PREDICTING CHANGES IN PHOSPHORUS LEVELS IN LAKE SURFCE WATER THROUGH MACHINE LEARNING TECHNIQUES

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ABSTRACT

Phosphorus (P) loading to lakes is degrading the quality and usability of water globally. Accurate predictions of lake P dynamics are needed to understand whole-ecosystem P budgets, as well as the consequences of changing lake P concentrations for water quality. Hence in this paper we will discuss about a model which can estimate the P concentration in a lake.

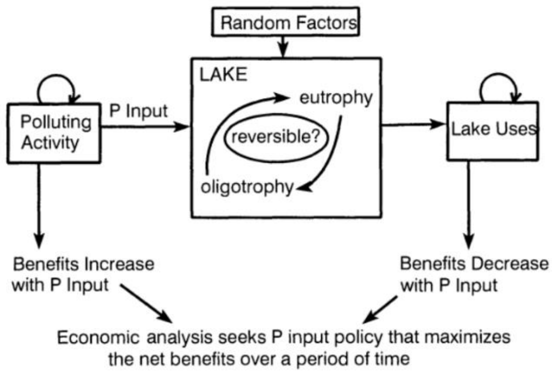
INTRODUCTION

Phosphorus plays a significant role in lake degradation as excessive levels can lead to eutrophication. When high amounts of phosphorus enter lakes, it acts as a nutrient, promoting excessive growth of algae and aquatic plants. This overgrowth can disrupt the natural balance of the ecosystem, causing problems such as reduced water clarity, oxygen depletion, and the creation of harmful algal blooms. These changes negatively impact aquatic life, water quality, and recreational activities, ultimately degrading the overall health and function of the lake ecosystem. Controlling phosphorus inputs is crucial to mitigating lake degradation and maintaining a sustainable aquatic environment.

Two ecosystems of lakes are considered:

Oligotrophy: Oligotrophic lakes are characterized by low nutrient inputs, low to moderate levels of plant production, relatively clear water, and relatively high value of ecosystem services.

Eutrophy: Eutrophic lakes have high nutrient inputs, high plant production, murky water, anoxia, toxicity, and relatively low value of ecosystem services.



Our goal is a model that is consistent with the mechanisms of eutrophication and the state changes known from lakes, yet simple enough to be integrated with an economic model in a comprehensible way. We show that the model is supported by major patterns from comparative limnology, consistent with many case studies of lake eutrophication and its mitigation, and provides a reasonable fit to long-term ecological data.

LAKE EUTROPHICATION

Eutrophication, caused by excess inputs of nutrients, is a widespread and growing problem of lakes, rivers, estuaries, and coastal oceans. The main source of phosphorus pollution is runoff from agriculture and urban lands. Because sources are diffuse, this pollution is difficult to measure and regulate.

Lake response to P input and recycling: a model

$$X_{t+1} = X_t + a - bX_t + f(X_t)$$

where *a* and *b* are functions of the original parameters and

$$f(X_t) = X^q / (1 + X^q)$$

X(=P/m) is the state variable to be managed, *a* is the input which is the single control variable, and *b* is a parameter that determines whether the lake is reversible, hysteretic, or irreversible for a given value of *q*.

b and q are unique for every lake.

USAGE OF R IN PREDICTING PHOSPHOROUS LEVELS

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

lake problem script.R

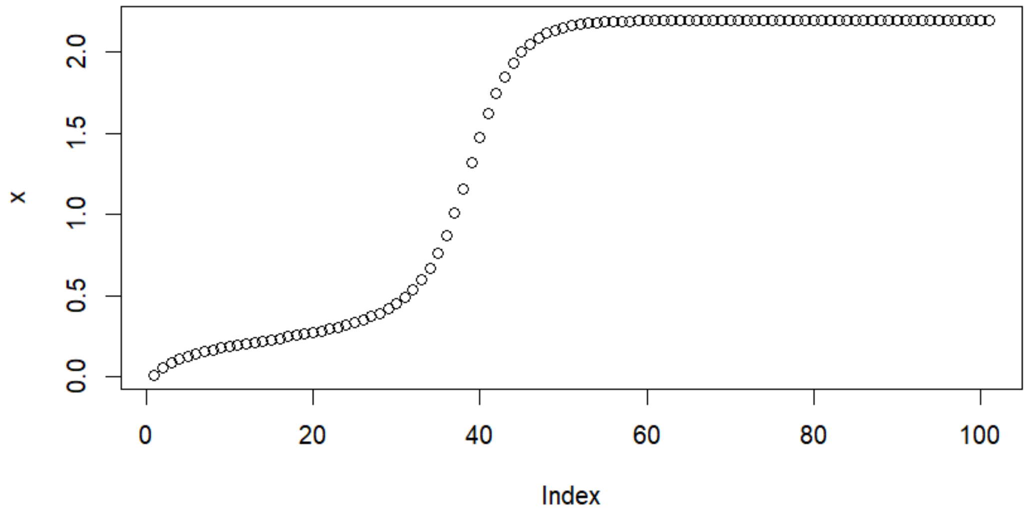
```r
#lake problem script

rm(list=ls())

#define values of b and q
b      = 0.4
q      = 2.0
nyears = 100
x      = array(NA,nyears)
x[1]   = 0.01
anth   = array(0.05,nyears)

#source = array(NA,nyears)
#sink   = array(NA,nyears)

for(t in 1:nyears){
x[t+1] = x[t] - b*x[t] + anth[t] + x[t]^q/(1+x[t]^q)


#source term

#source[t] = anth[t] + x[t]^q/(1+x[t]^q)

#sink term

#sink[t] = b*x[t]
}



plot(x)
```

33:1 (Top Level) R Script

Console

ANALYSING THE RESULTS OBTAINED

Following plot is obtained when the above program is executed



In the given above expression the source term and sink term are defined as follows:

source[t] = anth[t] + x[t]^q/(1+x[t]^q)

sink[t] = b*x[t]

The anth[t] term is the anthropogenic man-made input added to the lake every year which is assumed to be constant in the above calculation

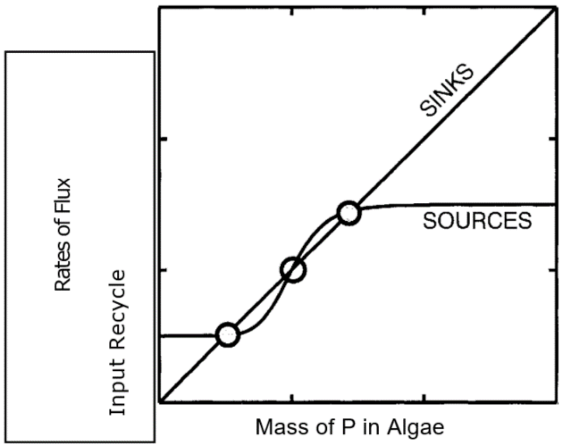


FIG. 2. Rates of P flux vs. P mass in the water, according to Eq. 1. The diagonal line is the rate of P loss. The sigmoid line represents the P sources (inputs + recycling). Intersections of these lines are the steady states. The open circle denotes the unstable steady state. Shaded circles denote stable steady states.

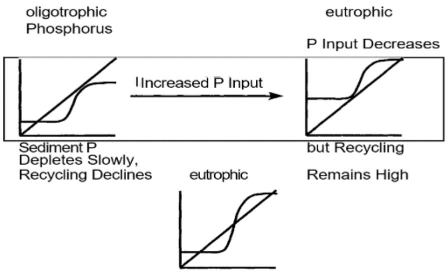


FIG. 7. Explanation of delayed response to P input reduction using the model. Increased P input converts an oligotrophic lake to a eutrophic lake. Management decreases P input, but recycling remains high. Eventually sediment P is depleted, recycling declines, and again the lake becomes oligotrophic.

The effects of increasing P input can have changes the state of the lake which is shown in the figure.

Increasing the P input changes the oligotropic equilibria into eutrophic equilibria and the recycling declines.