Estuarine management and bio-geomorphological evolution of estuaries

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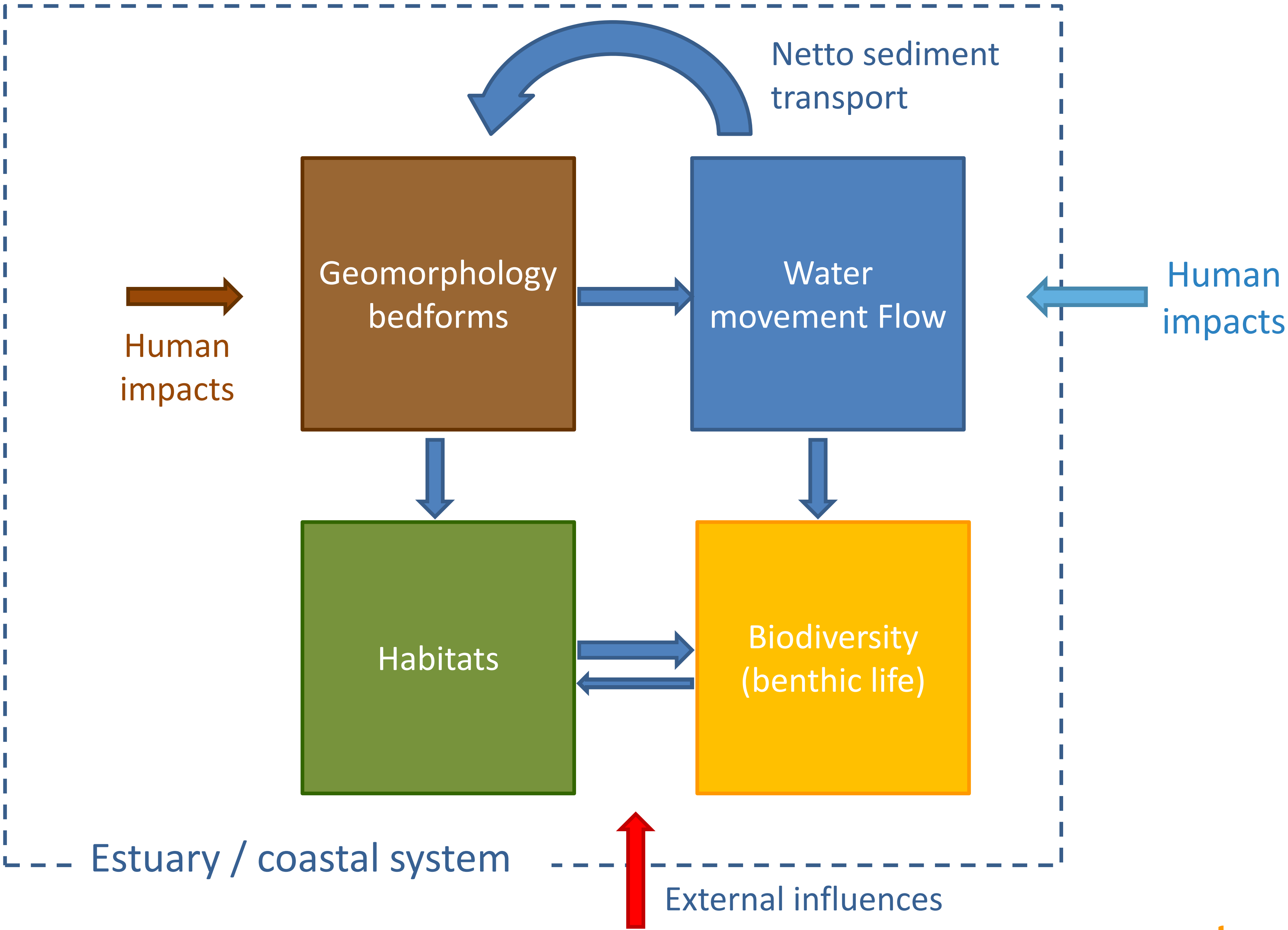
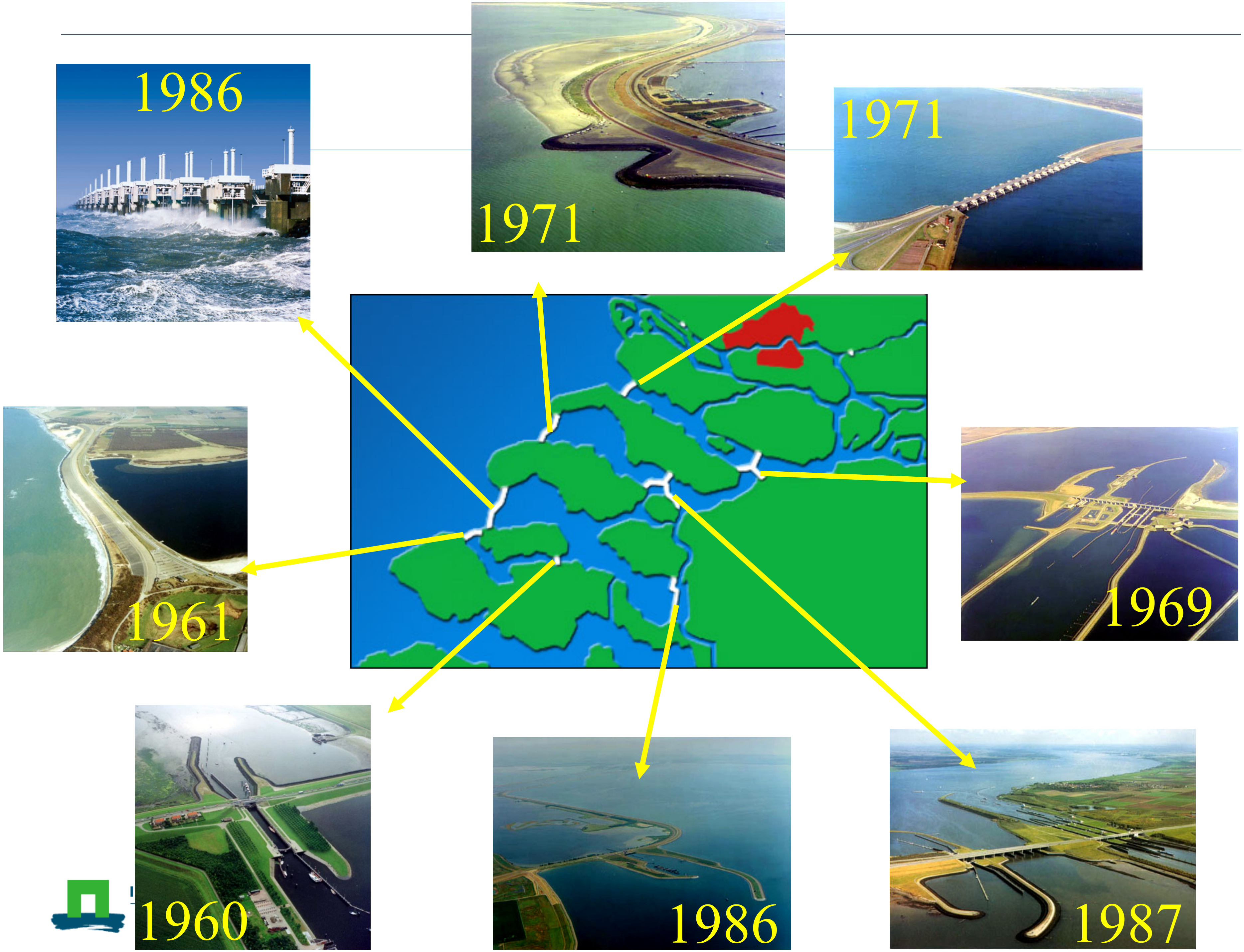
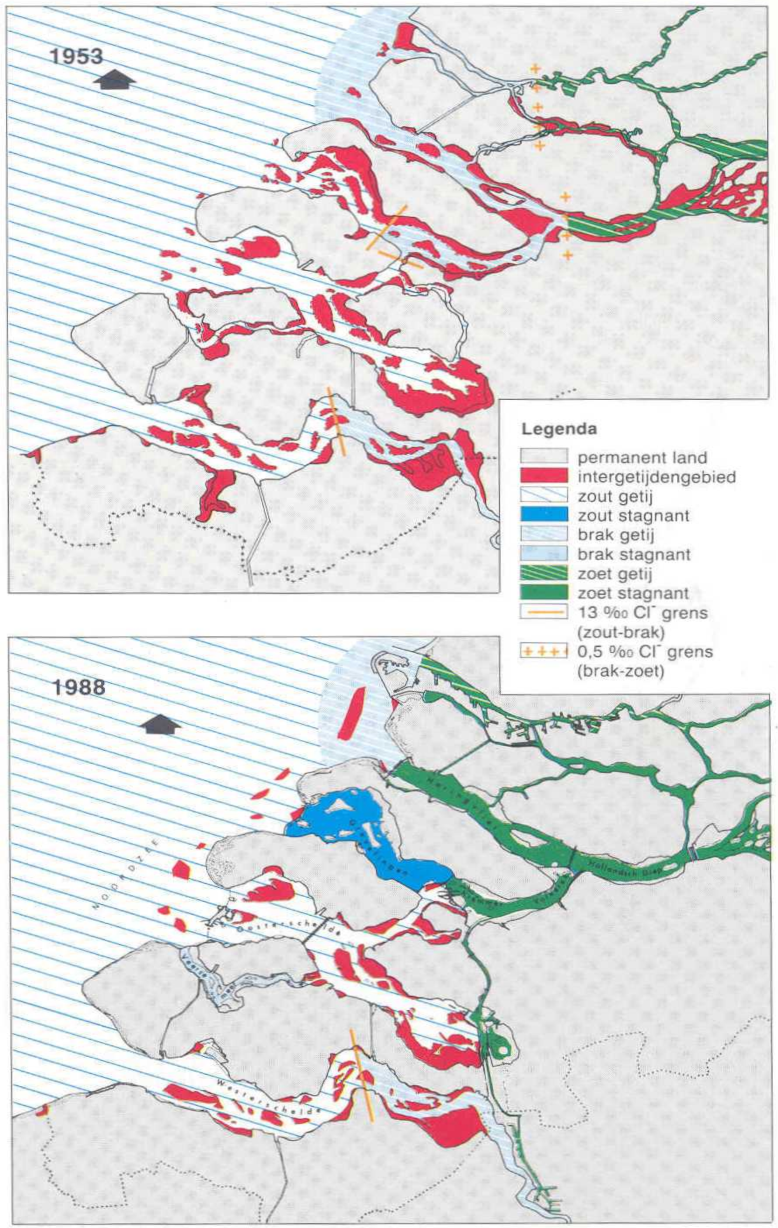

Netto sediment transport
Geomorphology bedforms
Water movement Flow
Human impacts
Human impacts
Habitats
Biodiversity (benthic life)
Estuary / coastal system
External influences



1986
1971
1971
1961
1969
1960
1986
1987

Loss of estuarine dynamics in SW Delta

- SW Delta: before – after
  - (estuarine) dynamics disappeared through Delta works
  - Loss of intertidal areas
  - hard-engineered barriers, no transition zones
  - Two tidal systems left: Oosterschelde and Westerschelde



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The Oosterschelde storm surge barrier

Initially a closure dam was planned.

Organised protest against closure dam started in 1970, for ecological *and* economical reasons.

1974 decision for alternative solution = open storm surge barrier that maintains tidal system (accepting high additional costs to preserve nature and shellfish culture).

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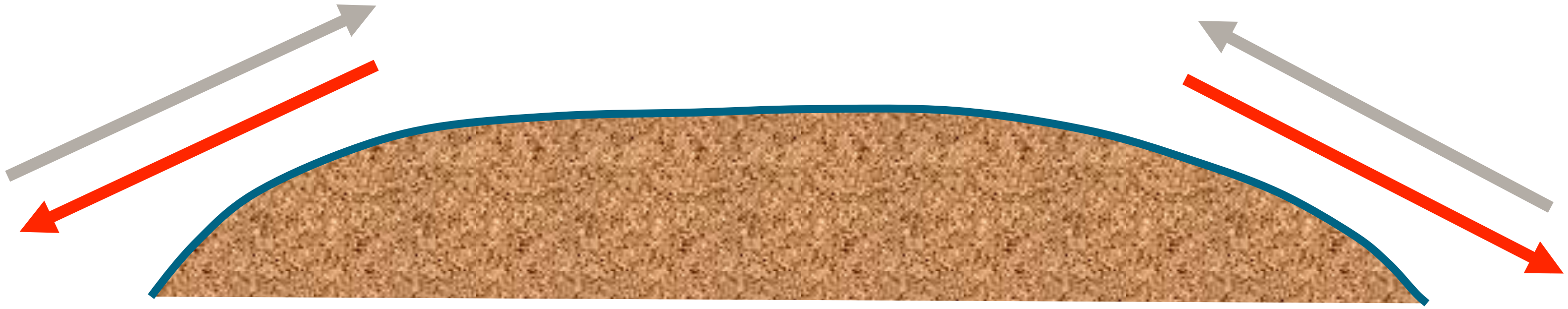
Direct consequences of Oosterschelde project

	Pre-barrier	Post-barrier	% change
Total surface area (km^2)	452	351	-22
Intertidal surface area (km^2)	183	118	-36
Tidal volume (10^6 m^3)	1283	915	-29
Average current velocity (m/s)	1.2	0.8	-33
Residence time water (days)	50	100	+100
Fresh water input (m^3/s)	70	25	-63
Salinity (%o)	>25	>30	+15
Average tidal range (Yerseke) (m)	3.7	3.25	-12
Average concentration suspended matter (mg/l)	25	15	-40

Nienhuis and Smaal, 1994

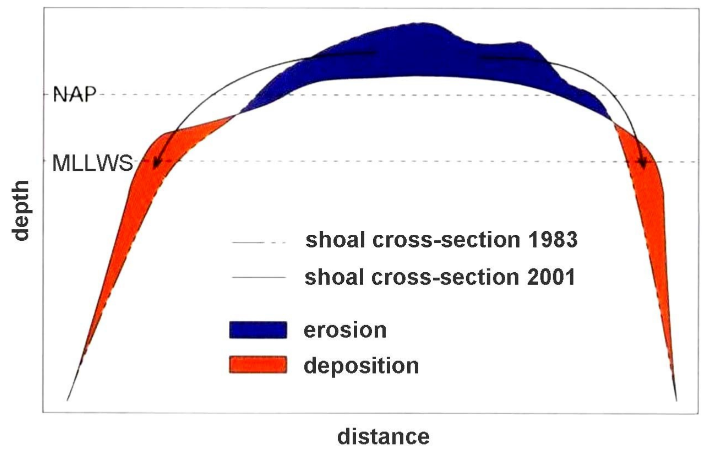
Tidal landscape still present

But balance between erosion and sedimentation on tidal flats changed



Sediment is deposited on the flats by tidal flow

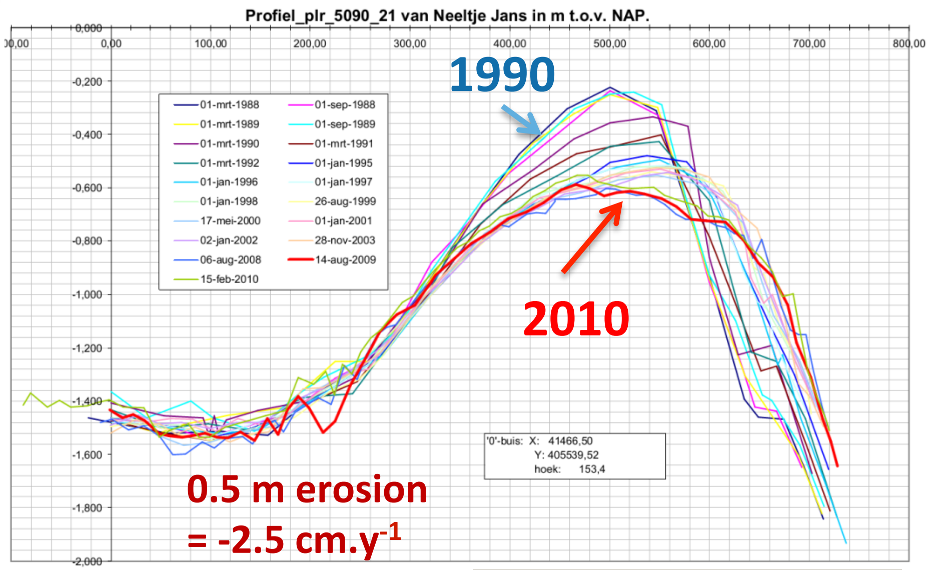
Sediment is eroded by waves (+ removal by tidal and wind-driven flow



Current issue: sediment starvation

- **0.5 - 1.5** Mm^3 annual loss due to erosion of the flats
- **0.4 - 1.5** Mm^3 annual loss due to sea level rise (20-85 cm / century)

Total: 1 – 3 Mm^3 annual loss = 50 Ha annually



Source: Rijkswaterstaat

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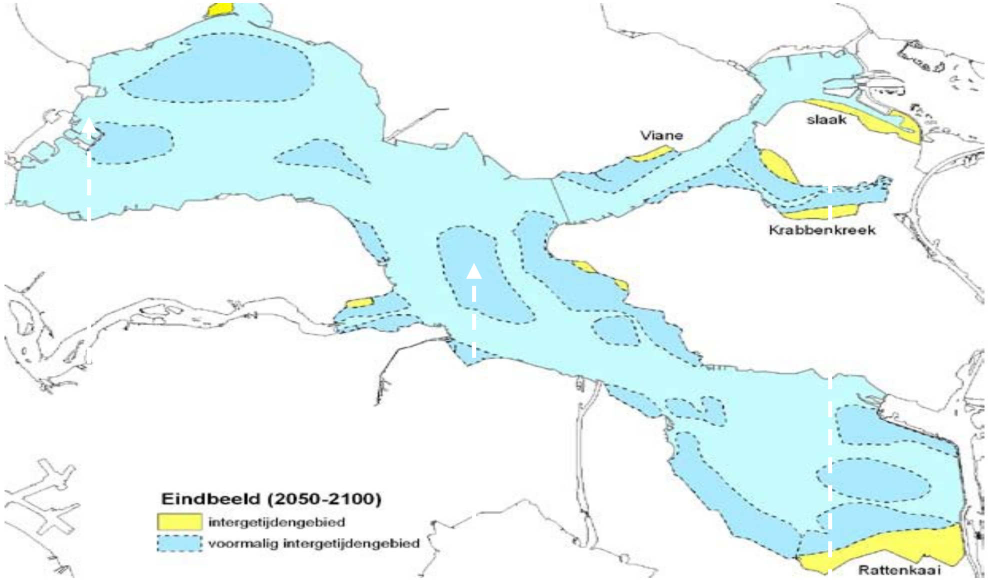
Future of the Oosterschelde

Consequences for nature and safety

- ‼ Issues of natural values: Oosterschelde is an important area for wading birds
- ‼ Issues of safety: less inter-tidal area, larger fetch, larger waves



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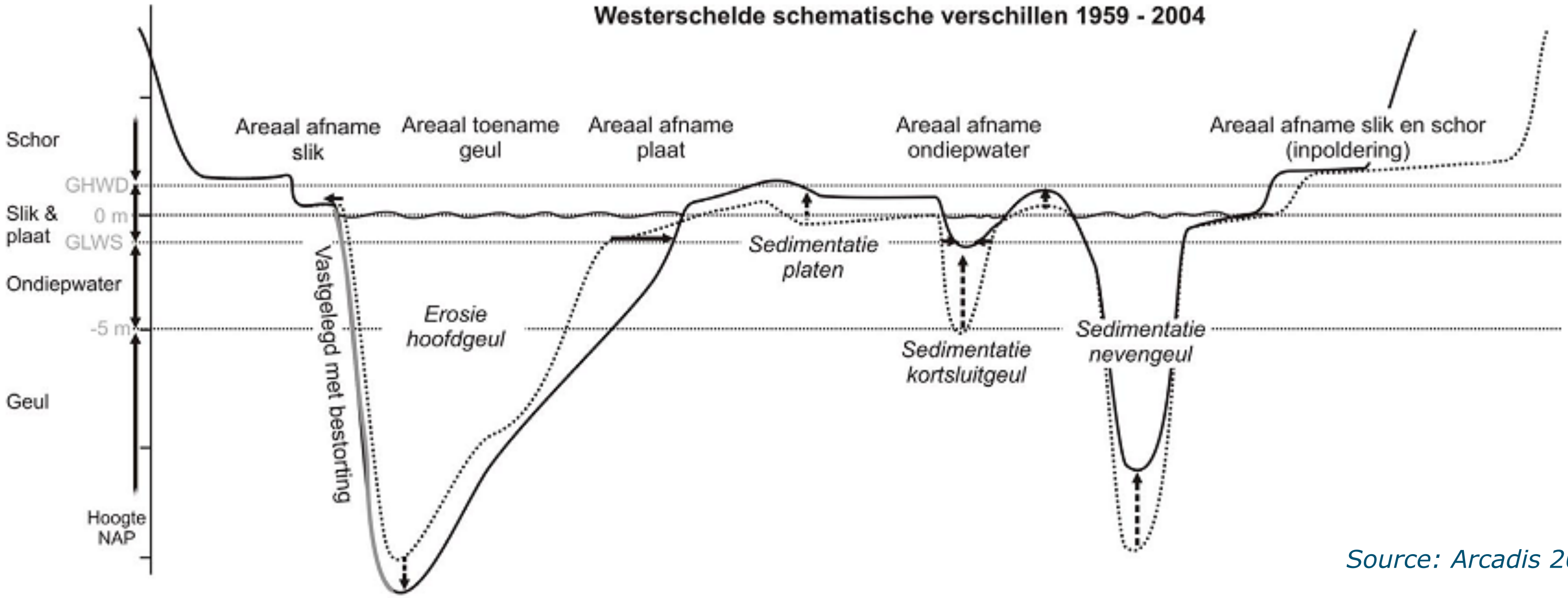
Westerschelde

- Deepening and widening of the navigation channel



Source: Arcadis 2007

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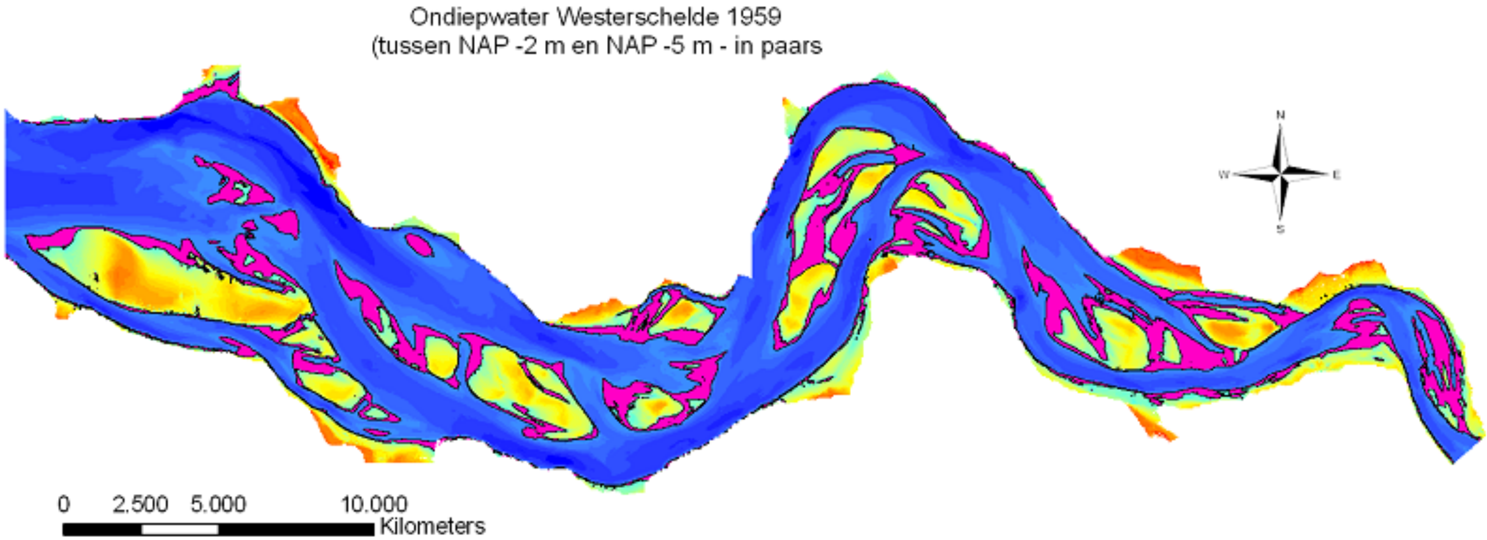
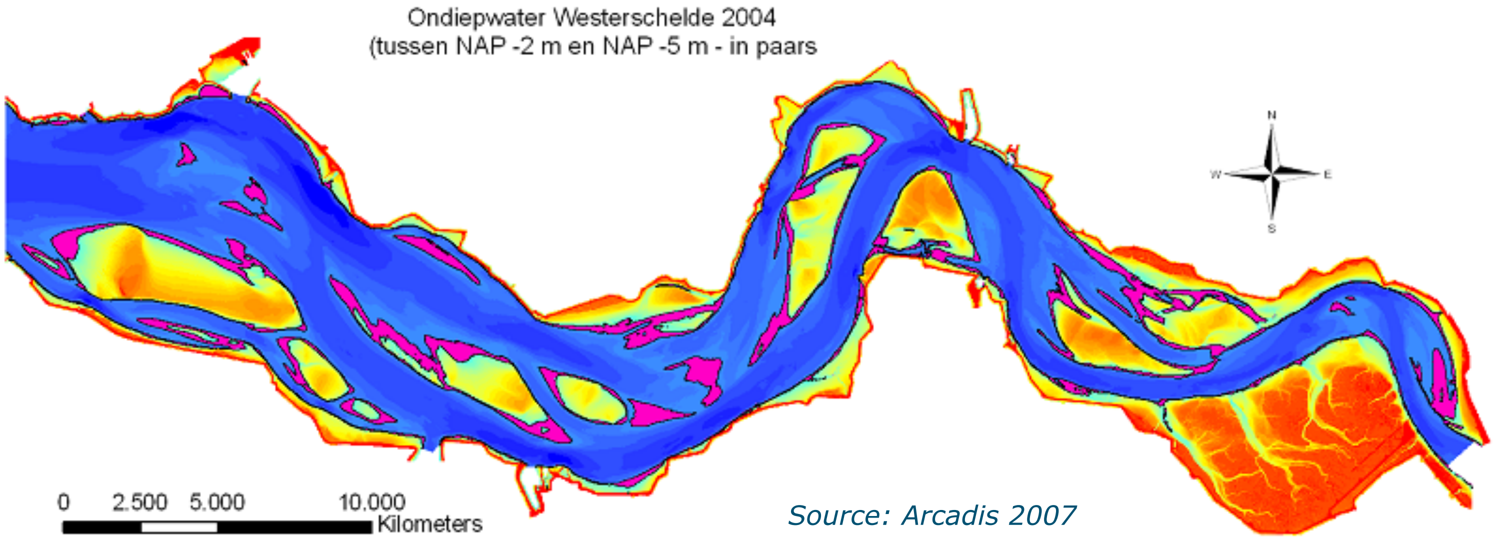
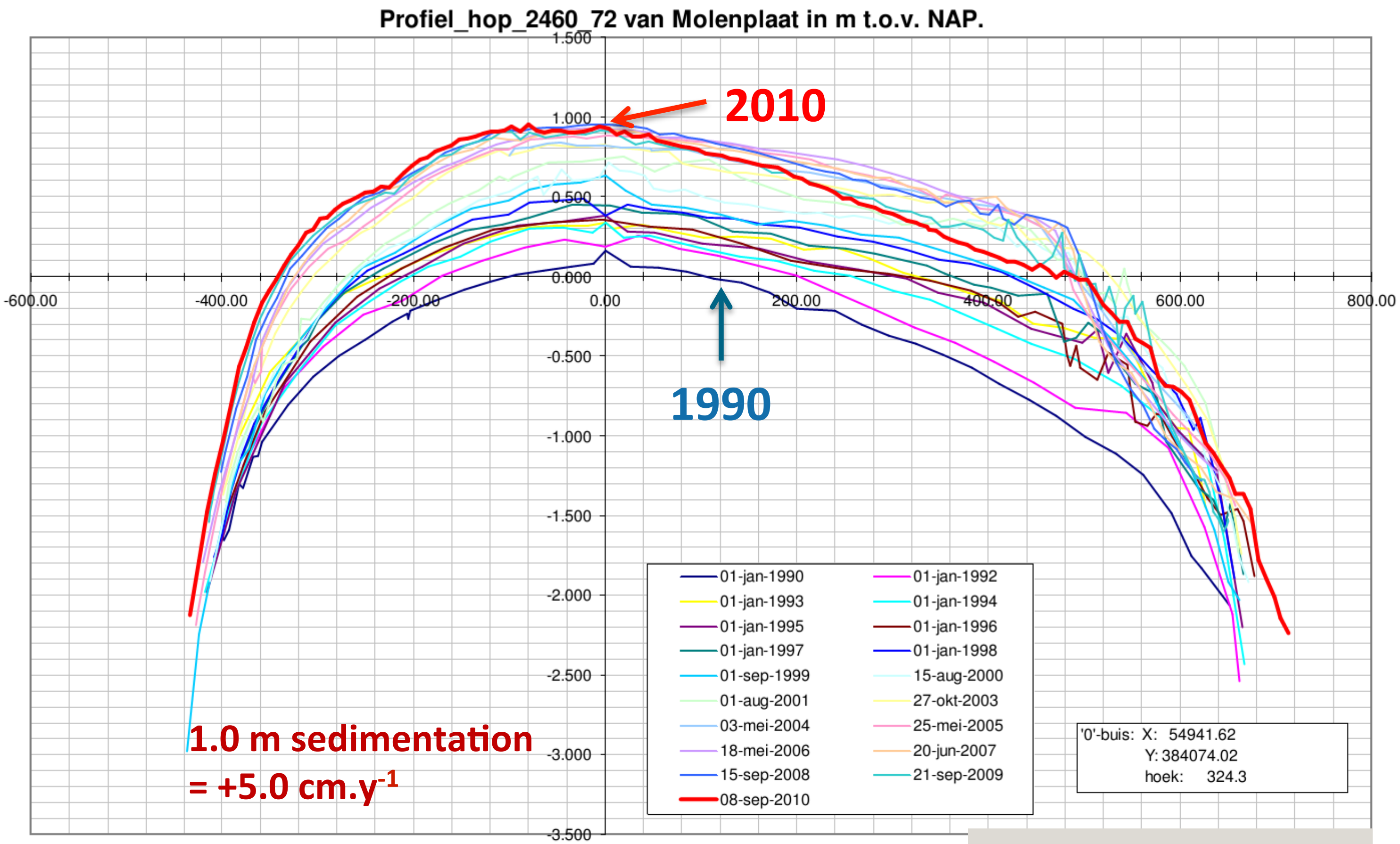
Westerschelde intertidal and shallow subtidal habitats





Source: Arcadis 2007

Westerschelde tidal flat profile



Source: Rijkswaterstaat

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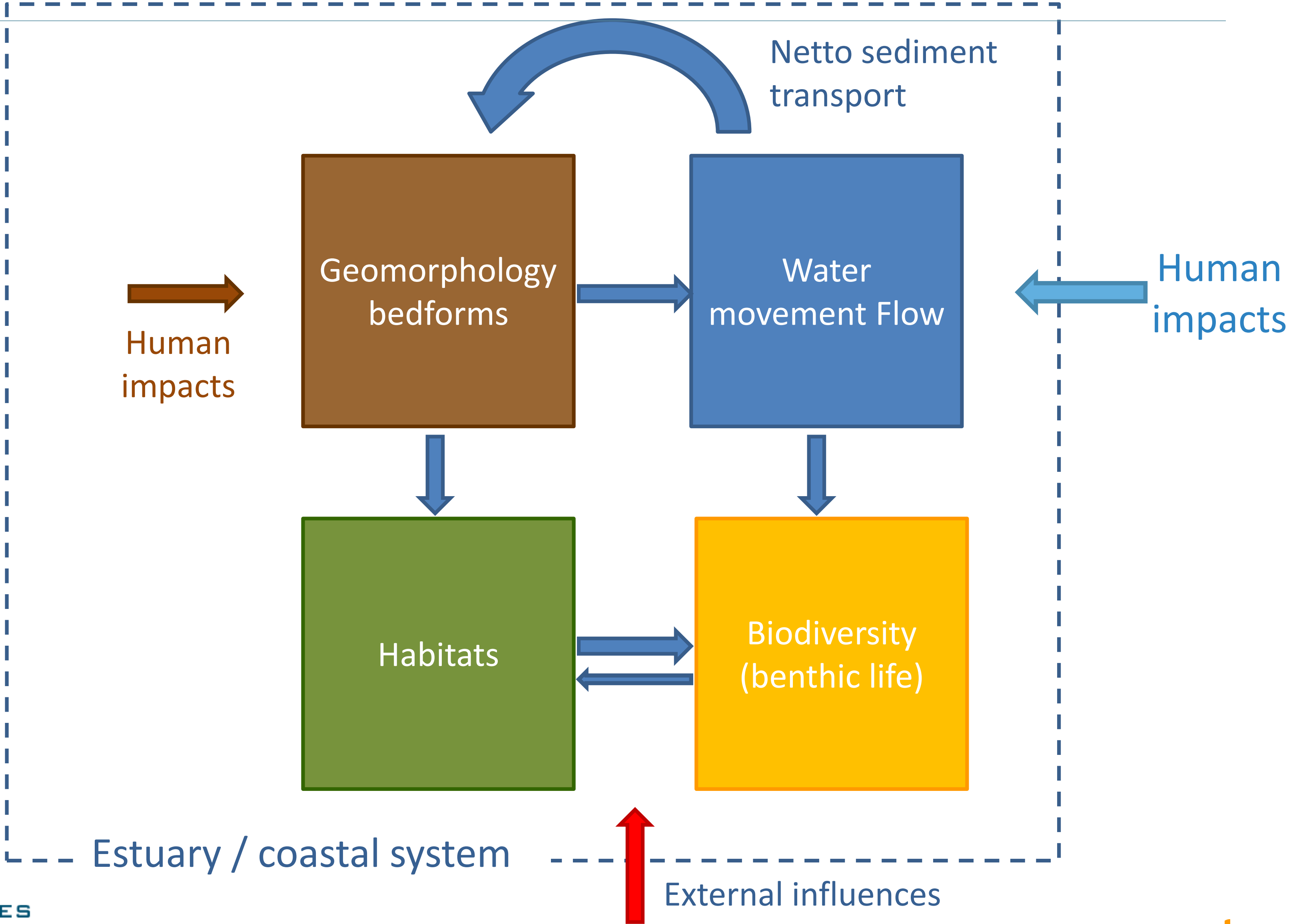
Estuarine management OS and WS

- The Oosterschelde and Westerschelde, two adjacent water systems, evolved differently over the past decades due to human interventions.
- The Oosterschelde was partly closed off by a storm surge barrier
- In the Westerschelde the main channel has been deepened.
- This is part of a much longer ongoing change due to human interventions.

Estuarine management OS and WS

- These changes evoked changes and feedback mechanisms between hydrodynamics and sediment dynamics, channel dynamics and tidal flat morphology.
- Tidal flat and salt marsh habitats clearly responded differently: intertidal habitats in OS eroded/flattened and in WS accreted/steepened.
- Also subtidal habitats changed, with increased hydrodynamics in WS and more calm conditions in OS.

Ecological consequences



Distribution of benthic macrofauna

Physical-chemical factors

- Silt content (< 63 mm)
- Sand content
- salinity
- hydrodynamics

Biological factors

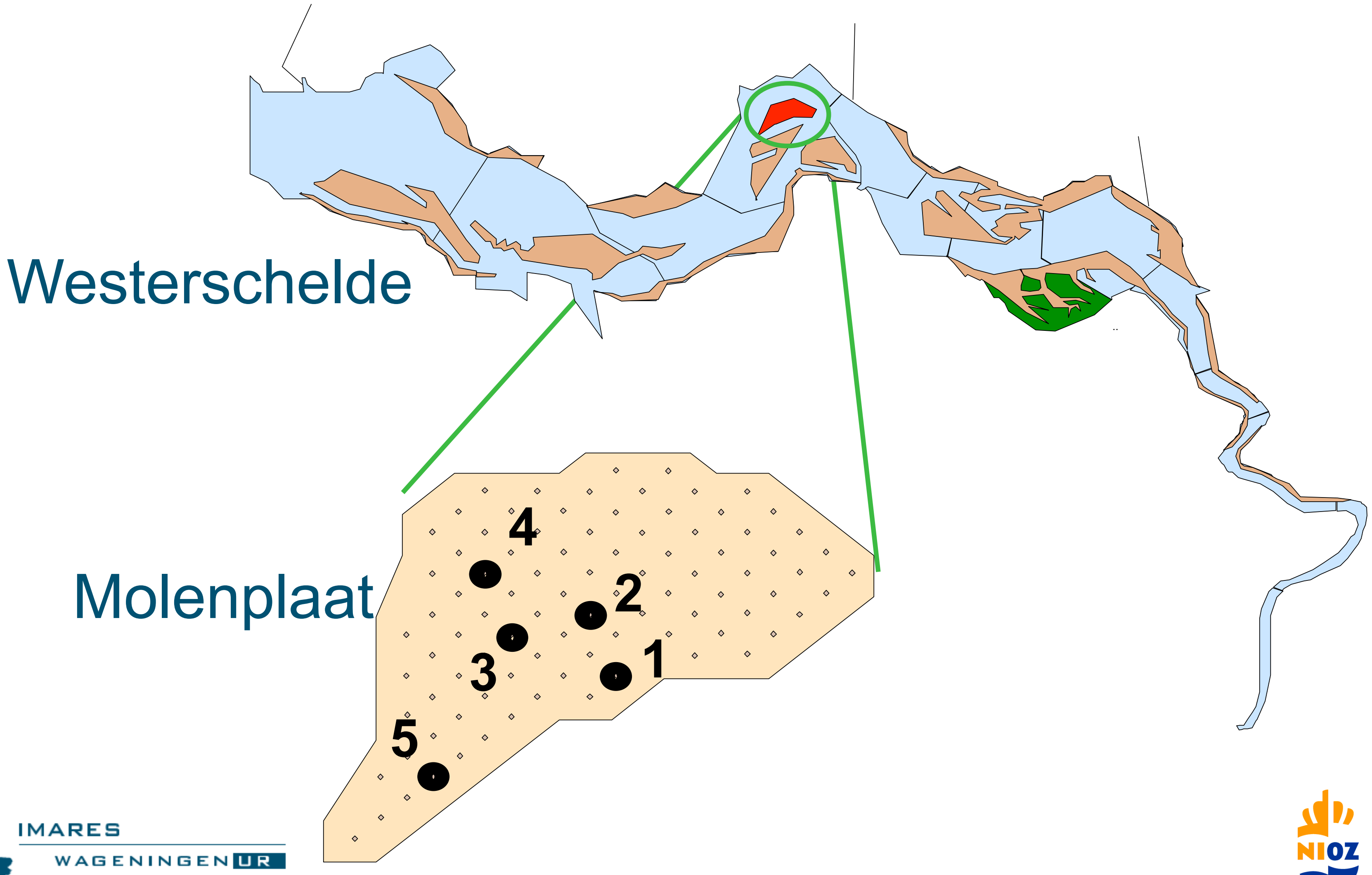
Top-down

predation → carrying capacity
- birds
- fishes

Bottom-up

food availability
(microphytobenthos,phytoplankton)
- stock
- production

Small scale patterns: physical stress and benthic macrofauna



Shear stress and benthic macrofauna

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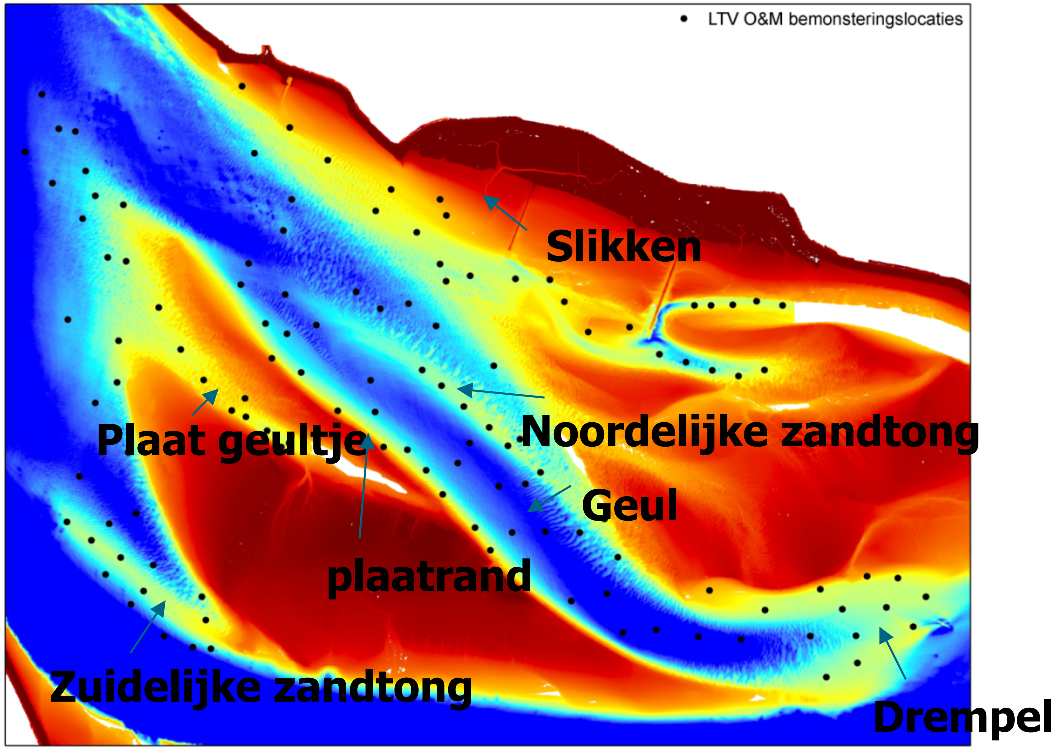
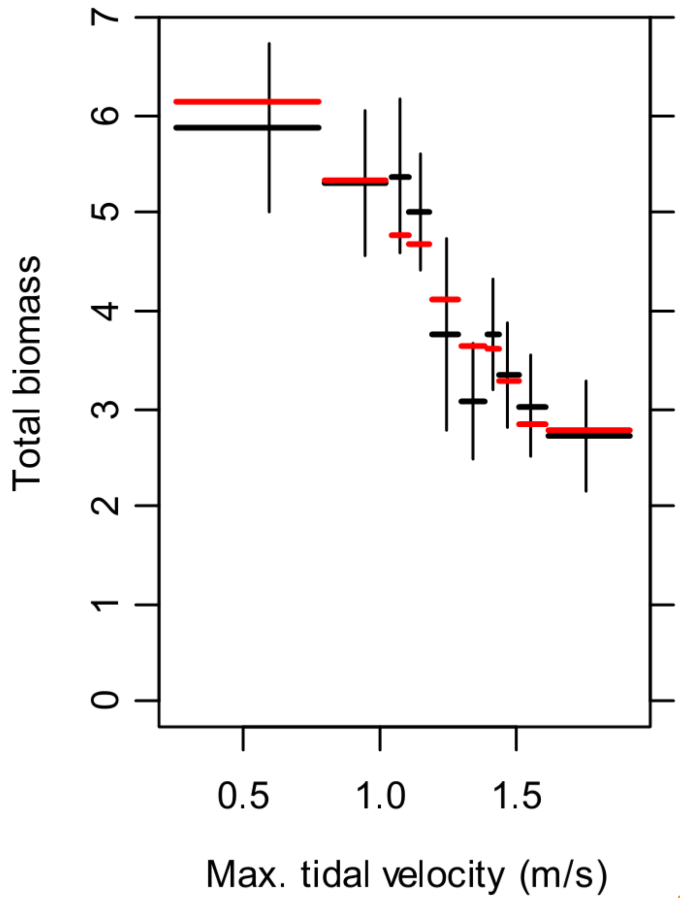
Source: Herman et al. 2001

Current velocity and benthic biomass





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Source: *Ysebaert et al. 2010*

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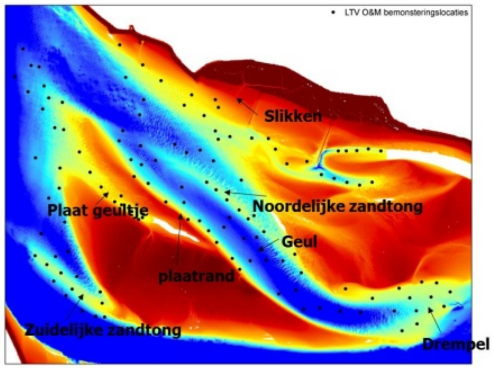
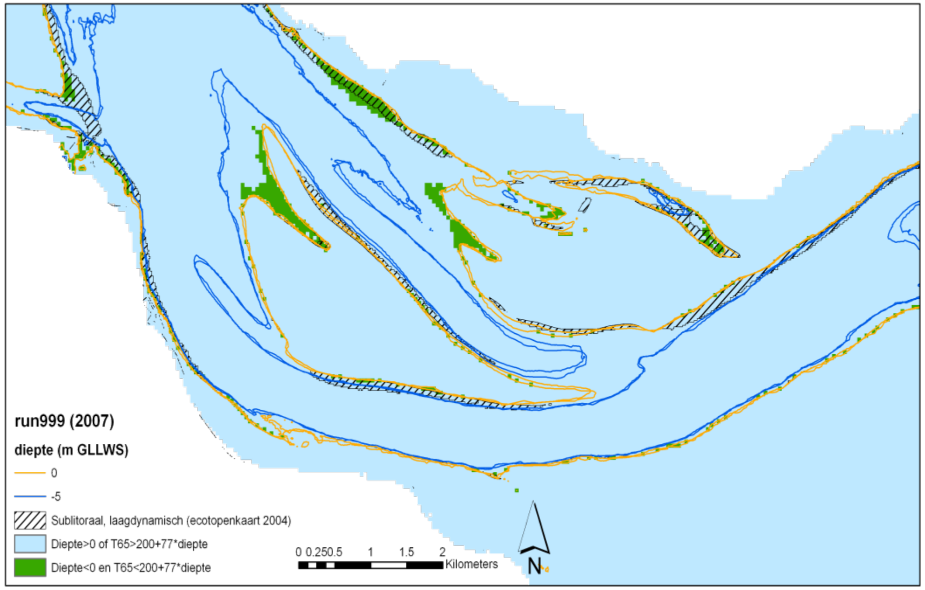
Ecological richness subtidal

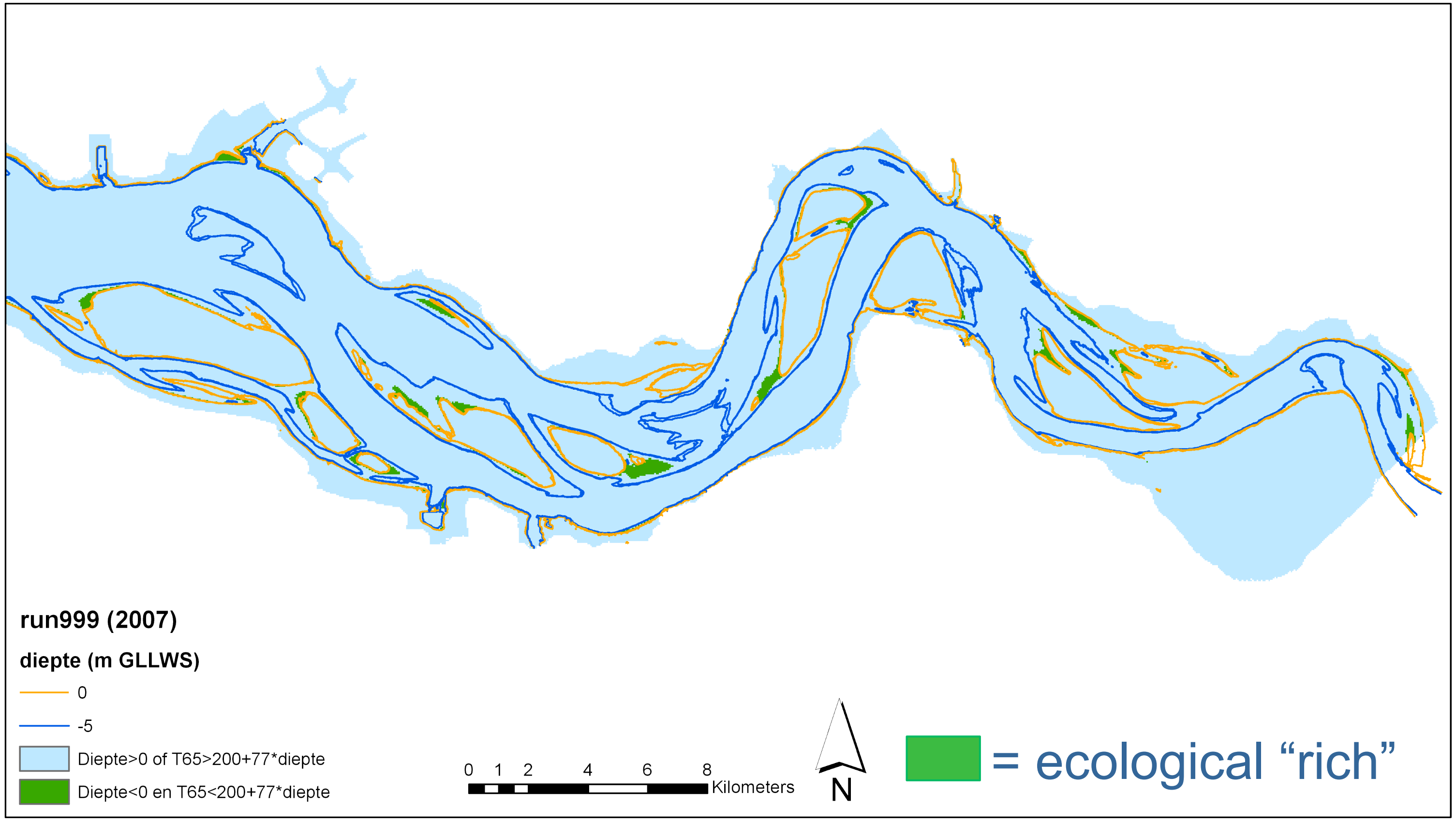
- Based on depth and current velocity distinction between ecologically “rich” and “poor”
- Current velocity = time a certain current speed is exceeded





Source: Ysebaert et al. 2010

Current state Westerschelde



Habitatmap “ecological subtidal richness” Westerschelde

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Source: Ysebaert et al. 2010

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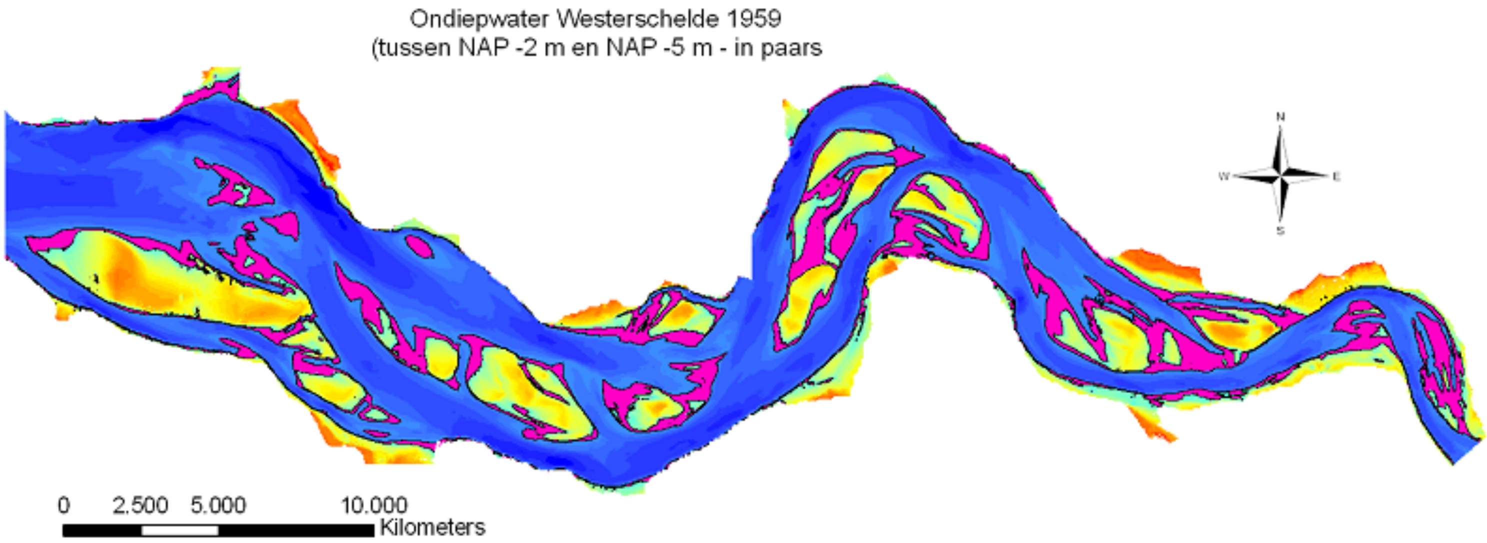
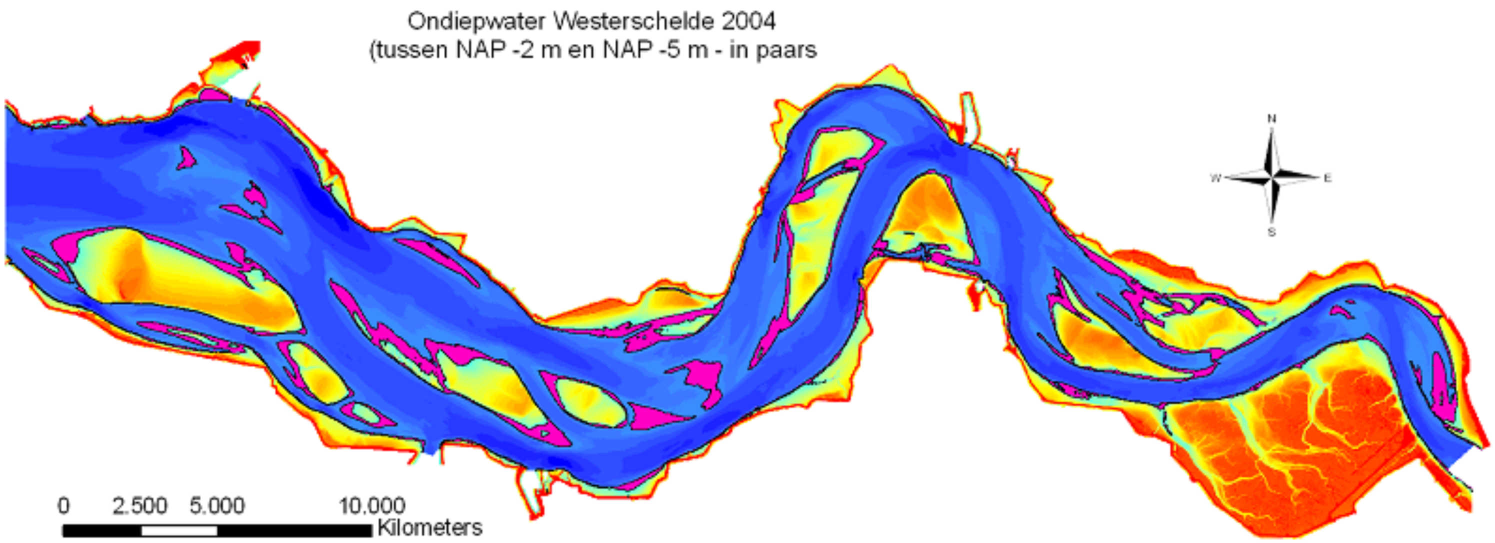
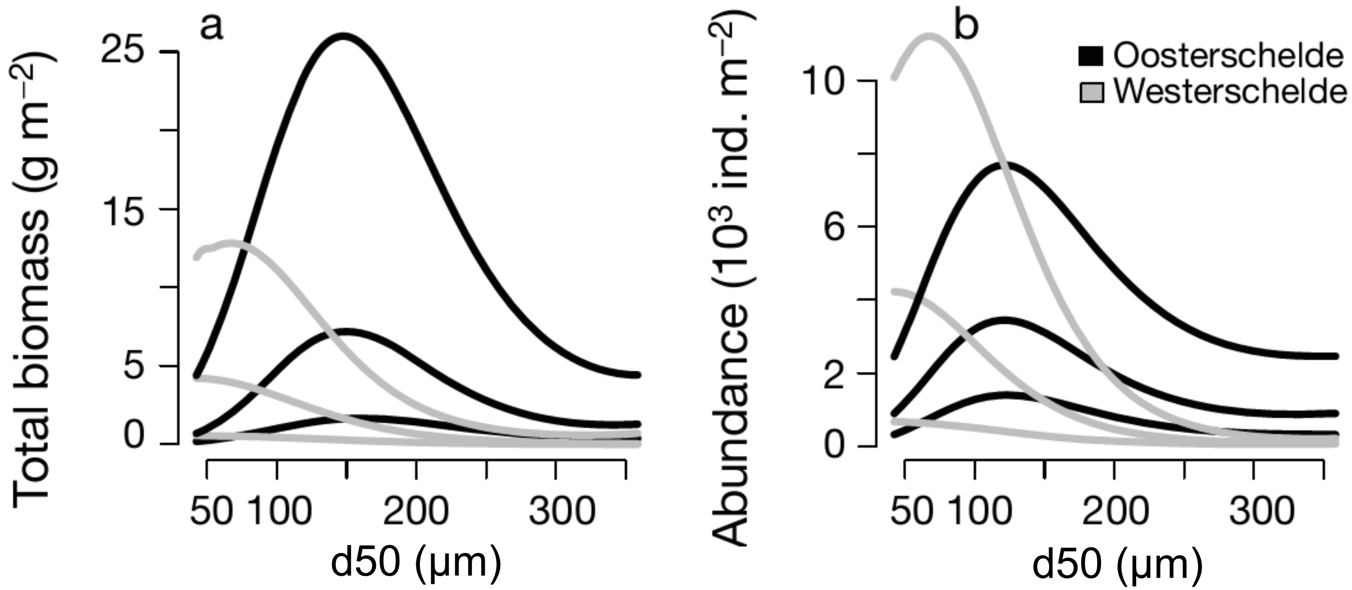
Shallow subtidal





Comparison Westerschelde and Oosterschelde



- mud-preferring species dominate the benthic assemblage in the Westerschelde, and sand-preferring species in the Oosterschelde.
- in the WS strong hydrodynamic stress is correlated with sandy habitats, causing impoverishment of assemblages at sandy sites. In the OS, sandy sediments are usually associated with much more benign conditions and have the richest species assemblage.

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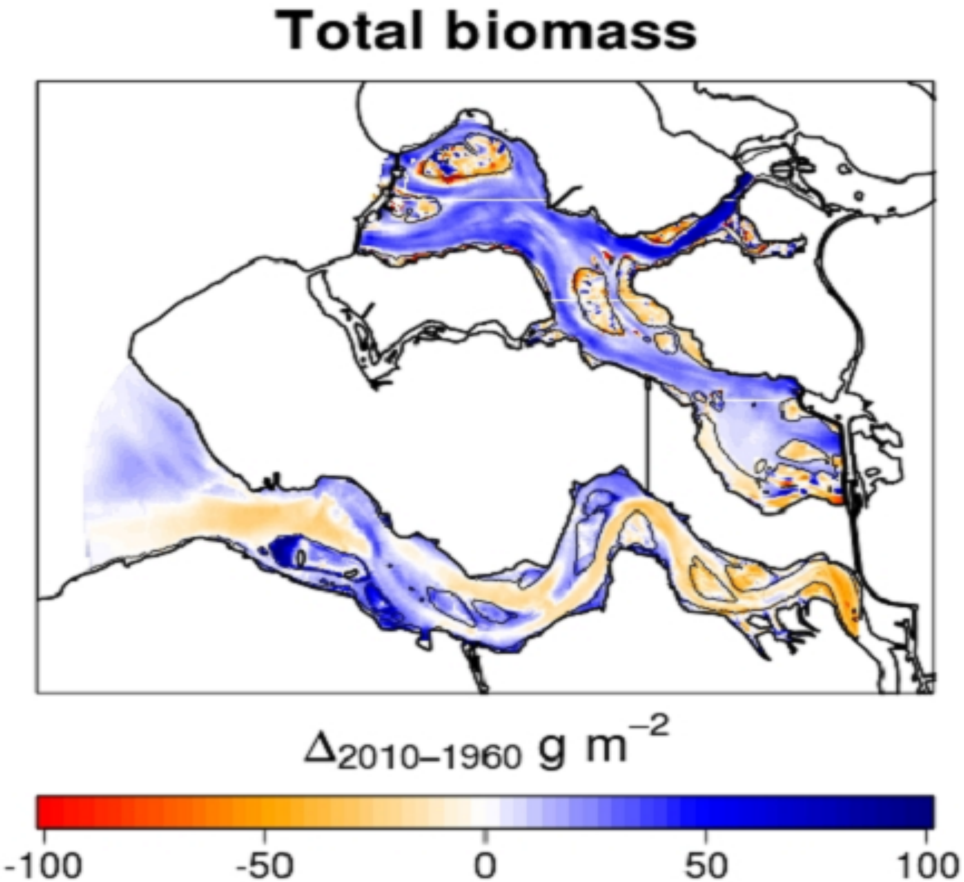
Cozzoli et al., MEPS 2013

Development Oosterschelde and Westerschelde



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Cozzoli et al., in prep.

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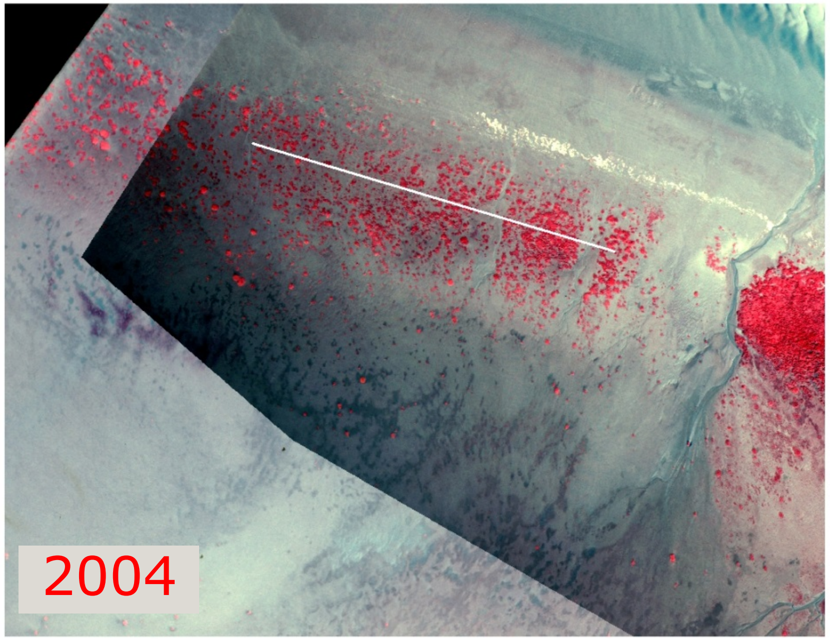
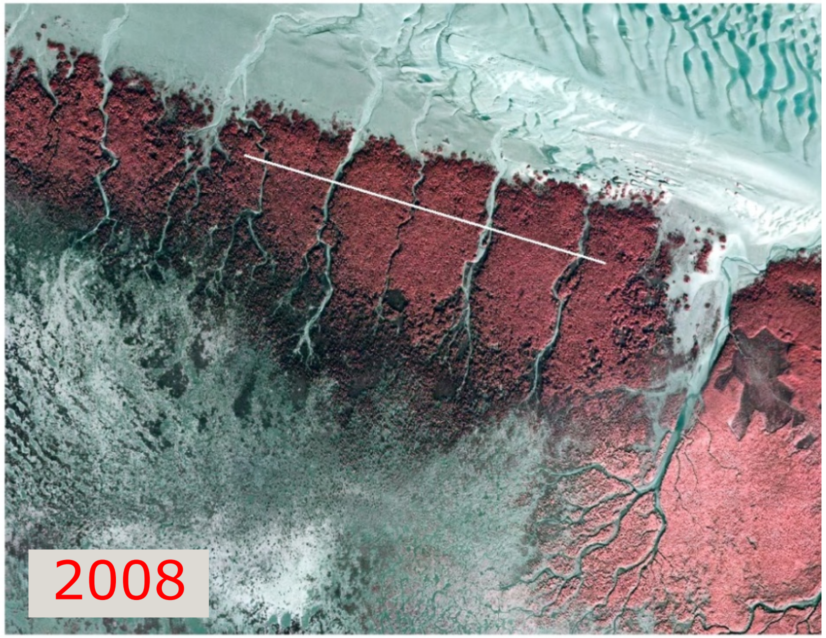
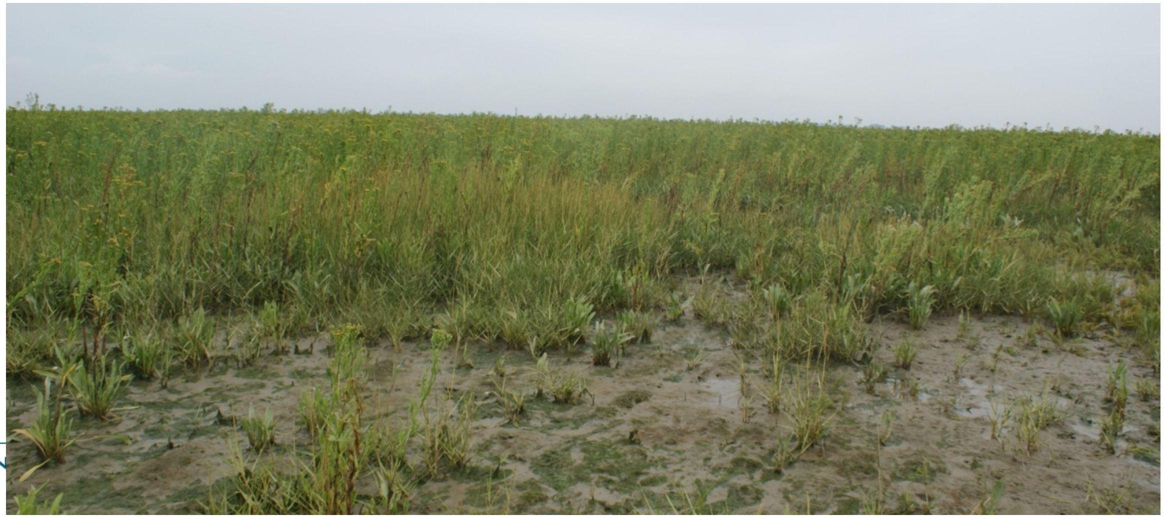
Salt marsh development Westerschelde







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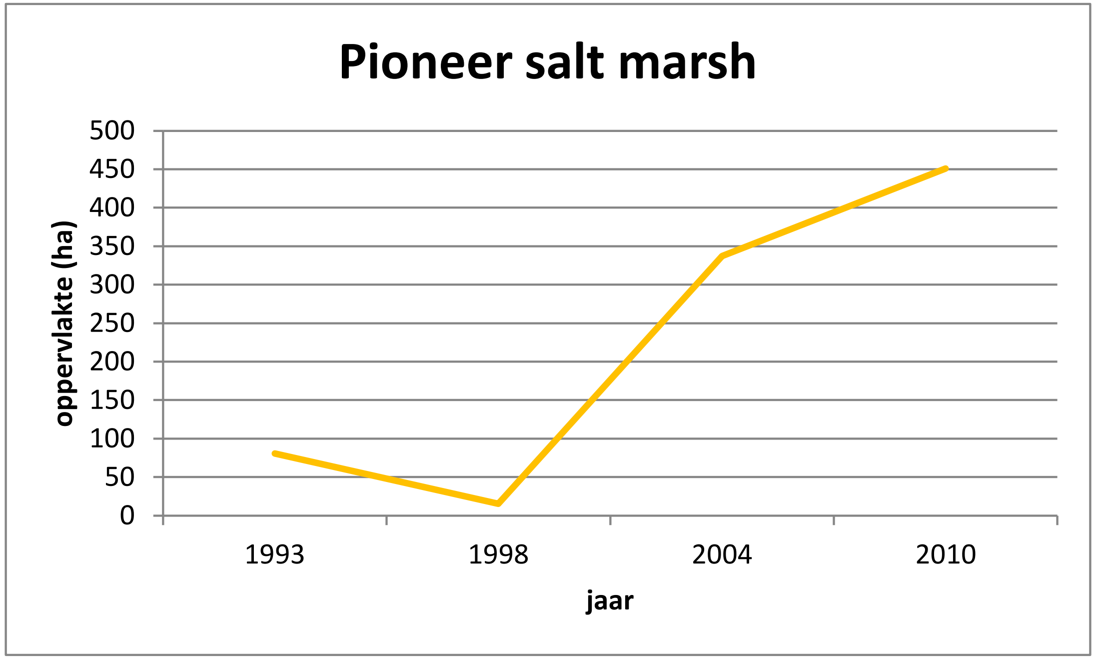
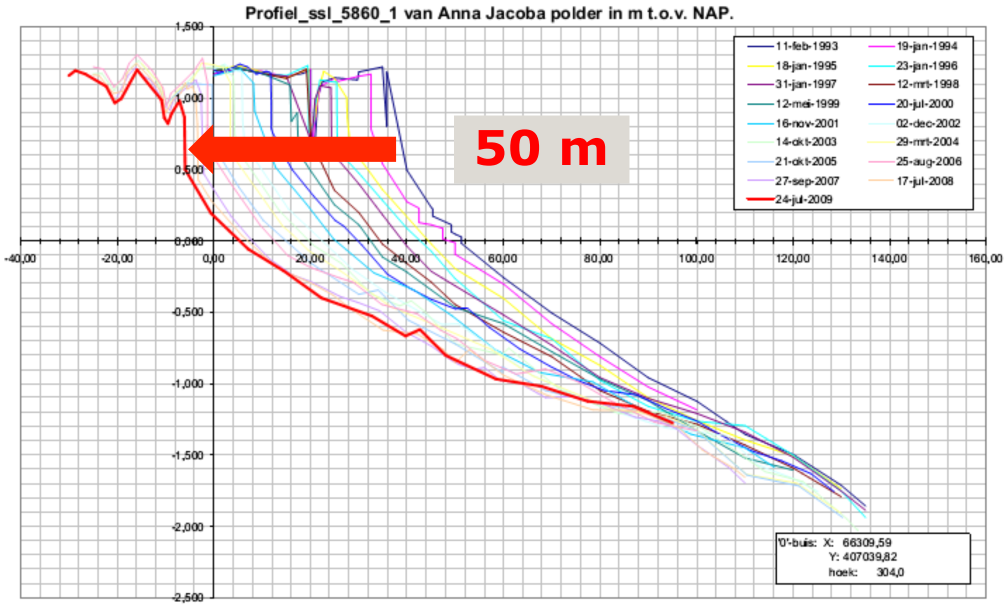
Salt marsh development Westerschelde



Ecosystem engineering effects of salt marsh plants on macrofauna are conditional.
Organic enrichment of the sediment and mechanical hindering of macrofaunal activity by plant roots are plausible mechanisms for the influence of salt marsh plants on macrofauna. (Van der wal et al., Estuaries and Coasts 2012)

Cliff erosion salt marshes Oosterschelde



Estuarine management OS and WS

- Human interventions in OS and WS evoked changes and feedback mechanisms between hydrodynamics, sediment dynamics, tidal flat morphology, and ecological processes.

- This has far going consequences for the animal and plant species inhabiting these habitats, with redistributions and changes in species community as a consequence.

Current measures

- Westerschelde: new disposal strategy for dredged material: relocate material along sandbars, safeguarding multi channel system, while creating ecologically valuable areas

Current measures

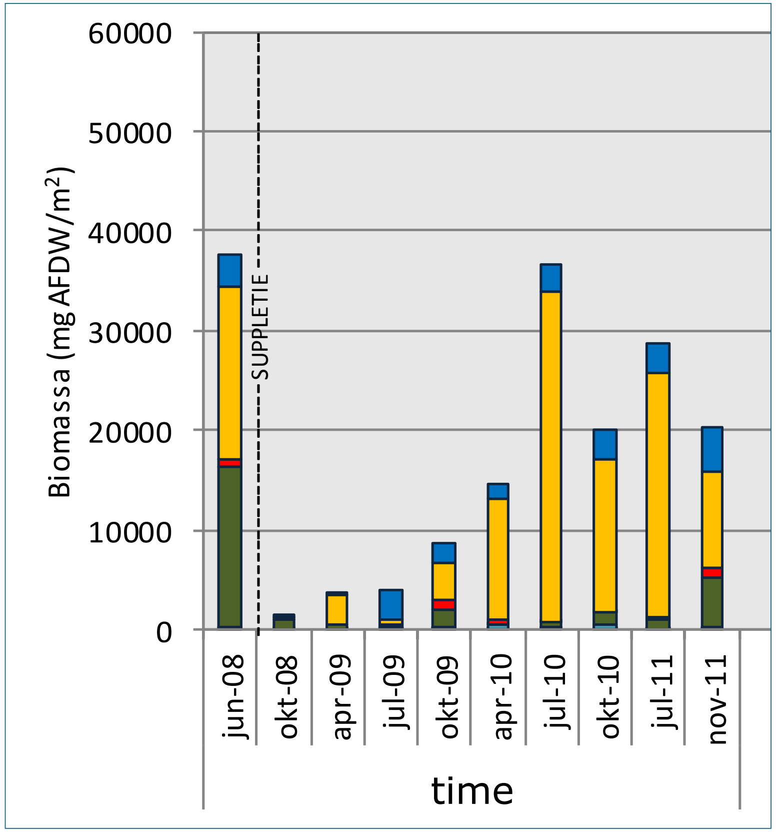
- Short / midterm solutions for erosion problem in the Oosterschelde:
    - Nourishments to replenish the tidal flats
    - Reef structures (e.g. ecosystem engineers) to stabilize tidal flats and create valuable habitats

Galgeplaat nourishment

- In order to (temporarily) stop the loss of intertidal area, a pilot nourishment was executed at the Galgenplaat, a tidal flat in the Oosterschelde.

Monitoring - ecology

- Recolonization: Recovery of total biomass of benthic macrofauna



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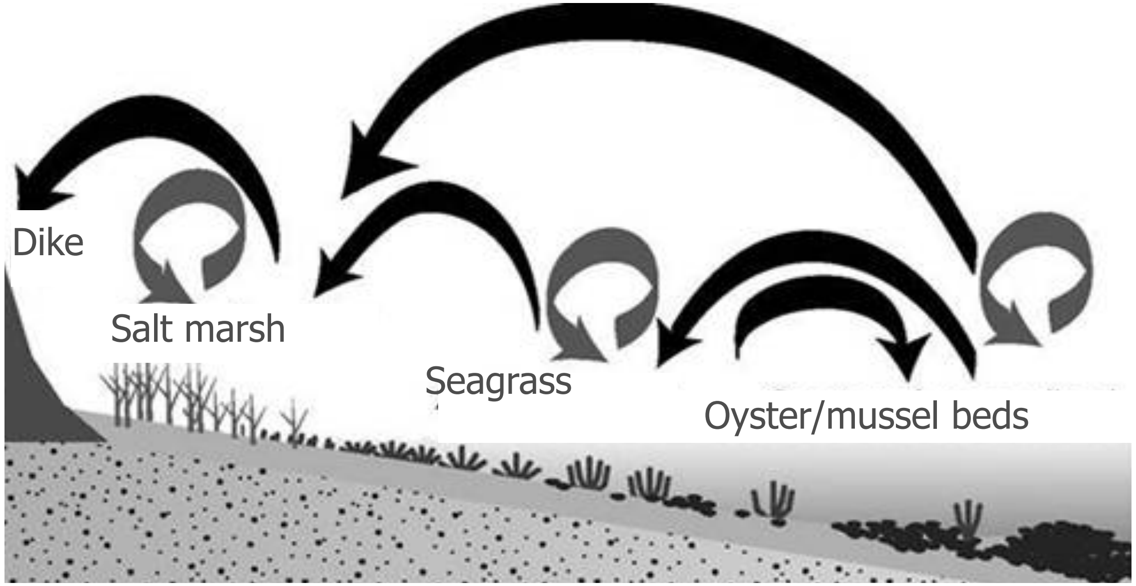
Coastal protection by ecosystem engineers

Ecosystem engineers such as reef building oysters can protect tidal flats from erosion, reduce wave energy, trap sediment, … and protect dikes (and deliver many other ecosystem services): Test in experimental study



Natural oyster reef in the Oosterschelde

Artificial oyster reefs

Small scale pilot 2009

(4x) 12 x 1 m

12 x 4 m

Large scale pilot 2010

200 x 10 m

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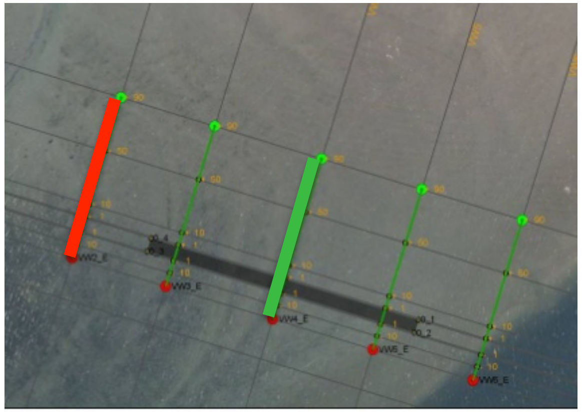
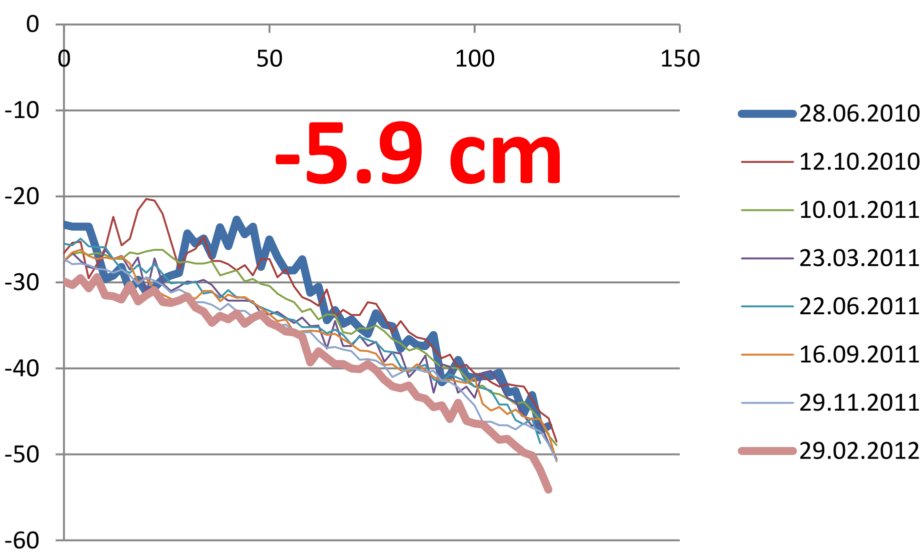
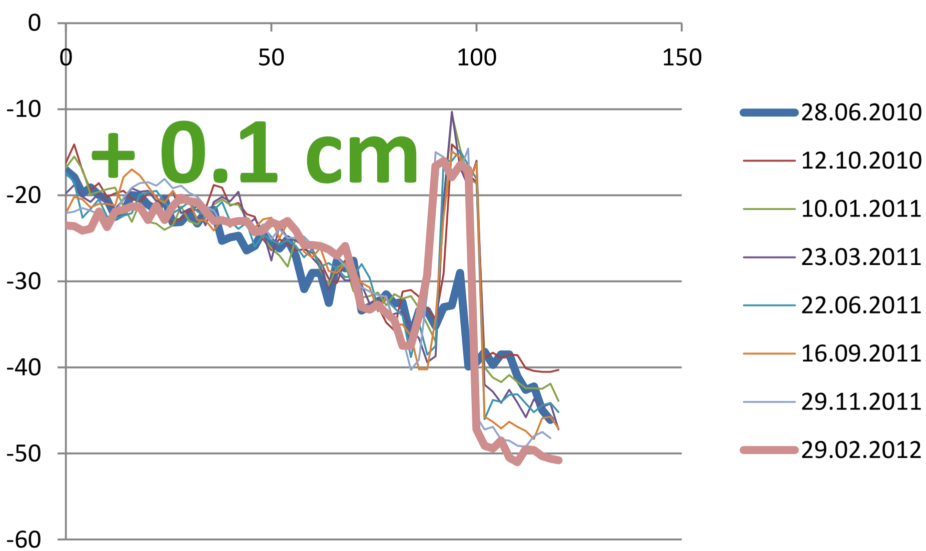
Sedimentation – erosion patterns



Reference transect



Reef transect



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Ysebaert et al., in prep.

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Development of artificial reef into living reef

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- Human interventions in OS and WS evoked changes and feedback mechanisms between hydrodynamics, sediment dynamics, tidal flat morphology, and ecological processes.
- This has far going consequences for the animal and plant species inhabiting these habitats, with redistributions and changes in species community as a consequence.
- The (habitat) problems that arise nowadays in the WS and OS call for new management strategies.
- Pressing need for better understanding of the eco-morphological development and ecosystem functioning of estuarine systems at different spatial and temporal scales.

Thank you

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