Perspectives for the WFD

from

ERSEM ecosystem simulations

by

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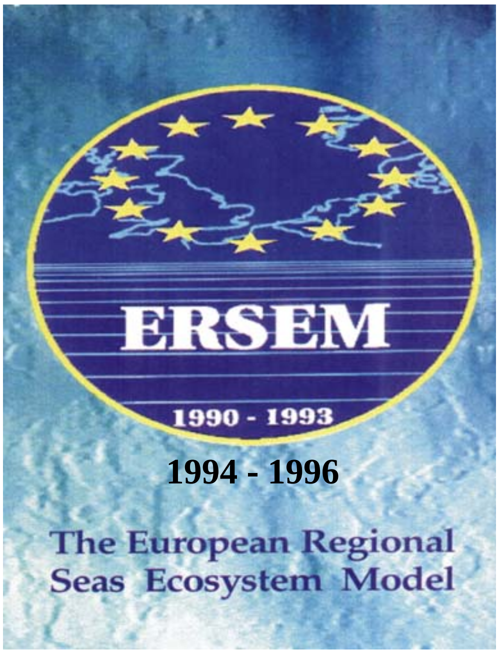
Overview:

- **ERSEM Introduction**
- **Lessons from 50% N-Reduction Scenario**
- **Simualtion towards Reference Values**
- **Reduction strategies in EUROCAT**
- **Future Perspectives**



The ERSEM Project

EU-Marine Science and Technology (MAST) Program

Funded:

1. **Period: 1990-1993**
2. **Period: 1994-1996**

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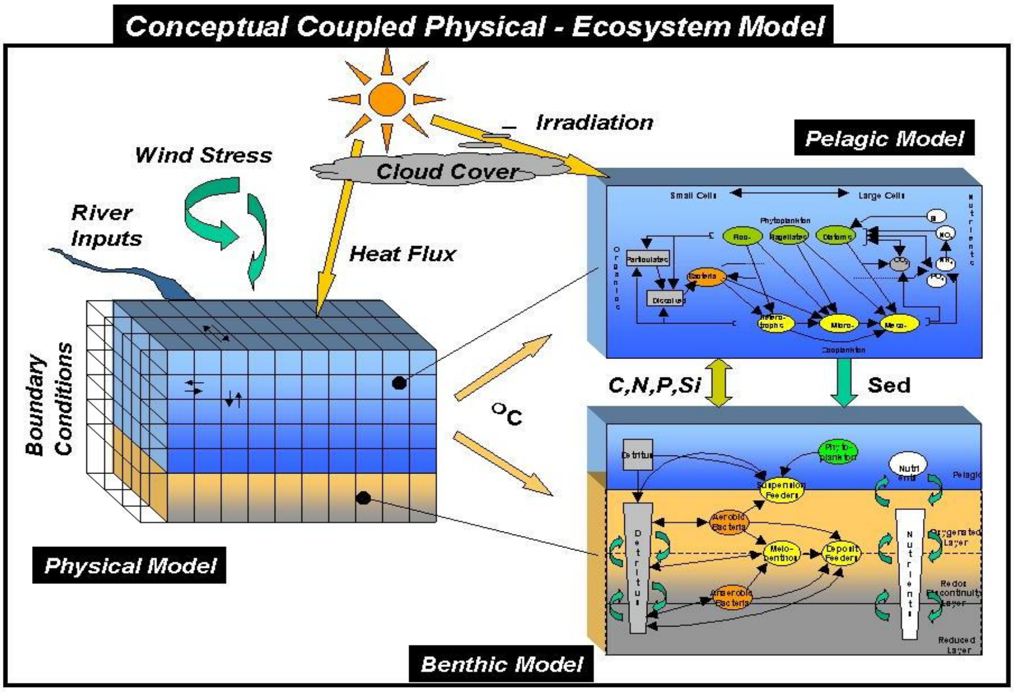
Short Overview on the ERSEM Project.

ERSEM: European Regional Seas Ecosystem Model



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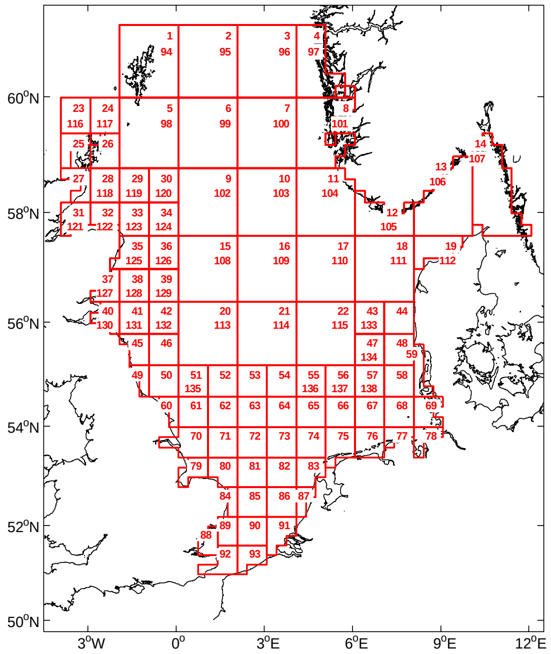
Conceptual diagram of the ERSEM model taken from the 3D Version of ERSEM by I. Allen (PML).



COCOA Setup

138 boxes in total

93 surface plus coastal boxes

45 lower boxes

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The Continental Coastal Application (COCOA) is an application of the ERSEM model which is based on a box model approach.

The box setup provides smaller boxes at the coast in order to resolve the coastal gradients.

The central North Sea is devided into an upper and a lower box, separated at 30 m depth,

to reflect the effects within the euphotic zone.

For details see:

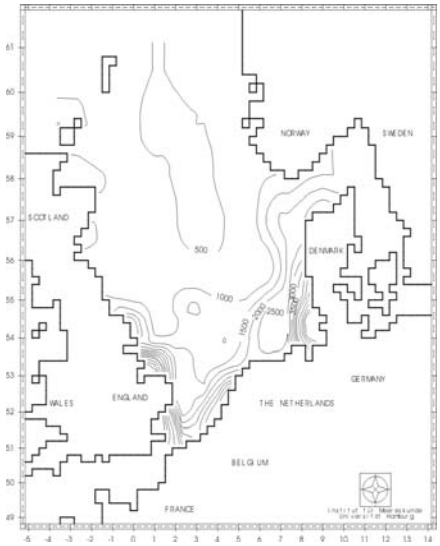
Lenhart, H.J., Radach, G., Ruardij, P., 1997.

The effects of river input on the ecosystem dynamics in the continental coastal zone of the North Sea using ERSEM.

J. Sea Res. 38, 249-274.

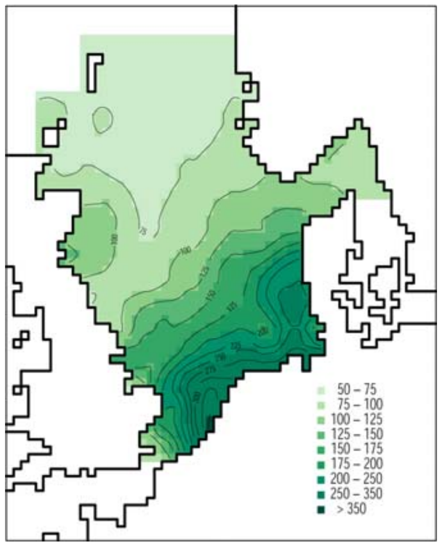
Suspended Matter Concentration

[mg m^{-3}]



Net Primary Production 1988

[g C m^{-2} a^{-1}]



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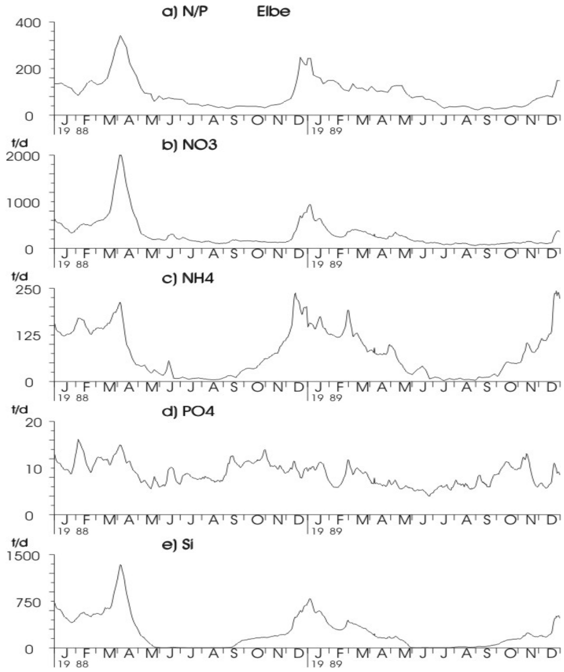
The two figures reflect the importance of the light climate in the coastal zone on the primary production within the ERSEM simulation for the year 1988.

On the left figure one can see the increased suspended matter concentration in the coastal areas,

especially in the German Bight. On left side a local maximum in the net primary production can be observed west of the Denmark coast. This maximum can be explained by a light limitation within the Elbe plume region based on high suspended matter concentrations. The consequence is that the nutrients imported by the Elbe can not be taken up in the plume region but downstream, when sufficient light climate for primary production is available.



Elbe nutrient load

	1988	1989
[kt/y]		
	145.	80.
	29.	26.
	4.	3.
	107.	67.

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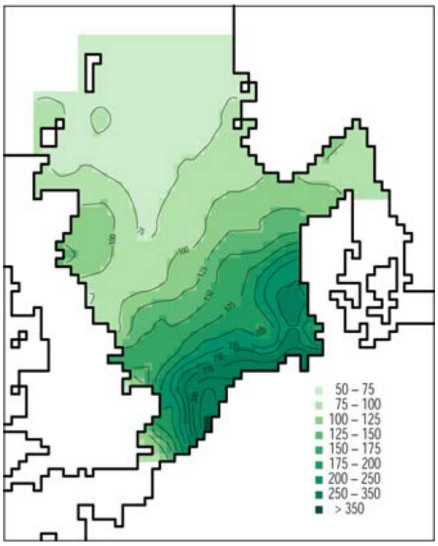
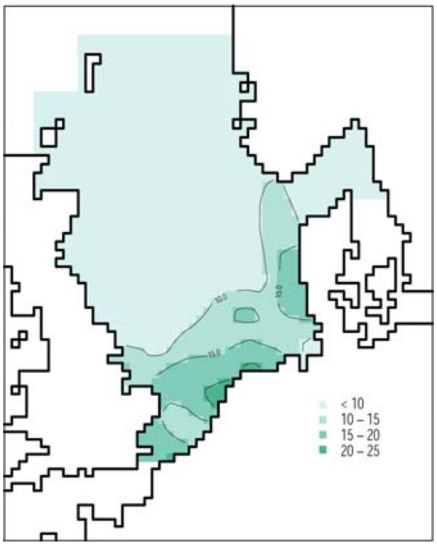
The figure shows the time series for the daily nutrient load and the resulting N/P ration for the Elbe input for the years 1988 and 1989.

The total yearly loads for the individual nutrients are expressed on the right.

Net Primary Production 1988 — Standard- vs. Reduction Run

[g C m^{-2} a^{-1}] — [Difference in %]





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The left figure shows the net primary production for the year 1988, based on realistic forcing data for that year.

The left figure expresses the difference to a reduction secenario, where the river inputs for N and P are reduced

by 50 % while all other forcing is kept the same as for the standard run on the left.

Taking 10 % as a threshold level one can see the major effects in the southern North Sea

with a resulting reduction of the net primary production up to 20 %, but only in small local spots.

Reduction scenario of river nutrient loads by 50 % with ERSEM showed:

- No poportional reduction in the ecosystem parameters

  **(e.g. winter nutrient concentration 40 % reduced;
  net primary production about 10 %, locally up to 20 %)**

- Changes are restricted to the continental coastal region

- Strong differences in dynamical response of the system

  (e.g. nutrient limitation N, P even Si; microbial loop more important)

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Summery from the 50 % reduction scenario.

For details see:

Lenhart, H.-J., 2001. Effects of River Nutrient Load Reduction on the Eutrophication of the North Sea, Simulated with the Ecosystem Model ERSEM. In: Kröncke, I. & Türkay, M. & J. Sündermann (eds), Burning issues of North Sea ecology, Proceedings of the 14th International Senckenberg Conference North Sea 2000, Senckenbergiana marit. 31(2), 299-311.

Open questions after 50 % reduction exercise:

A: Define reasonable reduction scenarios

WFD: When good status is failed

=> management steps required !

=> EUROCAT

B: Criteria to judge the effects of the Nutrient reduction: What is an „improvement" for the ecosystem ?

WFD: not as vague as „sustainable use" target

=> Reference conditions required !

=> Decribed in terms of Indicators

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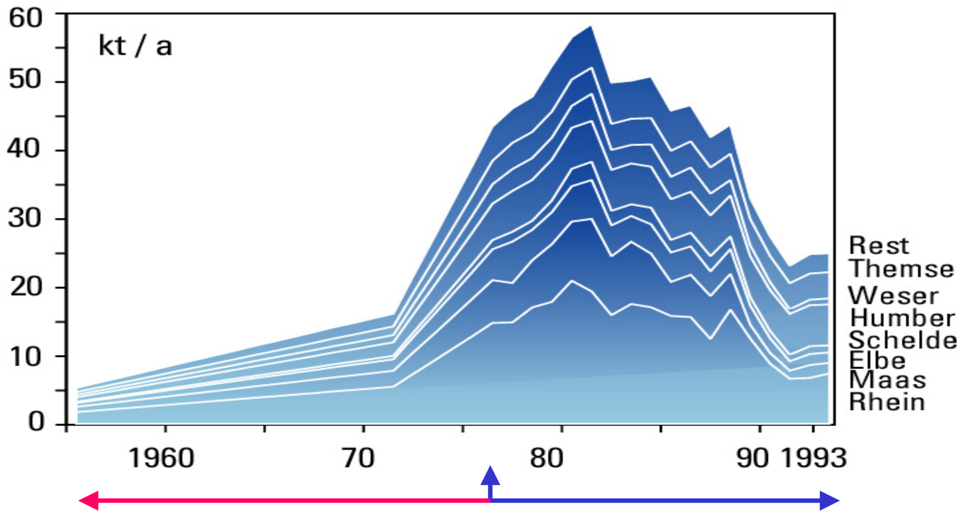
Cumulative phosphate load by rivers into the North Sea



Extrapolation - Interpolation **of measurements**

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Cumulative presentation of the phosphate river inputs into the North Sea.

Before the year 1977 the load data were extrapolated by sparce single measurements.

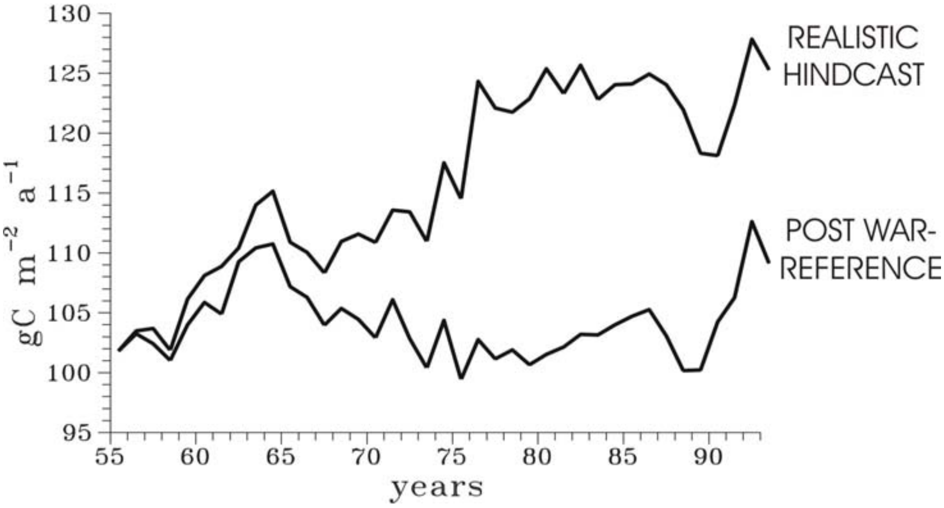
From 1977 on the data for the continental coastal region are based on interpolation from regular measurements form monitoring stations.

For details see:

Pätsch, J. and Lenhart, H.-J., 2004. Daily loads of nutrients, total alkalinity, dissolved inorganic carbon and dissolved organic carbon of the European continental rivers for the years 1977-2002. Berichte aus dem Zentrum für Meeres- und Klimaforschung; Reihe B: Ozeanographie, No 48, 159pp.

ERSEM: Long Term Simulation

North Sea Net Primary Production



Pätsch & Radach, JSR 38, 1997

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Estimates for the integrated Net Primary Production over the North Sea from the Long Term Simulation (1955-1993) with ERSEM.

The upper curve reflects a realistic hindcast where all the forcing for the years is taken as realisic as possible.

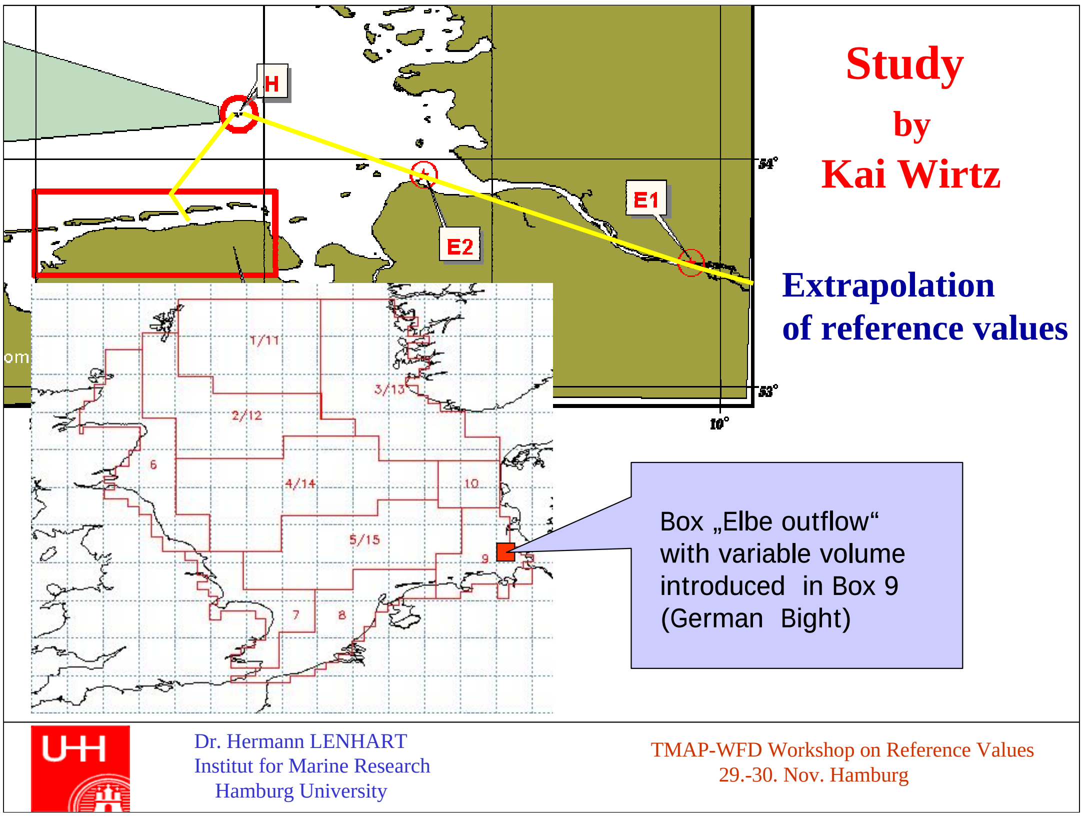
The lower curve, referred to as „post war-condition“, is based on the model output with a realistic forcing as

the upper curve except that the river input is kept on a level of 1955.

One should not that the lower curve shows a steep increase in the net primary production for the first ten years and also in the last years.

For details see:

Pätsch, J. and Radach, G., 1997. Long-term simulation of the eutrophication of the North Sea: temporal development of nutrients, chlorophyll and primary production in a comparison to observations. J. Sea Res. 38, 275-310.



Overview on the model combination used for the study by Kai Wirtz

(ICBM, Uni Oldenburg, now GKSS Research Center Geesthacht):

Extrapolation von Hintergrundwerten und Unsicherheitsanalyse mit Hilfe von Modellierungsverfahren

Bericht im Auftraqg des Niedersächsischen Landesamtes für Ökologie (Forschungsstelle Küste, Außenstelle WHV)

Projekt „Ermittlung von Hintergrundwerten von biologischen und chemischen Meßgrößen in dt. Küstengewässern

(EU-Wasserrahmenrichtlinie)“

Derived Background Concentrations for German Bight Box

Parameter	Jan-Mar.	April-Jun.	July-Sep.	Oct.-Dec.	Yearly Mean
PO4 (m mol m^{-3})	0.4	0.1	0.1	0.2	0.2
NO3 (m mol m^{-3})	2.7	0.8	0.2	0.4	1.0
NH4 (m mol m^{-3})	3.2	1.2	0.4	1.7	1.6
SiO (m mol m^{-3})	9.0	8.1	7.4	8.8	8.3
Chl (mg m^{-3})	0.6	1.6	1.1	0.9	1.1
TN (m mol m^{-3})	9.7	8.6	6.4	7.0	7.9
TP (m mol m^{-3})	0.6	0.5	0.4	0.5	0.5

=> including estuary processes + boundary conditions

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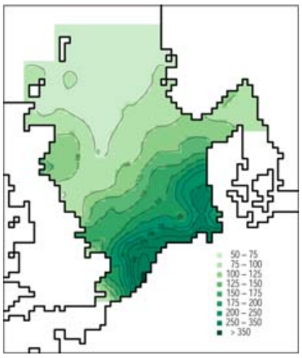
Table on the derived background concentration for the German Bight Box from the Kai Wirtz study.

The values appear to be very low, the reason might be that estuary processes are dealt wich in great detail

and the appropriate boundary condition were chosen with great care.

EUROCAT-Project:

Combining River Basin Management with Marine Ecosystem Modelling



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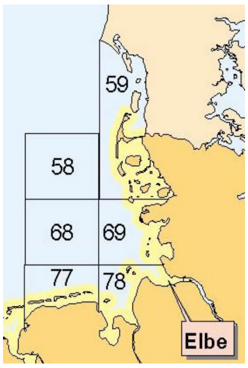

Comparing 1995 data

K. Hesse
FTZ-Büsum

Box	68		69		78	
	Model	Field	Model	Field	Model	Field
Mean winter DIN concen. (mmol N m^{-3})	31.1	36.5	119.0	65.6	135.9	139.2
Mean winter DIP concen. (mmol P m^{-3})	1.2	0.9	3.4	1.7	3.6	2.5
Mean winter DIN / DIP ratio	26.2	40.4	34.9	40.9	39.3	50.8
Mean winter DIN / Si Ratio	2.5	3.0	1.8	1.8	1.6	2.3
Mean winter DIP/ Si Ratio x 10^2	9.5	10.3	5.3	4.6	4.0	4.8
Timimg of spring bloom	17	n.a.	16	16	18	n.a.

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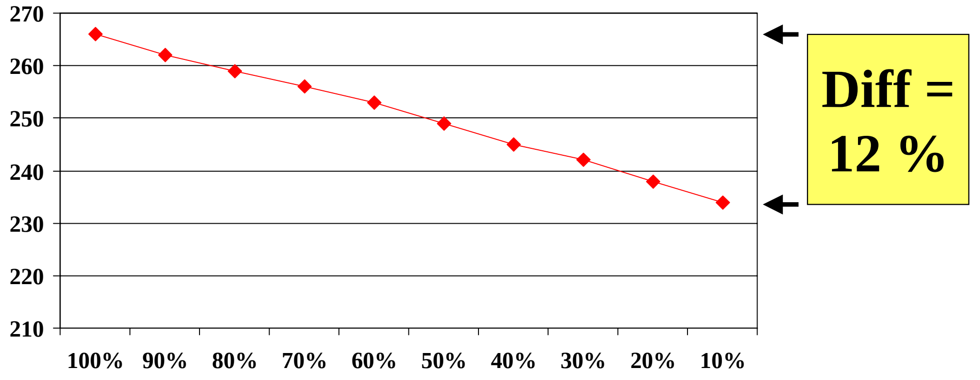
Comparison between ERSEM results within the COCOA box setup and aggreagated field data compiled by K. Hesse from the FTZ Büsum. The map defines the 6 boxes from the COCOA setup which are used as „Elbe box“ within EUROCAT.

Net Primary Production [g C m^{-2} a^{-1}]
vs. river load reduction for the Elbe region



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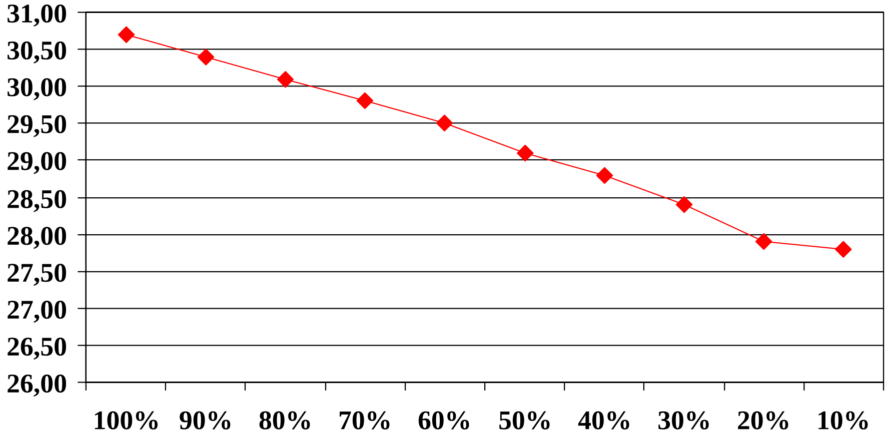
Results from a sensitivity analysis from the COCOA application in relation to a linear stepwise 10 % decrease in the

Elbe river input by P and N. The total difference between the standard run for the year 1995 and a reduction of the

Elbe river input to 10 % of the standard value for the net primary production is only 12 %.

DIN / DIP ratio
in relation to river load reduction
for the Elbe region



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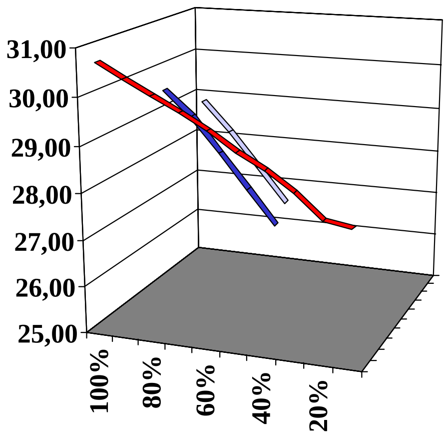
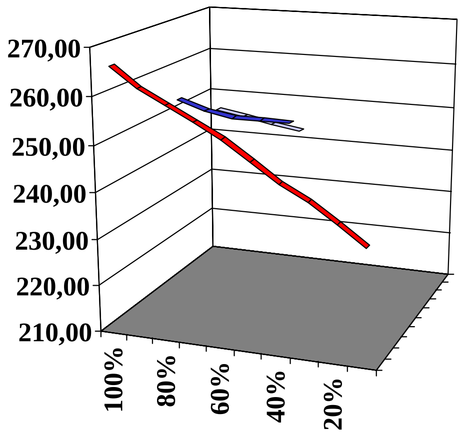
Overview on the DIN / DIP ratio related to a linear 10 % stepwise reduction in the Elbe river load by 10 %.

Linear vs. non-linear reduction strategies for Elbe region

DIN/DIP ratio



Net Primary Production
[g C m^{-2} a^{-1}]



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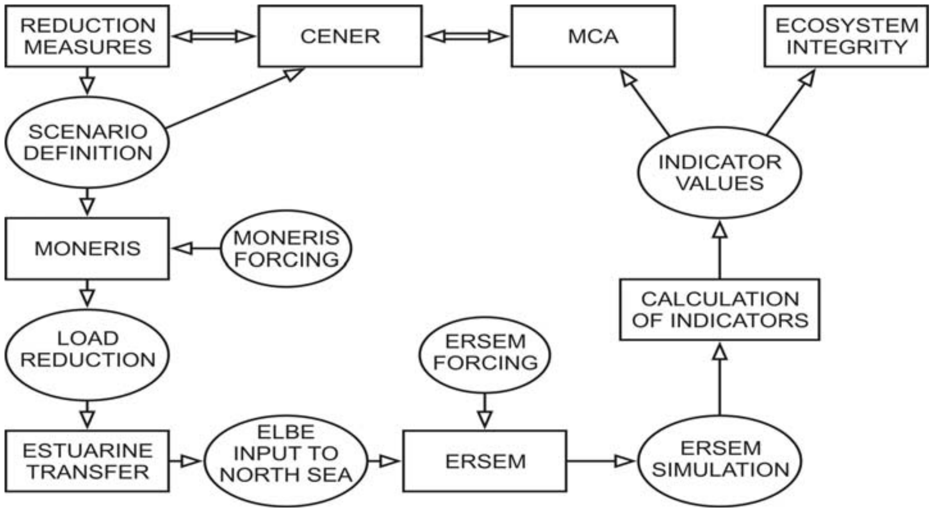
Comparison between a linear (red) and a non-linear (blue, gray) stepwise reduction of the Elbe river input by 10 %.

In the non-linear approach the P load of the Elbe is kept constant e.g. at 80 % while the the N load is further reduced in 10 % steps. One can notice that the DIN/DIP ration in the non-linear approach is drastically reduced in the ongoing reduction, while in the net primary production the reduced level of N load is hardly noticable. This can be interpreted as a hint that within the Elbe region even with the stron reduction in the Elbe river load no nitrogen-limitation is reached.

EUROCAT information flow



Hofmann et al., Regional Environmental Change, 2004

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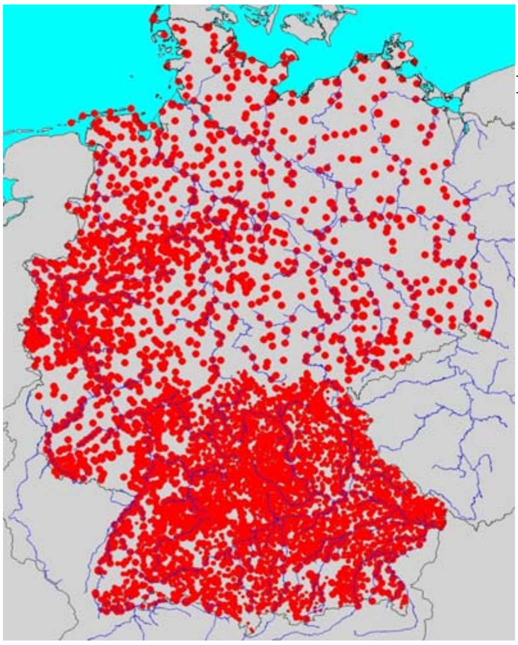
Conceptual diagram representin the information flow between the different models in EUROCAT.

The aim in EUROCAT is an integrated approach combining a nurient emission model for river basins,

a North Sea ecosystem model and socio-economical assessments. From the ecosystem simulations

Ecological Quality Indicator (EQI) are derived to describe changes in the ecosystem

MONERIS: MOdelling Nutrient Emissions in RIver Systems
CENER: Cost Effective Nutrient Emmission Reduction
ERSEM: European Regional Seas Ecosystem Model
MCA: Multiy Criteria Analysis



MONERIS

Modelling Nutrient Emission in River Systems

Estimate nutrient inputs into river basins

7 pathways considered:

- point sources
- atmospheric deposition
- erosion
- surface runoff
- groundwater
- tile drainage
- paved urban areas

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Scenarios in EUROCAT for Elbe

BAU (Business as usual) — **N + P at 80 %**

- 50 % Reduction of emissions (point- + diffuse sources) in Czech Republic
- increased storage volume of combined sewer systems (50 % retention)

PT (Policy Target) — **N + P at 70 %**

- conservative tillage on 50 % of arable land
- reduction of tile drained areas by 10 % of their total length
- 100 % retention of particulate sewage (no leakages of septic tanks)

DG (Deep Green) — **N + P at 60 %**

- Increased storage volume of combined sewer systems (100 % retention)
- conservative tillage on 90 % + reduction of tile drained areas by 25 %
- Introduction of Denitrification in wastewater treatment plants
- Establishment and usage of wetlands as retention areas
- Introduction of nitrogen taxation

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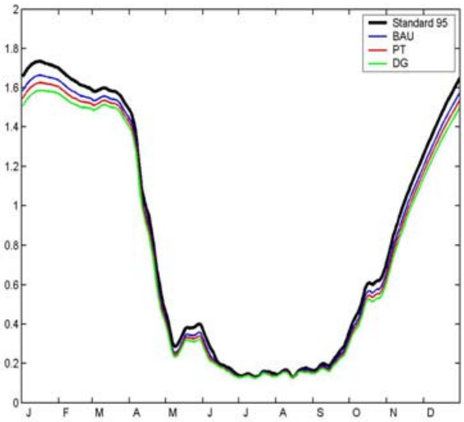
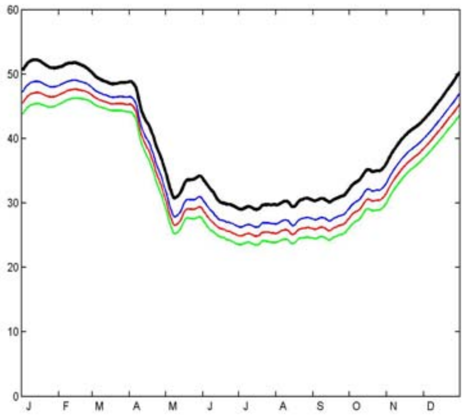
Time series of DIP and DIN for the Elbe Box for standard run & scenarios

DIP (m mol P m^{-3})



DIN (m mol N m^{-3})



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Simulated time series from COCOA for the integrated Elbe box.

The black line represents the standard run for 1995, while the coloured one indicate the different reduction scenarios

(blue: BAU; red: PT; green: DG)

As already indicated within the non-linear reduction exercise the Elbe box appears not to be nitrogen-limited for all three reduction scenarios.

Elbe Box	Standard 95	BAU		PT		DG	
		Elbe-Red	NS-Red	Elbe-Red	NS-Red	Elbe-Red	NS-Red
Mean winter DIN concen. (mmol N m^{-3})	**51.4**	**48.5**	**44.3**	**45.9**	**40.8**	**45.5**	**37.2**
Mean winter DIP concen. (mmol P m^{-3})	**1.7**	**1.6**	**1.5**	**1.6**	**1.4**	**1.5**	**1.3**
Mean winter DIN / DIP ratio	**30.7**	**30.9**	**29.9**	**29.8**	**29.4**	**29.5**	**28.9**
Net Primary Production (gC m^{-2} a^{-1})	**266.**	**259.**	**245.**	**256.**	**233.**	**253.**	**221.**
Diatom / Non-Diatom ratio	**0.37**	**0.37**	**0.39**	**0.38**	**0.42**	**0.38**	**0.44**

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Comparison between local reduction scenarios related to the Elbe river input (Elbe-Red.) and North Sea wide reductions

(NS-Red) for all rivers entering the North Sea. The difference between the two runs within each reduction level (BAU, PT, DG) is a first indication of the trans-boundary processes acting within the EUROCAT Elbe box.

WFD – Perspective I

A suit of indicators combining ecosystem models and WFD is needed

=> focus ecosystem state variables for WFD

=> especially for sediment

From reduction scenario additional requirement

=> Responsiveness of state variables as indicators

WFD – Perspective II

For Reference condition:

=> Accepted set of boundary condition

For Reference condition and reduction scenario:

=> Estuary model for German rivers

=> Wadden Sea model

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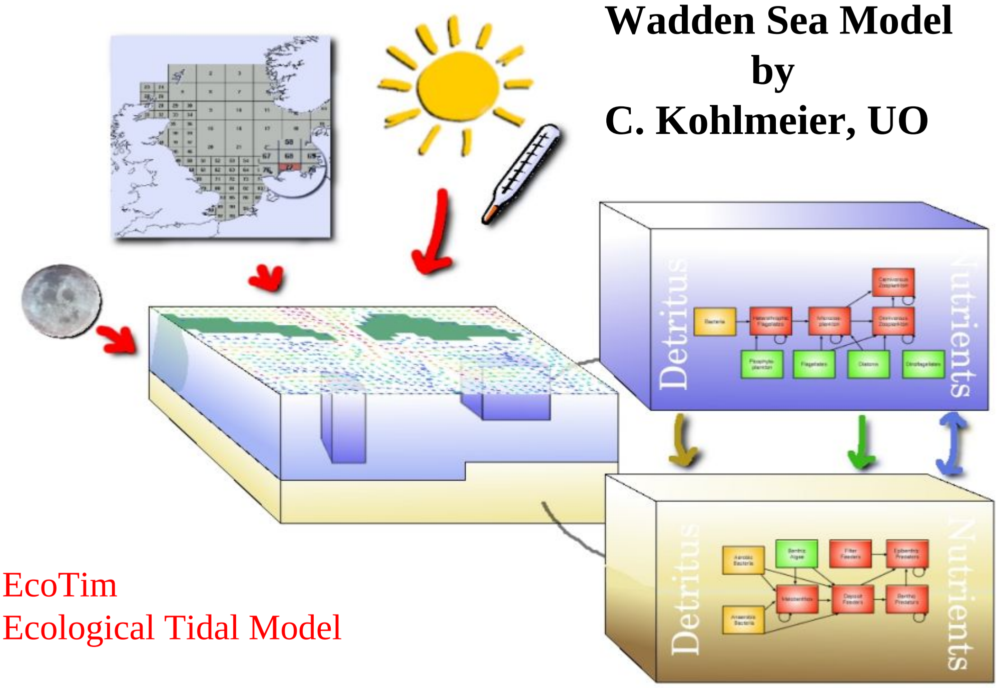
Wadden Sea Model
by
C. Kohlmeier, UO



EcoTim
Ecological Tidal Model

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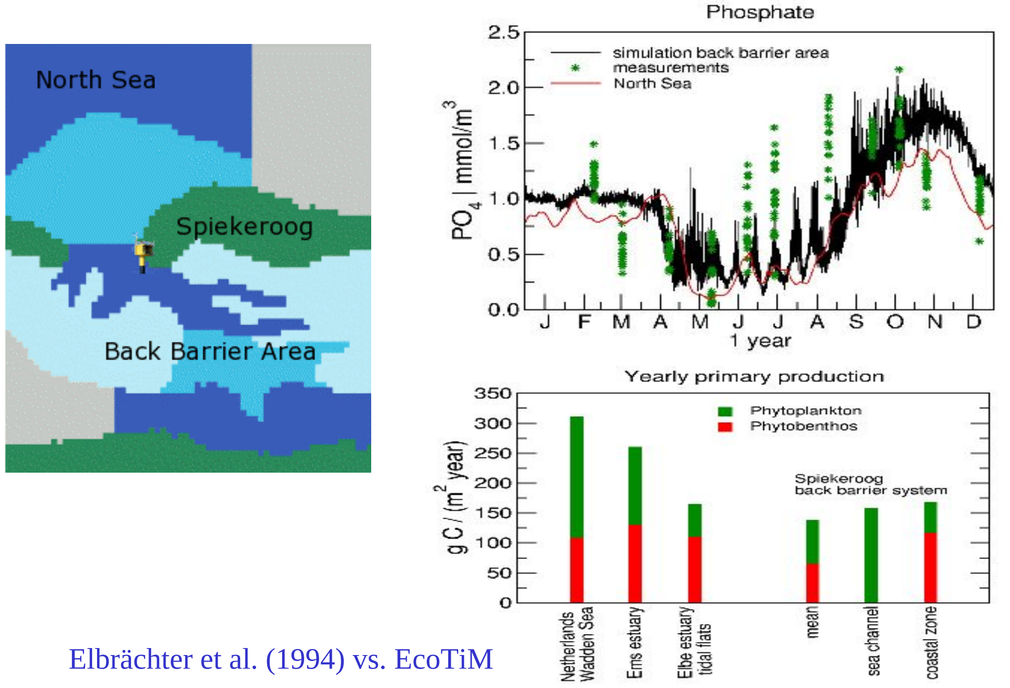
An example for a new Wadden Sea model, the conceptual diagram of EcoTim.



Elbrächter et al. (1994) vs. EcoTiM

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First results from the EcoTim model.

For details see:

Kohlmeier, C.: Modellierung des Spiekerooger Rückseitenwatts mit einem gekoppelten Euler-Lagrange-Modell auf der Basis von ERSEM. 2004. 224 S. Dissertation, Carl von Ossietzky Universität Oldenburg

Ebenhöh W, Kohlmeier C, Baretta JW, Flöer G (2004) Shallowness may be a major factor generating nutrient gradients in the Wadden sea. Ecological Modelling 174 (3): 241-252

Kohlmeier C (2003) ECOTIM - Ecological tidal model. In Rullkötter J. (ed.), BioGeoChemistry of Tidal Flats - Proceedings of a Workshop held at the Hanse Institute of Advanced Study, Delmenhorst (Germany), 14-17 May. Forschungszentrum Terramare, Wilhelmshaven, Berichte Nr. 12, 77-80. ISSN 1432-797X.

Thanks for support

	J. Pätsch		I. Allen
	K. Wirtz		J. Hofmann
	C. Kohlmeier		K. Hesse

Daily Loads of Nutrients, Total Alkalinity, DIC and DOC of the European Continental Rivers for the Years 1977 - 2002

J. Pätsch & H. Lenhart
ZMK Report 48; Nov. 2004

ftp.ifm.uni-hamburg.de/pub/data/riverload/

=> abstract on handout