Tidal River Development

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The Interreg IVB North Sea Region Programme

WP5 Measures

Basic analysis reports

Measure nr° 16. Paddebeek wetland - small scale tidal wetland restoration in the freshwater zone of the Sea Scheldt (Zeeschelde)

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1 Description of measure

- Measure Category: Biology/Ecology
- Estuary: Scheldt
- Salinity zone: Limnic
- Pressure: Habitat loss and degradation
- Status: Implemented (in 2002-2003)
- River km: Scheldt-km 137.5-146; TIDE-km 14-22.5
- Country: Belgium
- Specific location: Sea Scheldt (Zeeschelde), Flanders, Schoonaarde, between Schoonaardebrug and Paddebeek, right bank of Seascheldt
- Responsible authority: Waterwegen en Zeekanaal NV
- Costs: 2,221,300 €
- Cost category: 1,000,000 – 5,000,000 €

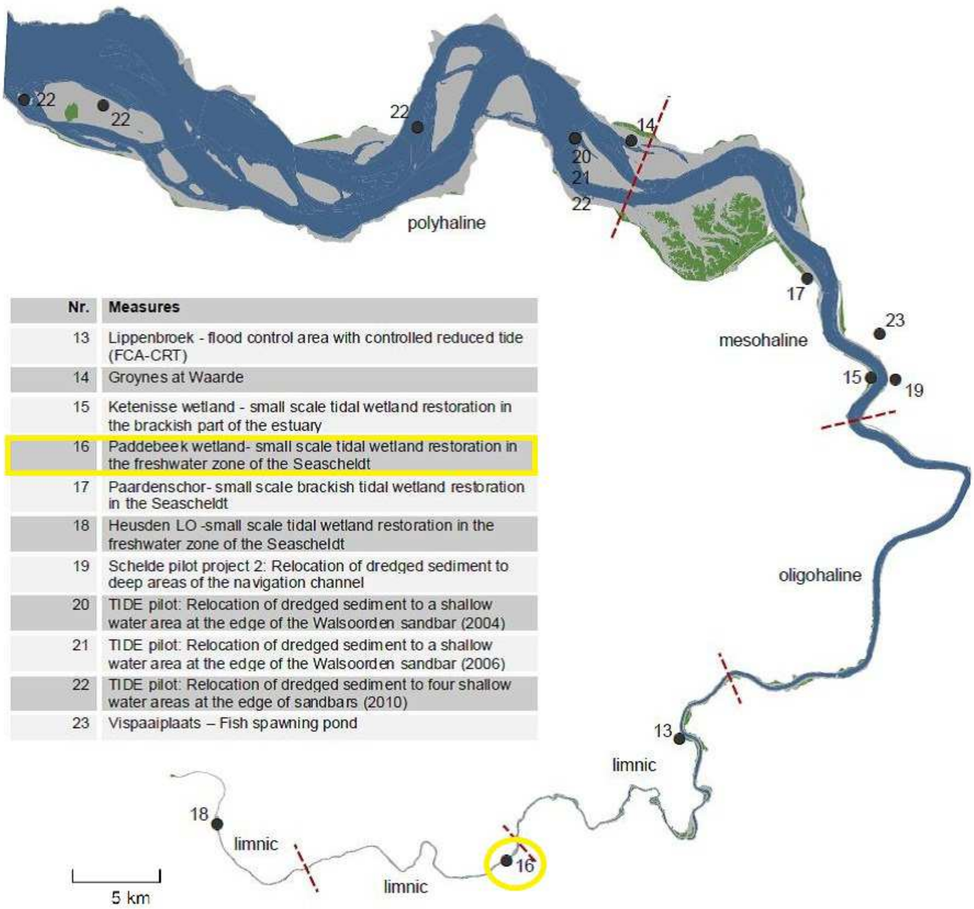


Figure 1. Location Paddebeek wetland

1.1 Measure description

The Paddebeek wetland is a long and small area of 1.6 hectare in the freshwater zone of the Sea Scheldt (Zeeschelde), between Schoonaardebrug and Paddebeek, at the right bank of the Sea Scheldt (Zeeschelde).
At the location of the Paddebeek, they decided to shift the dike landward to the fishing lake and corn field. By doing so, a small tidal wetland could develop in an area of the Sea Scheldt (Zeeschelde) where tidal wetlands with mudflats and marshes are scarce (fresh water zone). This opportunity came along when the existing dike needed to be elevated to "Sigma-height", and several alternative locations were considered. Only at the ends, the dike was reinforced with stone rubble. In the central part, 3 terraces were installed (using wooden poles and willow wicker) at different heights to protect the dike. Where the old dike was removed, the substrate was reinforced with gabions (schanskorven) and a small stone rubble dike.

Besides the possibility to improve the connectivity in this area, developing this kind of habitat is expected to contribute in de reduction of tidal energy, increase of flood protection, improvement of oxygen condition, improvement of nutrient conditions, and improvement of self-purifying power.

The construction of the Paddebeek wetland fits in the frame of the Sigmaplan (management plan for flood defence in the Scheldt estuary), the dike needed to be broadened and elevated. Analysis of the evolution after restoration fits in with the decisions about the Development outline 2010 and Long Term Vision 2030 (Dutch and Flemish agreement on integrating accessibility, naturalness and flood safety) and the updated Sigmaplan (Flemish plan for flood protection combined with ecological objectives), of the Dutch and Flemish governments, that committed them to leap forward with the ecological rehabilitation of the Scheldt estuary. An important challenge is the creation of tidal wetlands by transformation of woods or agricultural land into tidal mudflats and marshes. In order to assess the feasibility and to identify possible problems any similar small scale projects, such as Paddebeek, already in place are studied in detail to improve our apprehension of the larger scale future plans.

1.2 Monitoring

Monitoring is still in progress and is included in the global monitoring of the Scheldt estuary (Moneos). Also, a multidisciplinary monitoring program is installed similar to the monitoring of the other restoration projects (Paardenschor, Ketenisse, Heusden-LO): changes in geomorphology (sedimentation-erosion plots (sederoplots), sederoplates, profile measures, orthophotos), sediment characteristics (granulometry, organic %, pigment, physicochemistry), benthos (oligochaeta) and vegetation (mapping and PQ’s). These developments were compared as much as possible to the situation on nearby tidal wetlands.
In the Paddebeek wetland there are four permanent sample locations at one transect perpendicular to the shoreline central in the area (Figure 2: red spots). All sample locations are on the restored site: PA1 and PA2 are on the high marsh terraces (at start of the monitoring resp. on 5.8 and 5.3mTAW), PA3 is at start on the new mudflat terrace (4.8mTAW) and PA4 is near the old dike (4.7mTAW) (Van den Neucker et al. 2007). Two extra transects are used with PQ’s to monitor vegetation (Figure 2: yellow spots).

Figure 2. Overview Paddebeek wetland with sample locations: sedimentation-erosion plots ("sederoplots": red triangles) and vegetation PQ's (yellow cubes). Orthophoto January 2009. (Speybroeck et al. 2011)

1.3 Monitoring results

1.3.1 Geomorphology and topography

The global gradient of the Paddebeek wetland is 3.7% and constant during the monitoring period (Speybroeck et al. 2011). From the elevation profile we can conclude that only limited changes occurred in the elevation of the Paddebeek wetland (Figure 3). Three zones could be identified (Figure 3).

For the first zone with sederoplots PA1 and PA2, located at the terraces in the zone 0-12m from the reference point at the dike, no clear observations were made because the sample plots could not be found back every time and had to be replaced several times (Van den Neucker et al. 2007). In the second monitoring period, both plots were not monitored anymore (Speybroeck et al. 2011). Note that the flood risk is limited at both terraces (9% and 39% respectively) (Figure 3).

The central zone of the wetland (12-36m from the dike with plots PA3 and PA4) is flat with a river-oriented gradient of 0.5% and a gradual sedimentation rate of 4 to 6cm per year during the first monitoring period (Van den Neucker et al. 2007) and of approximately 2cm per year during the second monitoring period (Speybroeck et al. 2011).

Behind spot PA4 (behind 36m) the wetland is shaped by the remains of the old dike and is covered with rubble stone (Van den Neucker et al. 2007, Speybroeck et al. 2011). This resulted in a steep gradient of about 12% (Speybroeck et al. 2011).

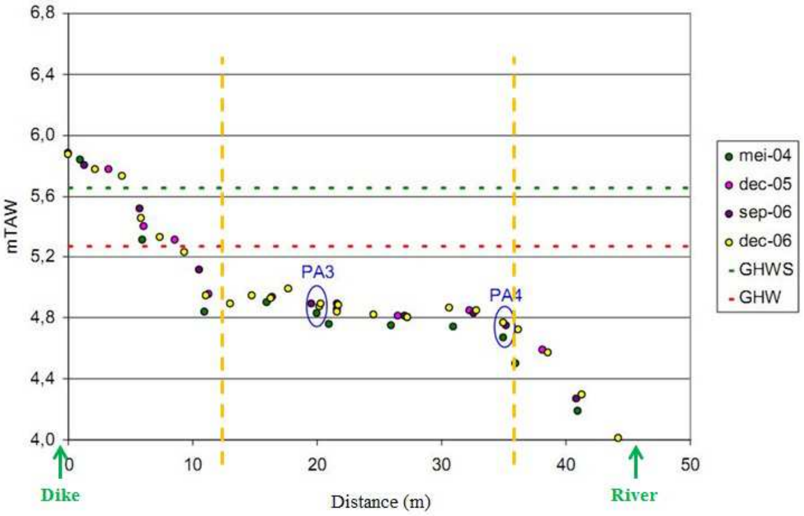


Figure 3. Elevation profile of the Paddebeek wetland, with average high water (GHW) and average high water at spring tide (GHWS) (Van den Neucker et al. 2007, Speybroeck et al. 2011)

1.3.2 Sediment characteristics

In addition to the limited geomorphological and topographical change, also the median grain size does not show a clear trend (Speybroeck et al. 2011). Despite a few outliers, the variation in the median grain size (and probably the sediment at total) mainly decreases in the upper centimeter (fraction 0-1cm). However, it is mainly a matter of erratic changes.

Location PA1 is rich in silt content with a median grain size mainly smaller than 60 µm, both in the upper (0-1cm) and deeper (0-10cm) fraction (Van den Neucker et al. 2007). The variation in the first six months after the construction was large (Figure 4).

At location PA2, the median grain size decreased during the first three months after construction: from 170 to 105 µm in the upper fraction (0-1cm) and from 80 to 35 µm in the deeper fraction (0-10cm) (Figure 4) (Van den Neucker et al. 2007). After that, the median grain size increased again in both fractions. The sediment consisted mainly of fine sand.

Locations PA3 and PA4 are rich in silt content during the entire monitoring period with a median grain size, in both depth fractions, mainly smaller than 40 µm (PA3) and 50 µm (PA4) (Van den Neucker et al. 2007). From the end of 2005 at location PA3, the median grain size in the upper centimetre (0-1cm) was always a little smaller than in the deeper fraction (0-10cm) (Figure 4).

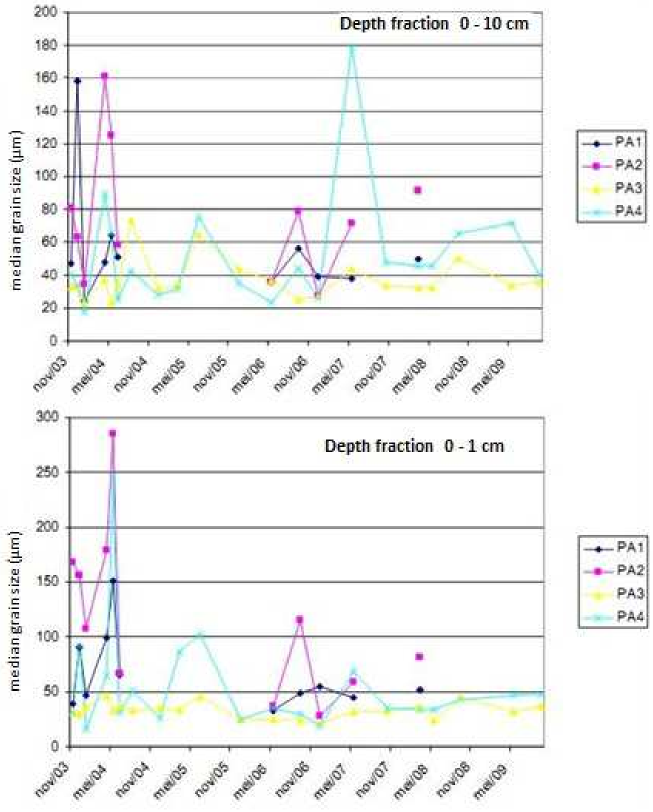


Figure 4. Sediment in the fraction 0-10cm depth (up) and in the fraction 0-1cm depth (down): median grain size in function of the time (Speybroeck et al. 2011)

At locations PA1 and PA2, the organic matter concentration remained almost constant during the first year after the construction. At both locations, the concentration was low, always below 4% (Figure 5). In 2006, the concentration increased up to 5% in the deeper fraction (0-10cm). In the top fraction (0-1cm), the concentration increased even more but the variation was large (Van den Neucker et al. 2007).

At locations PA3 and PA4 the organic matter concentrations were higher but fluctuated during the first eight months around 4% (PA3) and 5% (PA4) (Figure 5) (Van den Neucker et al. 2007). After that, the concentration increased at both locations, mainly in the top fraction (0-1cm). And the increase was more intense at location PA3 which is probably related to the protected orientation of PA3 and the settlement of higher plants (Speybroeck et al. 2011).

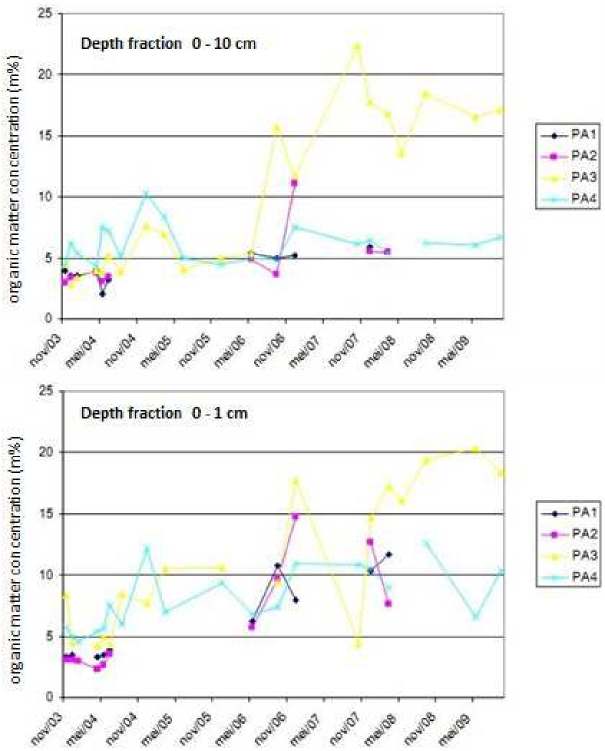


Figure 5. Sediment in the fraction 0-10cm depth (up) and in the fraction 0-1cm depth (down): organic matter concentration (mass percentage) in function of the time (Speybroeck et al. 2011).

1.3.3 Sediment quality

The global sediment quality (expressed in Triade score) remained constant over time with a triade score of 3 “moderately abnormal”. The main pollutants are mercury, PAHs and PCBs, followed by cadmium, copper and zinc (Speybroeck et al. 2011). The sediment quality is not really good at the Paddebeek wetland but is (almost) not affected by the sedimentation. However, the evolution to smaller sediment particles (clayish) causes a higher bioavailability of most pollutants with a negative impact on the general ecotoxicological condition of the Paddebeek wetland (Speybroeck et al. 2011).

1.3.4 Vegetation

In the fresh water part (Paddebeek) there were 6 vegetation types, which is much less than the 11 vegetation types in the brackish parts (Paardenschor and Ketenisse schor) (Van den Neucker et al. 2007). In general, the colonization at the Paddebeek is relatively slow as well as the turnover between different vegetation types. In contrast, at the brackish areas the colonization rate was also low but the turnover was high.

Until now, 140 species of macro-algae and higher plants and mosses were identified (Speybroeck et al. 2011). The willow wickers, used at the edge of the constructed terraces, are grown up to a shrub layer. The bare mud, developed between the terraces and the shoreline, is colonized by pioneer species like Vaucheria (*Vaucheria sp.*), Water-pepper

(*Polygonum hydropiper*), Blue Water Speedwell (*Veronica anagallis-aquatica subsp. Anagallis-aquatica*), etcetera. Common Reed (Phragmites australis) colonised the pioneer vegetation and dominates now the entire zone between the terraces and the shoreline, except for a small area of bare mud. Further succession did not happen until now. This is possibly due to the gradual elevation by sedimentation (average elevation of the PQs between the terraces and the shoreline amounts 17 mm per year), but even more by the local hydrological conditions (groundwater drops only limited or not under the surface level). The presence of the shoreline limits the floods but also the drainage. However, the drainage is mainly limited by the compaction of the sediment and dumping of construction waste. At the more dynamic and exposed locations (PQ263), situated between the Sea Scheldt (Zeeschelde) and the shoreline, vegetation remains at pioneer stage with Water Pepper and Blue Water Speedwell (*Veronica anagallis-aquatica*).

Based on the flood frequency and the appearance of different vegetation types on the Paddebeek wetland, two zones can be distinguished: the lower elevation zone (with a flood frequency between 81 and 92%) which is mainly colonized by vegetation types 12, 13 and 14, and the higher elevation zones (with a flood frequency between 23 and 33%) which is mainly colonized by vegetation types 15, 16A and 16B (Figure 6). At the lower elevation zone, pioneer vegetation type 12 (*Polygono-Veronicetum anagallidis-aquaticae*) first colonized bare mud (type 17 “slik”) and then evolves to type 13 (*Alismato-Scirpetum/Typho-Phragmitetum*) and type 14 (*rough Polygono-Veronicetum*) (Figure 7 & Figure 8). At the higher elevation zone with only few estuarine influences, dry pioneer vegetation type 15 (*Stellarietea mediae*) changed to roughness type 16B (*rough Circium vulgare*) and sometimes also type 16A (*rough Artemisia*).

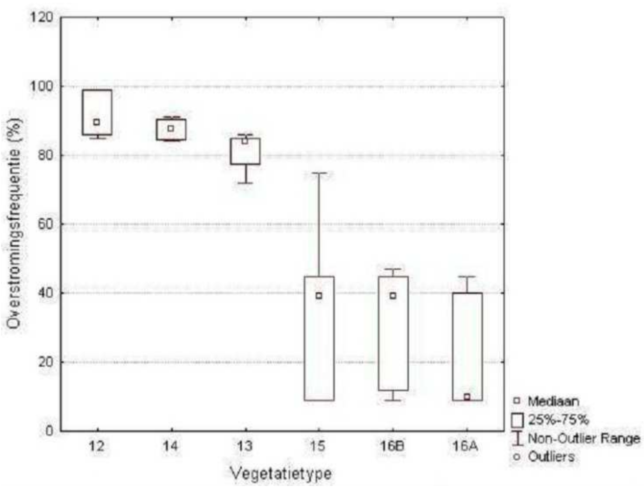


Figure 6. Boxplot of flood frequencies per vegetation type in the freshwater part (Paddebeek)

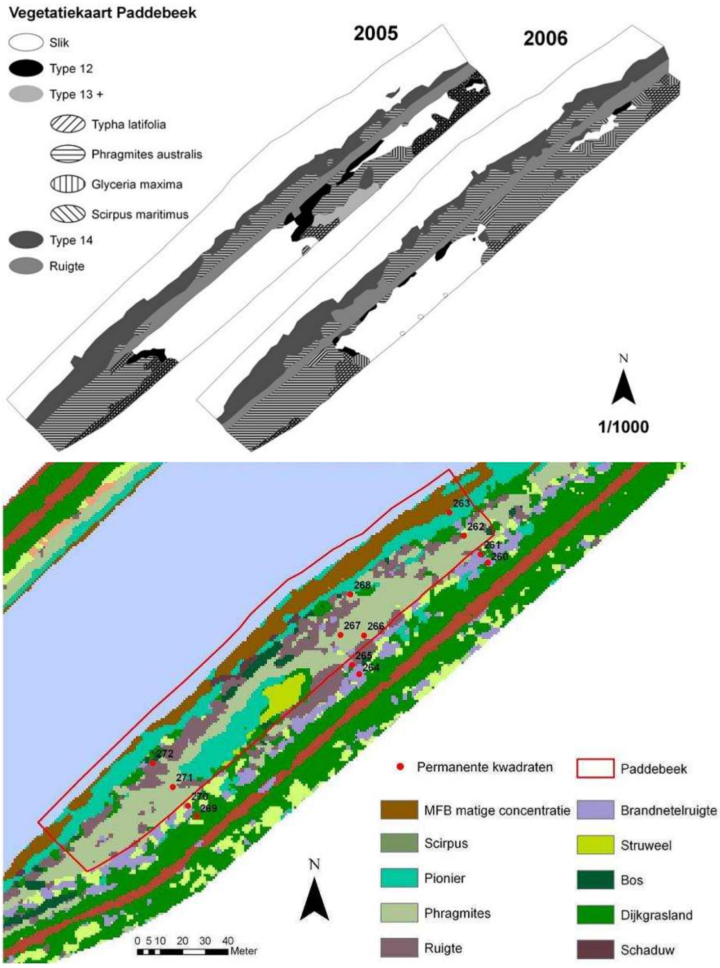


Figure 7. Vegetation map of Paddebeek from 2005 and 2006 (Van den Neucker et al. 2007) (Up) and 2007 (Speybroeck et al. 2011) (Down, MPB: microphytobenthos)

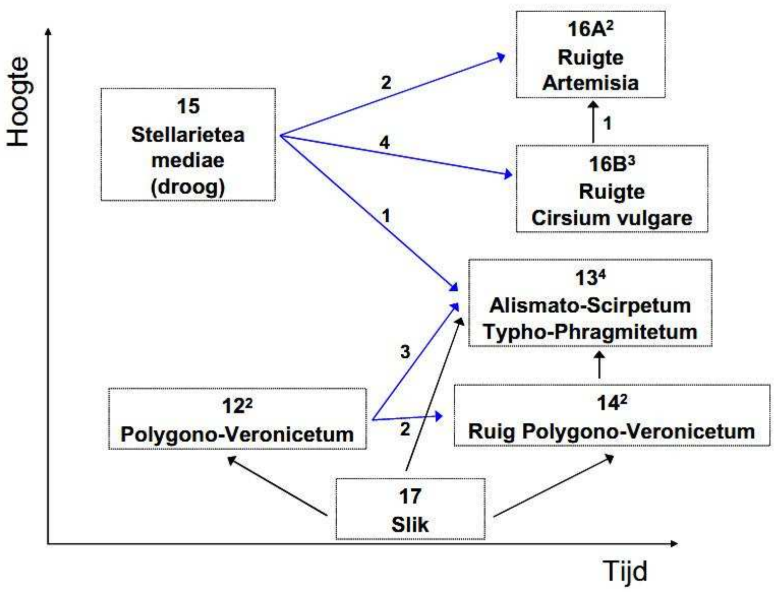


Figure 8. Transition scheme of Paddebeek in function of the time and elevation. The arrows represent the transition of one type to another. Blue arrows represent progressive succession, red arrows regressive. The number of transitions is indicated by the subscript at the arrows. Digressive succession is quantified by the subscript at the vegetation types. Black arrows indicate transitions based on the vegetation maps. (Van den Neucker et al. 2007)

1.3.5 Macrozoobenthos

At the Paddebeek the monitoring of benthos was based on the Oligochaeta population because this wetland is situated in the fresh water zone of the Sea Scheldt (Zeeschelde). At Paddebeek low abundances of Oligochaeta were found immediately after restoration but they quickly increased significantly (Van den Neucker et al. 2007). Five different taxa of Oligochaeta could be distinguished with certainty at location PA3 and PA4 during the first monitoring period (May 2004-December 2005). In the Oligochaeta samples, also nine other taxa of benthos were identified (such as insect larva or pupal) and Acari, Collembola and Carychium (Van den Neucker et al. 2007).
At location PA3 no Oligochaeta were found immediately after the construction (May 2004), but the density increased afterwards (almost 125,000 individuals/m² in December 2004 and almost 100,000 individuals/m² in December 2005), see Figure 9. Tubificiden without hair were always dominant (Van den Neucker et al. 2007). The tubificiden without hair were mostly juveniles from the Limnodrilus-species (L. claparèdeianus, L. hoffmeisteri en L. udekemianus) and Tubifex blanchardi. At location PA4 low Oligochaeta densities (less than 4,000 individuals/m²) were found immediately after the construction (May 2004), mainly tubificiden with hair (Figure 9). The tubificiden with hair were mostly juveniles from T. tubifex. After May 2004, Oligochaeta was not sampled anymore at location PA4.

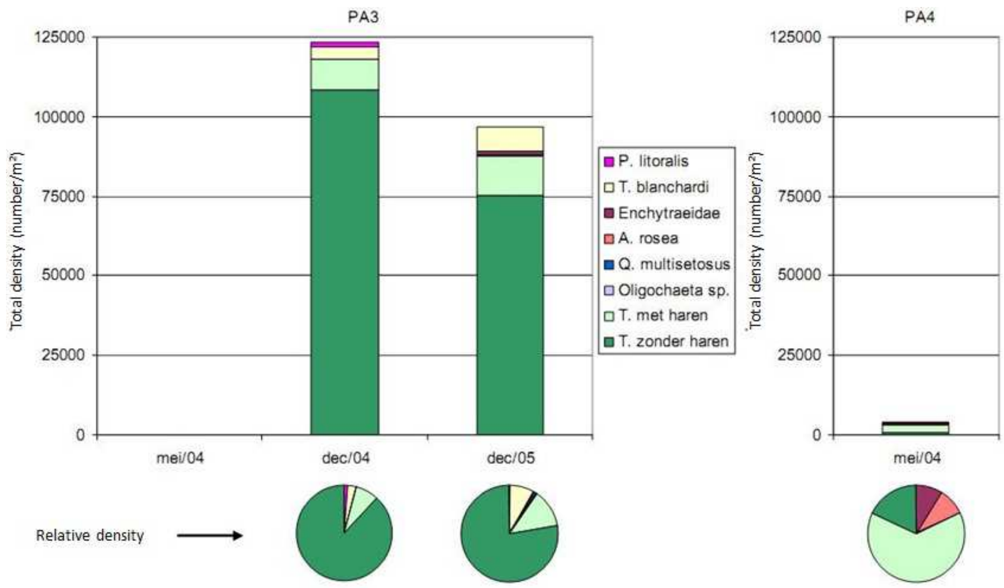


Figure 9. Total and relative density of Oligochaeta at locations PA3 and PA4 at Paddebeek (May 2004 – December 2005) (Van den Neucker et al. 2007)

The Oligochaetataxa that were found at Paddebeek were representative for the freshwater zone of the Sea Scheldt (Zeeschelde) (Van den Neucker et al. 2007). The low number of benthos taxa that was found at Paddebeek is also not abnormal for this zone of the Sea Scheldt (Zeeschelde). Also on other wetlands in the area the number of species was comparable (Scheldedatabank INBO). The low species richness can be the consequence of the sometimes low oxygen concentration in the Upper Sea Scheldt (Boven-Zeeschelde) (Van Damme et al., 2005). Some species are known as opportunistic species (*Tubifex tubifex*, *Limnodrilus*-species and *Quistadrilus*) that can be found on places were oxygen supply is sometimes limited (Brinkhurst & Gelder, 1991).

1.3.6 Avifauna

Avifauna is not monitored in the Paddebeek.

1.3.7 Fish

The fish density in the creeks is very low. At the restoration site, only one carp (*Cyprinus carpio*), three roach (*Rutilus rutilus*) and two Three-spined stickleback (*Gasterosteus acculeatus*) were caught during one day (sample in 2007) (Van den Neucker et al. 2007). However, no data is available from the original mudflat to compare.

2 Execution of main effectiveness criteria

2.1 Effectiveness according to development targets of measure

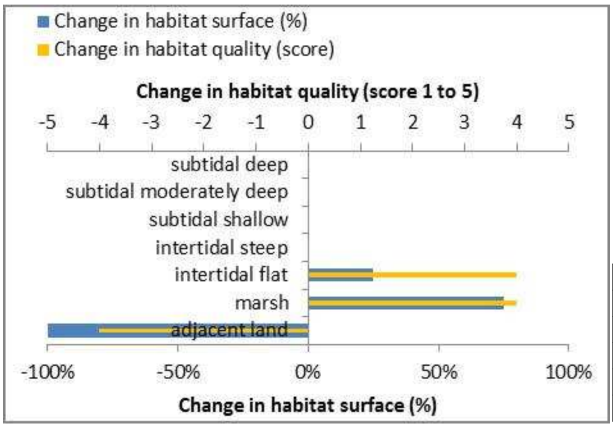
Step 1: Definition of development target
The creation of new ecological valuable intertidal wetlands can contribute to estuarine restoration as it enables habitat development and biodiversity. Success factors are related to the improvement of estuarine processes (such as sedimentation-erosion, creek formation and soil development).

Step 2: Degree of target achievement
In general, the restoration of the Paddebeek was a success to create a tidal wetland in the freshwater zone of the Sea Scheldt (Zeeschelde). By the inland shifting of the dike a small tidal area could develop in an area of the river Scheldt where mudflats and marshes are scarce. The constructed terraces were rapidly colonized by estuarine vegetation species: pioneer communities of Vaucheria (*Vaucheria sp.*), Water speedwell (*Veronica anagallis-aquatica*), Cursed buttercup (*Ranunculus sceleratus*), etc., followed by helofytes like Alkali Bulrush (*scirpus maritimus*), Common Reed (*Phragmites australis*), Common Bulrush (*Typha latifolia*) en Reed Sweet Grass (*Glyceria maxima*).
Because of the construction of terraces with willow wicker, stone rubble was not necessary to protect the new dike. Unfortunately the greater part of the old dike remained in place, hindering proper drainage, creek formation and colonisation. To allow some drainage several stones should be removed. The terraces were constructed with life willow wicker. As a consequence, willow shrubs established very quickly, which accelerated vegetation succession.
The site has limited habitat functions for birds. Nevertheless, it is valuable for the connectivity of the tidal wetlands in this part of the Sea Scheldt (Zeeschelde).

2.2 Impact on ecosystem services

<u>Step 1</u>: Involved habitats

The measure Paddebeek wetland in the freshwater zone of the Scheldt estuary was about the creation of intertidal habitat by transforming adjacent land (agricultural land and a lake) into mainly marshland and also some intertidal flat habitat with a high change in the habitat quality.



Score habitat quality
1 = very low quality
2 = low quality
3 = medium quality
4 = high quality
5 = very high quality

Figure 10. Ecosystem services analysis for Paddebeek wetland: Indication of habitat surface and quality change, i.e. situation before versus after measure implementation. The change in habitat quality, i.e. situation after the measure is implemented corrected for the situation before the measure, is '1' in case of a very low quality shift, and '5' in case of a very high quality shift.

<u>Step 2</u>: Expected impact on ecosystem services, compared with targeted ecosystem services, and expected impact on beneficiaries

More information about the methodology and the correct interpretation of the results could be found in the overall measures report (Saathoff et al. 2013).

(1) Overall expected impact on ES: From the ES assessment it is concluded that this measure generates overall a positive expected impact for many ES, mainly for "biodiversity"; cultural service (Aesthetic information); and some regulating services: Erosion and sedimentation regulation (by water bodies); Water quality regulation: reduction of excess loads coming from the catchment; Climate regulation: Carbon sequestration and burial; Regulation extreme events or disturbance: Flood water storage.

(2) Expected impact on targeted ES: The key objective of this measure is the creation of a new intertidal wetland to improve the general functioning of the Scheldt estuary (habitat services "biodiversity"). The expected impact for the development target "biodiversity" is very positive.

(3) Expected impact on beneficiaries: The expected impact for the different beneficiary groups is overall positive, with a very positive expected impact for future use.

TIDE Tidal River Development

Table 1. Ecosystem services analysis for Paddebeek wetland: (1) expected impact on ES supply in the measure site and (2) expected impact on different beneficiaries as a consequence of the measure

Paddebeek wetland- small scale tidal wetland restoration in the freshwater zone of the Seascheldt

Cat.	Ecosystem Service	Score
S	"Biodiversity"	3
R1	Erosion and sedimentation regulation by water bodies	3
R2	Water quality regulation: reduction of excess loads coming from the catchment	3
R3	Water quality regulation: transport of polutants and excess nutriënts	0
R4	Water quantity regulation: drainage of river water	0
R5	Erosion and sedimentation regulation by biological mediation	2
R6	Water quantity regulation: transportation	0
R7	Water quantity regulation: landscape maintenance	2
R8	Climate regulation: Carbon sequestration and burial	3
R9	Water quantity regulation: dissipation of tidal and river energy	0
R10	Regulation extreme events or disturbance: Wave reduction	1
R11	Regulation extreme events or disturbance: Water current reduction	1
R12	Regulation extreme events or disturbance: Flood water storage	3
P1	Water for industrial use	0
P2	Water for navigation	0
P3	Food: Animals	0
C1	Aesthetic information	3
C2	Inspiration for culture, art and design	2
C3	Information for cognitive development	2
C4	Opportunities for recreation & tourism	2

Beneficiaries:	
Direct users	0
Indirect users	2
Future users	3
Local users	2
Regional users	2
Global users	1

X Targeted ES

Legend: expected impact*	
3	very positive
2	positive
1	slightly positive
0	neutral
-1	slightly negative
-2	negative
-3	very negative

*: Indicative screening based on ES-supply surveys and estimated impact of measures on habitat quality and quantity. Quantitative socio-economic conclusions require local supply and demand data to complement this assessment.

2.3 Degree of synergistic effects and conflicts according to uses

Some corn field had to be replaced for the construction of the Paddebeek, but the area is so small (less than 1.6ha) that there was not a real conflict. The development of wetlands like the Paddebeek has the opportunity to combine nature conservation with flood protection. However, the Paddebeek is a small scale pilot project without any substantial influence on the Scheldt estuary.

3 Additional evaluation criteria in view of EU environmental law

3.1 Degree of synergistic effects and conflicts according to WFD aims

The creation of tidal wetlands in the freshwater part of the Sea Scheldt (Zeeschelde) is in the first place important because this type of habitat is scarce. Besides, it offers the opportunity to give some land back to the river and to enlarge the dynamic possibilities of the river. This has an impact on the hydrographic regime of the river and can provide flood protection. Finally, wetlands proved to improve the water and sediment quality and sedimentation on the wetland can reduce the need for maintenance dredging in the main river.

Indicator	code	Main pressures freshwater zone Scheldt	Effect?					Description
			- -	-	0	+	++	
S.I.	1.1	Habitat loss and degradation during the last about 100 years: Intertidal				X		Development of scarce tidal wetlands in the freshwater part of the Sea Scheldt (Zeeschelde)
S.I.	1.5	Gross change of the hydrographic regime during the last about 100 years				X		Opportunity to give more “space” to the river
S.I.	3.1/3.2	Decrease of water and sediment chemical quality				X		Wetlands proved to improve the water and sediment quality
D.I.	1.3	Land claim during the last about 100 years				X		Opportunity to give some land back to the river
D.I.	1.7	Relative Sea Level Rise				X		Opportunity to increase the flood areas at locations without (or with less) socio-economic costs
D.I.	2.4	Maintenance dredging				X		Sedimentation on the wetland means less sediment in the main river

S.I. = state indicator; D.I. = driver indicator

3.2 Degree of synergistic effects and conflicts according to Natura 2000 aims

The Paddebeek wetland is part of the ‘Scheldt and Durme estuary from the Dutch border to Gent’ (BE2300006), a protected area under the Habitat Directive. This measure is about the creation of a new tidal wetland in the freshwater zone of the Sea Scheldt (Zeeschelde), where mudflats and marshes are scarce. Hence, this measure contributes to the protection and conservation of intertidal wetlands in this protected area and enhances the connectivity in the area.
The Paddebeek wetland does not belong to the Bird Directive areas.

Conservation objectives (Sea Scheldt; Zeeschelde)	Specification	Effect?					Short explanation
		- -	-	0	+	++	
Protected habitats: estuary	Tidal wetland (freshwater)				X		Newly created freshwater tidal wetland in the protected area BE2300006, and quality improvement for this type of habitat.

4 Crux of the matter

Lessons can be learned from the way the Paddebeek is restored. A positive result came from the life willow wickers, used to construct the terraces. As a consequence, willow shrubs established very quickly, which accelerated vegetation succession. In addition, there was no need to use stone rubble to protect the new dike, except for the edges. A negative part of the restoration project was however that a greater part of the old dike remained in place, hindering proper drainage, creek formation and colonisation. To allow some drainage several stones should be removed.

A detailed evaluation of the monitoring methods is available. For future projects it is recommended to start with the monitoring plan already in the planning phase with clear cost estimation and clear agreements on execution and reporting; make a clear distinction between “site success monitoring” and “impact verification monitoring”; make a photographic survey on a yearly basis to improve interpretation of collected data; optimise the comparability of monitoring results of zoobenthos with that of other countries; monitoring of birds and fishes needs to be done from the beginning following fixed protocol; experimental research is needed to monitor benthic primary production; and investigate the monitoring of floristic quality of marsh vegetation.

An important knowledge gap exists on the identification of factors that can explain all changes in vegetation development. The inundation frequency cannot be the only factor. Also changes in elevation should be investigated better and the impact of local estuarine characteristics, such as sediment balance and wave impact should be taken into account better.

In general, the restoration of the Paddebeek was a success to create a tidal wetland in the freshwater zone of the Sea Scheldt (Zeeschelde), but some aspects could be done even better when executing a new wetland restoration project.

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