Functions and behaviour of mud in estuarine and coastal ecosystems

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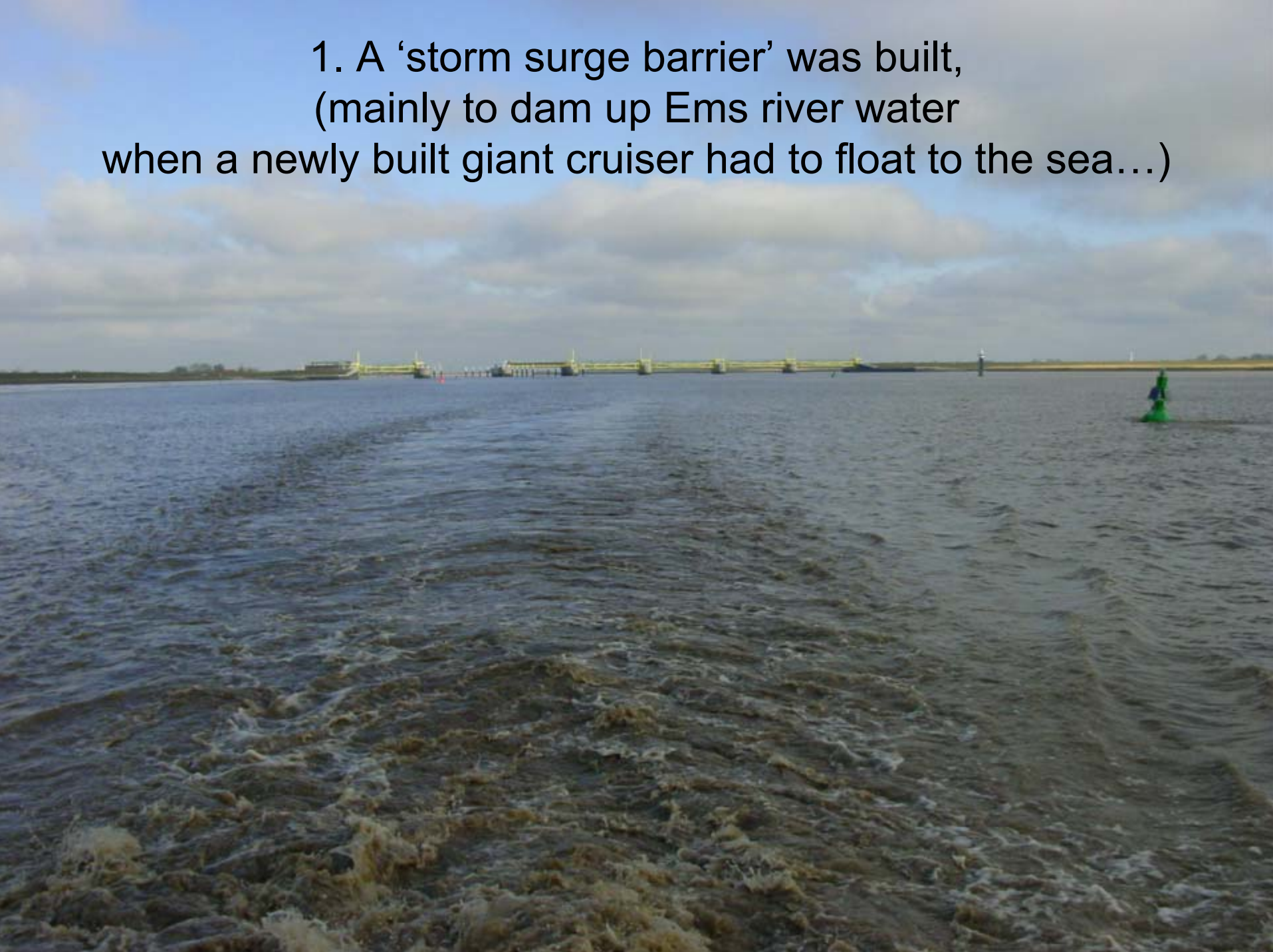
to keep 1 warf at place ….

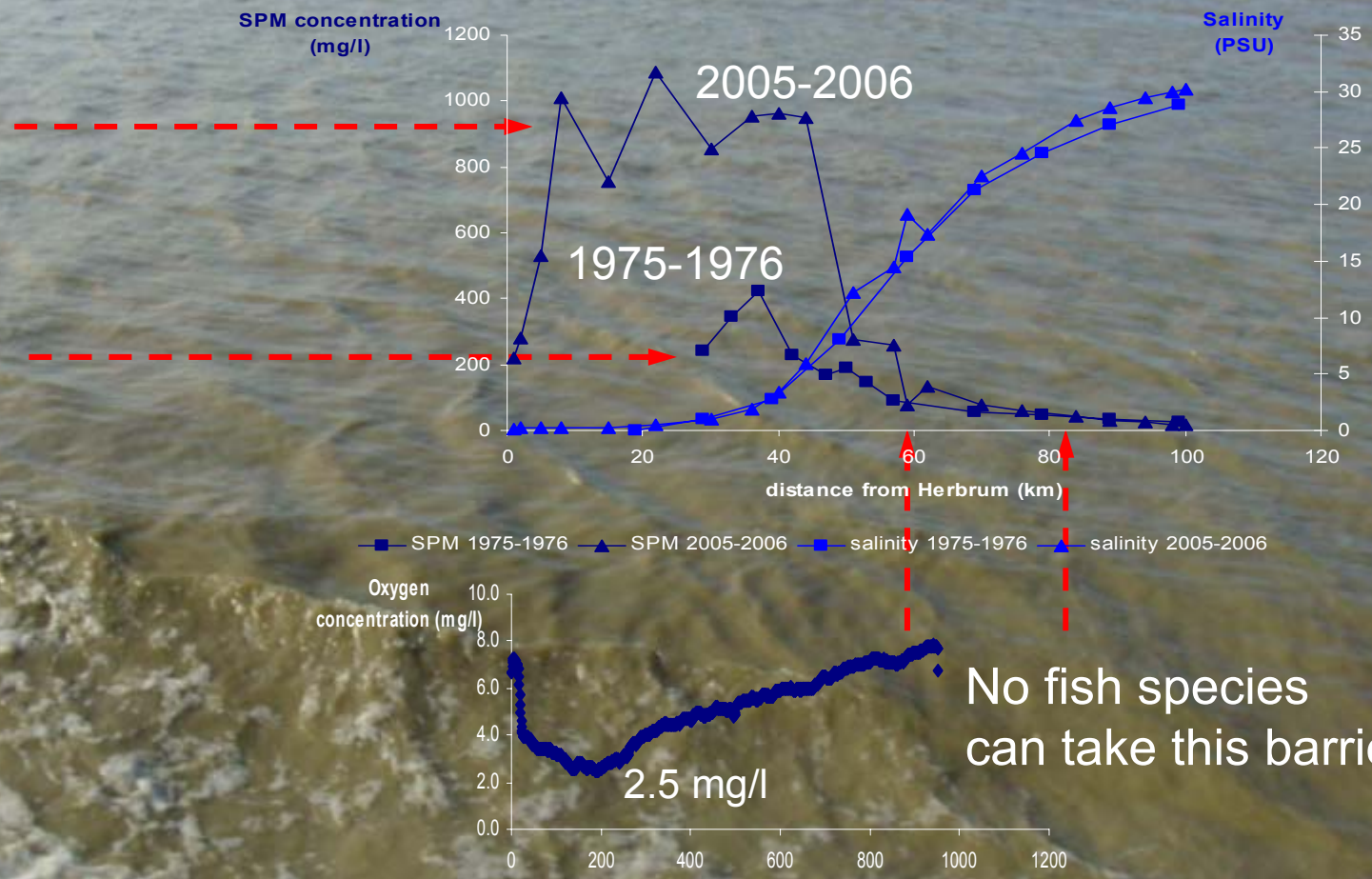

1. A ‘storm surge barrier’ was built,
(mainly to dam up Ems river water
when a newly built giant cruiser had to float to the sea…)

2. river deepening and canalisation was executed
&
3. river dredging takes place continuously

Resulting in

3. a tremendous change in the river and estuarine light climate

….



Thanks to N-Ports Emden, (Rewert Wurpts) for help in sampling!

River Ems: ‘Yellow river’

Power failure hits Europe

Danna Avsec
Created: 11/5/2006 2:20:56
PMUpdated:11/5/2006 2:21:34 PM

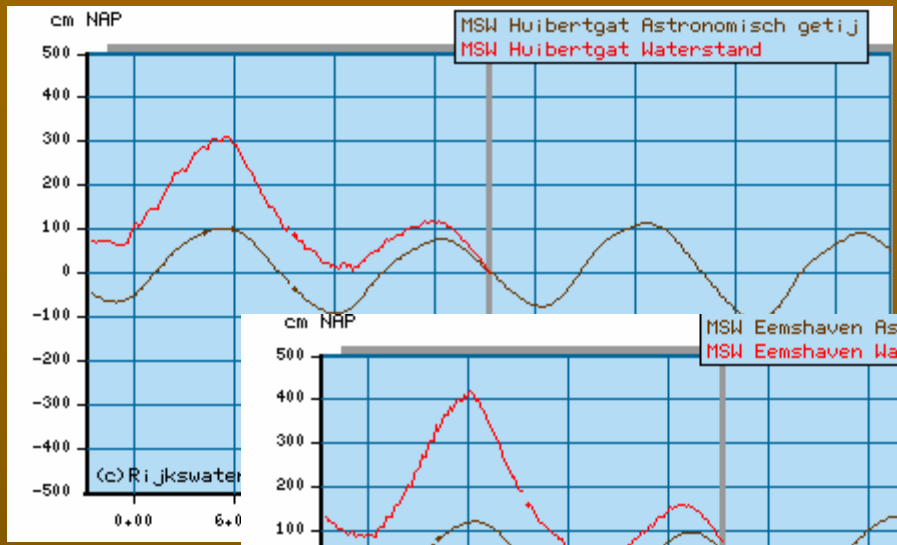
4. About half of W Europe without power for 1 hour because this high voltage power cable over the river Ems was shut down

BERLIN (AP)
-- A German electric company says it may know the cause of yesterday's chain-reaction blackout that hit parts of Europe.

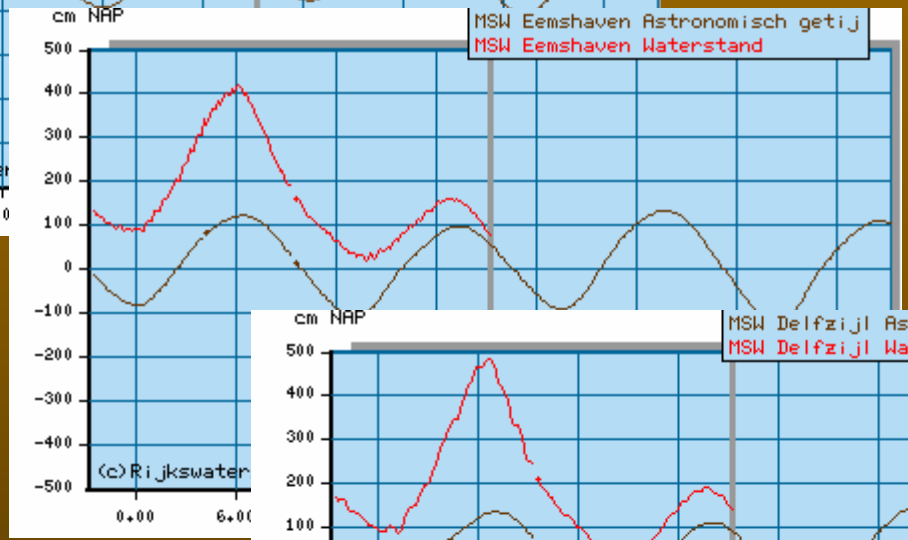
The company says systems may have become overloaded after a high-voltage transmission line was shut down over a river to let a ship pass.

'The river' was the river Ems and 'a ship' was a giant cruiser 'Norwegian Pearl'

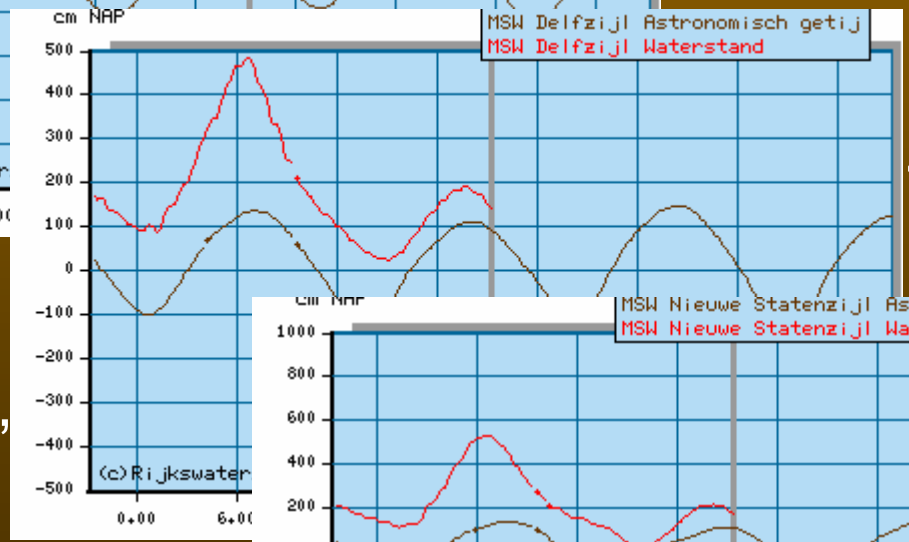
[01-11-2006]



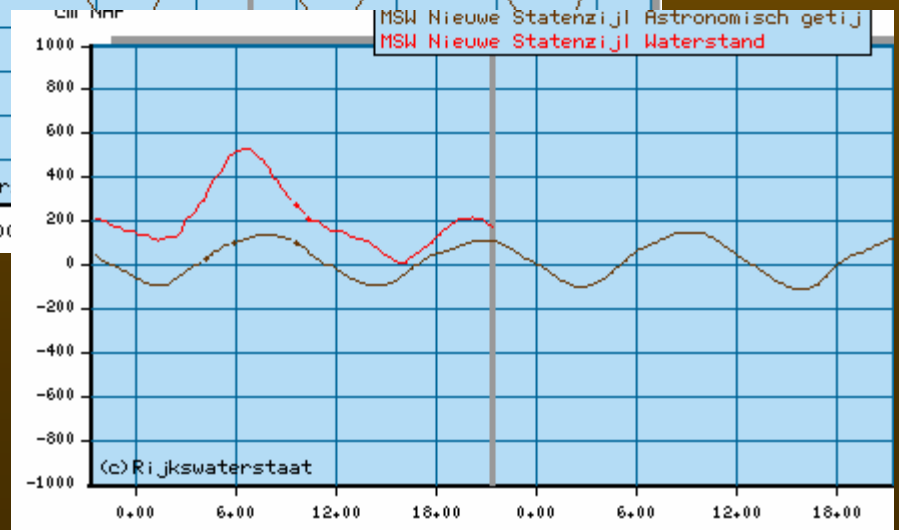
305 cm (+ 2m)



410 cm (+ 3m)



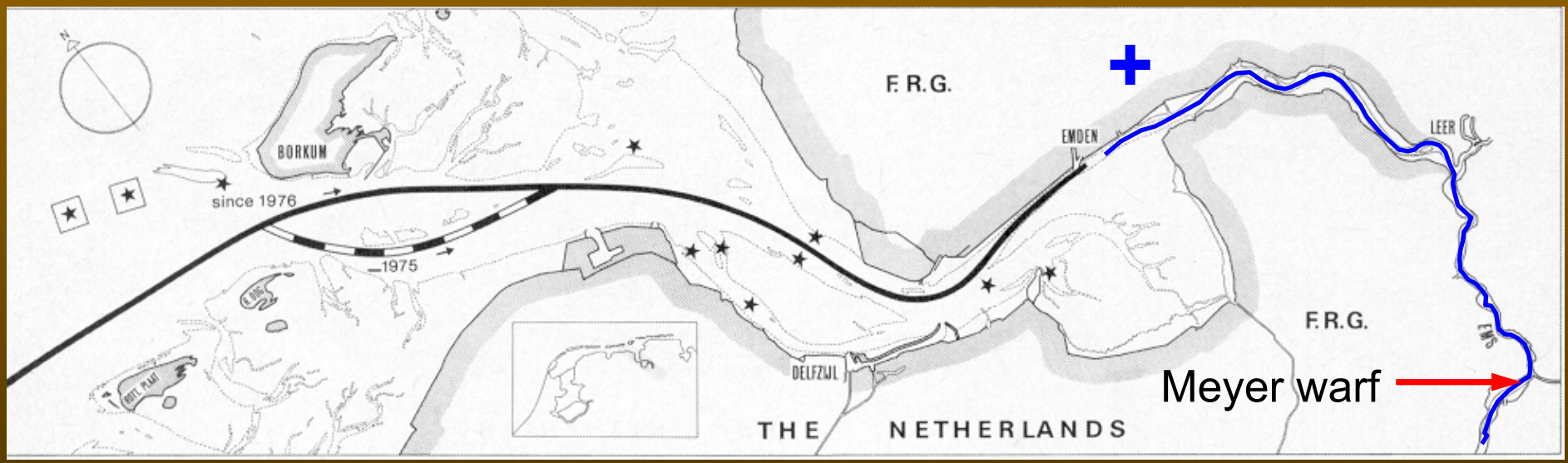
483 cm (+ 3.5m)



‘Ems Sperrwerk’ was needed!
Highest water level ever measured in the Ems estuary: 01-11-2006


Denmark
København
(Copenhagen)
Sylt
Ærø
Amrum
Rügen
Douglas
Cliath
(Dublin)
Hamburg
Juist
Groningen
United Kingdom
Berlin
Amsterdam
Netherlands
London
Nelson's Column, London, England
Germany
Brussel
(Prague)
Saint Peter Port
© 2006 Europa Technologies
Image © 2006 GeoContent
Image © 2006 TerraMetrics
Image © 2006 NASA
Pointer 54°30'48.29" N 5°57'26.21" E elev -28 ft
Streaming 100%

Together with the channel maintenance dredging in the Ems estuary, the scale of the activity and its impact is large



Why this example ?

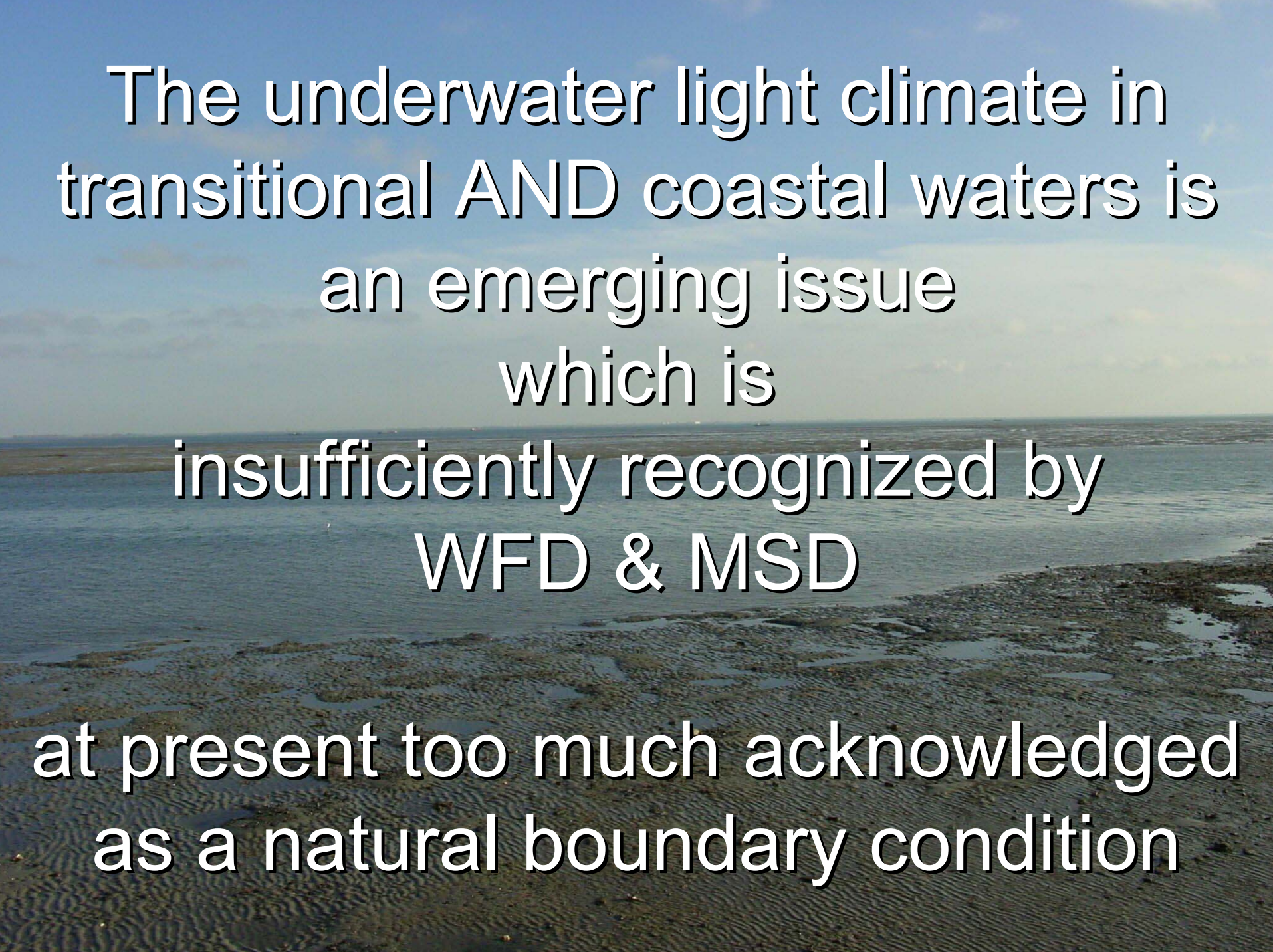
1. Light is a resource for algae which are responsible for creating the food for the aquatic system

2. Light is easily and heavily influenced by human activities

3. Light is an emerging problem!!

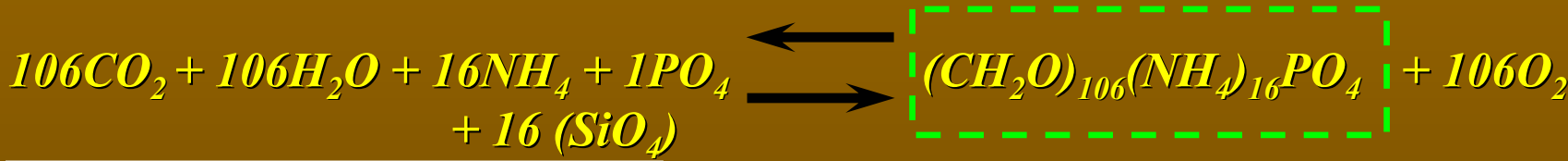
Other functions of mud

- Suspended ‘particles’ / ‘solids’
- Extincting light
- Substrate
- Habitat
- Source of compounds
- Adsorbance for chemical compounds
- Substrate for benthic diatoms and bacteria
- Carrier for transporting micro-organisms
- By-product of food
- Resource for brick production


The underwater light climate in transitional AND coastal waters is an emerging issue
which is
insufficiently recognized by WFD & MSD
at present too much acknowledged as a natural boundary condition

What matters basically in any ecosystem and for modelling it:

1. Resources:



a. Light
b. Nutrients: N, P, Si

a. System functioning
b. Species structure
c. Species interactions

2. Environmental conditions:

Related to spirit of WFD & MS

a. temperature
b. dilution rate (τf)

3. Balance between channels & intertidal flats

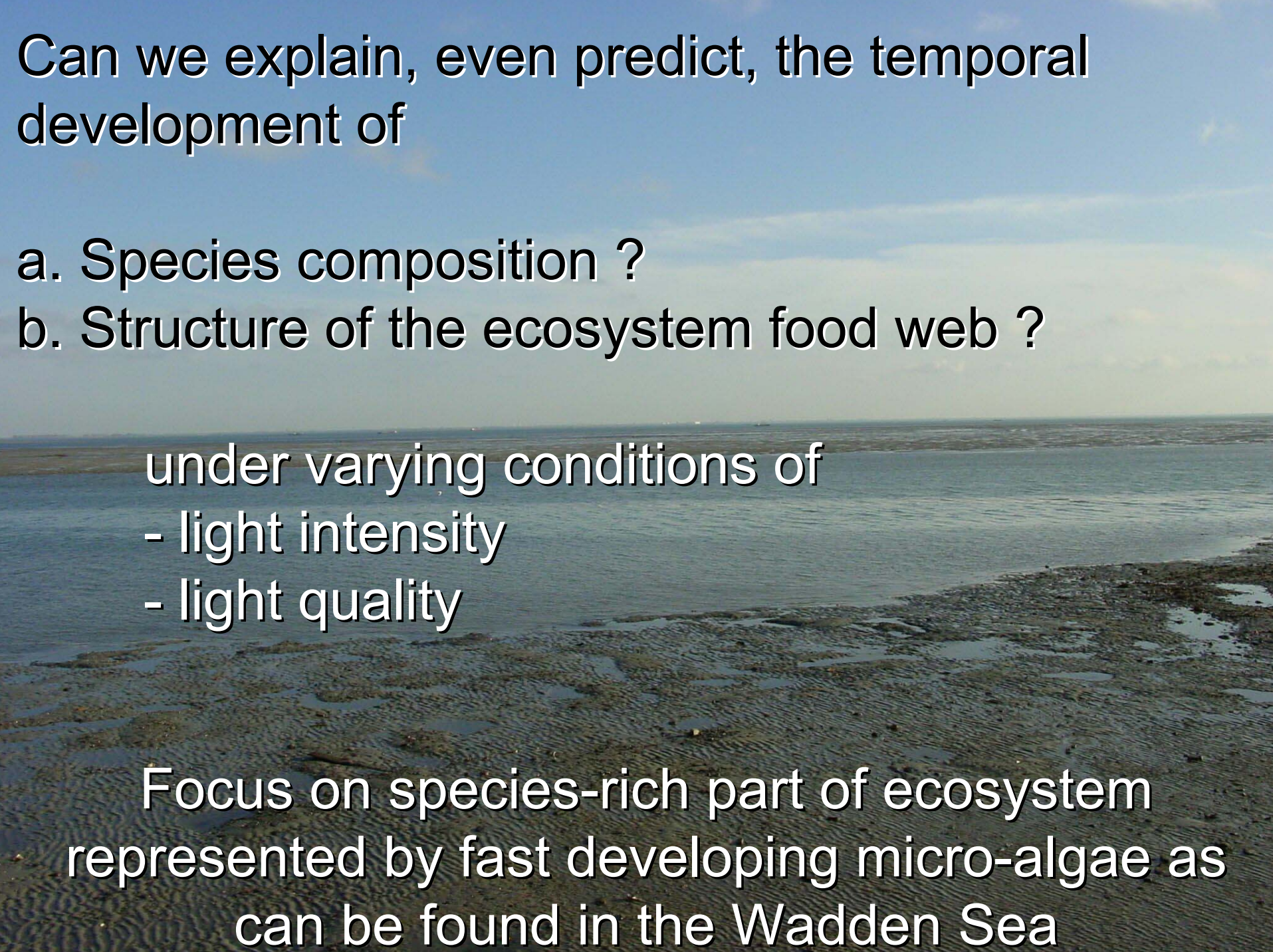
a. sediment - water interaction

We understand part of the general functioning level:
e.g. the primary production process

We do not understand the general structure level:
e.g. systems quality by its species composition

How does (systems ecology) the combination of e.g. light, nutrients, temperature regulate

1. functioning of the system
2. species structure of the system



Can we explain, even predict, the temporal development of

a. Species composition ?
b. Structure of the ecosystem food web ?

under varying conditions of
- light intensity
- light quality

Focus on species-rich part of ecosystem represented by fast developing micro-algae as can be found in the Wadden Sea

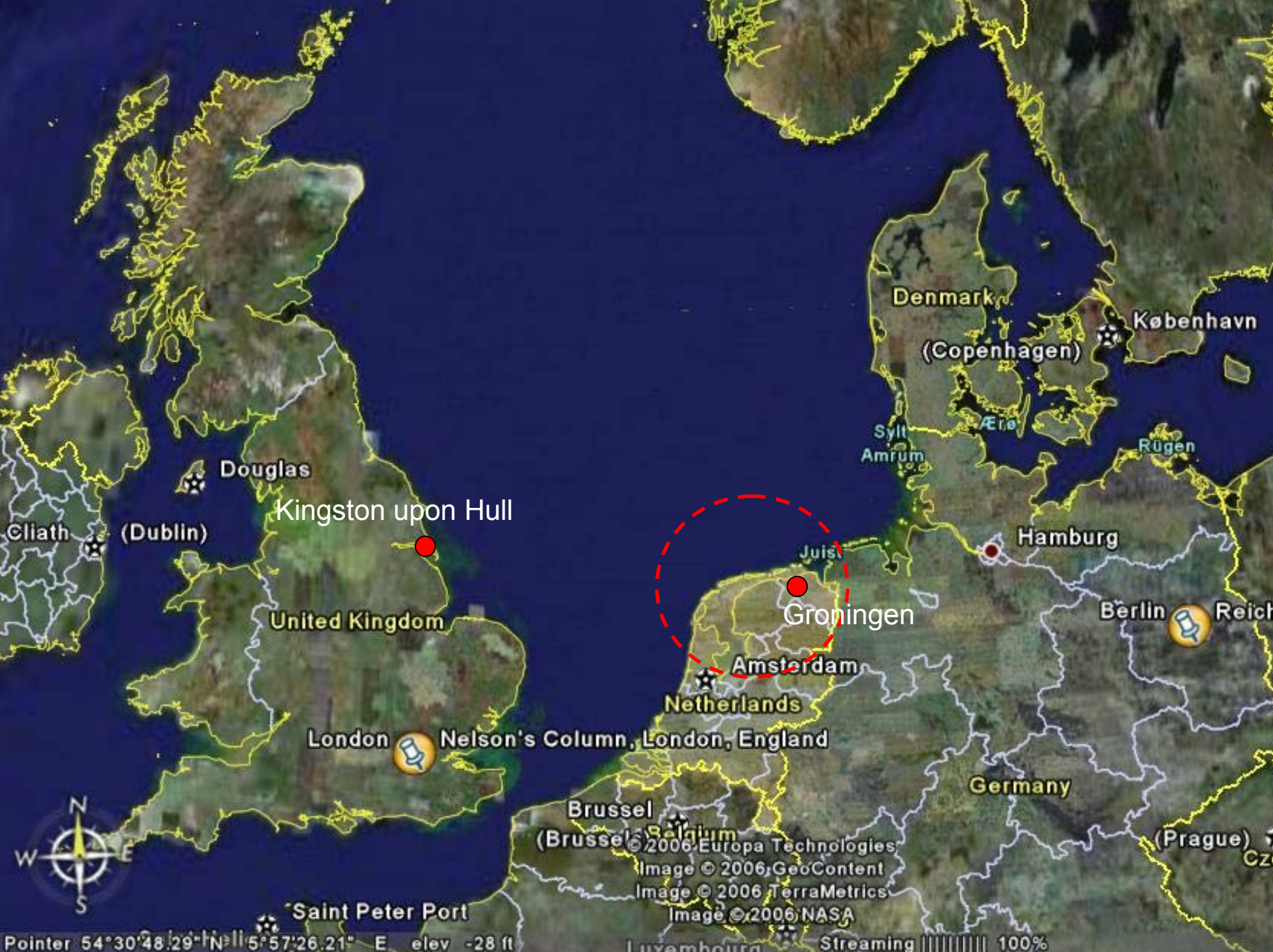

Kingston upon Hull
Groningen
Douglas
Cliath
(Dublin)
United Kingdom
London
Nelson's Column, London, England
Amsterdam
Netherlands
Brussel
(Brussel)
Belgium
Germany
Denmark
(Copenhagen)
København
Sylt
Amrum
Rügen
Hamburg
Berlin
(Prague)
Saint Peter Port
© 2006 Europa Technologies
Image © 2006 GeoContent
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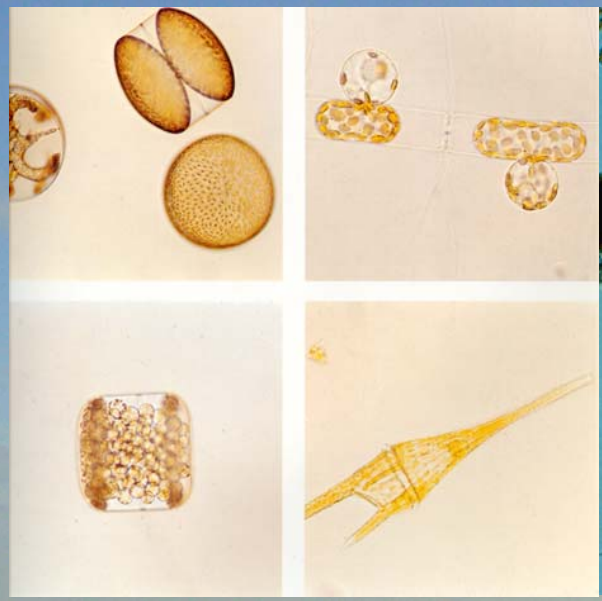
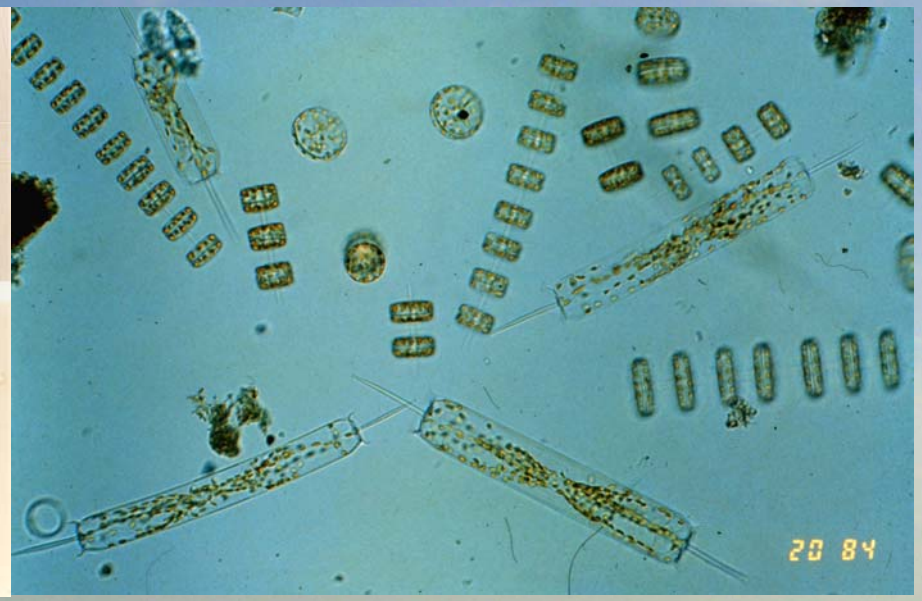
Image © 2006 NASA
Pointer 54°30'48.29" N 5°57'26.21" E elev -28 ft
Streaming 100%

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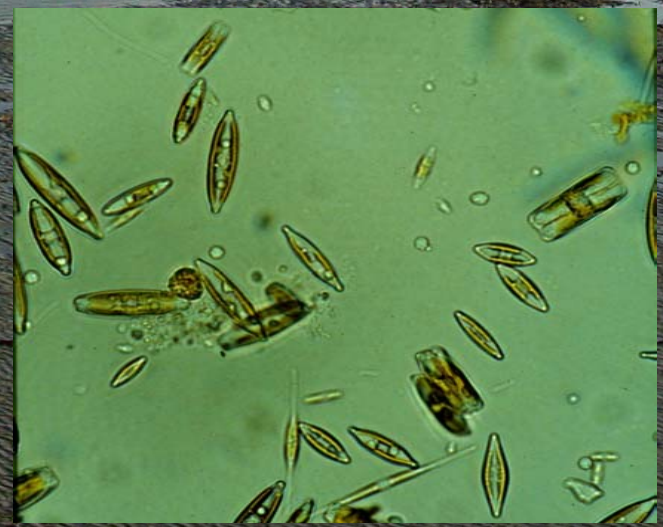
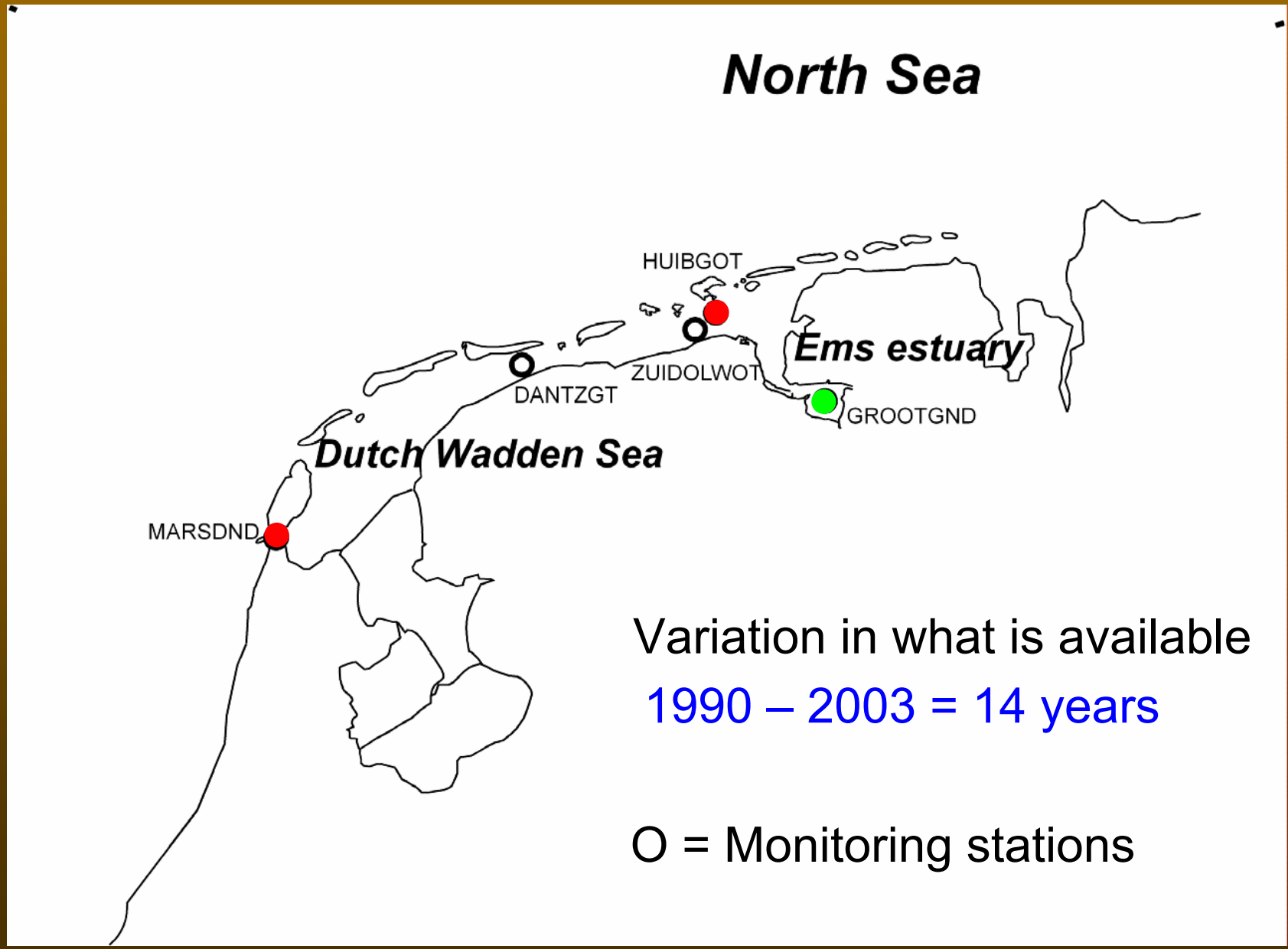




Variation in what is available

1990 – 2003 = 14 years

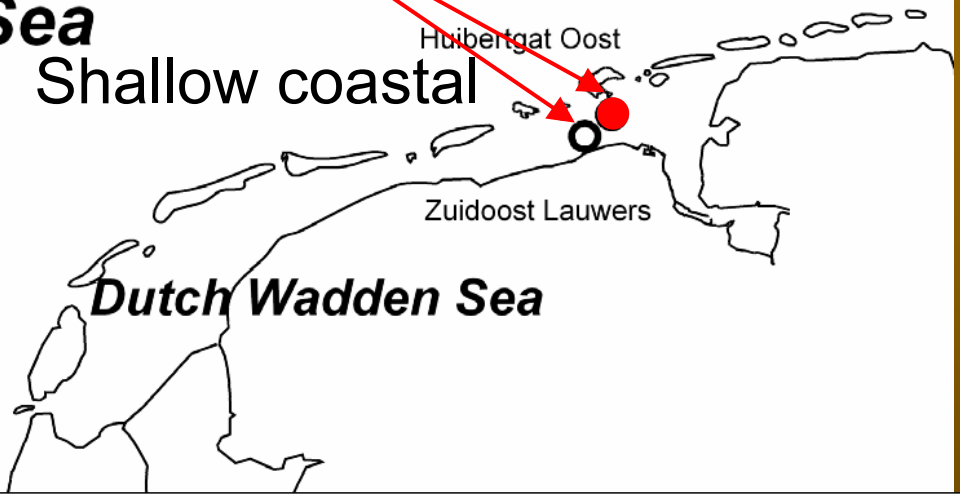
O = Monitoring stations

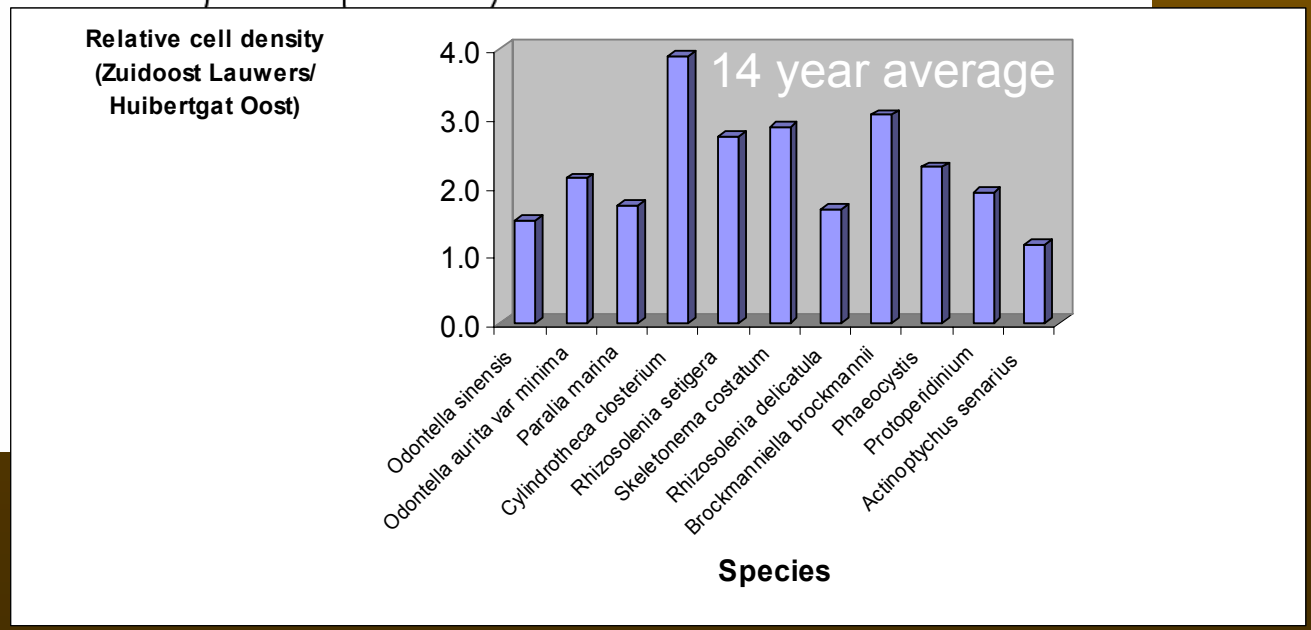
30 km apart

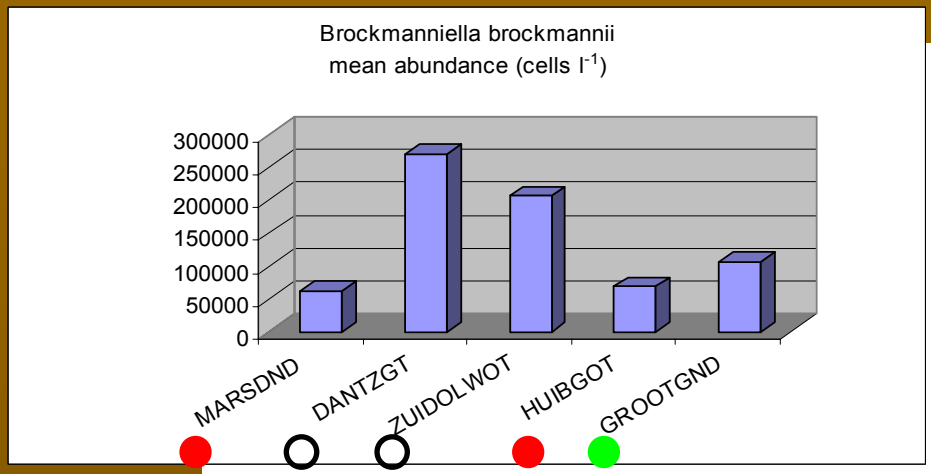
Deep coastal

North Sea

Shallow coastal

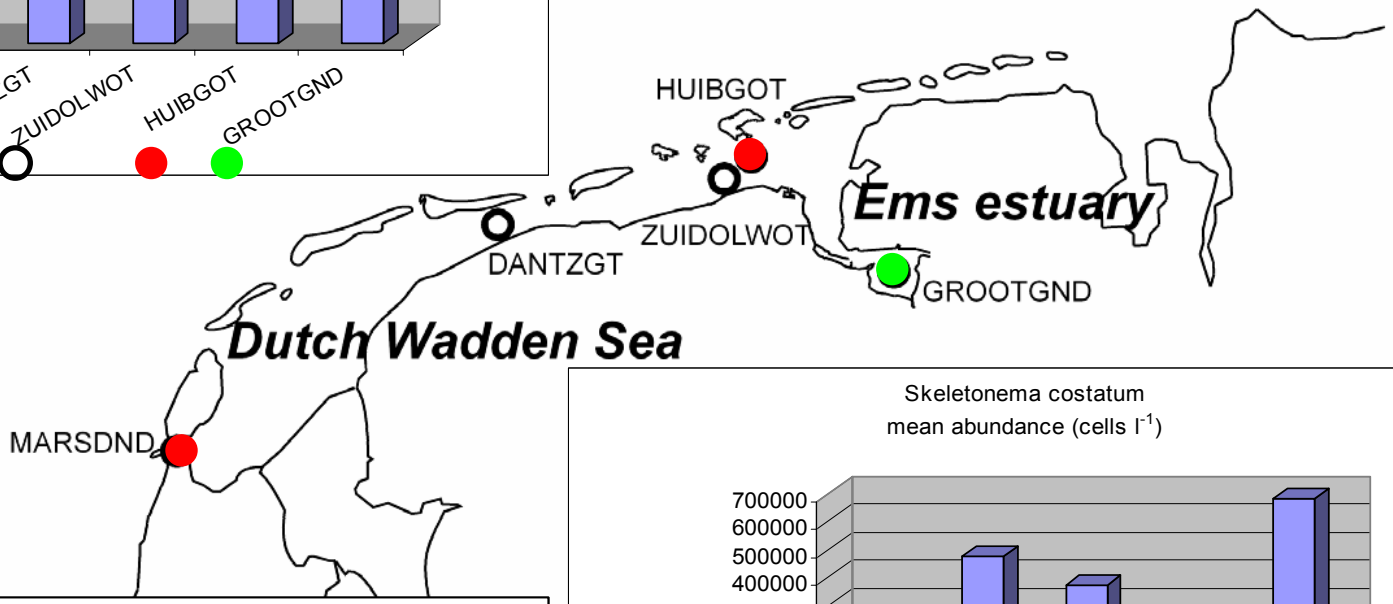


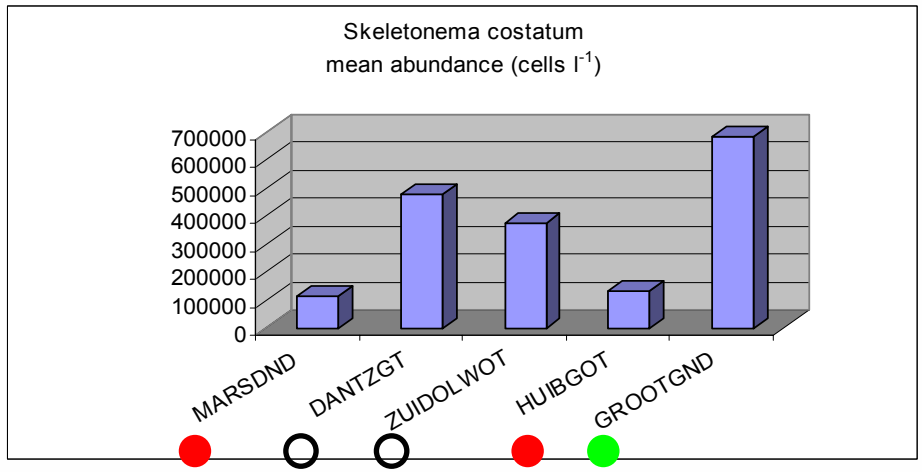


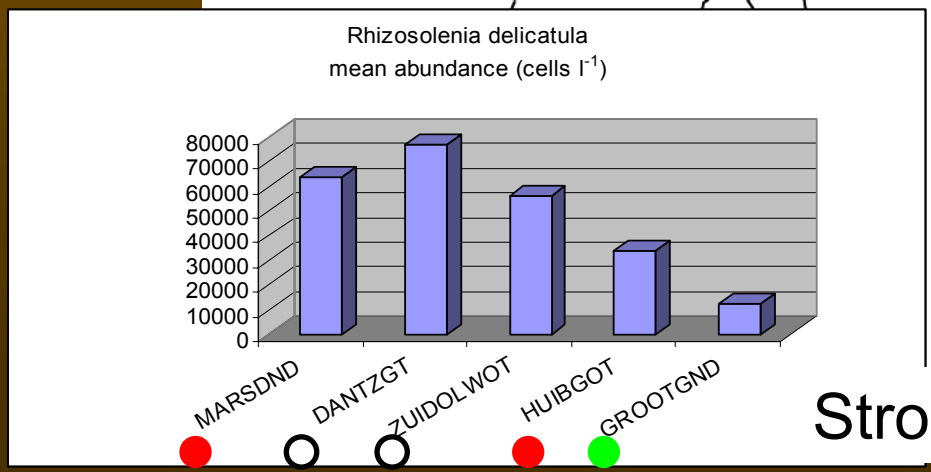


North Sea

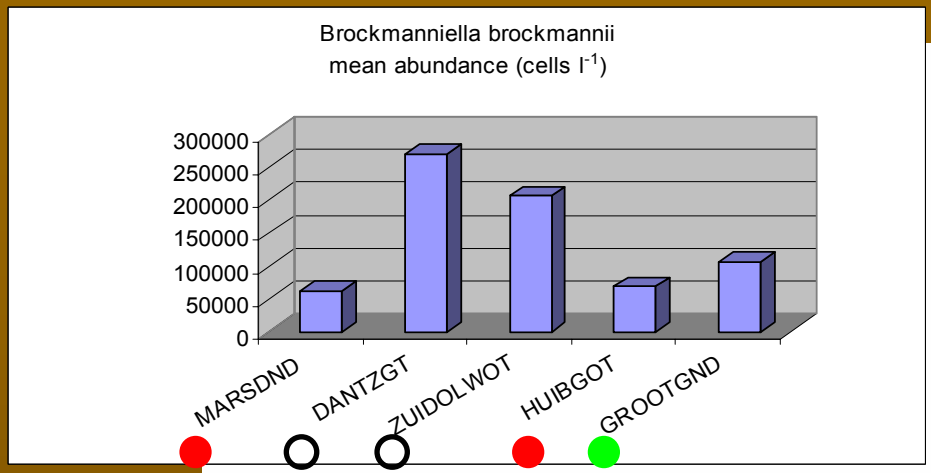
(13 yr average)







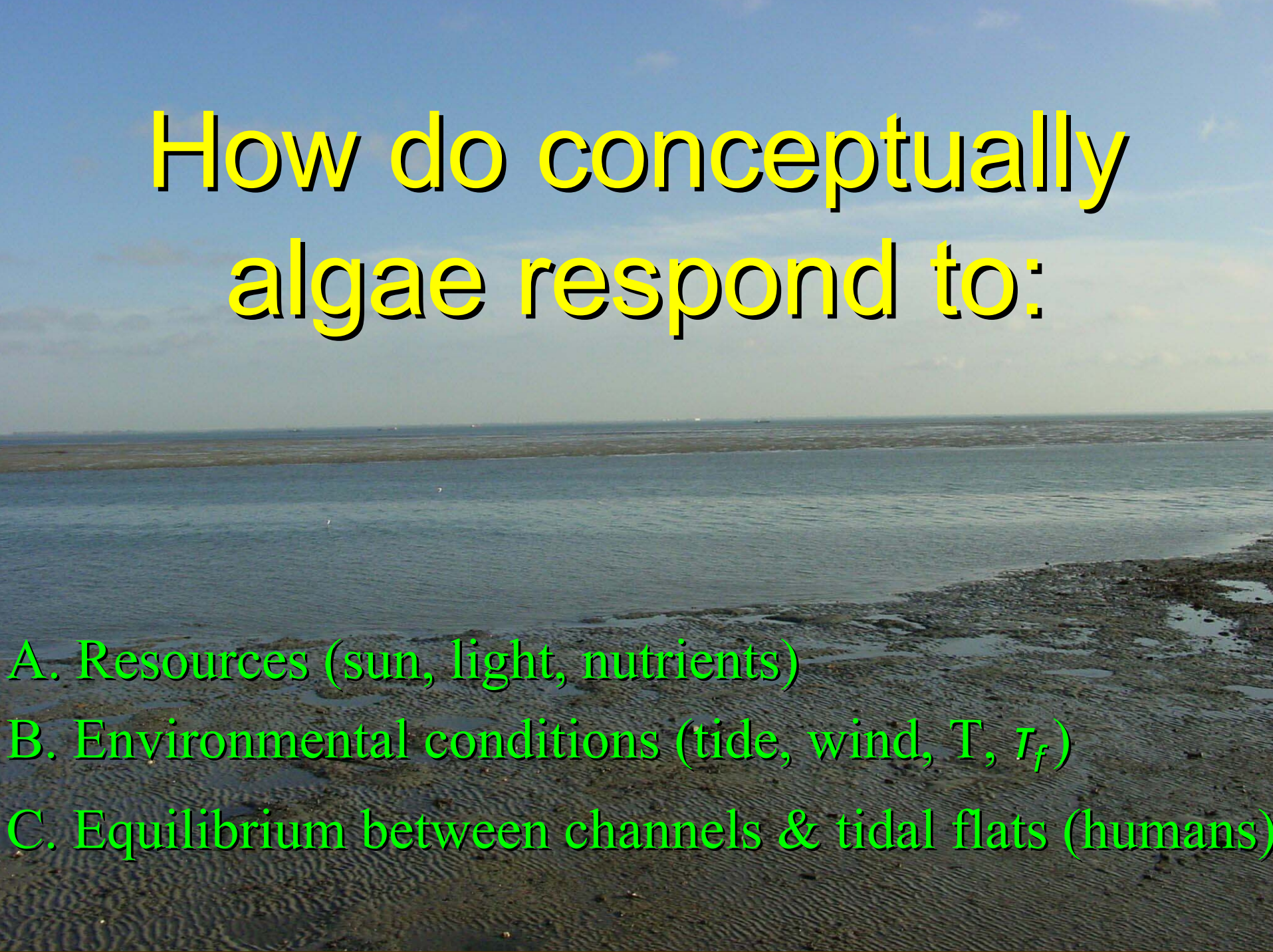
Strong variations in time and space



Options:

1. Mathematical and statistical analysis as description for what has been observed

2. Searching for concepts with general applicability behind the observed picture to support
   - stochasticity
   - determinism (mechanistic explanations for observed developments in space and time)

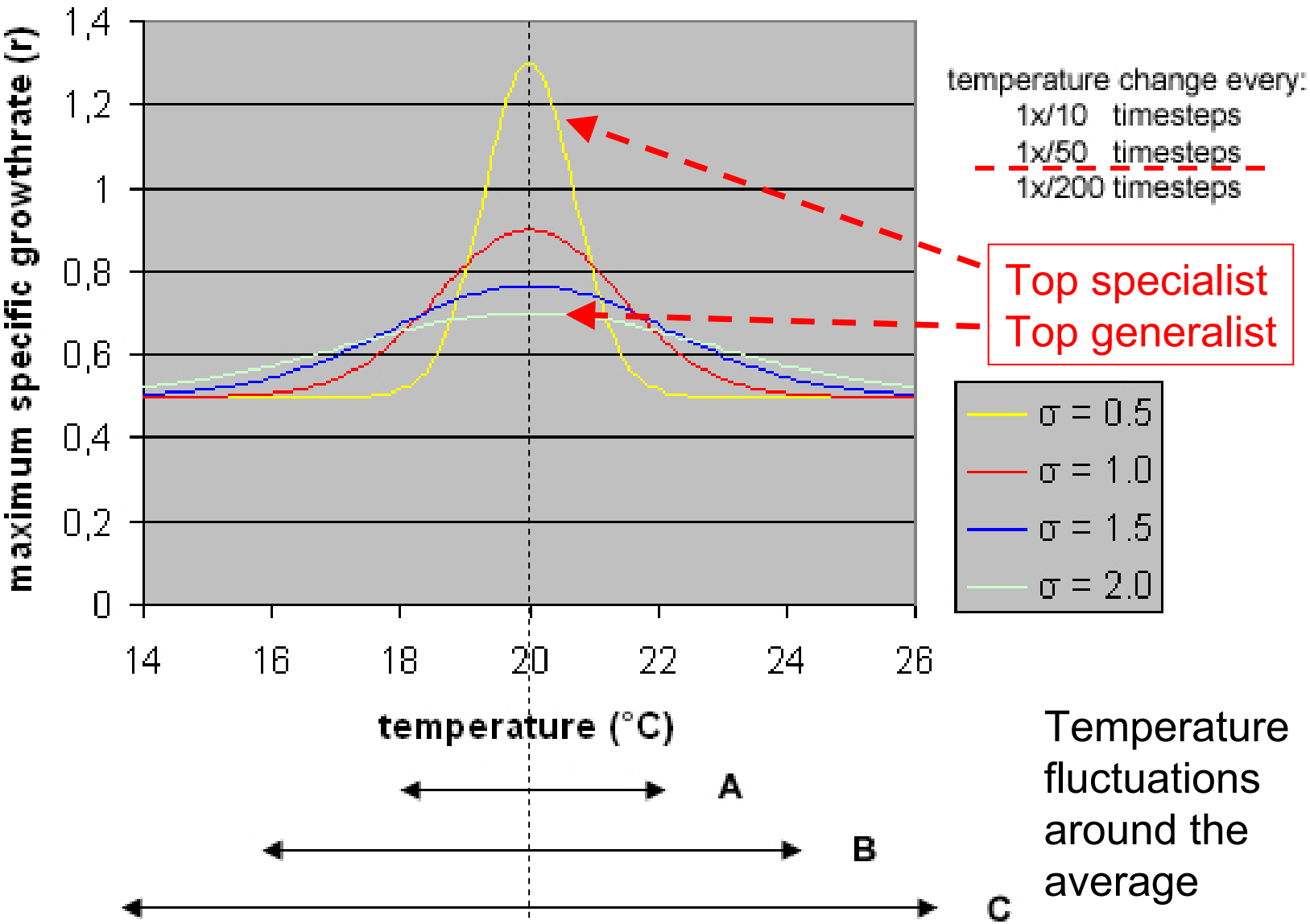


How do conceptually algae respond to:

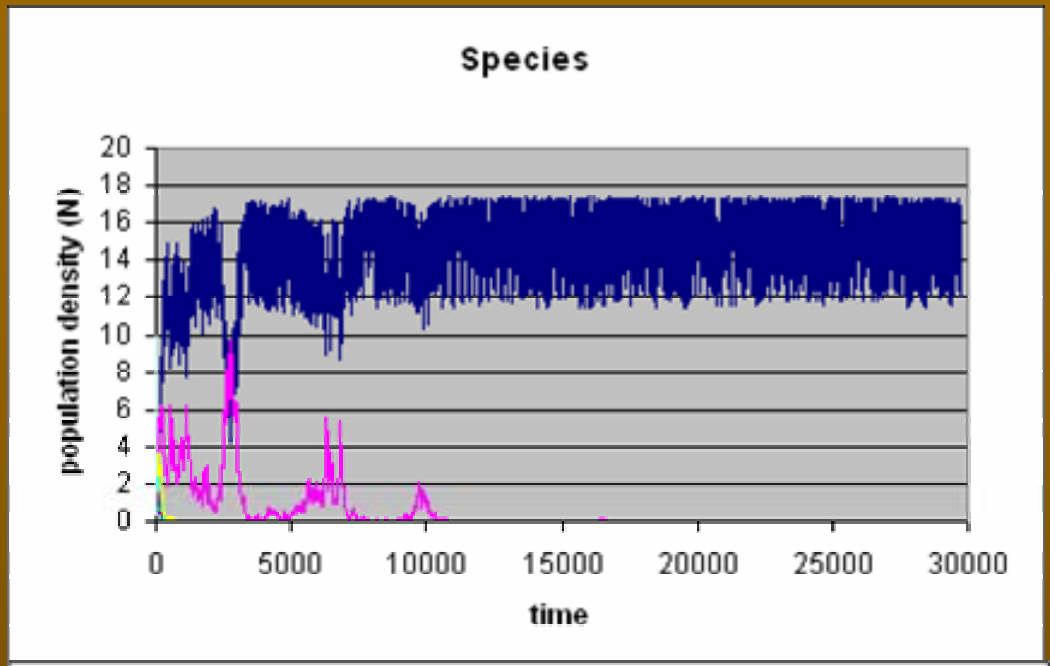
A. Resources (sun, light, nutrients)

B. Environmental conditions (tide, wind, T, τ_f)

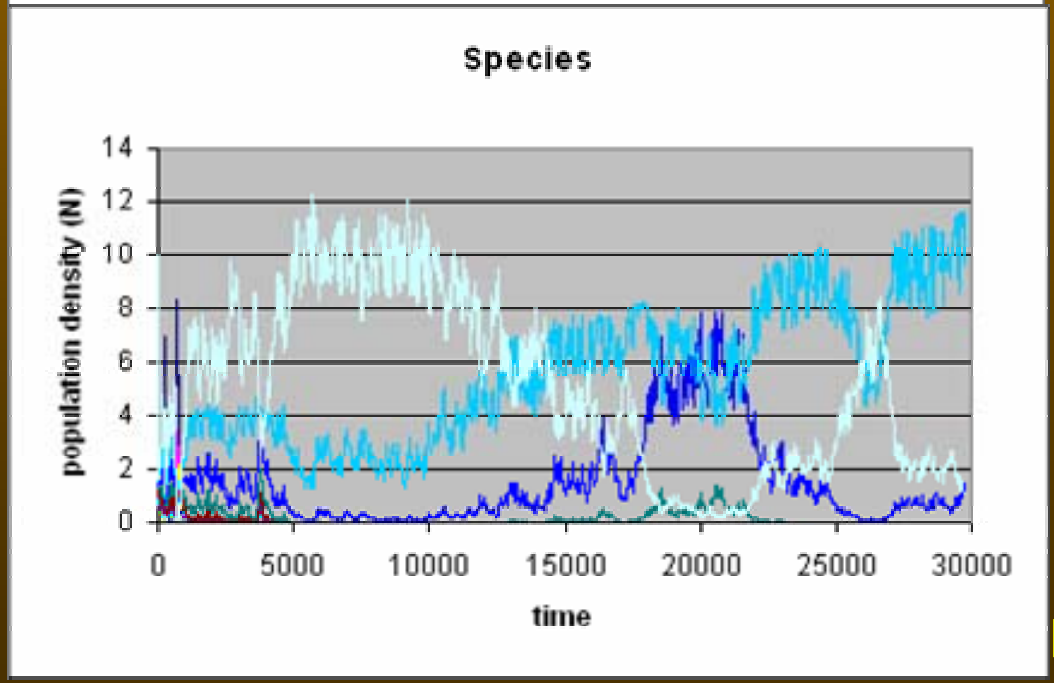
C. Equilibrium between channels & tidal flats (humans)



The factor temperature could also have been LIGHT or LIGHT QUALITY due to changed spectrum by humic substances or ….



Fluctuations of 2 °C around 20 °C



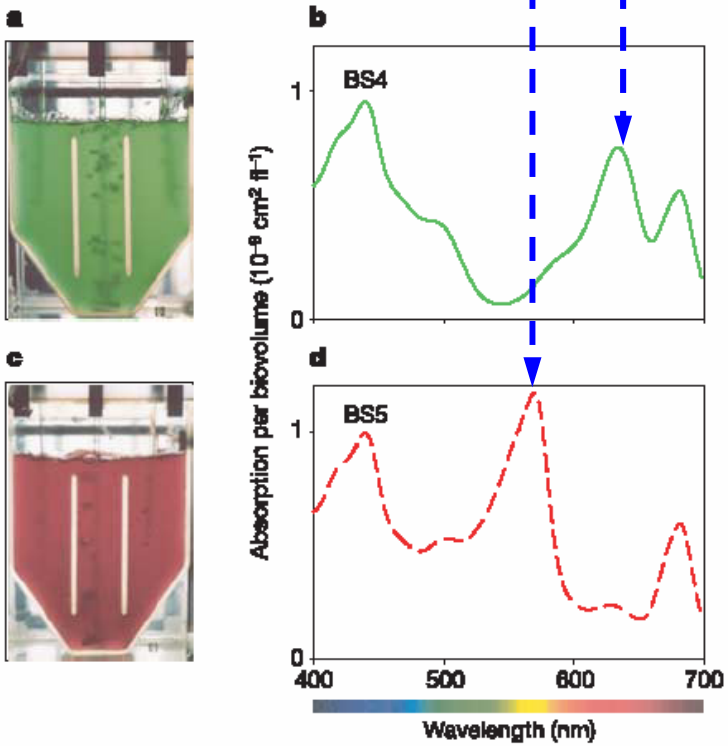
top specialist

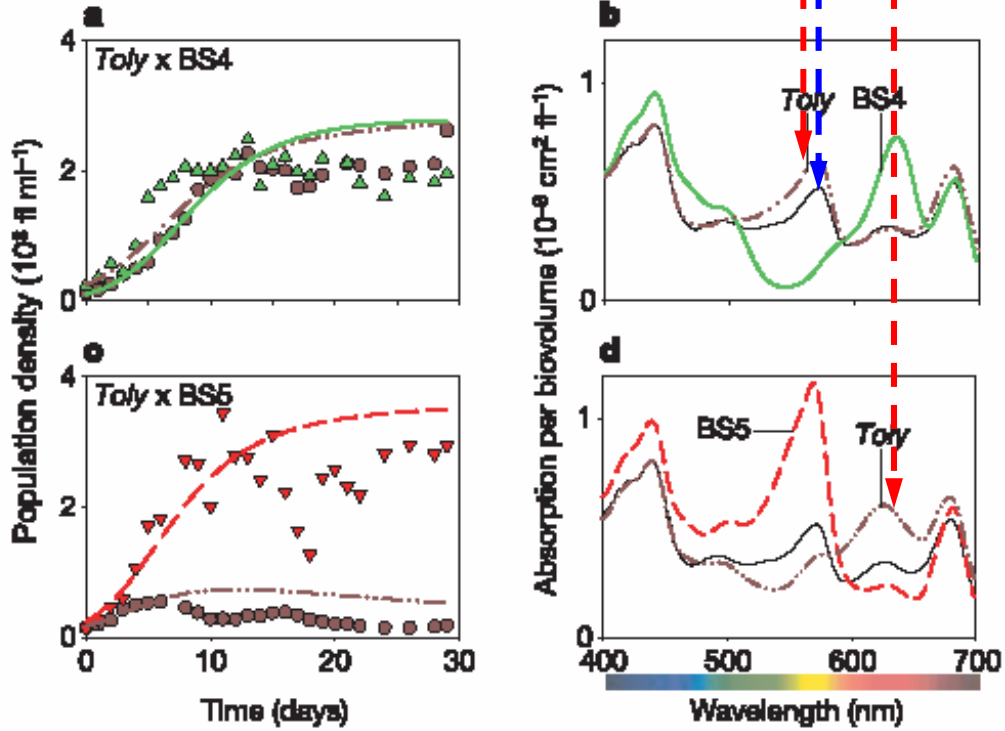
species 1
species 2
species 3
species 4
species 5
species 6
species 7
species 8
species 9
species 10

top generalist

Fluctuations of 8 °C around 20 °C

de Jonge & Brauer, in press. MPB





Different species are in a different way adapted to light conditions. They have different pigments and thus different light absorption spectra.

Surprisingly, after mixing the 2 BS species with a Tolypothrix species, the last one adapt to the new light conditions by changing its pigment composition. This ‘adaptive behaviour’ improves its competition for the new situation.

Stomp, M. et al. 2004. Adaptive divergence in pigment composition promotes phytoplankton biodiversity. Nature, 432, 104 – 107.

Does this help us in understanding, exploring and predicting?

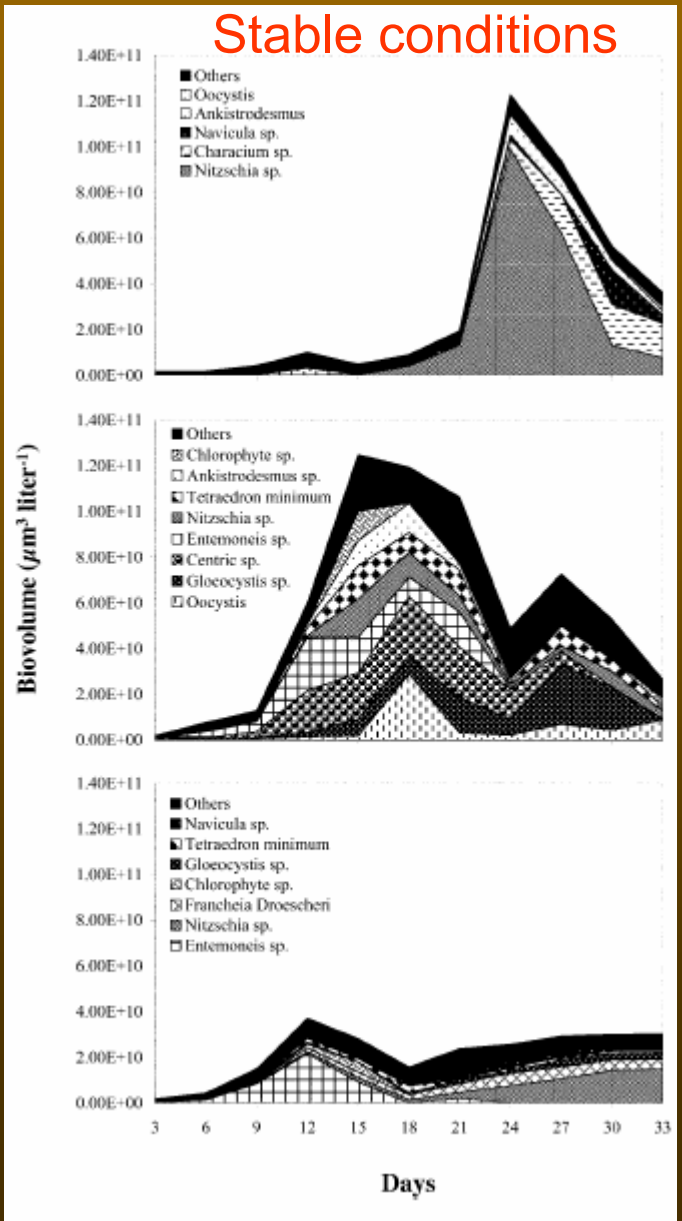
I think so given next example.

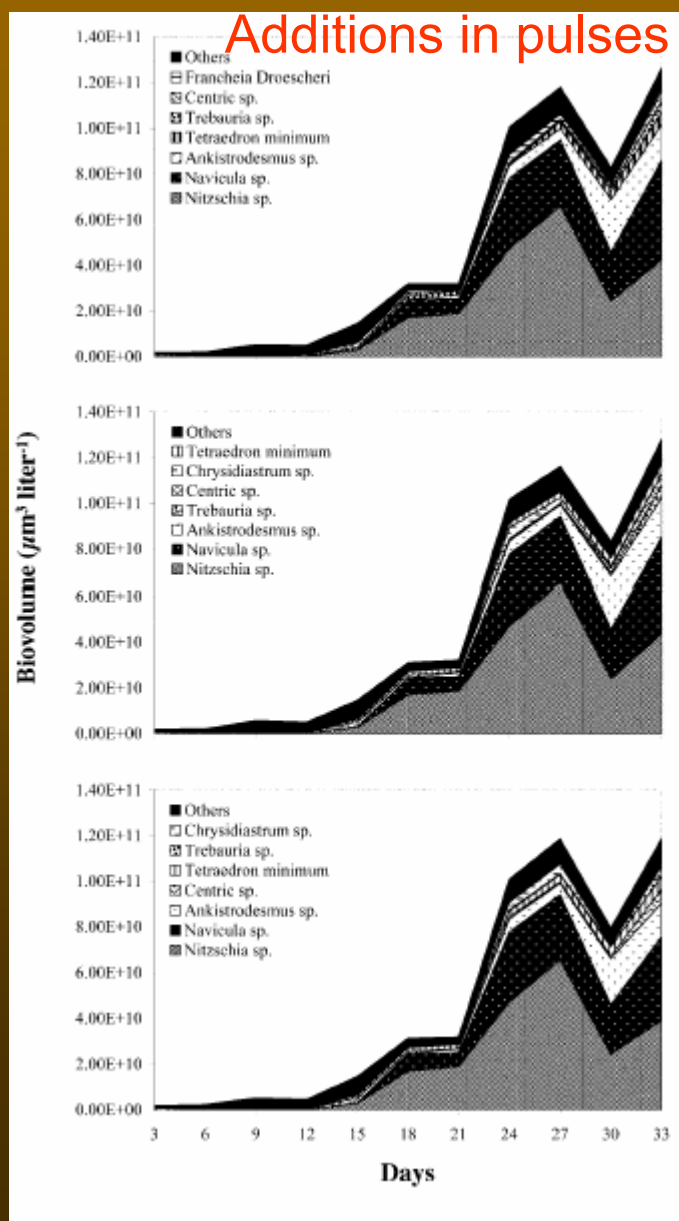
Predictability by external disturbances simulated by models and tested experimentally (Roelke et al. 2003)

2x3 replicates brought under different conditions.

1. Steady input of medium.
2. Pulse-wise input of medium.

Result:
Series 1: unpredictable development of spp composition
Series 2: predictable development of spp composition





Pulse frequency & pulse intensity may both determine diversity development

Pulse:
light, N, P, Si, t or river discharge

Thus at the general level the occurrence of species assemblages and their abundance might be at least ‘understandable’ !

We should take the chance to integrate the modern scientific ‘state of the art’ with current environmental monitoring practice by authorities and the requirements by e.g. the WFD & MS.

Because light is ecologically of utmost importance

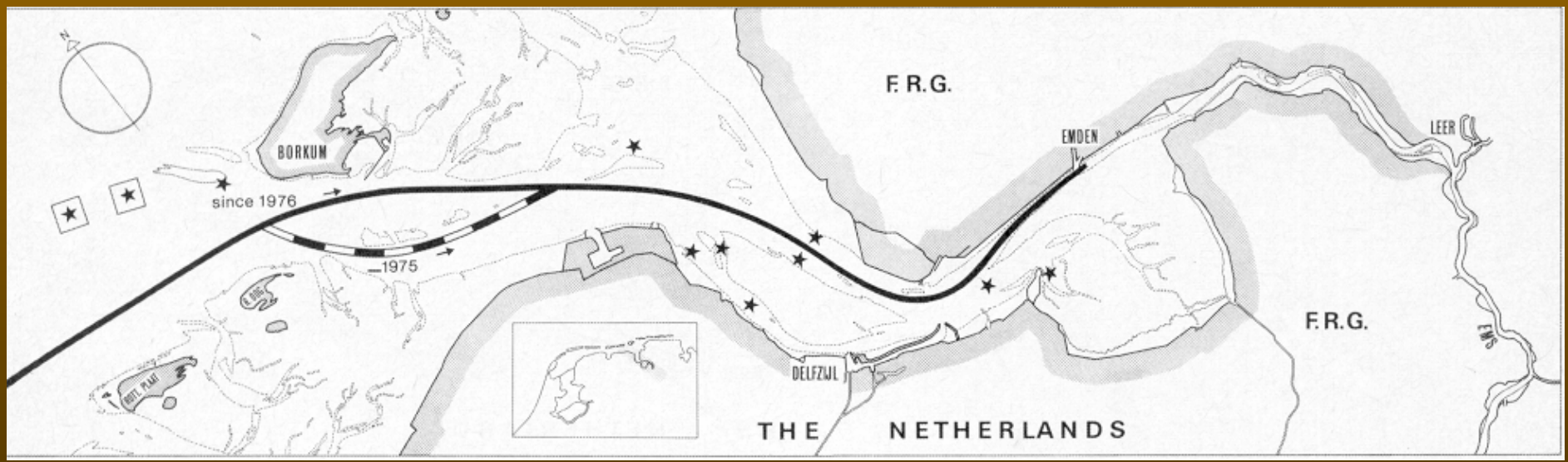
l move to the most important impact in coastal waters wind, dredging, sludge disposal, mining, extraction, fisheries, …as a source for changes in light climate.

The Ems estuary

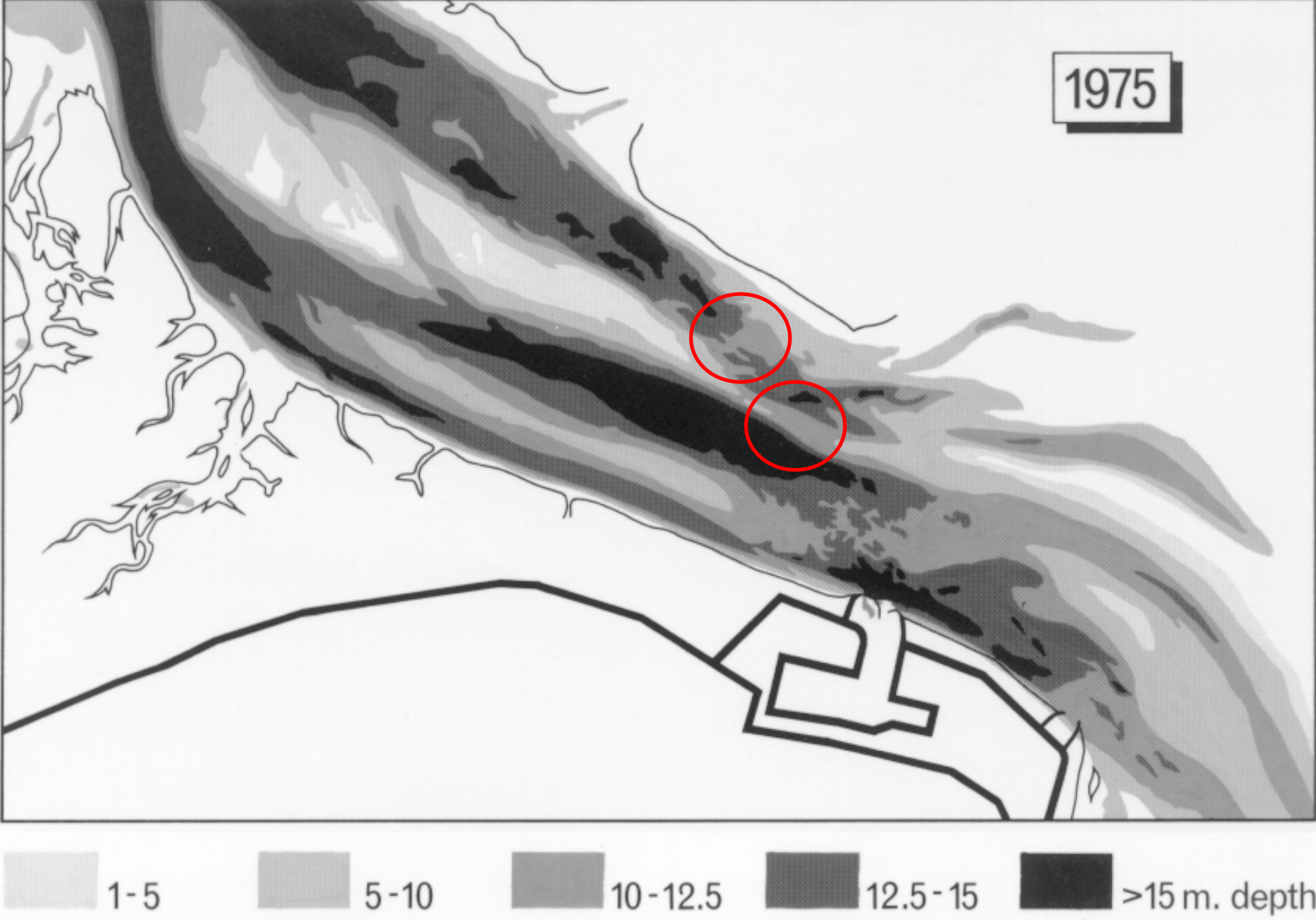
The underwater light climate in transitional AND coastal waters is an emerging issue which is insufficiently recognized by Marine Strategy

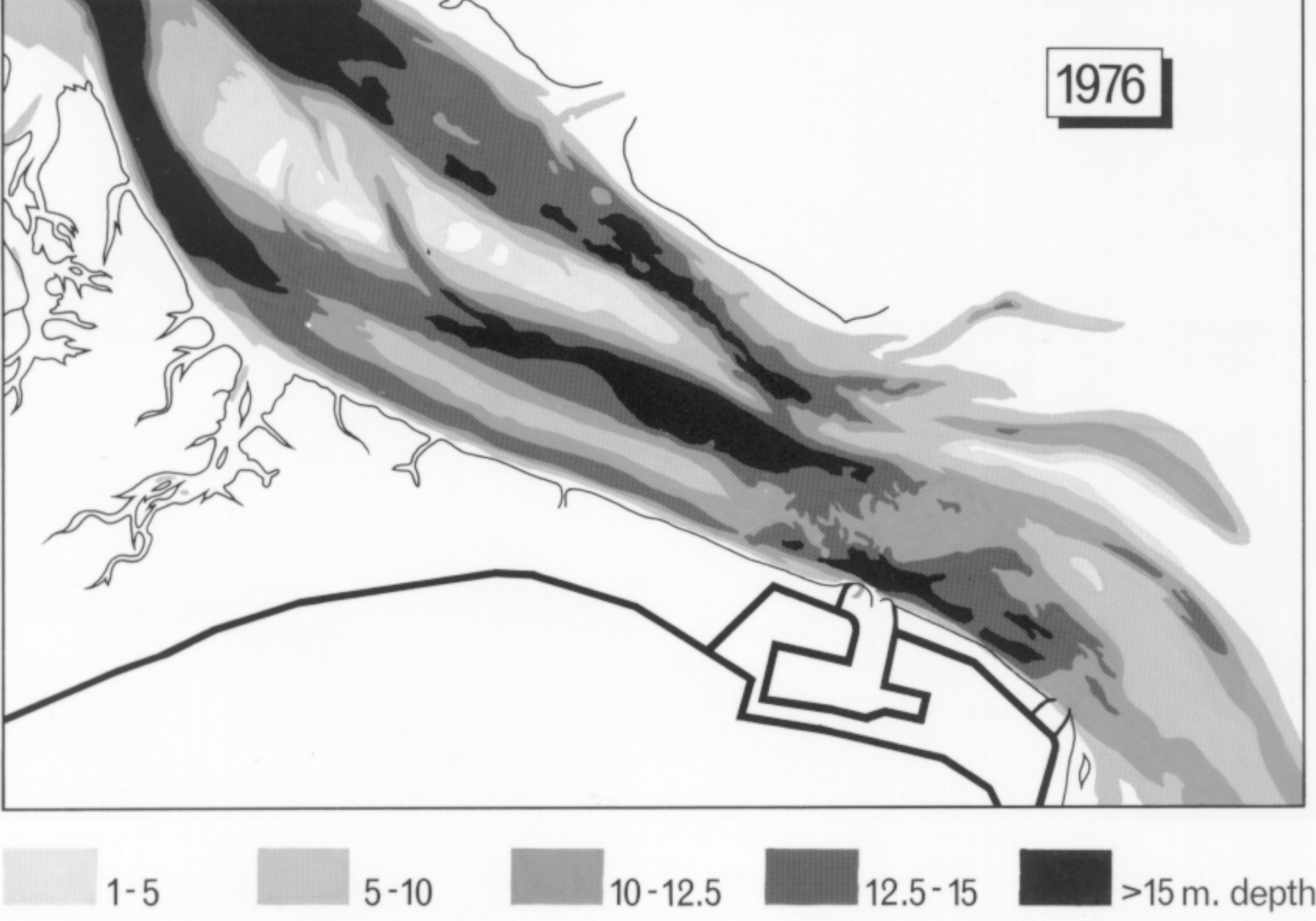
Channel maintenance dredging:

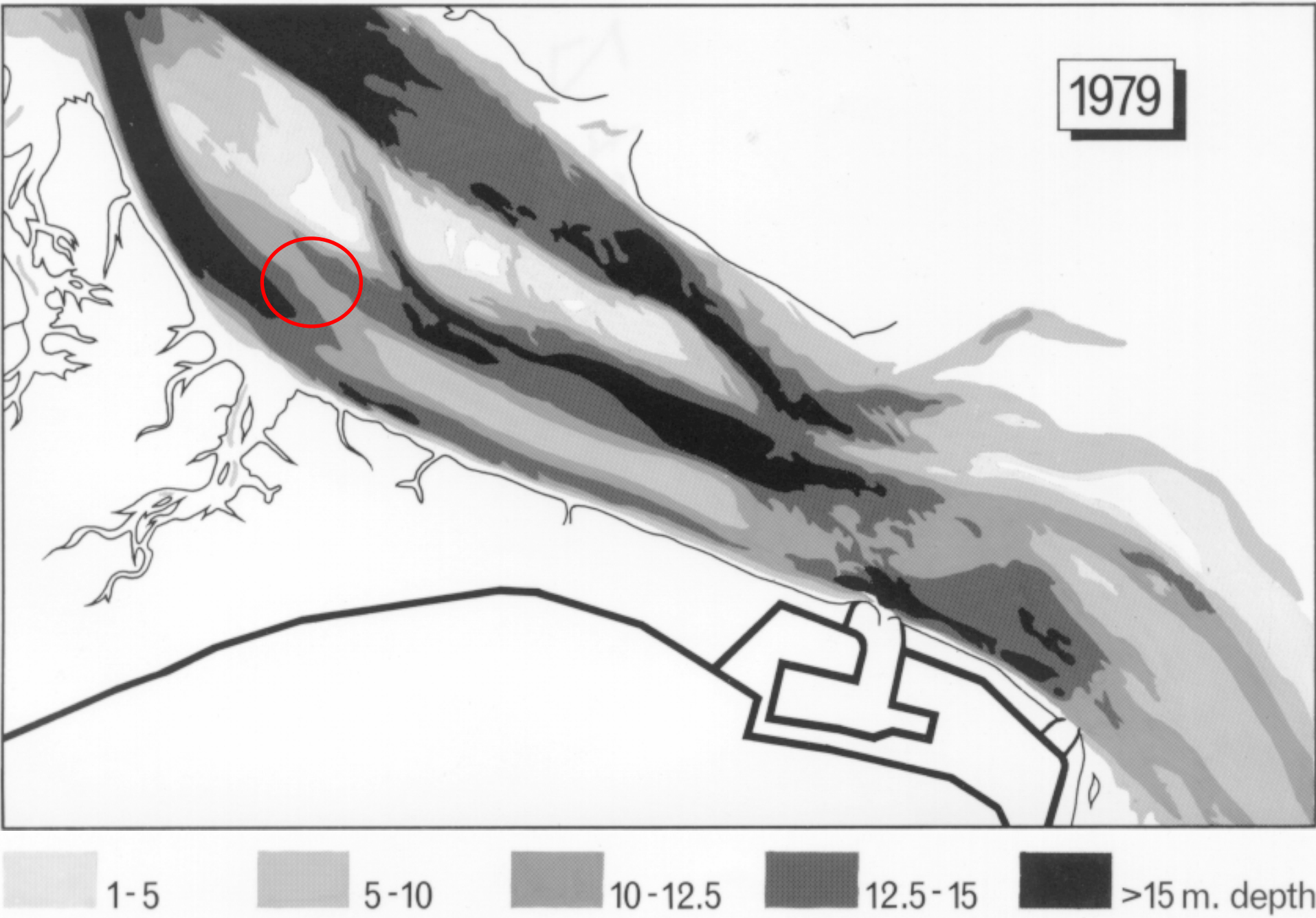
1. Changes morphology, flow current field & tidal wave
2. Increases erosion – sedimentation cycle

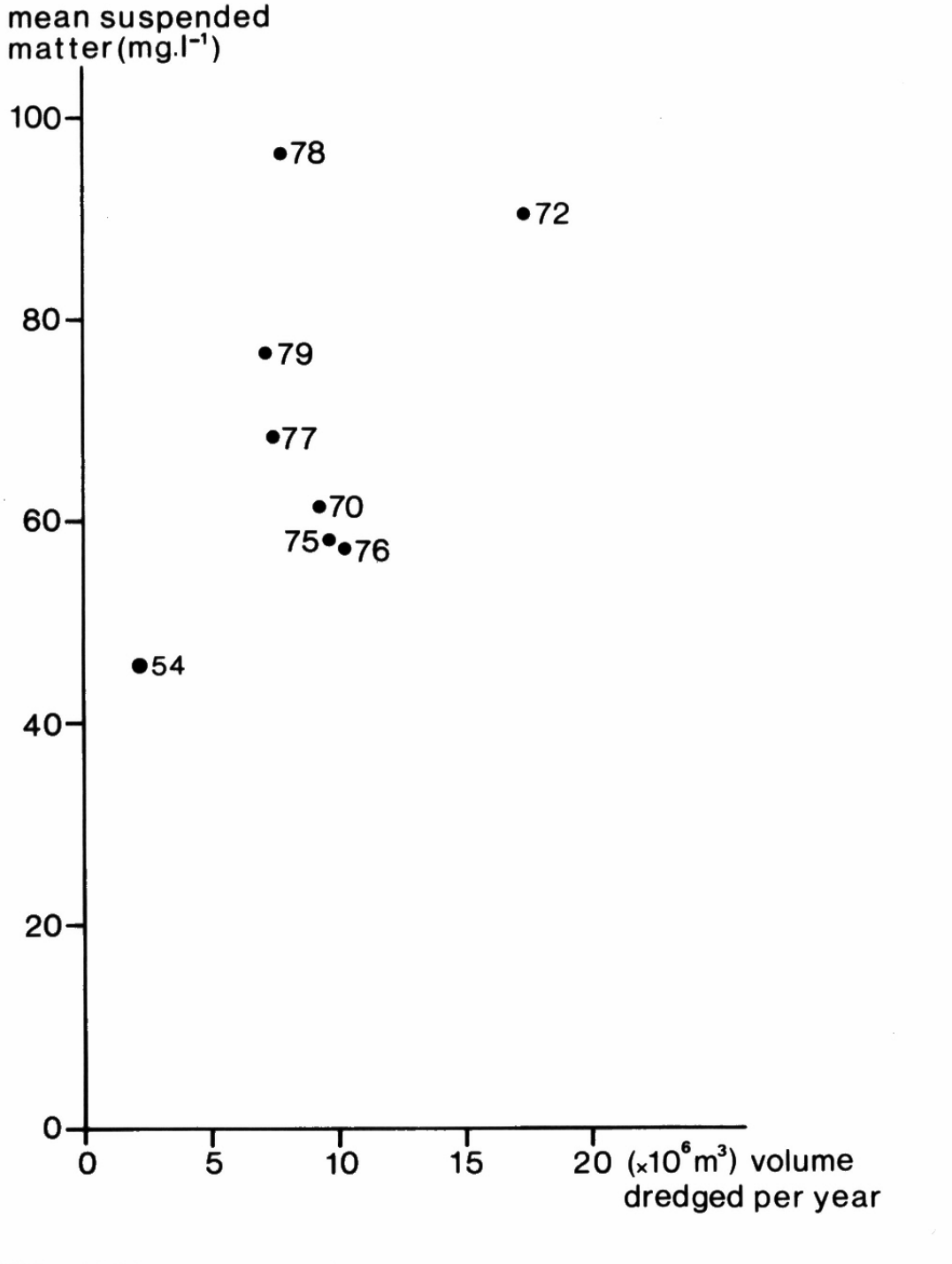


Situation before 1980, thus excluding all the river changes & river dredging

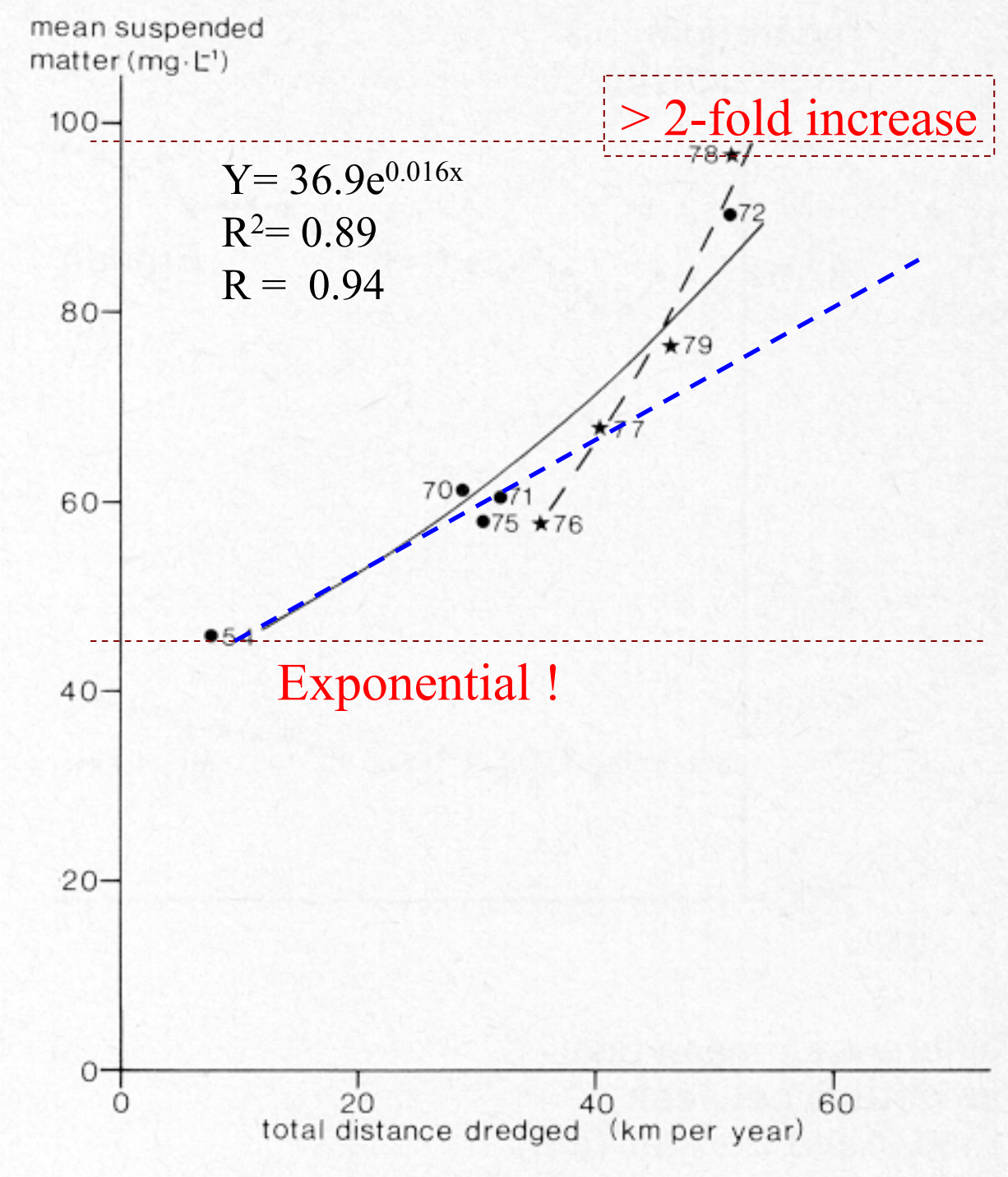

1975
1 - 5
5 - 10
10 - 12.5
12.5 - 15
>15 m. depth


1976
1-5
5-10
10-12.5
12.5-15
>15 m. depth


1979
1 - 5
5 - 10
10 - 12.5
12.5 - 15
>15 m. depth

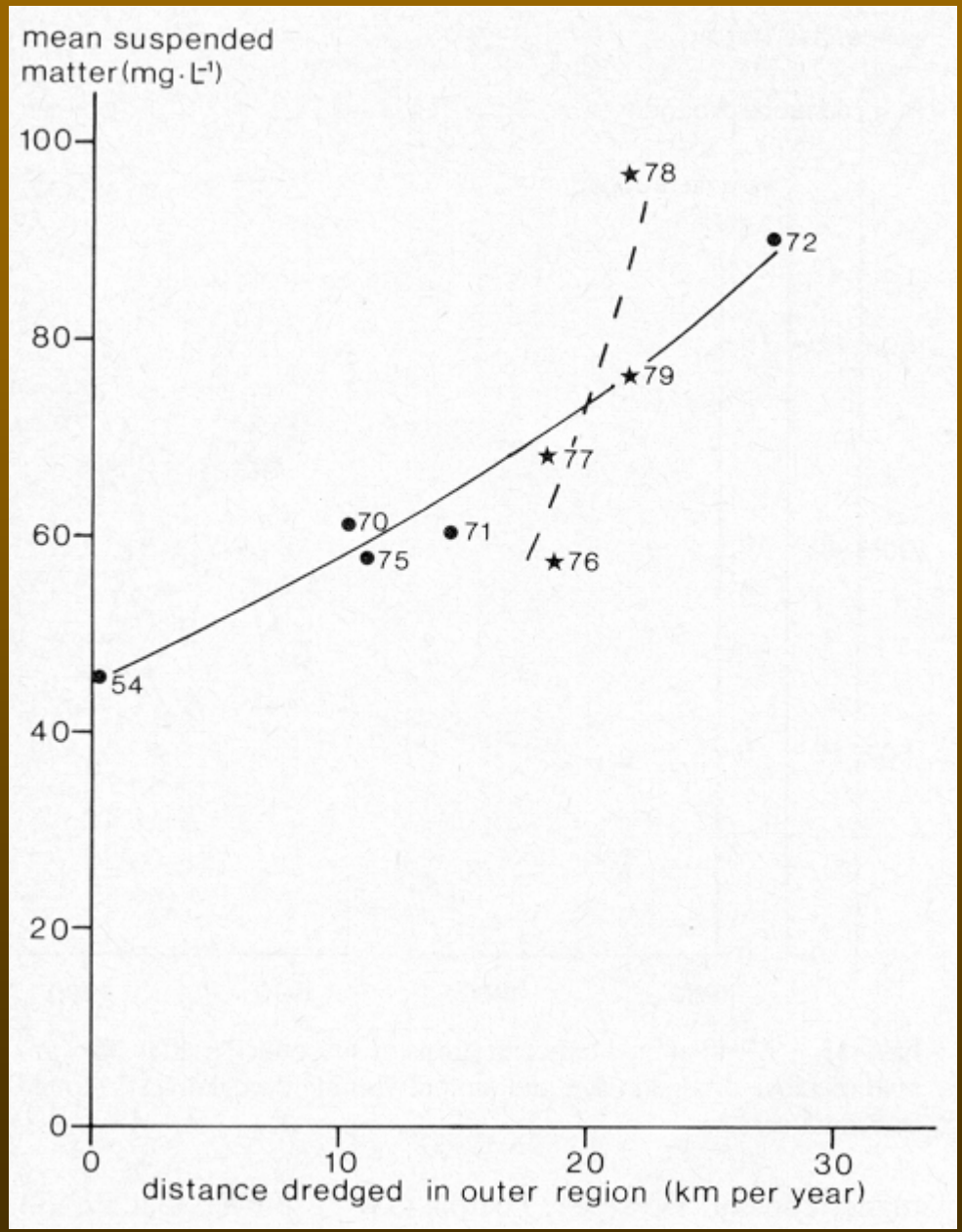


SPM as function of volume dredged



SPM as function of distance dredged

de Jonge, V.N., 1983. Relations between annual dredging activities, suspen-ded matter concentrations, and the development of the ti-dal regime in the Ems estu-ary. Can. J. Fish. Aquat. Sci. 40 (Suppl. 1): 289-300.

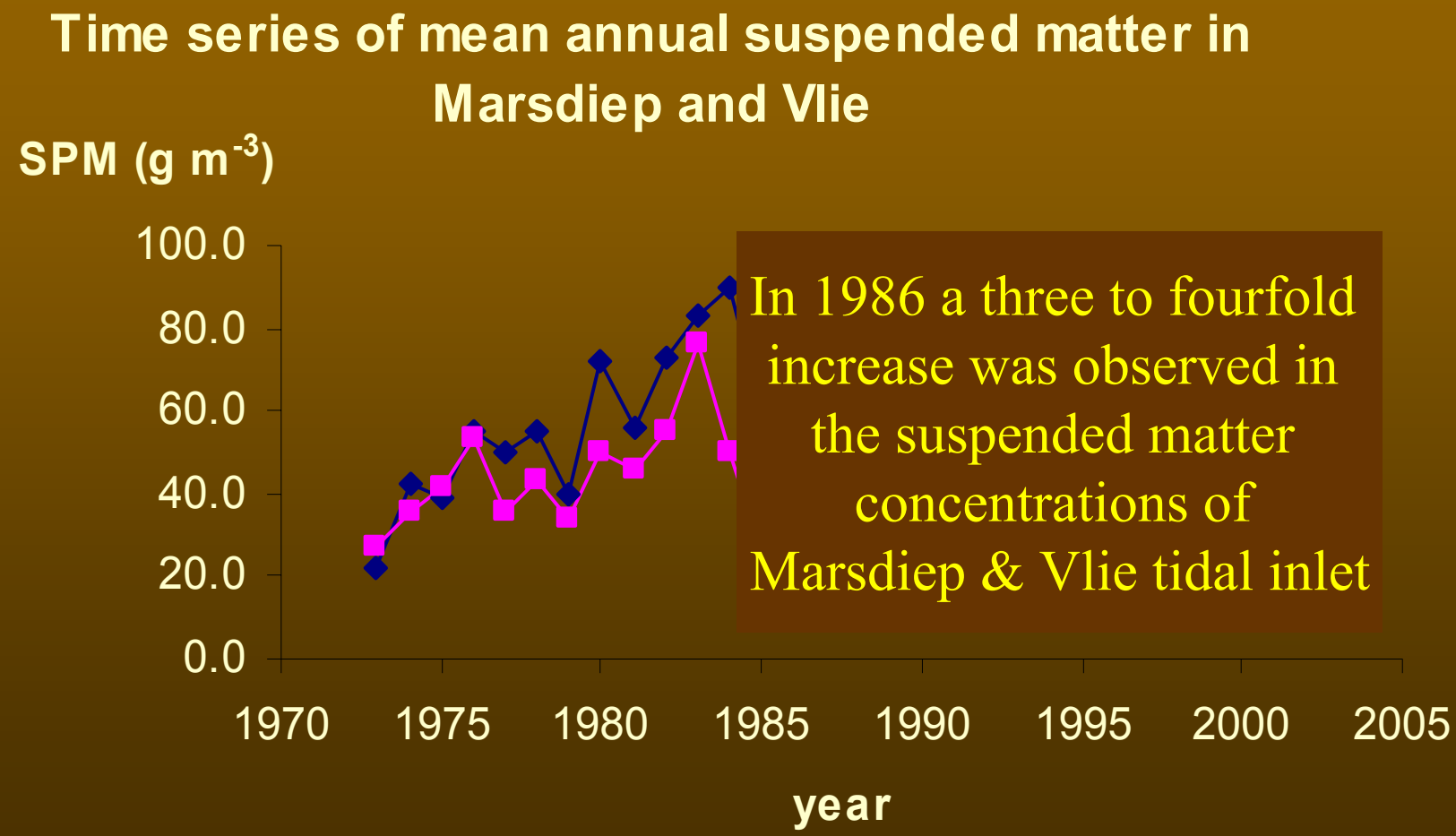


System is more sensitive to dredging the tidal inlet (outer and inner delta) than further upstream

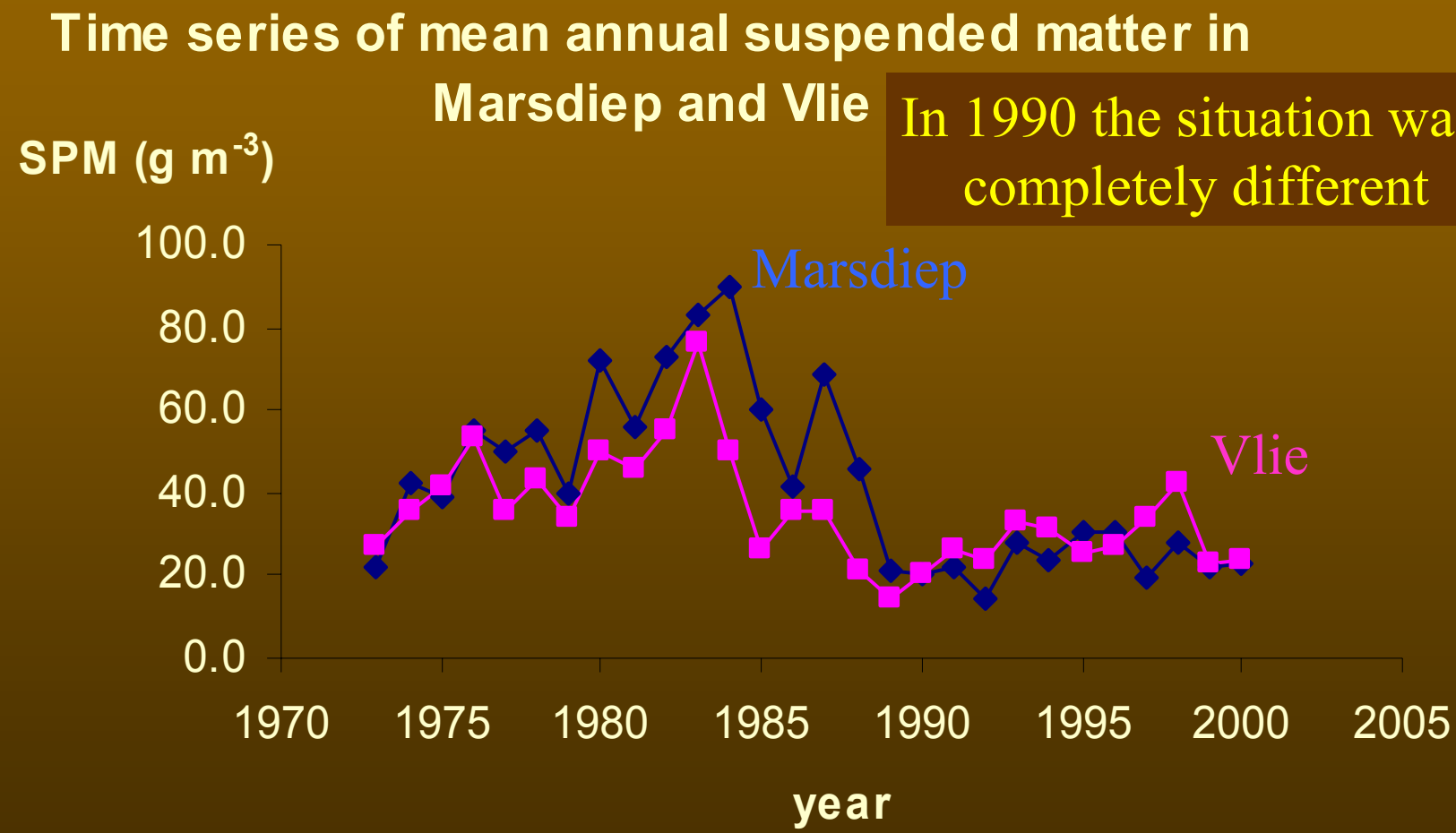
The Rhine - Wadden Sea system

The underwater light climate in transitional AND coastal waters is an emerging issue which is insufficiently recognized by MSD

Turbidity: an important problem



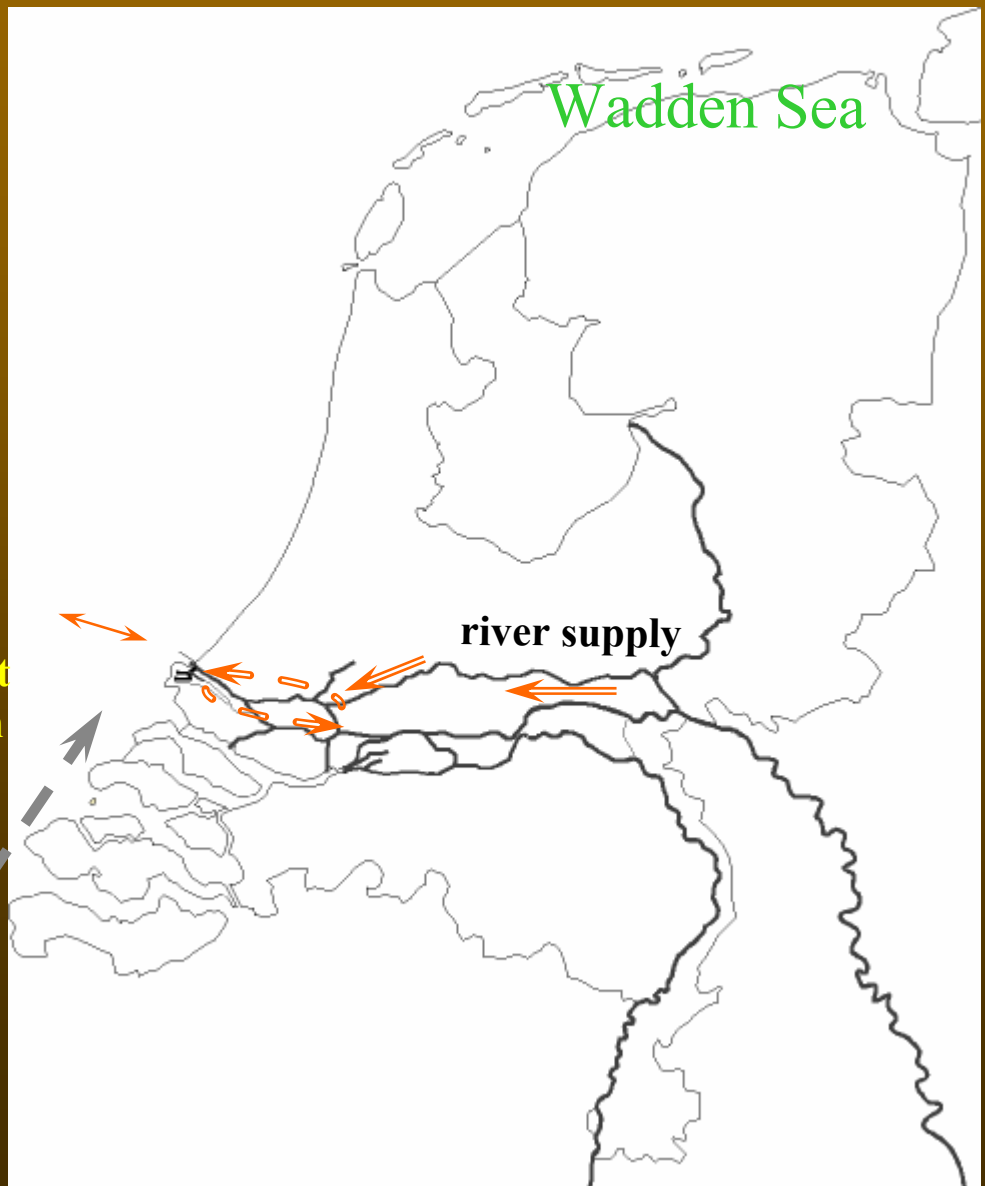
Now the time series was as follows:

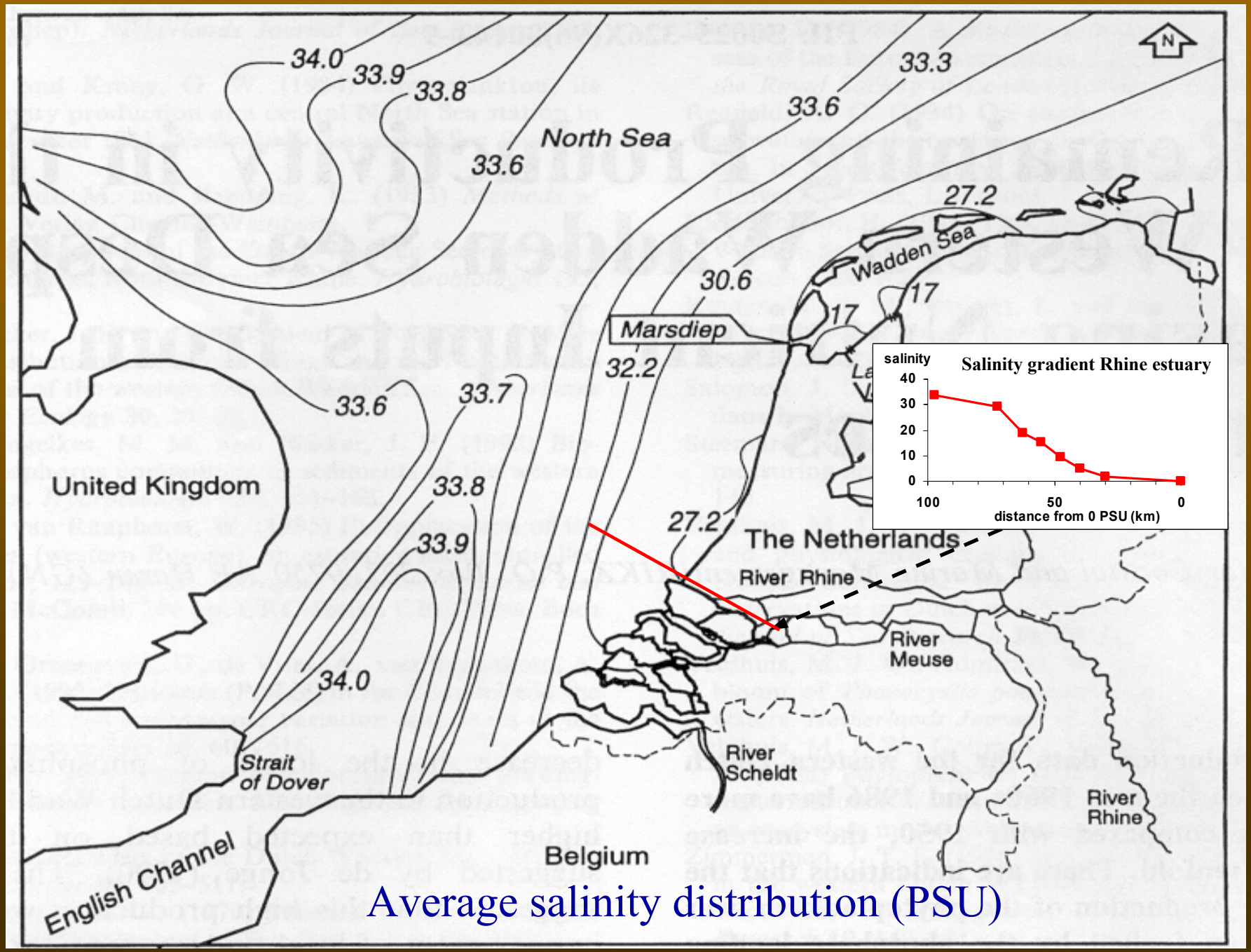


In 1990 the situation was completely different

Supply and accumulation of mud in the estuary

- sources for mud are Flemish Banks, river Rhine, Strait of Dover
- accumulation occurs due to several mechanisms



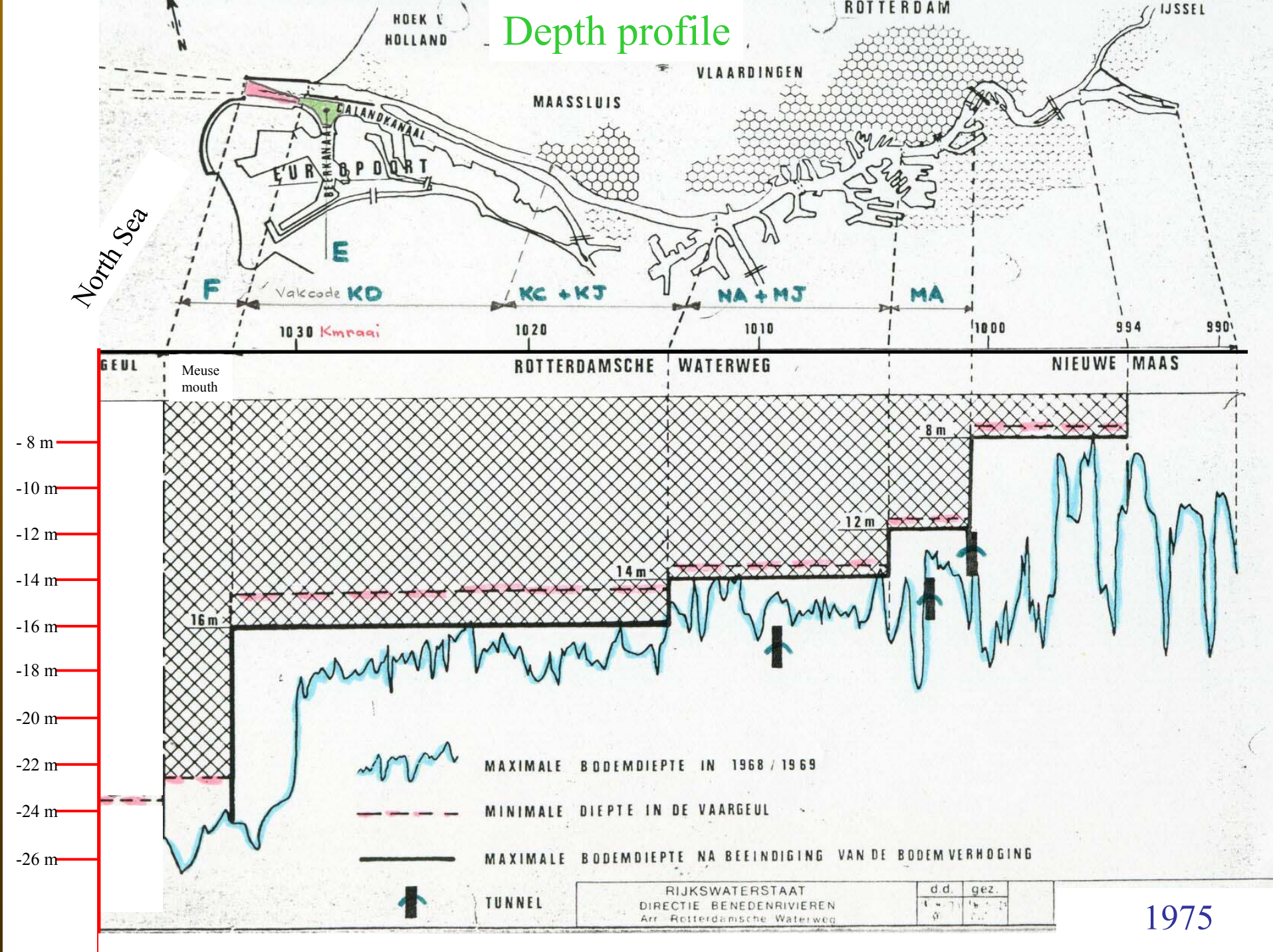


Average salinity distribution (PSU)

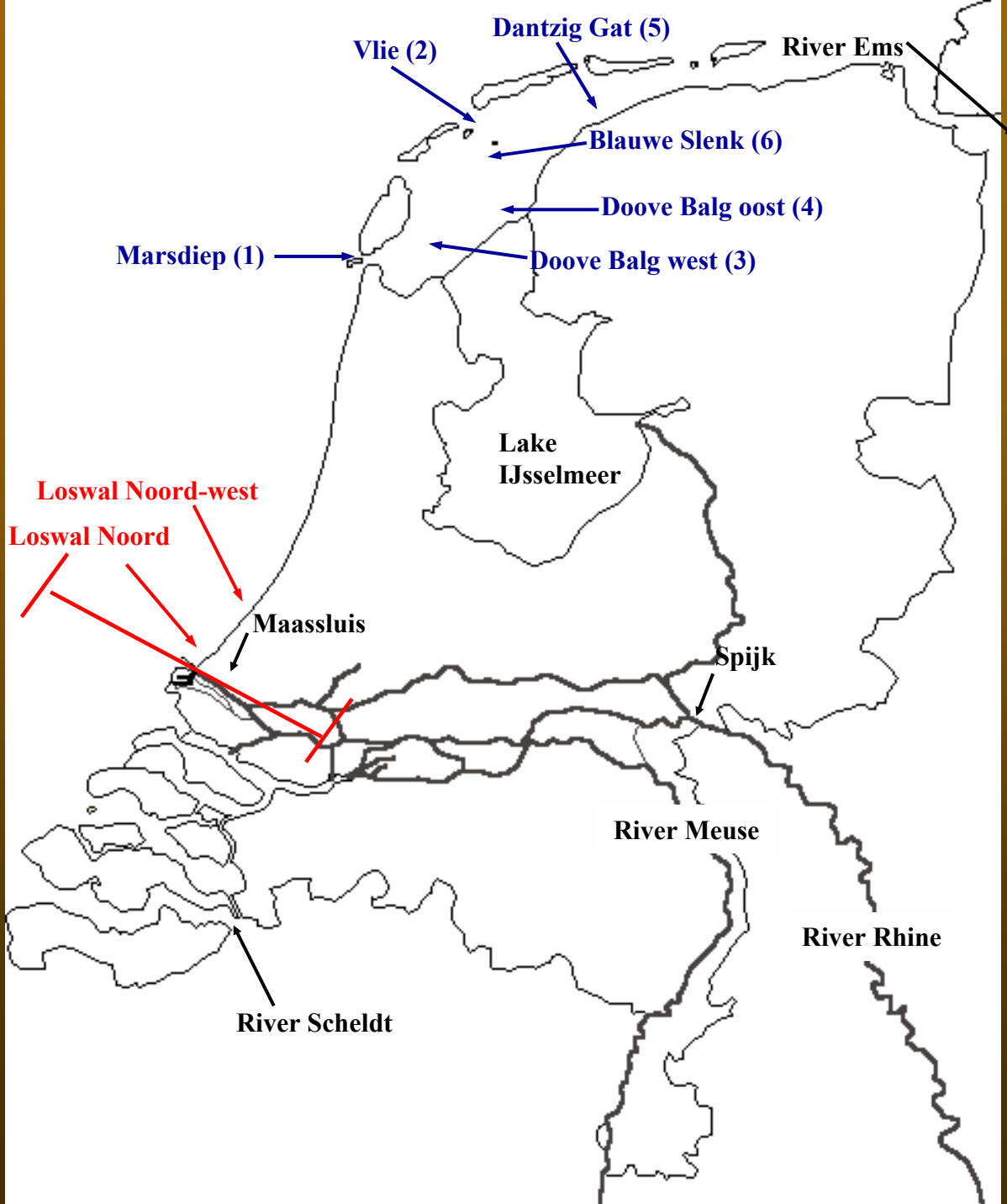

Van Dixhoorn triangle
(land reclmation)
Estuary has disappeared.
Europoort 29012006 © V.N. de Jonge


Dutch Delta 29012006 © V.N. de Jonge

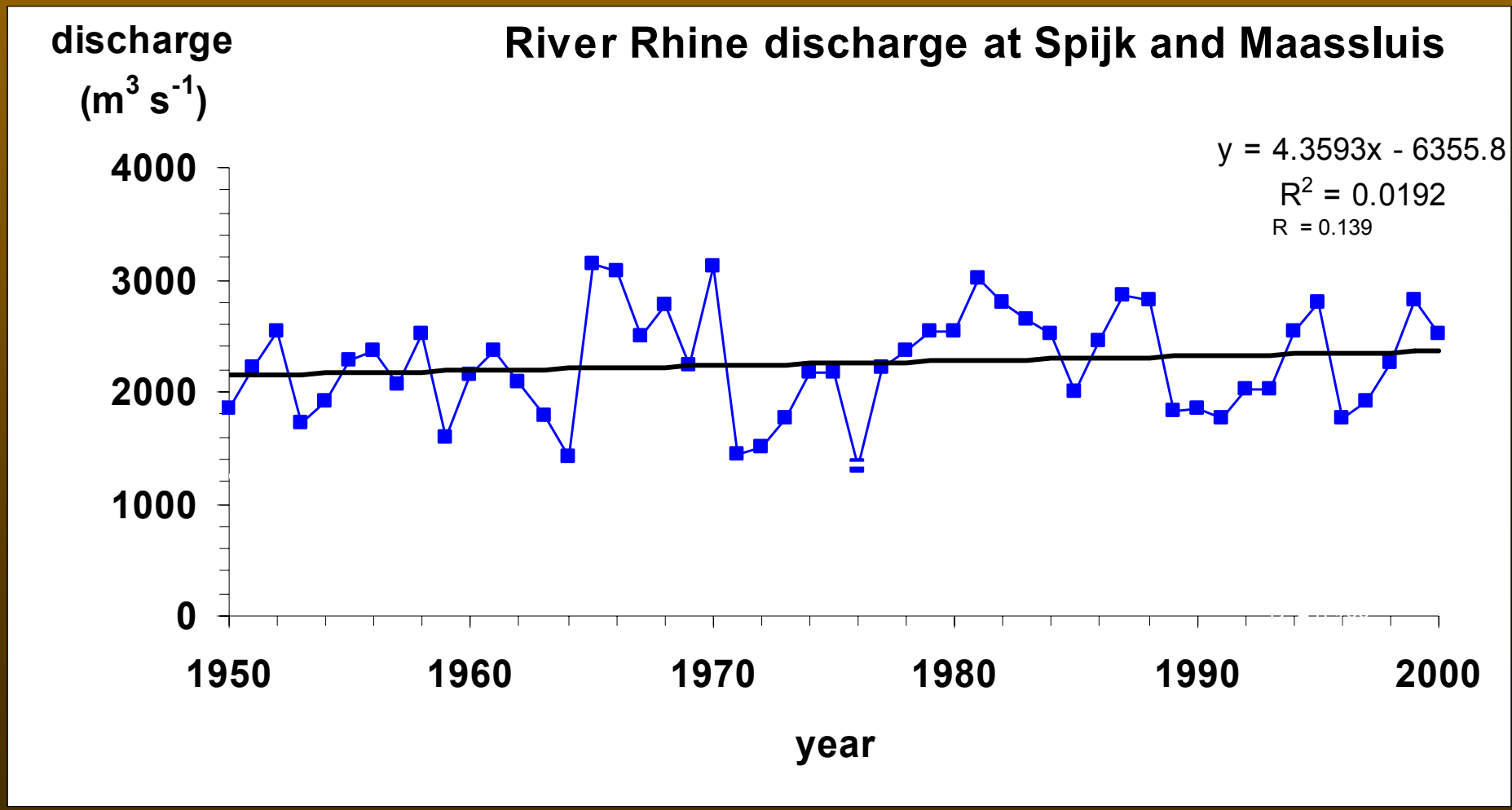
Depth profile



1975

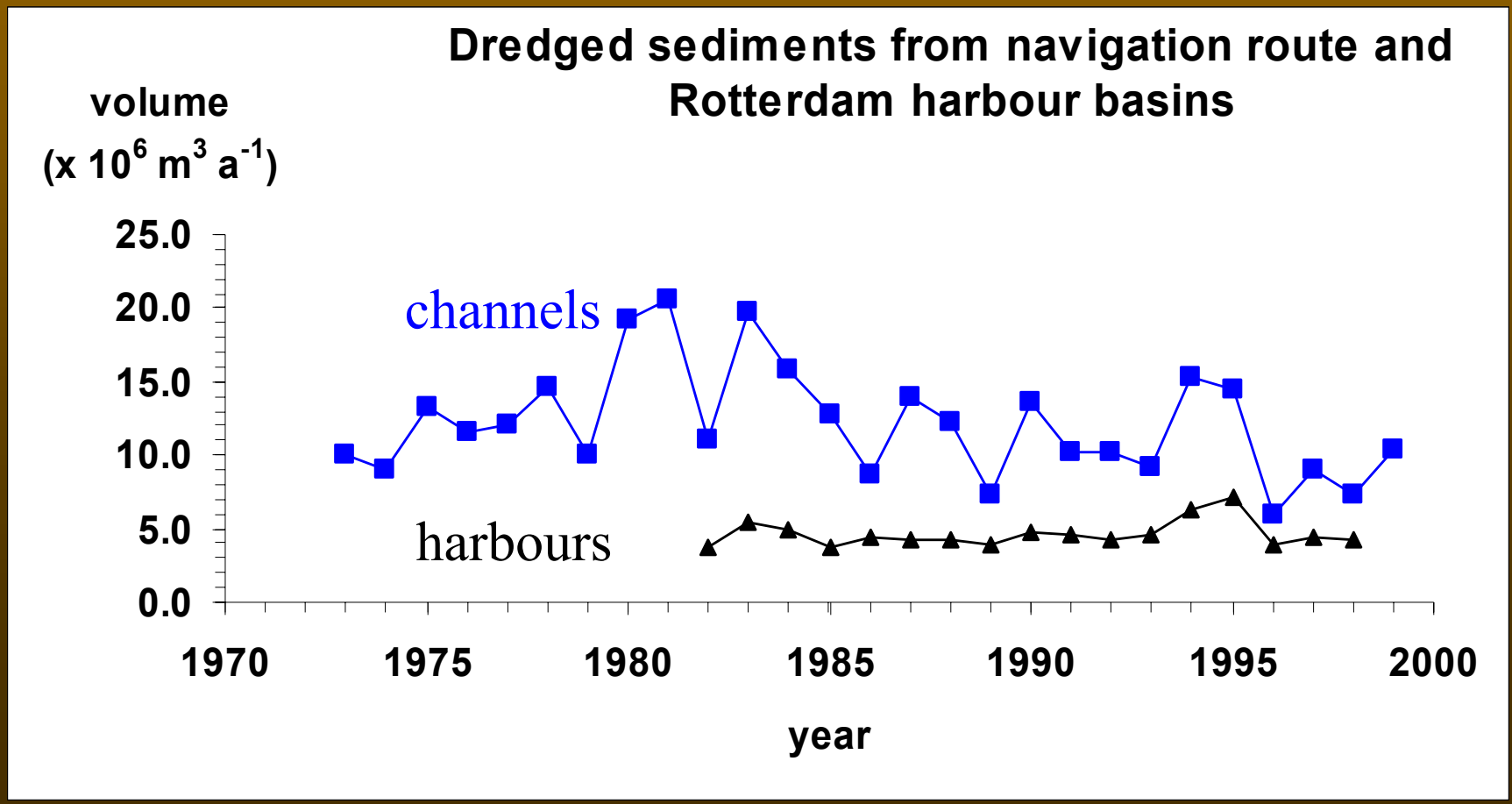

Dantzig Gat (5)
Vlie (2)
River Ems
Blauwe Slenk (6)
Doove Balg oost (4)
Marsdiep (1)
Doove Balg west (3)
Lake
IJsselmeer
Loswal Noord-west
Loswal Noord
Maassluis
Spijk
River Meuse
River Rhine
River Scheldt

Apart from variation in SPM in Wadden Sea also long term variation in
1. river discharge



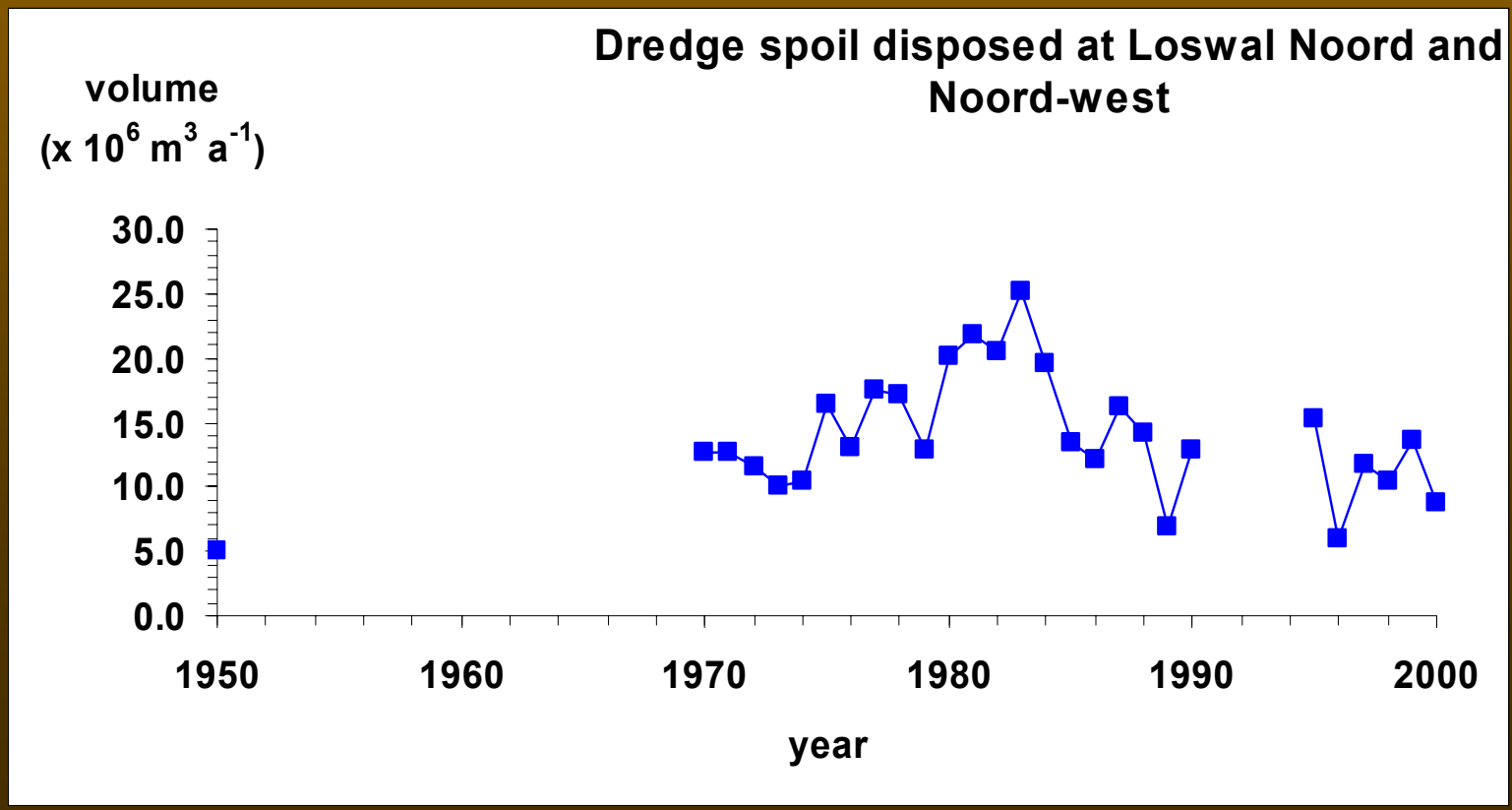
Apart from variation in SPM in Wadden Sea also long term variation in

1. river discharge
2. dredging in channels and harbours

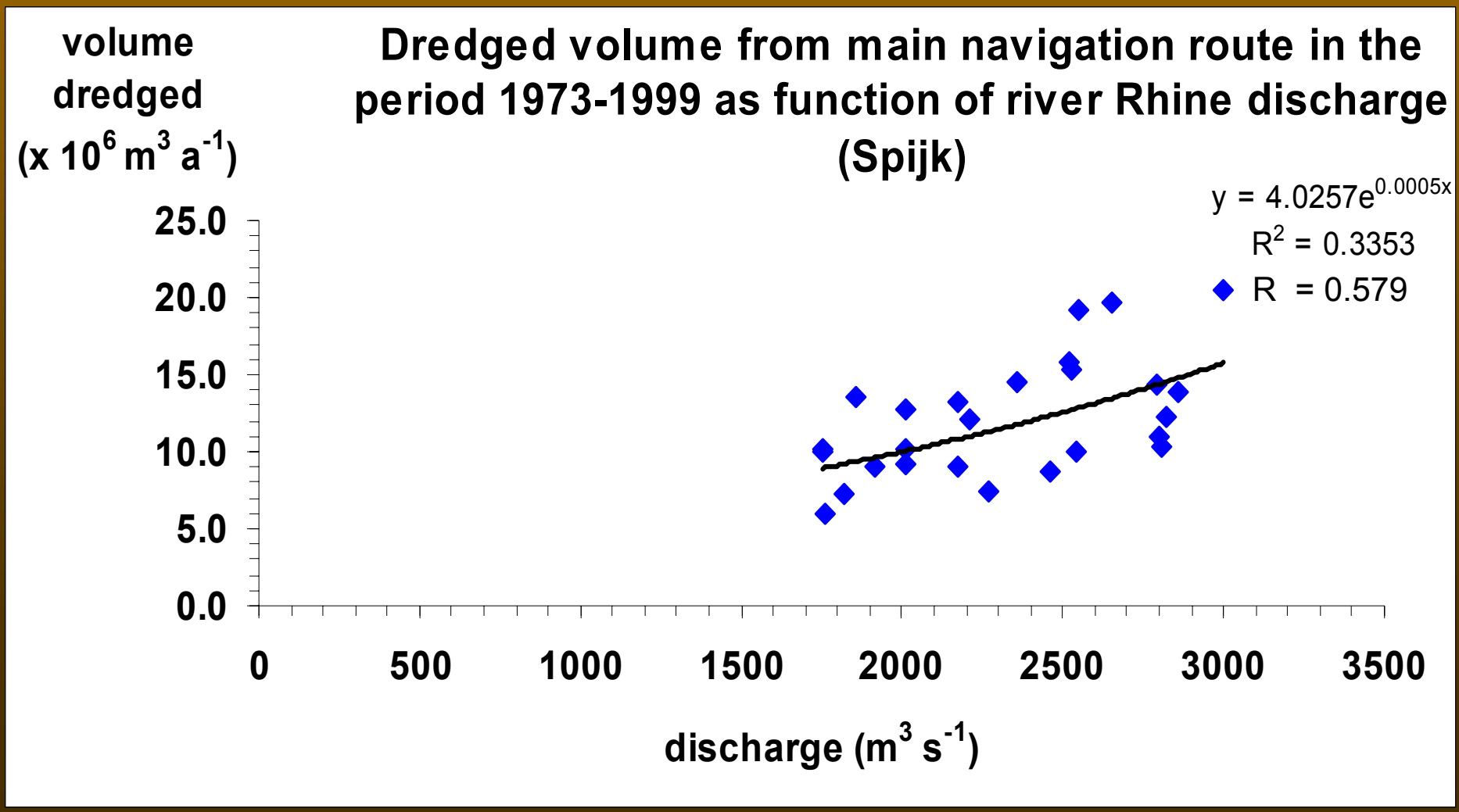


Apart from variation in SPM in Wadden Sea also long term variation in

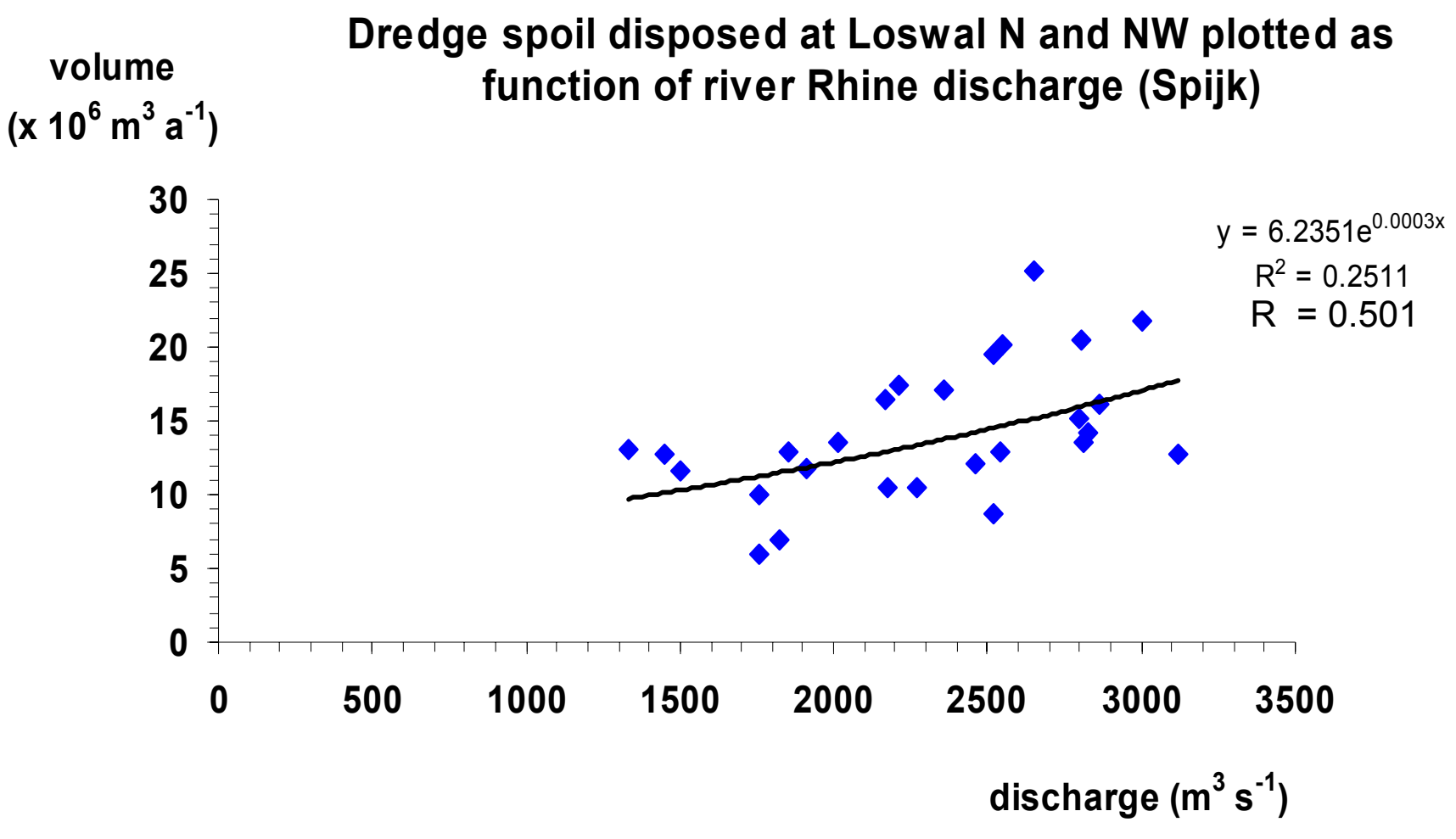
1. river discharge
2. dredging in channels and harbours
3. disposal of harbour sludge in coastal zone



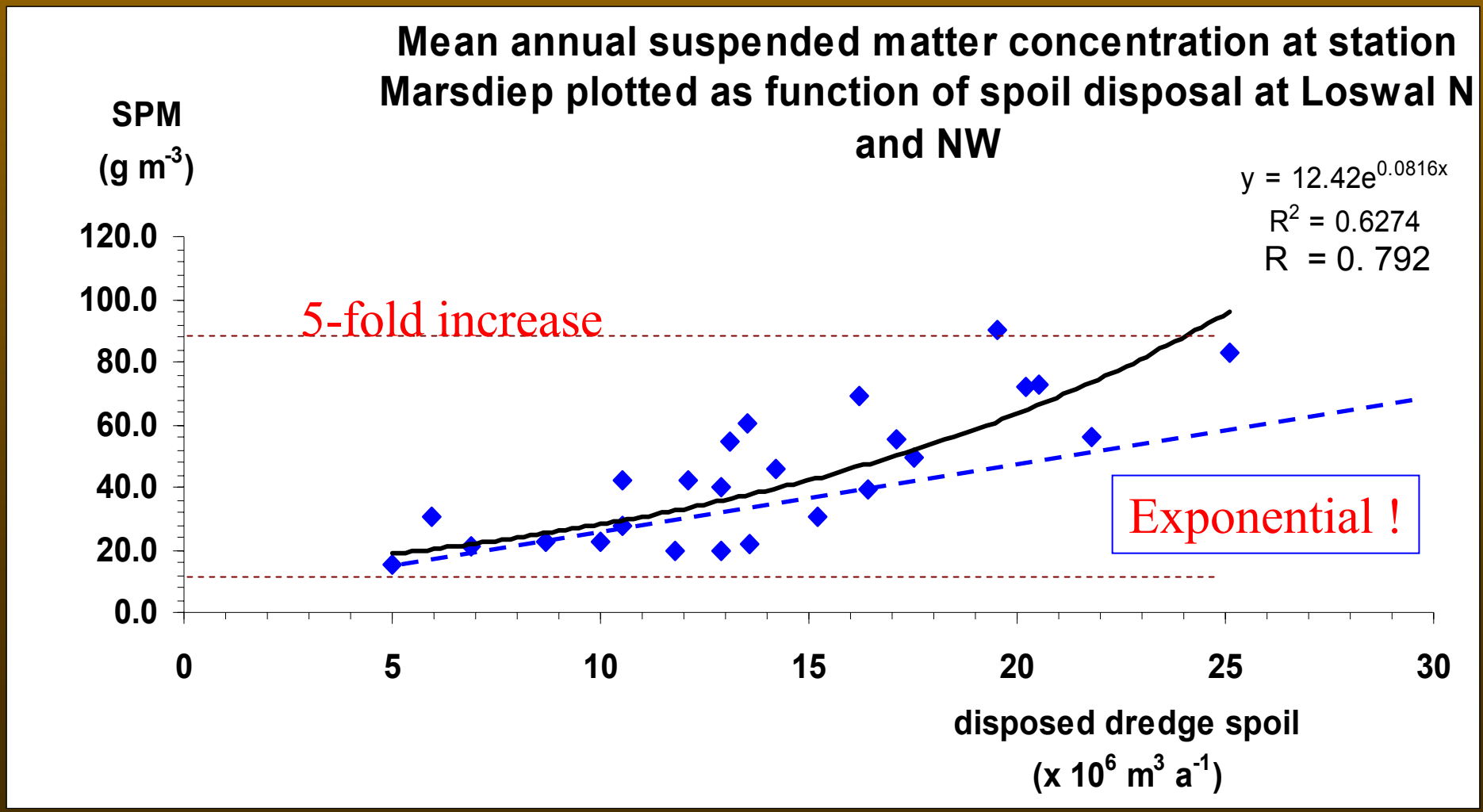
There are patterns recognizable! dredging seems a function of river discharge and may thus be 'global change' related!



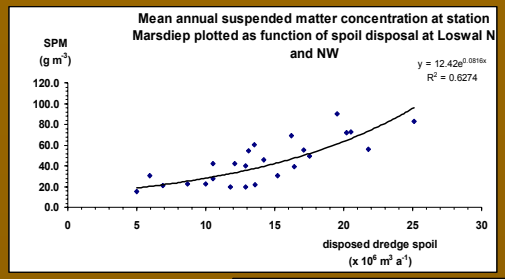
disposed harbour sludge seems also a (weaker) function of river discharge, but part is brought on land due to heavy pollution



Most interesting are the 5 plots where SPM is plotted as a function of the dredge spoil disposal

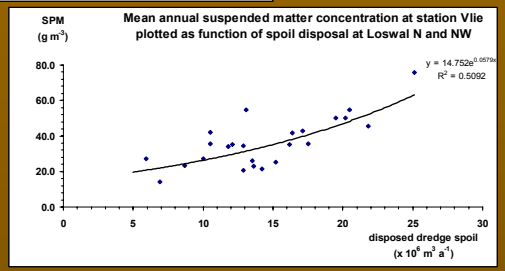


Marsdiep

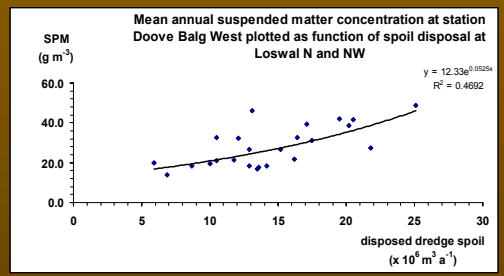


Jonge, V.N. & D.J. de Jong, 2002. 'Global Change' impact of inter-annual variation in water discharge as a driving factor to dredging and spoil disposal in the river Rhine system and of turbidity in the Wadden Sea.
Estuarine Coastal Shelf Science 55: 969-991.

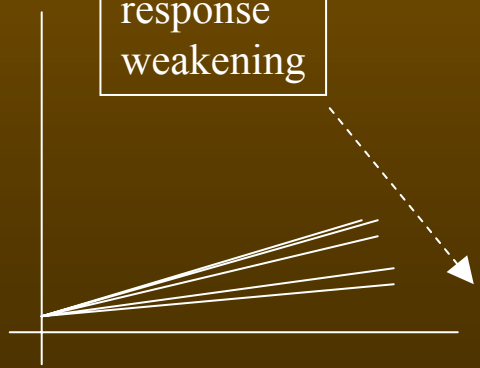
Vlie



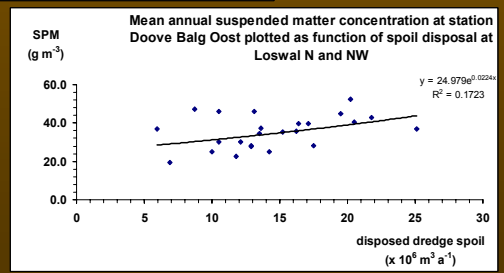
Doove Balg west



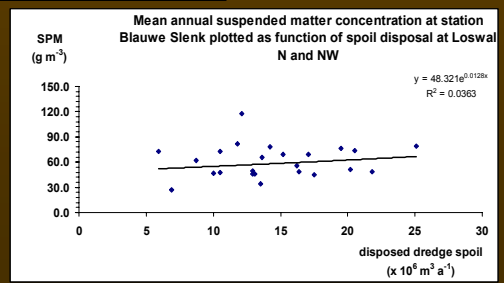
response weakening



Doove Balg oost



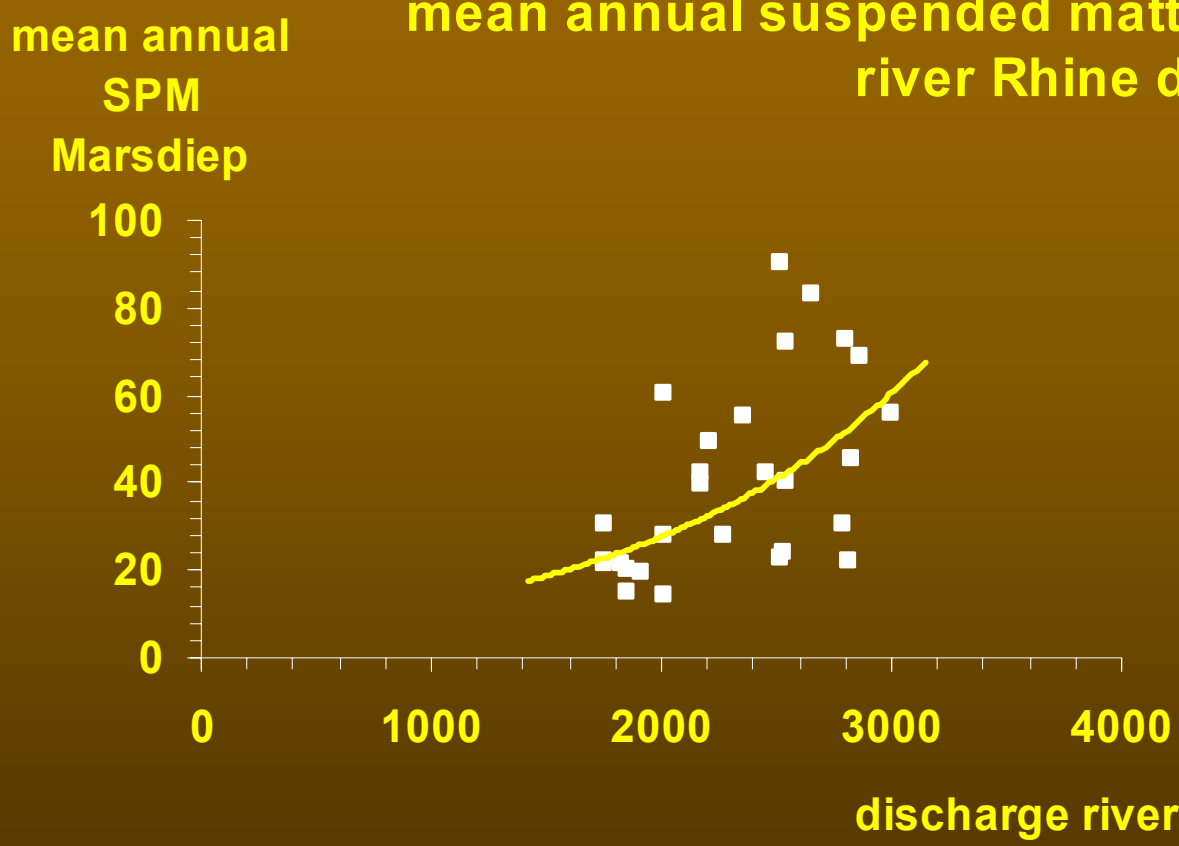
Blauwe Slenk



Weekening of the slope is suggesting:

1. In tidal inlets mainly the spoil + tide
2. In the shallow basins mainly the wind

mean annual suspended matter Marsdiep as function of river Rhine discharge



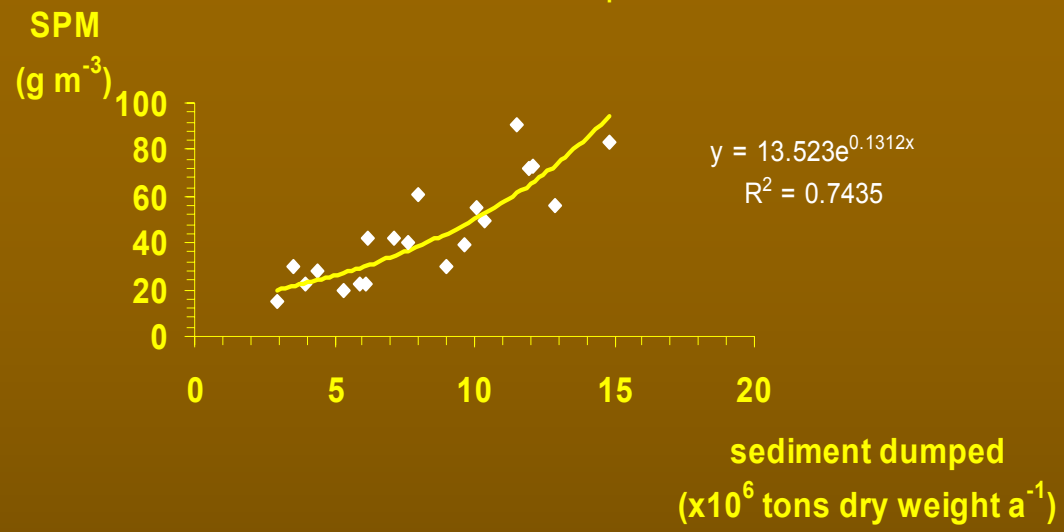
$y = 5.8339e^{0.0008x}$

$R = 0.45$

For station Marsdiep the relationship between SPM and dredge spoil disposal ($r = 0.8$; $P<0.001$)
SPM and river discharge ($r = 0.4$; $0.01<P<0.02$)

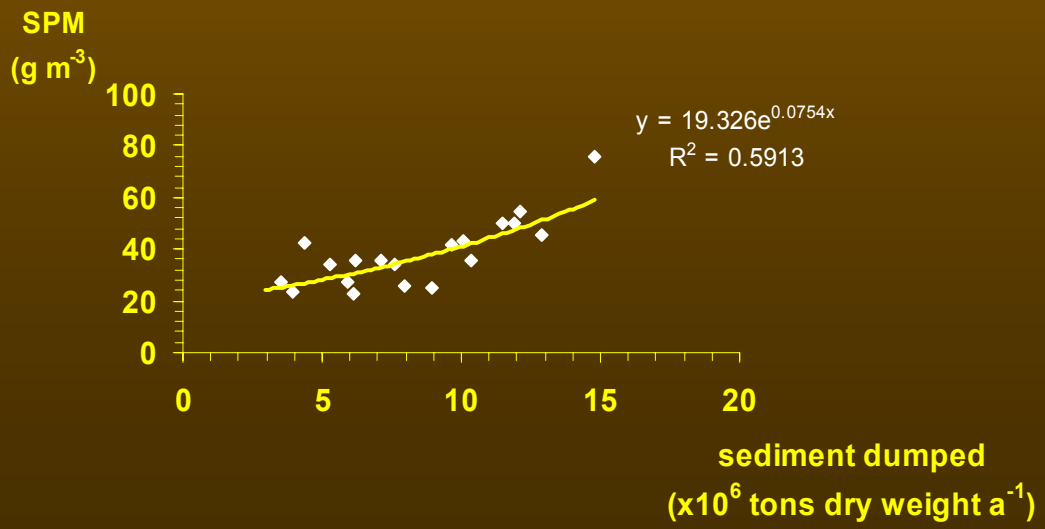
This suggests that both play a role

Mean annual suspended matter Marsdiep as function of dumps at Loswal Noord



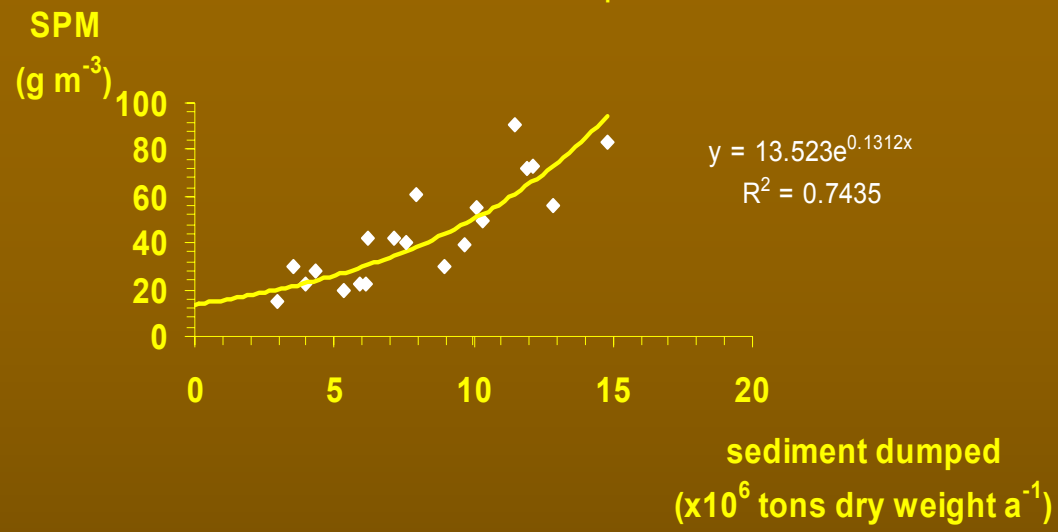
Marsdiep tidal inlet

mean annual suspended matter Vlie as function of dumps at Loswal Noord



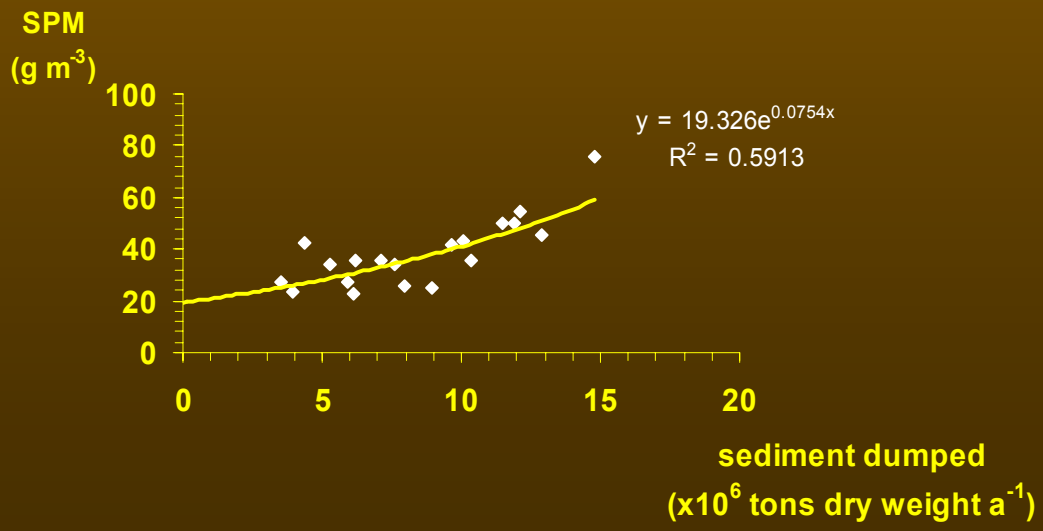
Vlie tidal inlet

Mean annual suspended matter Marsdiep as function of dumps at Loswal Noord



Marsdiep tidal inlet

mean annual suspended matter Vlie as function of dumps at Loswal Noord



Vlie tidal inlet

Some conclusions:
Natural background concentration <20 mg l^{-1}
Mean increase in SPM about 250%
Max increase about 700%

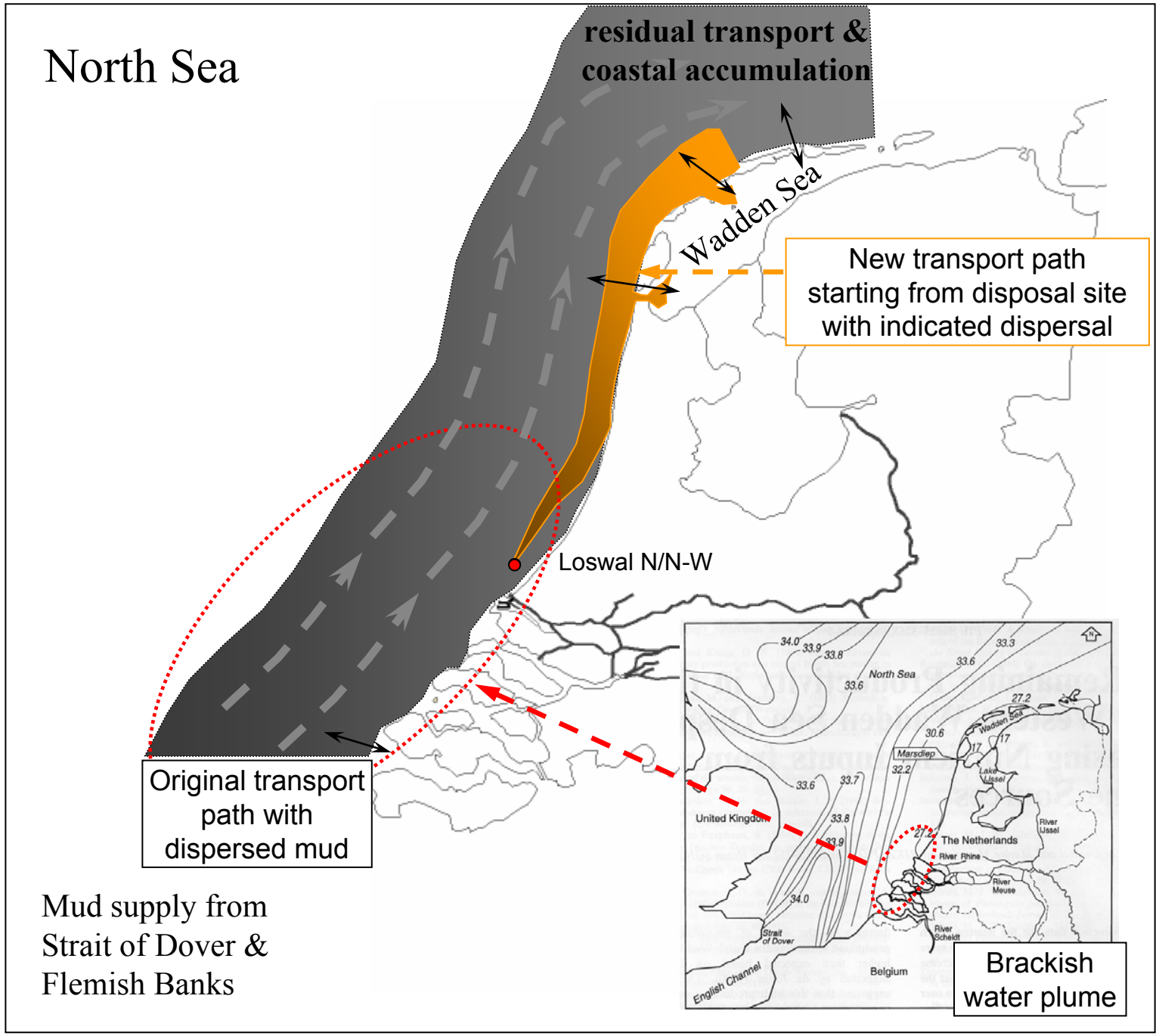
Causes
1. River discharge
2. Dredge spoil disposal

Under expected 10% increase in river discharge further structural increase in SPM by about 15%

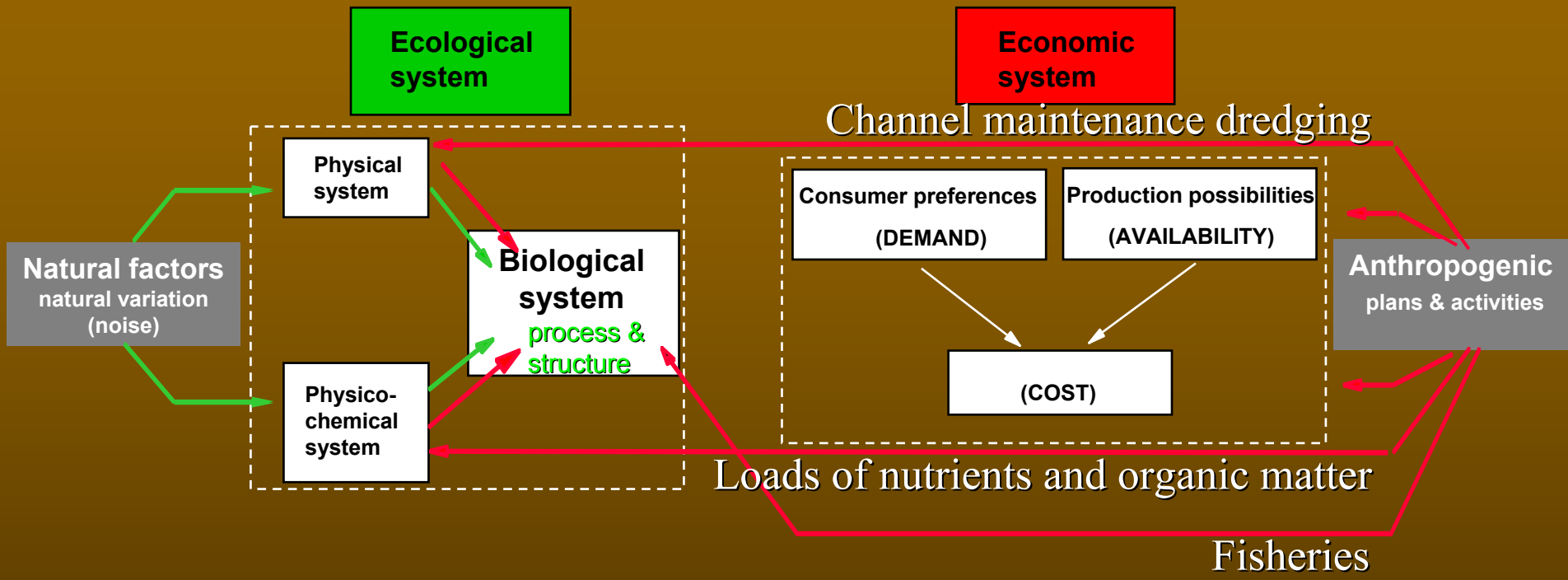
How to explain this correlation?

Rotterdam harbour authorities do nothing else then recharging the coastal zone with mud which was accumulated by the tide and the estuarine density circulation. However, …….

Mud accumulated from an unknown large part of the brackish river Rhine
(+ Meuse, Scheldt, etcetera)
water plume is deposited at one point close to the coastline. It can not escape from that area!!


North Sea
residual transport &
coastal accumulation
Wadden Sea
New transport path
starting from disposal site
with indicated dispersal
Loswal N/N-W
Original transport
path with
dispersed mud
Mud supply from
Strait of Dover &
Flemish Banks
Brackish
water plume
North Sea
Wadden Sea
Marsdiep
Lake Ijssel
River Ijssel
The Netherlands
River Rhine
River Meuse
River Scheldt
Belgium
United Kingdom
Strait of Dover
English Channel
34.0
33.9
33.8
33.6
33.3
33.7
32.2
30.6
27.2
17

The integral system



If we do not know what the natural signal drives and how it behaves then we can not detect the anthropogenic signal.

If we do not know the anthropogenic signal then we can not work on the restoration or conservation of human influenced coastal systems.

Total system variation = natural variation + effects of anthropogenic stress

Conclusion:

SEDNET may take the opportunity to focus on all aspects related to ‘mud’ (also ‘clean’ mud) to support the protection of functioning & structure of aquatic ecosystems (WFD annex V)

Thank you