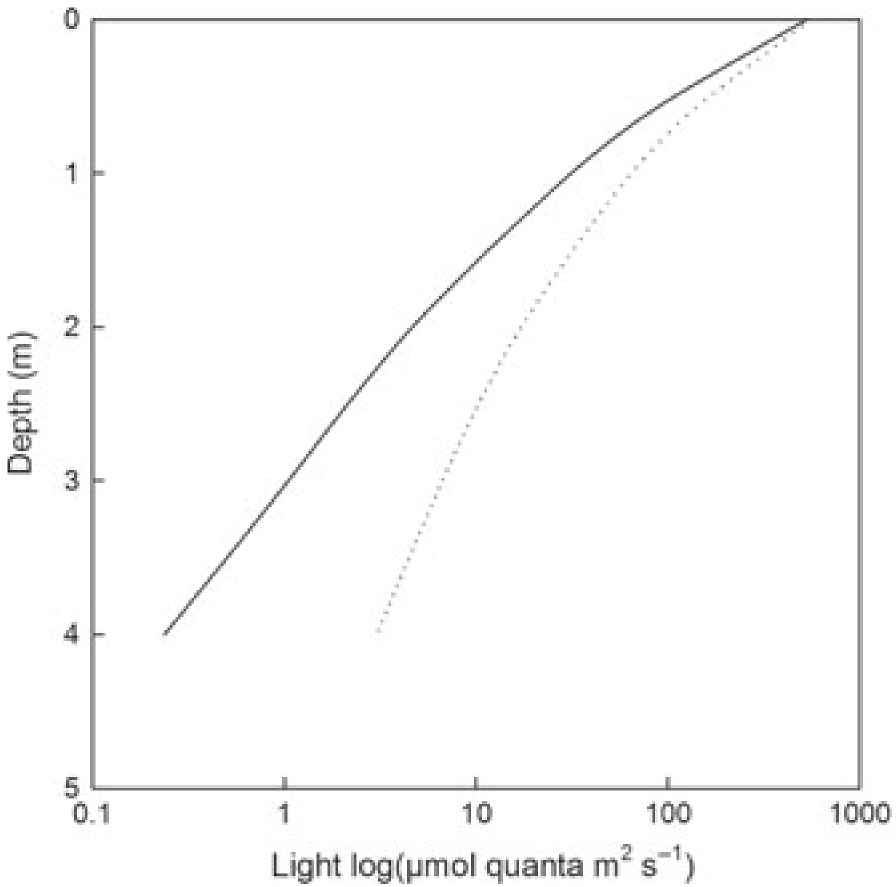
Lefebure et al. 2013, GCB

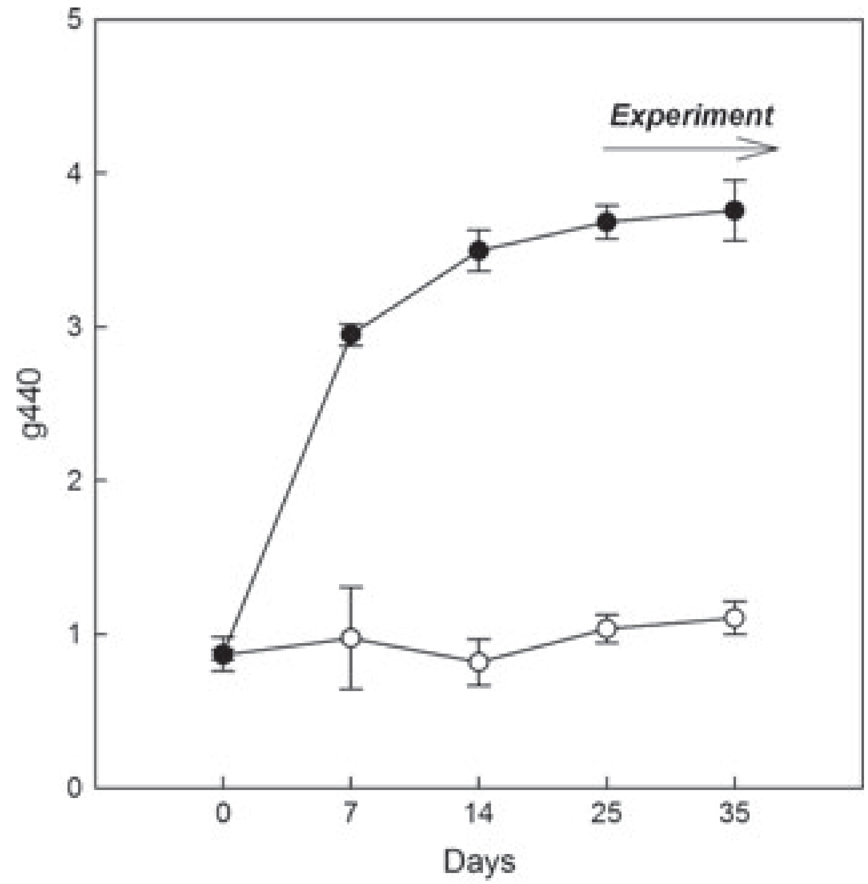
Added natural terrestrial dissolved organic matter (TDM=ADOM) according to the climate change scenario, +30%

Increased temperature 4oC: 15-19oC.

Indoor mesocosm facility at Umeå Marine Sciences Centre used in paper II and III. Photo K.Viklund.

Decreased light due to TDM addition.
TDM concentrations 4 times higher due to TDM enrichment.

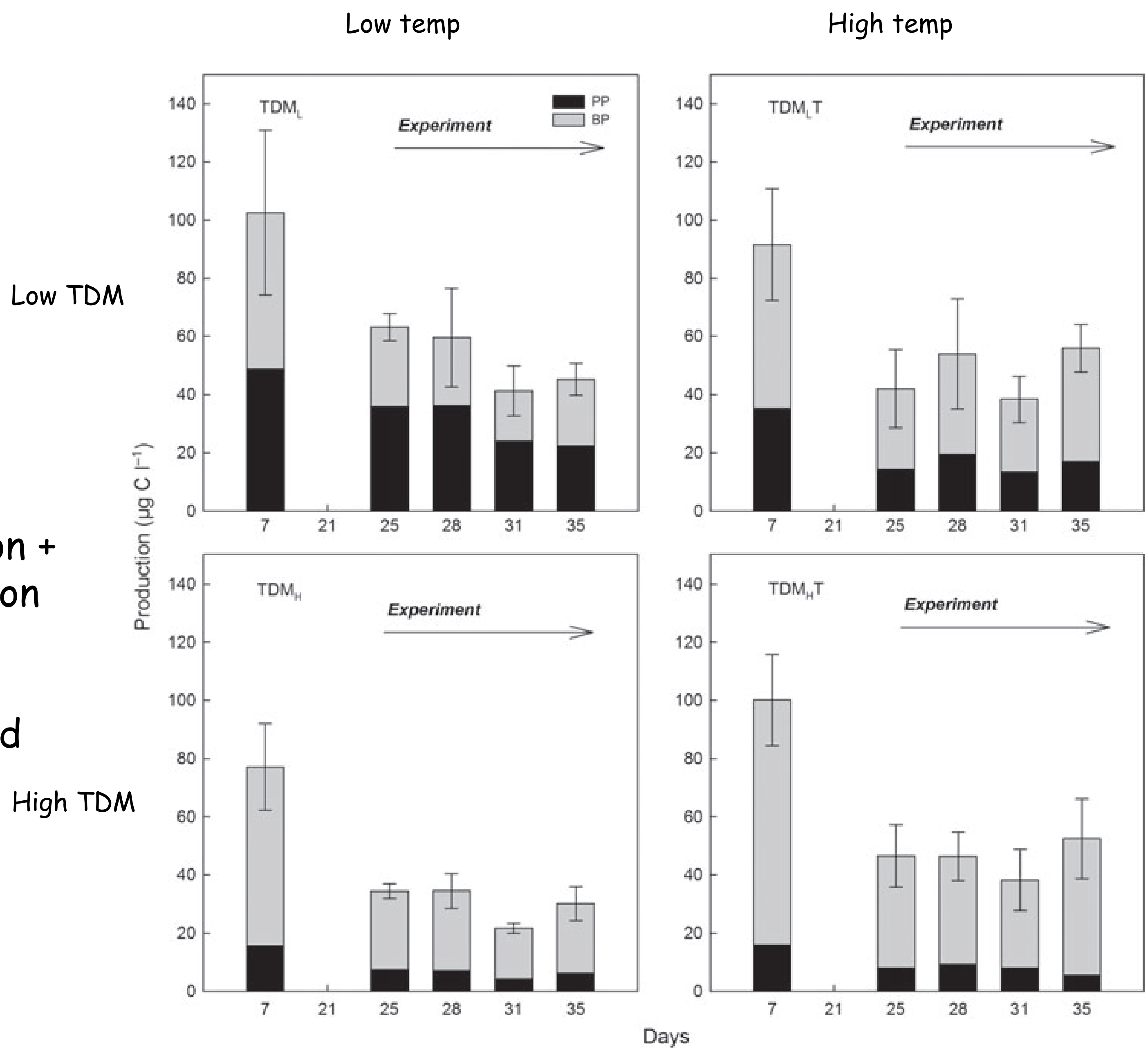




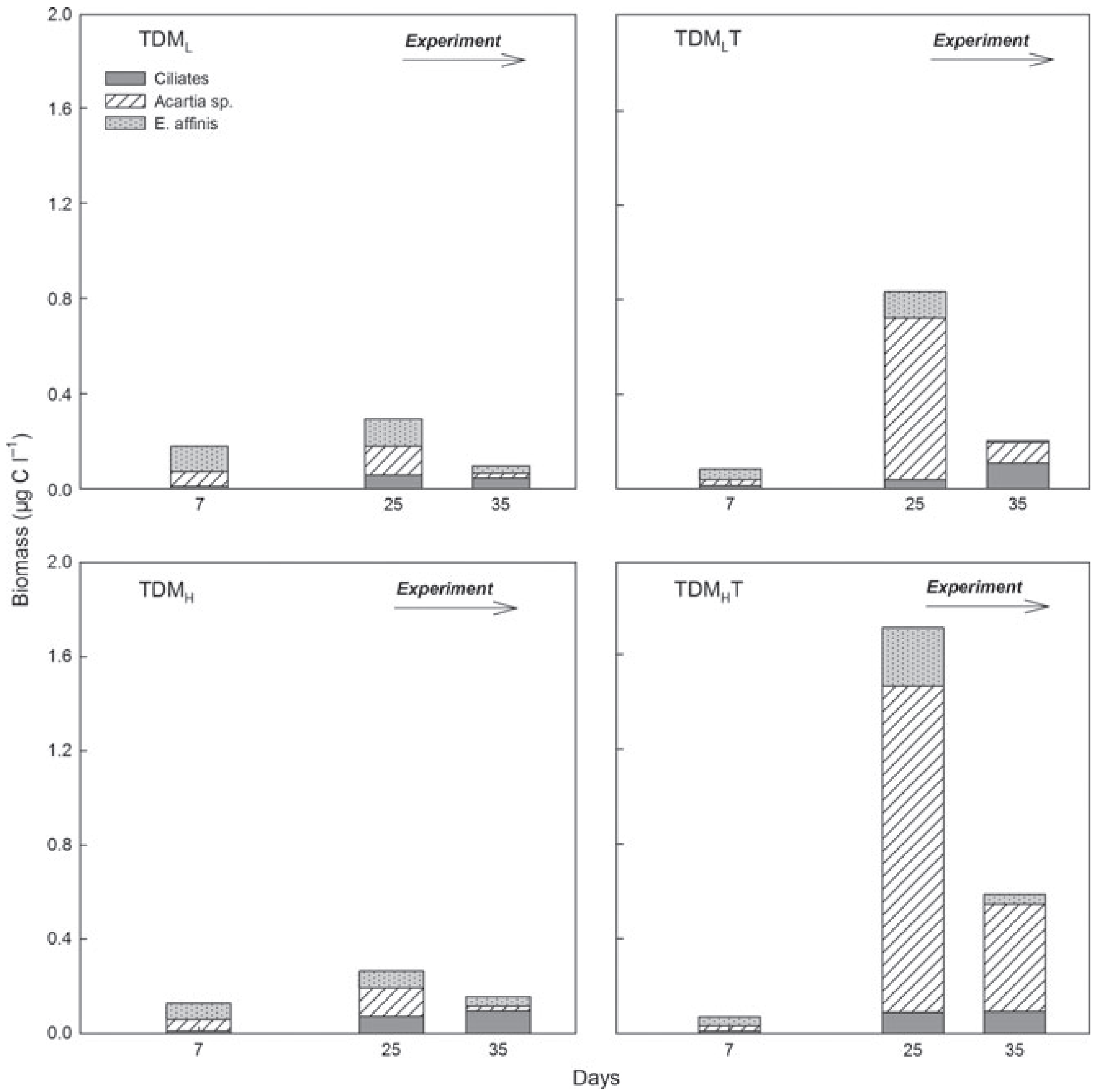
Basal production =

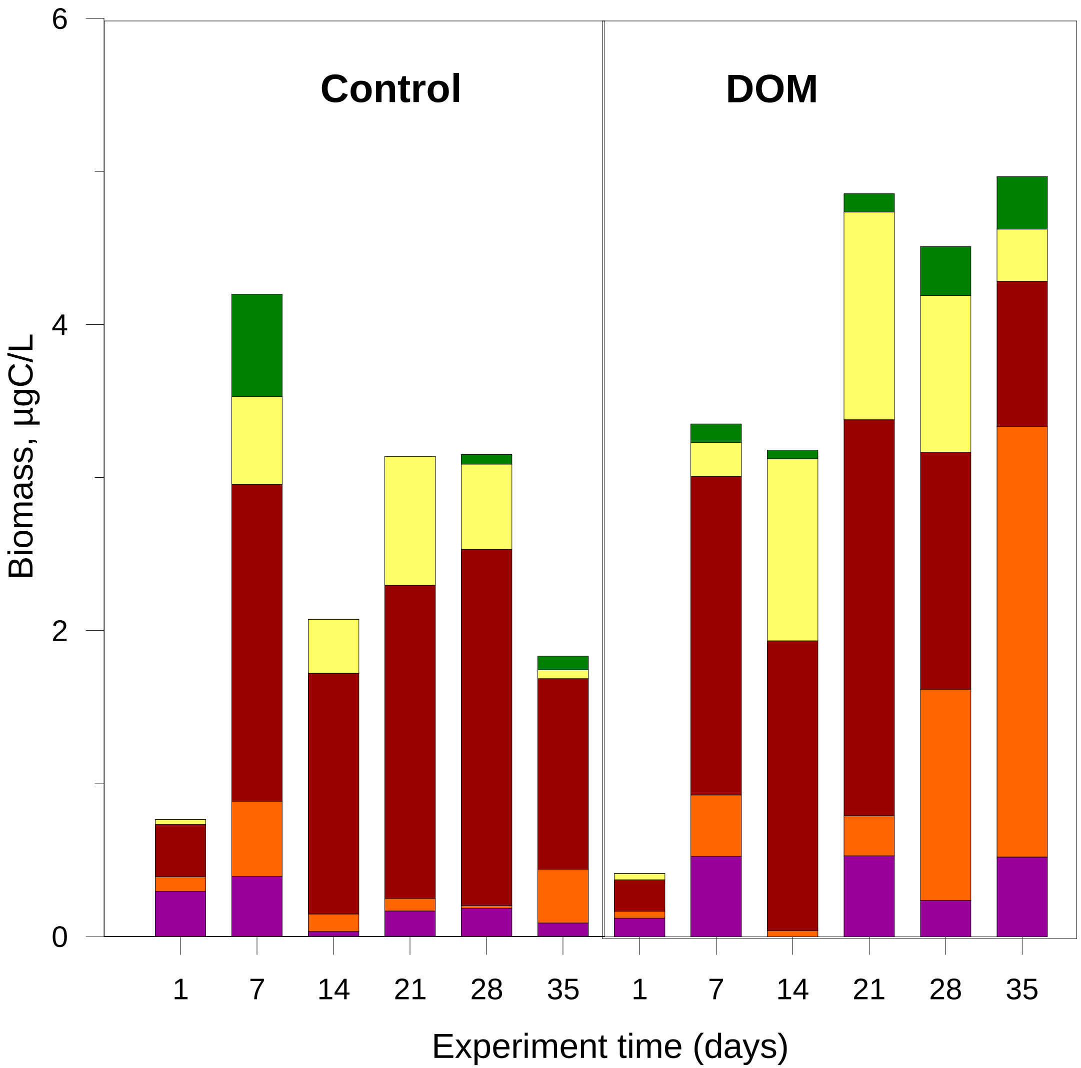
Primary production + Bacterial production

TDM (AOM) decrease prim prod and increase bact prod



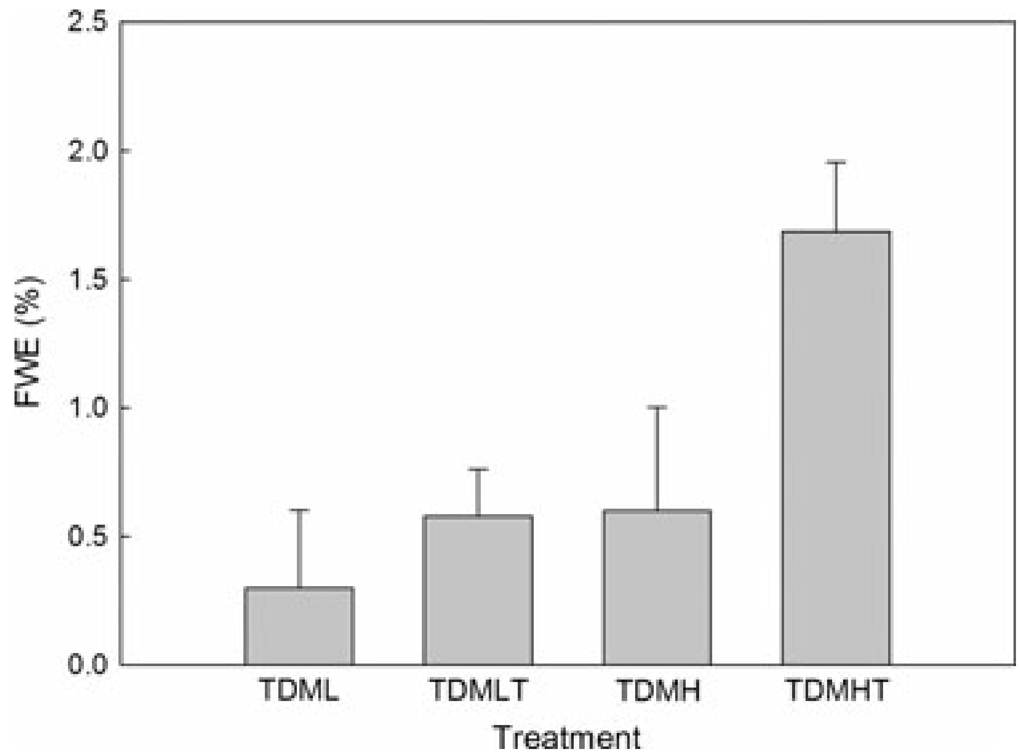
High TDM (AOM) and high temperature stimulate ciliates and mesozooplankton





Omnivorous ciliates promoted.

High TDM inputs and high temperature caused higher fish production and Food Web Efficiency



Conclusion:

Colored natural TDM (AOM) can stimulate fish production even though primary production is lowered and bacterial production is promoted.

Modelling effects of increased river inflow of dissolved organic carbon on coastal production

Degerman et al. Manuscript

Dynamic ecosystem modelling tool developed in collaboration with the comapny BIORAS, Denmark.

Driven by diffusion uptake of dissolved substances, photosynthesis, clearance rates.

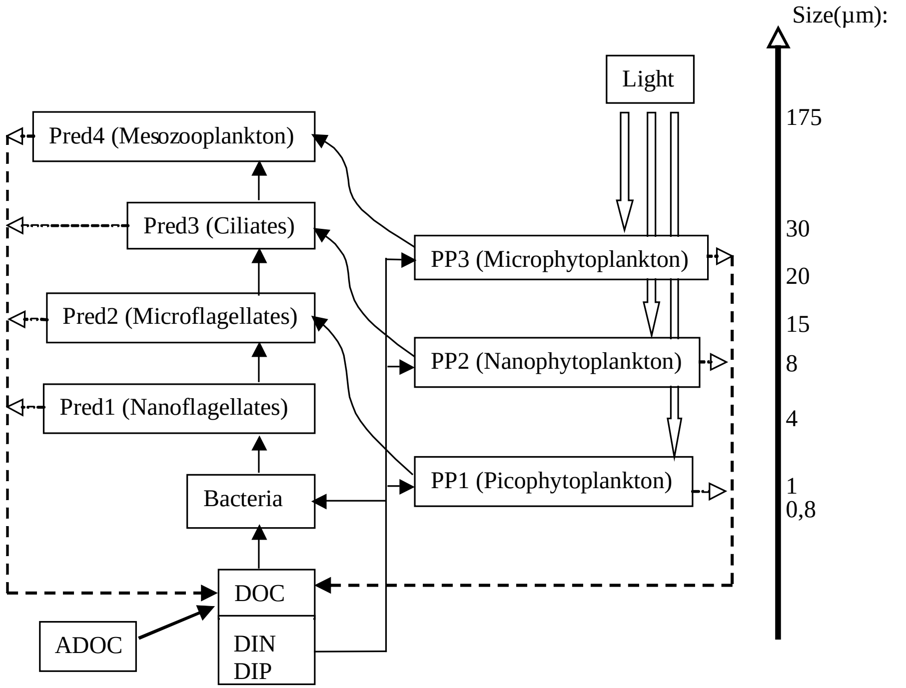
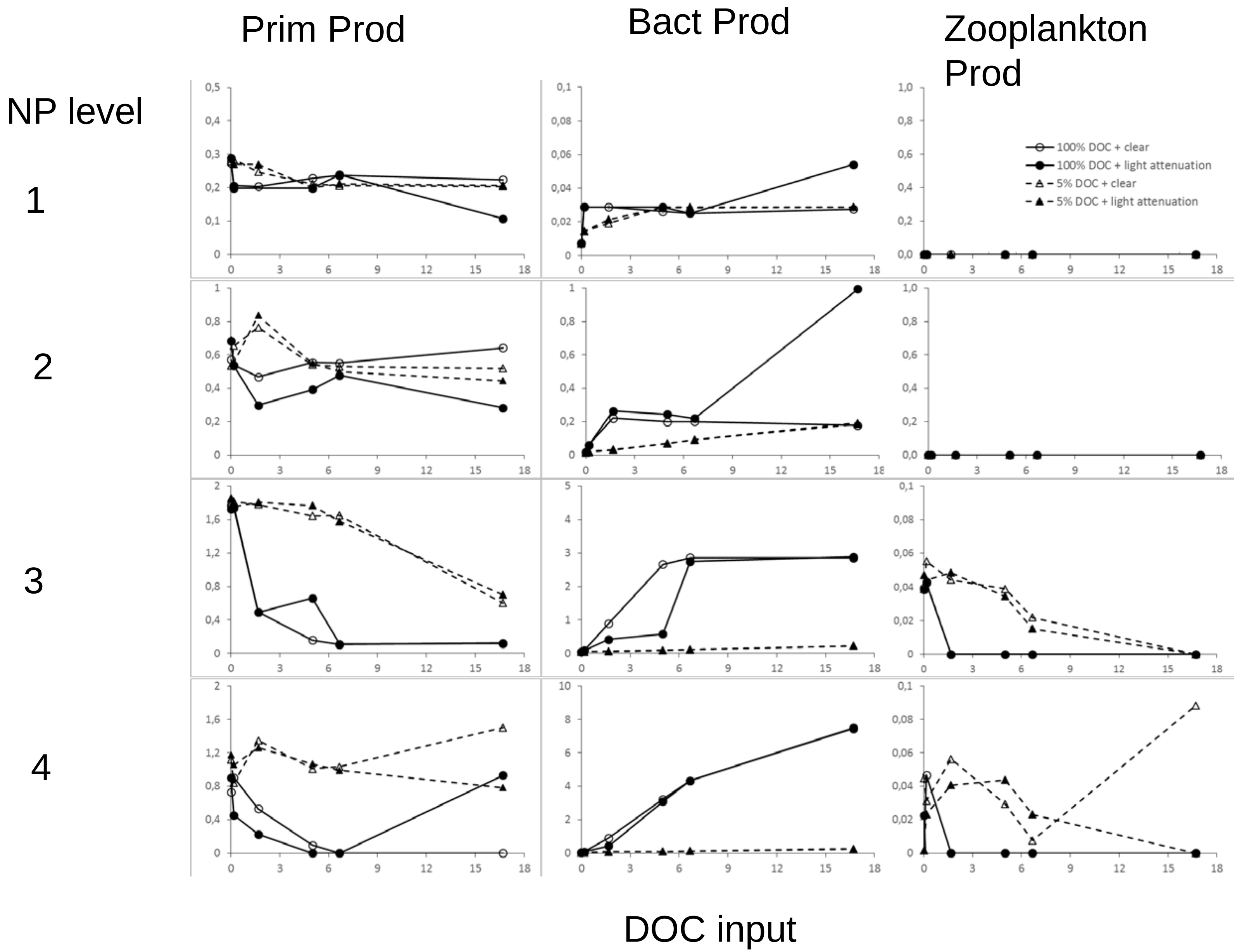


Table 4: Additions of dissolved organic carbon (DOC) and levels of photosynthetically active radiation (PAR) in the model simulations.

DOC inputs:	$DOC_{0\%}$ (µmol C L^{-1} d^{-1})	$DOC_{100\%}$ (µmol C L^{-1} d^{-1})	$DOC_{5\%}$ (µmol C L^{-1} D^{-1})	PAR clear DOC (µmol quanta m^{-2} s^{-1})	PAR colored DOC (µmol quanta m^{-2} s^{-1})
1	0	0	0	100	100
2	0	0.2	0.01	100	98
3	0	1.7	0.08	100	85
4	0	5.0	0.2	100	61
5	0	6.7	0.34	100	51
6	0	16.7	0.83	100	19

NP inputs:	DIN (µmol N L^{-1} D^{-1})	DIP (µmol P L^{-1} D^{-1})
1	0.065	0.002
2	0.325	0.008
3	0.650	0.017
4	1.301	0.034

Run the model until equlibrium, calculate production, trophic balance and food web efficiency.


Prim Prod
Bact Prod
Zooplankton Prod
NP level
1
2
3
4
100% DOC + clear
100% DOC + light attenuation
5% DOC + clear
5% DOC + light attenuation
DOC input

DOC input cause heterotrophy

But depends on bioavailability of DOC

Food Web Efficiency negatively affected by DOC inputs

Trophic balance

FWE

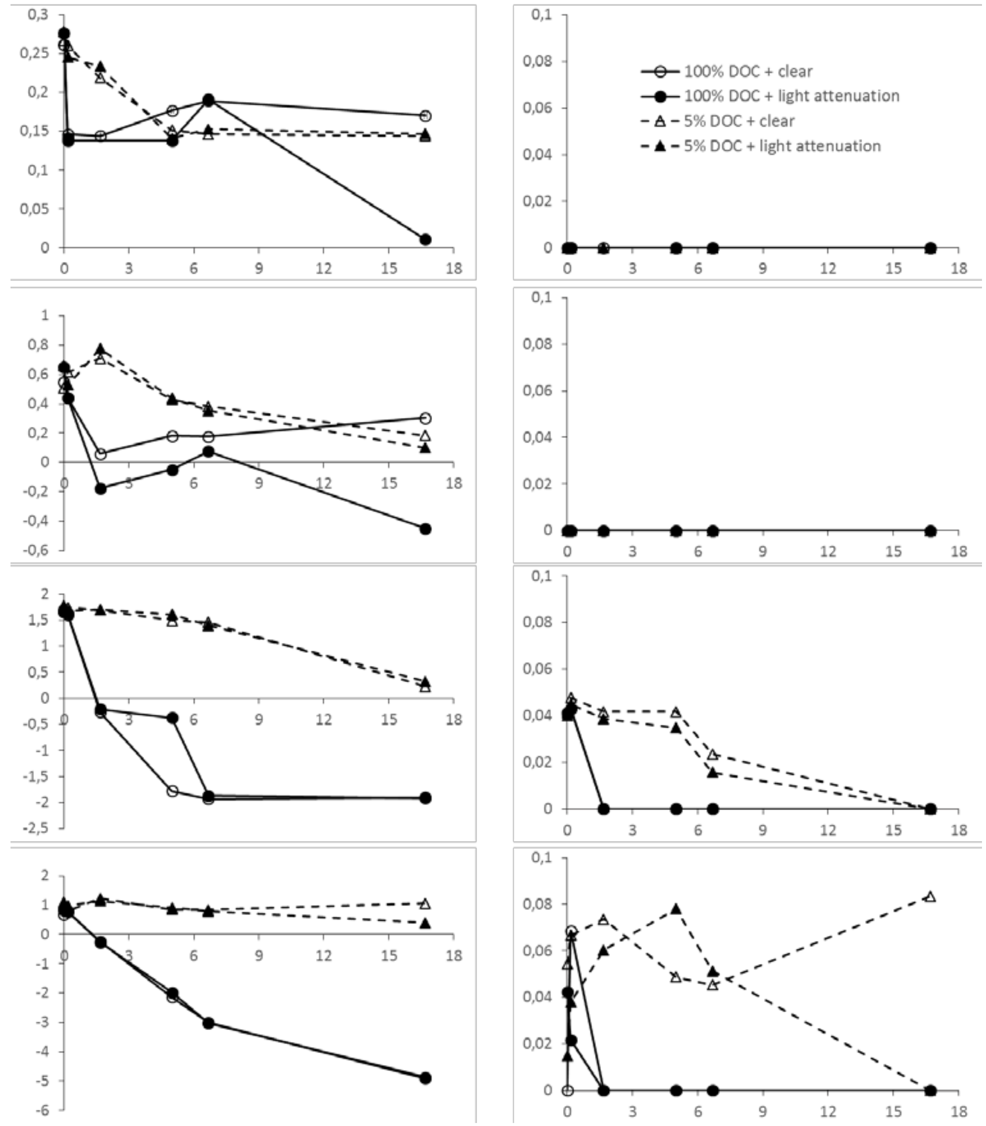
NP level

1

2

3

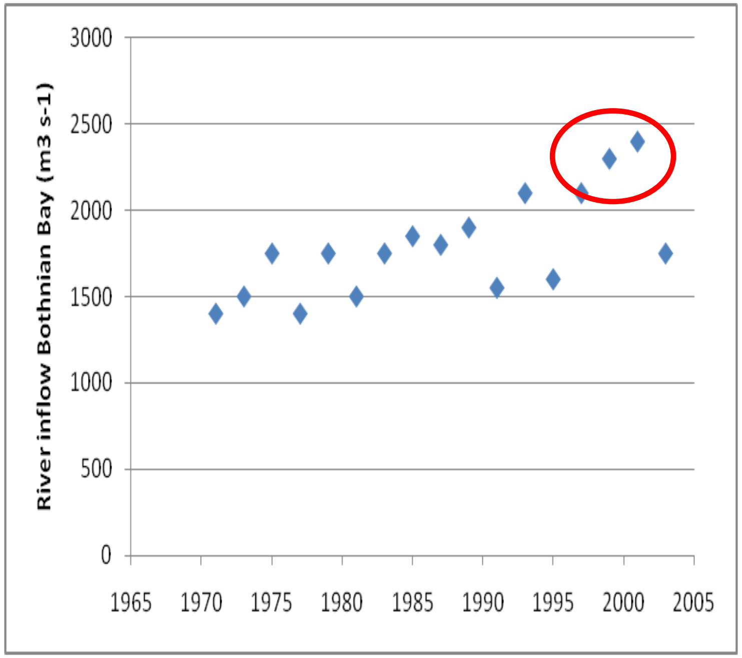
4

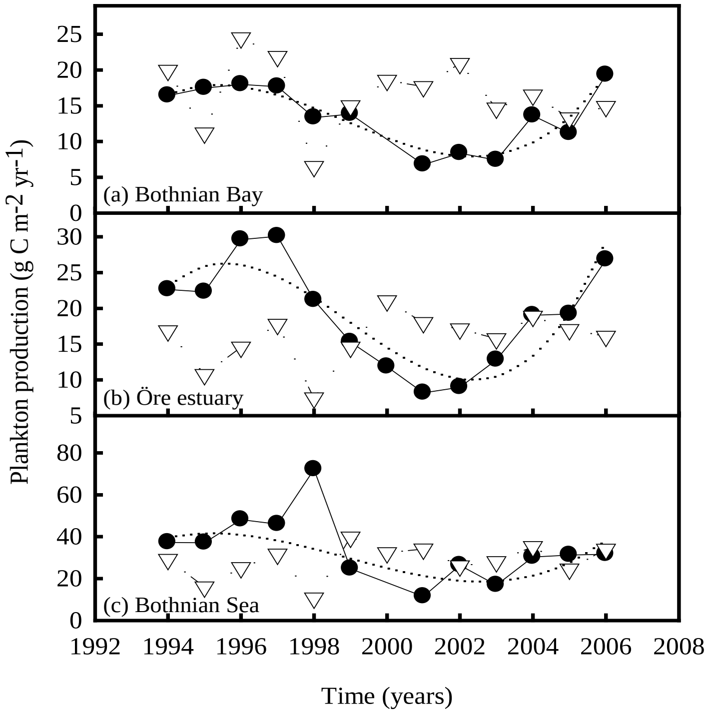


DOC input

- **Conclusions of empirical and modelling experiments:**
- Climate induced inputs of AOM to coastal areas may lead to structural changes in the food web where heterotrophs are promoted, e.g. heterotrophic bacteria and ciliates.
- Net heterotrophy
- Increased AOM inputs may cause decreased FWE in shallow coastal systems, which may lead to lower fish production.

Time series analysis in the Gulf of Bothnia





Large river inflow during 90´s.

Primary production decreased in the entire Gulf of Bothnia

Bacterial production increased.

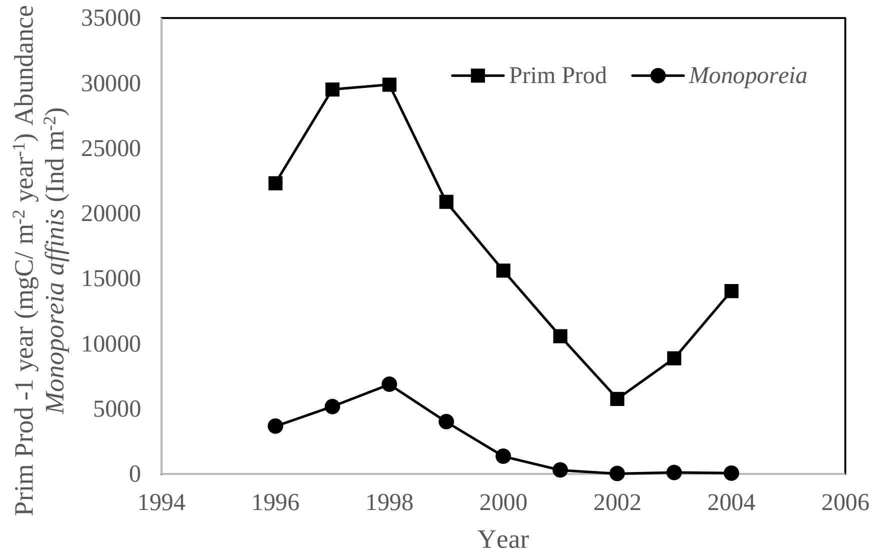
Wikner and Andersson GCB 2013

Did any other group of organism change during the rainly period 1998-2002?

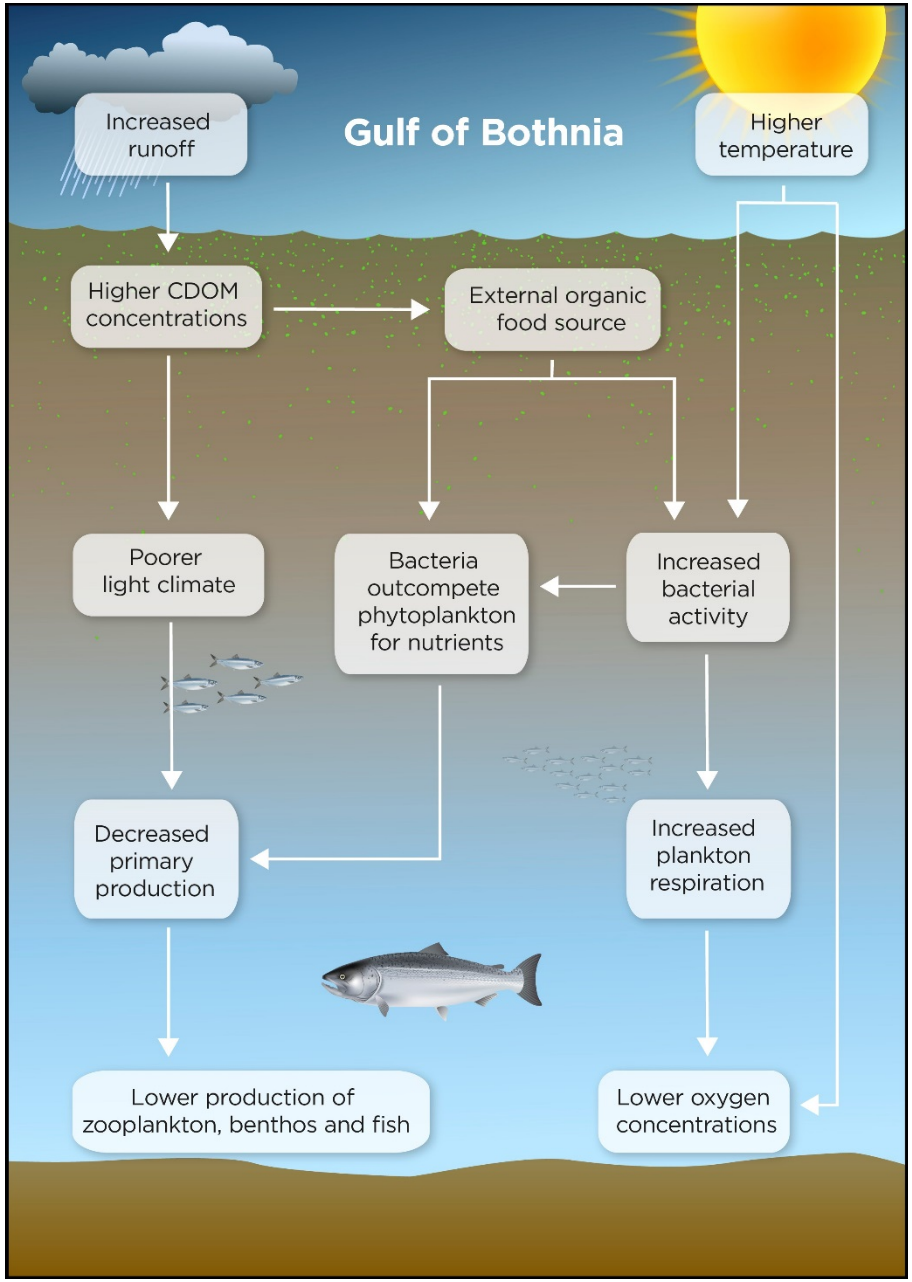
Monoporeia decreased due to decreased food availability (decreased primary production)

This led to possibility by the polycaete to invade the system.

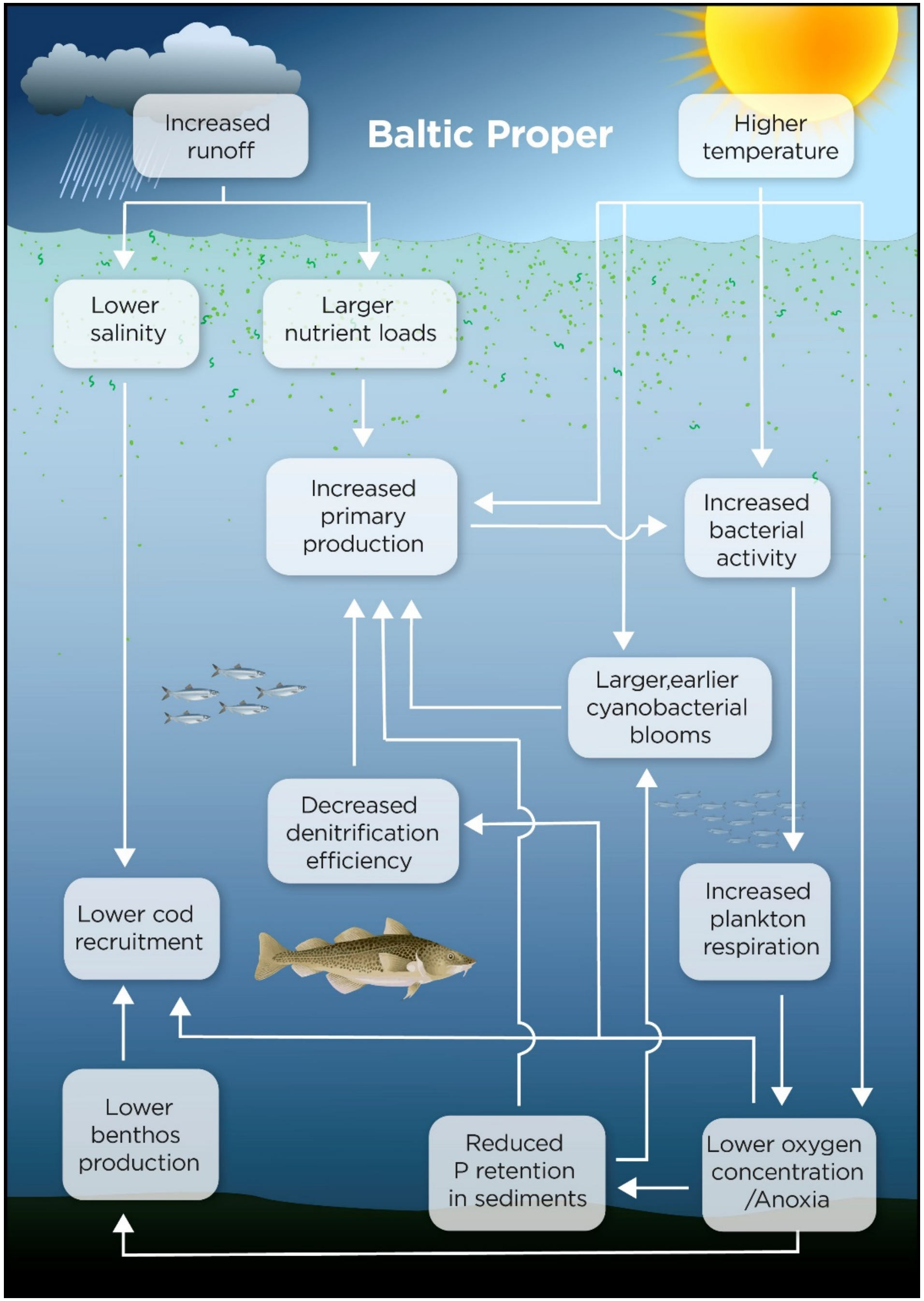
This may have led to a new "equilibrium" in the system. The amphipod recovers slowly.



Eriksson-Wiklund and Andersson ECSS 2014



Andersson et al. Ambio 2015



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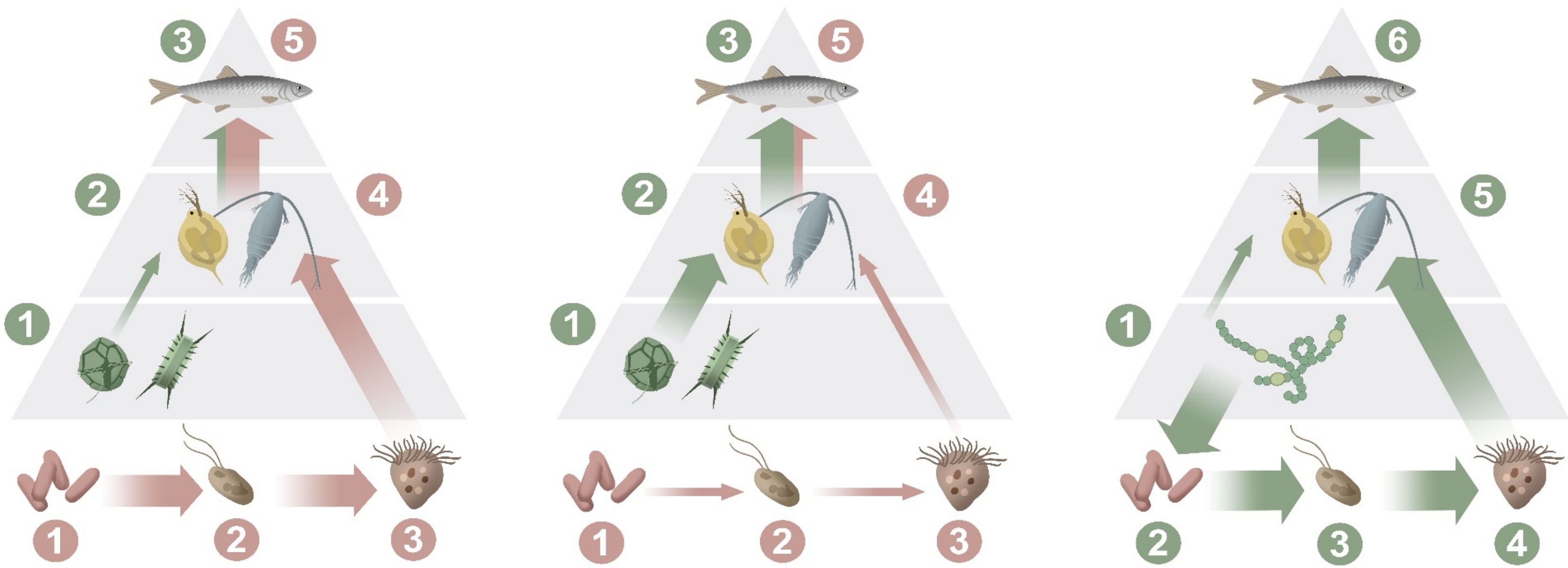
Future: Bothnian Bay | Present | Future: Baltic proper



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Ecosystem management

Climate change induce complex and interactive alterations in the Baltic Sea

It is crucial that future Baltic Sea management is ecosystem-based.

Increased inflow of terrestrial organic matter (AOM: humic substances, DOC, CDOM) can:

Increase chlorophyll a, but decrease primary production
Promoted bacterial activity (respiration)
Lower oxygen concentration.
Increase inflow of organic pollutants

Therefore monitor not only nutrients, chlorophyll a and primary production, but also AOM variables and organic pollutants in the Baltic Sea.

Andersson et al. Ambio 2015

Thank you for listening!