Restoring river catchments with special emphasis on the role of tidal marshes

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Take home message

- Present environmental legislation is not able to cope with major changes in estuaries
- A more integrated approach is necessary
- The concept of Ecosystem Services is a promising way
- We can identify services and calculate surface of habitat needed for delivering ES
The nature conservation Approach

- designation of sites
- management

RAMSAR convention
EU Bird directive
EU Habitat directive
... National regulations
Changing tidal characteristics

Van Braeckel et al. 2006
Continuing habitat loss

Slope ↑, current speed ↑ ➔ marsh erosion ↑
Continuing habitat degradation ➔ Increase high dynamic flats

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![Chart](chart.png)

% High dynamic
% Low dynamic

1920 1940 1960 1980 2000 2020

0 20 40 60 80

Courtesy Dick de Jong, RIKZ
Water quality management aims at reaching certain concentrations of different substances. Successful BUT... 

Soetaert et al., L&O 2006
Changing nutrient ratio’s

For plankton not concentration is important but nutrient ratio’s!

Soetaert et al., L&O 2006b
diatoms

Silica (mM)

distance from mouth (km)

time (year)

Antal sorte benthos

Zoet Brak Zout
Fresh
Brackish
Marine

Expected number of species
The system is the result of 1000 years of human activities

- Fundamental characteristics of the system are still changing as a combined consequence of anthropogenic and natural factors
- The system is not in equilibrium!
- This is leading to long term trends and complex interactions
- The present environmental legislation is not able to cope with this
- A more integrated approach is needed
The System

Dredging/ sand extraction
Embankments
Infrastructure (breakwaters etc.)

Sea level rise
Changes in the catchment

Pollution
Disturbance

Habitats

Ecological functioning

Hydrodynamics

Geomorphology
Can the WFD provide the answer?

- probably not because:
  - It looks mainly at the structure rather than the function of an ecosystem
  - Not a system approach
  - It is a very static and not a dynamic description of a system we now is permanently changing
  - .......
  - So what else???
for different habitats

Tidal marshes as an example

habitat function
water storage
source or sink for nutrients, SS,
protection against erosion for
dikes
reducing tidal energy
Role of marshes

Exchange between marsh and pelagic

150 – 300 ton BSi

100 – 200 ton Si

Struyf et al. 2005
Marshes import biogenic Si, and export dissolved Si

BSi is imported along with suspended matter

Relative DSi export is highest, when DSi concentrations in inundation water are low

Struyf et al. 2005
Does marsh Si recycling matter?

- In summer months, 43% of Si load in the estuary is recycled through the marshes.
- In summer months, marshes are essential DSi suppliers to estuarine ecosystem.
Methodology

- For the estuary, a detailed analysis was made of the different goods & services
  - Which ones are relevant
  - What is the present state

- Analysis of trends indicated major problems with:
  - Tidal characteristics
  - Water quality
  - Habitats and species

- MAJOR LOSS OF GOODS & SERVICES
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<th>Goods and services problems</th>
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Defining goals

Central concept: CARRYING CAPACITY

- For the system we can estimate and/or define a carrying capacity with regard to the different functions, or goods & services
Defining goals

How?

- Work out management strategy to increase ecosystem services and economic functions or increase the carrying capacity of the system starting from the philosophy that improving the delivery of goods and services is crucial to the socio economic development

- Formulate goals for different ecosystem services
Conservation Objectives (CO)

Final CO: \(\text{Max} (\text{surface } S_1, \ldots, S_n; F_1, \ldots, F_m)\)

⇒ Habitat quality
Defining goals

- Identify amount of ES which is wanted
- Work out surface of habitats needed for a certain amount of service
- Work out measures for habitat quality
  - Planning
  - Management
Conservation objectives

- Formulated as:
  - Required area
  - Required conditions concerning
    - Water quality
    - Water quantity
    - ..
  - Include clear spatial aspects
How far must protection go?
Conservation objectives
Birds and their food

Data Tom Ysebaert NIOO- CEMO

macrobenthos biomass * surface intertidal flats

number

0 10000 20000 30000 40000

0 20000 40000 60000
Carrying capacity for benthos

Pristine

Actual

N, P, C

A

i

B

i

j

B

j

N, P, C

A

j
Diversity

Dissolved oxygen

B_i \times A_i = (B_j + B_c) \times (A_j + A_c)

Mudflat area

History

Immission

History

Pi

Pj
Diversity

\[ B_i \times A_i = (B_j + B_c) \times (A_j + A_c) \]

Dissolved oxygen

Mudflat area

History

Immission

\( P_i \)

\( P_j \)
Area evolution

The graph illustrates the area evolution of Mudflat and Tidal marsh over time. The area decreases significantly from 1850 to 2004 for both categories, with the Mudflat area decreasing more steeply than the Tidal marsh area.
**Benthos and its food**

System primary production (gC.m$^{-2}$.y$^{-1}$)

System-averaged macrofauna biomass (g AFDW m$^{-2}$)

$$B = -1.5 + 0.105 \, P$$

$$r^2 = 0.77$$

Source: P. Herman NIOO-CEMO
Diversity

Dissolved oxygen

Mudflat area

Immission

History

\[ B_i \times A_i = (B_j + B_c) \times (A_j + A_c) \]
Phytoplankton and organic load

Herman et al., CEMO
Diversity

Dissolved oxygen

History

Mudflat area

\[ B_i \times A_i = (B_j + B_c) \times (A_j + A_c) \]
Reconstruction historical emission from the catchment

Billen & Garnier, University of Paris
particulate biodegr orgC flux, ktonC/yr

detritic orgC

algal C


Billen & Garnier, Univ. de Paris
Nitrogen flux, ktonN/yr

total N

Billen & Garnier, Univ. de Paris
Phosphorus flux, ktonP/yr

total P

o-Phosphate

Pristine


Billen & Garnier, Univ. de Paris
Diversity

Dissolved oxygen

Mudflat area

Immission

History

\[ \text{Diversity} \]

\[ \text{Dissolved oxygen} \]

\[ \text{Mudflat area} \]

\[ \text{Immission} \]

\[ \text{History} \]

\[ B_i \times A_i = (B_j + B_c) \times (A_j + A_c) \]
Eurytemora affinis

A $O_2$
Response fish on $O_2$

![Graph showing the relationship between dissolved oxygen concentration and catch probability for different fish species. The graph is labeled with species names: bittervoorn, bot, dunlipharder, fint, snoekbaars, spiering. The x-axis represents dissolved oxygen concentration (mg L$^{-1}$) and the y-axis represents catch probability. There are separate lines for summer and winter conditions.](image)
Reconstruction estuarine quality

Dissolved $O^2$ ($\mu M$)

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

1950 (modelled)
2001 (data)
Conservation goal

Gent  Vlissingen
Distance (km)

Modelling OMES: T. Cox
particulate biodegr orgC flux, ktonC/yr

detritic orgC

egal C

pristine

Billen & Garnier, Univ. de Paris
Up again from plankton to benthos
Carrying capacity: all elements

- **Calculation formula:**
  
  \[ B_i \times A_i = B_j \times (A_j + S_j) \]

- \( B = \) system averaged benthos biomass (in g AFDW.m\(^{-2}\))
- \( A = \) natural area surface (in ha)
- \( S = \) required area
- \( i = \) scenario \( i \)
- \( j = \) scenario \( j \)

- **For the Belgian part of the Scheldt this results in a required extra area of 500 ha of mudflats, suitable for benthos and birds.**
Light climate phytoplankton

Z_m Mixing depth

Z_p Photic depth

Survival chance \sim \frac{Z_p}{Z_m}
Depth $Z_m$: deepening

![Depth $Z_m$](image-url)

- Depth (dm GLLWS)
- Year
- Borssele, Hansweert, Bath, Zandvliet
Evolution of the tide

Tavernier, E., 1998
Photic depth $Z_p$: turbidity

Photic depth $Z_p$ 
~ suspended matter
Estuaries: Sediment trap

P. Herman, NIOO-CEME
Asymmetry of tidal curve

Diagram showing the relationship between distance from the river mouth and the duration of rising tide.
Import from the catchment: erosion

Erosion factor:
- Forest: 0.001
- Meadow: 0.01
- Field: 0.37

Sediment input in the estuary is totally anthropogenic.
Linking tidal range history with the relation between tidal range, tidal length and SPM

1 meter less mean spring tidal range would give for an estuary of 160 km long an SPM concentration of about ten times less.

Van der Spek et al., 1997

Log 10 of mean spring tidal range
Uncles et al., 2002
Planalternatief B

overschede
swaalsluizen
aanleg knippen
ophopen geulen
schuurverparding
uitpoldering
verdiepen geulen
gou
hoogdynamisch
laagdynamisch
onderp
schorren

Ministerie van Verkeer en Waterstaat
Directie Waternetwerk - Regionaal Waterstaatbureau
Regionaal Water en Rijkswaterstaat
Kruislaan 2, 3020 Leuven, Belgium
Concept FCA - CRT

safety, ecology and a new ecosystem

Safety:
- Lowered dike stretch
- Critical tides: whole storage capacity
- Only few times/year!

‘New’ ecosystem: Lippensluizen since March 2006!
- Area below high water level
- Separate in- and outlets sluices at different levels
- First CRT in the world near-spring tide.

Ring Dike  Lowered FCA dike
Gradient in inundation characteristics

- Schelde estuary
- Lippenbroek

Timeline:
- 01 apr
- 15 apr
- 30 apr
- 15 mei
- 30 mei
Conclusions

- Past management and expected changes have a very negative impact on the delivery of ecosystem services by the estuary.
- This results in growing socio-economic problems.
- The piecemeal application of present environmental legislation is not sufficient to change the negative trends.
- A holistic approach is needed where the system characteristics are changed in such a way that negative developments are stopped or at least slowed down.
Conclusions

- Conservation objectives translate the aim to reduce negative developments in surfaces of different habitats necessary, including, geomorphological, hydrodynamic, ecological and quality aspects.

- Formulation of CO’s in this way gives the possibility to sustain the estuary in a healthy state to reduce management costs and increase benefits from ES.
Conclusions

- This can be incorporated in a river basin management plan after confrontation with other sectorial needs.
- It requires a major investment in research to better understand the system functioning and the interactions between the different compartments.
- We will need to develop integrated models and monitoring.
- Pilot projects are crucial to increase our insight into the system.
- New methods are needed to bring together all the different stakeholders and work over all the disciplines.
Concept of Dalrymple

ENERGY DISTRIBUTION IN THE SCHELDE ESTUARY

Vlissingen

Antwerp

(Wartel & Chen, 2002)
Energy Distributions in the Scheldt Estuary

- wave-energy
- tide-energy
- river-energy
- total-energy

Distance to the River Mouth (km)

Energy Flux (J/m²)

Dominance of tide or discharge determines plankton community species dominance

Stephanodiscus

Cyclotella