The Baltic Sea as a natural ecosystem to study the significance of the phytoplankton/bacterio-plankton production ratio for pelagic food-web efficiency

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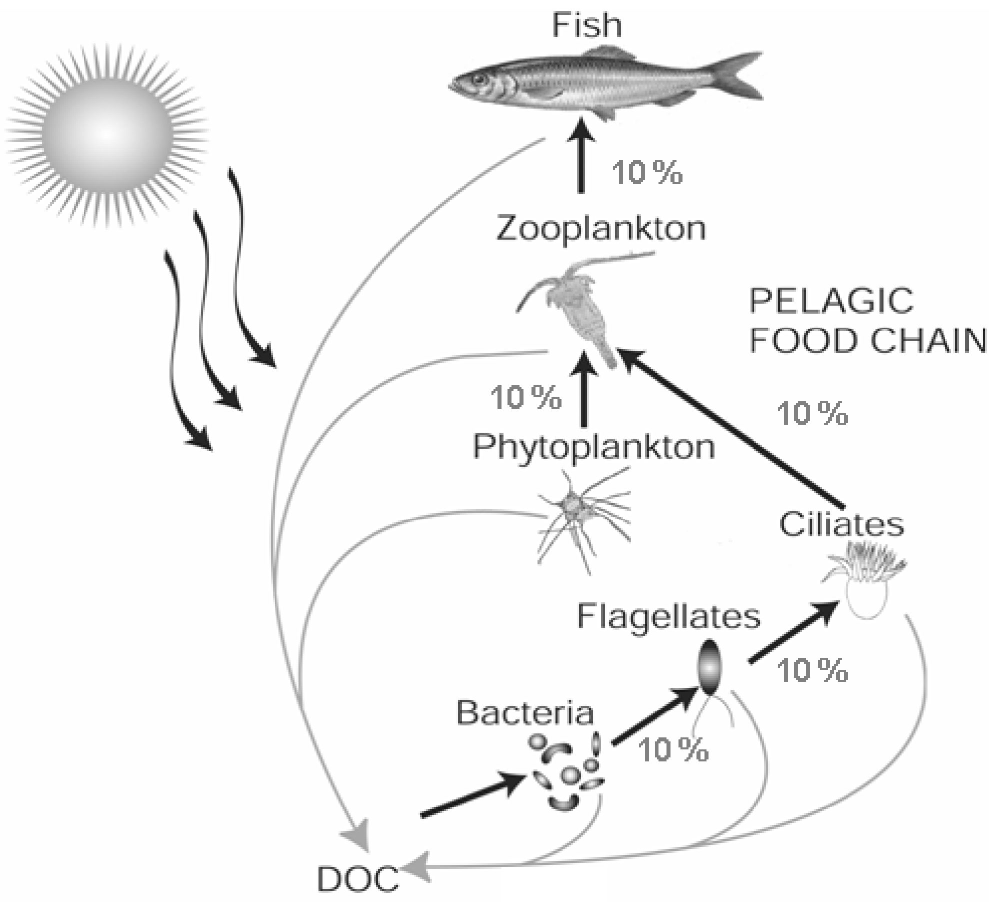
Simplified pelagic food web



"Classical" food chain: Fish production = 0.1^2 = 1 % of phytoplankton production

"Microbial" food chain: Fish production = 0.1^4 = 0.01 % of bacterial production

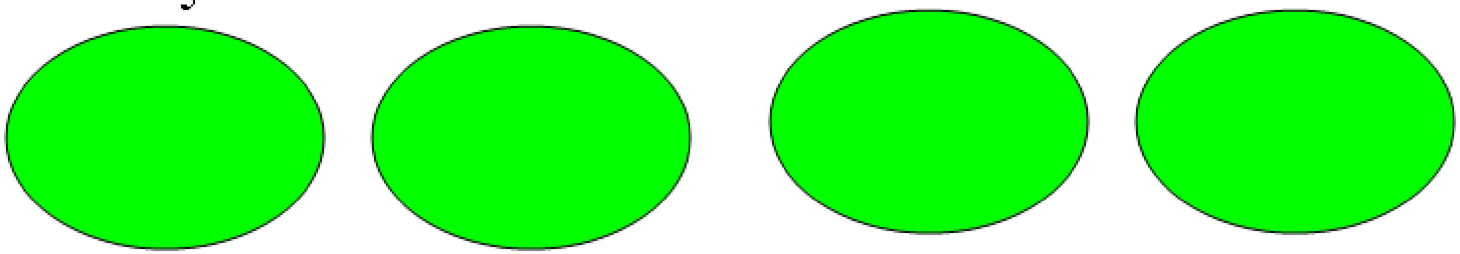
Laboratory experiment (mesocosms)

Berglund et al. 2007

Limnol. Oceanogr. 52 (1):121-131

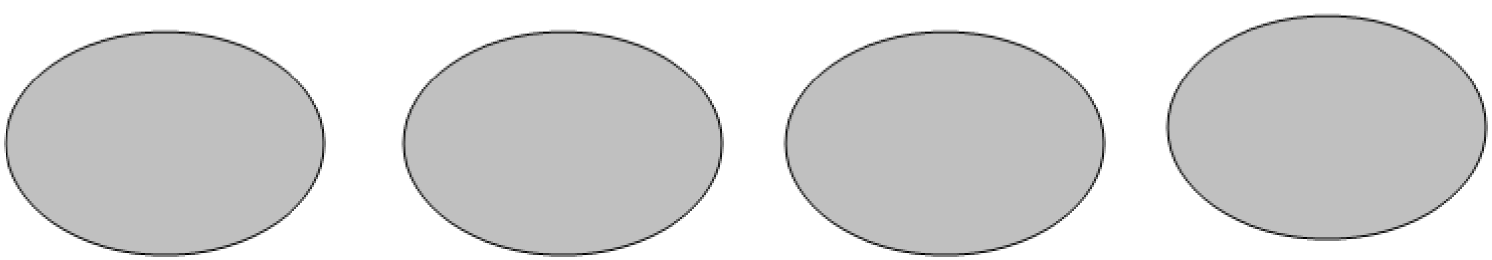
NP treatment: 100 µmol quanta m^{-2} s^{-1}, 400 l, chemostat, turnover time 100 days, 15° C

Addition: Ammonium 0.33, Nitrate 1.97 and Phosphate 0.23 µmol l^{-1} day^{-1}.



CNP treatment: 15 µmol quanta m^{-2} s^{-1}, 400 l, chemostat, turnover time 100 days, 15° C

Addition: Glucose 10.7, Ammonium 0.33, Nitrate 1.97 and Phosphate 0.23 µmol l^{-1} day^{-1}.

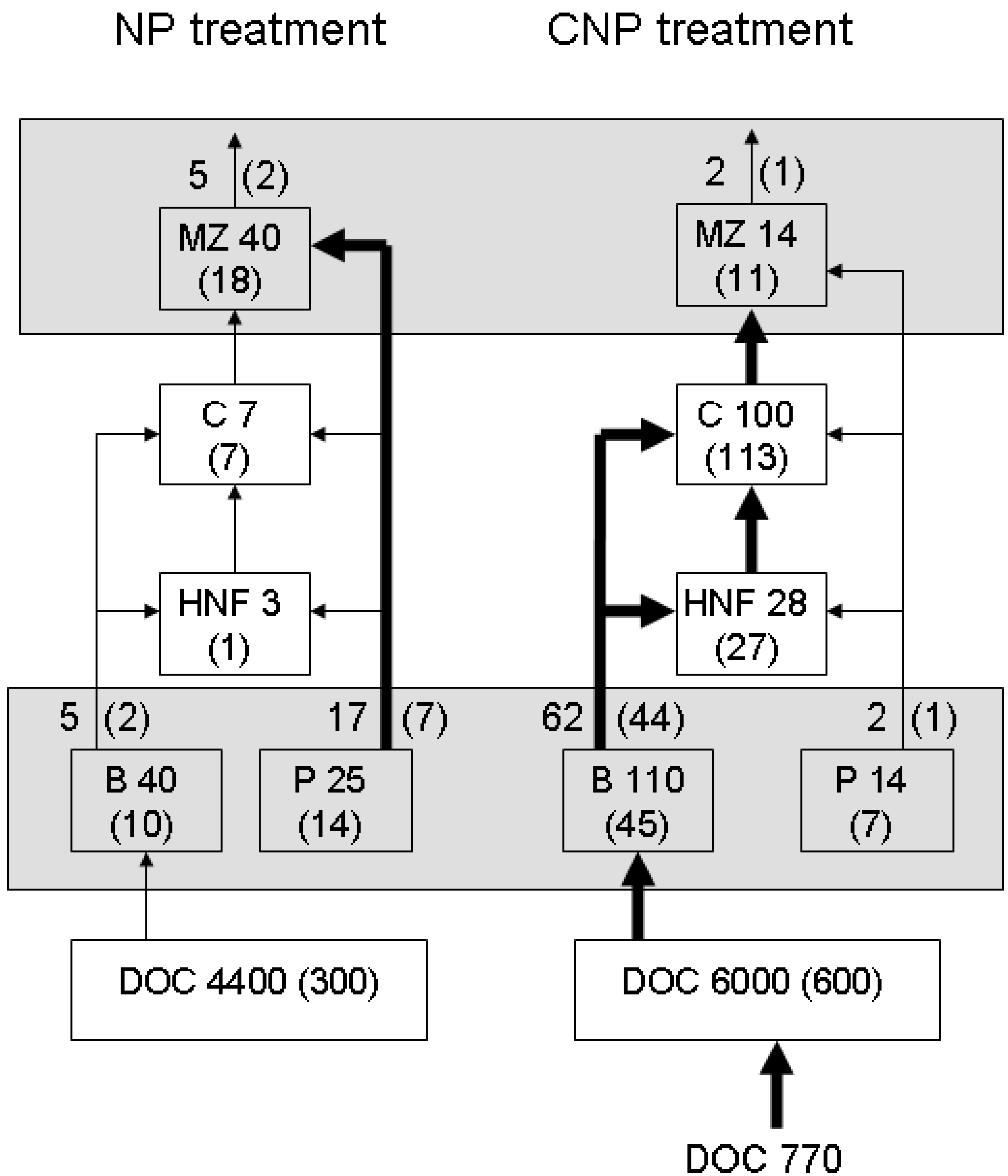


Definitions used:

- Basic production = Production of bacteria and phytoplankton (BAP)
- Bacterial production (BP)
- Production of phytoplankton (PP)
- Production of mesozooplankton (MZP)

Food-Web Efficiency (FWE) = MZP/BAP x 100 % = MZP/(BP+PP) x 100 %

Simplified model of the food web in the NP and CNP treatment. The average carbon biomass of each functional group is given in the corresponding box as µg C l^{-1}. The production rate of respectively bacteria, phytoplankton and mesozooplankton is given above the box as µg C l^{-1} d^{-1}. Values within parentheses denote one standard deviation. The major carbon flow in the respective treatment, inferred from stable isotope analysis, is bold-marked. MZ= mesozooplankton, C= ciliates, HNF= heterotrophic nanoflagellates, B = bacteria, P=phytoplankton, DOC= dissolved organic carbon.



Calculated FWE

CNP treatment:

FWE = MZP/(BP + PP) x 100 = 2 +/- 1 %

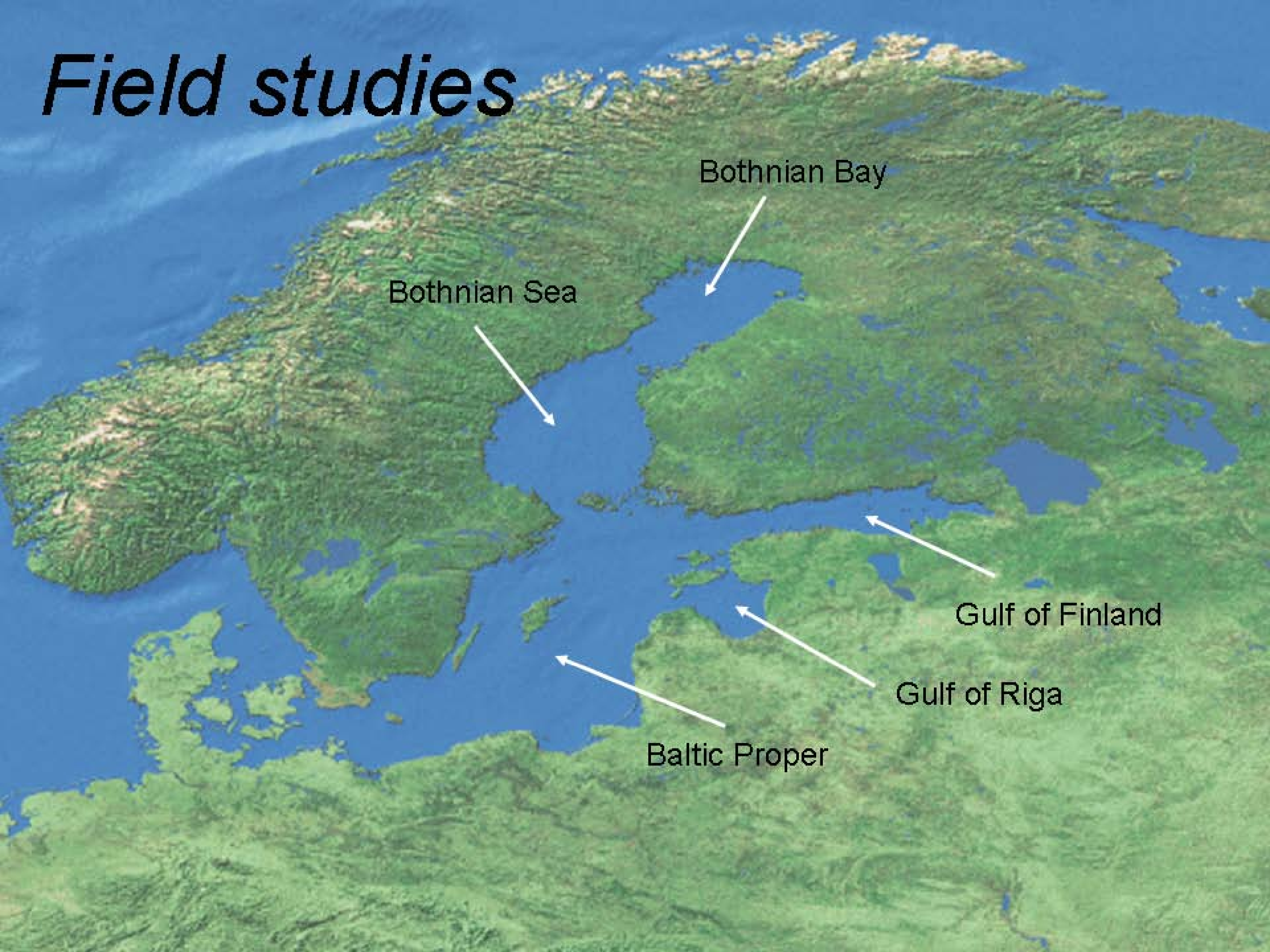
NP treatment:

FEW = MZP/(BP + PP) x 100 = 22 +/- 8 %

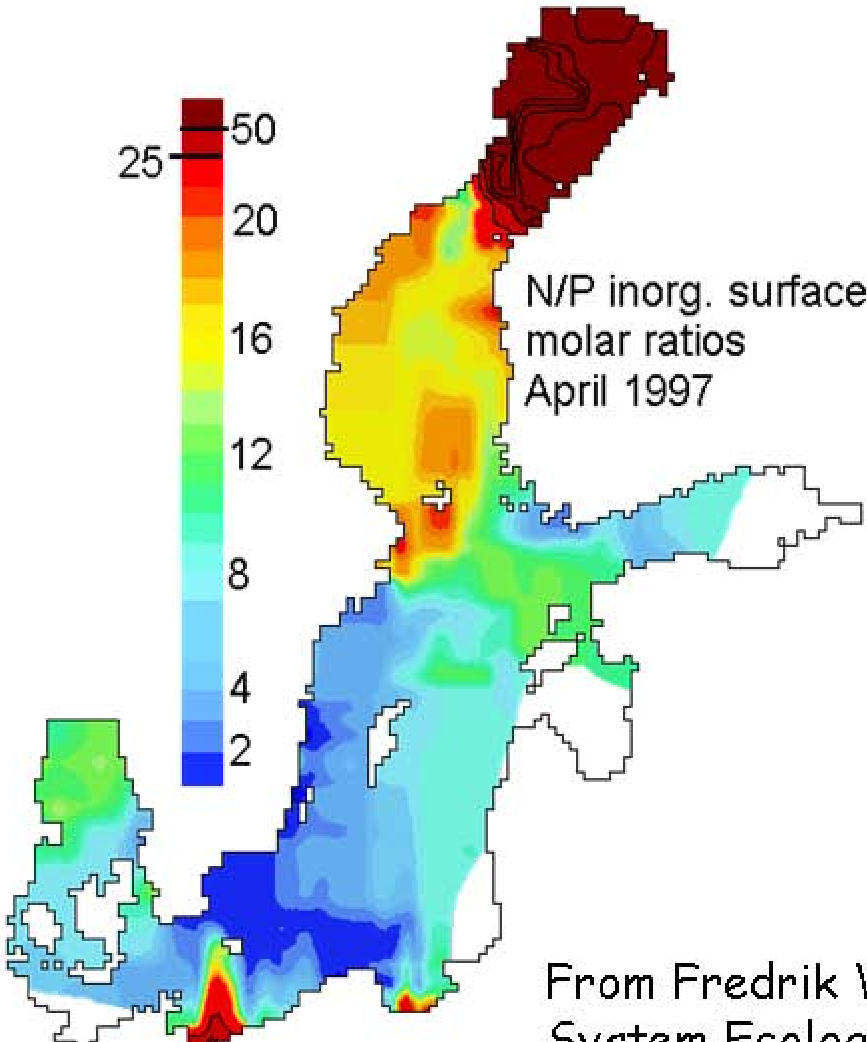
Conclusion:

The phytoplankton dominated system generated 11 times higher FWE than the bacteria dominated one

Field studies



Inorganic N/P molar ratio in the surface water of the Baltic Sea

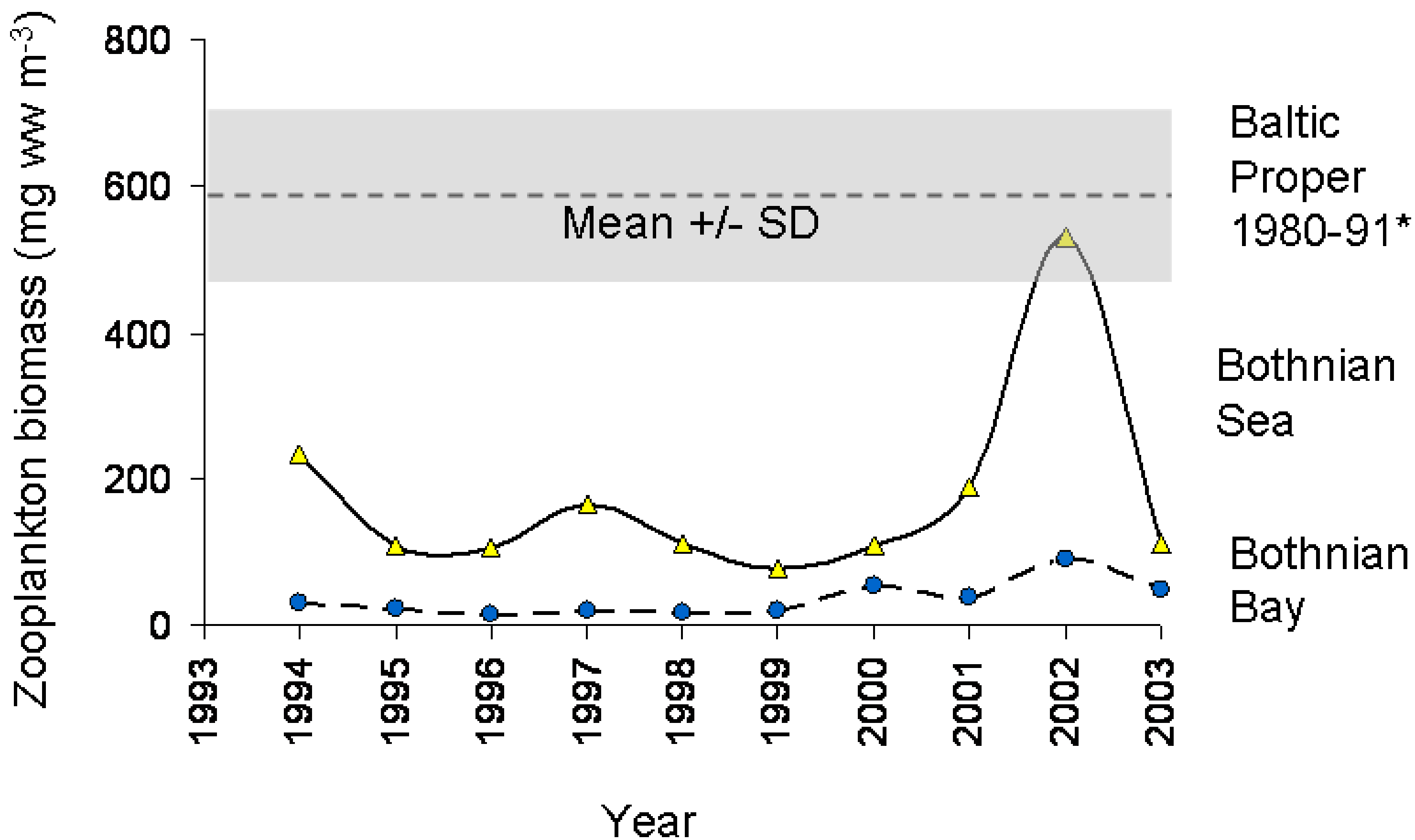


From Fredrik Wulff, Department of System Ecology, University of Stockholm


Cyanobacterial blooms…..


…. cause unsuitable
conditions for human
utilisation of the Baltic Proper

Average annual mesozooplankton biomass

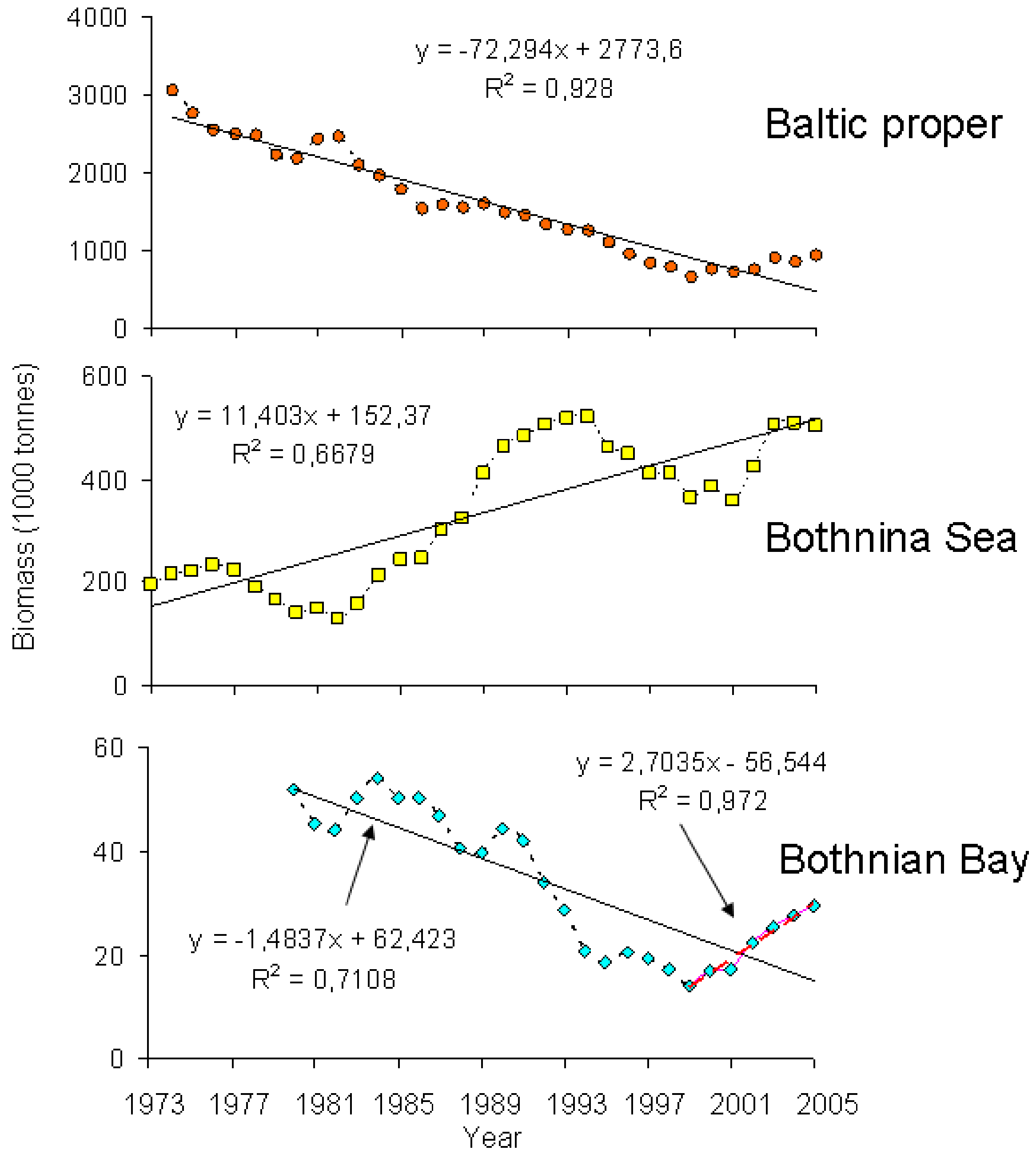


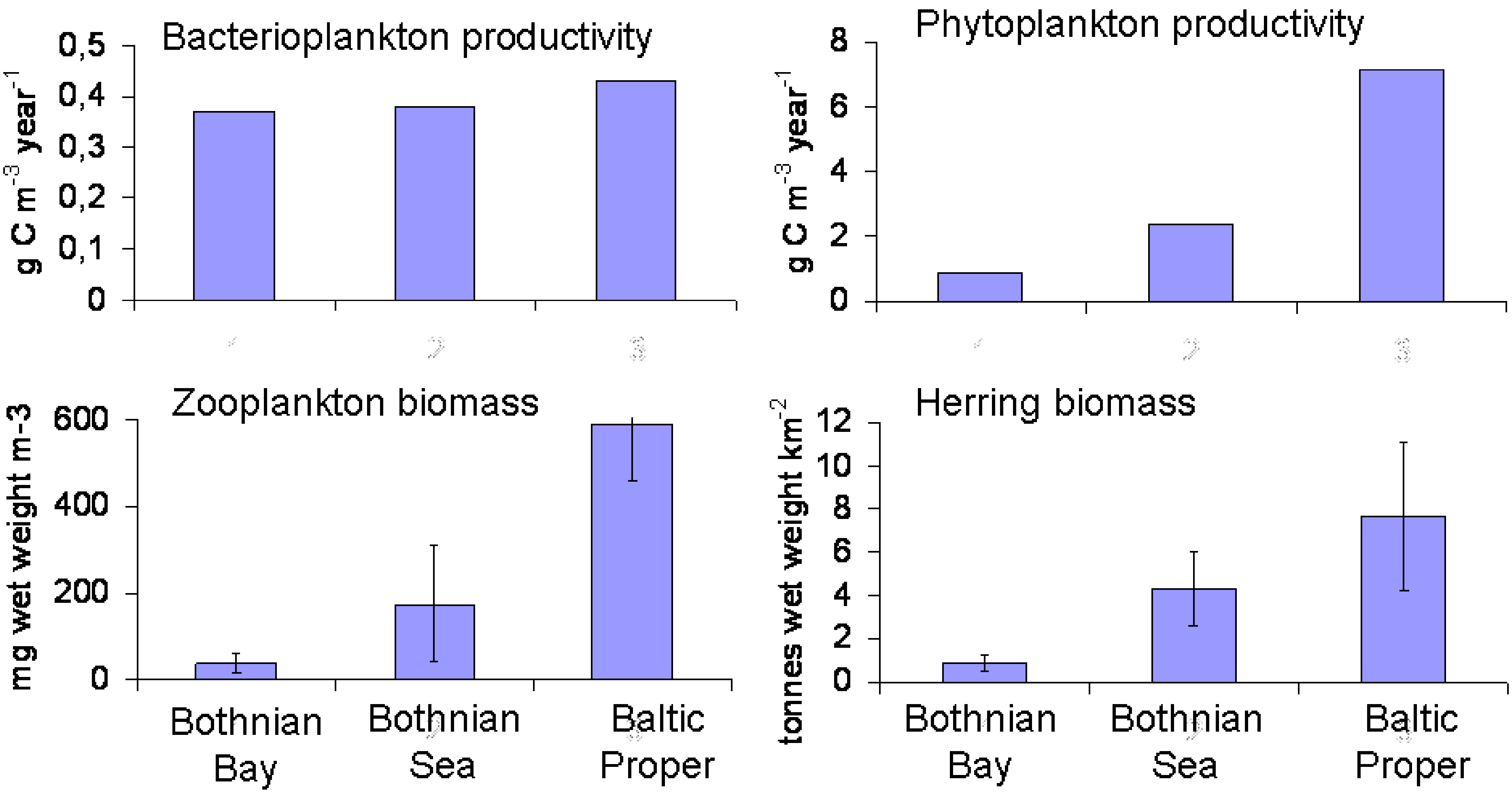
*Baltic Proper data from Flinkman et al. 1998 MEPS 165:127-136

Baltic Herring

Data from ICES reports

Equations give the total herring stock biomass in respective basin (y) as a function of year number (x), where 1973 is year number 0.

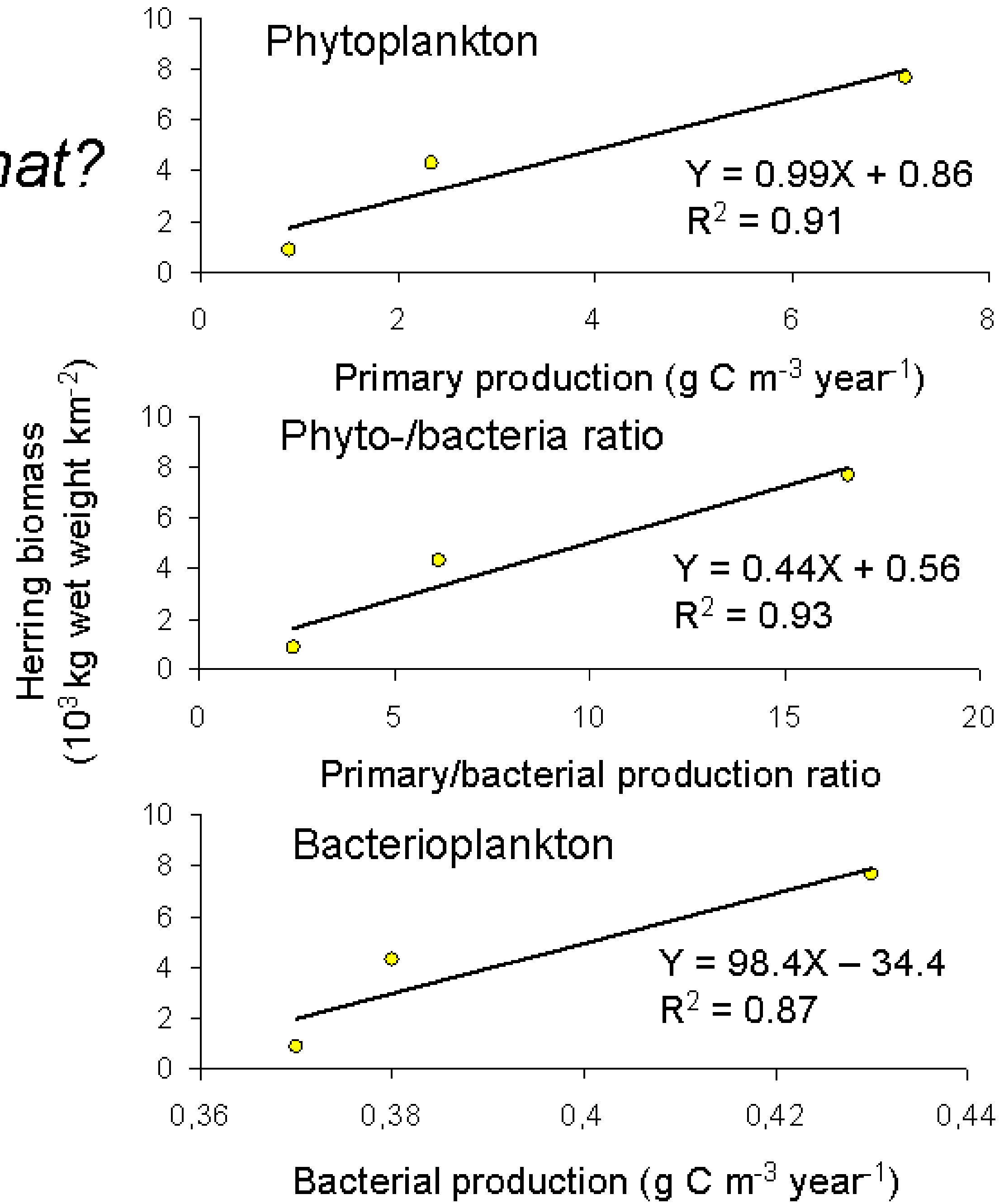




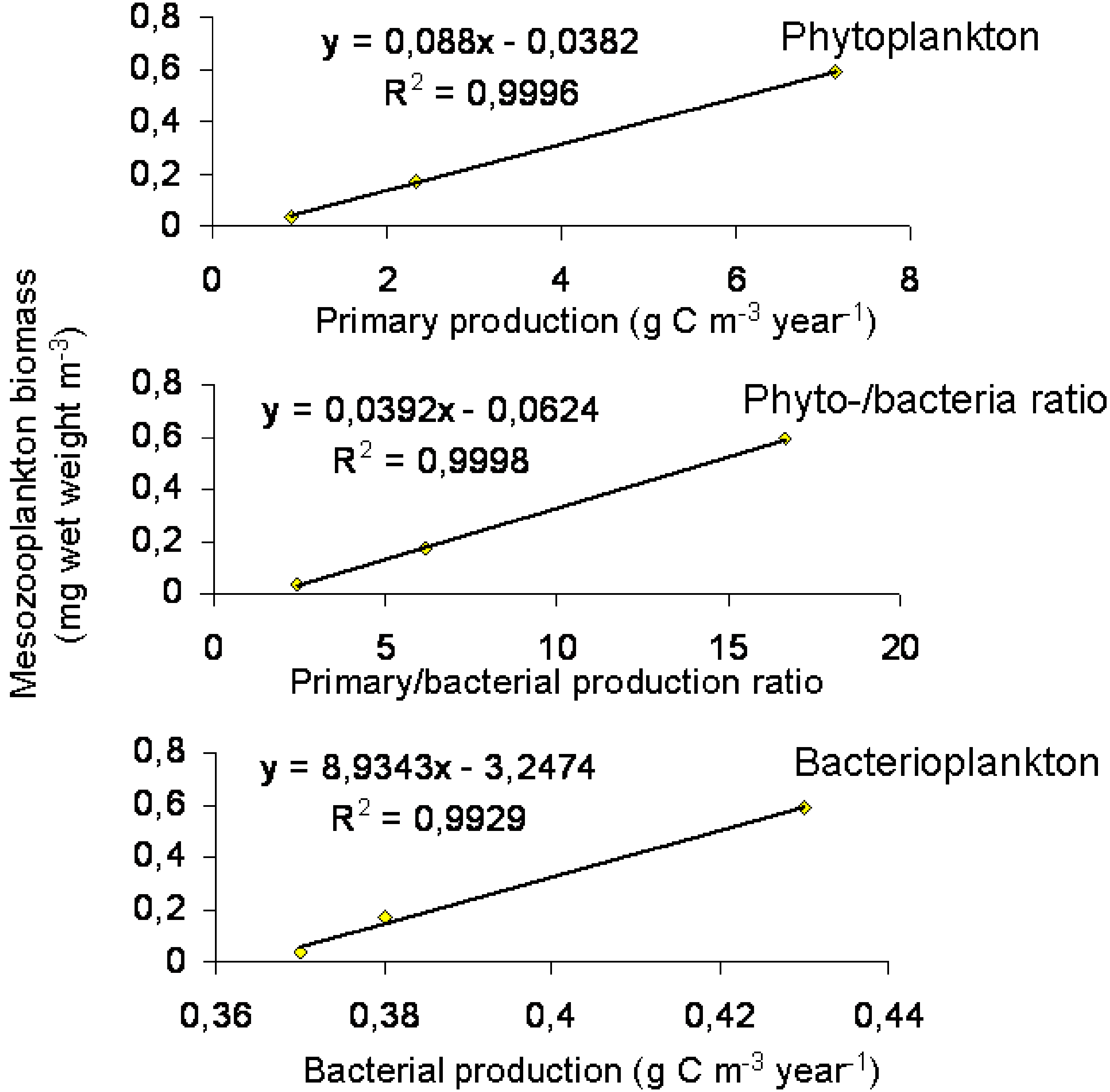
Ratio Primary production/bacterial production: 2.4 6.2 16.6

Data from UMSC monitoring program 1993-2003; Larsson & Hagström 1982; Elmgren 1989; Flinkman et al. 1998; Johansson et al. 2004, ICES herring statistics

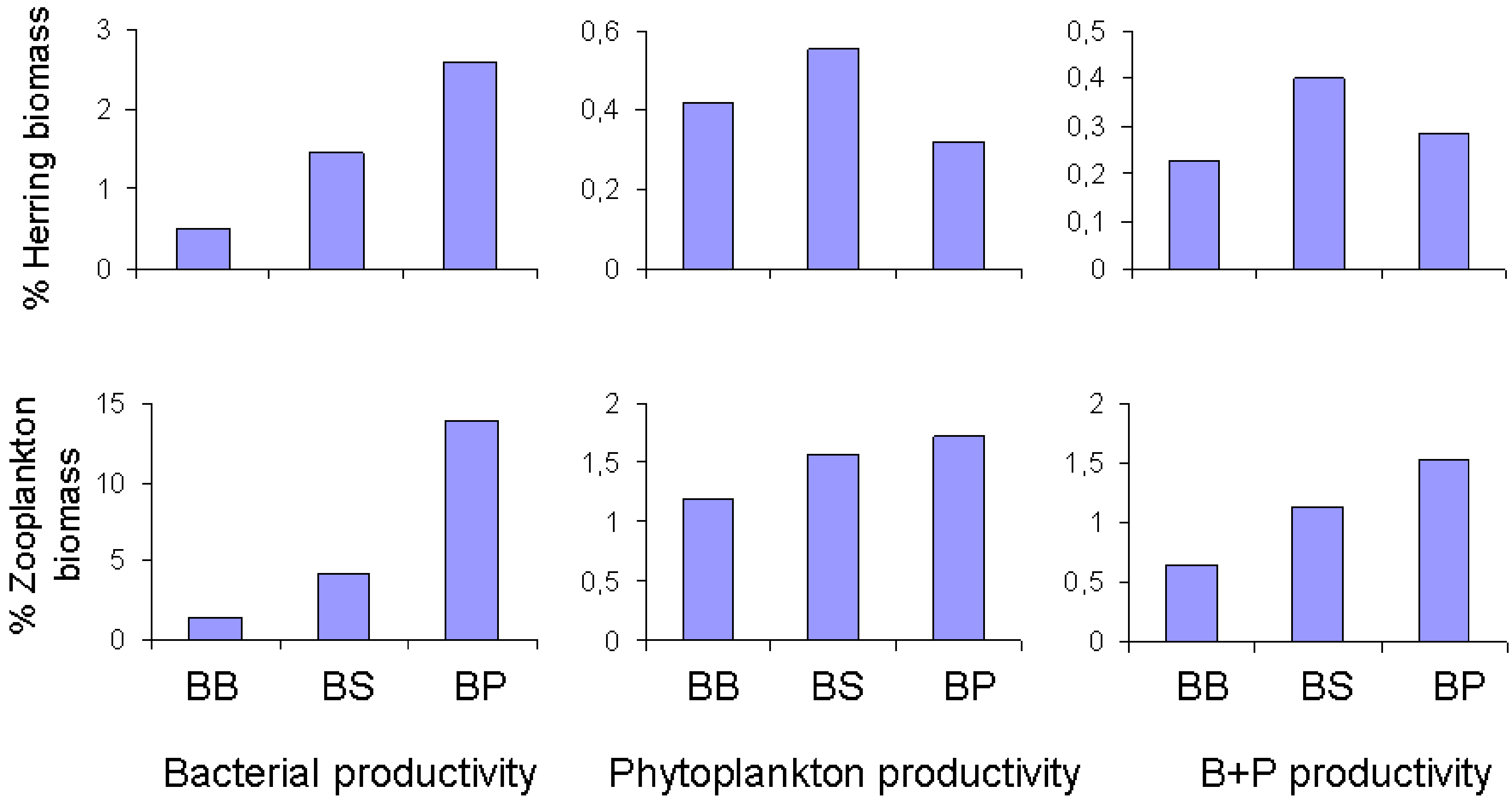
Herring biomass correlates with what?



Zooplankton biomass correlates with what?



Herring biomass (upper row) and zooplankton biomass (lower row) as percent of annual bacterial productivity (column 1), phytoplankton productivity (column 2), and bacteria + phytoplankton productivity (column 3)



Climate change in the Baltic Sea according to worst scenario in the Rossby Centre Atmosphere Ocean model (Meier 2006)

- Land runoff increases by 15 %
- Salinity decreases by 45 % through the water column
- The halocline deepens by 10-20 m
- Temperature in the surface water increases by 3.9°C
- Maximum ice coverage decreases from 45 % to < 10 %
- Extreme weather conditions with average wind speed increase 25-30 % (Feb-March) or 5-15 % (other times)
- Annual solar radiation increases by 9 %

Potential effects of climate change on the Baltic Sea pelagic ecosystem

Climate factor	Bacteria	Phytoplankton	Fish
Land runoff increase	↗	↓	↓
Salinity decrease	→	→	↓
Halocline deepening	→	↓	↓
Temperature increase	↑	↘	↗
Less ice and shorter ice period	→	↗	→
Increased wind speed	↑	↑	↑
Increased solar radiation	↗	↑	↗

Concluding remarks

- Experimental results support the theory of low food-web efficiency in microbial-based pelagic systems
- Field observations indicate that the basin differences in phytoplankton productivity is reflected in both zooplankton and herring biomasses in the Baltic Sea
- Decreased phytoplankton/bacteria productivity ratio from south to north causes reduced food-web efficiency up to zooplankton
- The proposed climate change will probably cause elevated bacterial productivity and reduced phytoplankton productivity in the Baltic Sea, with reduced productivity at higher trophic levels

Thank you for your attention!