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Tools

Atmospheric data

Catchment data

Riverine and marine data

BaltSem marine model

Marine model

Watershed model

Fish model

Cost calculation

File



Forcing

Results

Account:

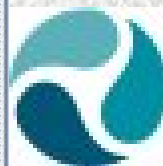
VIII BSSC 2011, St. Petersburg, 22-26 August 2011

BALTSEM - a marine model for decision support at the Baltic Sea

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Bo G. Gustafsson

Bärbel Müller-Karulis



Baltic Nest
Institute



UUID:

Baltic Nest Institute, Stockholm University

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The Baltic Sea Action Plan

A new environmental strategy
for the Baltic Sea region



Helsinki Commission
Baltic Marine Environment Protection Commission

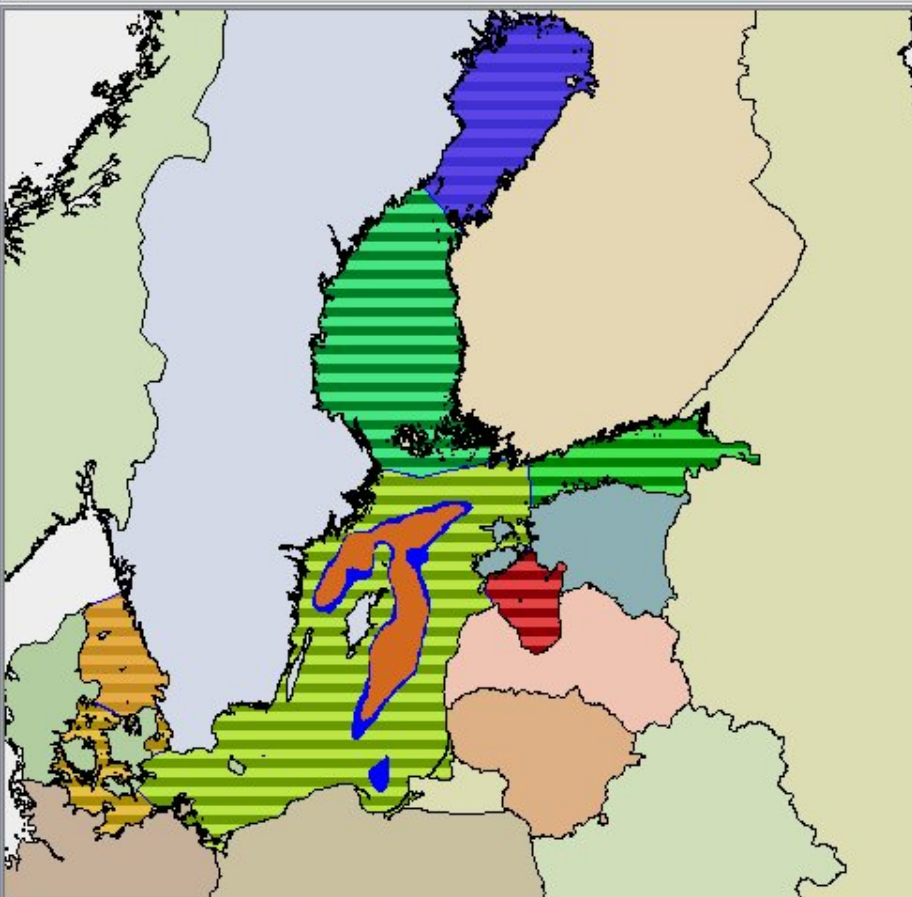
Eutrophication segment of the BSAP:

- ❖ *is based on allowable nutrient inputs from the land of 600,000 tonnes nitrogen and 21,000 tonnes phosphorus annually*
- ❖ *with actual average (1997-2003) land loads of 737,720 t TN and 36,310 t TP the total required reductions are about 135,000 t TN and 15,000 t TP*
- ❖ *these numbers have been estimated with the marine biogeochemical model SANBALTS, which is a component of the decision support system Baltic Nest*

Tools

Cost calculation Marine model Watershed model Fish model Riverine and marine data EMEP data

File



Palette

Flip



Min Step Max
21.32 0.10 259.52

Primary production

Draw

#0: Contemporary

#1: BSAP

☒ Automatically calculate Min and Max values for the palette

Hypoxic area: #0 = 41974, #1 = 26928 Difference = +15045.5 [km²]

Forces

Atmospheric depositions

Loads from Skagerrak

River loads

Point sources loads

	Labile Org...	Stable Or...	Inorganic N	Labile Org...	Stable Org...	Inorganic P
Bothnian ...	7114	28455	15867	1549	172	864
Bothnian ...	8192	24576	24018	1371	152	934
Baltic Pro...	34672	81900	116686	3731	1081	1934
Gulf of Fin...	15116	45350	46214	3401	489	970
Gulf of Riga	12680	23548	42174	588	93	749
Danish St...	3888	5832	21173	653	73	684
Kattegat	7177	10765	26315	862	96	615

<http://nest.su.se/nest>

Comment: BSAP

Calculate

Result

Variables

Biogeochemical fluxes

Transport

Network analysis

	Total N	Total P	Transparency
Bothnian Bay	22.5	0.2	5.8
Bothnian Sea	19.5	0.4	7.0
Baltic Proper: 0 - 60m	18.5	0.5	7.0
Gulf of Finland	24.6	0.6	6.0
Gulf of Riga	41.6	0.7	4.5
Danish Straits	18.9	0.6	7.7
Kattegat	17.0	0.6	8.5
Baltic Proper: 60m - ...	20.9	1.5	

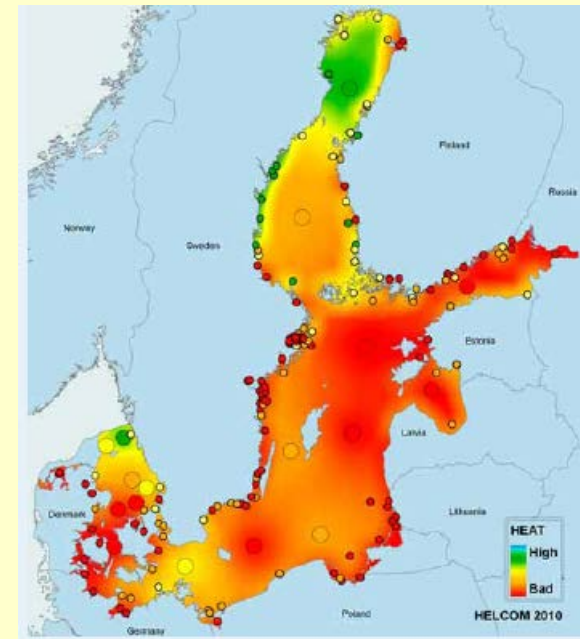
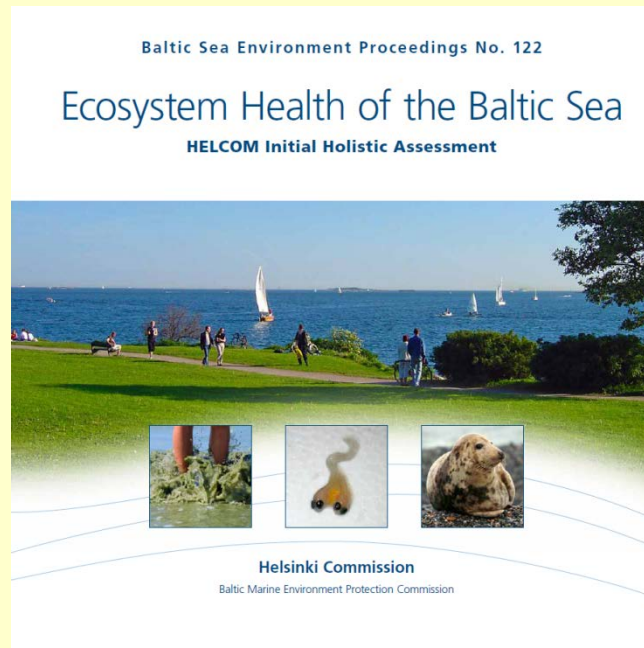
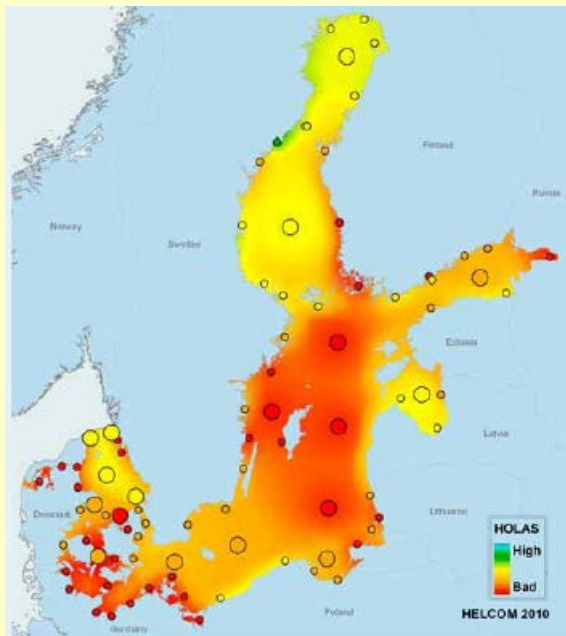
SANBALTS, validated and published

#1: BSAP

Clear history

State of **ART**: within EAM an important role in defining ES and EO set forward, e.g. by BSAP, MSFD, WFD, UWWTD, ND and many other acronyms to come, belongs to some conventional numbers that are used for relevant painting. Often, such numbers include winter surface nutrients and summer chlorophyll, i.e. seasonally varying indicators. Concurrently, climate fluctuations in a system with long residence times demand multi-decadal time scales

Policy driver	Status classification				
	Unaffected/Acceptable		Affected/Unacceptable		
HELCOM BSAP	Unaffected by eutrophication		Affected by eutrophication		
MSFD	Good Environmental Status		Polluted		
WFD	High ES	Good ES	Moderate ES	Poor ES	Bad ES
UWWTD	Unpolluted/non-sensitive		Polluted/sensitive		
ND	Unpolluted		Polluted		

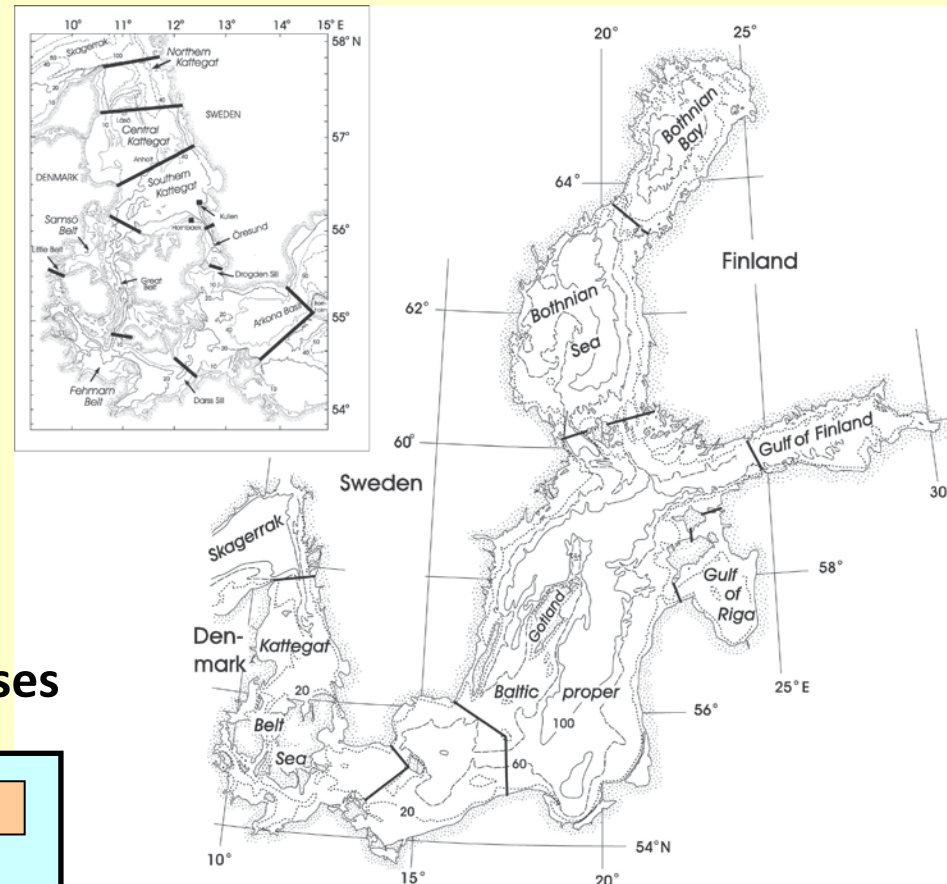
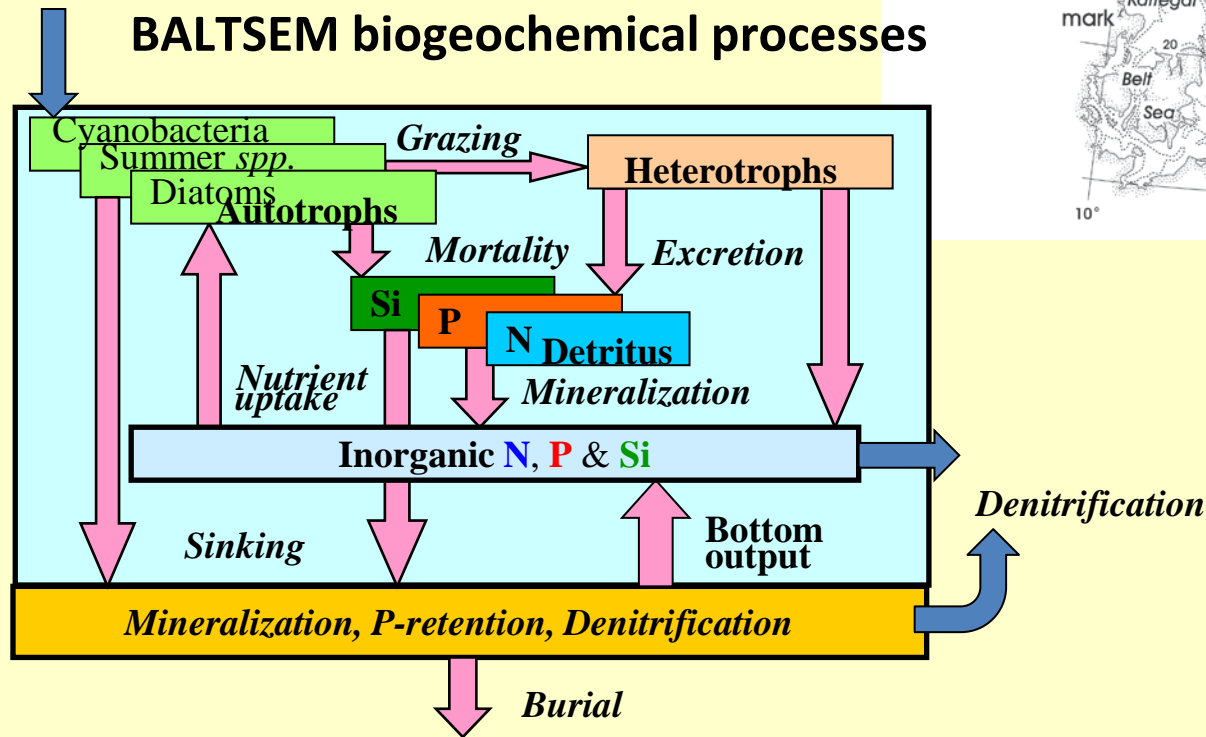


BALTic sea Long-Term large-Scale Eutrophication Model

Main characteristics:

- 13 sub-basins
- High vertical resolution
- Water exchange between- and water mixing within sub-basins are described from well-founded HD principles
- Meteorological and nutrient loading boundary conditions are reconstructed from the best available data, here for 1970-2006

Nitrogen fixation



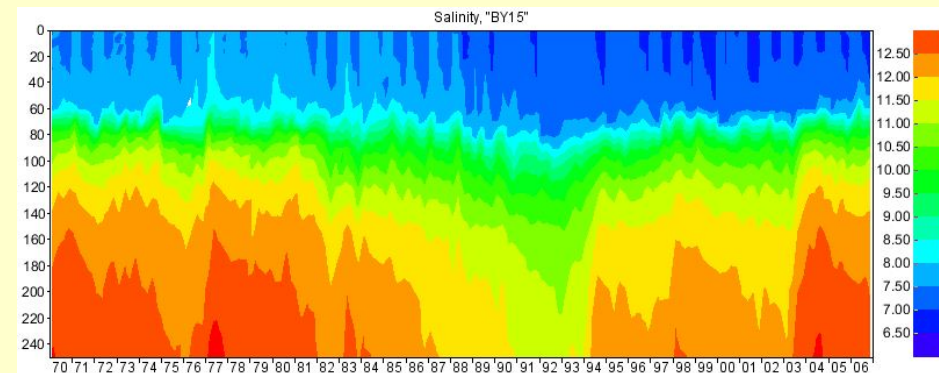
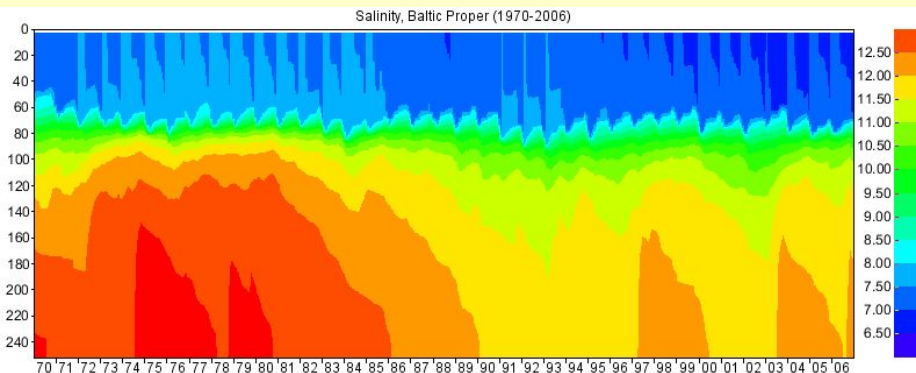
Sub-basin boundaries

Long-term dynamics in the Gotland Sea (1970 – 2006)

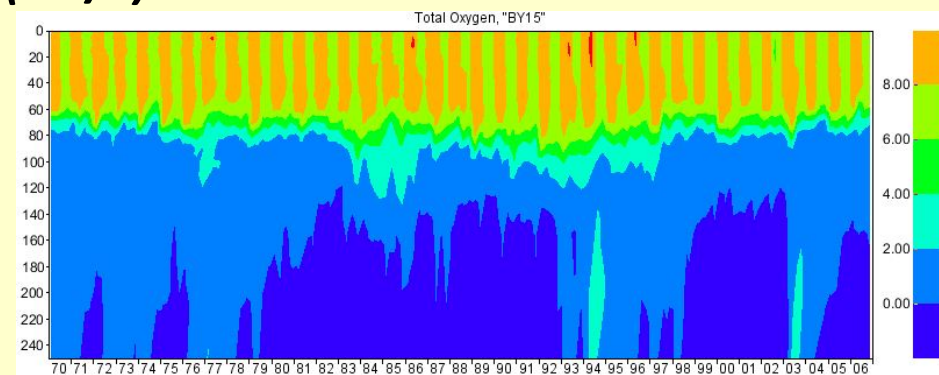
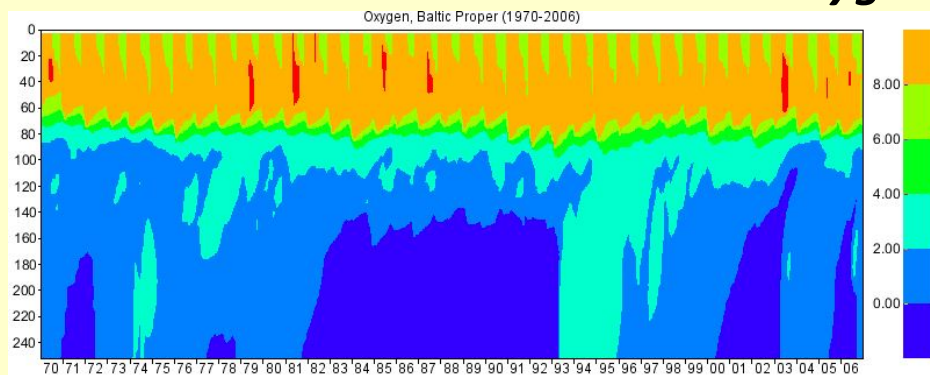
Simulation

Observations

Salinity (psu)



Oxygen (mL/L)

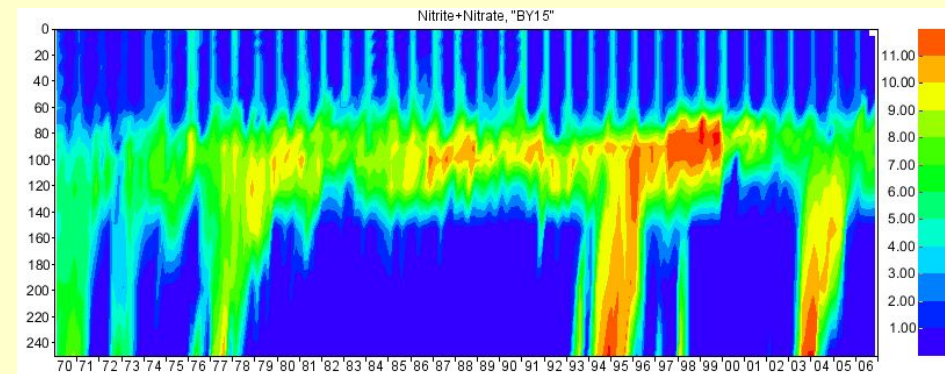
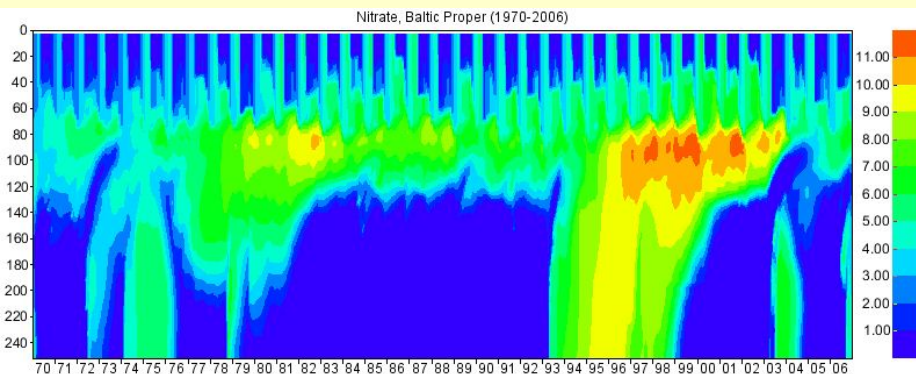


Long-term dynamics in the Gotland Sea (1970 – 2006)

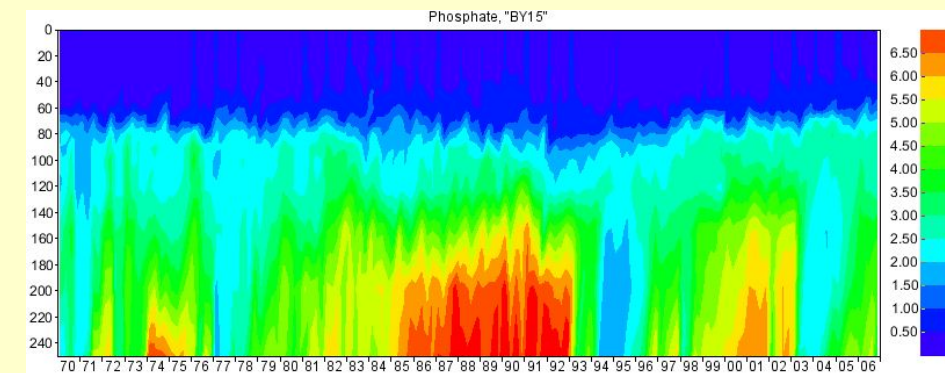
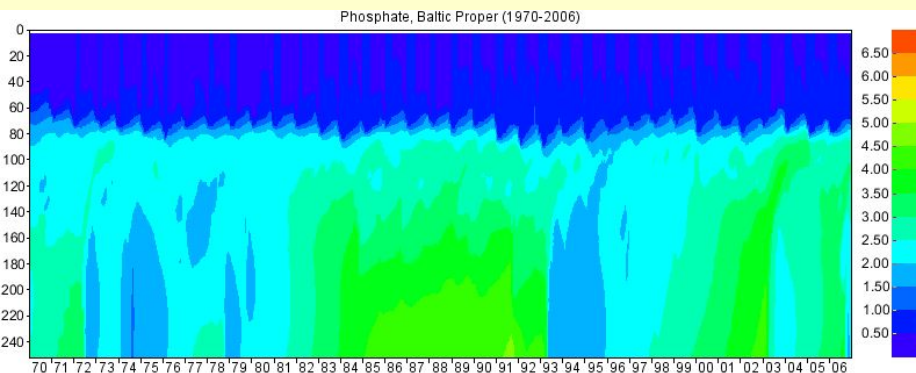
Simulation

Observations

Nitrate (μM)

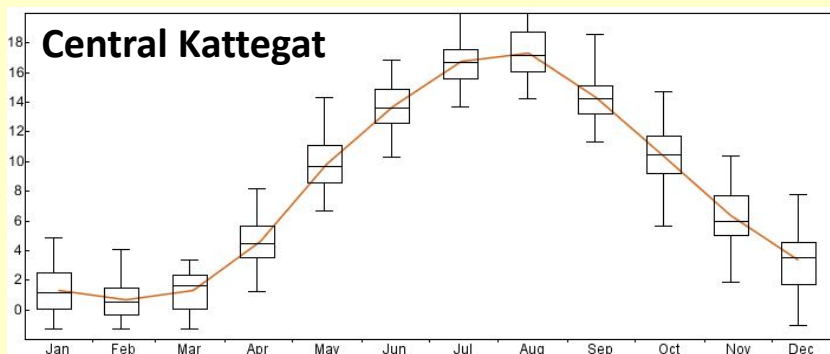
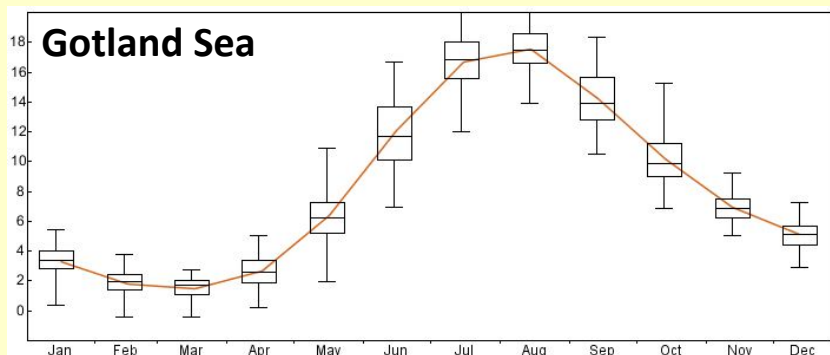
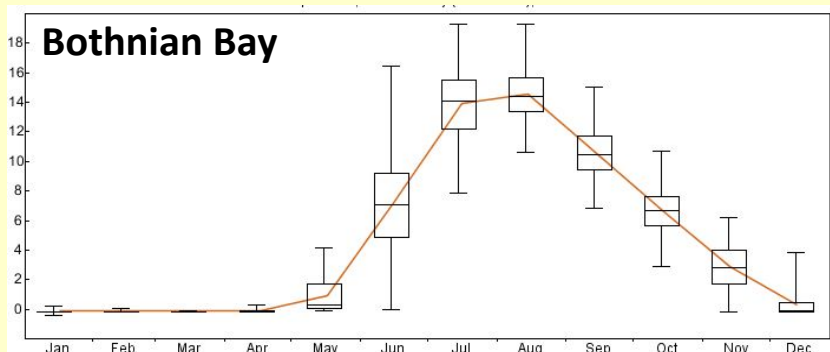


Phosphate (μM)

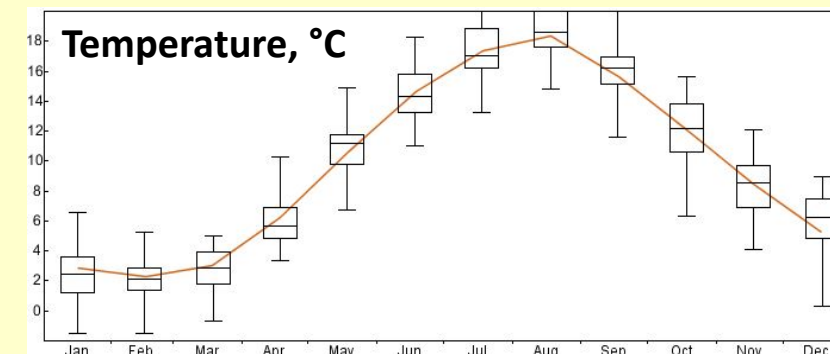
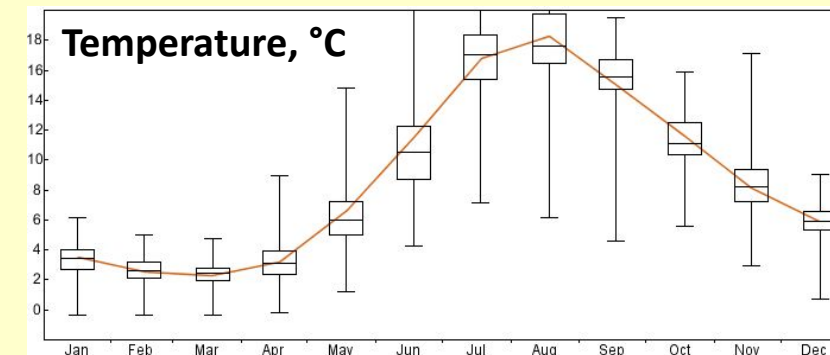
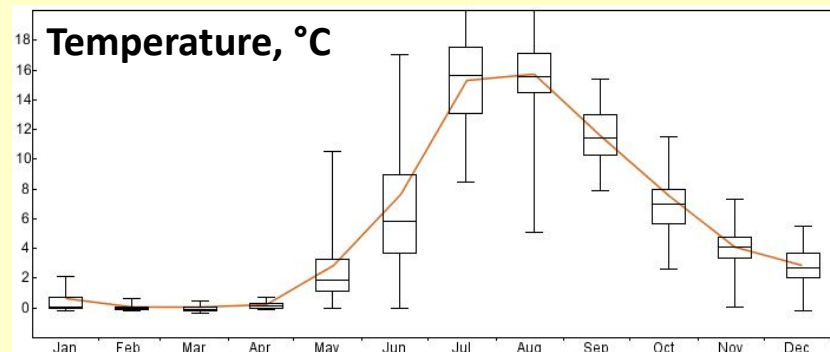


Meridional gradients of seasonal dynamics

Simulation

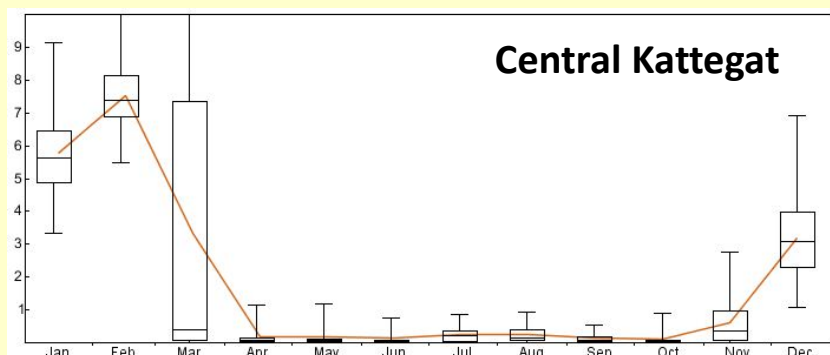
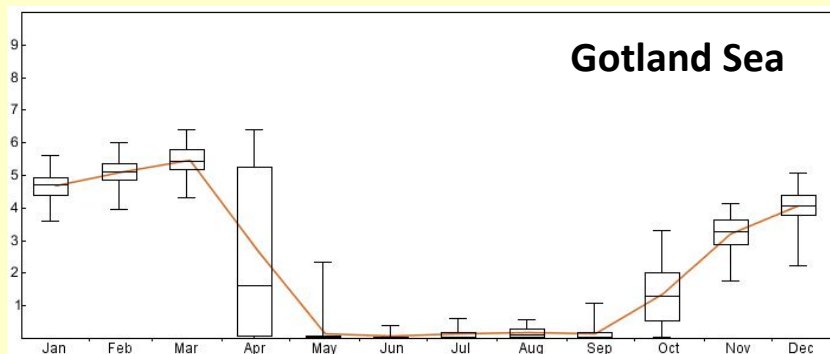
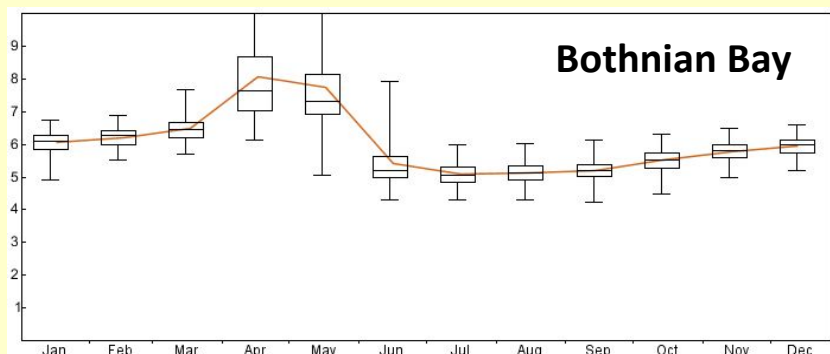


Observations

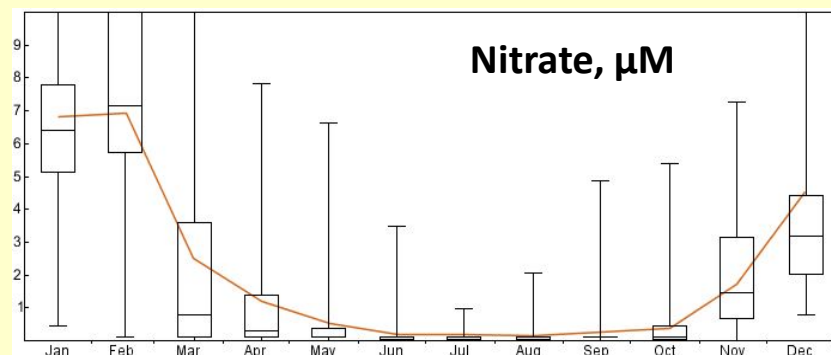
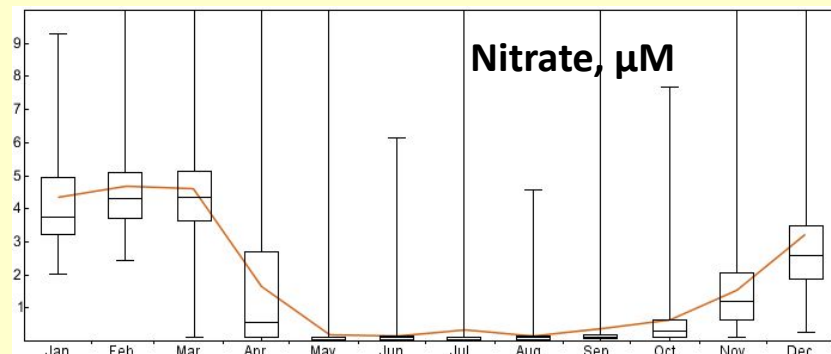
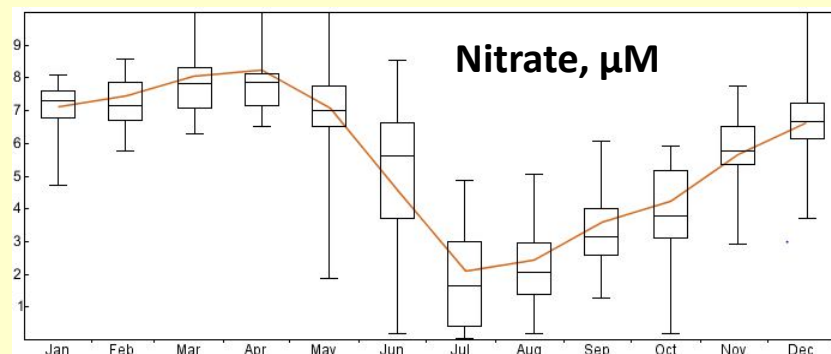


Meridional gradients of seasonal dynamics

Simulation

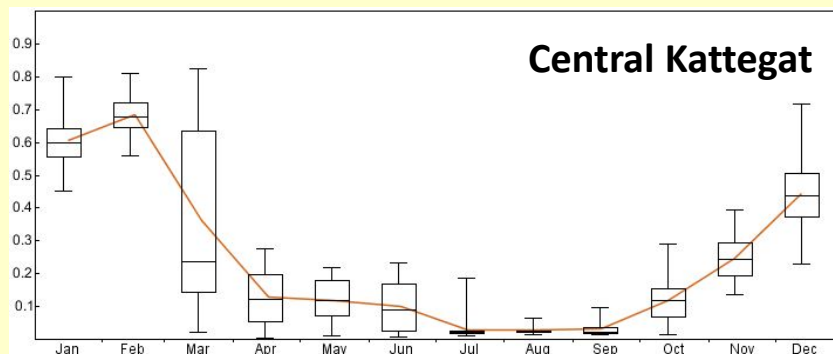
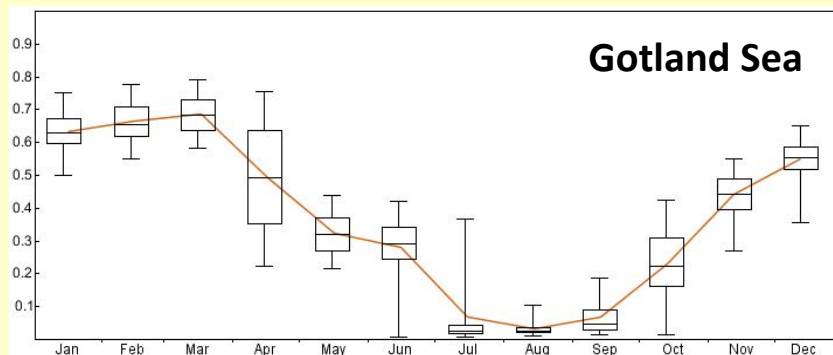
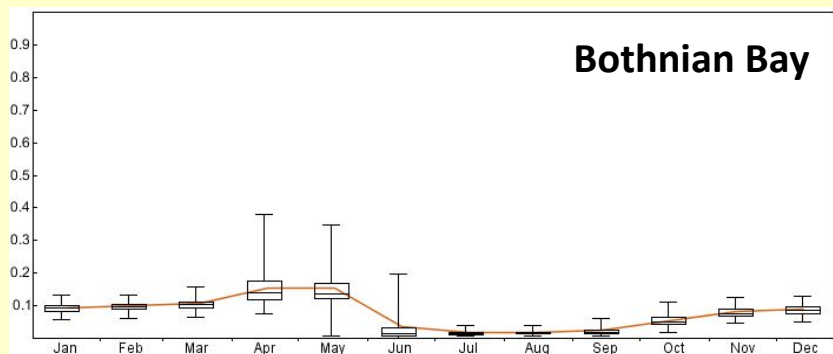


Observations

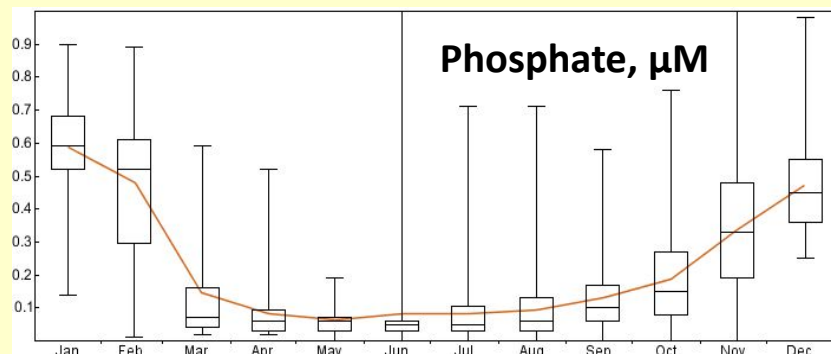
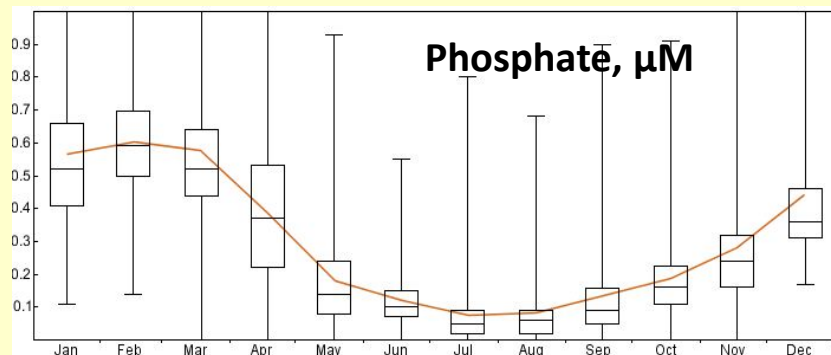
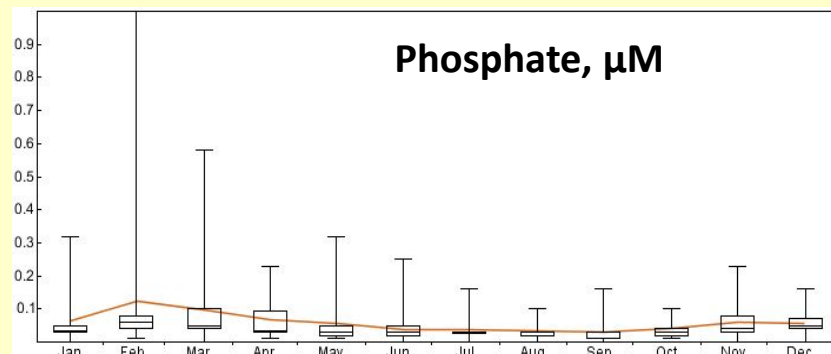


Meridional gradients of seasonal dynamics

Simulation



Observations



Quantitative comparison with a “cost function”

$$\omega = \frac{\sum \left| (C_{\text{mod}}^i - C_{\text{obs}}^i) \right|}{N \times \text{SD}_{\text{obs}}};$$

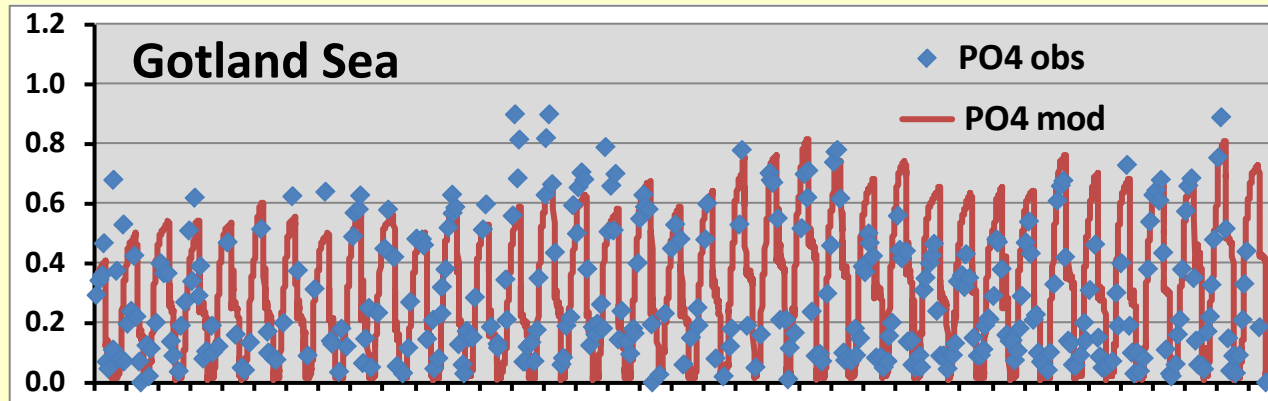
C_{mod} – modelled concentration,
 C_{obs} – observed concentration,
 SD_{obs} – standard deviation of observations;
 N – number of compared pairs i

Quantitative comparison with a “cost function”

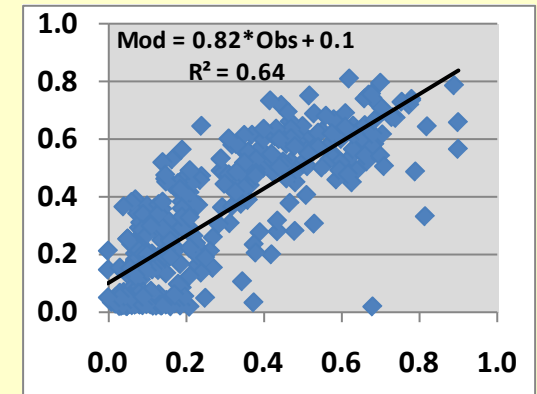
$$\omega = \frac{\sum \left| (C_{\text{mod}}^i - C_{\text{obs}}^i) \right|}{N \times \text{SD}_{\text{obs}}};$$

C_{mod} – modelled concentration,
 C_{obs} – observed concentration,
 SD_{obs} – standard deviation of observations;
 N – number of compared pairs i

Daily simulated and monthly averaged observations



Monthly means

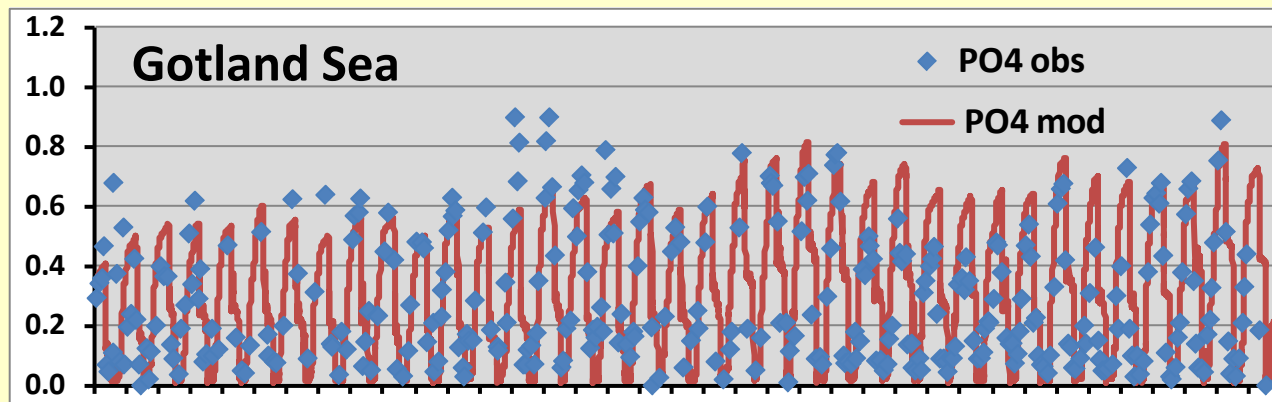


Quantitative comparison with a “cost function”

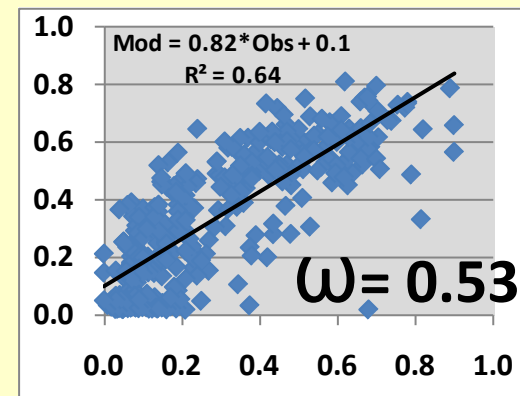
$$\omega = \frac{\sum \left| (C_{\text{mod}}^i - C_{\text{obs}}^i) \right|}{N \times \text{SD}_{\text{obs}}};$$

C_{mod} – modelled concentration,
 C_{obs} – observed concentration,
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Daily simulated and monthly averaged observations



Monthly means

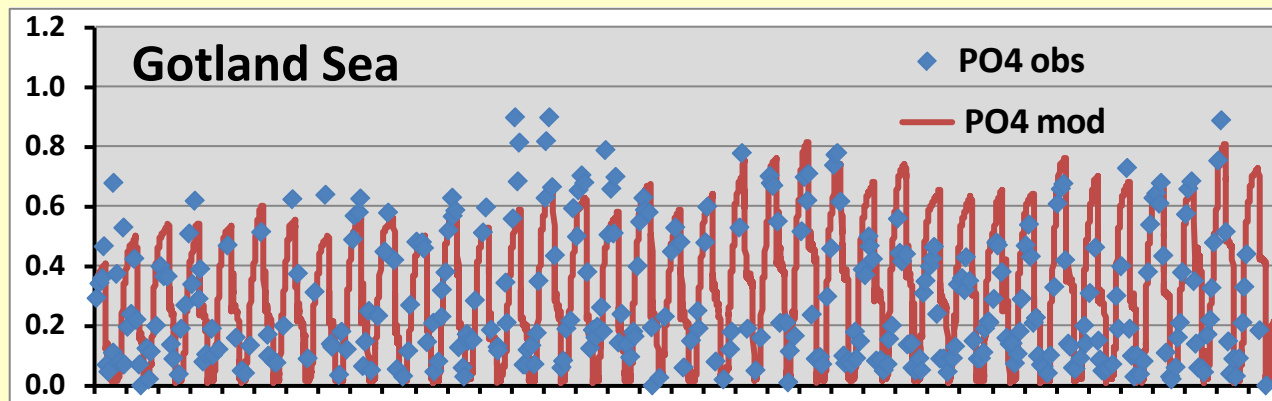


Quantitative comparison with a “cost function”

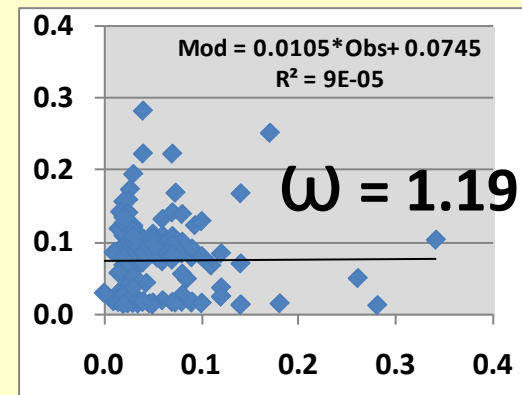
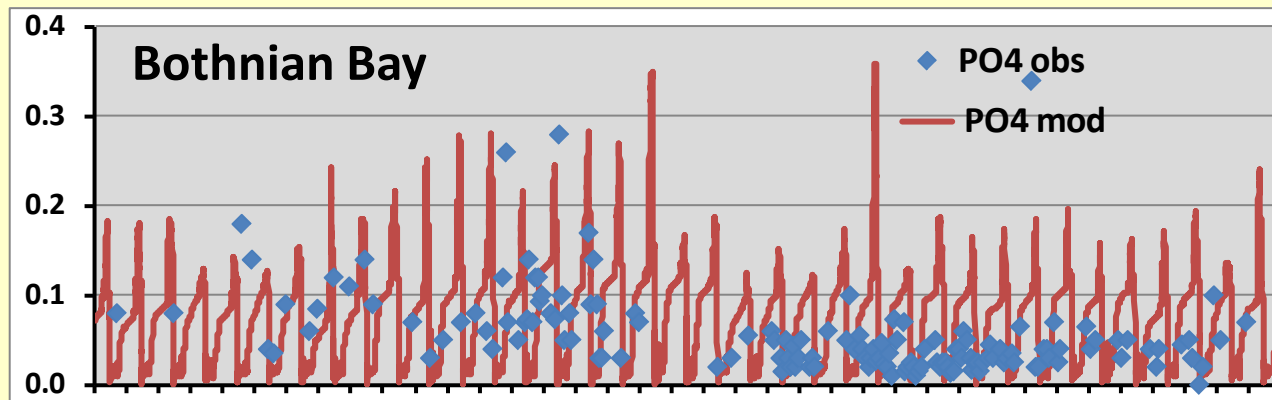
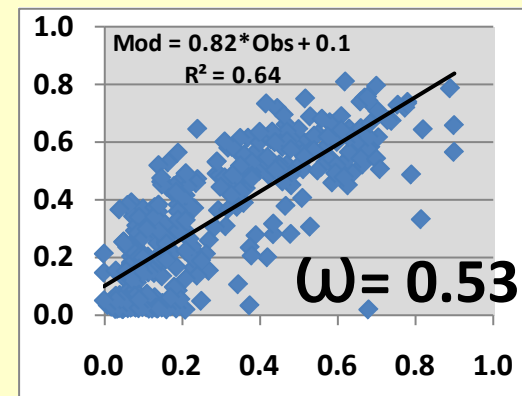
$$\omega = \frac{\sum |C_{\text{mod}}^i - C_{\text{obs}}^i|}{N \times \text{SD}_{\text{obs}}};$$

C_{mod} – modelled concentration,
 C_{obs} – observed concentration,
 SD_{obs} – standard deviation of observations;
 N – number of compared pairs i

Daily simulated and monthly averaged observations



Monthly means





Depth

0

10

20

30

50

70

90

110

150

200

240

Depth	Kattegat		Straits		Baltic Proper				Gulfs			
	CK	SK	FB	OS	AR	BN	GS	BS	BB	GR	GF	
0	0.23	0.23	0.18	0.19	0.18	0.17	0.21	0.18	0.24	0.17	0.22	
	0.23	0.22	0.16	0.19	0.19	0.19	0.20	0.18	0.21	0.19	0.22	
10	0.24	0.24	0.17	0.30	0.19	0.17	0.21	0.22	0.26	0.19	0.26	
	0.31	0.32	0.21	0.50	0.24	0.20	0.28	0.34	0.33		0.33	
20	0.33	0.41	0.28	0.52	0.37	0.27	0.41	0.48	0.51	0.42	0.44	
	0.33	0.33		0.42								
30	0.35	0.29		0.39	0.44	0.45	0.49	0.51	0.50	0.37	0.49	
	0.49	0.39		0.39	0.31	0.62	0.54	0.67	0.60	0.62	0.49	
50	0.55	0.48				0.83	0.68	0.74	0.67	1.26	0.61	
						0.66	0.83	0.90	0.84		0.73	
70						1.03	1.06	0.96	0.78			
						1.26	1.03	1.10	0.78			
90						1.30	1.16	1.29	0.71			
							1.06	1.30	0.80			
110									0.93			
								1.34	1.40			
150								1.46	1.56			
								1.40	1.64			
200								1.27				
								1.25				
240								1.24				

Temp

Depth	Kattegat		Straits		Baltic Proper				Gulfs			
	CK	SK	FB	OS	AR	BN	GS	BS	BB	GR	GF	
0	0.28	0.36	0.35	0.39	0.33	0.35	0.41	0.41	0.55	0.37	0.46	
	0.27	0.32	0.39	0.39	0.34	0.38	0.41	0.44	0.56	0.36	0.45	
10	0.38	0.42	0.44	0.57	0.34	0.38	0.41	0.44	0.55	0.41	0.47	
	0.65	0.67	0.48	0.78	0.35	0.39	0.46	0.55	0.64		0.56	
20	0.62	0.58	0.46	0.75	0.41	0.40	0.62	0.62	0.61	0.73	0.64	
	0.66	0.44		0.64								
30	0.72	0.44		0.64	0.57	0.70	0.94	0.93	0.71	0.76	0.71	
	0.78	0.56		0.66	0.66	0.75	1.05	0.85	0.62	0.60	0.74	
50	0.84	0.64				0.86	1.14	1.08	0.78	0.72	0.76	
						0.90	0.96	1.07	0.86		0.93	
70						0.91	0.93	1.29	1.16			
						1.02	0.76	1.47	1.00			
90						1.17	0.91	1.81	1.24			
							0.89	2.02	1.06			
110									1.07			
								1.32	3.42			
150								1.05	2.60			
								0.84	3.05			
200								0.69				
								0.70				
240								0.83				

O₂

Depth	Kattegat		Straits		Baltic Proper				Gulfs			
	CK	SK	FB	OS	AR	BN	GS	BS	BB	GR	GF	
0	0.75	0.50	0.54	0.44	0.66	0.54	0.48	0.62	1.07	0.55	0.82	
	0.69	0.46	0.57	0.48	0.65	0.58	0.48	0.65	0.93	0.68	0.80	
10	0.60	0.53	0.68	0.63	0.65	0.55	0.48	0.67	0.86	0.57	0.80	
	0.75	0.86	0.69	0.77	0.61	0.55	0.46	0.80	1.10		0.89	
20	0.66	0.79	0.73	0.78	0.53	0.54	0.47	1.02	1.20	0.60	0.96	
	0.67	0.65		0.61								
30	0.82	0.71		0.53	0.80	0.54	0.49	1.23	1.08	0.70	0.92	
	1.06	0.93		0.49	0.83	0.75	0.57	1.31	0.79	0.55	0.78	
50	1.14	0.99				0.78	0.64	1.32	0.99	0.75	0.63	
						0.78	0.76	0.93	0.77		0.69	
70						0.65	0.89	0.64	0.65			
						0.61	0.88	0.54	0.45			
90						0.73	1.01	0.56	0.50			
							1.14	0.52	0.48			
110									0.61			
								0.89	0.53			
150								0.74	0.52			
								0.66	0.52			
200								0.75				
								0.74				
240								0.77				

Sal

Depth

0

10

20

30

50

70

90

110

150

200

240

Depth	Kattegat		Straits		Baltic Proper				Gulfs			
	CK	SK	FB	OS	AR	BN	GS	BS	BB	GR	GF	
0	0.79	0.79	0.53	0.83	0.68	0.71	0.73	1.02	1.24	0.72	0.76	
	0.80	0.81	0.58	0.86	0.86	0.75	0.80	1.24	1.18	0.70	0.83	
10	0.78	0.79	0.70	0.90	0.59	0.57	0.71	1.16	1.34	0.83	0.82	
	0.78	0.78	0.73	0.88	0.91	0.69	0.83	0.93	1.27		0.79	
20	0.75	0.74	0.86	0.89	0.64	0.61	0.73	1.04	1.21	0.84	0.83	
	0.77	0.76		0.96								
30	0.76	0.77		0.87	0.84	0.57	0.83	1.10	1.43	0.83	0.85	
	0.81	0.81		0.93	0.90	0.70	0.83	1.17	1.16	0.72	0.96	
50	0.76	0.76				0.69	0.88	1.22	1.35	0.75	0.85	
						0.71	0.81	1.24	1.21		0.76	
70						1.25	0.63	1.39	1.23			
						1.89	0.62	1.20	1.33			
90						1.76	0.80	1.21	1.31			
							0.64	1.36	1.43			
110									1.69			
								0.57	1.25			
150								0.65	1.25			
								0.60	1.17			
200								0.56				
								0.64				
240								0.83				

NH₄

Depth	Kattegat		Straits		Baltic Proper				Gulfs			
	CK	SK	FB	OS	AR	BN	GS	BS	BB	GR	GF	
0	0.31	0.30	0.34	0.37	0.38	0.38	0.46	0.35	0.61	0.68	0.80	
	0.29	0.28	0.29	0.36	0.34	0.43	0.49	0.41	0.59	0.64	0.66	
10	0.30	0.29	0.38	0.52	0.36	0.41	0.47	0.35	0.60	0.70	0.67	
	0.47	0.53	0.81	0.80	0.38	0.49	0.57	0.39	0.62		0.81	
20	0.60	0.75	0.98	0.83	0.46	0.55	0.71	0.50	0.71	0.96	0.96	
	0.64	0.66		0.81								
30	0.77	0.66		0.82	0.80	0.78	1.03	0.81	0.78	0.93	1.40	
	1.09	0.87		0.86	0.79	0.96	1.22	0.94	1.01	0.81	1.62	
50	1.32	1.05				1.28	1.49	0.98	1.31	0.89	1.80	
						0.93	1.31	0.98	1.64		1.88	
70						1.18	0.88	0.99	1.67			
						1.16	0.64	0.92	1.72			
90						1.25	0.88	0.74	1.78			
							1.07	0.62	2.05			
110									2.60			
								1.07	0.69			
150								0.87	0.80			
								0.78	0.89			
200								0.60				
								0.55				
240								0.51				

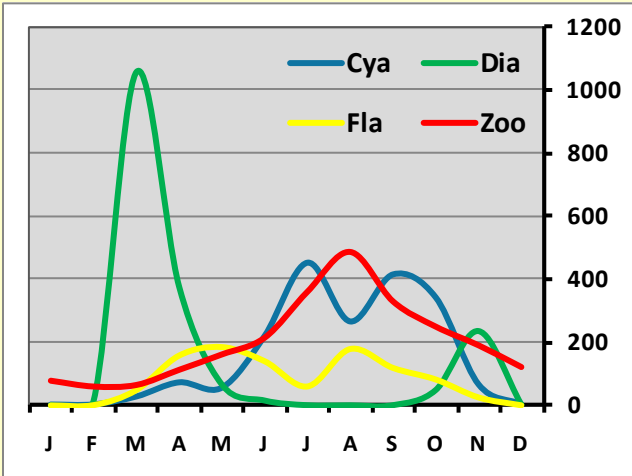
NO₃

Depth	Kattegat		Straits		Baltic Proper				Gulfs			
	CK	SK	FB	OS	AR	BN	GS	BS	BB	GR	GF	
0	0.48	0.50	0.68	0.70	0.66	0.63	0.53	1.10	1.19	0.64	0.79	
	0.44	0.48	0.65	0.65	0.58	0.53	0.53	1.27	1.80	0.59	0.80	
10	0.46	0.49	0.71	0.61	0.65	0.60	0.53	0.94	1.36	0.64	0.88	
	0.59	0.77	1.01	0.77	0.69	0.61	0.62	1.31	1.61		1.02	
20	0.69	1.27	0.76	0.86	0.77	0.67	0.77	1.70	1.59	1.11	1.26	
	0.61	1.32		1.02								
30	0.75	1.02		1.04	0.93	0.74	0.95	2.32	1.95	1.47	1.81	
	1.28	1.06		1.19	0.79	0.84	0.94	2.15	2.97	1.74	2.16	
50	1.36	1.17				0.93	1.07	2.03	3.25	0.99	1.75	

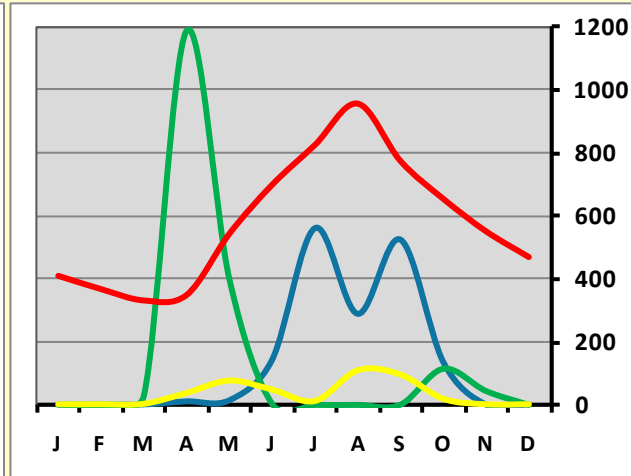
Seasonal dynamics of plankton variables

Long-term (1970-2006) monthly means,
Note different scales

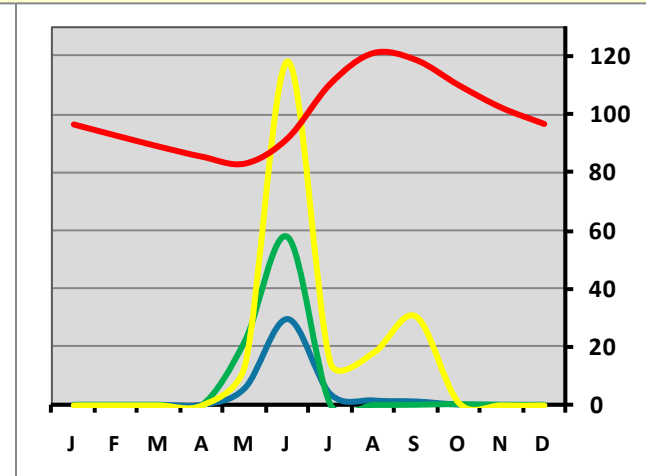
Central Kattegat



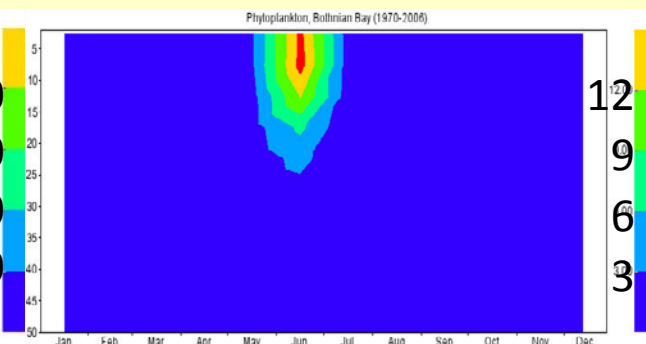
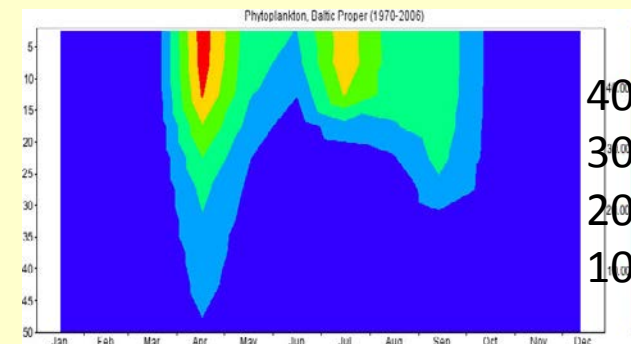
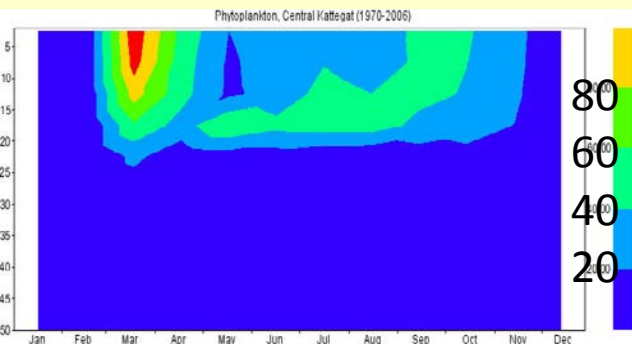
Gotland Sea



Bothnian Bay



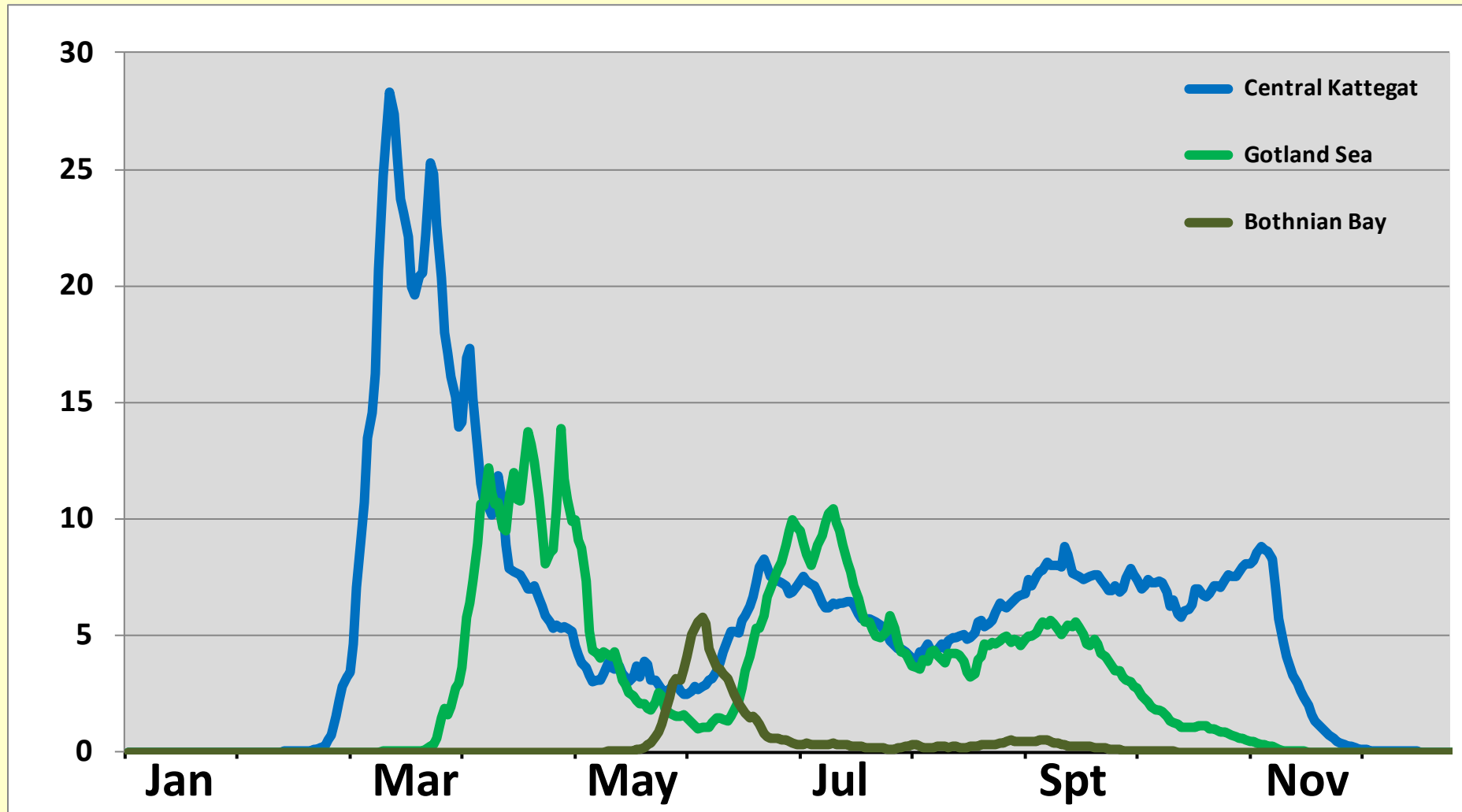
Vertically integrated plankton groups (mg C m^{-2})



Time-depth distribution of total phytoplankton (mg C m^{-3})

Seasonal dynamics of total phytoplankton

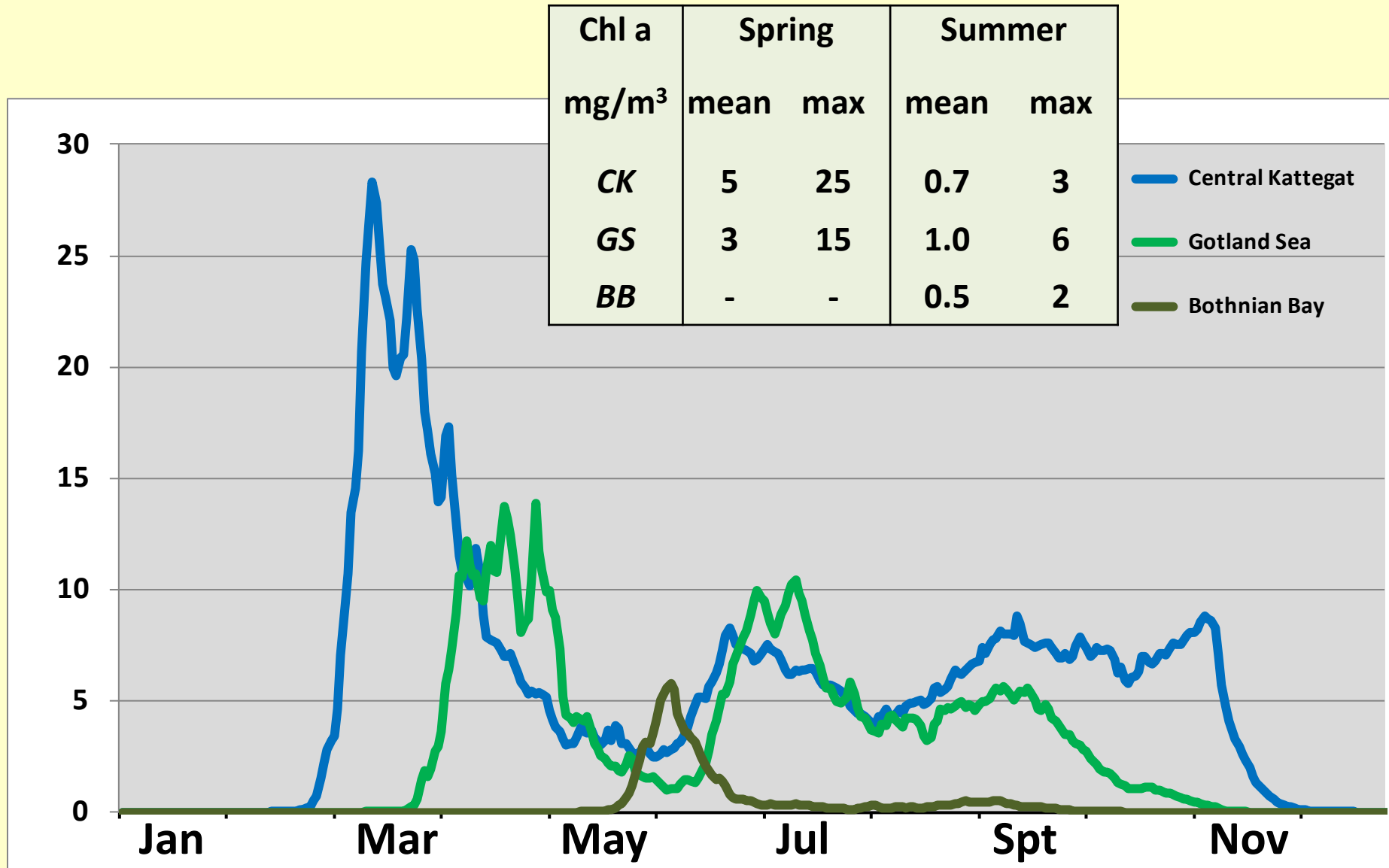
Long-term (1970-2006) surface daily means (mg N m⁻³)



Seasonal dynamics of total phytoplankton

Long-term (1970-2006) surface daily means (mg N m^{-3})

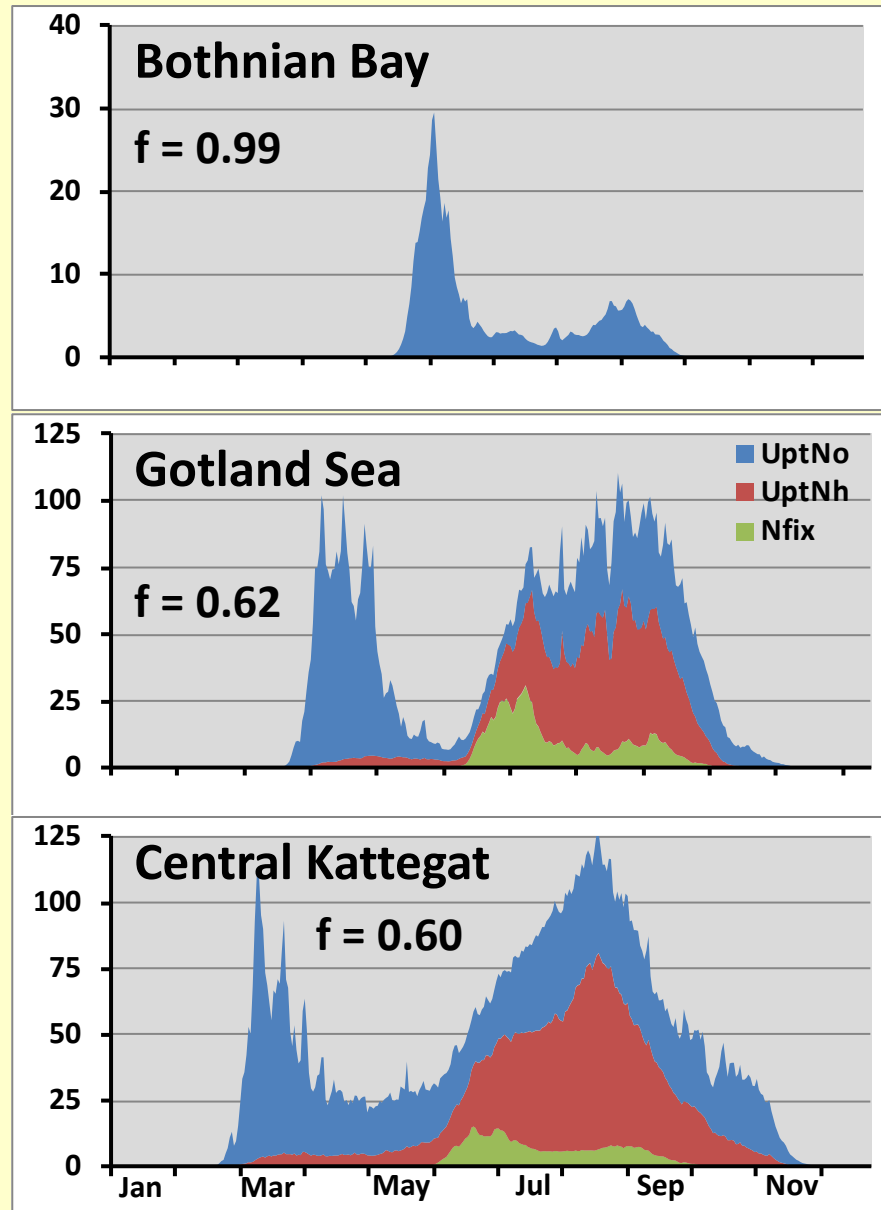
C:Chl "a" = 30 (spring) or 60 (summer)





Seasonal dynamics of nitrogen uptake

Long-term (1970-2006) daily mean water column integrals (mg N m^{-2})



Long-term (1970-2006) average budget

$10^3 \text{ tonnes year}^{-1}$

	N fixation	Atm dep	Landload	
	296	198	291	
		3.4	23	
<= to DS	Uptake	Recycling	<= fr Gulfs	
64	2757	2073	90	
15	436	311	20	
fr DS=>	Sinking	Output	to Gulfs=>	
52	1053	331	58	
12	138	114	17	
	77			
	Burial	Denitrification		
	90	592		
	16			

Baltic Proper

$\text{mg m}^{-2} \text{ day}^{-1}$

	N fixation	Atm dep	Landload	
	3.6	2.4	3.5	
		0.04	0.28	
<= to DS	Uptake	Recycling	<= fr Gulfs	
0.8	33	25	1.09	
0.18	5.2	3.7	0.24	
fr DS =>	Sinking	Output	to Gulfs=>	
0.6	13	4	0.7	
0.15	1.7	1.4	0.21	
	0.9			
	Burial	Denitrification		
	1.1	7.1		
	0.19			

	N fixation	Atm dep	Landload	
	22	27	52	
		0.3	2	
<= to Ska	Uptake	Recycling	<= fr DS	
146	357	209	117	
30	54	31	28	
fr Ska =>	Sinking	Output	to DS =>	
124	156	53	92	
24	21	19	22	
	0.0			
	Burial	Denitrification		
	11	91		
	2			

Kattegat

	N fixation	Atm dep	Landload	
	2.7	3.4	6.4	
		0.04	0.29	
<= to Ska	Uptake	Recycling	<= fr DS	
18	44	25.7	14	
3.7	6.7	3.8	3.4	
fr Ska =>	Sinking	Output	to DS =>	
15	19	6	11	
3.0	2.6	2.3	2.7	
	0.0			
	Burial	Denitrification		
	1.4	11.2		
	0.28			

Long-term (1970-2006) average budget of the entire Baltic

10^3 tonnes year⁻¹

	N fixation	Atm dep	Landload
	425	333	600
		6.2	50
<= to Ska	Uptake	Recycling	
146.2	4614	3281	
29.9	720	492	
fr Ska =>	Sinking	Output	
123.9	1873	626	
24.0	250	205	
	78		
	Burial	Denitrification	
	156	1025	
	32		

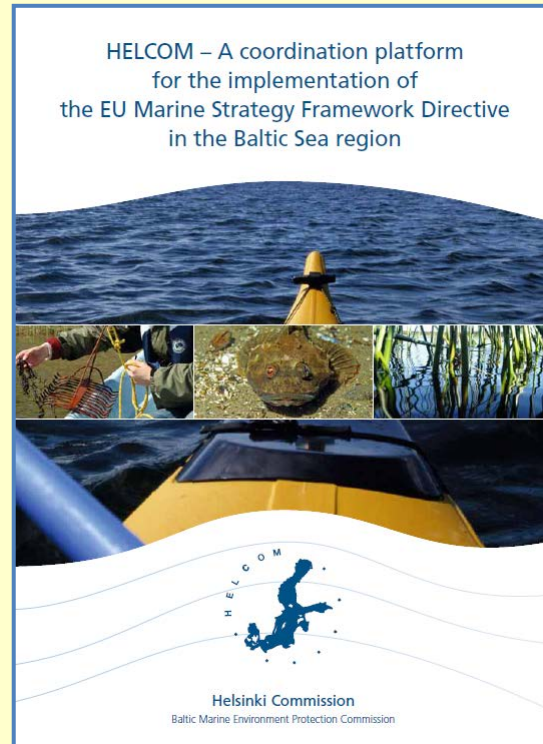
mg m⁻² day⁻¹

	N fixation	Atm dep	Landload
	2.8	2.2	4.0
		0.04	0.33
<= to Ska	Uptake		Recycling
1.0	31		21.7
0.2	4.8		3.3
fr Ska =>	Sinking		Output
0.8	12.4		4.1
0.2	1.7		1.4
		0.5	
	Burial	Denitrification	
	1.0	6.8	
	0.2		



HELCOM's good intentions

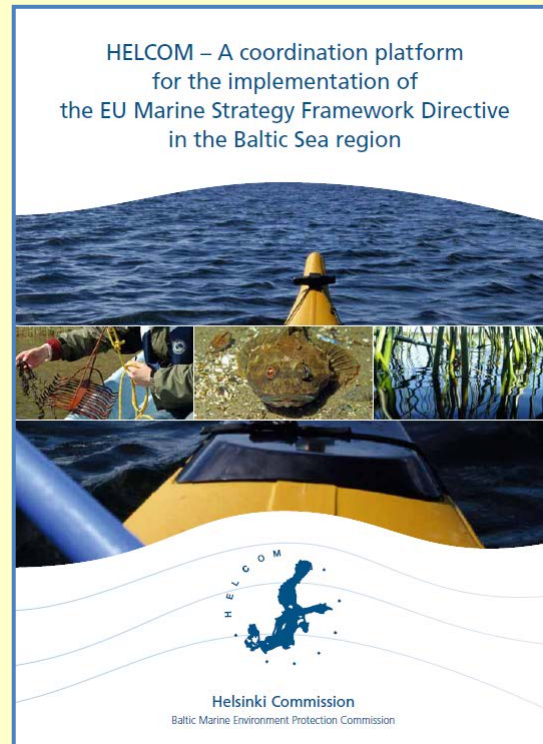
(when science meets management, then politics beats science)





HELCOM's good intentions

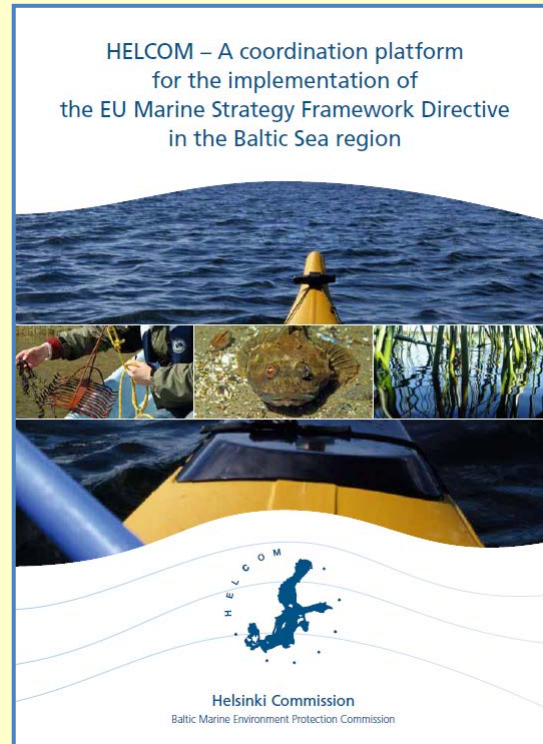
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HELCOM's good intentions

(when science meets management, then politics beats science)

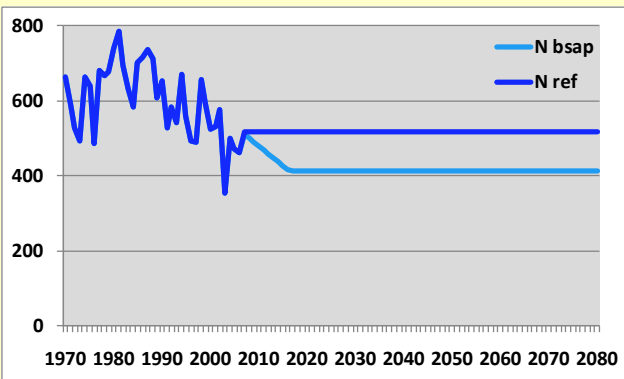




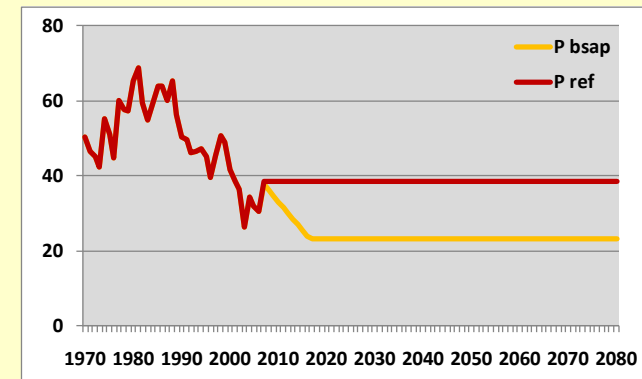
HELCOM's wishful thinking

(when science meets management, then politics beats science)

Nitrogen loads (Kt N/yr)



Phosphorus loads (Kt P/yr)





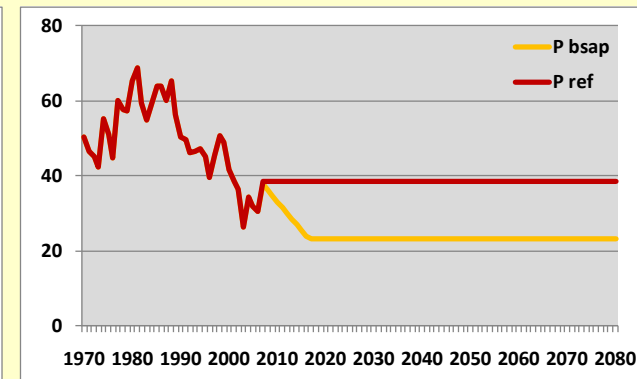
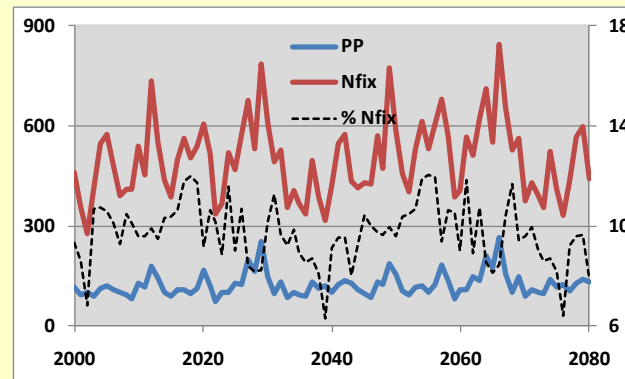
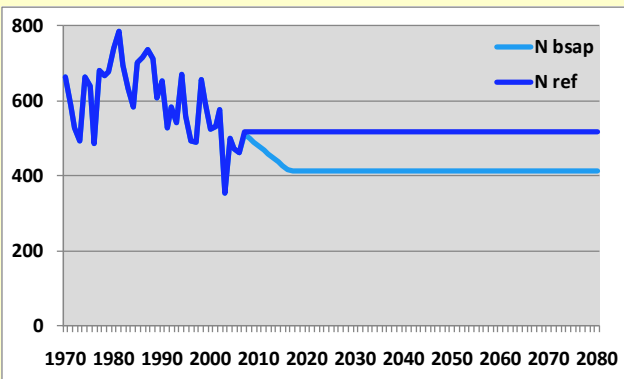
HELCOM's wishful thinking

(when science meets management, then politics beats science)

Reference dynamics, Baltic Proper
net primary production (PP, gC/m²/yr),
nitrogen fixation (Nfix, Kt/yr)
direct contribution of Nfix in PP (%)

Nitrogen loads (Kt N/yr)

Phosphorus loads (Kt P/yr)



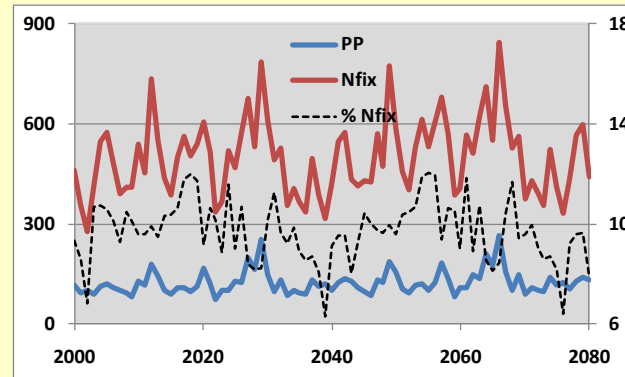
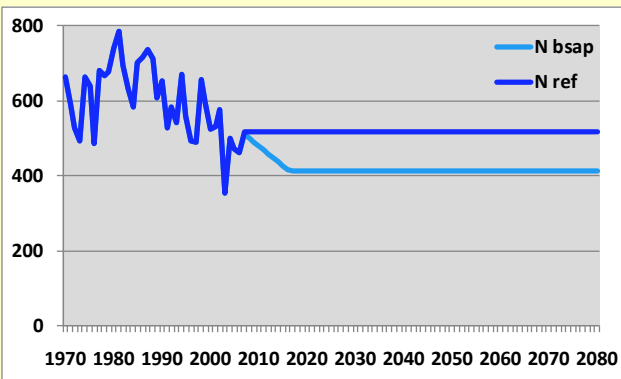


HELCOM's wishful thinking

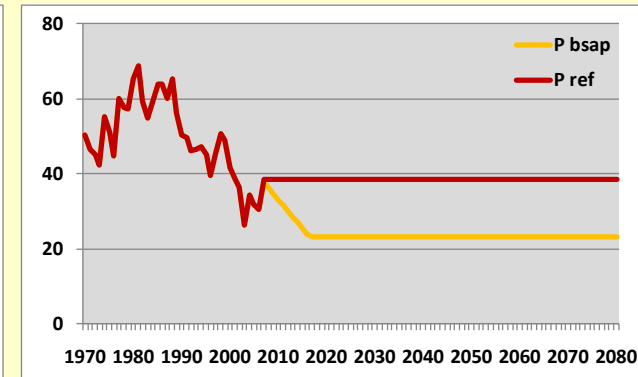
(when science meets management, then politics beats science)

Reference dynamics, Baltic Proper
net primary production (PP, gC/m²/yr),
nitrogen loads (Nfix, Kt/yr)
direct contribution of Nfix in PP (%)

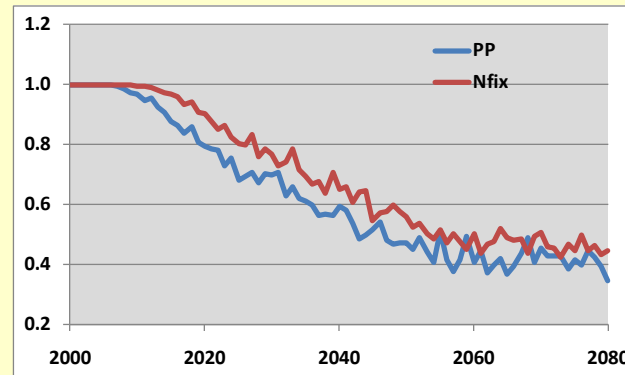
Nitrogen loads (Kt N/yr)



Phosphorus loads (Kt P/yr)



Both N & P reduction

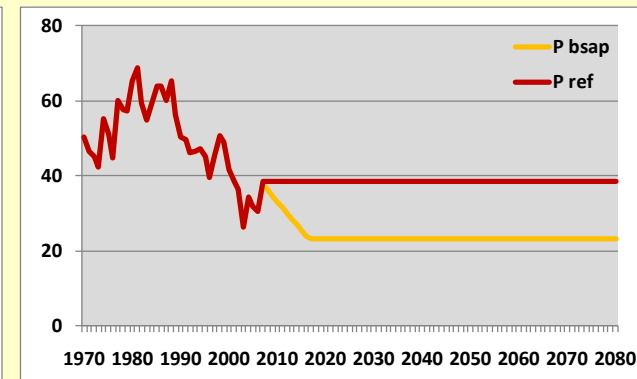
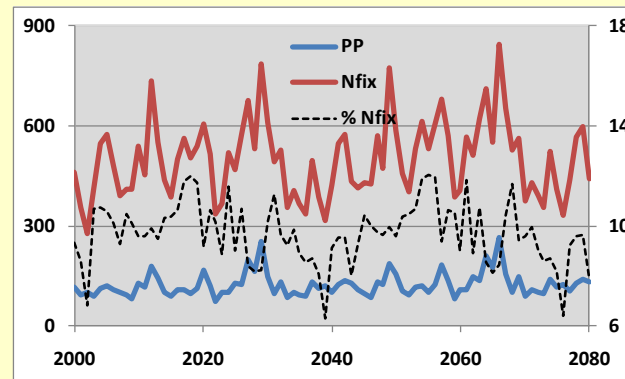
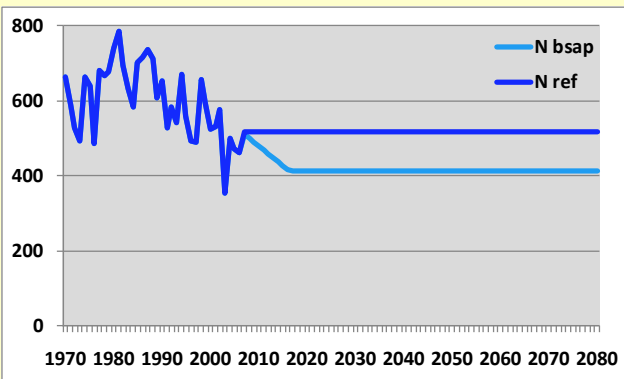




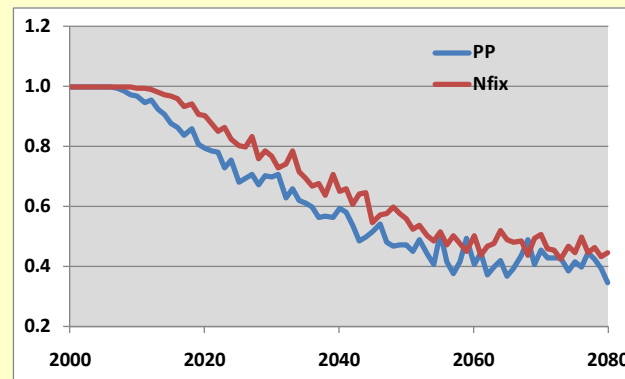
HELCOM's wishful thinking

(when science meets management, then politics beats science)

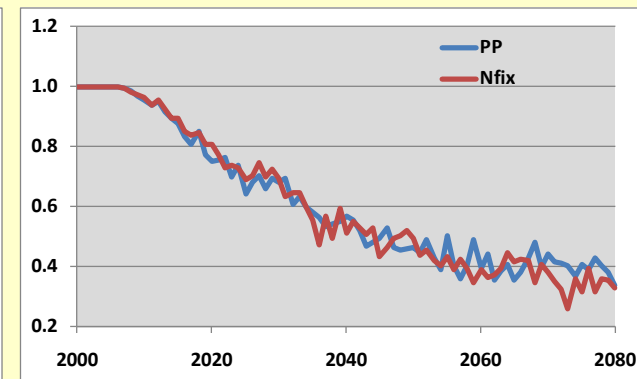
Reference dynamics, Baltic Proper
net primary production (PP, gC/m²/yr),
nitrogen loads (Kt N/yr) nitrogen fixation (Nfix, Kt/yr) Phosphorus loads (Kt P/yr)
direct contribution of Nfix in PP (%)



Both N & P reduction



Only P reduction

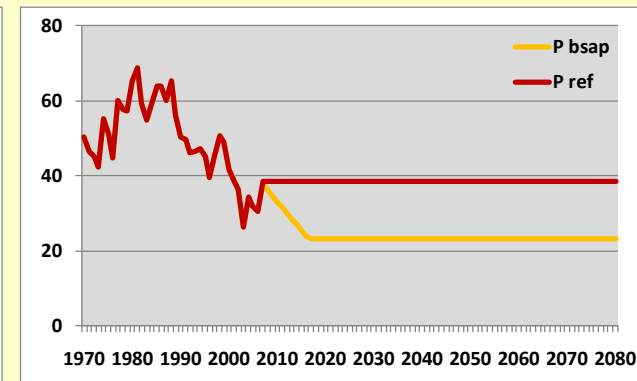
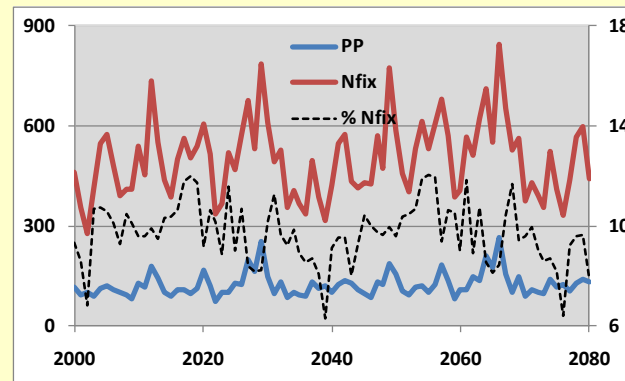
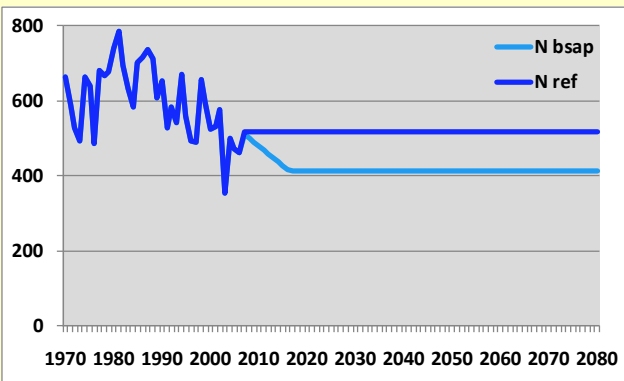




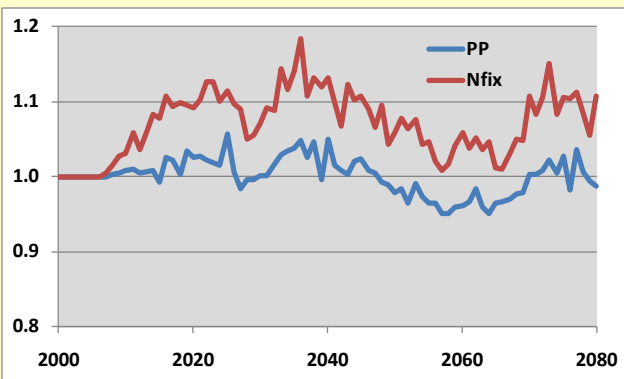
HELCOM's wishful thinking

(when science meets management, then politics beats science)

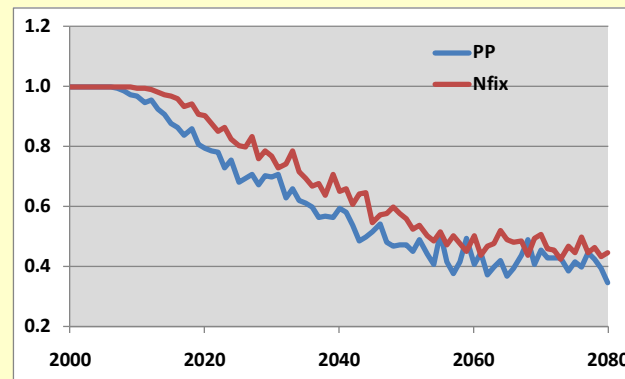
Reference dynamics, Baltic Proper
net primary production (PP, gC/m²/yr),
nitrogen loads (Kt N/yr) nitrogen fixation (Nfix, Kt/yr) Phosphorus loads (Kt P/yr)
direct contribution of Nfix in PP (%)



Only N reduction



Both N & P reduction



Only P reduction

