



Total primary production and the balance between benthic and pelagic plants at different nutrient regimes in a shallow estuary

Stieg Markager (markager@dmu.dk), Dorte Krause-Jensen (dkj@dmu.dk) and Tage Dalsgaard (tda@dmu.dk)

Aim

Our aim was to quantify the total primary production in the shallow estuary Limfjorden and the distribution among major ecological types of primary producer under different nutrient regimes.

Background

In this contribution we challenge the hitherto ruling concept that the total gross primary production (GPP) in shallow coastal areas, i.e. the combined production of micro- and macroscopic plants living in the water and at the bottom, does not increase with nutrient enrichment. Our hypothesis is that in a phase with decreasing loadings the phytoplankton based production will decline rapidly, whereas the benthic production will only slowly increase. Thus a significant drop in total production will, at least temporarily, occur.

Results

Nutrient loadings have declined by 50% (N) and 80% (P), respectively, since the mid 1980s. However, from 1900 to the mid 1980s nitrogen loadings have increased by a factor of 6.

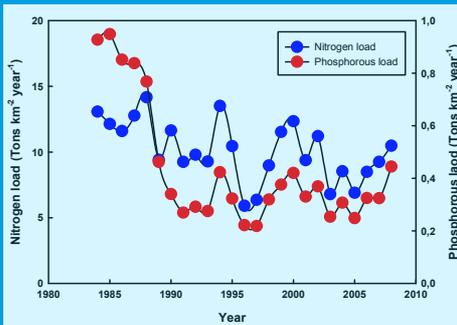


Figure 1
Nutrient loadings from 1993 to 2008 for Limfjorden



Figure 2
Nitrogen surplus in Danish farming, 1900 to 2005

Total production was approximately the same in 1900 and 1980, but with benthic (eelgrass) dominance in 1900 as opposed to planktonic dominance in 1980. This is as expected from previous studies (Borum and Sand-Jensen 1996).

From the mid 1980s to 2000 nutrient loadings were significantly reduced. Phytoplankton production declined accordingly. However, eelgrass biomass and area distribution have remained at a low level and unclear waters and widespread anoxia prevent the recovering process. The result is that the total primary production has declined by about one third from the mid 1980s to 2000.

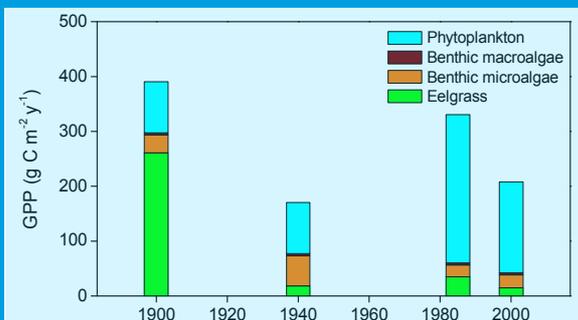


Figure 3
Total primary production in Limfjorden and the distribution on the four major ecological groups of primary producer

Conclusions

Between 1900 and the mid 1980s nitrogen loadings increased about a factor of 6, but the total primary production did not change.

The distribution between primary producers changed markedly from benthic to pelagic dominance.

When nutrient loadings decreased in late 1980s phytoplankton production declined.

However, water clarity did not improve and anoxia is still widespread. Both factors prevent eelgrass to regain its former depth distribution and biomass.

The consequence is a significant decline in the total primary production of the system following oligotrophication.

Conceptual model

The results are summarized in a conceptual model where we hypothesize that an oligotrophication phase with decreased total production is a general phenomenon in shallow water estuaries because phytoplankton production reacts fast while macrophytes do not return before oxygen conditions and water clarity have improved.

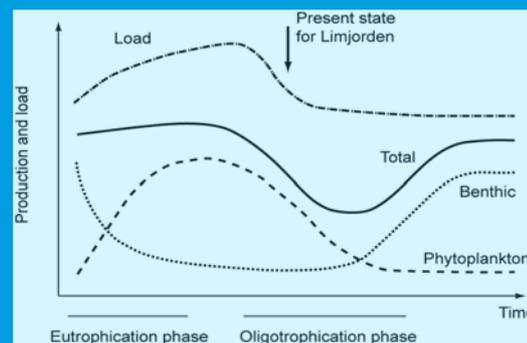


Figure 4
A conceptual model for the development in primary production in response to increasing and decreasing nutrient loadings in shallow water estuaries.

Methods

- Phytoplankton was measured as ^{14}C -uptake in 1955 and from 1983 and onwards.
- Benthic microalgae production was estimated from oxygen profiles (Dalsgaard 2003).
- Production by macroalgae and eelgrass (*Z. marina*) was estimated from data for biomass and cover and literature values for P/B-ratios.
- Basin production was calculated from production values and data for light penetration, depth distribution of primary producers and bathymetry.

