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Hypereutrophic Lakes: Can They Be Saved?

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Hypereutrophic lakes represent the ultimate stage of the eutrophication process, which is ecologically unstable and irreversible. Excessive input of nutrients from external sources leads to the "vicious circle" phenomenon, where the internal input of nutrients regenerated from the anoxic sediments is sufficient enough to drive the lake productivity by itself. Different strategies and radical in-lake measures are needed to rehabilitate them to some use. A summary of these is presented.

KEYWORDS: eutrophication, stability, algae blooms, lake restoration

Hypereutrophic lakes and reservoirs represent the ultimate stage of the eutrophication process. However, unlike in the case of "normal" eutrophic systems, where conventional nutrient loading reductions (advanced sewage treatment and basin-wide agricultural practices) may bring about reversal of the process (see successful examples from the Great Lakes - IJC 1991), these measures are seldom feasible in hypereutrophic lakes. This is mainly due to uncontrollable diffuse and non-point sources of nutrients, originating from overfertilized soils, and domestic animal farming. The lakes suffer from nuisance blooms of blue-green algae, episodes of algal bloom collapses resulting in massive fish kills, cattle mortality from algal toxins, foul beaches, impaired recreational use, swimmers itch, etc. They are often considered an ecological "write-off" and sometime drained and filled-in. Yet, assuming adequate sanitation to minimize health hazard, they are an integral part of the landscape ecology, providing sanctuaries for migratory birds and an important wetland habitat.

There are, however, some ways how to improve their poor water quality and make them acceptable for some uses, particularly fish production and limited recreational use. Brief summary of these is presented below.

Specific features of hypereutrophic lakes

Specific features of hypereutrophic ecosystems were treated in some detail elsewhere (Barica 1981). In relation to their potential rehabilitation, I shall mention their two most characteristic features:

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1. Unsustainable productivity and irreversibility of the eutrophication process

As a result of excessive nutrient loadings (often in excess of 25 g m^{-2} y^{-1}; Barica 1981), growth of algae progresses exponentially, as the number of algal cell, usually Cyanophytes, doubles about every day. Figure 1 presents three generalized patterns of algal population development. Lake 1 (oligo- to mesotrophic) is a stable, steady-state system, where the initial exponential growth soon levels off, reaching an equilibrium with the nutrient supply, and gradually declining towards the fall. This system is ecologically sustainable. Lake 2 represents an advanced eutrophic system which exhibits signs of instability as it begins to oscillate, i.e. undergoes series of partial die-offs of the bloom. This erratic system has already reached the limits of sustainability (or surpassed them), and is becoming vulnerable to external factors (Barica 1993). From the rehabilitation point of view, the eutrophication process at this stage can be still stopped or reversed by conventional point-source nutrient controls. Lake 3 illustrates the ultimate stage of bloom development, where the nutrient and/or energy input becomes inadequate to sustain the magnitude and the physiological requirements of the bloom. Under these conditions, the entire algal biomass (bloom) collapses and dies-off. This catastrophic event ends with severe or total oxygen depletion, causing massive fish mortality and die-offs of some zooplankton. This system is ultimately unstable, unsustainable and irreversible for rehabilitation, unless some drastic measures are undertaken within the lake itself.

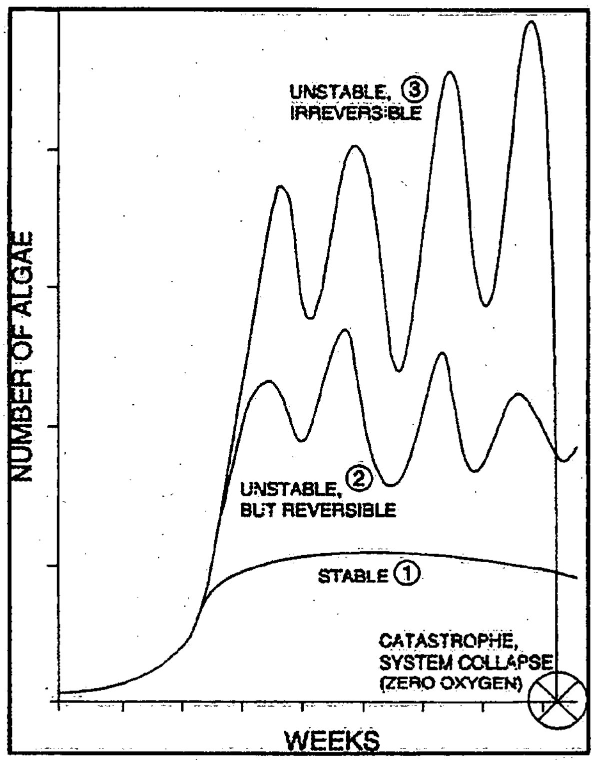

Fig.1. Generalized pattern of algal growth in 1: oligo-to mesotrophic lake, 2: eutrophic lake, and 3: hypereutrophic lake undergoing bloom collapse, in regard to its ecological sustainability and reversibility of eutrophication through nutrient controls. Modified from Barica 1993.

2. The "vicious cycle": internal versus external nutrient loading

In addition to high external loading of nutrients from the drainage basin (both point- and diffuse sources), internal loading of nutrients through oxic and anoxic regeneration is significant, and can occasionally exceed the external load, especially during the low-oxygen periods. This phenomenon is accelerated in shallow non-stratified lakes, where bottom anoxic and nutrient-rich layers of water mix up frequently with the surface layers due to wind action. This means that once a lake has reached a hypertrophic state, its dependence on solely external sources of nutrients is diminished and the lake

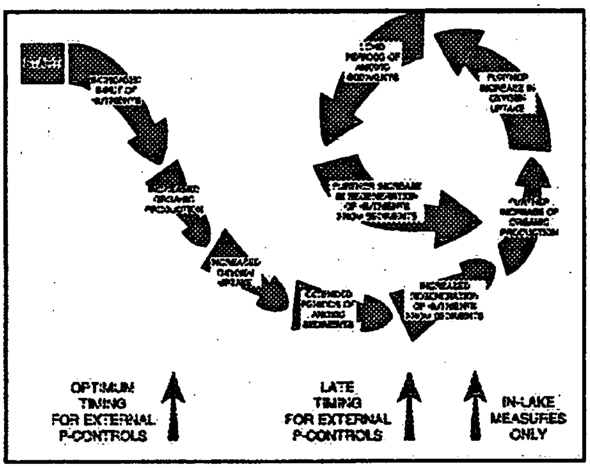

Fig.2. A "vicious circle" in a self-propelled operation of a hypereutrophic lake. Internally regenerated nutrients are able to operate the whole system even when the external loading is stopped. Modified from Oláh 1975 and Barica 1981.

can function as a self-propelled system (Fig. 2), with the sediments providing an adequate supply of nutrients, even when the external sources are reduced (Barica 1981). A good example of such situation is the hypolimnion of Lake Erie, which was expected to recover its oxygen conditions soon after introduction of phosphorus controls. While the lake itself showed positive results (dramatic reduction of algal biomass within a few years), the hypolimnetic oxygen depletion still persists, even after more than twenty years of controls (Charlton 1980, IJC 1991).

Approaches and strategies to rehabilitation of hypereutrophic lakes

Since the hypereutrophic lakes are past the "point of no return" in the eutrophication sense, conventional remedial measures to reduce their nutrient input are unrealistic. There are enough nutrients already recycled in the system, so the "vicious" internal nutrient circle (Fig. 2) operates at full swing. In some extreme cases, bacteria take over the overall lake production (saprobic level). Drastic corrective measures have to be performed within the lakes themselves,to bring about expected improvements. The selection of the corrective measure depends on the expected use of the lake: for truly hypereutrophic lakes this will be mostly fish production and no-contact water sports/ recreation.

<u>Manipulation of phytoplankton composition by changing N:P ratios</u> was used to stop fish kills from collapsing Aphanizomenon blooms in prairie lakes of western Canada used for rainbow trout aquaculture (Barica 1994). Since the hypereutrophic systems have as a rule very low N:P ratios (less then 5) as compared to oligo-or mesotrophic ones (over 20), rising these ratios either by nitrogen addition (in a fertilizer form) or by phosphorus reduction in the water column (by P precipitation) is a logical approach (Fig. 3). Addition of nitrogen fertilizer (as ammonium nitrate) to elevate the N:P ratios to about 20-50 would stop the collapse by either substantial reduction of the Aphanizomenon biomass, or by an overall shift in composition to non-collapsing species (green algae or non-fixing blue-greens). However, the algal biomass remained high and the aesthetic quality for recreation did not improve. The fish kills were definitely stopped. On the other hand, precipitation of phosphorus from the water column by surface application of lime (Murphy *et al.* 1988), which raised the N:P ratios also, achieved both: the overall reduction of algal biomass and better water clarity for recreation.

<u>Dredging of sediments</u> with high concentrations of organic carbon and nutrients has been also successful, but very expensive (well-known classic case of Lake Trummen in

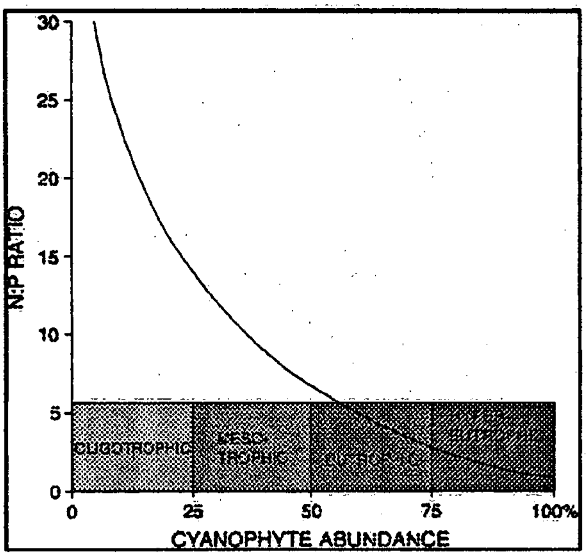

Fig.3. Relationship of the blue-green algae-abundance (per cent) to N:P ratios in lake water of different trophic state. Generalized from own and literature data.

Sweden; Björk 1978, Chain Lake in British Columbia; T. Murphy, pers. comm.). Lake aeration by compressed air did not work in shallow unstratified lakes (it stirred-up the toxic sediments and caused fish mortalities), but has been successful in other instances in stratified lakes, particularly combatting mid-winter anoxia (Manitoba Dept. of Fisheries, unpublished data) and summer hypolimnetic oxygen depletion (Ashley *et al.* 1990). Some attempts have been made to seal-off or cap the sediments by fly-ash or bentonite layer; no concrete positive results have been so far available to the author. Algae control by herbicides, usually copper sulphate, has been practiced around the world for some time with conflicting results and a potential danger to the fisheries. If performed correctly and at the optimum time, i.e. at the beginning of the bloom rather than at its peak, and with minimal concentrations of copper, i.e. 0.040-0.080 mg/l instead of about 2 mg/l as practised by lake operators, this method can be successful and safe. The free toxic ionized copper, that kills the algae, quickly precipitates as insoluble carbonate (Whitaker *et al.* 1978, Mattos *et al.* 1992). Algae control by herbicides is truly the "last resort" solution, a piecemeal band-aid measure to treat the symptoms rather tan the cause of the disease, but justifiable if no other methods are feasible and affordable.

In dealing with the hypereutrophic lakes we have to be very pragmatic: fixing up the lake first and returning it to the landscape and a beneficial use should be the primary objective. Only then we can apply preventive strategies of the ecosystem approach.

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