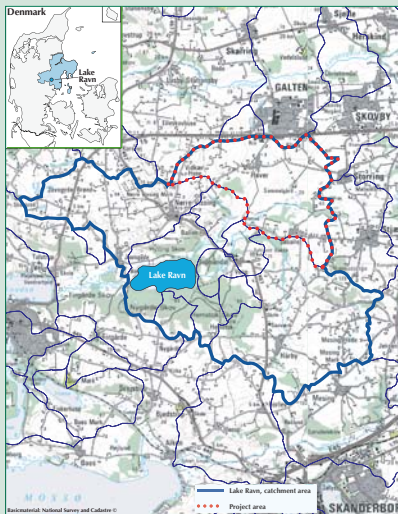


Critical phosphorus load of a stratified lake calculated by an ecological model

Henrik Skovgaard, M.sc. in Biology, Environment Centre Aarhus, Ministry of the Environment (hesko@aar.mim.dk)



Introduction

According to the Water Framework Directive the lakes in EU must achieve as a minimum a "good ecological status" by the year 2015. Phosphorus is the main environmental stressor in Danish lakes and the primary determining factor for numerous biological variables. In an EU-Life project called Agwaplan (www.agwaplan.dk) we have determined the critical phosphorus load of lake Ravn in Jutland, DK.

Study site

Lake Ravn (area 182 ha) is a deep (maximum depth 33 meters) lake stratifying in the summer time. It has been included in the Danish national monitoring programme since 1989. Mean (summer) concentration of phosphorus, chlorophyll and secchi depth is 25 µg P/l (total-P), 8-10 µg/l and 3-3,5 meters respectively. In warm periods the lake is often subjected to blooms of very poisonous bluegreen algae.

Since 1989 there has been a significant ($P < 0,001$) reduction of the mean P-inlet concentration mainly due to improved waste water purification. There is a substantial variation of annual P-load with high loads in years with a high precipitation like 1994 and low loads in the dry period 1996-1997 (figure 1).

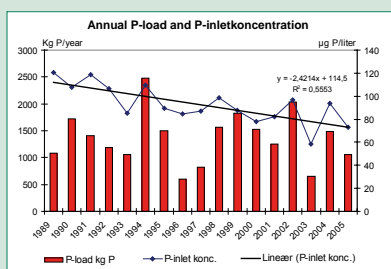


Figure 1: Annual load of phosphorus and P-inlet concentration in Lake Ravn.



Ecological model

A hydrodynamic and ecological model was established. The model was able to describe the seasonal dynamic and suitable for predictions of ecological status of the lake in various scenarios of external nutrient load. Data on phytoplankton biomass (carbon weight) were used to model a chlorophyll concentration reflecting the true phytoplankton biomass, since chlorophyll is one of the present EU-intercalibrated indicators of ecological status in lakes.

Data from the calibration period (1992-2002) indicated a need of a 50% reduction of the average phosphorus load at that time in order to achieve 6,5 µg chla/l (figure 2). In this scenario the phosphorus concentration in the lake could be reduced to app. 15 µg P/l and the secchi depth increased to app. 4 meters enhancing the chance of a higher distribution of submerged macrophytes.

The present phosphorus load was calculated using data from 2000-2005 (figure 2).

The main P-source now is natural washout and erosion of phosphorus in the catchment area (reference condition), waste water and diffuse washout and erosion from agricultural areas along the streams. The reduction target of phosphorus load is app. 0.1 kg P/ha in the

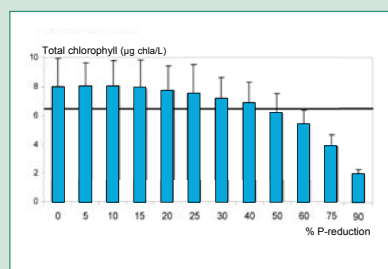


Figure 2: Calculated chlorophyll concentration (summer mean) after 0, 5, 10, ..., 90% reduction of external phosphorus load. The line represents good ecological status (6,5 µg chla/l).

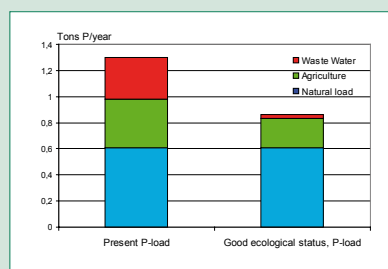


Figure 3: Present annual P-load and a calculated P-load resulting in a good ecological status. The colours of the columns indicate main P-sources.

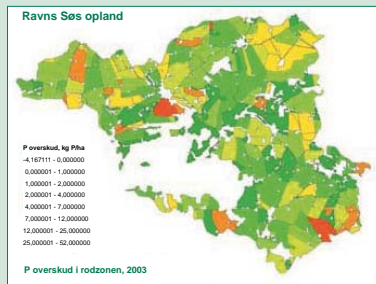


Figure 4: Map showing the catchment area of Lake Ravn. Red fields are overloaded with phosphorus. Green colours show input/output balance but not necessarily low risk of P-leakage or erosion.

catchment area, which may be achieved by improved waste water purification and by focusing on fields in agricultural areas with a high phosphorus concentration in the soil and high risks of erosion. These fields have been mapped and analyzed (texture, drainage conditions, slope etc.) and meetings with local farmers using GIS data and a manual of good agricultural practice were held in order to minimize the future manuring of vulnerable spots.

Conclusions

- Chemical and biological indicators in a lake can be described with a hydrodynamic and ecological model.
- The present P-load (baseline) should be based on data from more than one year. Alternatively the measured load of phosphorus could be adjusted to a standard year based on average precipitation or by modelling.
- The sources of phosphorus are determined using measured or estimated data on waste water treatment plants, scattered dwellings and reference concentrations in streams (40 µg P/l in this case).
- The contribution from agriculture can not be measured but is calculated by subtracting the other sources from the total load. Deviations of the true size of natural load and phosphorus loss from scattered dwellings may lead to inexact conclusions on the diffuse contribution from agriculture.

The final indicator boundaries between good ecological status and moderate ecological status in various types of lakes will be identified in the EU- intercalibration network and published in the beginning of 2008.

References

- Danmarks Miljøundersøgelser og Århus Amt: Modelling af scenarier for næringsstoftilførsels påvirkning af den økologiske kvalitet i Ravn Sø. Dennis Trolle. In Danish.
- Søndergaard M., Jeppesen E., Jensen J.P., Amsinck S.I. (2005): Water Framework Directive: ecological classification of Danish lakes. Journal of Applied Ecology, 42.



Analysis of the diffuse P loss is part of a LIFE project, AGWAPLAN (www.agwaplan.dk) concerning the possibilities to reduce the diffuse load to improve waterquality, as described in the WFD.