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BIOMANIPULATION IN THE NETHERLANDS: APPLICATIONS IN FRESH-WATER ECOSYSTEMS AND ESTUARINE WATERS – AN INTRODUCTION

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INTRODUCTION

This issue of the Hydrobiological Bulletin has a special significance in that all the ten papers it encompasses are solely devoted to the theme 'Aquatic Ecosystem Biomanipulation', a subject which has increasingly been receiving attention of both the water quality restorer and the aquatic ecologist. The papers present in a nutshell our recent, but first, experiences with aquatic ecosystem restoration; they are confined to the 'top-down' approach (McQUEEN *et al.*, 1986; BENNDORF, 1988) of curing a eutrophicated ecosystem. The technique is now, perhaps very rightly, considered by many of us as complementary to the 'bottom-up' technique of lake restoration and water management, namely reduction in allochthonous nutrient loading, especially of phosphorus (*e.g.* BJÖRK, 1985). However, one has to bear in mind that there may be an upper limit of the external and internal phosphorus load which should not be exceeded if the food web control is to operate successfully (BENNDORF, 1988).

SYNDROMES, SYMPTOMS AND STRATEGIES

In The Netherlands the only experience available with the lake restoration strategy, based on reducing the external nutrient inputs, concerns the Loosdrecht lakes and Lake Veluwe (VAN LIERE, 1986, HOSPER and MEIJER, 1986), which are shallow highly eutrophic lakes in the centre of the country. It, however, only underlines the global experience which shows dismal delays in recovery in many shallow eutrophic lakes in which only nutrient input was decreased (*e.g.* SAS and VERMIJ, 1989; BENNDORF, 1988; HOSPER, 1989). We now know that a deeper insight is needed into the internal ecological processes which retard, or even obscure, the recovery processes. Biomanipulation concerns the biotic aspects of the food chain, which need to be brought into some sort of a trophic equilibrium from the present complete disarray (SHAPIRO, 1984; BENNDORF, 1988; SCHEFFER, 1989). Most eutrophic lakes have a series of common syndromes, or comparable symptoms of ecosystem breakdown and water quality deterioration (see *e.g.* HOSPER, 1989). In these lakes the poor under-water light climate (Secchi-depth <30 cm) is caused by excessive algal growth (chlorophyll-a concentrations up to 300 $\mu g.l^{-1}$), usually filamentous blue-green algae (cyanobacteria), such that the submerged macrophytes first become scarce and then completely disappear. Also piscivore fish decrease markedly but the planktivore fish, usually bream (*Abramis brama*), became highly abundant (LAMMENS, 1989). These changes lead to a virtual disappearance of large-bodied crustacean zooplankton, namely *Daphnia* spp. (GULATI, 1989).

Thus, biomanipulation is an attempt to regulate the planktivorous fish by way of mechanical eradication initially, but by predator control, *i.e.* by enhancement of piscivore fish stocks, in the long run. In this regard pike (*Esox lucius*) and pike perch (*Stizostedion lucioperca*) have been tried (VAN DONK *et al.*, 1989b; VAN DENSEN and GRIMM, 1988; BENNDORF *et al.*, 1988). This sets in motion a series of food chain processes, directed downwards in the food chain at relieving predation on zooplankton by planktivorous fish; the zooplankton in their turn reduce the seston, including algae, improving the light climate (SHAPIRO,

1984; LAMPERT *et al.*, 1986; LAMPERT, 1988; GULATI, 1989). Once the under-water light conditions improve, the macrophytes can colonize (or recolonize) the lake bottom so that the piscivores, like pike *Esox lucius*, feel 'at home' (see *e.g.* GRIMM, 1989) and the 'feed-back' effects may lead to a new equilibrium between the planktivores, their predators and prey. It may be emphasized that future improvements in biomanipulation will give more attention to conditions that promote the success of *Daphnia* spp. (EDMONDSON and ABELLA, 1988).

The simplified sketch of steps in biomanipulation as mentioned, though an ideal one, may not be easy to achieve. But this is certainly the crux of the problems in the lakes under restoration. From the successes or failures there is a lot to learn. It is important to share the knowledge with the global community of aquatic ecologists, water-quality managers and, not to forget, with their fund givers (HOSPER, 1989).

COOPERATIVE STUDIES, PLANS

Even though biomanipulation as a restoration technique, like in most of the West-European countries, does not have a long history in The Netherlands, it has made rapid strides in the last half a decade. A literature review study on biomanipulation by RICHTER (1986) helped pave the way for some serious thinking among the water managers and the ecologists and also marked the start of at least five cooperative studies among the Institute of Inland Water Management and Waste Water Treatment, the Limnological Institute of the Royal Netherlands Academy of Arts Science, the Organization for the Improvement of Inland Fisheries and the Provincial Waterboard of Utrecht. The projects in which these institutions have been cooperating are fish ponds at Beesd (MEIJER *et al.*, 1989b; RAAT, 1989), Lake Bleiswijk (MEIJER *et al.*, 1989a), the experimental ponds near Lake Wolderwijd (GULATI and HEUTS, 1987), Lake Zwemlust (VAN DONK *et al.*, 1989a; VAN DONK *et al.*, 1989b; GULATI, 1989), and the enclosure study at Tjeukemeer (RICHTER *et al.*, 1987). As this issue goes to press, at least two more biomanipulation projects, Lake Breukeleveen and Lake Wolderwijd, are in an advanced preparatory phase. Bream removal from the lakes and the associated studies will start in early 1989 and 1990, respectively, as a first step towards biomanipulation of these lakes, but on top of the chemomanipulation (phosphate removal) already effectuated (VAN LIERE, 1986; HOSPER and MEIJER, 1986). This, together with the projects already in progress, would amount to having covered shallow freshwater lakes (mean depth *ca.* 2 m) varying in their area by about 4 orders of magnitude, viz. Lake Zwemlust (1.5 ha), Lake Bleiswijk (14 ha), Lake Breukeleveen (180 ha), and Lake Wolderwijd (2900 ha). These water bodies also differ in some other limnological characteristics, particularly their hydrological regimes. The success of the projects will depend considerably on the tripartite cooperation between aquatic ecologists, water managers and the fishermen (HOSPER, 1989).

THE PRESENT EFFORT

Six of the ten papers presented in this issue were read at the October, 1988, meeting of the Netherlands Hydrobiological Society, held at Amsterdam. Two papers deal with the Dutch estuaries and, therefore, depart from the main theme (LEEWIS *et al.*, 1989; OORTHUYSEN and IEDEMA, 1989). Due to the enormous size and continuity of the estuaries and oceans, biomanipulation practices, like in freshwater ecosystems, are difficult to imagine. However, there is no denying that the geography of The Netherlands has necessitated the building of barrages, dikes and storm-surge barriers (*e.g.* in the Oosterschelde), all of which have led to alterations in abiotic factors (*e.g.* hydrology, chemistry and substrate). Manipulation with these factors, to create new or better niches for biota and to preserve the biotic diversity, is some sort of biomanipulation. Thus, even though the objectives and measures taken differ from those in the freshwater studies, there is certainly a parallel with regard to effects on the ecosystem structure and functioning.

In the papers presented there is sufficient diversity of approach. For example, type and nature of biomanipulation in Lake Zwemlust (VAN DONK *et al.*, 1989) were unique in that during the process of planktivore fish removal, the lake was completely drained empty, but refilled quickly. The ecosystem development could be monitored from the very early stage. This also offered an unique opportunity to follow some classical cause-and-effect phenomena at the nutrient-phytoplankton and phytoplankton-zooplankton levels and *vice versa*, before the biological complexity increased. In the case of Bleiswijk (MEIJER *et al.*, 1989) the partitioning of the lake led to two parts, with similar water chemistry initially, but one with planktivorous fish (Zeeltje) and the other without fish (Galgje). This made it feasible to draw better comparisons on zooplankton-phytoplankton interactions, with Zeeltje acting as a control. The

grazing zooplankton species are apparently very efficient pumping and filtering systems that can daily filter water up to 5 orders of magnitude of their own volume and in doing so remove large amounts of food from the system (GULATI, 1989). The reader will discover from the three papers dealing with fish (GRIMM, 1989; LAMMENS, 1989; RAAT, 1989) how crucial the role of fish in the ecosystem is. Even though our theoretical basis for the biomanipulation is rather week, the minimal model (SCHEFFER, 1989) applying a simplified, three trophic-level system 'algae-zooplankton-bream', is a useful exercise. We hope such theoretical studies will find an adequate stimulus in the future biomanipulation studies. Hosper (1989) gives a global picture of the complex two-way feed-backs 'the bottom-up/top-down interactions' in the ecosystem.

Unfortunately, it has not been possible to include in the present Volume investigations carried out in the laboratory or on mesocosm scale, e.g. the enclosure studies at Tjeukemeer (RICHTER *et al.*, 1987). Also, the papers included give only an overall view of the projects in operation rather than describe in depth the mechanisms involved. We are happy to have been able to get the manuscripts in time for publication in early 1989, thus well before the International Symposium 'Biomanipulation Tool for Water Management' (8-11 August 1989) starts at Amsterdam. We do not have the pretentions to present these proceedings as a forerunner of, nor is it our intention to offer them as *hors d'oeuvre* to the International Symposium in August 1989. Hopefully, the reader will get a bird's eye-view of the Dutch exercise, experience and expertise in the ecotechnology of biomanipulation, notwithstanding that this complementary approach of lake restoration may have surprises as well as successes in store for us.

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