Some Aspects of Indirect Interactions in Aquatic Ecosystems:

Case Study of Rostherne Mere and Implications for Environmental Management & Comparative Theoretical Ecosystem Analysis

Vladimir Krivtsov

Examples of Important Indirect Relationships

- Mesozoic volcanic activity – extinction of dinosaurs
- Increased use of fertilisers – eutrophication and deterioration of water quality
- Increased consumption of fossil fuels – greenhouse effect, global warming and increased frequency of natural disasters
- Increased use of CFC – depletion of ozone layer
- Activity of proterozoic cyanobacteria – development of modern atmosphere & *Homo Sapiens*

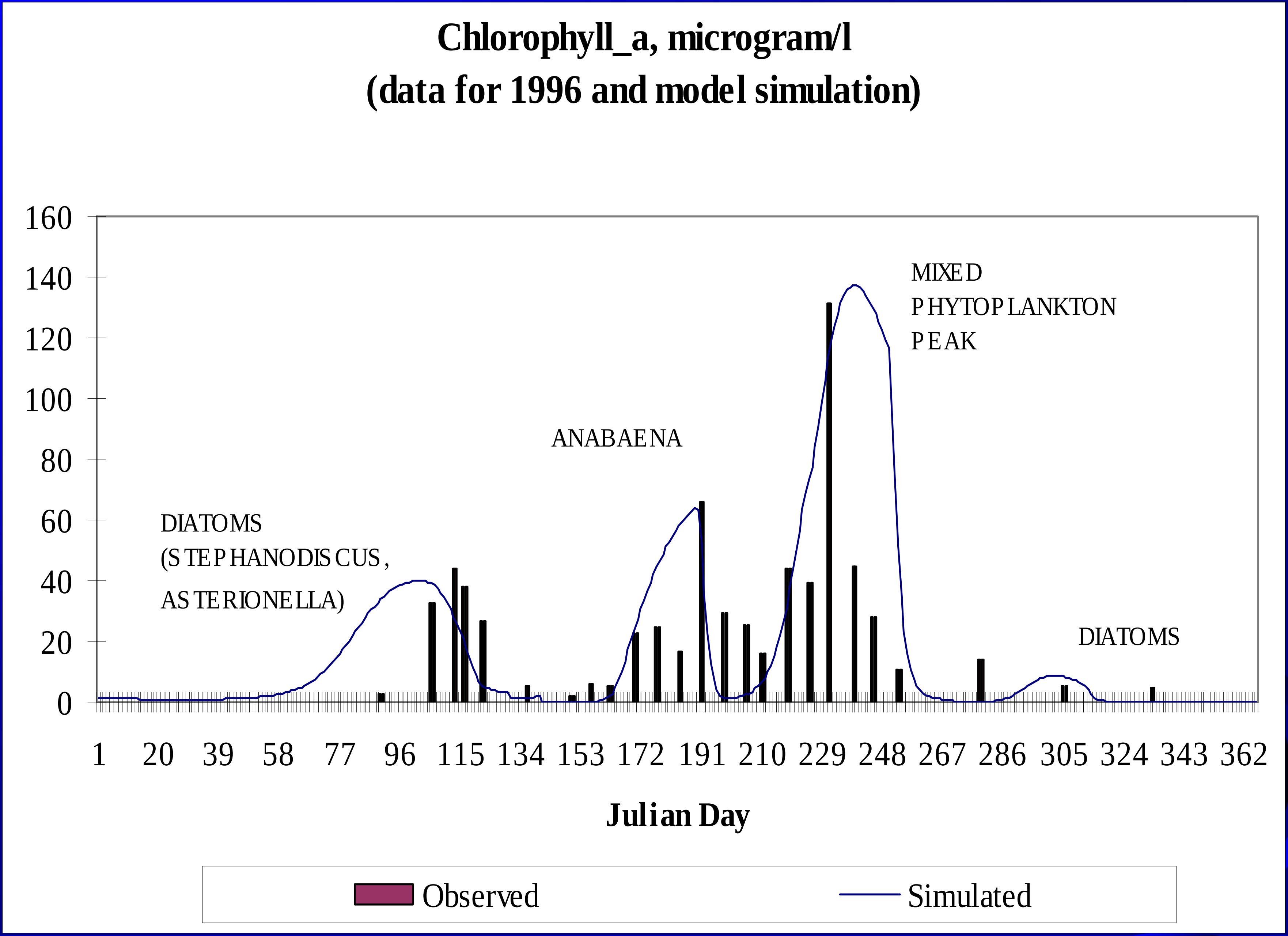
Approaches to Study Indirect Relationships

- ☞ *Theoretical*
- ☞ *Experimental*
- ☞ *Observational*

The above are combined in the Comparative Theoretical Ecosystem Analysis (CTEA)

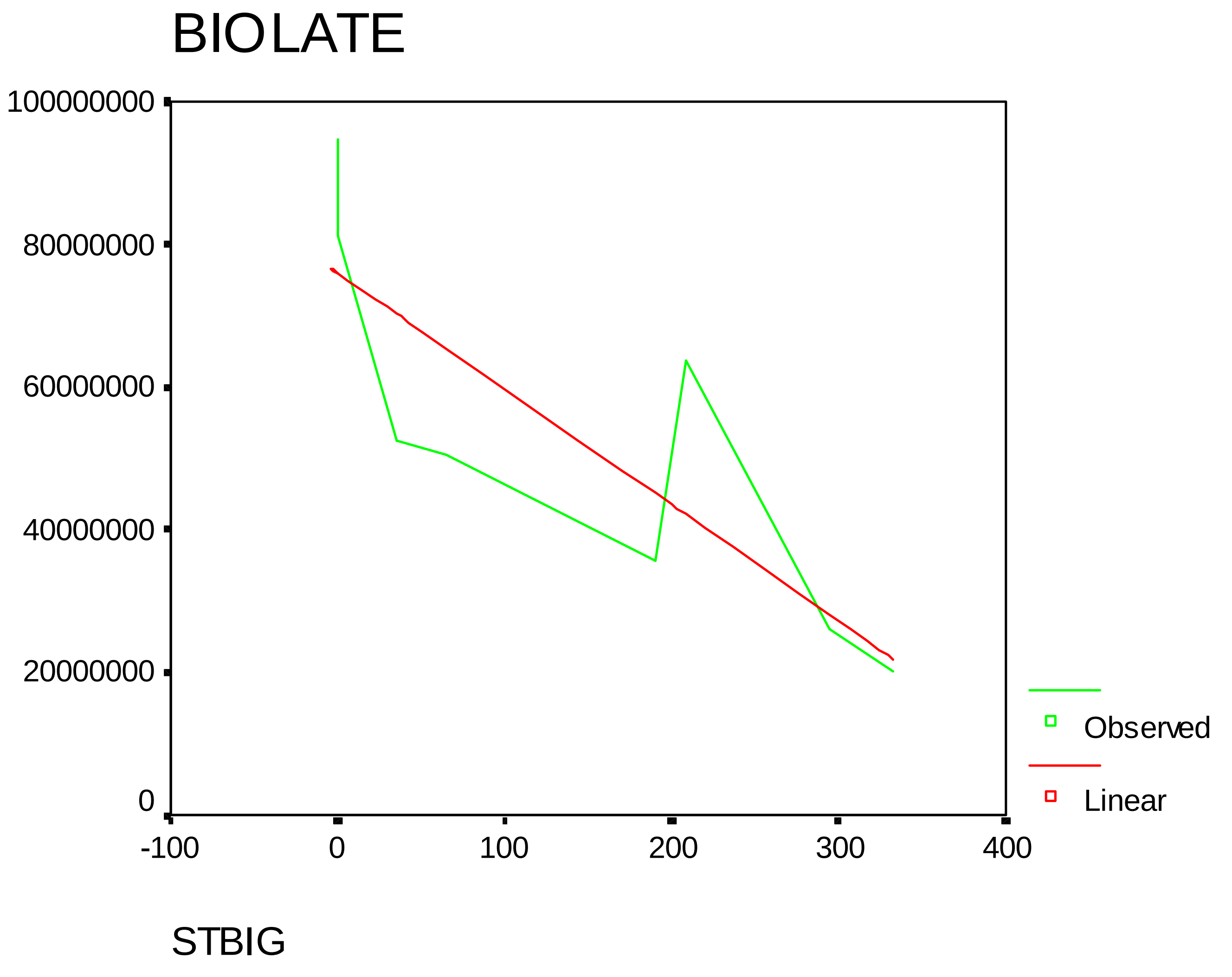
(*Ecol. Modelling 174, 37-54*)

Case Study of Coupled Biogeochemical Cycles in Rostherne Mere

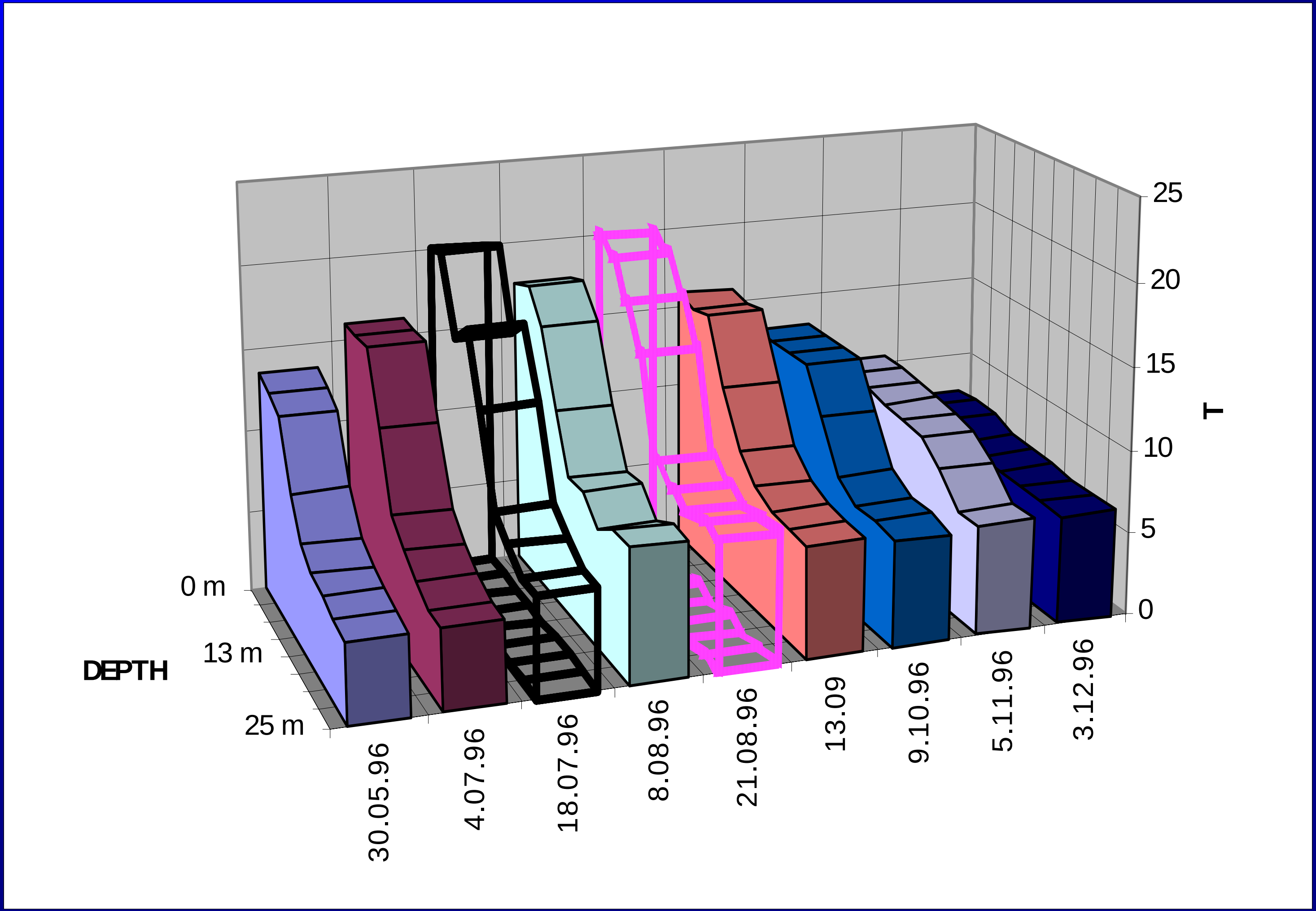

Chlorophyll_a, microgram/l
(data for 1996 and model simulation)
160
140
120
100
80
60
40
20
0
MIXED
PHYTOPLANKTON
PEAK
ANABAENA
DIATOMS
(STEPHANODISCUS,
ASTERIONELLA)
DIATOMS
1 20 39 58 77 96 115 134 153 172 191 210 229 248 267 286 305 324 343 362
Julian Day
Observed
Simulated

BIOLATE = 7.6E7 –162617* STBIG

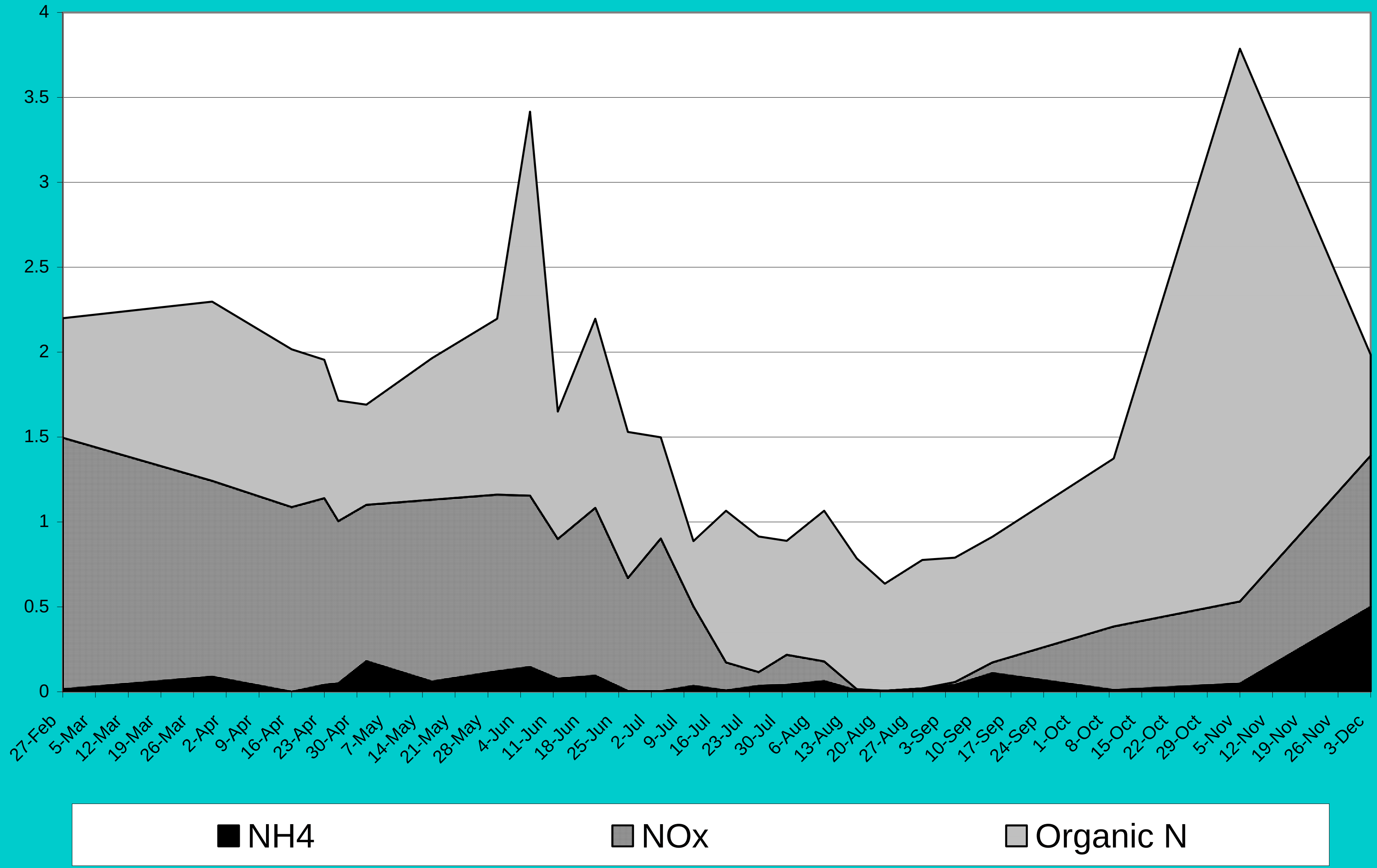
BIOLATE was calculated as sum of the maximum plankton counts (*Anabaena*, *Aphanizomenon*, *Ceratium*, *Microcystis*) multiplied by characteristic biovolume values (found in Reynolds & Bellinger, 1992).



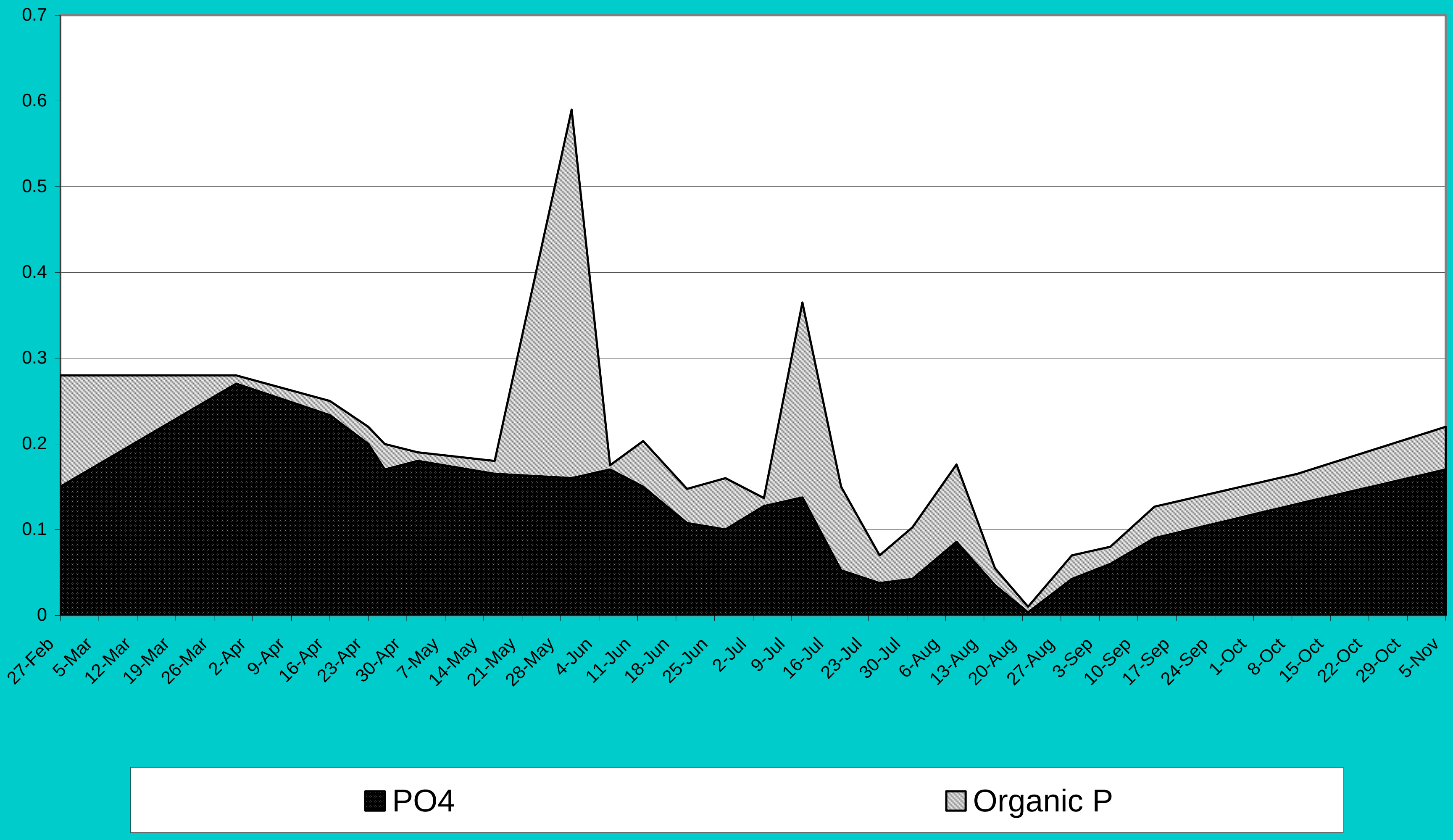
Changes in Temperature Profile



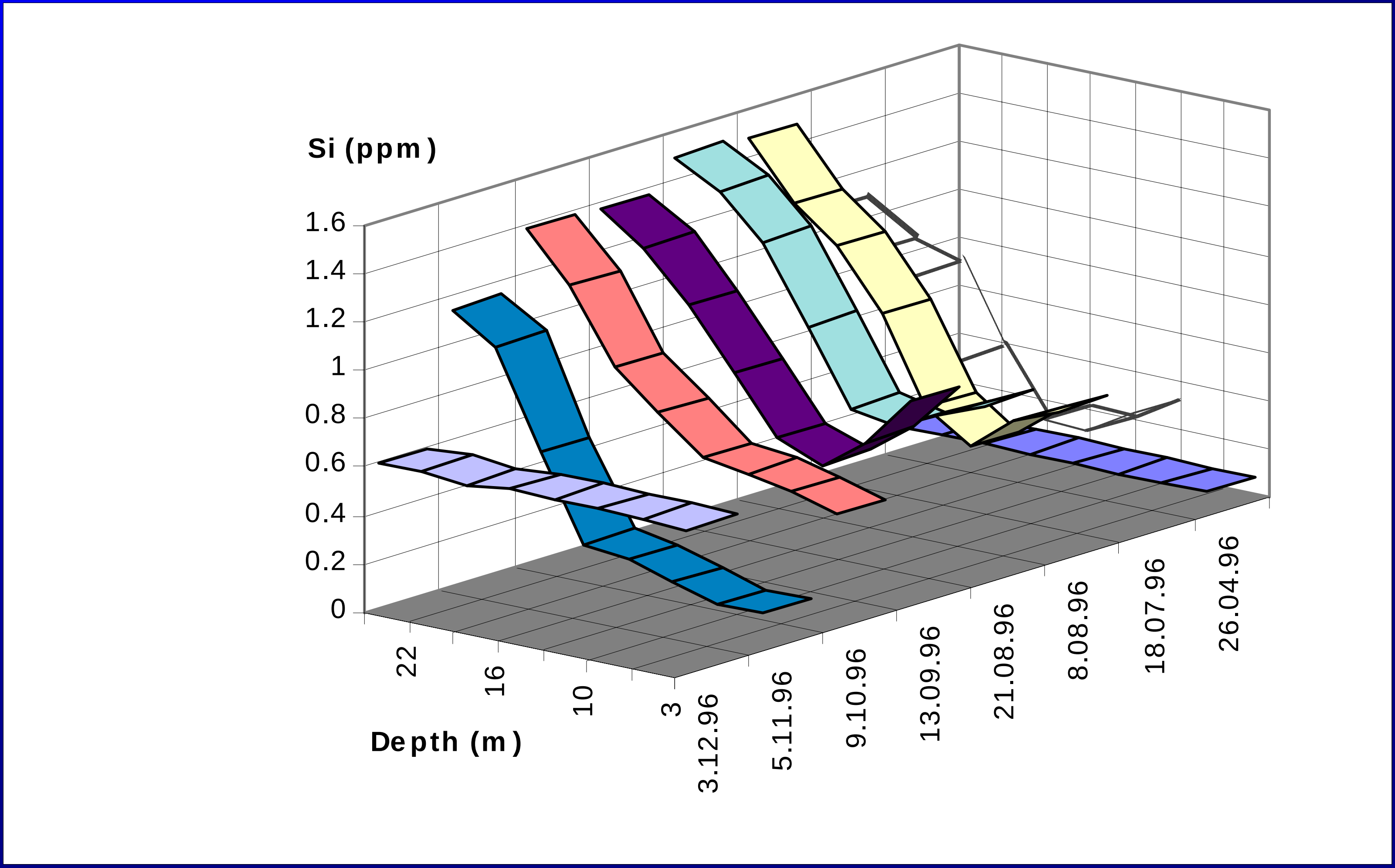
Changes in dissolved N species (ppm)

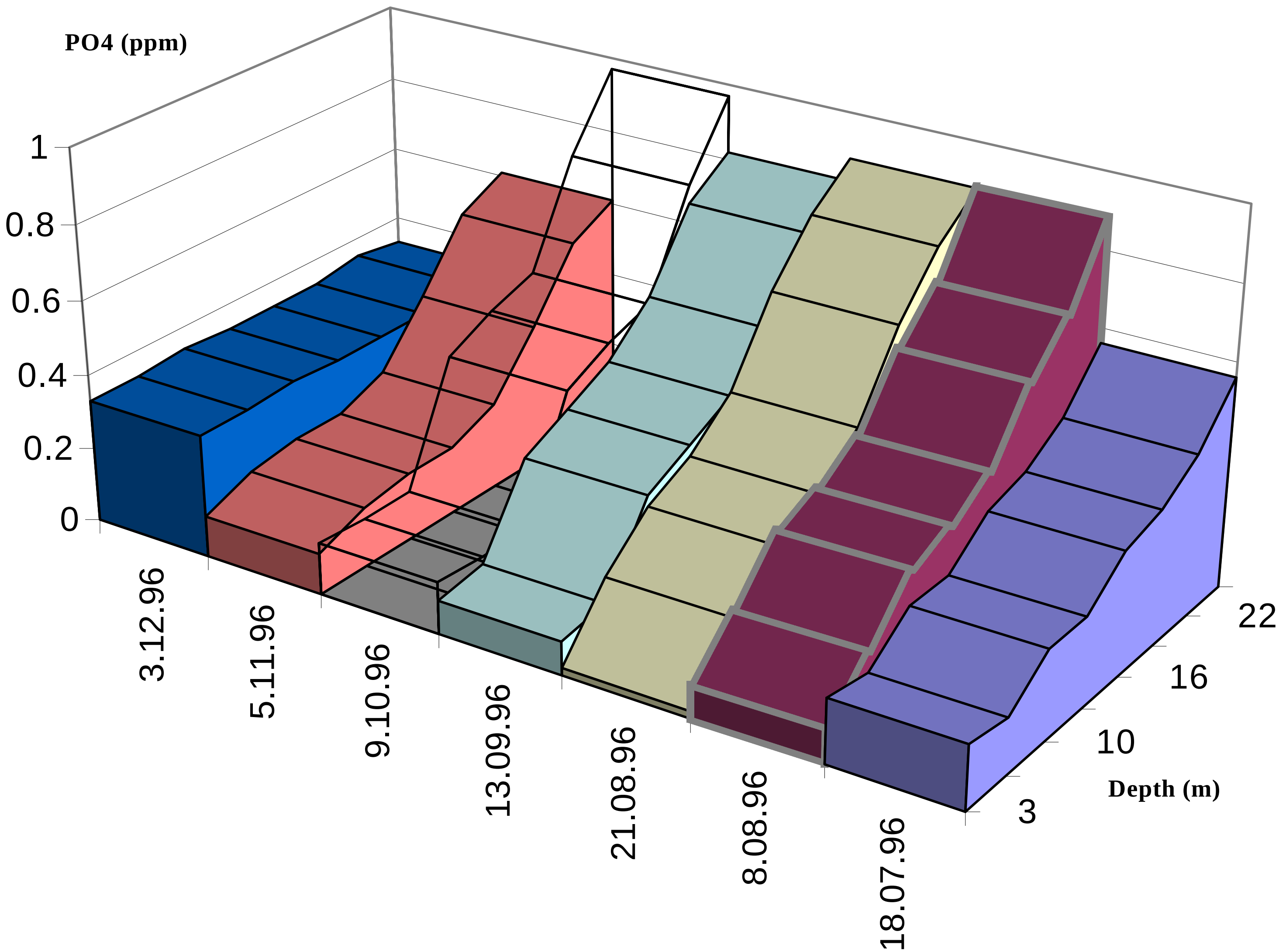


Changes in dissolved P species (ppm)



Changes in Si Profile




PO4 (ppm)
1
0.8
0.6
0.4
0.2
0
3.12.96
5.11.96
9.10.96
13.09.96
21.08.96
8.08.96
18.07.96
22
16
10
3
Depth (m)

Increased concentrations of phosphates

- ☞eutrophication of waterbodies
- ☞unsightly cyanobacterial blooms
- ☞depreciation of the amenity value
- ☞decrease of the water quality
- ☞poisoning of people and livestock

MODEL 'ROSTHERNE'

(*Hydrological Processes 14, 1489-1506, Ecol. Modelling 113, 95-123*)

- **CATCHMENT SUBMODEL**
- **EVAPORATION & EVAPOTRANSPIRATION**
- **SURFACE RUNOFF**
- **INFLOW AND OUTFLOW**
- **STRATIFICATION**
- **BIOGEOCHEMICAL CYCLES OF P, SI, N.**
- **INTERDEPENDENCIES OF NUTRIENT UPTAKE**
- **VARIABLE INTERNAL STORES**
- **TEMPERATURE AND LIGHT LIMITATION**
- **LOSS: MORTALITY, SEDIMENTATION, WASHOUT**

- **d Phyto(j)/dt = Phyto(j) * (Growth(j) - Mortality(j) - SedimentRate(j) / D - 1 / FlushRate),** **where**

Growth(j) = Light_Lim * MaxGrowth(j) * *QOLim(LimitingChemical, j)

- **d Q(i,j)/dt= CellUptake(i, j) - Excretion(i, j) - Growth(j),** **where**

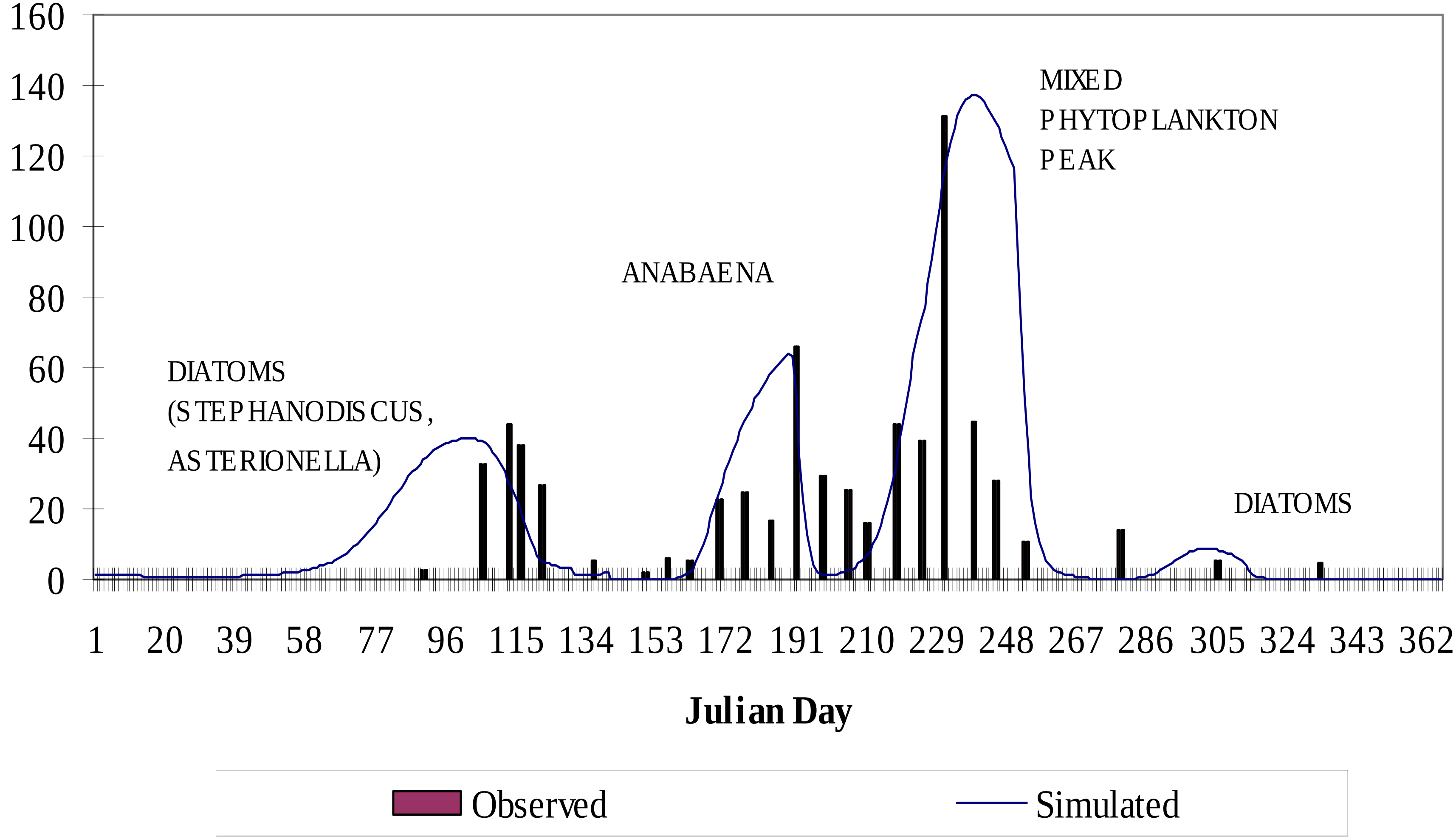
CellUptake(i, j) = BigestUptake(i, j) * eLim(i, j) * QmLim(i, j) * Tlim*QOLim(LimitingChemical,j) ^ Correction

- **d DeadPhyto(j)/dt=Mortality(j) * Phyto(j) - (Smax(j) / D + DECOMP + 1 / FlushRate) * DeadPhyto(j)**

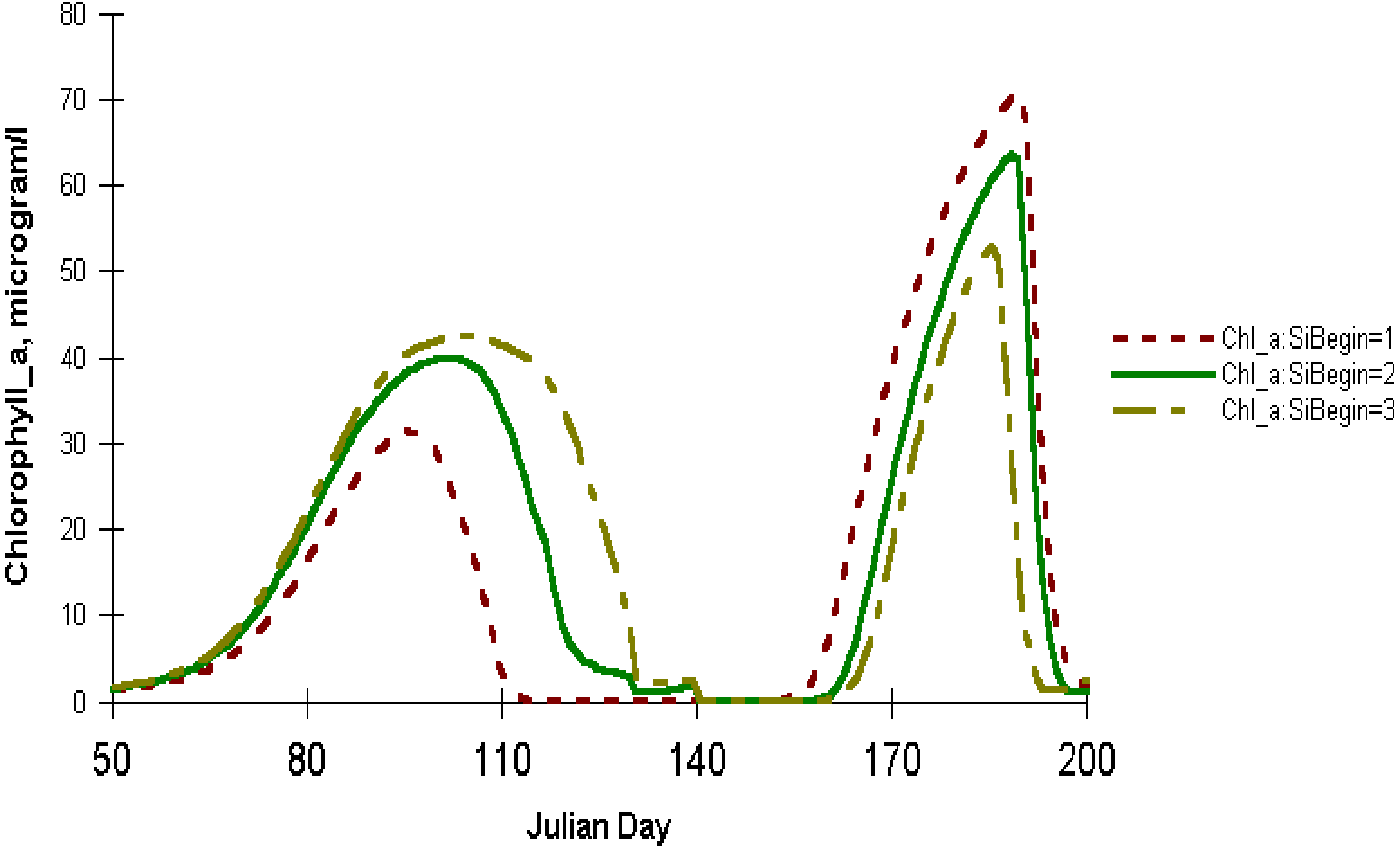
- **d DetritusChemicalPhyto(i, j)= Mortality(j) * Phyto(j) * Q(i,j) - DECOMP * DetritusChemicalPhyto(i, j) * TLim - (Smax(j) / D + 1 / FlushRate) * DetritusChemicalPhyto(i,j)**

- **d Conc(i)/dt= (InConc(i) - Conc(i)) / FlushRate – ∑∑(Phyto(j) * CellUptake(i, j) - DECOMP * DetritusChemicalPhyto(i, j) * Tlim)**

Chlorophyll_a, microgram/l
(data for 1996 and model simulation)



Sensitivity analysis of Chlorophyll_a on initial Si concentration



<u>BIOGEOCHEMICAL MANIPULATION - CONCEPT DEVELOPMENT</u>

phytoplankton community in temperate lakes

in <u>**Spring**</u>

- dominated by <u>***diatoms***</u>
- limited by **Si**

In <u>**Summer**</u>

- dominated by <u>***cyanobacteria***</u>
- limited by **P**
- **(+ also N, trace elements)**

Increase of available Si in Spring

- increased diatom growth
- increase of P uptake by Diatoms
- increased P removal from the epilimnion
- decrease of a nuisance Summer bloom

IMPLEMENTATION REQUIRE:

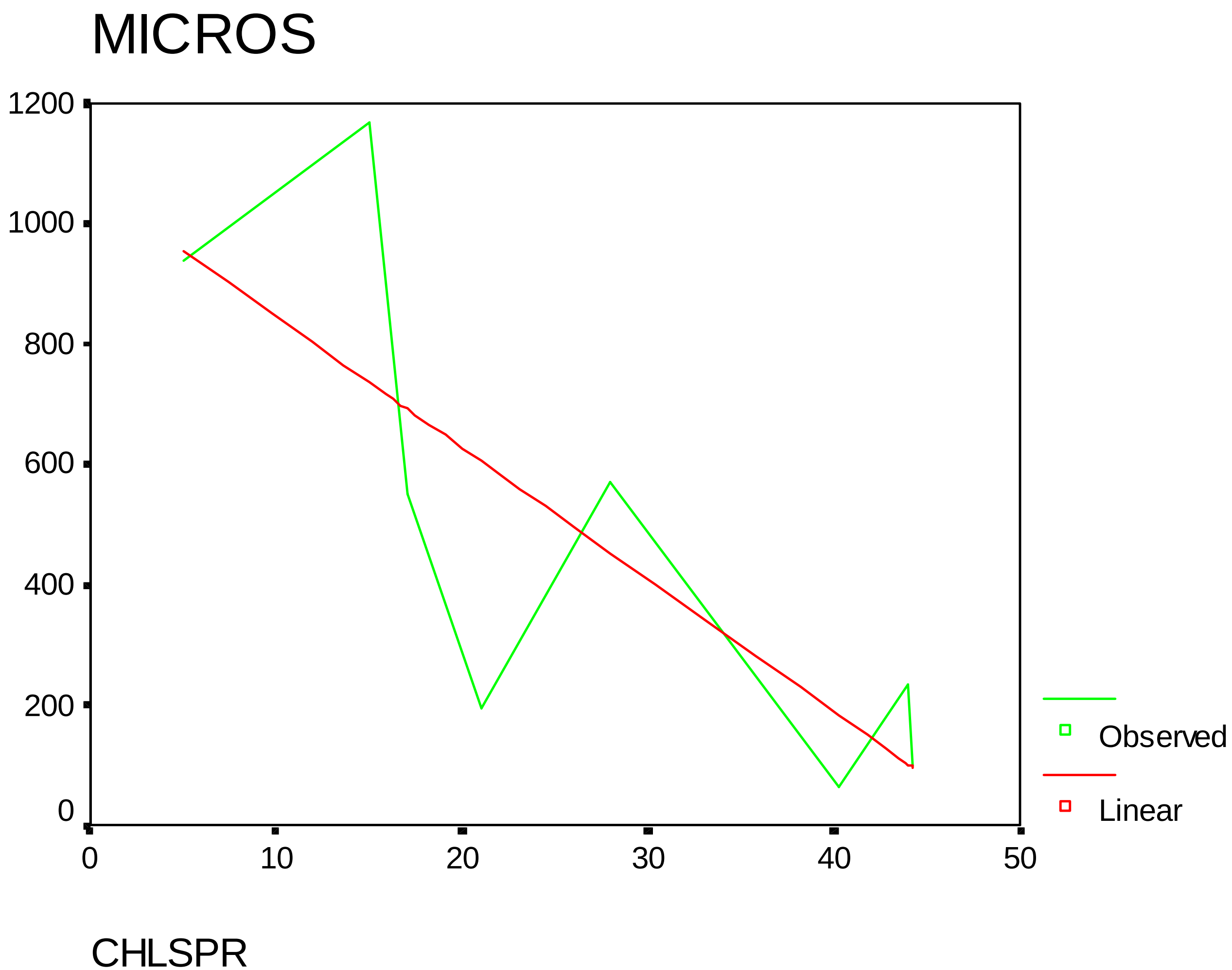
- Prediction of timing and other parameters of the bloom
- Calculation of the necessary amount of Si and means of its delivery (e.g. additions to inflows, spreading over the terrestrial catchment, increasing weathering)
- Detailed account of terrestrial processes in the watershed

----

i.e. **SPECIAL SIMULATION MODEL IS INDISPENSABLE**

Relationship between maximum spring chlorophyll levels (CHLSPR, ppb) and late summer maximum of *Microcystis* counts (MICROS, colonies/ml). Straight regression line ($r^2 = 0.64$, $p=0.018$) is described by the following equation:

$$MICROS = 1065.22 - 21.915 * CHLSPR$$



If in the model Diatoms are limited by Zooplankton, then decrease of Zooplankton in Spring results in the decrease of Cyanobacterial Dominance in Summer

If Diatoms are limited by Stratification, then earlier establishment of stratification will result in the decrease of Cyanobacterial Dominance in Summer

(*Ecol. Modelling 133, 73-82*)

However, complex interaction between temperature, zooplankton and fish may offset the interdependence between the spring and the summer blooms!

(*Ecol. Modelling 138, 153-171*)

Indirect Regulation Rule for Consecutive Stages of Ecological Succession

If Component A is dominant at Stage 1 and limited by X
And Component B is dominant at Stage 2 and limited by Y

Then, provided functioning of A also results in the decrease (e.g. Consumption) of Y, and the regeneration of Y is sufficiently slow,

Any process alleviating the limitation of A at Stage 1 will inevitably result in the decrease of the Dominance of B at Stage 2

(*Russian Journal of Ecology 32, 230-234*)

CONCLUSIONS

- In lakes and their terrestrial catchments **P biogeochemical cycle** could be **regulated by Si cycle**
- Magnitude of the Summer **cyanobacterial bloom** could be **regulated by** alteration of the spring **diatom bloom**, and, therefore, by **Si supply from terrestrial catchment**
- For the above a special **simulation model** such as “**ROSTHERNE**” is **indispensable**

Conclusions

Because the flushing rate of the lake is low and the estimated **internal loading** is relatively **high**, rapid **changes in the trophic status** of the ecosystem without chemical and/or biological measures seem very **unlikely**.

Conclusions

- Indirect interrelations between ecosystem processes are often realised after a considerable time lag and/or separated spatially, and are not obvious
- The understanding of these relationships is indispensable for sustainable development and ecomanagement
- An emerging framework of CTEA calls for the observational, theoretical and experimental methods to be applied in concert
- This will allow elucidation of the role of indirect effects in ecosystem succession, evolution, recovery after pollution, disturbance, and alterations of prevalent patterns due to changes in management practices.