TIDE

Tidal River Development

Zonation of the TIDE estuaries

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Summary

In the TIDE project a zonation approach was set up for cases when it was more sensible to compare only certain areas of the 4 estuaries Scheldt, Elbe, Weser and Humber instead of considering the whole estuary. In order to be able to directly compare certain characteristics e.g. ecological functioning, research questions, measures and management issues, basis zones of equal properties were chosen.
The zonation approach consists of a nested zonation of 3 or 4 scale levels: the whole estuarine system (the estuary corresponds to one compartment or zone) on the first level and more compartment numbers on every scale below. The project partners agreed on setting km “0” of all estuaries at the inland tidal boundary on the longitudinal axis and using the Venice system for a comparable zonation, even when this approach differed from those used by the different partners in the past. The freshwater zones were divided according to their morphology, residence time and/or usage, based on expert judgment by each TIDE-partner because they were too long for the intercomparison exercise.

This report describes the levels of the zonation and provides maps indicating the single zones as well as the basic characteristics of these zones (length, volume, surface, average depth, salinity, residence time, anabranches and tributaries). Residence times listed herein gave a good first indication, but they will be uniformly recalculated for all TIDE estuaries taking into account the tide.
For the zonation based on the Venice system salinity calculations were carried out, based on the median values of chlorinity for the 6 year period (2004-2006).

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1 Introduction

This report synthesizes the proposed zonation of the 4 TIDE estuaries: Schelde, Elbe, Weser and Humber. The zonation can be necessary for the spatial distribution resolution and to be able to compare the estuaries. For a common basis, zones of equal properties have to be chosen. This zonation approach will be used in cases when it is more sensible to compare only certain areas of the estuaries instead of considering the whole estuary, e.g. for the different issues of ecological functioning, research questions, monitoring schemes, measures and management issues, etc. This is required in TIDE, more specifically in the work packages 3 and 4 considering the ecosystem services survey, the conflict matrix and certain aspects of the interestuarine comparison for ecology, hydro- and geomorphology.

The zonation approach takes the following **conditions** into account:

1. The zonation system should be flexible enough to cover different issues.
2. It should allow the direct comparison of certain areas of each estuary.

The first condition is met by having a **nested zonation**, consisting of 3 or 4 scale levels: the whole estuarine system (the estuary corresponds to one compartment or zone) on the first level and more compartment numbers on every scale below. It is important to have a good representation of zones on every scale.
The second condition is met by the agreement to present the estuarine results according the standards that were set at the Bremen meeting (September 2010) and the Rouen meeting (June 2011): **setting km "0" of all estuaries at the inland tidal boundary on the longitudinal axis** and using the **Venice system** for a comparable zonation between the estuaries. Considering only the Venice system, the freshwater zone is too long to compare as a whole between estuaries. Therefore, it was decided to **split the freshwater zone according to morphology, residence time and/or usage, based on expert judgment by each TIDE-partner**.

In this report, first the levels of the zonation are described, maps indicating the single zones are presented, and the basic characteristics of these zones (length, volume, surface, average depth, salinity, residence time, anabranches and tributaries) are listed. Residence times listed herein give a good first indication, but will be uniformly recalculated by the hydrogeomorphological workgroup for all estuaries within TIDE, taking into account the tide.

Secondly, the zonation based on the Venice system is given for all estuaries. Therefore, salinity calculations are carried out, based on the median values of chlorinity for the 6 year period (2004-2006), wherefore the interestuarine comparison will be performed.

2 Zonation per estuary

a) Schelde

The zonation of the Schelde estuary consists of the following levels (see also figs. 1 and 2), in which level 1 and 2 are based on administrative criteria, whereas level 3 is a combination of administrative borders, salinity and residence time criteria. Level 4 consists of model compartments, giving some arbitrary small scale divisions.

Level 1 is the entire ecosystem, the Schelde estuary as a whole. The most upward boundary is a sluice complex near the city of Gent where the tidal action is stopped. At the seaward end, the mouth is usually defined as the line connecting the cities of Breskens and Vlissingen. In front of the so defined mouth there is however an alluvial deposition zone, called 'Vlakte van de Raan', stretching out in the coastal water, and which is often considered as the estuarine mouth area.

Level 2 consists of two zones, the Dutch part, called Westerschelde, and the Belgian or Flemish part, called Zeeschelde. The zonation criterium of level two is thus merely the national border line.

Level 3 is a zonation based on a mixture of administrative and physical criteria (mainly salinity and residence time). In the Zeeschelde, the Upper and Lower Zeeschelde are managed by different government bodies.

Level 4 is a modeling based zonation consisting of macrocells concept within the OMES project. They have been used in monitoring programs, scientific studies, descriptions etc.

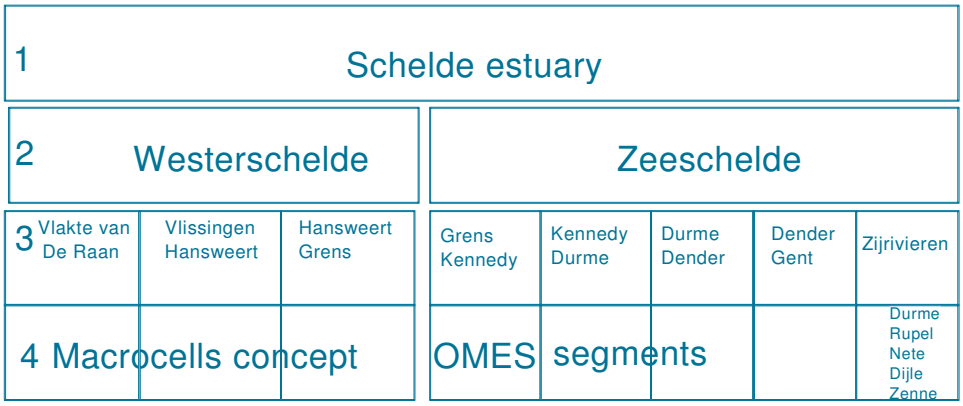


Fig. 1 Four level zonation of the Schelde estuary

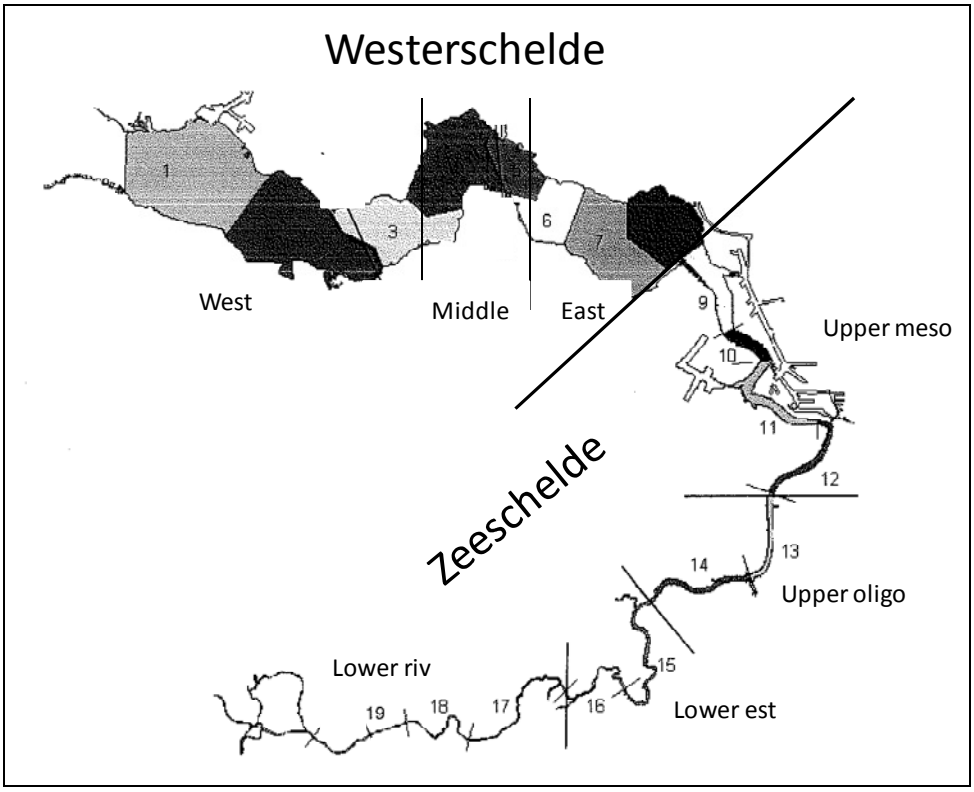


Fig.2: Map of the Schelde estuary zonation (level 3 and 4)

The basic characteristics of the Schelde zones at level 4 are (at an average tidal level) a salinity typology of the present condition (Venice system), the presence of morphological entities such as tributaries, anabranches and canals (Table 1). For the calculation of volume and surface area, an average tide was used. The freshwater compartments 17-20 have a short residence time less than 5 days. The freshwater compartments 15-16 have a long residence time more than 5 days.

Table 1: Zonation of the Schelde estuary with indication of the longitudinal position (km) and basic characteristics

Zonation				Schelde km	TIDE km	Length	Volume	Surface	Avg Depth	Salinity	Anabranches	Tributaries	Canals
level 1	level 2	level 3	level 4			(km)	(m^3)	(m^2)	(m)	Venice system			
Raan	Raan	Raan	Raan										
Schelde estuary	Westerschelde	East	1	0-13	147-160	12,9	8,73E+08	7,13E+07	12,3	polyhaline			
			2	13-25	135-147	11,7	5,94E+08	5,16E+07	11,5				Terneuzen
			3	25-30	128-135	5,8	3,00E+08	3,13E+07	9,6				
		Middle	4	30-37	121-128	6,5	3,13E+08	3,39E+07	9,2				
			5	37-42	116-121	5,5	1,58E+08	1,50E+07	10,5				
		West	6	42-47	110-116	4,9	1,06E+08	1,34E+07	7,9	gradient			
			7	47-52	105-110	5,3	8,66E+07	1,47E+07	5,9				
			8	52-58	99-105	5,5	1,31E+08	1,81E+07	7,2				
	Zeeschelde		9	58-71	89-99	9,7	9,54E+07	9,09E+06	10,5				Albert canal
			10	71-76	84-89	5,1	4,34E+07	3,89E+06	11,2				
		Upper meso	11	76-86	74-84	9,6	5,01E+07	4,70E+06	10,7				
			12	86-94	66-74	8,3	6,02E+07	5,73E+06	10,5				
		Upper oligo	13	94-102	58-66	8,0	1,53E+07	1,49E+06	10,3	oligohaline - limnetic		Rupel	
			14	102-115	45-58	13,0	2,54E+07	3,53E+06	7,2				
		Lower est	15	115-129	31-45	14,0	1,24E+07	2,20E+06	5,6		Durme		
			16	129-137.5	22.5-31	8,5	5,42E+06	9,31E+05	5,8				
		Lower riv	17	137.5-146	14-22.5	8,5	3,74E+06	7,85E+05	4,8			Dender	
			18	146-153	7-14	7,0	2,89E+06	6,49E+05	4,5				
			19	153-160	0-7	10,3	2,05E+06	4,75E+05	4,3		Gentbrugge		

b) Elbe

In the Elbe estuary three (administrative) zonation schemes exist at the moment:

1. Water Framework Directive (WFD),
2. Natura 2000,
3. Zonation based on the monitoring program of the fairway deepening in 1999.

However, the borders of the single compartments slightly differ from each other (see fig.3 and 4).
The zonation of the Elbe estuary consists of three levels (fig. 3).

Level 1 consists of the entire tidal Elbe. The most upward boundary is the sluice near the city of Geesthacht where the tidal action ends. At the seaward end, close to the city of Cuxhaven, the estuary passes into the coastal area of the North Sea.

Level 2 is based on a zonation of outer, middle and inner estuary, partly adjusted to the WFD, in which the outer estuary corresponds to the WFD compartment ´coastal water´ (polyhaline), the middle estuary corresponds to the WFD zone ´transitional water´ (oligo - polyhaline), and the inner estuary merges the three WFD compartments ´Elbe west, harbor, Elbe east´ and covers the freshwater part of the estuary. Within the WFD this zonation (Elbe west, harbour, Elbe east) is mainly chosen because the harbour area differs so much from the other zones concerning the morphological characteristics, e.g. concerning water depth. Elbe east consists of lower water depth, whereas the harbour and Elbe west have much deeper water depth because they are harbour area and contain the fairway respectively.

Level 3 consists of 7 zones based on the monitoring sections for the fairway deepening in 1999 (fig. 4). The border of zone 3 does not match exactly with the border of the inner estuary, a difference of about 5 km occurs. Zones 4 - 6 more or less correspond to the middle estuary. Zone 7 starts at the same border as the outer estuary. Due to modeling reasons its seaward border is set at km 164 (corresponding to Elbe km 750).

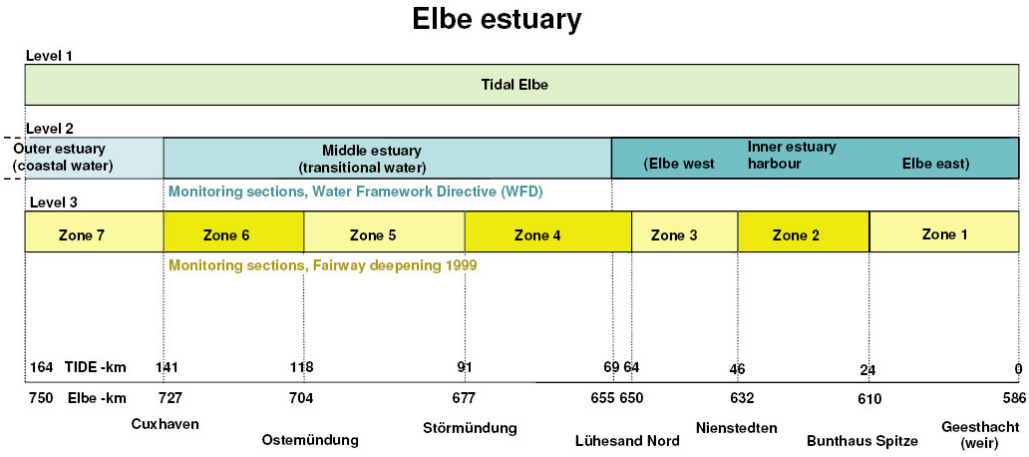


Fig. 3: Scheme of the zonation levels of the Elbe estuary

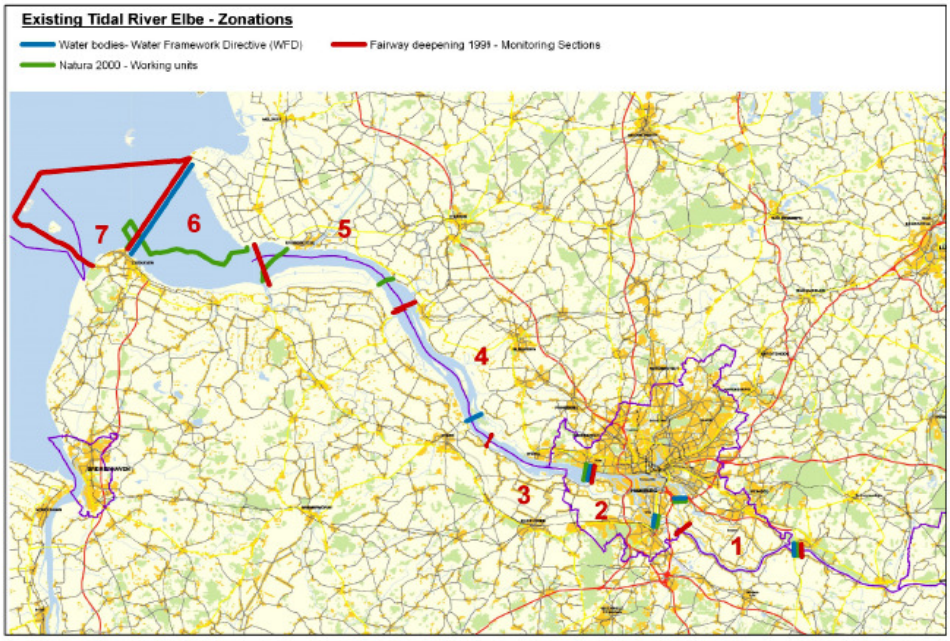


Fig. 4: Map of TIDE zonation of the Elbe estuary (red lines), on the basis of the monitoring sections of the fairway deepening 1999

A detailed description of the underlying parameters for the zonation is given in table 2 and 3. The basic characteristics of the Elbe zones at level 3 are hydrological and morphological characteristics, the average salinity distribution according to the Venice system and the influence of tributaries and anabranches.

Tab. 2: Description of the zones of the Elbe Estuary

Zone	Elbe- km	TIDE - km	Hydrology/morphology	Salinity	Anabranches	Tributaries
1: Geesthacht - Bunthaus-Spitze	586-610	0-24	Overlap of discharge and tides, tidal currents depend on relation discharge/tides	Limnic < 0,5 psu		Ilmenau, Luhe
2: Bunthaus Spitze - Niensteden	610-632	24-46	Split-up in northern Elbe and southern Elbe, long residence times of water body, low specific surface, intensive use of harbour	Limnic < 0,5 psu		
3: Nienstedten - Lühesand- Nord	632-650	46-64	Water level and currents mainly formed by tides, residence time of water body dependent of discharge, low specific surface	Limnic < 0,5 psu	Hahnöfer Nebenelbe, Lühesander NE, Hetlinger Binnenelbe	Lühe, Este, Wedeler Au
4: Lühesand-Nord - Störmündung	650-677	64-91	Broadening of the estuary, water level and currents mainly formed by tides, residence time of water body dependent of discharge,low specific surface	Oligohaline 0,5,-5 psu, influence of brackish water at low discharge until Lühesand-Nord, average of 0,5 psu	Haseldorfer BE, Bützflether Süderelbe, Pagensander NE, Wischhafener SE, Glückstädter NE	Schwinge, Pinnau, Krückau
5: Störmündung – Ostemündung	677-704	91-118	Broadening up to appr. 5 km, central area of turbidity zone	Mesohaline brackish water zone, variable salinities (>5-18 psu)	Wischhafener Fahrwasser, Freiburger Hafenpriel	Stör
6: Ostemündung – Cuxhaven	704-727	118-141	Broad estuarine funnel, deep main channels and shallow water areas, mudflats and sand banks	Brackish water zone, variable salinities between mesohaline(>5-18 psu) and occasio-nally euhaline (30-40 psu, on mudflats)	Neufelder Rinne	Oste
7: Cuxhaven - Scharhörn	727-750	141-164	Transition zone: estuary – North Sea, marine conditions dominate	Polyhaline >18-30 psu, occasionally euhaline (mudflats)		

Please note that in tabel 3 the borders of the zones of level 2 (WFD) in most cases not match with the borders of level 3 zones (see fig. 3 and annex). Volume and surface area are calculated for areas situated lower than mean tidal mean water and mean tidal low water respectively.

Tab.3: Basic characteristics of the single zones of the tidal Elbe

Zonation				Elbe km	TIDE km	Length	Volume	Surface	Residence time	Avg Depth	Salinity
level 1	level 2	(WFD)	level 3	Fairway Zonation		(km)	(m^3)	(m^2)	days	(m)	
Elbe estuary	Inner estuary	Elbe-East	1	586-610	0-24	24	4,30E+07	8,00E+06	0,7	5,4	<0.5 (limnic)
		Harbour	2	610-632	24-46	22	2,26E+08	2,20E+07	3,6	10,3	<0.5 (limnic)
		Elbe-West	3	632-650	46-64	18	2,10E+08	2,10E+07	3,3	10,0	<0.5 (limnic)
	Middle estuary	Transitional	4	650-677	64-91	27	5,20E+08	5,50E+07	8,3	9,5	0.5-5 (oligohaline)
			5	677-704	91-118	27	6,89E+08	6,20E+07	11,0	11,1	5.0-18 (mesohaline)
			6	704-727	118-141	23	9,69E+08	1,11E+08	11,0	8,7	gradient mesohaline - polyhaline
	Outer estuary	Coastal water	7	727-750	141-164	25	1,37E+09	1,48E+08	21,9	9,2	18-30/>30 (polyhaline)

c) Weser

There are five common (administrative) zonation schemes for the Weser estuary. The zonation of the Weser estuary includes four different levels; the zonation schemes according to WFD and BHD are both assigned to level 3 (fig. 5).

Level 1 includes the entire estuary from downstream of the weir Hemelingen (TIDE-km 0) where the tidal influence is stopped to the seaward border of the outer Weser estuary (TIDE-km 134, see level 2). The border of the outer Weser corresponds with the seaward border of the euhaline zone mentioned under level 4 (see also figure 5).

Level 2 is based on a common zonation scheme drawing a distinction between the lower Weser estuary (TIDE-km 0-69) and the outer Weser estuary (TIDE-km 69-134).

Level 3 includes the zonation schemes deduced according to WFD and BHD. Both comprise three zones. The zone borders according to the both directives differ slightly from each other and from the other zonation levels.

Level 4 consists of five different salinity zones defined according to the Venice system. The salinity zone borders correspond with level 1 and level 2. Figure 5 shows the geographical position of the five salinity zones along the Weser estuary. This zonation scheme was inter alia used for the recent fairway deepening.

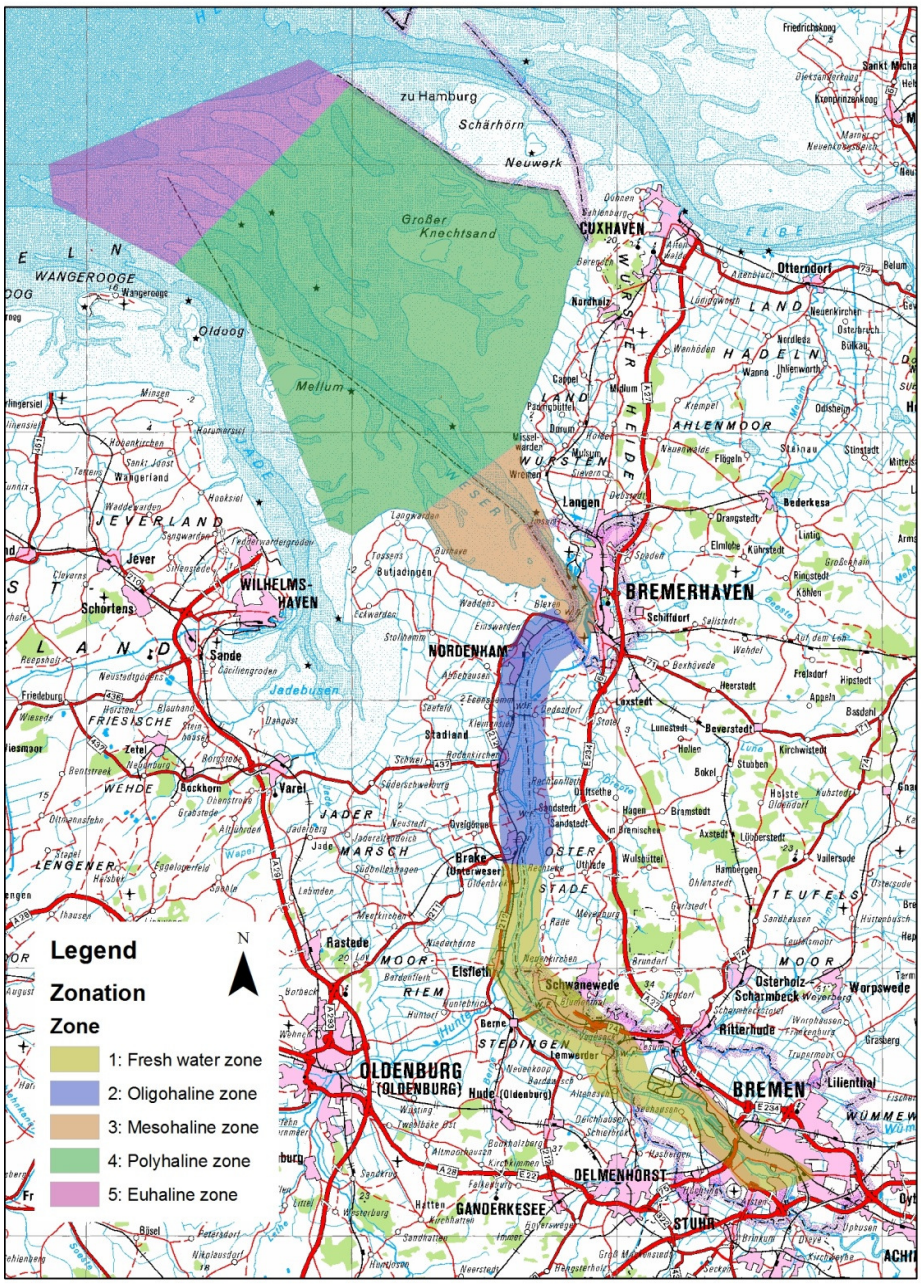


Fig. 5: Map of the zonation of the Weser estuary (level 4)

A detailed description of the underlying parameters for the zonation is given in table 4 and 5. The basic characteristics of the Weser zones at level 4 are hydrological and morphological characteristics, the average salinity distribution according to the Venice system and the influence of tributaries and anabranches.

Tab. 4: Zonation levels of the Weser estuary

Zonation		Weser-km	TIDE km		Weser-km	TIDE-km		Weser-km	TIDE km		Weser km	TIDE km
level 1	**level 2**			**level 3a (WFD)**			**level 3b (Integrated Management Plan Weser)**			**level 4 (fairway deepening)**		
	Lower Weser	-4-65	0-69	Streams of marshland	-4-40	0-44	Fresh water zone of the Lower Weser ('Funktionsraum 3')	-4-40	0-44	1: Fresh water zone	-4-40	0-44
				Transitional water	40-85,5	44-89,5	Oligohaline zone of the Lower Weser ('Funktionsraum 2')	40-65	44-69	2: Oligohaline zone	40-65	44-69
	Outer Weser	65-130	69-134	Coastal waters	85,5-130 (+x)	89,5-134 (+x)	Meso-/polyhaline zone of the Outer Weser ('Funktionsraum 1')	65-85	69-89	3: Mesohaline zone	65-80	69-84
										4: Polyhaline zone	80-115	84-119
										5: Euhaline zone	115-130	119-134

Tab. 5: Basic characteristics of the single zones of the Weser estuary

Zonation	Weser km	TIDE km	Length	Volume	Surface	Avg Depth	Salinity	Anabranches	Tributaries	Canals
level 4	Fairway deepening		(km)	(m^3)	(m^2)	(m)	psu			
1: Fresh water zone	-4-40	0-44	44	149	17,5	8,5	<0.5	Rekumer Loch, Woltjenloch, Westergate, Warflether Arm	Hunte, Lesum, Ochtum	
2: Oligohaline zone	40-65	44-69	25	188	23	8,2	0.5 - 5	Rechter Nebenarm, Schweiburg	Lune	Käseburger Sieltief, Barker Sieltief, Drepte
3: Mesohaline zone	65-80	69-84	15	226	50,5	4,5	5-18		Geeste	
4: Polyhaline zone	80-115	84-119	35	2810	406	6,9	18-30			
5: Euhaline zone	115-130	119-134	15				30-40			

d) Humber

The zonation of the Humber differs from that of the other three estuaries. A nested approach was not applied. However, besides the shown zonation (fig. 6), zonation schemes have been developed to meet new management needs, or schemes have been suggested e.g. under HARBASINS. It should be noted that Natural England do not very often divide the estuary up, considering instead, that it should be treated as a single system. However, when they do, they use the Environment Agency CHaMP zonations e.g. for saltmarsh conservation objectives and condition assessment the estuary is split into inner, middle and outer based on the fact that the saltmarshes are different in these sections of the estuary. The zones used are inner to the bridge, middle to Grimsby/ Hawkins Point and then the Outer estuary.

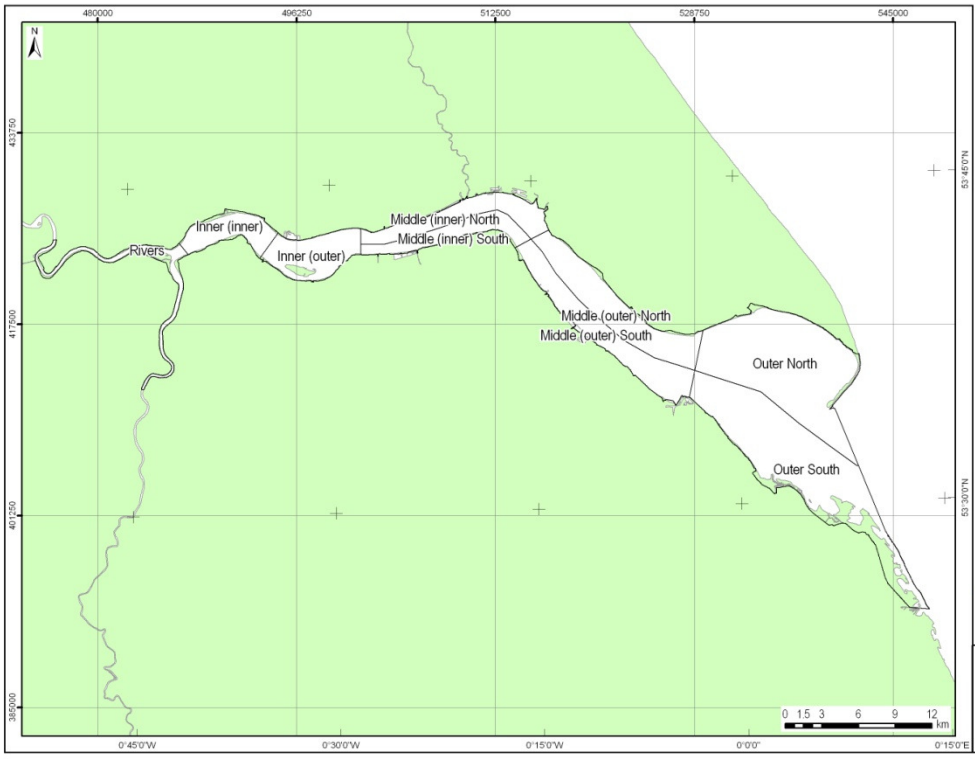


Fig. 6: Map of the general used zonation of the Humber estuary

Nevertheless for the TIDE focus, a zonation scheme is adopted, as a starting point for an objective interestuarine comparison. This was based upon calculations for salinity (see further, table 10). A map (fig. 7) and table (table 6) give an overview of this new zonation approach.

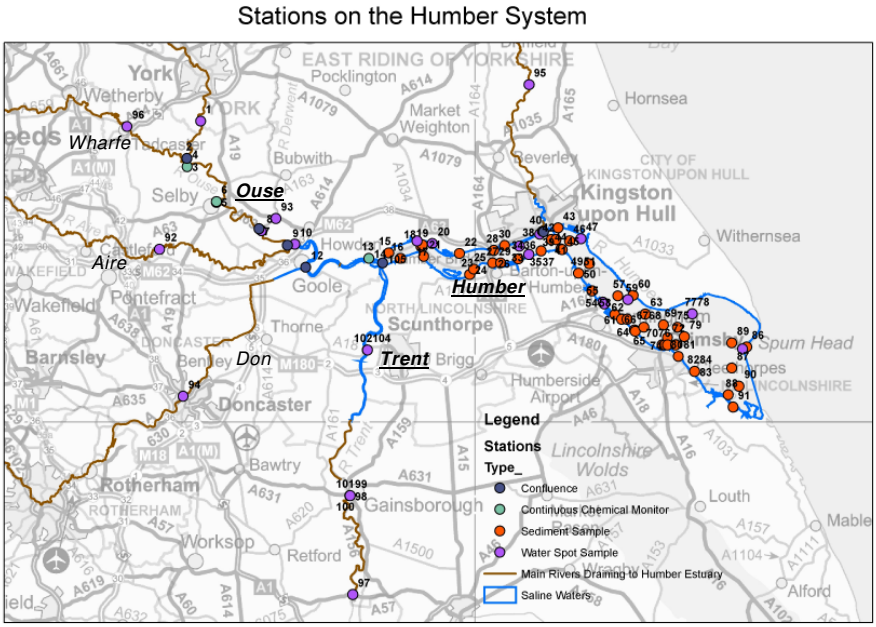


Fig. 7: Overview of the Humber stations (R. Freestone , Environment Agency)

The tidal limit at the Ouse is set at Naburn Lock (0 $TIDE_{Ouse\text{-}Humber}$-km). The Trent follows a separate $TIDE_{Trent}$-km numbering. The tidal limit of the Trent is not shown at this map, since the first measuring station is located at 18,89 $TIDE_{Trent}$-km (Gainsborough) downstream from the tidal limit at Trent. The Trent is about 84,78$TIDE_{Trent}$-km long starting from its tidal limit. It confluences with the Ouse & Humber at 59,5 $TIDE_{Ouse\text{-}Humber}$-km downstream from the tidal limit at Naburn Lock.

Tab. 6: Overview of chlorinity values with station numbers and tributaries

River	Station number	Tide-km	Cl (mg/l)	Cl min (mg/l)	Cl max (mg/l)	Cl median (mg/l)	Variation	Tributary
Trent	97	18,89	70,13	32,50	119,00	70,83	1,23	
Trent	98, 99, 100, 101	42,07	76,05	17,90	136,00	73,15	1,55	
Trent	102, 103, 104	69,18	106,61	37,20	473,00	99,03	4,09	
Ouse-Humber	1	0	30,57	13,20	49,10	30,25	1,17	
Ouse-Humber	3,4	8,99	27,33	12,40	56,30	28,17	1,61	Wharfe
Ouse-Humber	8	33,98	48,25	26,50	88,60	40,85	1,29	Derwent
Ouse-Humber	10, 11	40,22	132,98	28,60	2010,00	65,19	14,90	Aire, Don
Ouse-Humber	13, 14	59,5	1287,68	34,50	7780,00	1070,01	6,02	Trent
Ouse-Humber	33, 34	85,05	6472,67	281,00	12300,00	6208,00	1,86	
Ouse-Humber	38	87,69	6512,18	134,00	12300,00	6755,00	1,87	Hull
Ouse-Humber	47	92,55	8358,57	520,00	16800,00	8420,00	1,95	
Ouse-Humber	53, 54	101,94	11458,46	2400,00	15700,00	11270,83	1,16	
Ouse-Humber	58	104,24	12683,89	7590,00	15700,00	13600,00	0,64	
Ouse-Humber	77, 78	114,78	15636,11	12200,00	17900,00	15900,00	0,36	
Ouse-Humber	85, 86	122,61	15750,31	200,00	27100,00	16766,67	1,71	

3 Zonation according to Venice for all TIDE estuaries

From the detailed description of zonation schemes per estuary, as outlisted here before, it is obvious that different approaches exist and merely trying to compare these different approaches is not very evident. Therefore, it was decided in Rouen (June 2011), that the Venice approach in general should be used (Table 7).

Tab. 7: Chlorinity and corresponding salinity ranges according to the Venice approach

	Chlorinity			**Sal**inity		
FW		< 300	mg/l		< 0,5	PSU
Oligo	300	3000	mg/l	0,5	5	PSU
Meso	3000	11000	mg/l	5	18	PSU
Poly	11000	18500	mg/l	18	30	PSU

The Venice approach is a physiotope approach, in which different zones are assumed based on salinity range. Salinity is known as a conservative tracer, and as having the most influence on ecology. This approach has proven to be useful in the Harbasins project. Although, salinity is very variable in time and space, a six yearly average for the period of investigation (2004-2009) can be assumed as a good basis estimation for the distribution of different ecological entities. Herefore, annual and seasonal calculations of averages, median, minimum and maximum values for 2004-2009, per measuring station were performed (see table 8, 9, 10, 11, seasonal values here not included) with the data received from all estuaries.

Six yearly median values of chlorinity were eventually used as a guidance for zonation, because of the non-normal distribution of chlorinity data in the Schelde and Humber. This was due to different sampling methods in Schelde & Humber and also shows in the large variation of the Schelde & Humber compared to the Elbe & Weser (see table 8, 9, 10, 11). The variation is calculated as :
$(Cl_{max}- Cl_{min})/ Cl_{mean}$

Existing zonation schemes of each estuary, described above, are fitted as good as possible in this Venice approach, so previous calculations as volume and area,… can be reused.

The freshwater zone, which can not be further divided according to salinity, is splitted into zones based on existing zonation schemes and expert judgement when ought to be useful.

Tab. 8 & 9: Calculations of 6 yearly ('04-'09) averages, median, min, max & variation values for Schelde (boat campaign) and Elbe (helicopter campaign)

Schelde						**Elbe**					
Tide-km	Cl (mg/l)	Cl min (mg/l)	Cl max (mg/l)	Cl median (mg/l)	Variation	Tide-km	Cl (mg/l)	Cl min (mg/l)	Cl max (mg/l)	Cl median (mg/l)	Variation
9	78,51	53,31	112,93	81,89	0,76	0	126,61	111,89	139,72	119,00	0,22
15	78,48	52,01	106,24	81,15	0,69	3	125,03	111,39	136,61	119,25	0,20
20	77,71	52,84	114,19	79,39	0,79	13	124,44	111,44	135,50	117,50	0,19
35	80,30	52,84	127,24	83,46	0,93	24	122,13	112,11	131,11	116,50	0,16
39	82,15	50,26	140,70	83,64	1,10	29	121,44	110,72	130,78	116,50	0,17
47	89,36	55,20	152,03	86,31	1,08	37	121,07	109,92	129,69	120,67	0,16
56,5	133,78	45,38	341,38	155,87	2,21	43	123,16	112,89	131,94	122,50	0,15
62	170,16	59,04	436,43	176,77	2,22	50	124,54	114,39	134,33	124,33	0,16
66	231,65	73,87	612,10	552,51	2,32	55	123,64	114,67	133,00	124,83	0,15
75	489,64	96,41	1670,70	467,23	3,22	64	125,97	114,39	137,56	125,92	0,18
82	1214,46	140,67	3591,69	1247,12	2,84	69	138,06	124,11	152,72	132,92	0,21
89	2635,07	440,96	5510,85	2640,26	1,92	74	171,55	156,22	185,67	167,25	0,17
97	4122,10	1322,24	6494,33	4158,99	1,25	79	186,55	163,94	206,67	186,92	0,23
102	4567,96	2004,61	6700,18	5250,36	1,03	84	208,26	184,44	232,94	203,25	0,23
108	6516,49	4024,92	9312,50	6369,99	0,81	90	229,63	198,78	257,94	224,25	0,26
108,5	8454,08	5511,19	12113,74	8711,23	0,78	95	286,89	222,94	359,28	246,67	0,48
113,4	9923,04	7090,39	13142,60	9222,53	0,61	103	565,74	408,00	727,67	501,17	0,57
114,4	10187,33	7493,16	13117,92	10309,64	0,55	107	989,71	756,89	1233,44	907,25	0,48
117,2	10348,26	7341,93	13050,89	10474,12	0,55	118	2394,13	1917,89	2843,33	2407,83	0,39
124,8	12220,19	9588,24	14464,47	12444,78	0,40	124	3370,85	2836,22	3882,33	3369,17	0,31
136,7	13068,94	10806,15	15352,74	12960,42	0,35	135	6482,41	5801,67	7131,67	6586,67	0,21
149,7	15065,30	13221,00	16876,70	15044,10	0,24	141	7669,35	7047,78	8260,00	7775,00	0,16
153	13500,07	11853,00	15587,89	15404,60	0,28	160	13561,72	12868,50	14235,83	13766,67	0,10
160	16189,68	14099,21	17600,39	16122,44	0,22	171*	15486,56	14935,00	15975,00	15500,00	0,07
					1,10						0,22

Tab. 10 & 11: Calculations of 6 yearly ('04-'09) averages, median, min, max & variation values for Humber (mixed camaigns) & Weser (boat campaign)

Humber						**Weser**					
Tide-km	Cl (mg/l)	Cl min (mg/l)	Cl max (mg/l)	Cl median (mg/l)	Variation	Tide-km	Cl (mg/l)	Cl min (mg/l)	Cl max (mg/l)	Cl median (mg/l)	Variation
18,89	70,13	32,50	119,00	70,83	1,23	30,5	234,75	197,63	273,58	241,33	0,32
42,07	76,05	17,90	136,00	73,15	1,55	42	286,52	206,13	404,50	245,17	0,69
69,18	106,61	37,20	473,00	99,03	4,09	59,8	2987,81	1734,26	4269,35	2826,00	0,85
0	30,57	13,20	49,10	30,25	1,17	89	13595,56	12340,00	14643,33	13216,67	0,17
8,99	27,33	12,40	56,30	28,17	1,61						0,51
33,98	48,25	26,50	88,60	40,85	1,29						
40,22	132,98	28,60	2010,00	65,19	14,90						
59,50	1287,68	34,50	7780,00	1070,01	6,02						
85,05	6472,67	281,00	12300,00	6208,00	1,86						
87,69	6512,18	134,00	12300,00	6755,00	1,87						
92,55	8358,57	520,00	16800,00	8420,00	1,95						
101,94	11458,46	2400,00	15700,00	11270,83	1,16						
104,24	12683,89	7590,00	15700,00	13600,00	0,64						
114,78	15636,11	12200,00	17900,00	15900,00	0,36						
122,61	15750,31	200,00	27100,00	16766,67	1,71						
					2,76						

!!! The first three rows for the Humber table are Tide km for the Trent tributary (grey). Thereafter, the Tide-km start at the Ouse (blue) and goes further onto the Humber (confluence at 59,5km) (see also figure 7). Difference in km (km 164 in table 9 and fig. 3) is due to modeling reasons*

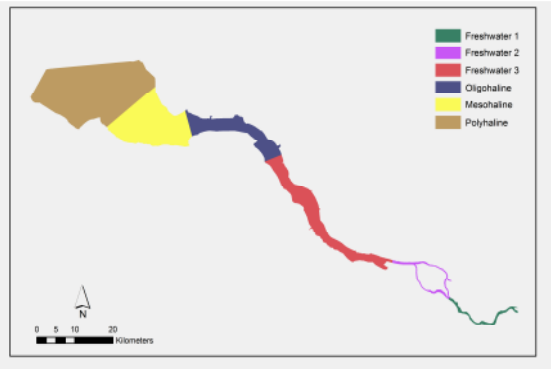
From all the considerations mentioned above, the following zonation scheme can be suggested:

Tab. 12: Zonation based on the Venice system for the saline part of the estuary and based on morphology, usage and/or residence time for the freshwater (see text) for all TIDE-estuaries

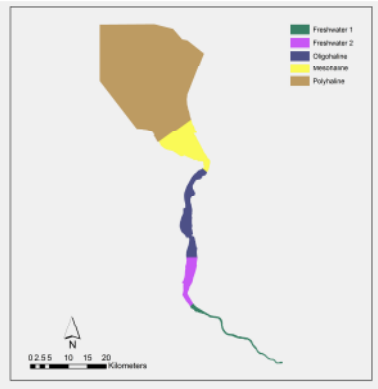
Chlorinity range	Elbe		Weser		Schelde		Humber
<300 mg Cl^-/l	0 - 91	0-24 (1)	0-44	0-31 (1)	0-58	0-31 (1)	Trent: 0-45 $TIDE_{Trent}$-km + Ouse till confluence with the Aire : 0-34 $TIDE_{Ouse-Humber}$-km
		24-46 (2)		31-44 (2)		31-58 (2)	
		46-91 (3)					
300-3.000 mg Cl^-/l	91-118		44-69		58-89		Trent: 45- 85 $TIDE_{Trent}$-km + Ouse further downstream: 34-60 $TIDE_{Ouse-Humber}$-km
3.000-11.000 mg Cl^-/l	118-141		69-84		89-116		Humber: 60-93 $TIDE_{Ouse-Humber}$-km
>11.000 mg Cl^-/l	141-171		84-119		116-160		Humber: 93-123 $TIDE_{Ouse-Humber}$-km

In the Schelde the freshwaterzone is splitted into 2 zones based on residence time (FW 1 short residence time ~ < 5 days, FW2 long residence time~ > 5 days; cf. Harbasins report – Physiotope system). In the Elbe three zones can be considered. This is based on morphology and use (harbour) (see earlier – table 2, p. 6). The Weser only dessignates two freshwaterzones based on the degree of urbanisation with the first freshwaterzone as the urban area from Hemelingen sluice up till Farge, and the second freshwaterzone as the rural area from Farge up to Brake. In the Humber no further splitting up for the freshwaterzone was suggested.

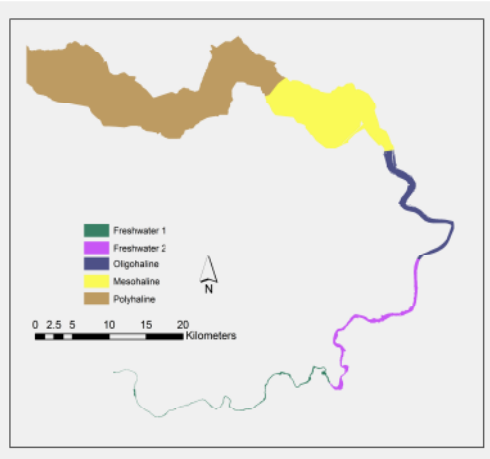
The four maps based on the agreed Tide zonation are presented beneath:



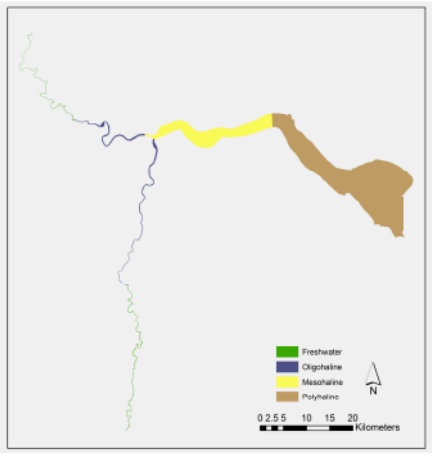
Elbe estuary



Weser estuary



Schelde estuary



Humber estuary

Fig. 8 Maps of the TIDE-zonation per estuary (by W. Vandenbruwaene)

4 Concluding remarks

As mentioned earlier, in every estuary already different approaches existed. It is not the aim of TIDE to replace them. However these existing zones were not easily comparable according to the aims of TIDE. Therefore the above described approach will be used in order to allow an interestuarine comparison between the different TIDE-estuaries. It has to be taken into account that not all zones have equal length and surface area, and that zones can move spatially depending on seasonal discharge and tidal phase. Furthermore, zones for different estuaries could differ in length because of differences in tidal range, river discharge etc. It can be concluded that this zonation has to be used and interpretated with care and can be used in a flexible way according to the research question to be adressed. Ideal would be to have a standardized normalization of the TIDE-km for all estuaries. On the longer term, by working with all the actual data available in TIDE, we might find a common parameter, other than chlorinity, to set out the data along the whole estuary gradient (also in the freshwaterzone). The latter approach can than be preferred for interestuarine comparison. Nevertheless, on short term, this zonation provides a good starting point for an objective interestuarine comparison for work packages 3 and 4 (conflict matrix, ecosystem survey, ecology and hydrogeomorphology).

Recommendation

In some cases existing zonations e.g. for the Water Framework Directive may not be useful when comparing the features of several estuaries. According to the aims a different zonation might be necessary for a sufficient spatial distribution resolution and to be able to compare the estuaries. For a common basis zones of equal properties have to be chosen. This zonation approach can be used in cases when it is more sensible to compare only certain areas of the estuaries instead of considering the whole estuary, e.g. for the different issues of ecological functioning, research questions, monitoring schemes, measures and management issues, etc…

The TIDE zonation approach takes the following conditions into account:

1. The zonation system should be flexible enough to cover different issues.
2. It should allow the direct comparison of certain areas of each estuary.

Due to the different length of the estuaries we advice to set km “0” of all estuaries at the inland tidal boundary on the longitudinal axis and use the Venice system for a comparable zonation between the estuaries. Considering only the Venice system, the freshwater zone is too long to compare as a whole between estuaries. Therefore, we split the freshwater zone according to morphology, residence time and/or usage, based on expert judgment by each TIDE-partner.
A six yearly average for the period of investigation (2004-2009) can be assumed as a good basis estimation for the distribution of different ecological entities. Herefore, annual and seasonal calculations of averages, median, minimum and maximum values for 2004-2009, per measuring station were performed.