Variability of nutrient concentrations in the western Baltic Sea between 1995 and 2017

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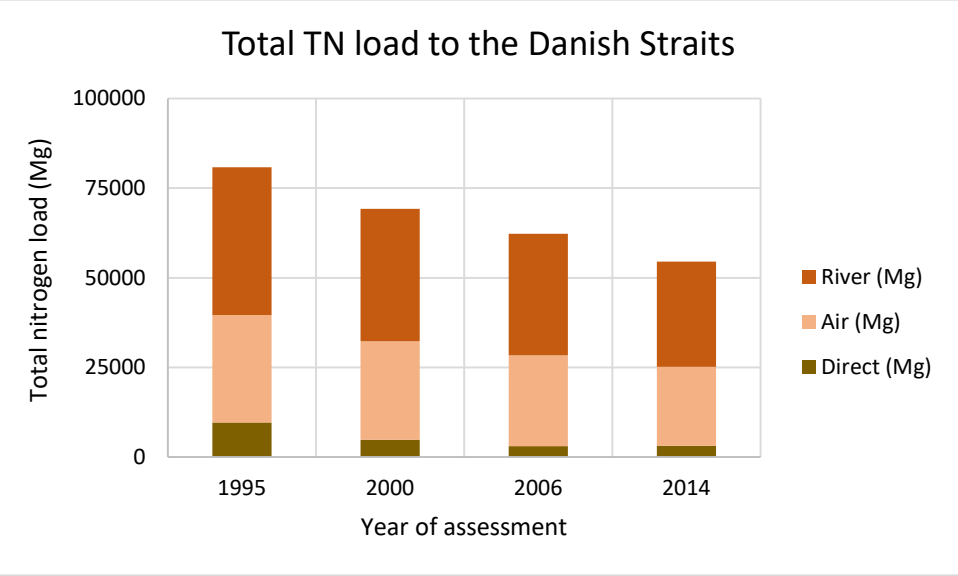
- Nitrogen and phosphorus input into the sea (PLC-6)
- Comparison of 20 year time series with a view on regional differences
- Nutrients versus salinity – no conservative mixing, but changes appear significant

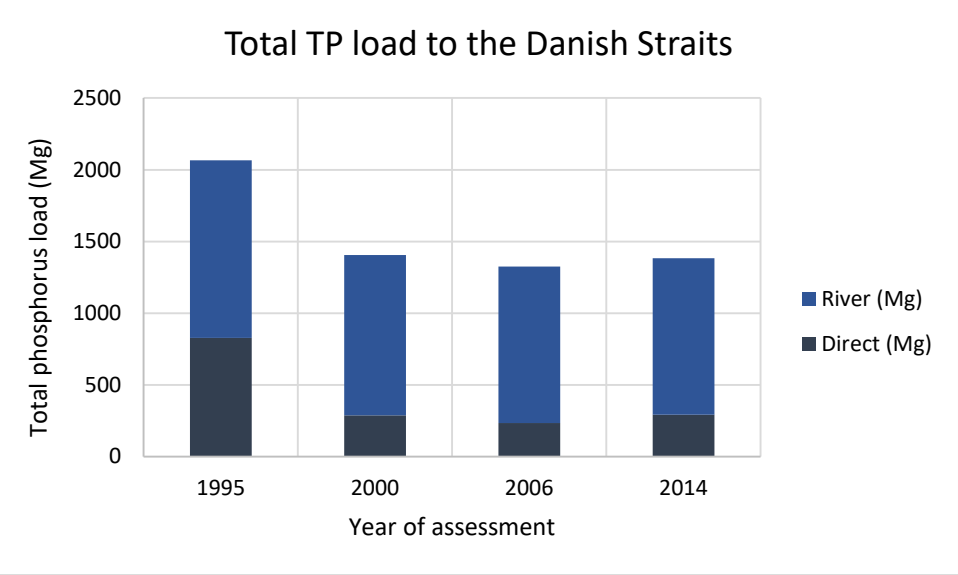


Nitrogen sources 2014

29 000 Mg River input

22 000 Mg Atmospheric N

3 000 Mg Direct point-sources



Phosphorus sources 2014

1100 Mg River input

300 Mg Direct point-sources

+ ~100 Mg Atmospheric P

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Homogeneous nutrient data set of IOW from 1995 to 2017

Monitoring campaigns in February, March, May, July/August and October/November

Analyses: Standard colorimetric methods by application of continuous-flow spectrophotometry

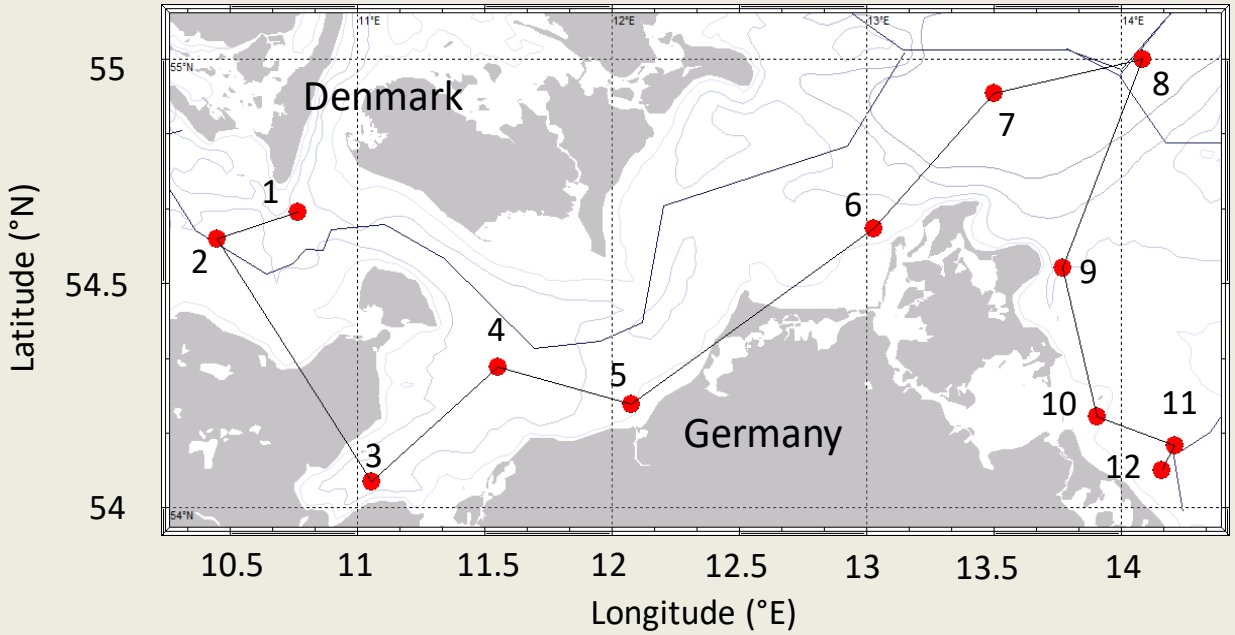
- Total nitrogen (TN):
- Total phosphorus (TP):

} Unfiltered seawater samples after peroxodisulfate digestion

- Dissolved inorganic nitrogen: DIN=$[NO_3^-]$ + $[NO_2^-]$+ $[NH_4^+]$
- Dissolved inorganic phosphorus (DIP): $[PO_4^{3+}]$

} GFF-filtered seawater

Transect Kiel bight – Odra Bank



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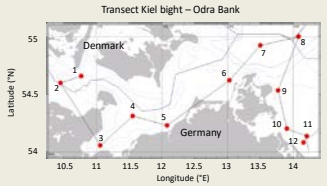
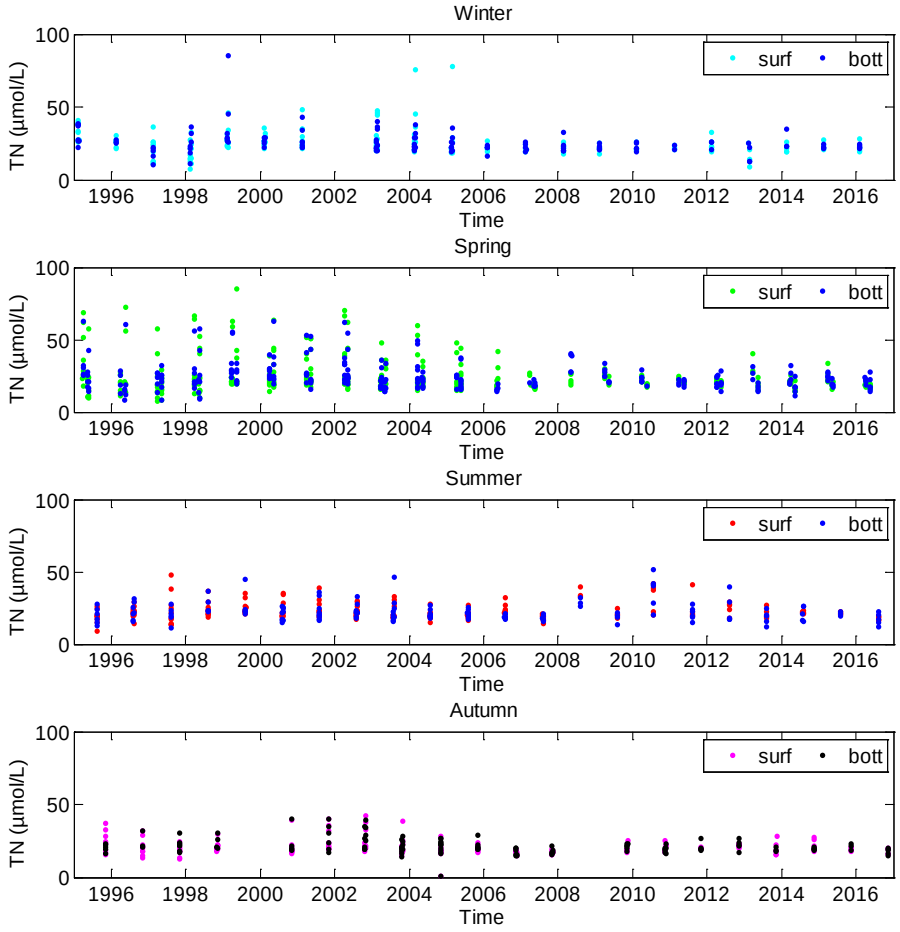
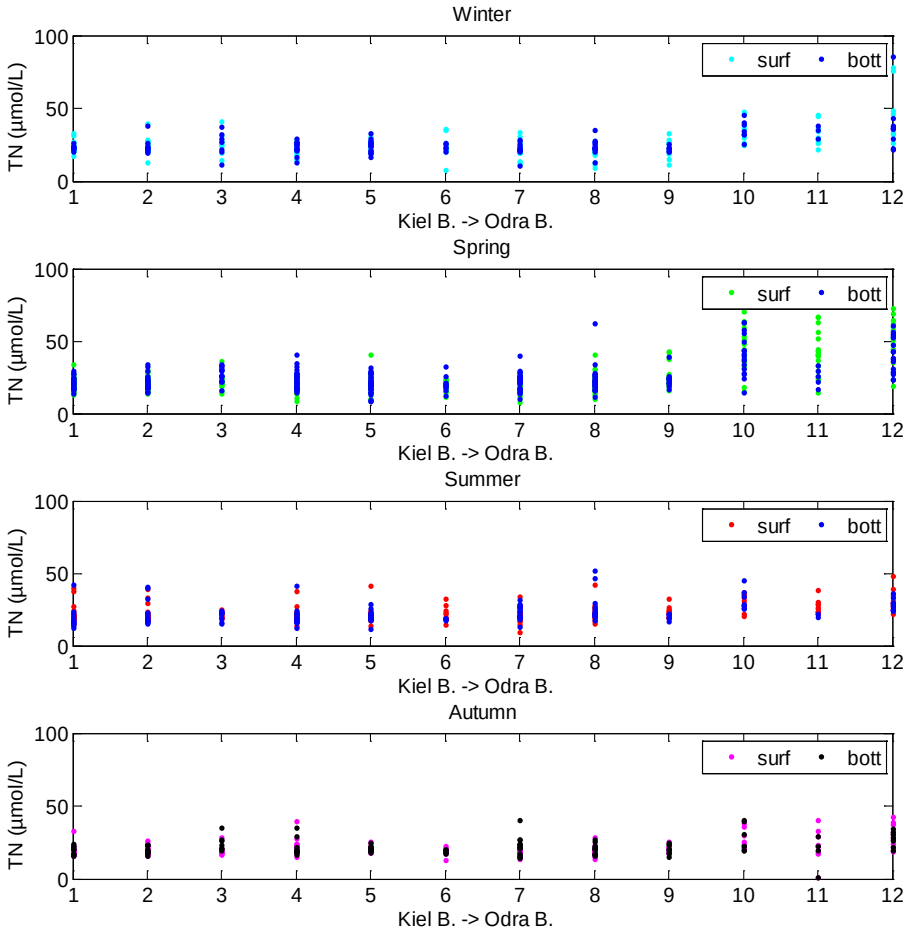
1995 - 2017

Total nitrogen (µM)







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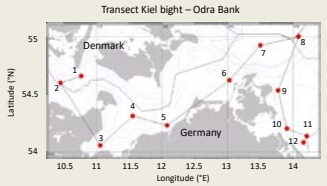
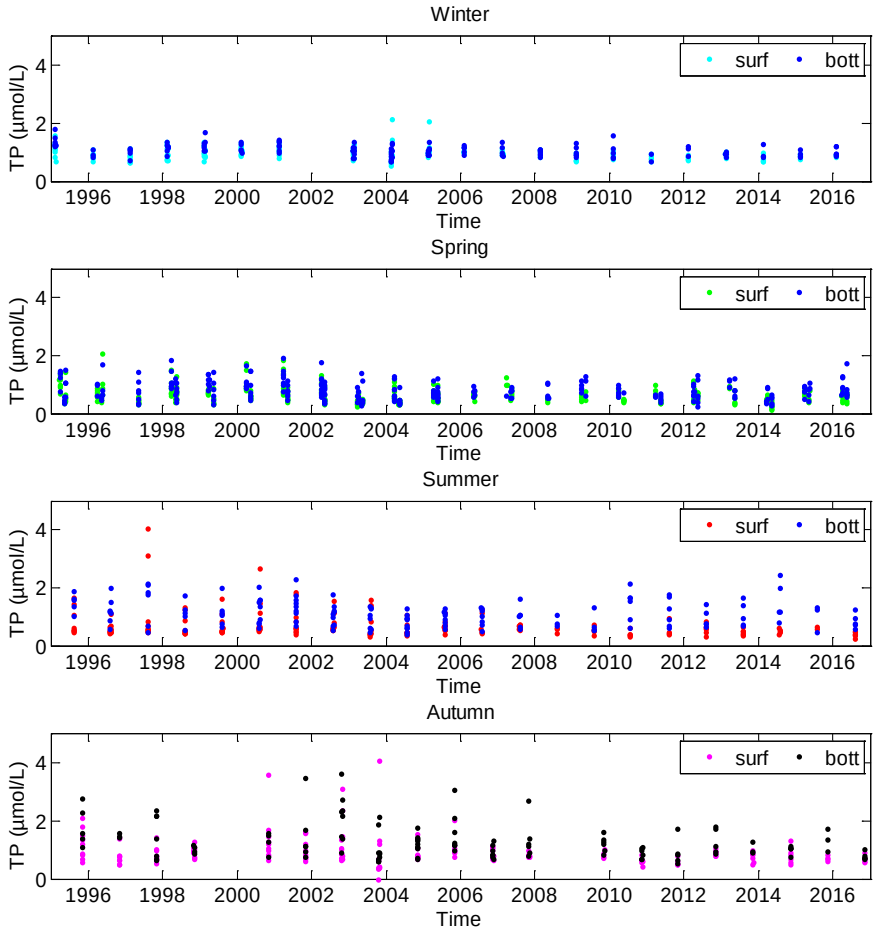
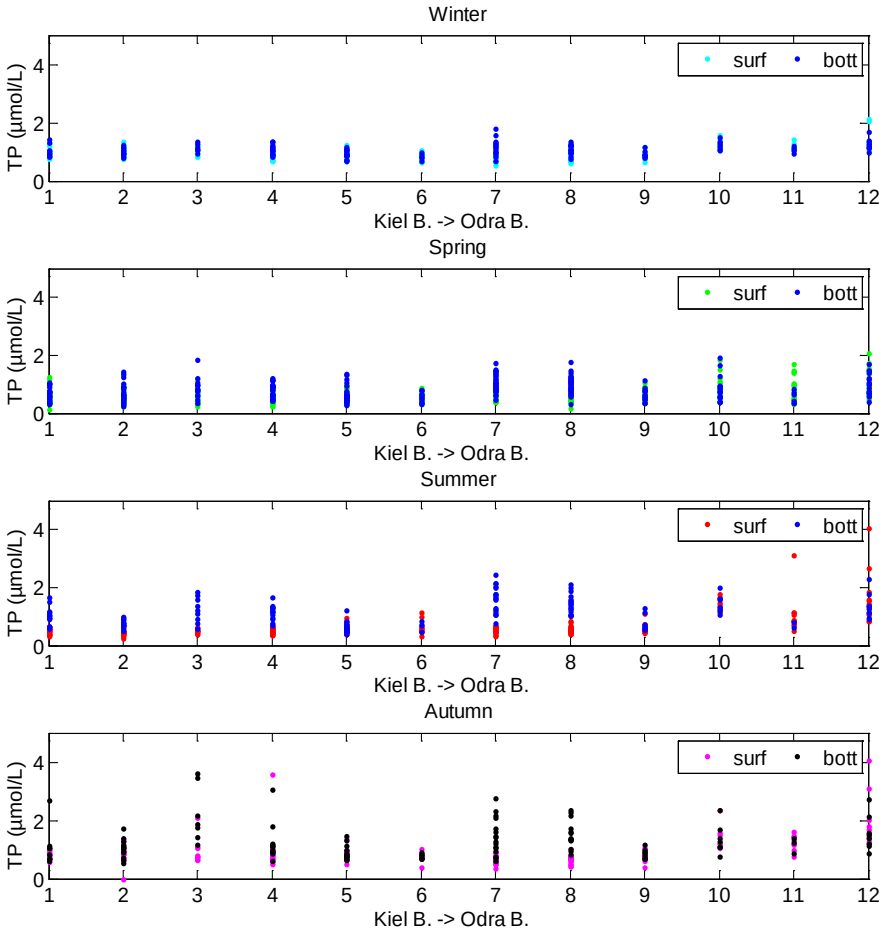
1995 - 2017

Total phosphorus (µM)







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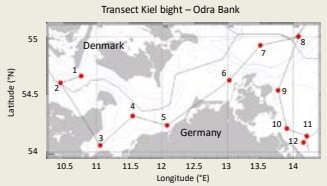
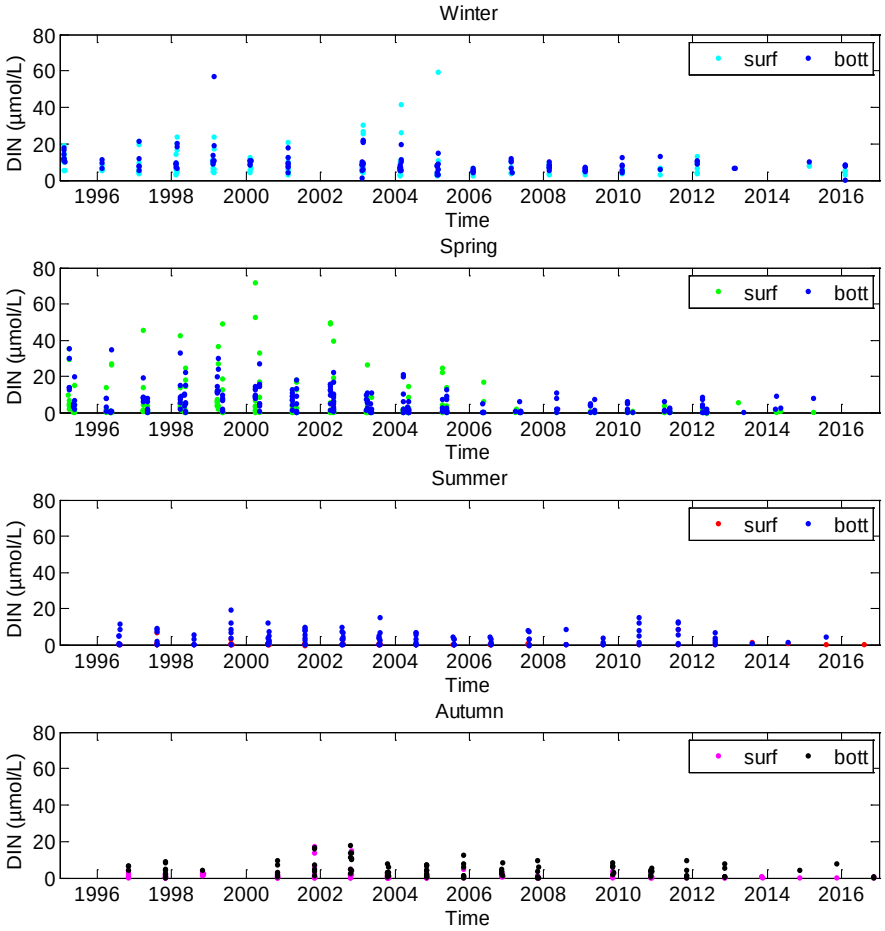
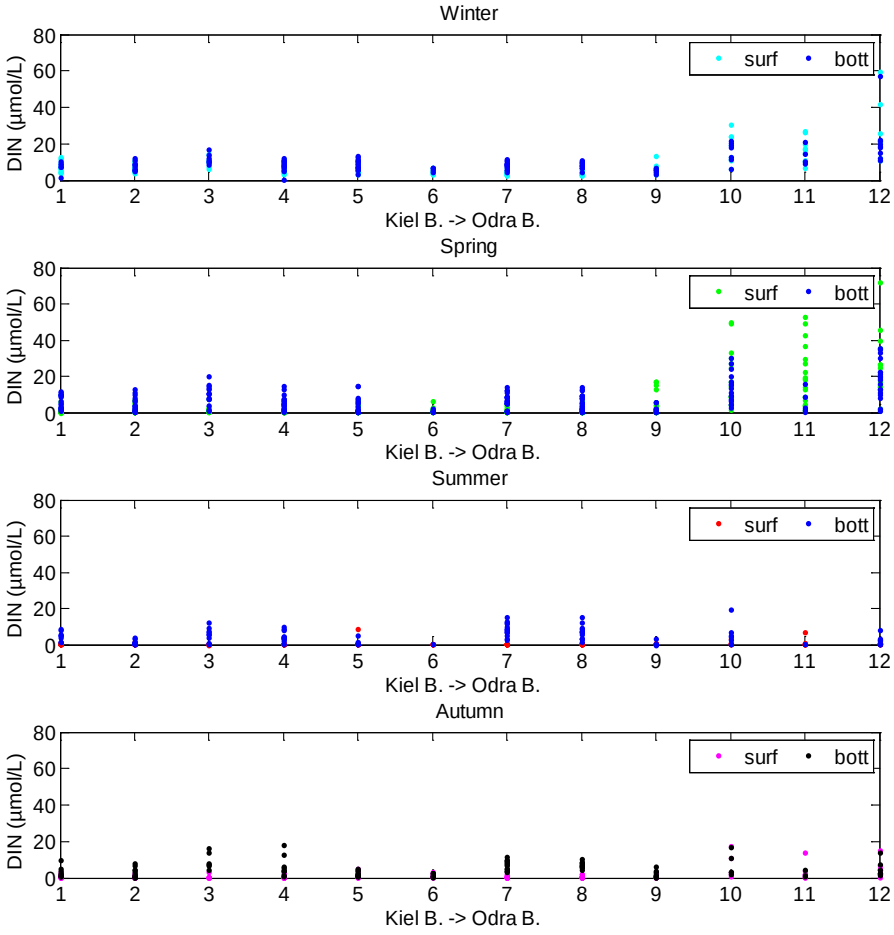
1995 - 2017

Dissolve inorganic nitrogen (µM)







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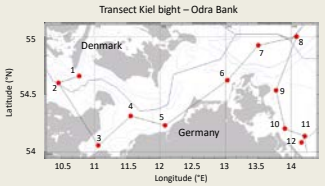
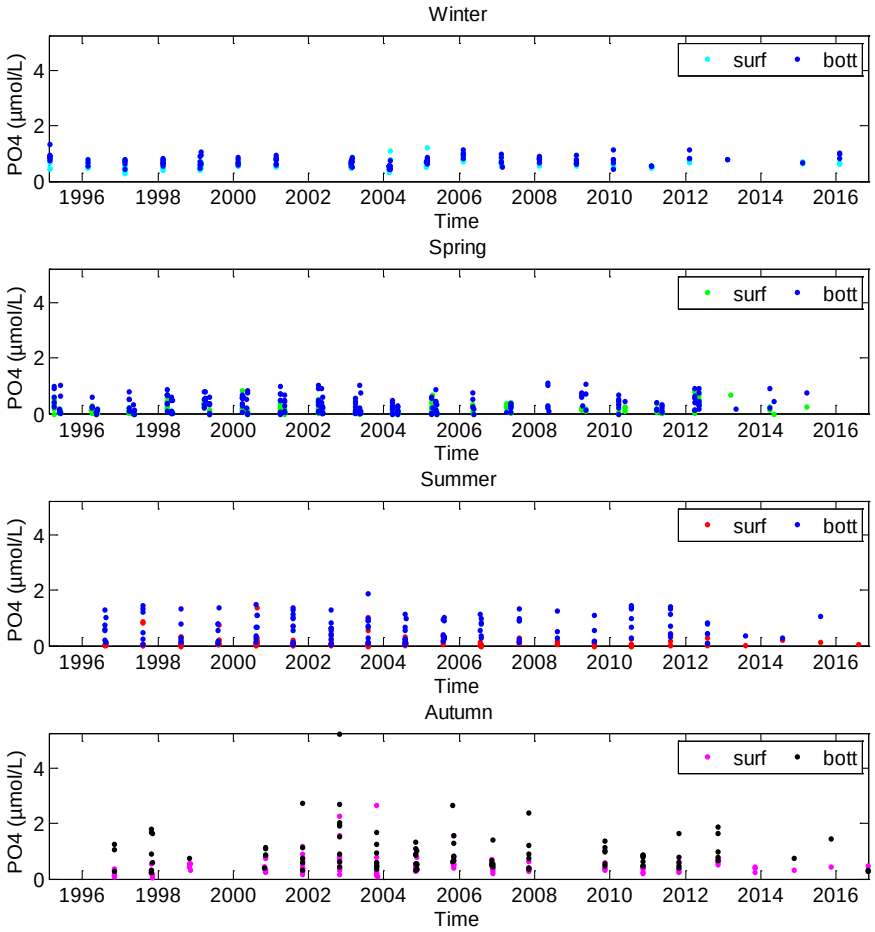
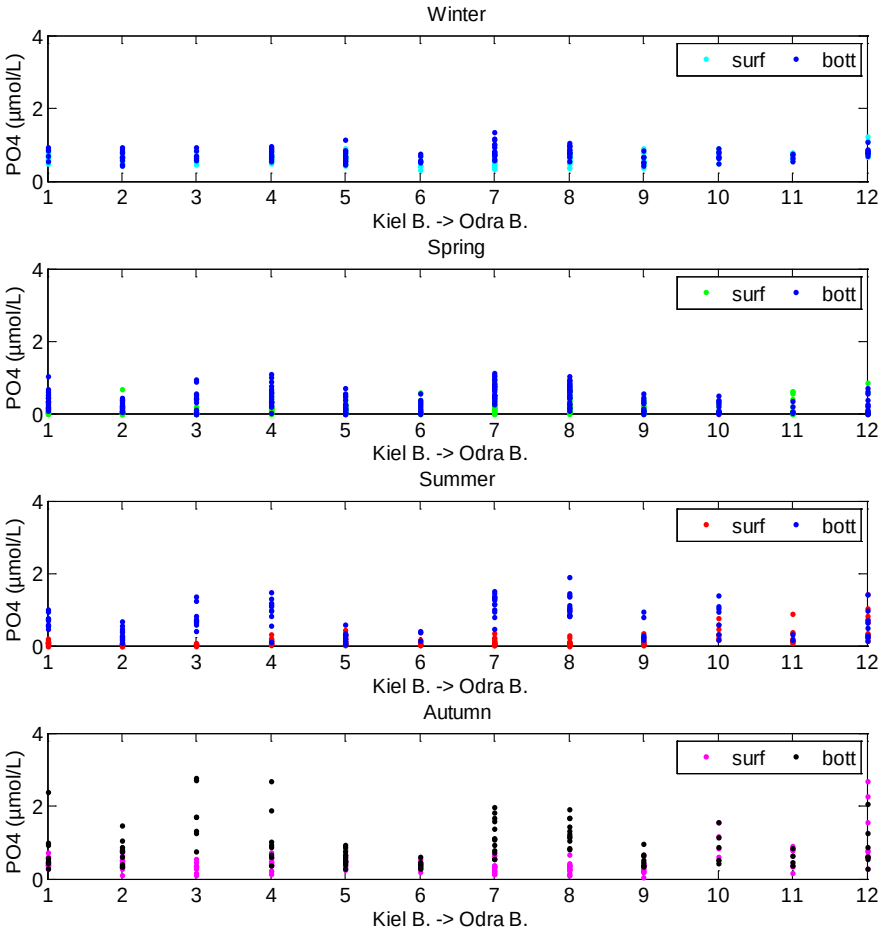
1995 - 2017

Dissolved inorganic phosphorus (µM)







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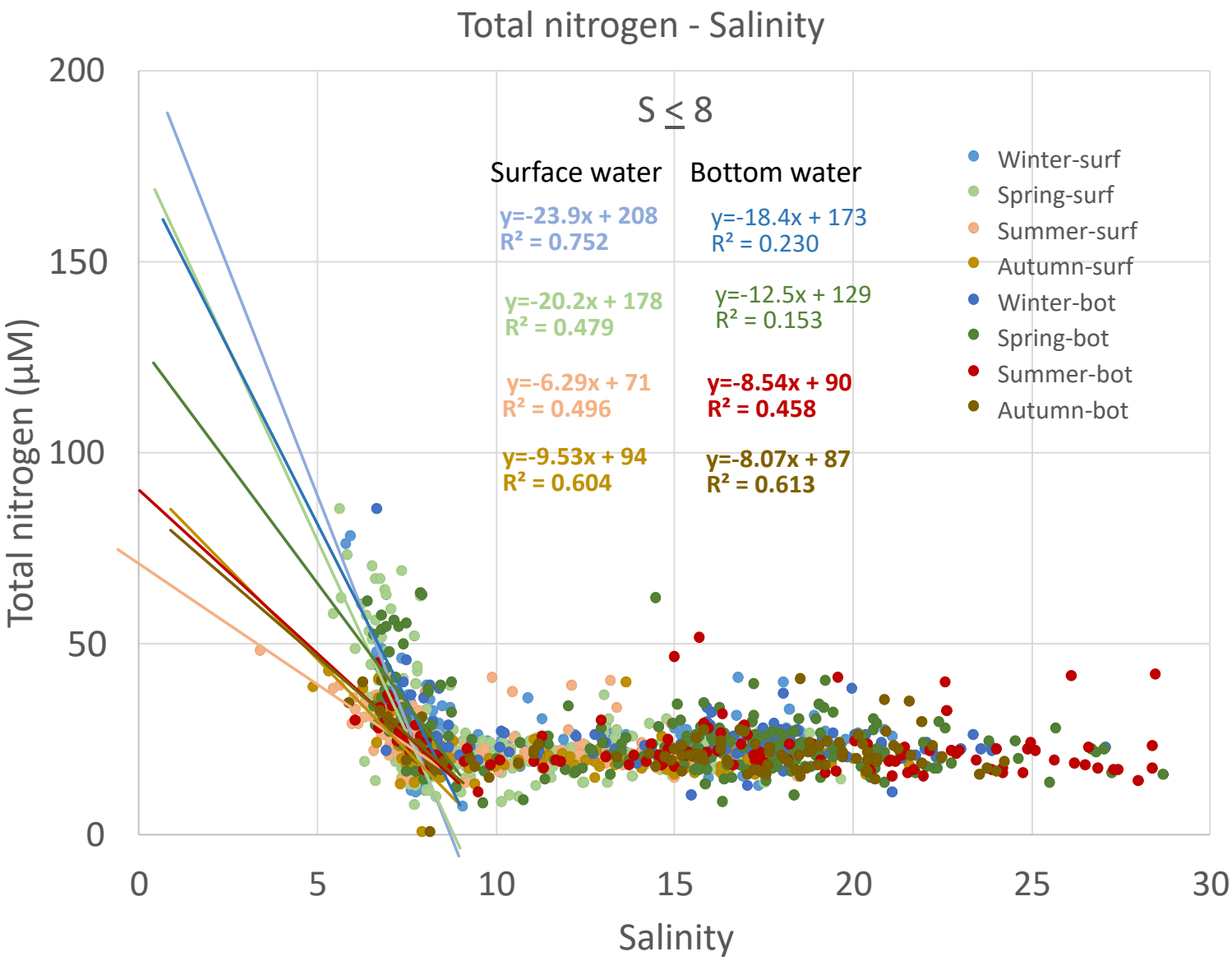

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Western Baltic Sea surface waters					
	slope	y-intercept	R^2	N	p
DIP-Sal		**DIP (µmo/L)**			
Winter	-0.243	**2.5**	0.566	38	$p < 0.001$
Spring	0.079	**-0.4**	0.047	126	$p < 0.05$
Summer	-0.246	**2.0**	0.448	75	$p < 0.001$
Autumn	-0.688	**5.7**	0.703	43	$p < 0.001$
DIN-Sal		**DIN (µmo/L)**			
Winter	-20.073	**163**	0.785	38	$p < 0.001$
Spring	-16.423	**129**	0.421	126	$p < 0.001$
Summer	-0.509	**4**	0.195	74	$p < 0.001$
Autumn	-3.812	**31**	0.359	43	$p < 0.001$
TP-Sal		**TP (µmo/L)**			
Winter	-0.482	**4.6**	0.653	38	$p < 0.001$
Spring	-0.215	**2.3**	0.110	121	$p < 0.001$
Summer	-0.702	**5.9**	0.649	73	$p < 0.001$
Autumn	-0.947	**8.1**	0.774	41	$p < 0.001$
TN-Sal		**TN (µmo/L)**			
Winter	-23.928	**208**	0.752	38	$p < 0.001$
Spring	-20.159	**178**	0.479	127	$p < 0.001$
Summer	-6.288	**71**	0.496	75	$p < 0.001$
Autumn	-9.533	**94**	0.604	43	$p < 0.001$

Extrapolation of significant linear regression lines to zero salinity

-> end-member as an indicator of the freshwater concentration perhaps in winter.

S = 0 /freshwater

DIP: 2.5 µmol/L

DIN: 163 µmol/L

TP: 4.6 µmol/L

TN: 208 µmol/L

WFD target values for the limnic-marine transition

TN: 186 µmol/L (2.6 mg/L)
TP: 3-10 µmol/L (0.1-03 mg/L)

What about temporal changes of nutrient-salinity fits since 1995?

- For 4 periods 1995-1999, 2000-2004, 2005-2009, and 2010-2016
- DIN, TN, DIP, TP versus salinity (S < 9) is investigated with

  the focus on the freshwater end-member (S = 0).
- This is done for all sampled depths, but data from July/August were excluded.
- First the graphs are shown then the findings are given in a table.

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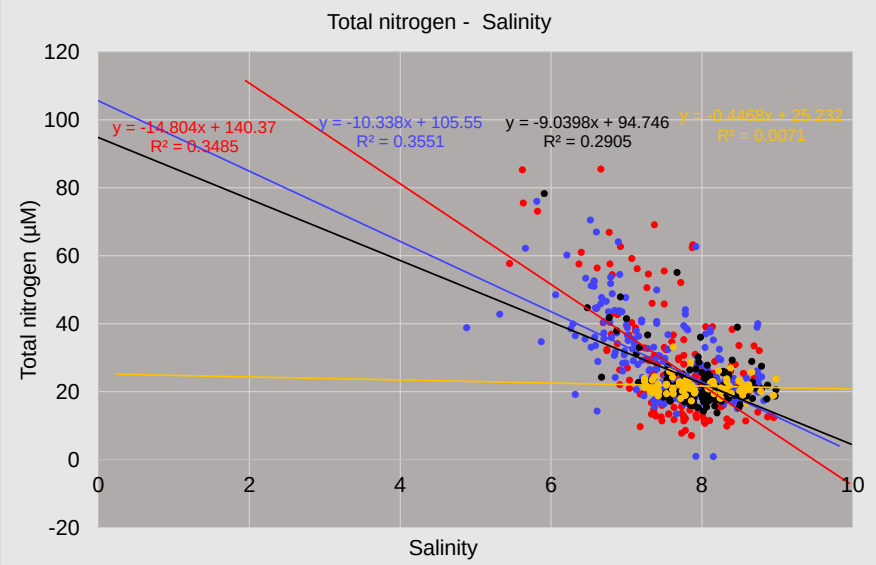
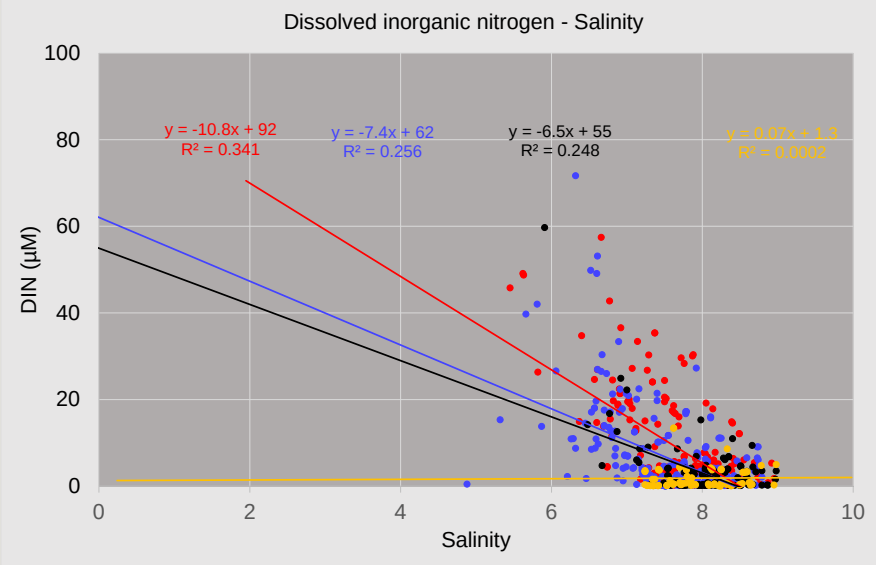
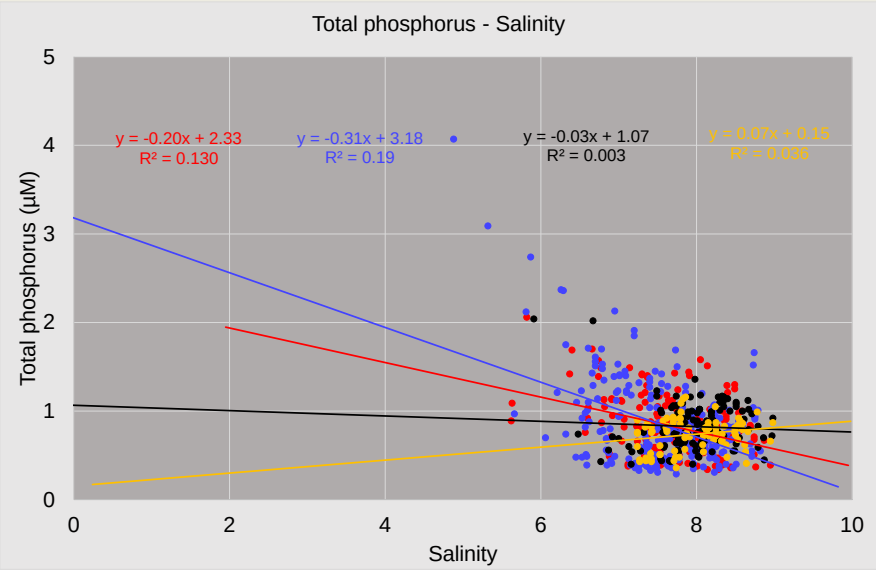
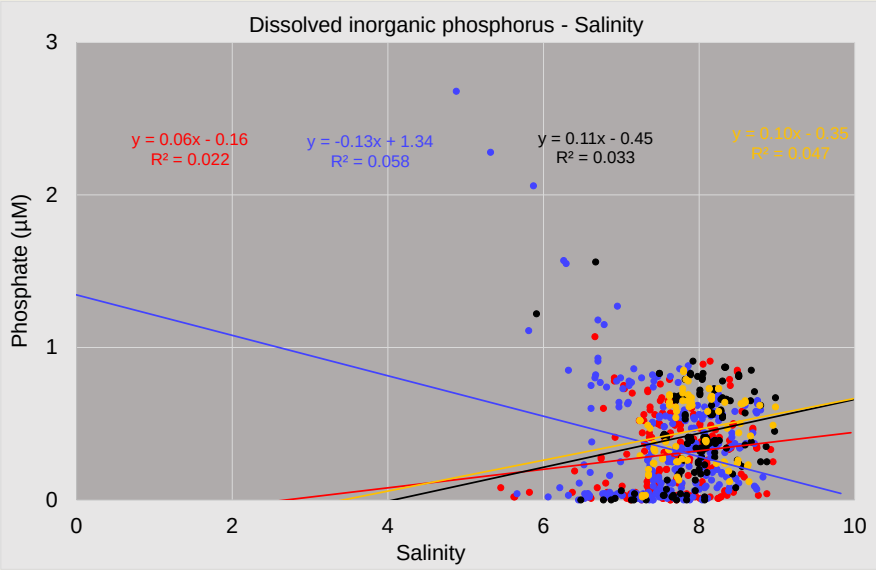
Four periods 1995-1999, 2000-2004, 2005-2009, 2010-2016, without summer data









1995-1999 2000-2004 2005-2009 2010-2016 Linear (1995-1999) Linear (2000-2004) Linear (2005-2009) Linear (2010-2016)

All data except summer - Western Baltic Sea					
	slope	y-intercept	R^2	N	P
DIP-Sal	**DIP (µmo/L)**				
1995-99	0.061	**-0.2**	0.022	200	$p < 0.05$
2000-04	-0.133	**1.3**	0.058	278	$p < 0.001$
2005-09	0.111	**-0.5**	0.033	143	$p < 0.05$
2010-16	0.101	**-0.3**	0.047	89	$p < 0.05$
DIN-Sal	**DIN (µmo/L)**				
1995-99	-10.775	**92**	0.341	200	$p < 0.001$
2000-04	-7.3638	**62**	0.256	279	$p < 0.001$
2005-09	-6.492	**55**	0.248	144	$p < 0.001$
2010-16	0.07	1	0.000	90	n. s.
TP-Sal	**TP (µmo/L)**				
1995-99	-0.195	**2.3**	0.13	188	$p < 0.001$
2000-04	-0.309	**3.2**	0.19	273	$p < 0.001$
2005-09	-0.03	1.1	0.003	144	n. s.
2010-16	0.073	0.2	0.036	88	n. s.
TN-Sal	**TN (µmo/L)**				
1995-99	-14.804	**140**	0.349	200	$p < 0.001$
2000-04	-10.338	**106**	0.355	281	$p < 0.001$
2005-09	-9.04	**95**	0.291	144	$p < 0.001$
2010-16	-0.447	25	0.007	90	n. s.

Extrapolation of significant linear regression lines to zero salinity -> end-member as an indicator of the freshwater concentration

TN and DIN show a decline over 20 years.

For DIP and TP freshwater seems not the dominant source.

Summary

- Anthropogenic nitrogen supply continues to decline (~20 %) whereas phosphorus remains almost on the same level in the western Baltic Sea since 2000 (BSEP 133, 153).
- A clear decline of nutrient concentrations in western Baltic Sea waters is not recorded. However, a slight decrease is indicated in the early 2000 years for nitrogen (TN and DIN).
- A view on freshwater end-member over the last 20 years by „5-year averages“ reveals a declining input of Total nitrogen and Dissolved inorganic nitrogen from the freshwater source. No trend for phosphorus -> the freshwater source seems less important.
- There is a need to better understand the Baltic Sea’s internal nutrient cycling, the nutrient legacy, and its mobilization to realistically estimate the success of reduction measures.

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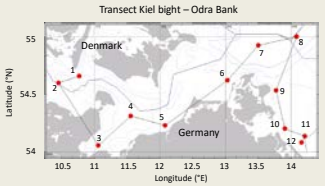
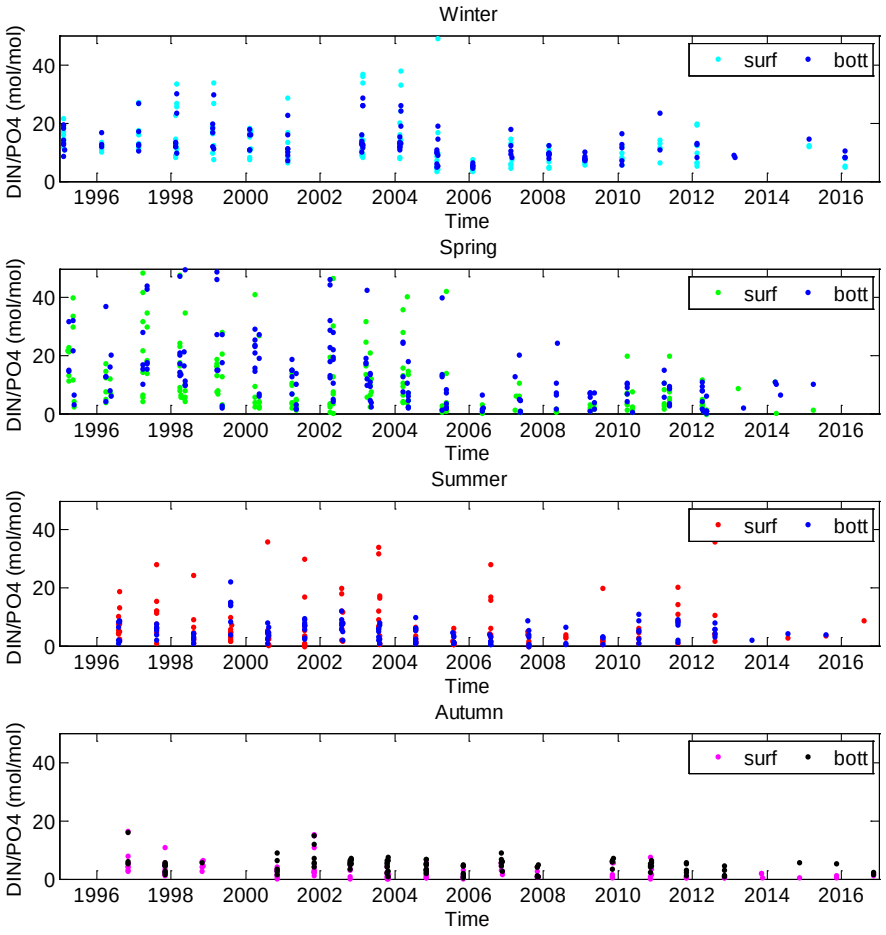
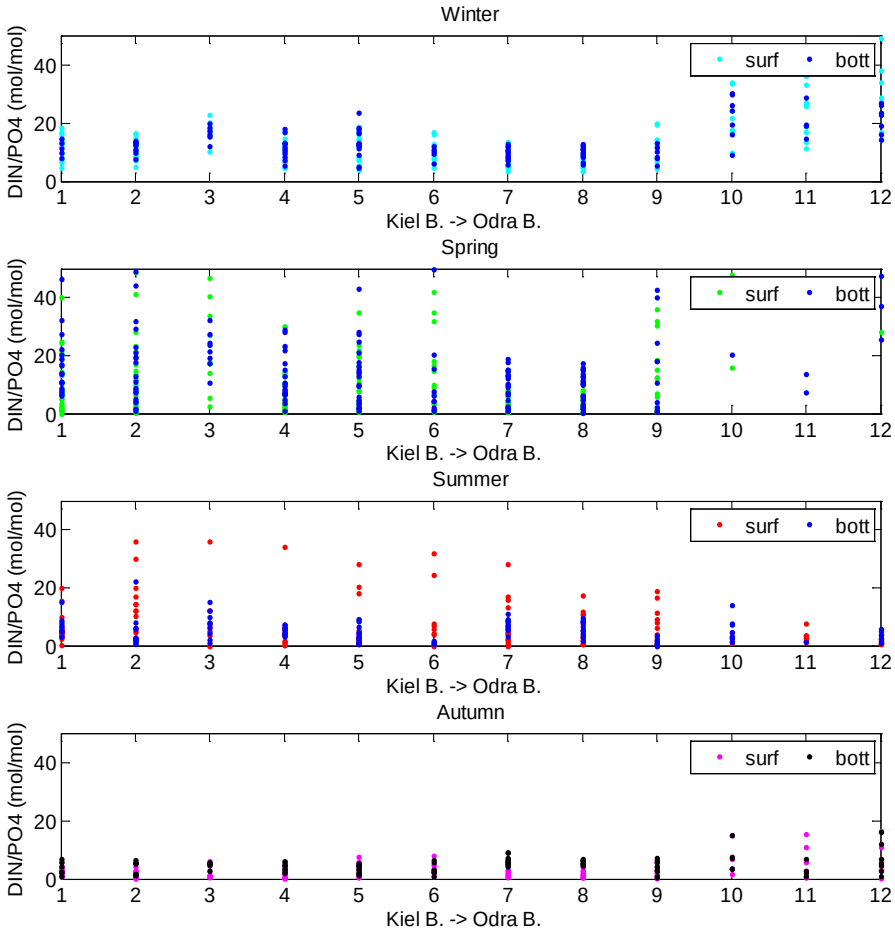
1995 - 2017

DIN/DIP (mol/mol) – scaled to 50 µM







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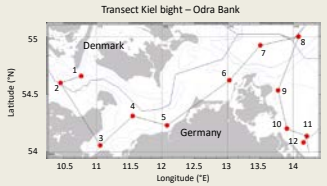
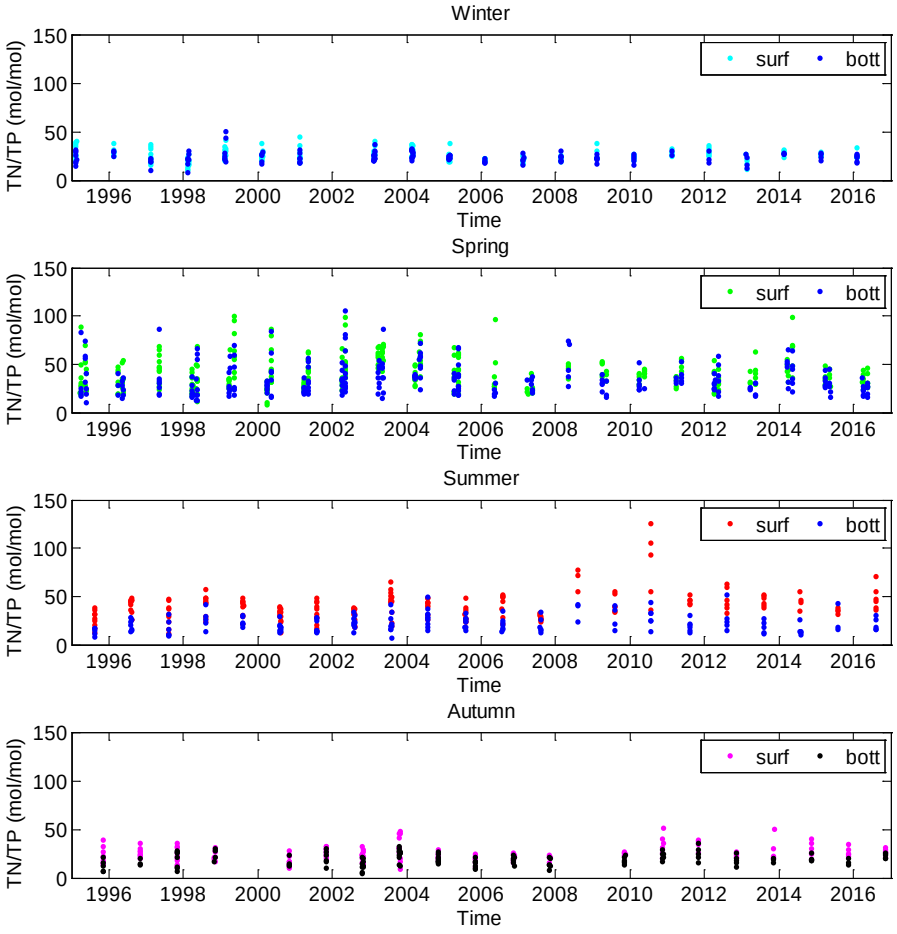
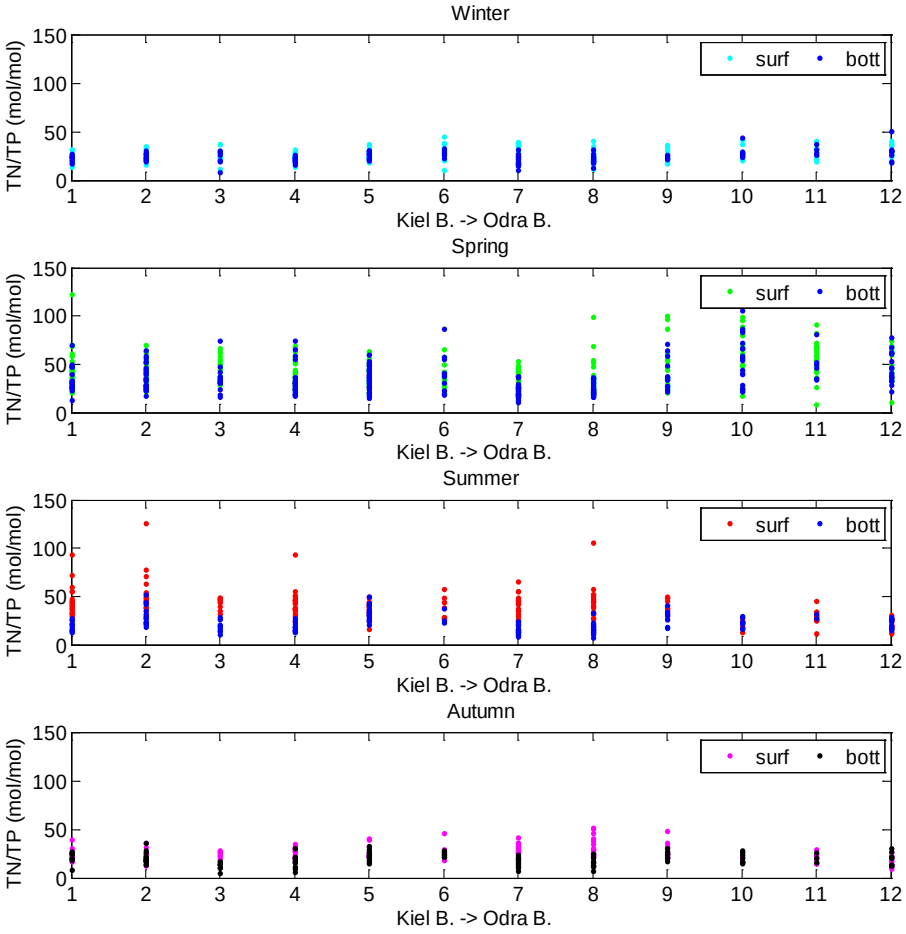
1995 - 2017

TN/TP (mol/mol)







Thanks to the IOW monitoring crew - the chief scientists, scientists, especially the technicians that indeed run the monitoring, and the *Federal Maritime and Hydrographic Agency of Germany* (BSH) for financial support of the monitoring,

and you for your attention!