Influence of recent droughts on carbon cycling in the Elbe estuary

Rewrie, L. C. V., Voynova, Y., Brix, H., Ollesch, G., Baschek, B.
Louise.rewrie@hereon.de

FGG ELBE

FerryBox Community

Helmholtz-Zentrum hereon

Influence of recent droughts on carbon cycling in the Elbe estuary

- FGG Elbe data 1997 – 2020
- The estuary is divided into seven zones.
- DIC increased from the freshwater to the mid to lower region (zones 4-6), followed by a slight decrease to the outer estuary (zone 7).
- Lower DIC in upper region (z1 and upstream) due to spring-summer drawdown via autotrophic activity.
- DIC increase along estuary is due to a shift to heterotrophic activity.
- DIC in the mid to lower estuary (zones 4-7) exhibits an increase from 1997-2020.

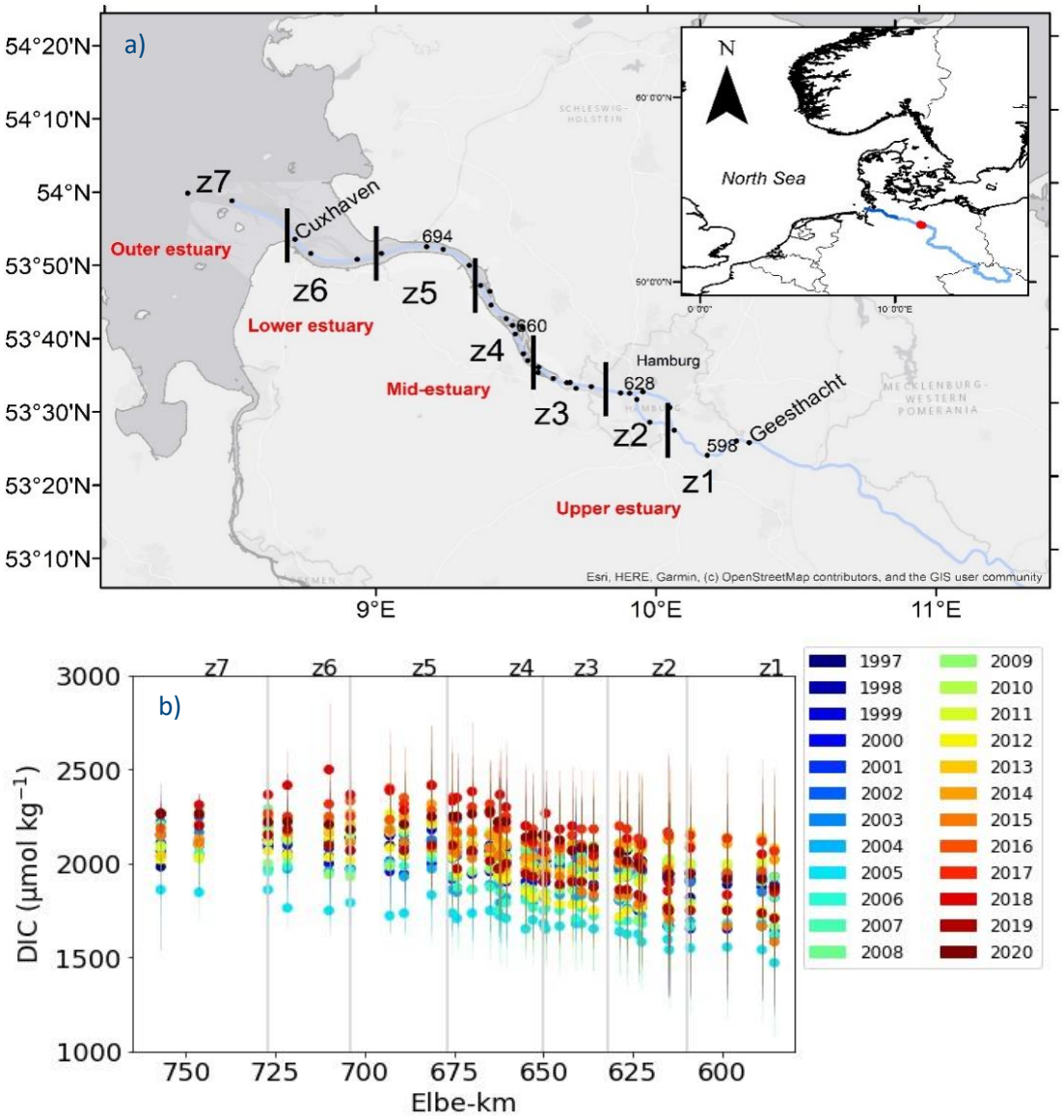


Figure 1: a) Map of the Elbe separated into seven zones, with regions in red. b) Mean annual DIC for each sampling station in the Elbe estuary from 1997-2020, where error bars represent the standard deviation of the mean.

Influence of recent droughts on carbon cycling in the Elbe estuary

- Mean Annual River Discharge

  754 ± 545 m^3 s^{-1} for 1960-2020

  468 ± 234 m^3 s^{-1} for 2014-2020

- Record low discharge 2018-2019:

  < 180 m^3 s^{-1} in August

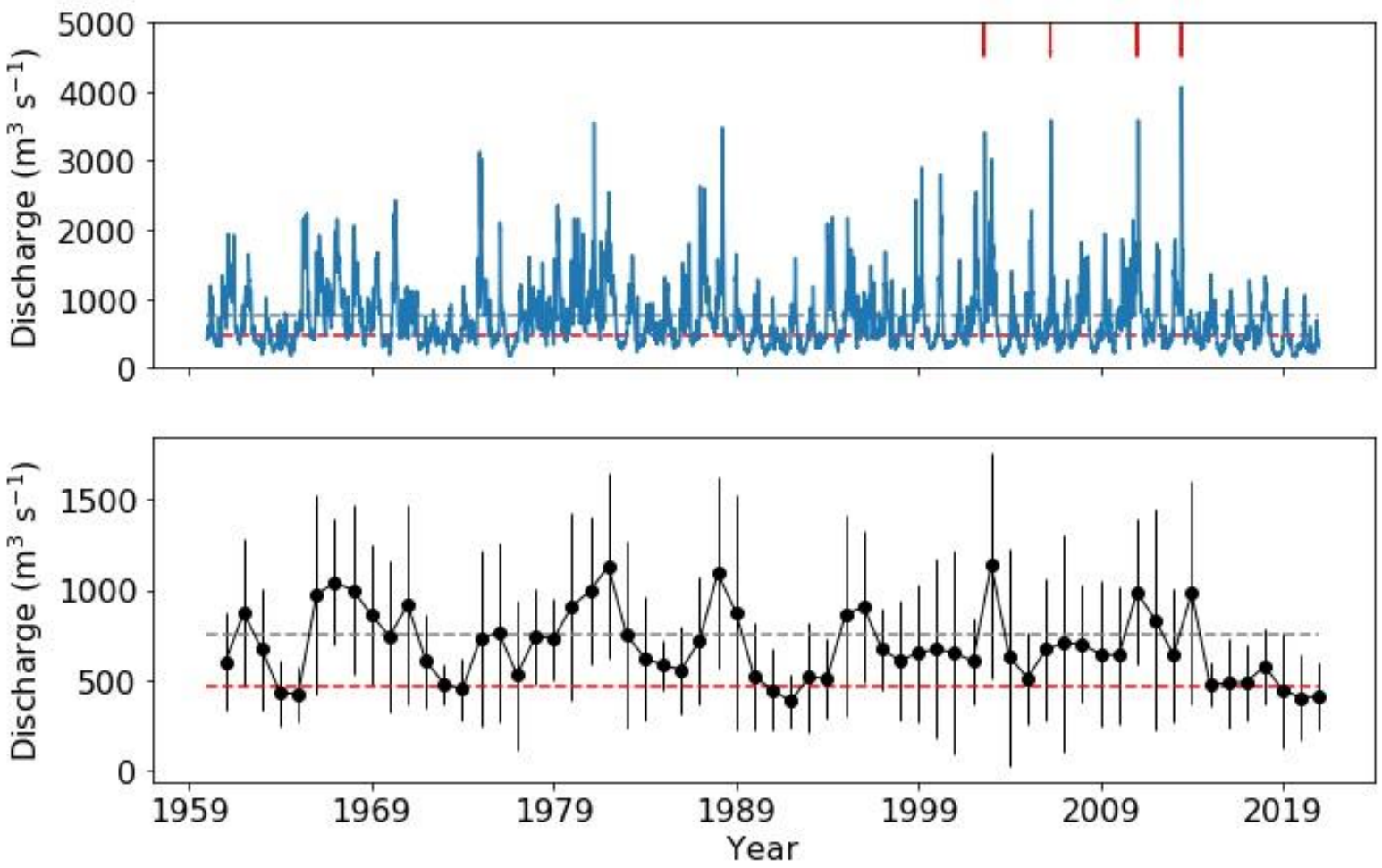
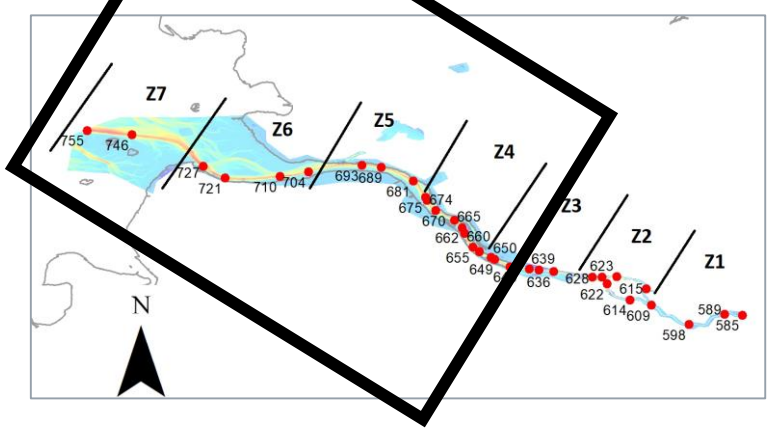


Figure 2: Daily river discharge and annual river discharge, error bars represent standard deviation.

Helmholtz-Zentrum hereon

Influence of recent droughts on carbon cycling in the Elbe estuary

- Significant increase in mean DIC for May-June and mean DIC for July-August over the entire period and recent decade.



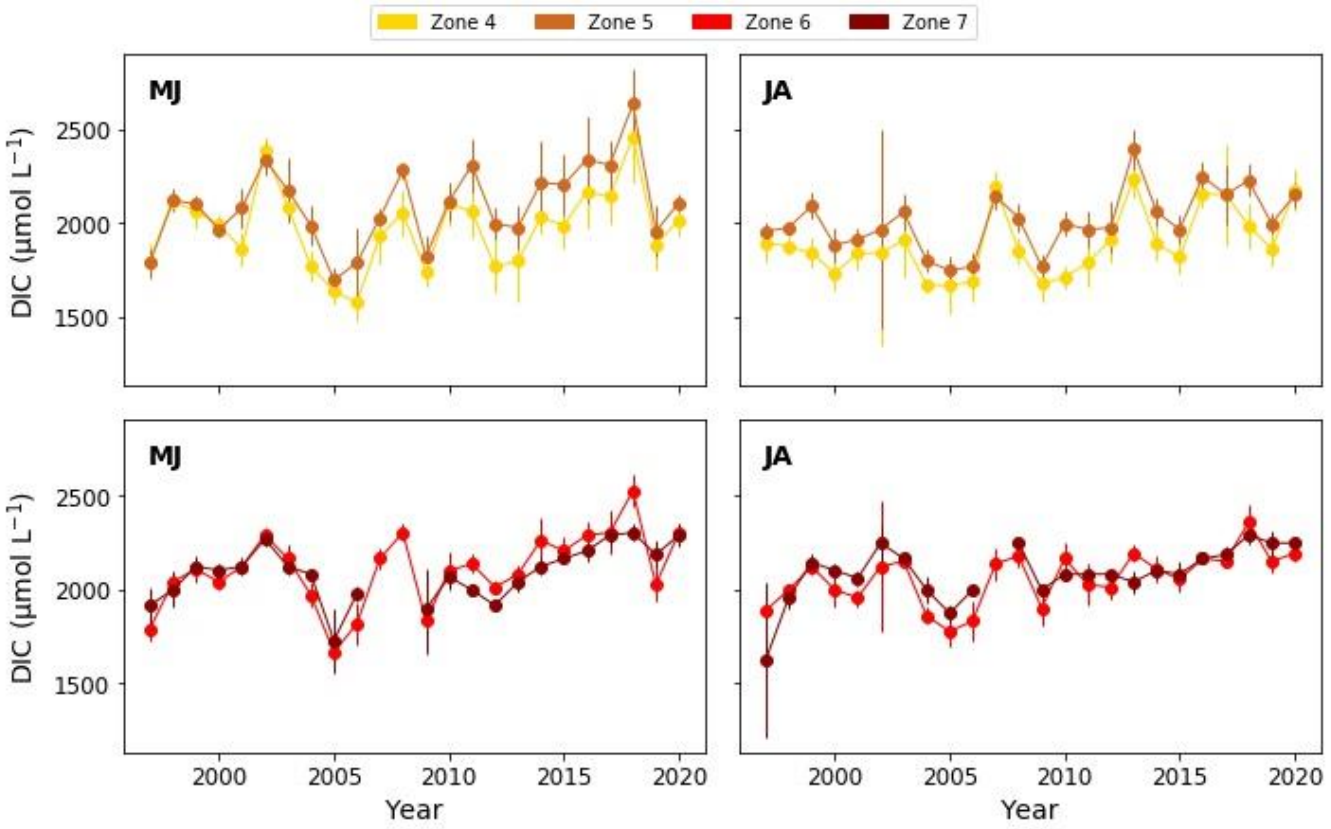


Figure 3: Mean DIC concentration for May-June (MJ) and July-August (JA) in zones 4-7 from 1997-2020.

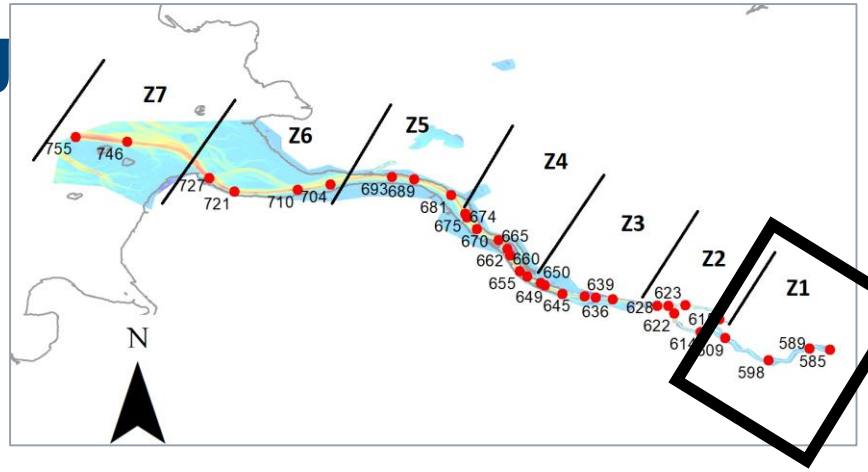
Table 1: Pearson Correlation Coefficient of spring-summer DIC change with time in the mid to outer Elbe estuary. Correlation is significant at $p < 0.05$.

Month	Zone	1997-2020	2010-2020	2008-2018
May-Jun	4	0.08	0.48	0.49
	5	0.38	0.17	0.60
	6	0.48	0.54	0.66
	7	0.43	0.87	0.93
Jul-Aug	4	0.41	0.36	0.63
	5	0.47	0.26	0.58
	6	0.54	0.49	0.50
	7	0.50	0.81	0.43

Helmholtz-Zentrum hereon

Influence of recent droughts on carbon cycling in the Elbe estuary

- Significant increase in mean POC for May-June over the entire period, with highest concentrations from 2014
- Significant decrease in mean POC for July-August during the last decade.



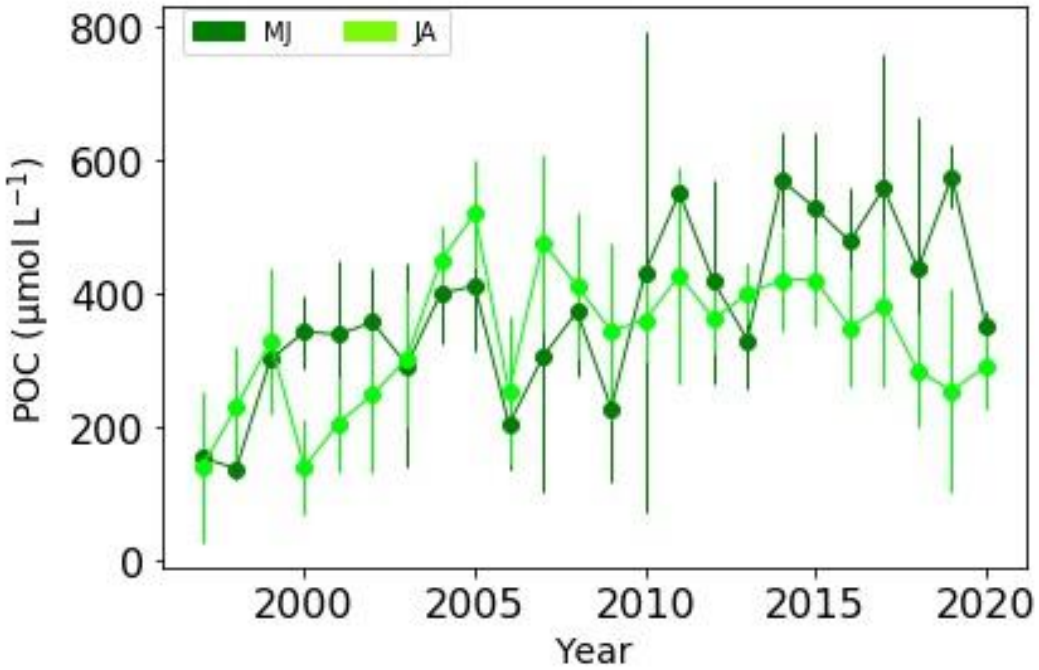


Figure 4: Mean POC for May-June (MJ) and July-August (JA) in zone 1 from 1997-2020. Error bars represent the standard deviation of the mean.

Table 2: Pearson Correlation Coefficient of spring-summer DIC in the mid to outer Elbe estuary. Correlation is significant at $p < 0.05$. Correlation is significant at $p < 0.10$.

Month	Zone	1997-2020	2010-2020	2008-2018
May-Jun	1	0.71	0.08	0.53
Jul-Aug	1	0.36	-0.69	-0.33

Helmholtz-Zentrum hereon

Influence of recent droughts on carbon cycling in the Elbe estuary

Summary

- Decrease in river discharge increases the residence time in the mid to lower estuary, providing extended time for organic matter recycling.
- Increase in POC in zone 1 (1997-2020) likely provides a higher load of organic matter for respiration processes in the mid to outer estuary.
- The combination of longer residence time and higher loads of organic matter can explain the observed increase in DIC concentrations in the mid to outer estuary in the most recent period.

Thank you

www.hereon.de

Helmholtz-Zentrum
hereon

SOM

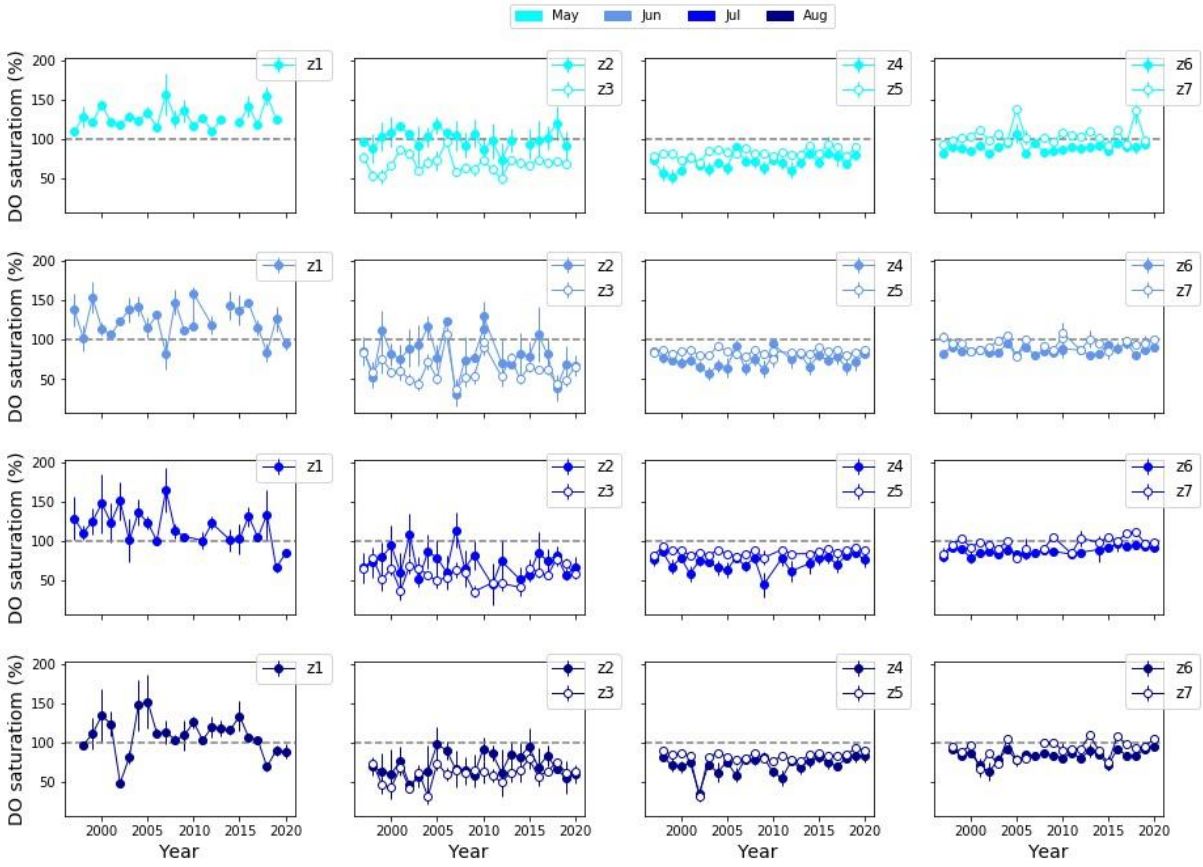


Figure S1: Mean annual DO saturation for zone 1-7 in the Elbe estuary in May-August, where error bars represent the standard deviation of the mean.

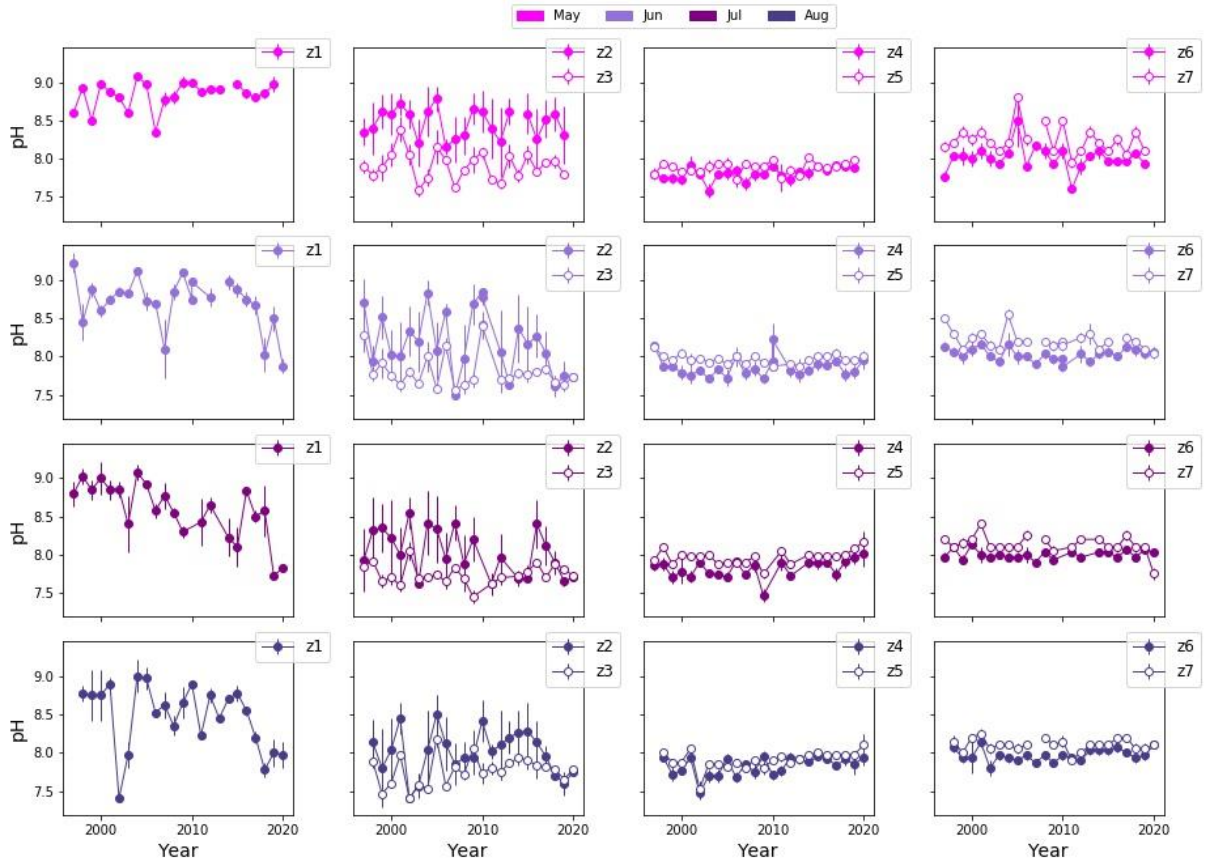


Figure S2: Mean annual pH for zone 1-7 in the Elbe estuary in May-August, where error bars represent the standard deviation of the mean.

SOM

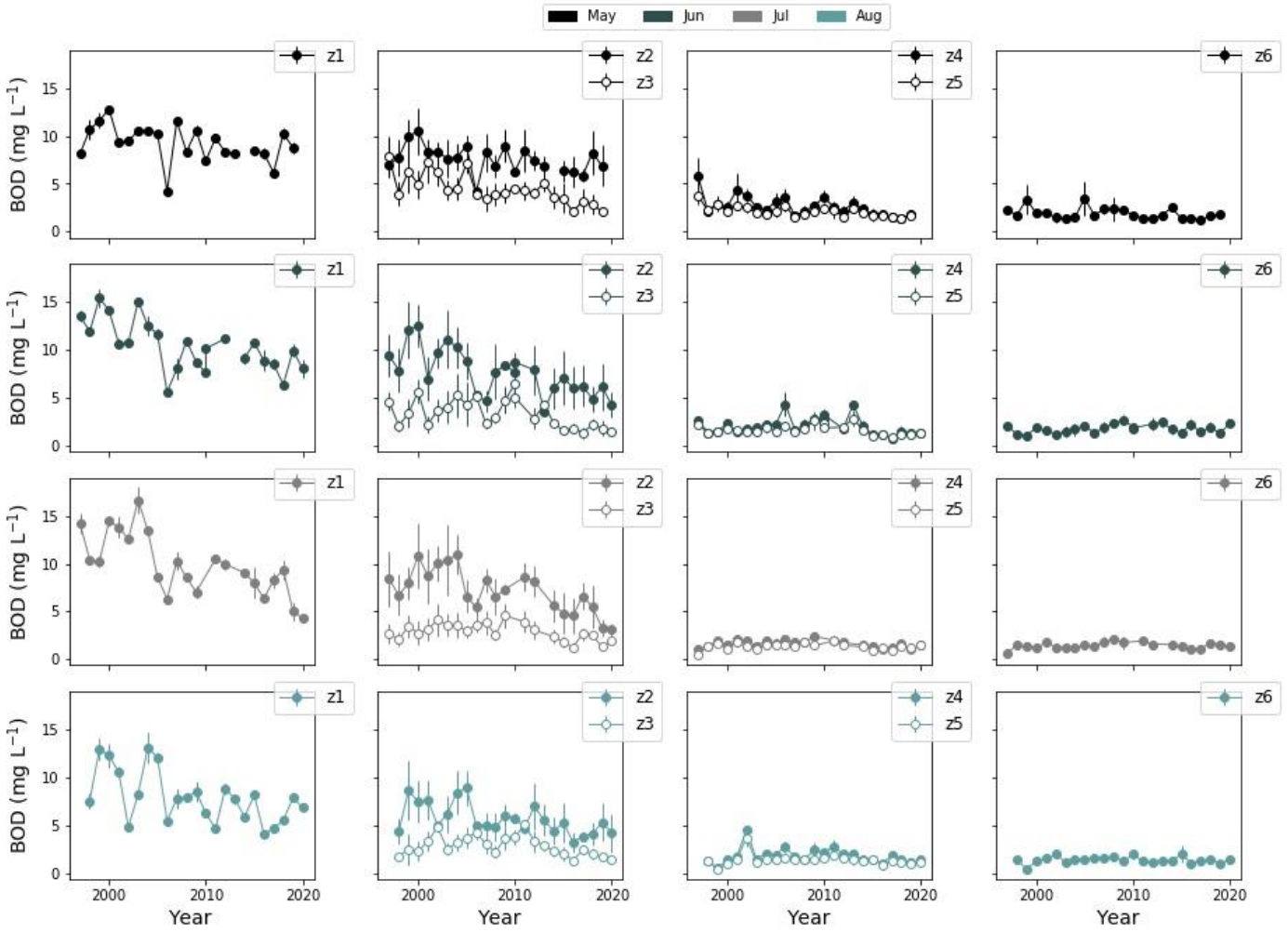


Figure S3: Mean annual BOD for zone 1-6 in the Elbe estuary in May-August, where error bars represent the standard deviation of the mean.

Helmholtz-Zentrum hereon

SOM

Why DIC low in May 2019?

- Sig. increases in the difference between DIC in zone 4-7 and zone 1, from 1997 to 2020.
- In May from 2015 to 2018, DIC in zone 1 increased from 1686 µmol L^{-1} to 2040 µmol L^{-1} however, in 2019 DIC decreased back to 1644 µmol L^{-1} in zone 1.
- Increasing DIC in zone 1 and the relatively higher amount of DIC produced along the mid to lower estuary led to the high DIC in zones 4-7 in the more recent years.
- DIC in 2019 in zone 1 was relatively lower, despite the large increase in DIC towards zone 4-6, the DIC in the mid to lower regions was not as high as the previous few years.

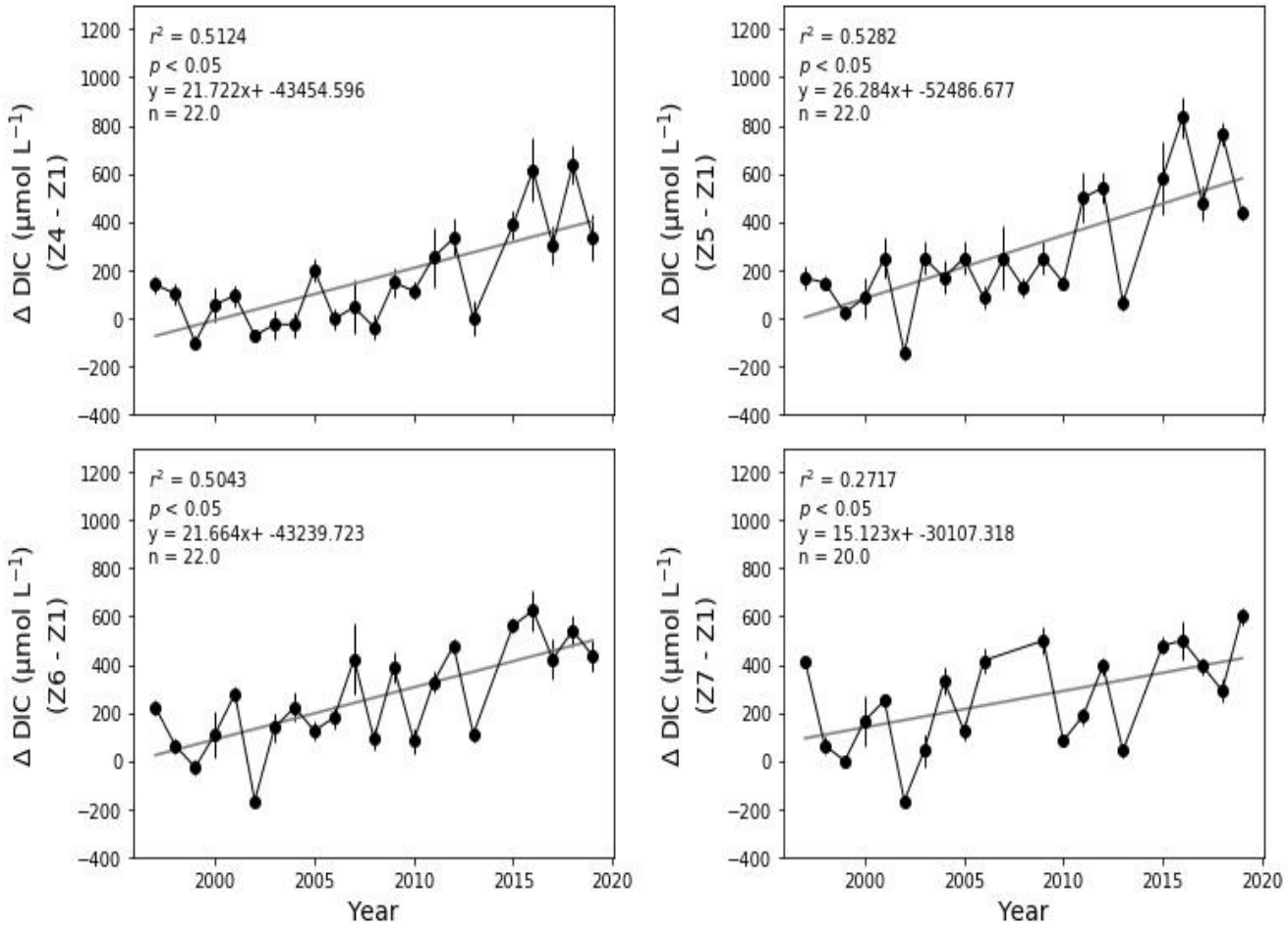


Figure S4: The difference between DIC in zone 4-7 and DIC in zone 1 in May from 1997-2020

Helmholtz-Zentrum hereon

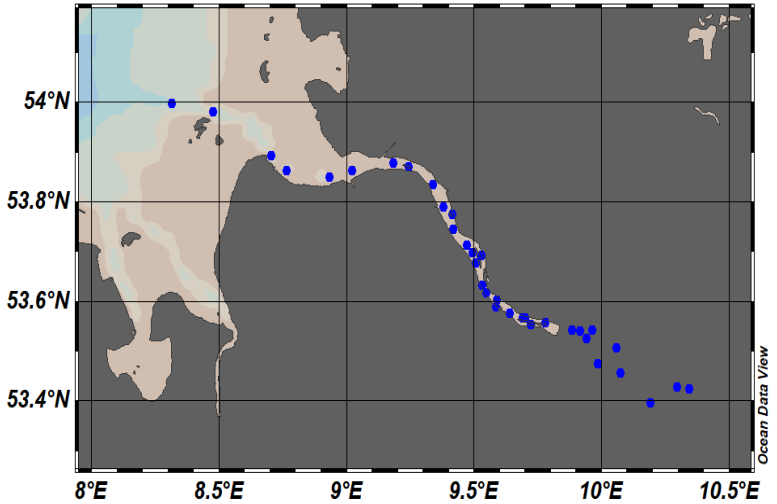
SOM

Table S1: Typical residence time in the six zones in the inner Elbe estuary as a function of low, mean and high river discharge (Q) (Bergemann et al., 1996).

Zone	Elbe-km	Residence time		
		Q = 250 $m^3 s^{-1}$	Q = 700 $m^3 s^{-1}$	Q = 1200 $m^3 s^{-1}$
1	586 – 610	< 2	< 1	< 1
2	610 – 632	3-4	2	1
3	632 – 650	7	2-3	1-2
4	650 – 677	17	5-6	3-4
5	677 – 704	24	9	6
6	704 – 727	30	11	6

Helmholtz-Zentrum hereon

SOM



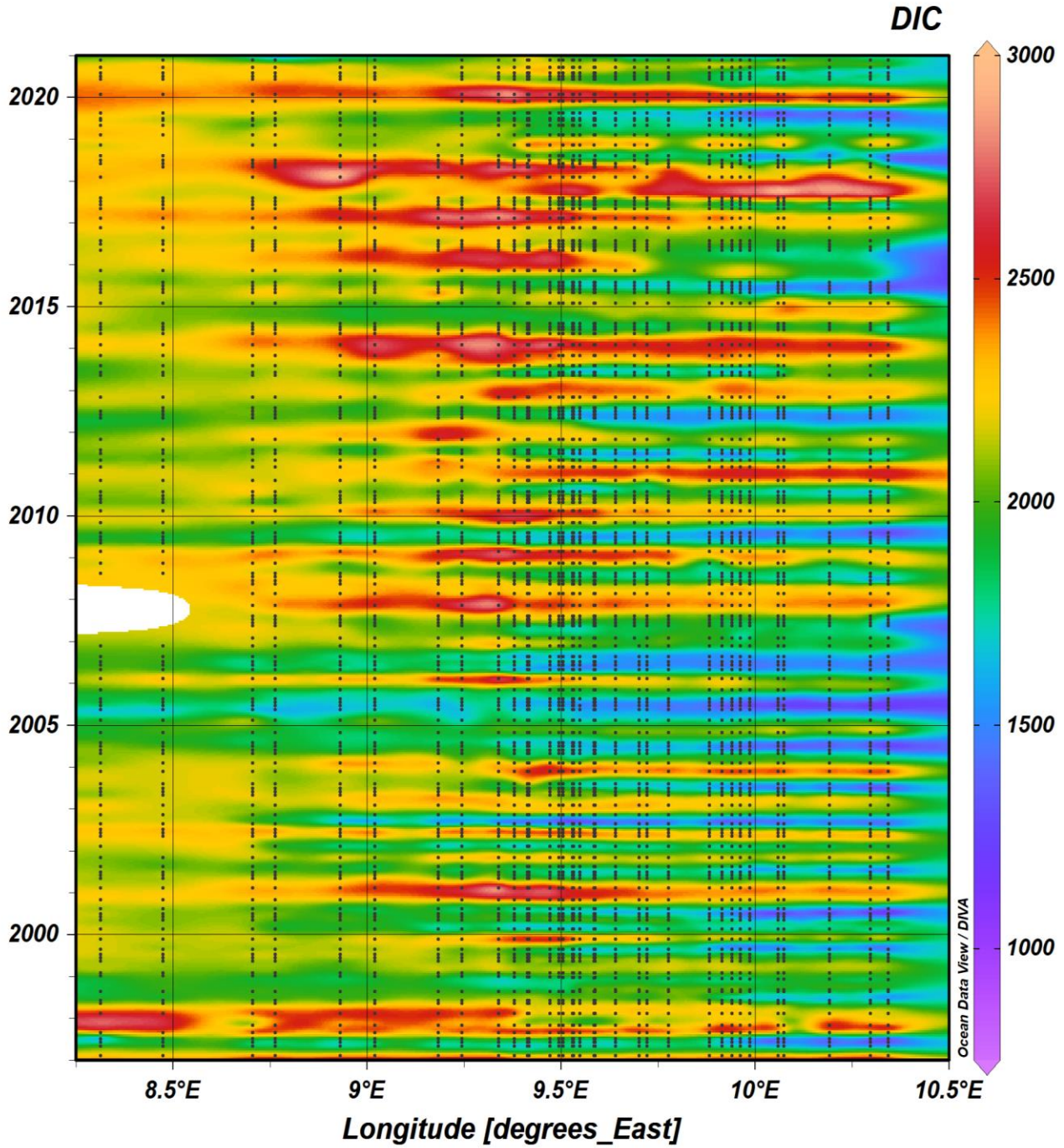


Figure S4: DIC in the Elbe estuary from 1997-2020, with extrapolation in ODV. Black dots represent stations samples.