

# Temporary and long-term sinks of PCB contaminated sediments and their impact on sediment quality and dredging management in the tidal Elbe River

Carmen Kleisinger<sup>1</sup>, Stephan Dietrich<sup>1,2</sup>, Mandy Hoyer<sup>1</sup>, Evelyn Claus<sup>1</sup>, René Schwartz<sup>3</sup>, Ilka Carls<sup>3</sup>, Maja Karrasch<sup>4</sup>, Birgit Schubert<sup>1</sup>

1: Federal Institute of Hydrology (BfG), Koblenz

2: International Centre for Water Resources and Global Change (ICWRGC), Koblenz

3: Behörde für Umwelt und Energie (BUE), Hamburg

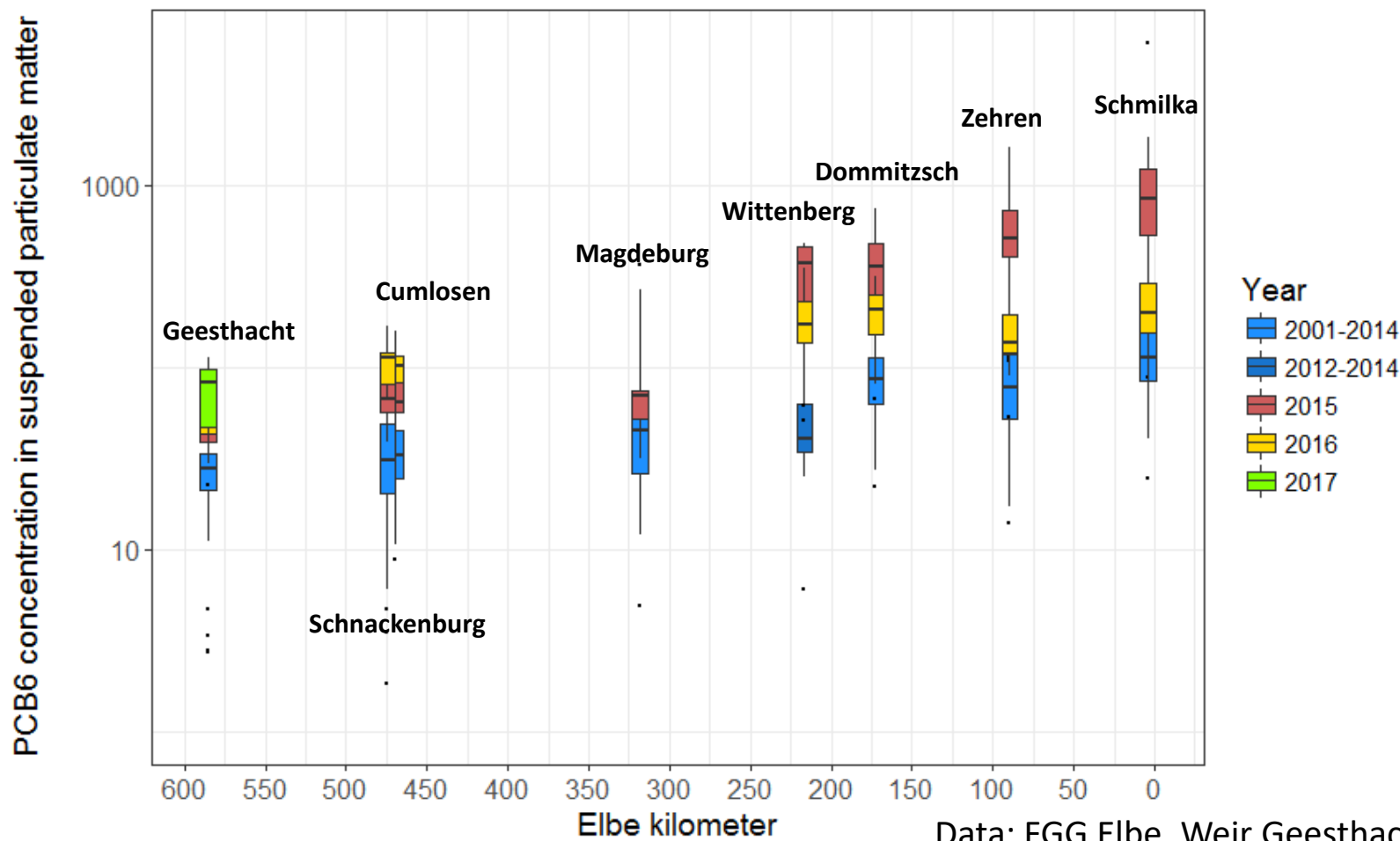
4: Hamburg Port Authority (HPA)



# PCB 6 concentrations along the fresh water part of the Elbe River in suspended particulate matter (SPM)



PCB6 concentration in suspended particulate matter in the Elbe River



## How fast...

### Method (Data basis Ratios)

- PCB ratio (chemical fingerprint) as tracer for suspended load transport
- Estimation of average transport velocities

## How much ...

### Method (Data basis Concentrations)

- Calculation of the monthly PCB loads
- Where and how much of the PCB-tagged SPM has settled?

## How bad...

.....for dredging activities in the estuary

### Method (Data basis Concentrations and Ratios)

- Measurement of the PCB concentrations and ratios in the tidal Elbe
- Estimation of the PCB concentrations under different discharge conditions

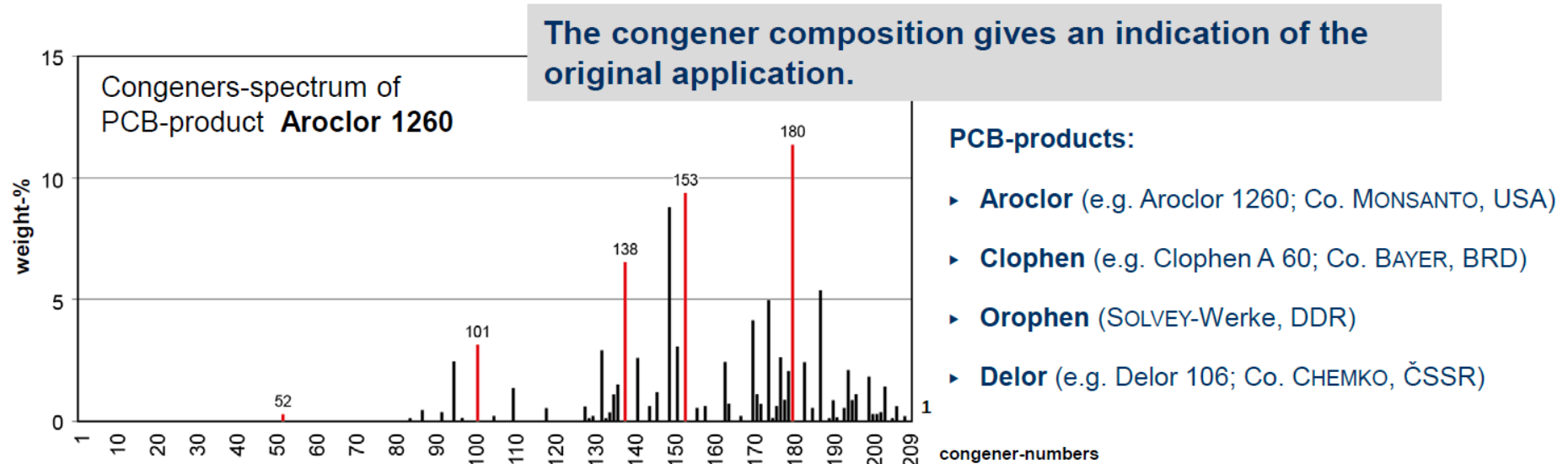
# PCB – Data

Data producer	Parameter	Observation frequency
FGG-Elbe (Federal states)	SPM <sup>1</sup> of the fresh water part of the Elbe	Monthly samples
BfG - permanent monitoring stations	Sediments of the fresh water part of the Elbe	Annual samples
BfG – permanent monitoring stations	SPM of the estuary and the entrance of the estuary	Generally monthly samples, since Dec. weekly at the entrance of the estuary
BfG – permanent monitoring stations	Sediments of the estuary	Generally monthly samples, since Dec. biweekly at two stations
BfG/WSÄ – monitoring of dredging sectors	Sediments of the estuary	Annual samples
FGG-Elbe (HU (BUE)) - permanent monitoring stations	SPM of stations in the estuary	Monthly samples
HPA – release test for sediment transfer	Sediments of the Hamburg Port Area	Annual samples

1: SPM: Suspended Particulate Matter



## PCB ratio (chemical fingerprint) as tracer for suspended load transport:



Source: EPA (2012), modified in ELSA (2016)

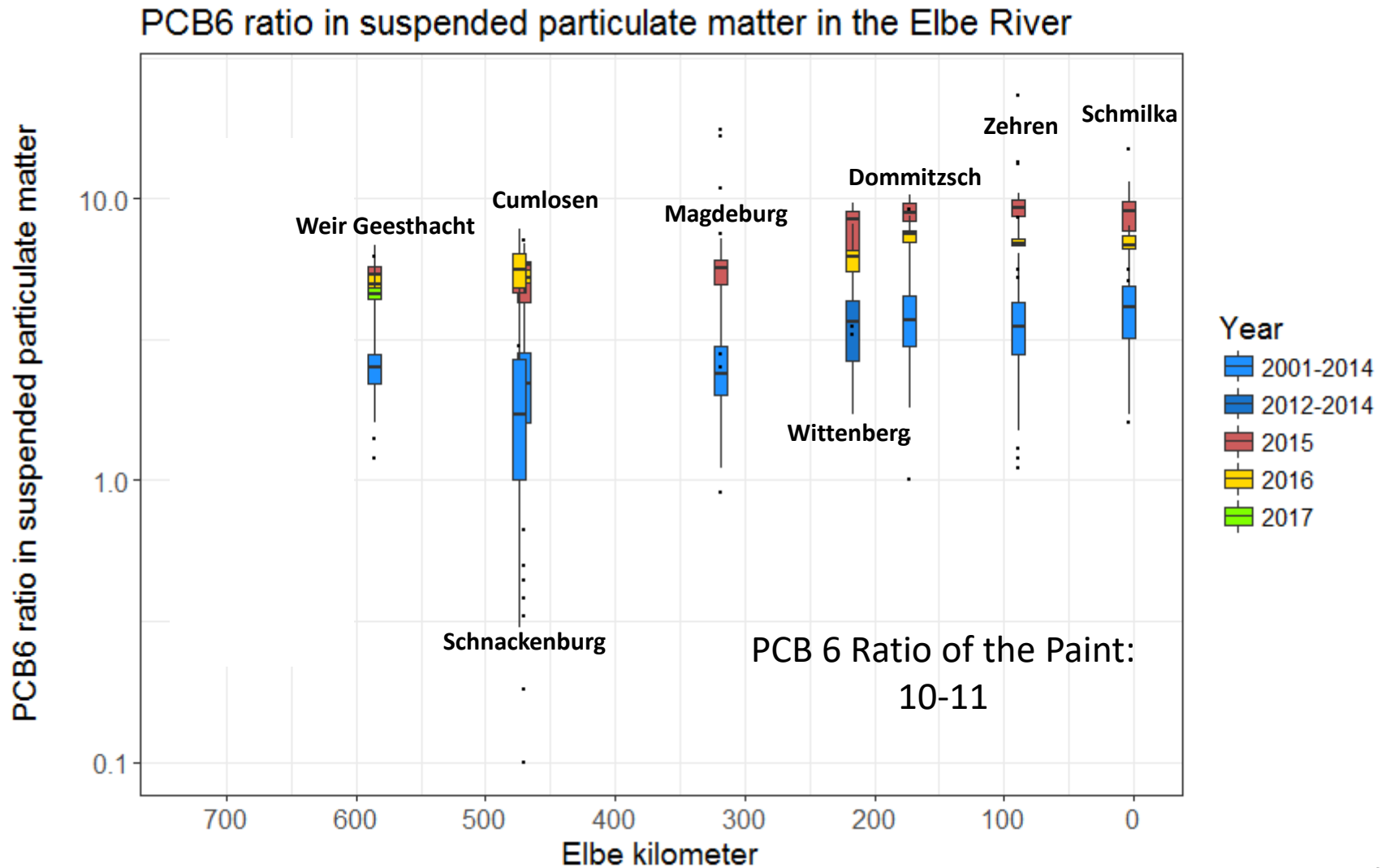
Amongst other applications, Aroclor 1260 was used in protective paints

Highly chlorinated congeners (PCB 180, PCB 153 and PCB 138) show a significant higher percentage in the mixture than the less chlorinated PCB (PCB 101, PCB 52 and PCB 28)

→ **Specific PCB 6 ratio:** 
$$\frac{PCB\ 180+PCB153+PCB138}{PCB\ 28+PCB52+PCB101}$$

# How fast.....

## PCB Ratio (chemical fingerprint) as tracer for suspended load transport:

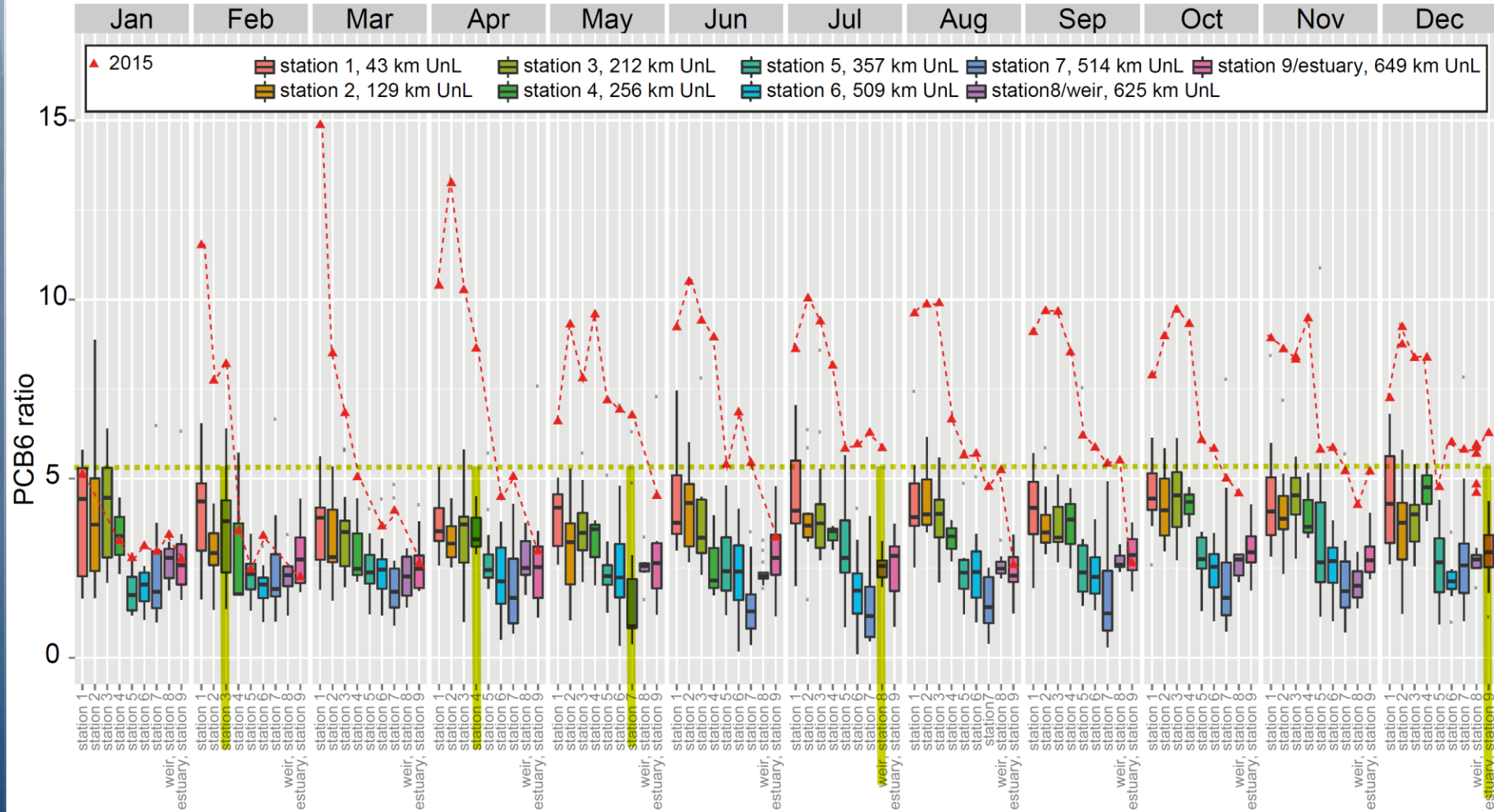


PCB pattern changes in 2015



Changing PCB ratio

## Estimation of average transport velocities in 2015 - PCB 6 Ratio as tracer

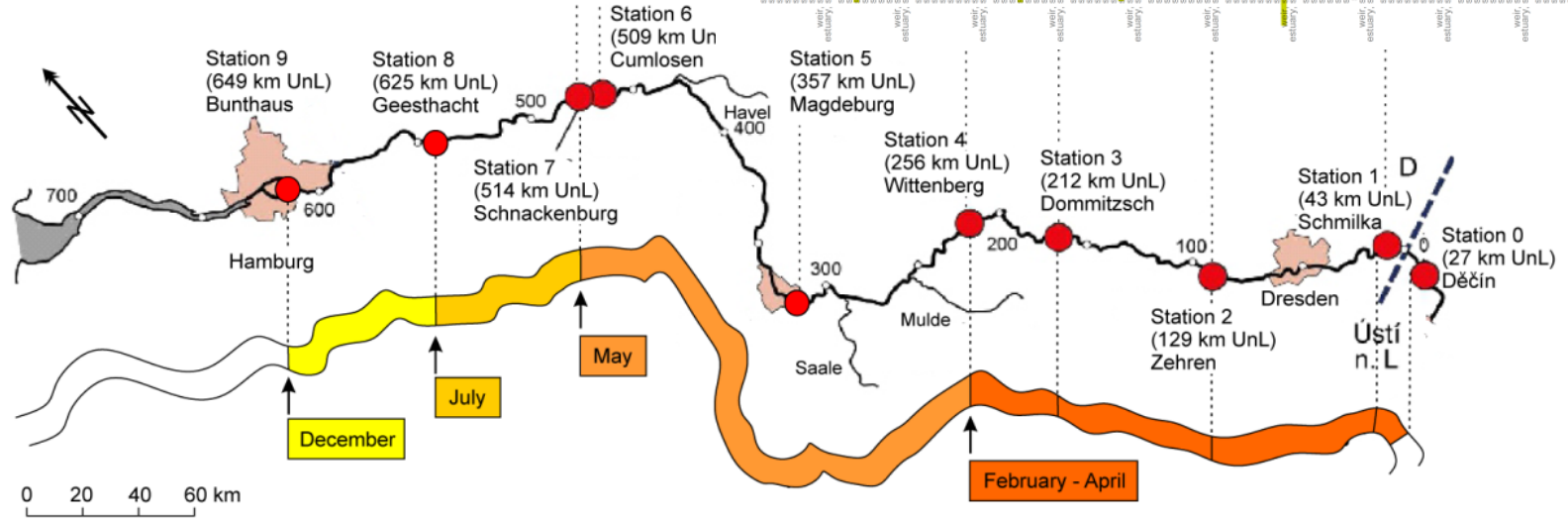
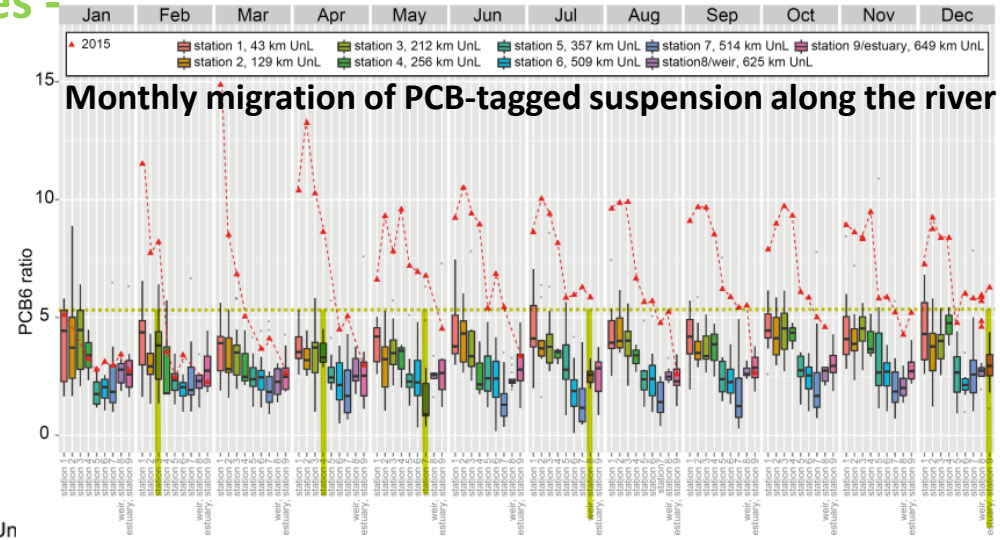


Monthly migration of PCB-tagged suspension along the river

# How fast.....

## Estimation of average transport velocities - PCB 6 Ratio as tracer

2015



- month of first PCB occurrence in river suspension
- April- February (period of bridge construction)
  - May
  - July
  - December



## How fast...

### Method (Data basis Ratios)

- Proxy for suspended load transport: PCB ratio (chemical fingerprint)
- Estimation of average transport velocities

## How much ...

### Method (Data basis Concentrations)

- Calculation of the monthly PCB loads
- Where and how much of the PCB-tagged SPM has settled?

## How bad...

.....for dredging activities in the estuary

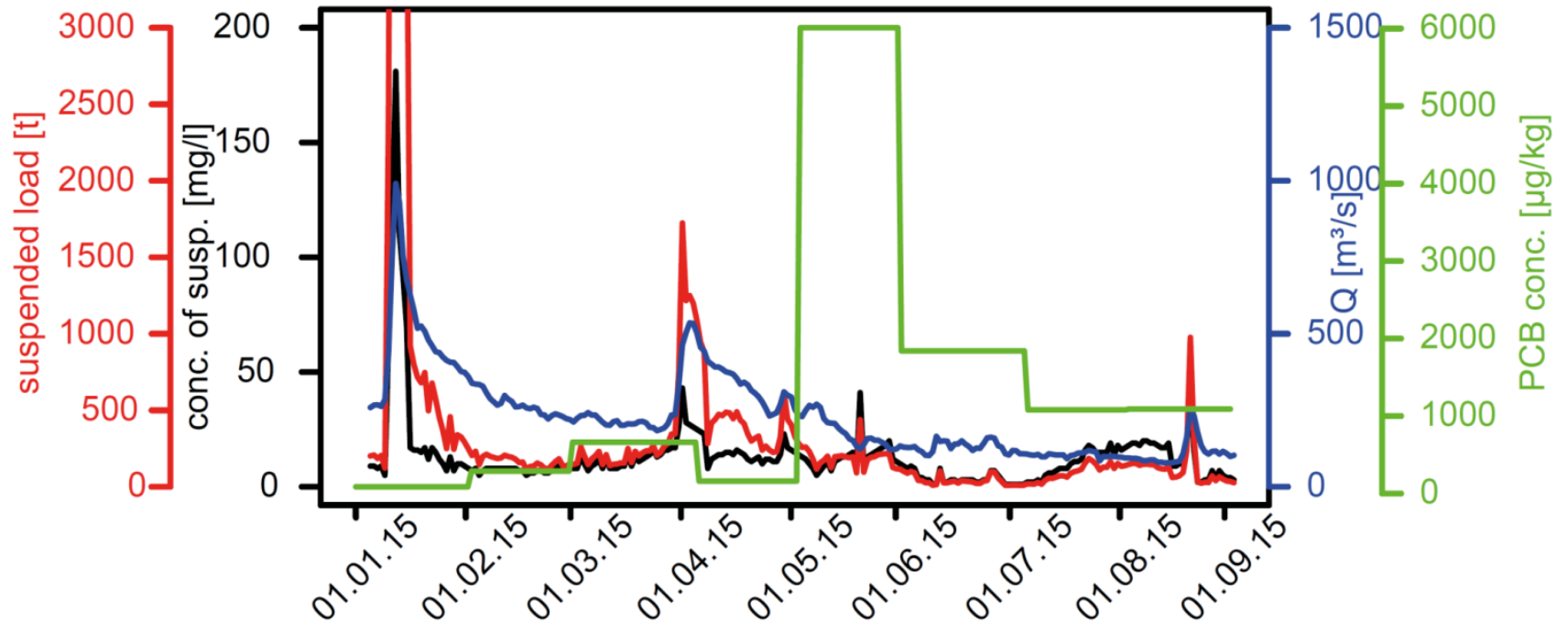
### Method (Data basis Concentrations and Ratios)

- Measurement of the PCB concentrations and ratios in the tidal Elbe
- Estimation of the PCB concentrations under different discharge conditions

## Calculation of the monthly PCB loads in 2015

### 1. Load Calculation according to IKSE, 2014

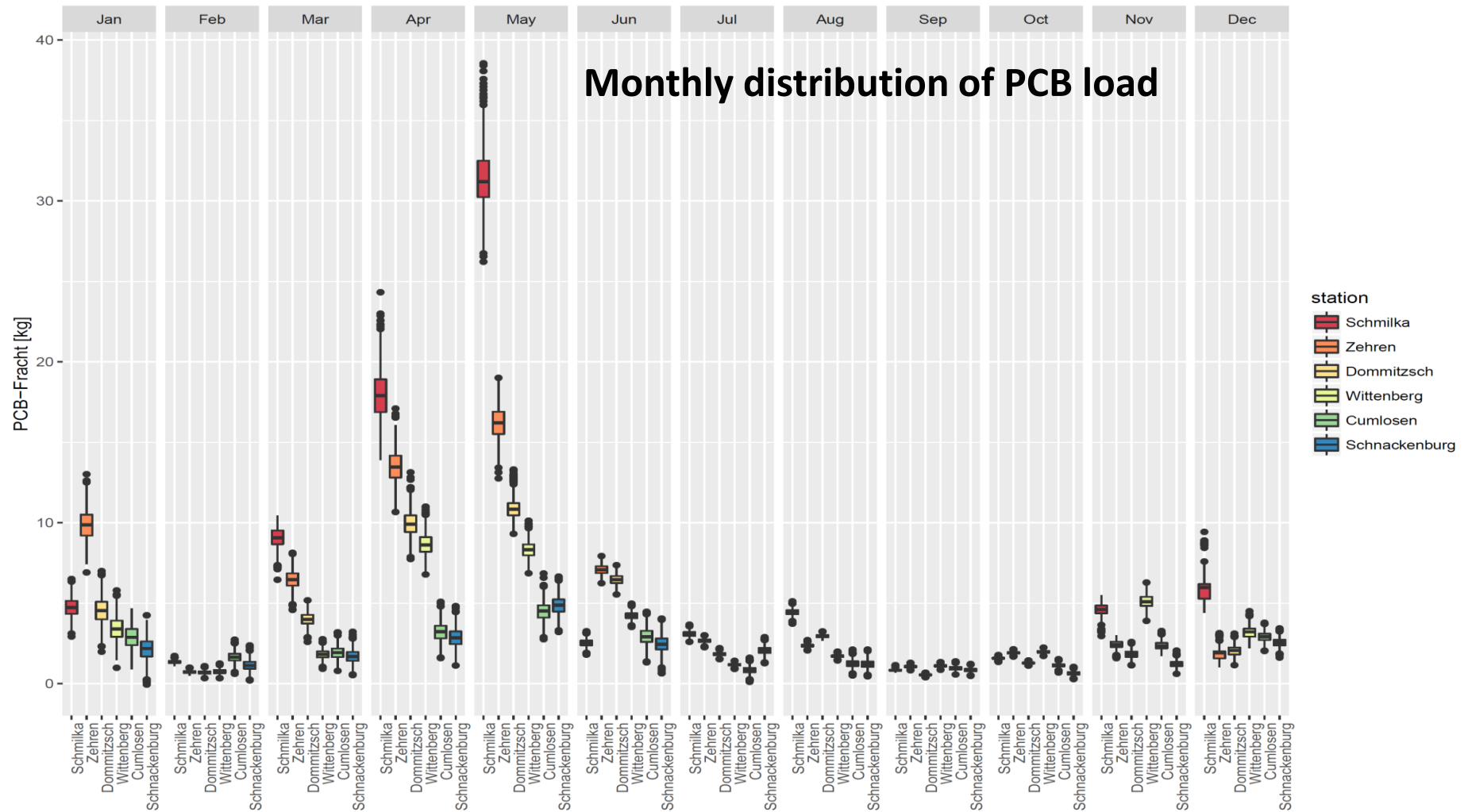
$$F_{PCB} = \sum_{i=1}^n C_{i(PCB)} \cdot \underbrace{SBZR_i}_{\text{monthly suspended load}}$$



### 2. Estimation of uncertainties via Monte Carlo Experiments

# How much ...

## Calculation of the monthly PCB loads in 2015 (with PCB concentrations)



## Where and how much of the PCB-tagged SPM has settled in 2015?

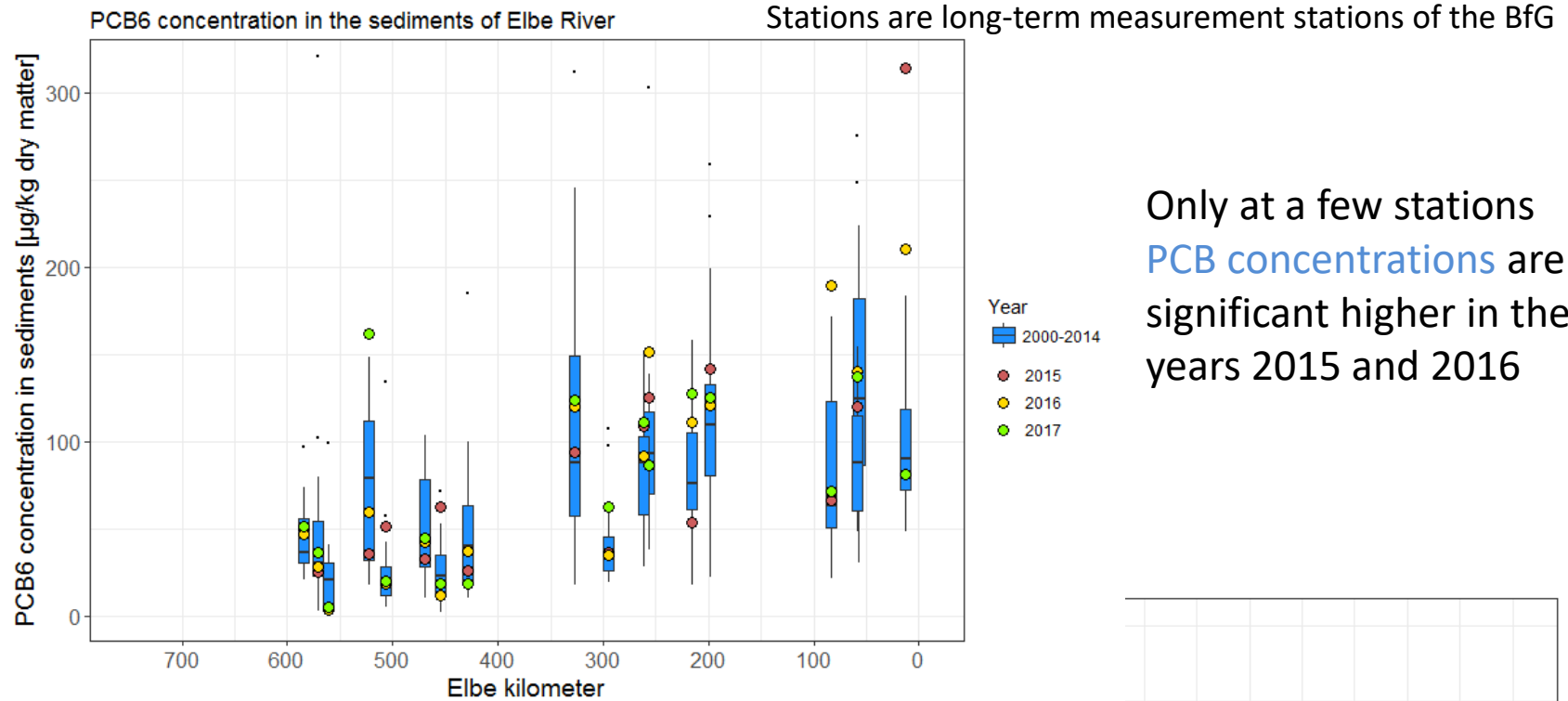
### PCB Load in the Elbe River in 2015

	Schmilka (3,9 km)	Zehren (89,6 km)	Dommitzsch (172,5 km)	Wittenberg (216,5 km)	Cumlosen (470 km)	Schnackenberg. (474,5 km)	Sum
F [kg] (p=90%)	76.6 – 98,6	58.1 – 74.0	40.9 – 53.5	35.4 – 47.7	19.1 – 33.7	16.9 – 30.9	
F [kg] (median)	87.3	65.9	46.9	41.4	26.4	23.7	
$\Delta F$ [kg]		21.4	19.0	5.5	15.0	2.7	63.6
$\Delta F_{\text{Schmilka}}$ [%]		25%	22%	6%	17%	3%	73%

- Significant reduction of total PCB tagged SPM load within the first 514 km downstream of the incident site
- Roughly 73% of the annual SPM load in 2015 (relative to station 1 “Schmilka”, 43 km downstream of the incident site) is stored in the sediments of storage areas of the Elbe River
- SPM in transport enters storage areas after a relatively short distance/time - low discharge conditions 2015
- Remobilisation of PCB tagged sediments with increasing discharge is likely - further transport downstream

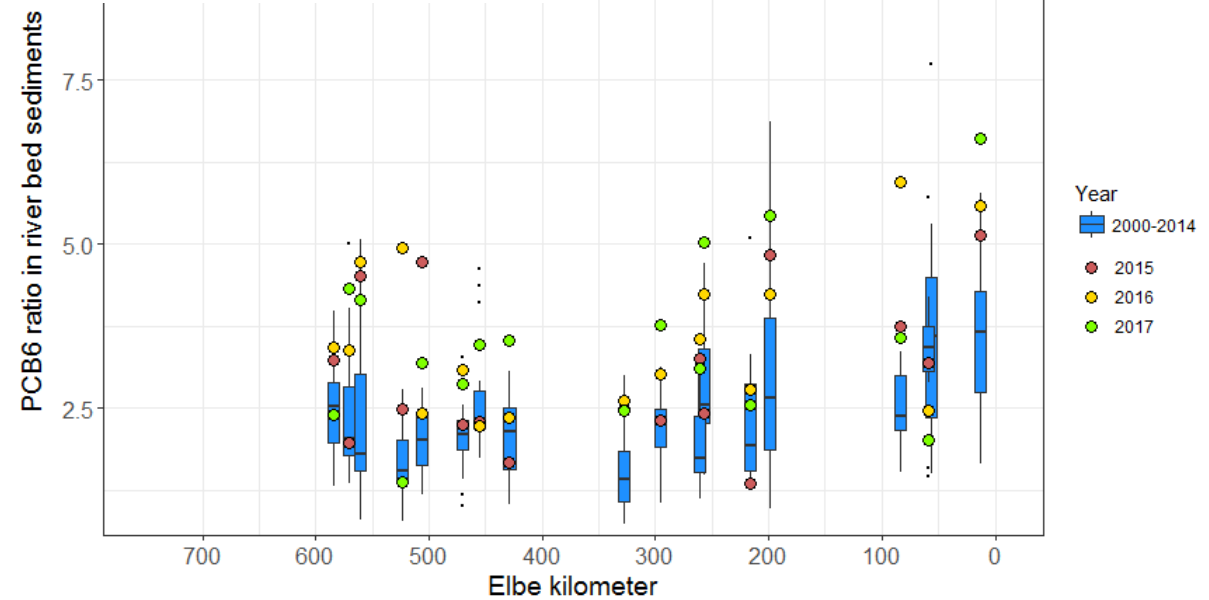


# PCB 6 concentrations and ratios along the river (sediments in storage areas)



Only at a few stations  
PCB concentrations are  
significant higher in the  
years 2015 and 2016

PCB 6 ratios show that  
PCB tagged SPM settled  
in storage areas,  
especially in 2017



## How fast...

### Method (Data basis Ratios)

- Proxy for suspended load transport: PCB ratio (chemical fingerprint)
- Estimation of average transport velocities

## How much ...

### Method (Data basis Concentrations)

- Measurement of the monthly PCB loads
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## How bad...

.....for dredging activities in the estuary

### Method (Data basis Concentrations and Ratios)

- Measurement of the PCB concentrations and ratios in the tidal Elbe
- Estimation of the PCB concentrations under different discharge conditions

# How bad... .....for dredging activities in the estuary





# How bad... .....for dredging activities in the estuary

## Action levels (AL) for dredging and depositing in the estuary (GÜBAK)

Parameter	Unit	Fraction	AL 1	AL 2
Arsenic	mg/kg TS	<20 µm	40	120
Cadmium	mg/kg TS	<20 µm	1,5	4,5
Chrome	mg/kg TS	<20 µm	120	360
Copper	mg/kg TS	<20 µm	30	90
Nickel	mg/kg TS	<20 µm	70	210
Lead	mg/kg TS	<20 µm	90	270
Zinc	mg/kg TS	<20 µm	300	900
Mercury	mg/kg TS	<20 µm	0,7	2,1
MKW (C10 - C40)	mg/kg TS	<63 µm	200	600
Sum PAH 16	mg/kg TS	<63 µm	1,8	5,5
Sum PCB 7	µg/kg TS	<63 µm	13	40
a-Hexachlorcyclohexane	µg/kg TS	<63 µm	0,5	1,5
g-Hexachlorcyclohexane	µg/kg TS	<63 µm	0,5	1,5
p,p'-DDT	µg/kg TS	<63 µm	1	3
p,p'-DDD	µg/kg TS	<63 µm	2	6
p,p'-DDE	µg/kg TS	<63 µm	1	3
PeCB	µg/kg TS	<63 µm	1	3
HCB	µg/kg TS	<63 µm	1,8	5,5
TBT	µg OZK/kg TS	<2000 µm	20	300
P- total	mg/kg TS	<2000 µm	500	
N - total	mg/kg TS	<2000 µm	1500	

### AL 2:

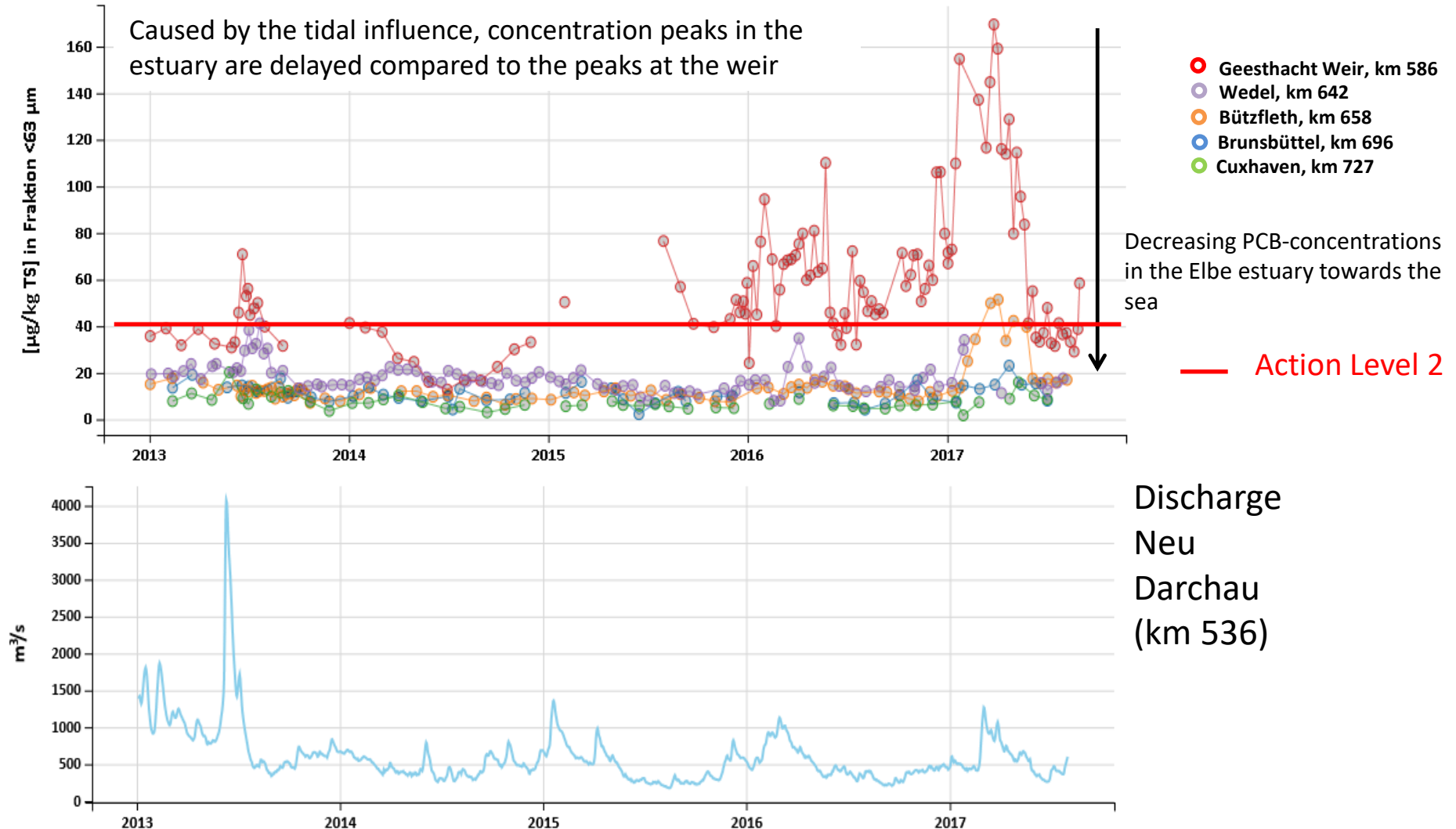
- Impact forecast has to be developed
- Depositing in the estuary has to be checked thoroughly



# How bad... .....for dredging activities in the estuary

## Measurement of the PCB concentrations and ratios in the tidal Elbe

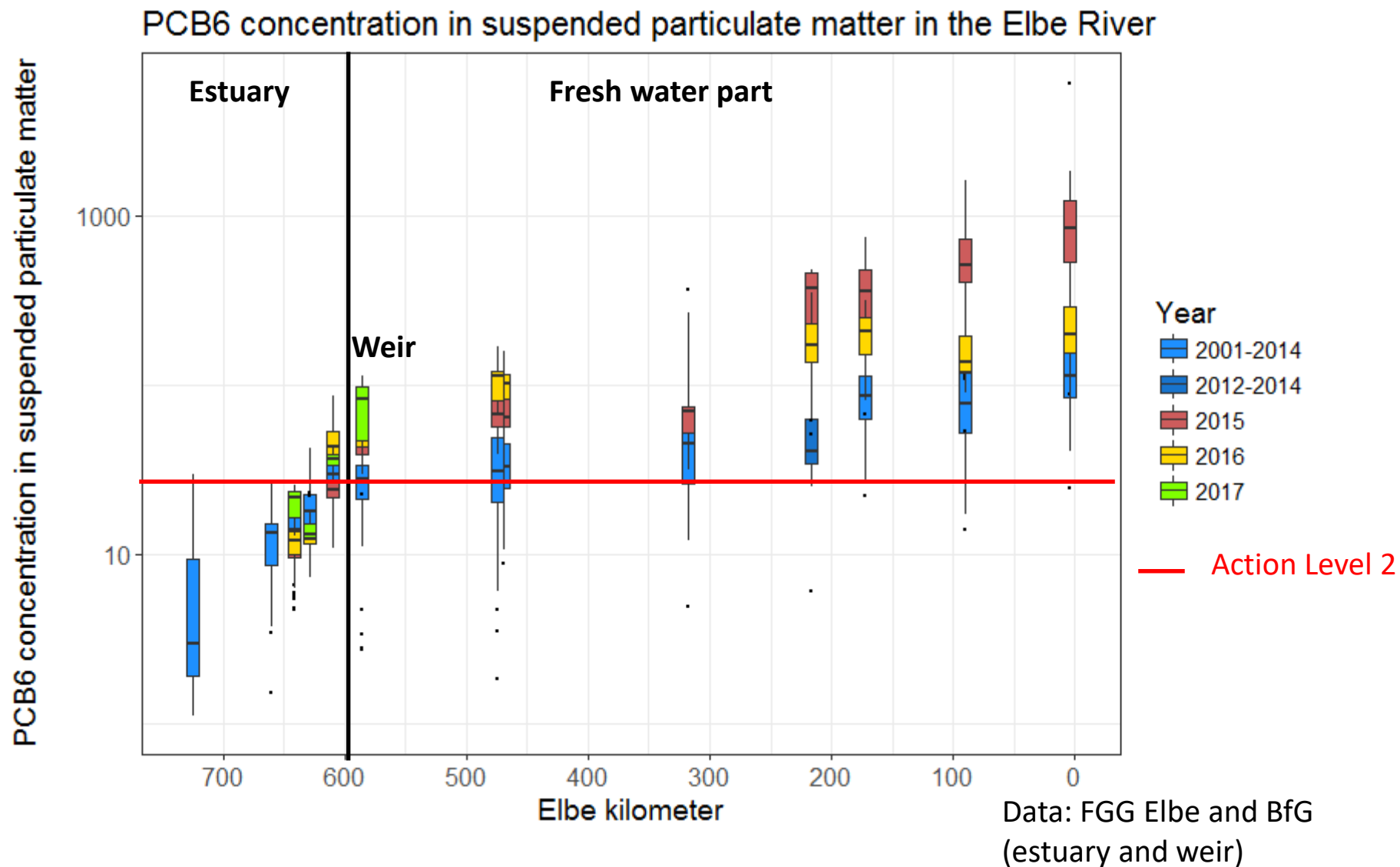
### Long-term measurements of the sum PCB 7 concentrations in the estuary



How bad...

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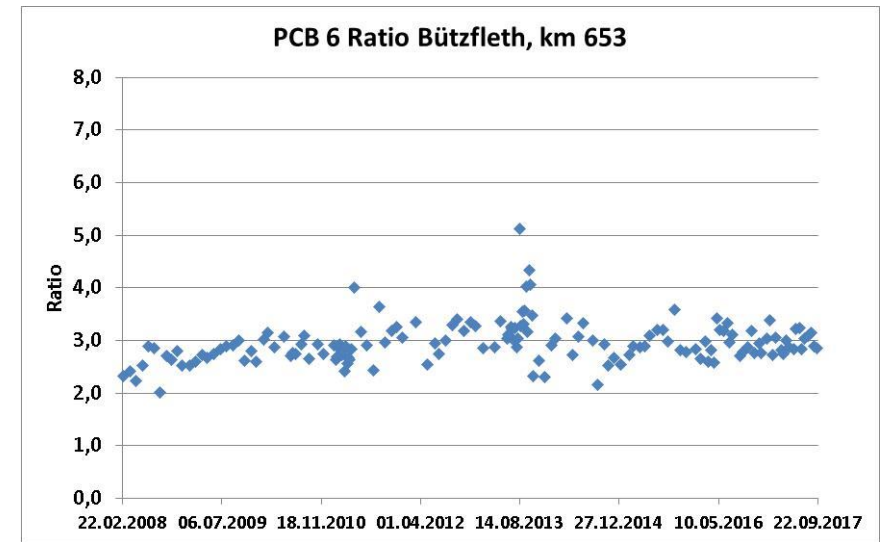
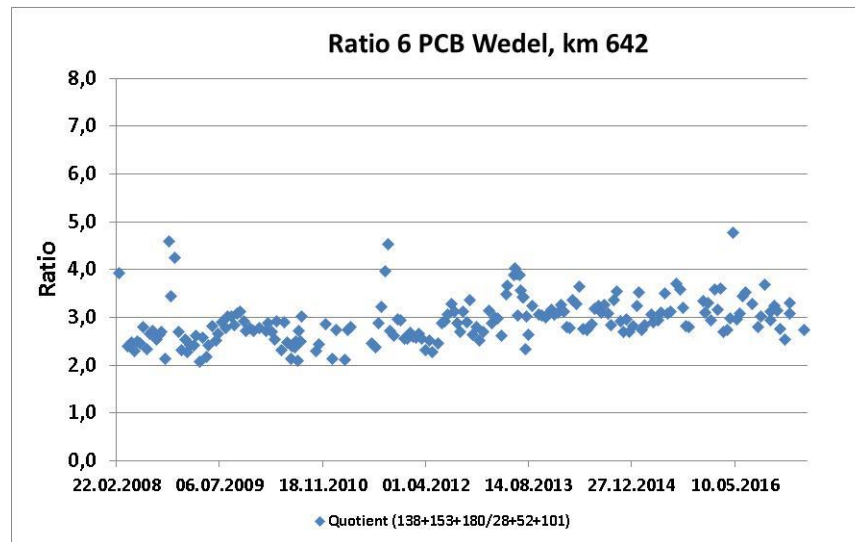
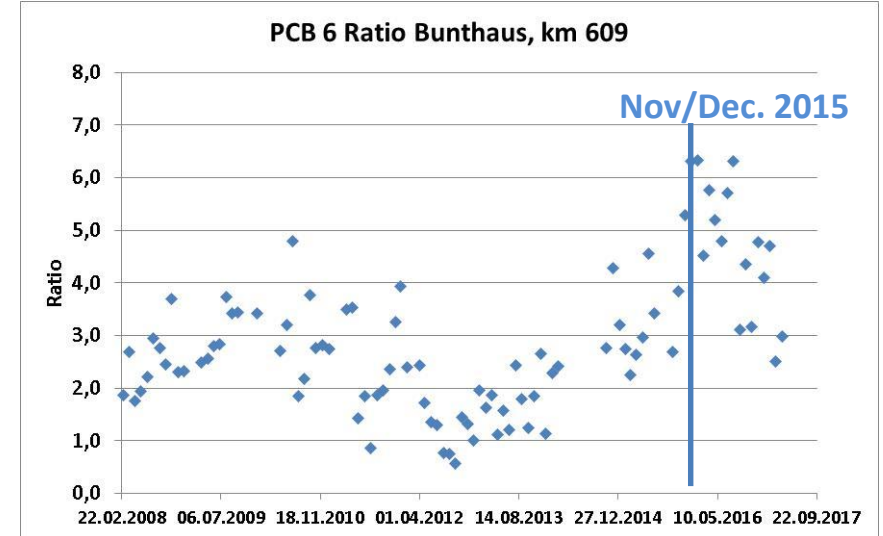
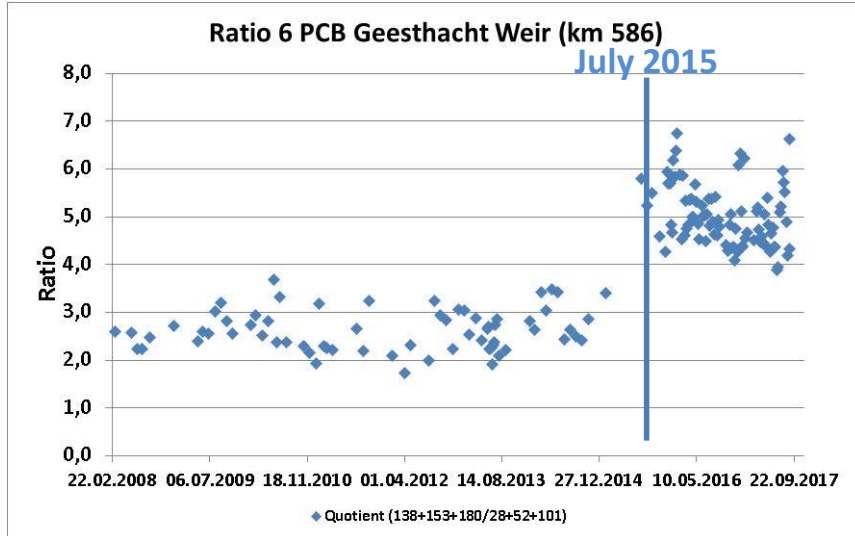
Measurement of the PCB concentrations and ratios in the tidal Elbe



How bad...

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Measurement of the PCB concentrations and ratios in the tidal Elbe

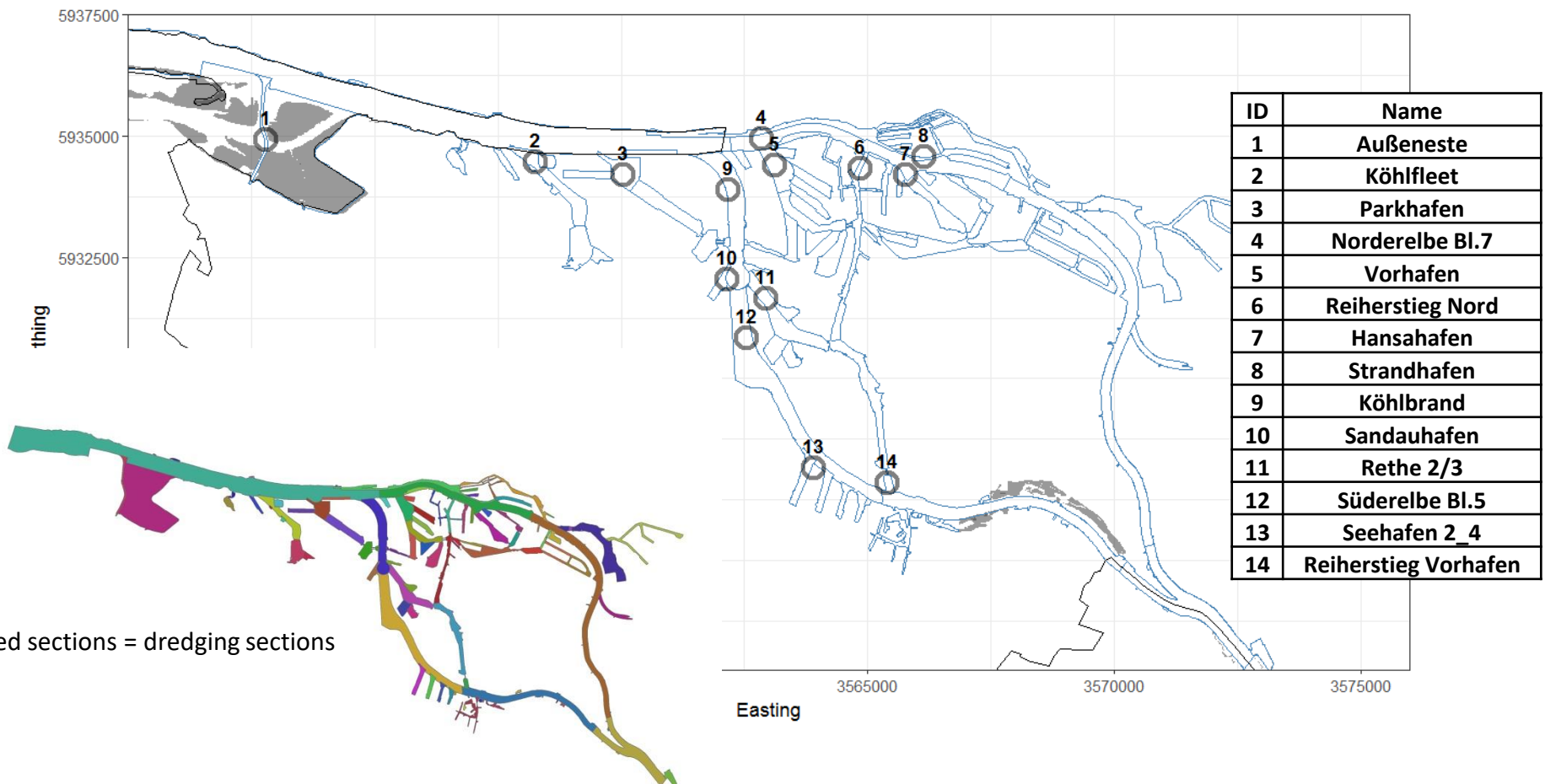


Significant change in PCB 6 ratio at the weir and in Bunthaus in the end of 2015 and beginning of 2016, but no change in the ratio at stations in the estuary

# How bad... .....for dredging activities in the estuary

## Measurement of the PCB concentrations and ratios in the tidal Elbe

### Sampling sites in dredging sections of the Port of Hamburg

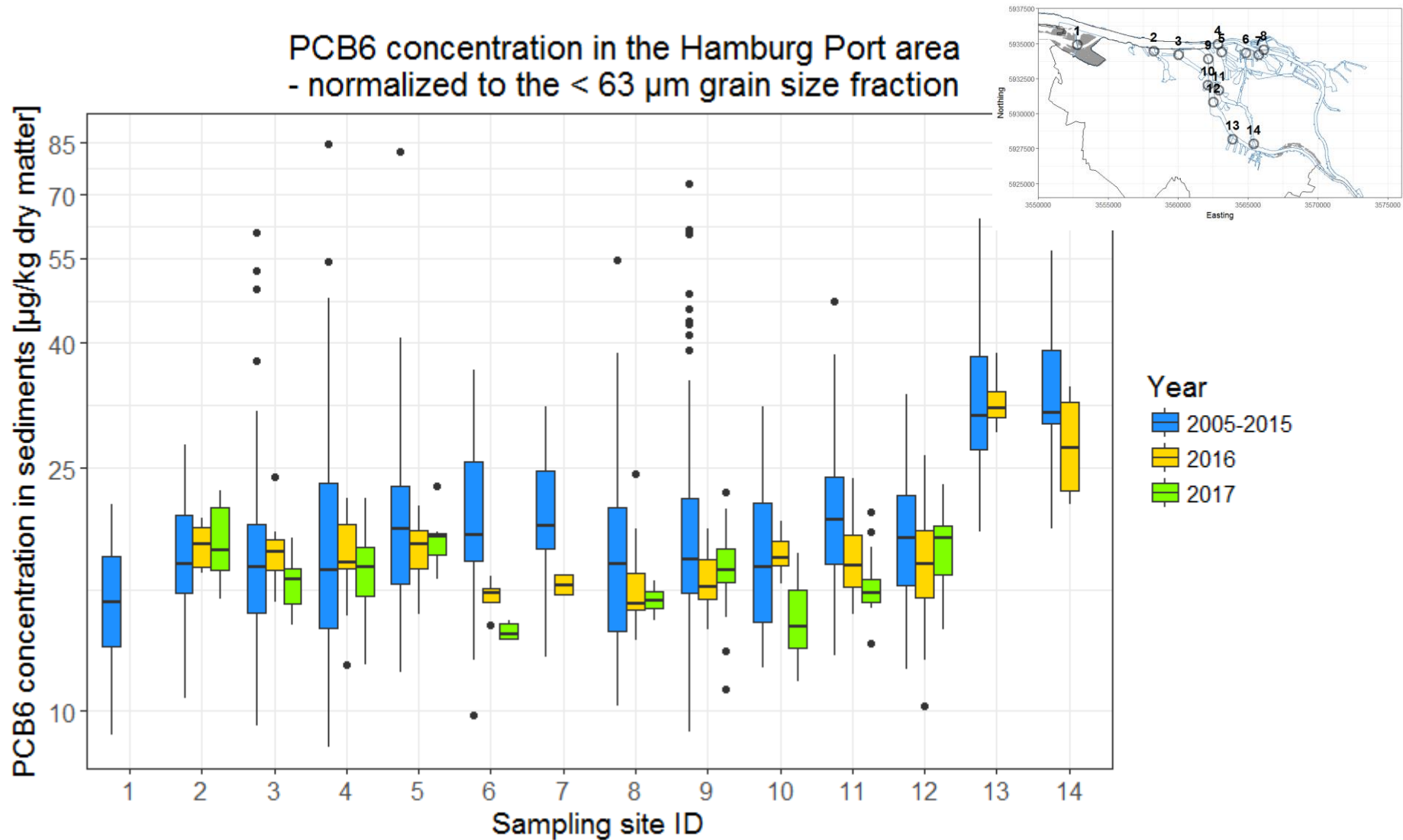




How bad...

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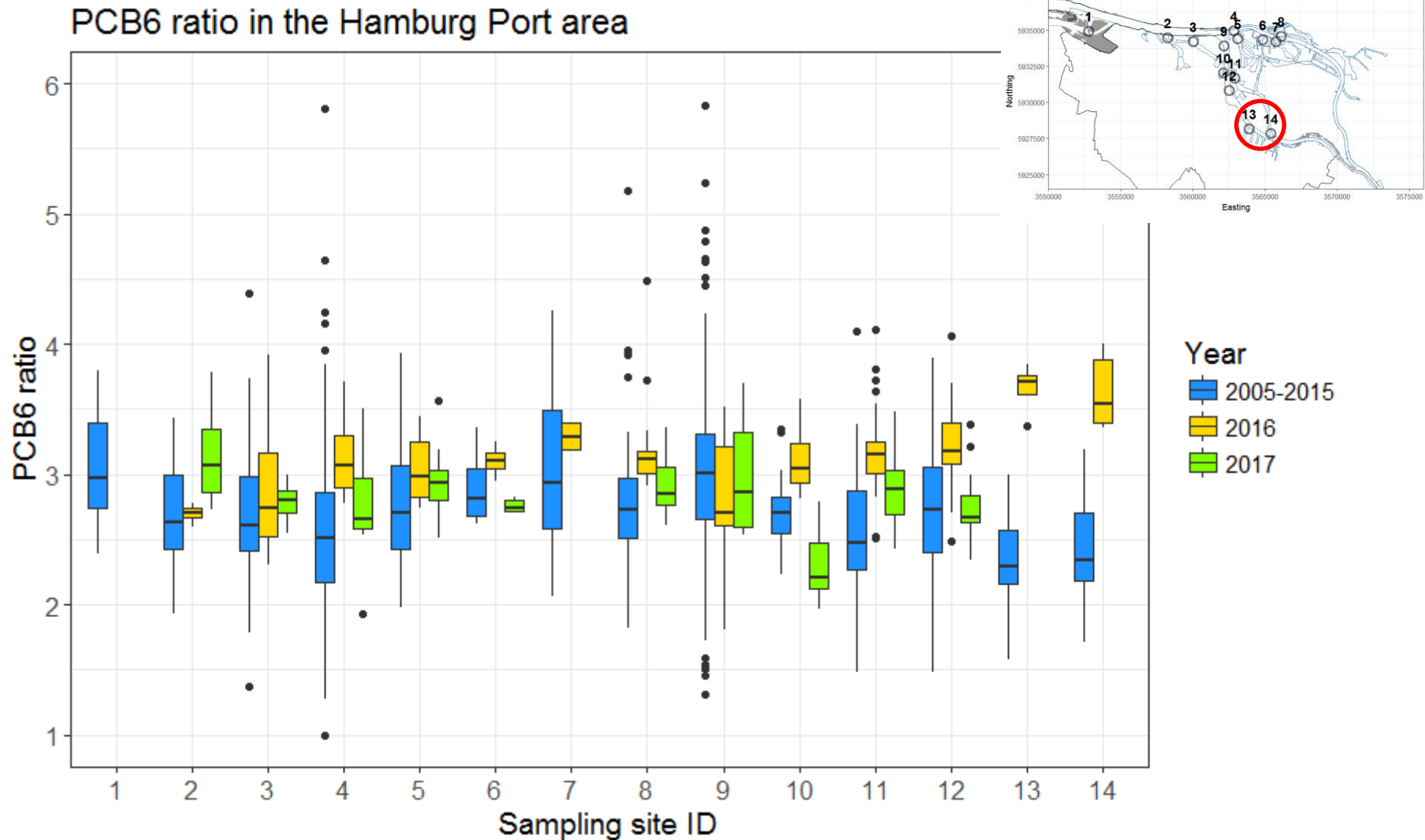
Measurement of the PCB concentrations and ratios in the tidal Elbe



So far, no significant elevated PCB concentrations in harbour sediments identifiable

# How bad... .....for dredging activities in the estuary

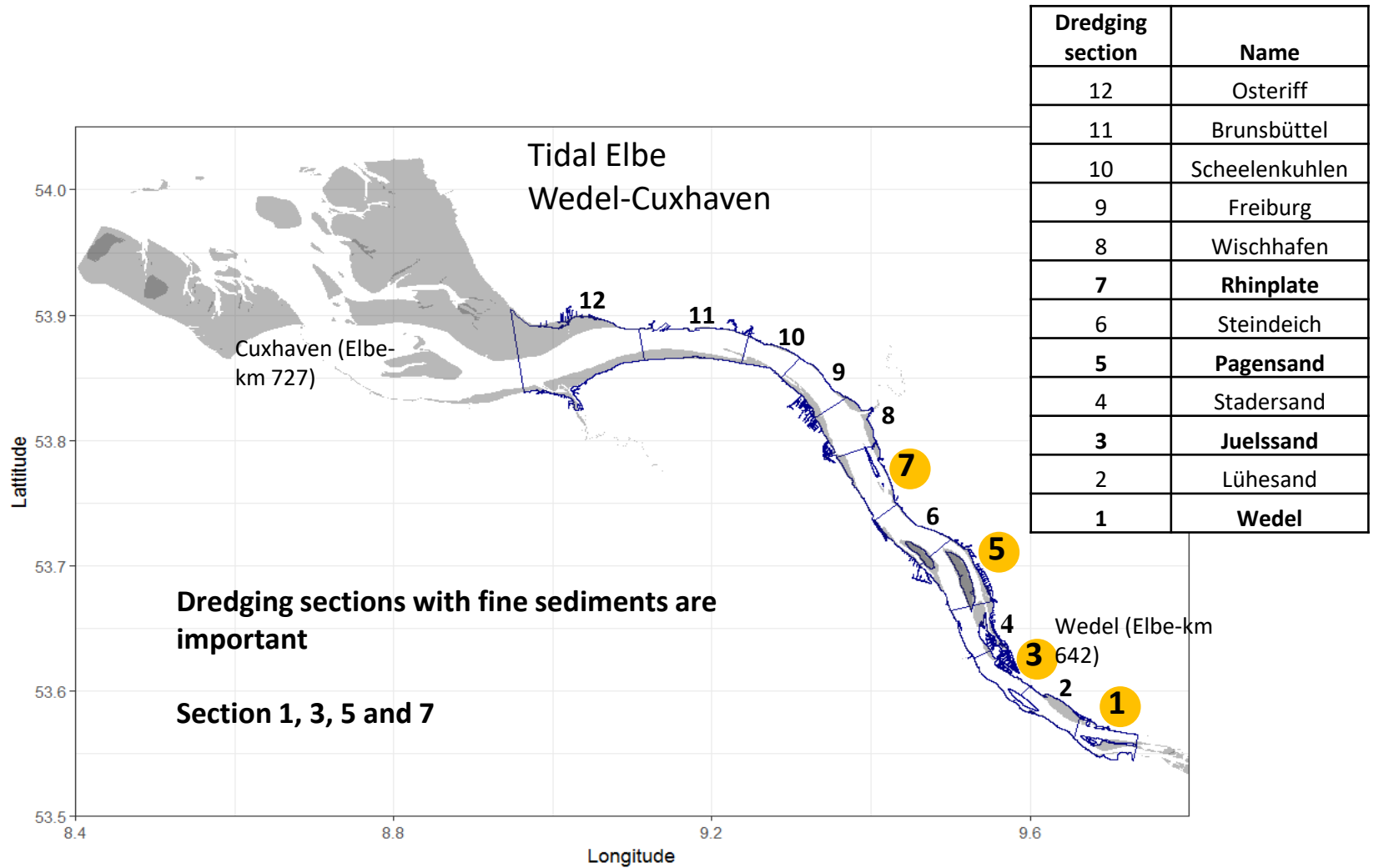
## Measurement of the PCB concentrations and ratios in the tidal Elbe



Significant change of PCB ratios only at sampling stations at the harbour entrance

# How bad... .....for dredging activities in the estuary

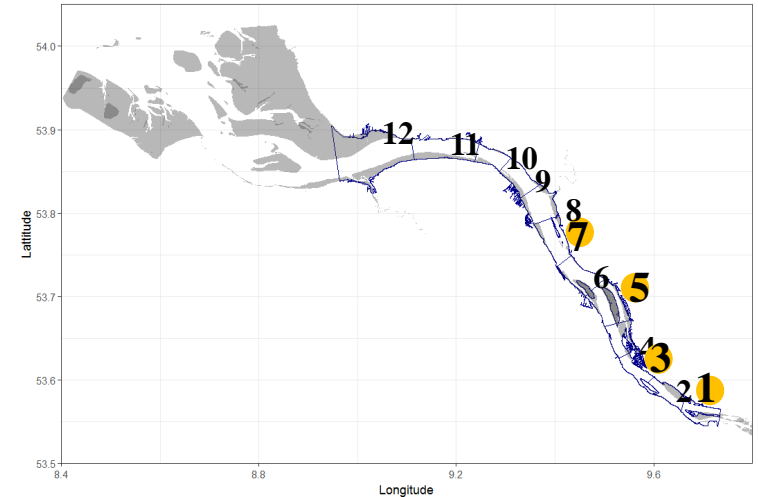
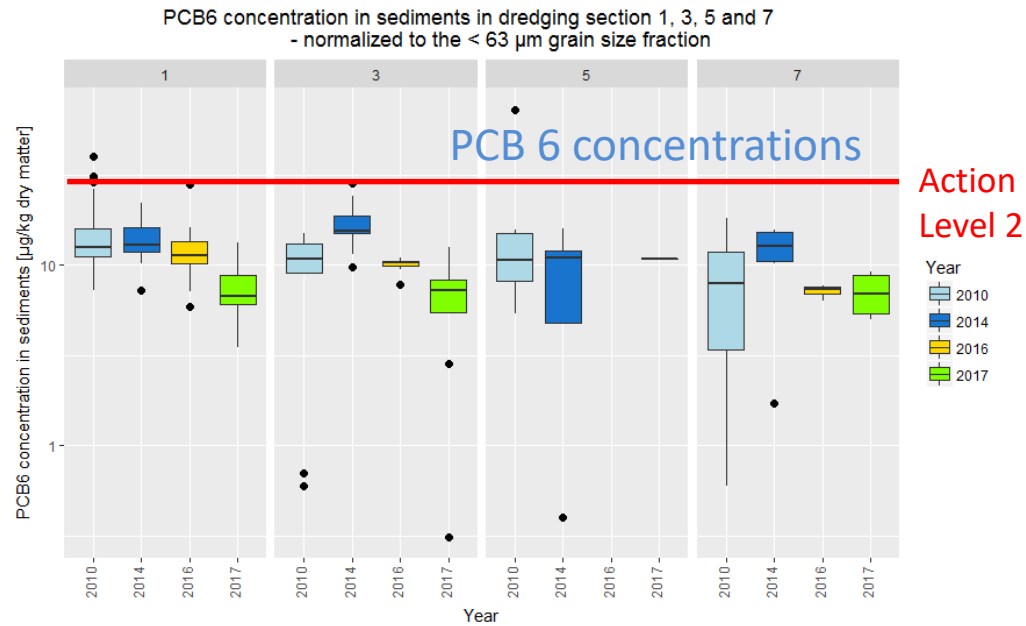
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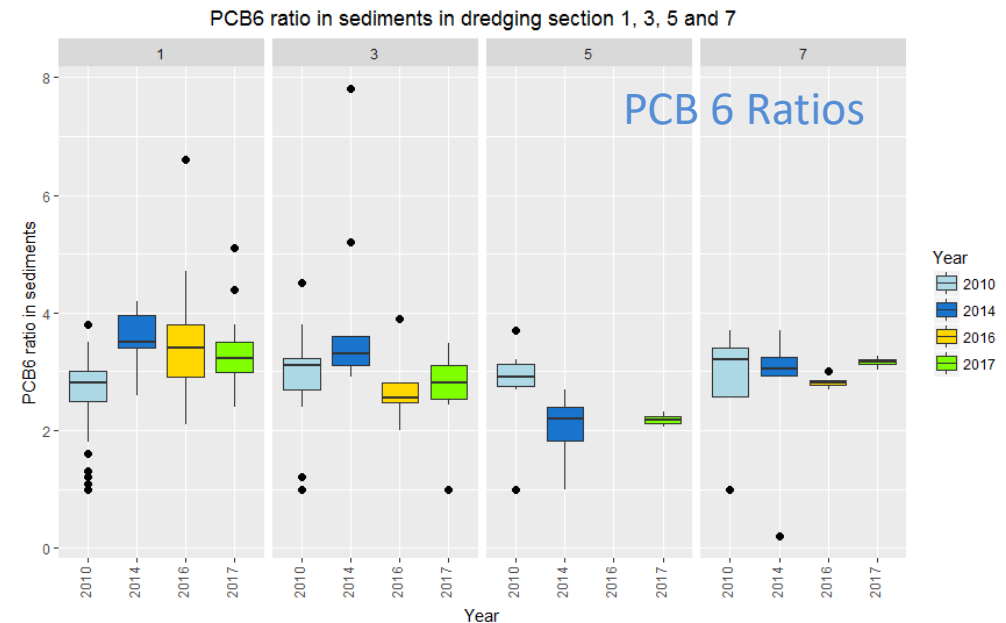
How bad...

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## Measurement of the PCB concentrations and ratios in the tidal Elbe



So far, no significant elevated PCB concentrations and changing ratios in the sediments identifiable

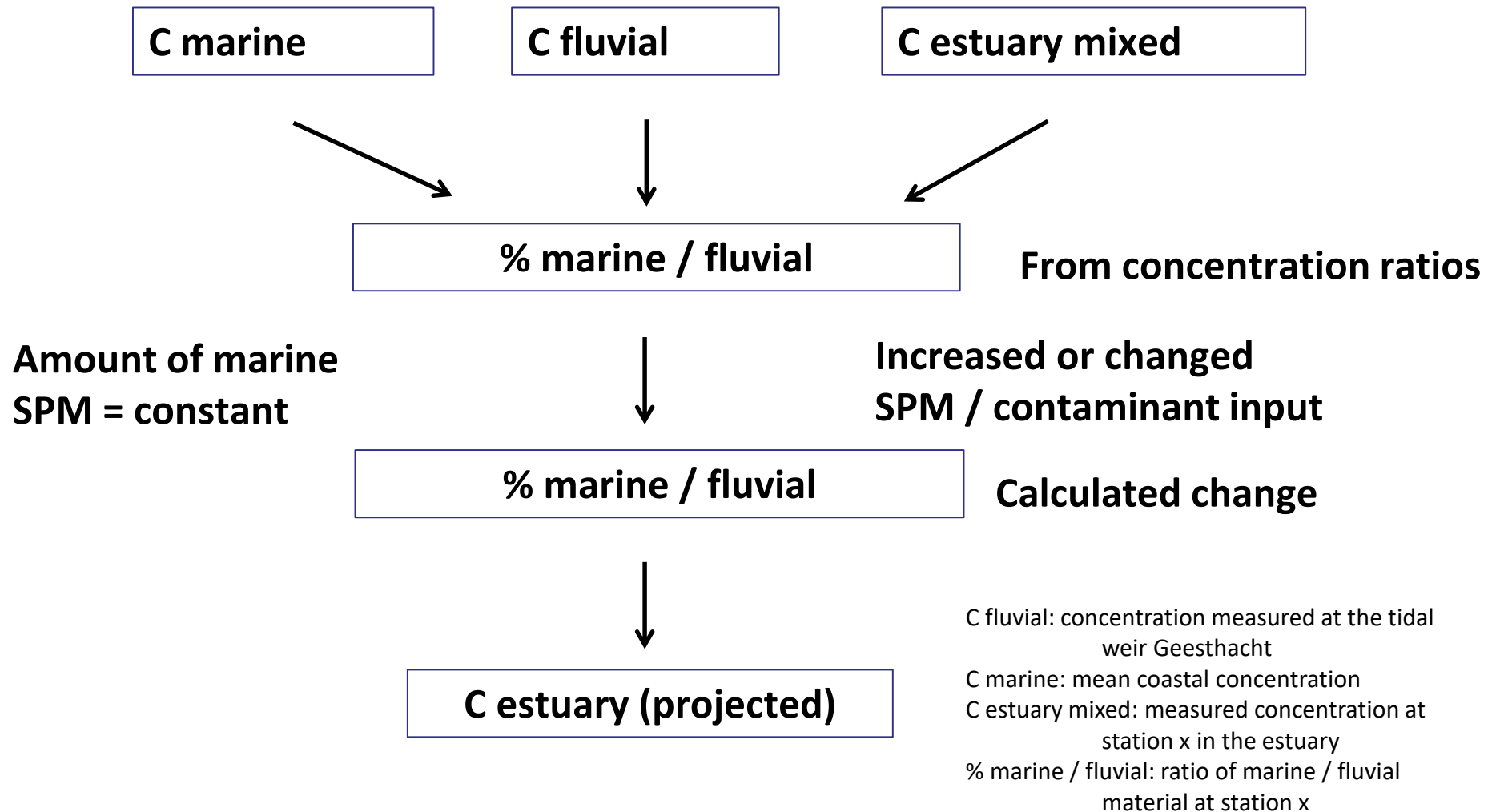




# How bad... .....for dredging activities in the estuary

Estimation of PCB concentrations in the tidal Elbe under different discharge conditions and fluvial input concentrations

## Mixing Model



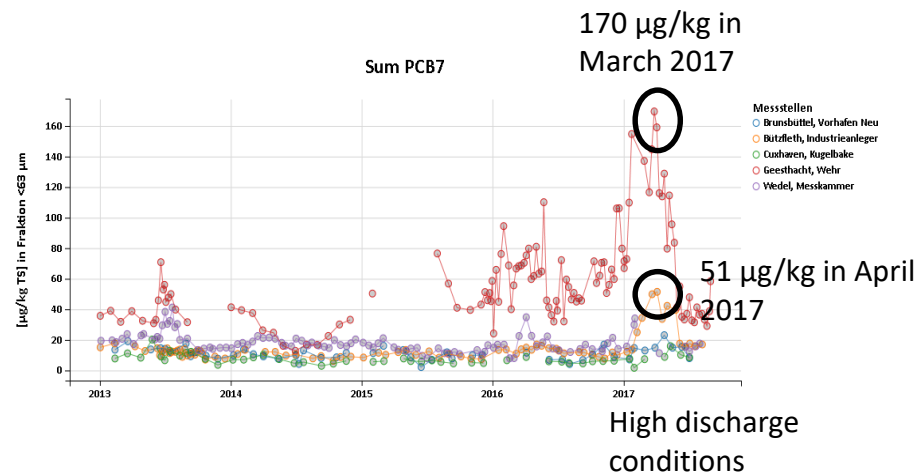
# How bad... .....for dredging activities in the estuary

## Estimation of PCB concentrations in the tidal Elbe under different discharge conditions and fluvial input concentrations

### Estimation under low discharge conditions

Date	Geesthacht Measured Conc.	Wedel Calculated Conc.	Date	Measured Concentration in Wedel
17.05.2016	65	15	17.06.2016	14
23.05.2016	110	23		
31.05.2016	46	12		
06.06.2016	41	11	04.07.2016	13
30.06.2016	39	11		
11.07.2016	72	16	05.08.2016	12
18.07.2016	32	10		
25.07.2016	60	14		
31.07.2016	55	13	01.09.2016	14
08.08.2016	47	12		
15.08.2016	51	13	16.09.2016	17
22.08.2016	45	12		
29.08.2016	47	12		
05.09.2016	46	12	05.10.2016	14
fictitious concentration in Geesthacht	220	41		

**Action Level:  
40 µg/kg**



Note: delayed transport in the estuary

### Estimation under high discharge conditions

Date	Geesthacht Measured Conc.	Wedel Calculated Conc.	Date	Measured Concentration in Wedel
15.02.2016	69	29	15.03.2016	23
22.02.2016	40	18		
29.02.2016	56	24		
07.03.2016	67	28		
14.03.2016	68	28	04.04.2016	35
fictitious concentration in Geesthacht	100	40		

## Conclusions

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- A direct transport of the SPM load via the mean flow velocity of the water **was not observed** (however: data gap at Geesthacht weir).
  - At the latest, in **July 2015 PCB tagged SPM** reaches the tidal weir at Geesthacht, 626 km downstream and enters the estuary.
  - Within the **tidal Elbe river the transport velocity strongly decreases** and 25 km downstream the tidal weir, the PCB6 ratio was not detected before December 2015.
- The **major part** of the PCB-tagged suspension is transported via **suspended load**.
  - Roughly **73% of the annual SPM load is stored in areas with low flow velocities** of the Elbe River, suggesting that suspended sediment in transport **enters storage areas after a relatively short distance**.
  - Once SPM settles, **significant storage can occur over short-term up to decadal time scales**. This might strongly complicate sediment management issues in the future.

## Conclusions

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- The transport path of SPM in rivers depends strongly on the discharge conditions and includes periods in which transport takes place as well as periods in which SPM is deposited, e. g. in areas with low flow conditions near the channel bed, at least temporarily.
- So far, no significant impact on sediment quality in the estuary could be observed
  - Low discharge conditions (like in the years 2015/2016) lead to a high percentage of relative clean marine sediments in the estuary – high dilution effect
  - BUT: high discharge conditions (especially long lasting) lead to a higher percentage of fluvial PCB-tagged SPM and consequently to a worse sediment quality (increasing PCB concentrations)



# Outlook

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- Analyses and evaluation of SPM samples collected during high discharge conditions in spring 2017 on mats in floodplains (BUE Hamburg)
- Continued sampling and evaluation of sediments and SPM in the estuary (especially at dredging locations)
- Continued evaluation of PCB Data in SPM of the fresh water part of the Elbe River (Data FGG Elbe)



# Thank you for Attention

Thanks to all Co-Authors and Data Suppliers