LAKE RESTORATION IN BERLIN

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1. HISTORICAL AND REGIONAL INFLUENCES AS THE CAUSE OF LAKE EUTROPHICATION

Interaction of scientific and political mechanisms in the evaluation of a single event, such as the restoration of a eutrophic lake or of a series of lakes, is not easily innovated without first establishing contact with the other processes of developing and laying out landscape, with or without man's influence. Natural geological events are without man's influence. Natural geological events are far from meaningless compared to man's intervention, when seen in the context of their long-lasting effects on the ecosystems. No human influences on ecosystems in our regions are conceivable compared to the Ice Ages with respect to the effects of creating and annihilating life, e.g. by creating biotopes and lakes. However, we should not overlook the ubiquitiously progressing destruction of complex ecosystems such as the tropical rain forests which are becoming victims of the same fate as the European post-glacial forests over the past 500 years. The genetic reserve potential for repopulating barren areas is being endangered. On the other hand, man's ubiquitous work does have one aspect which compels us to consider measures for the long-term conservation and restoration of ecosystems.

The economic development of this Greater Berlin Area and of Brandenburg as one of the triggering factors in the displacement of catchment areas

A decisive turning point in the life of the Brandenburg lakes historically coincides with the end of the forests in this region. In the historical accounts of this area, one finds, mostly as notes in the margins alongside illustrations of man's cultural and belligerent development, the remark that "the forests had been converted to fields for farming purposes" between 1200 and 1230. The city of Hamburg burned to the ground in 1290 and was rebuilt using oak from Brandenburg. In the subsequent periods, the forest was not given an opportunity to let several-century-old oak trees grow again. The rain washed its fertile soil into the rivers and lakes insuring the first phase of eutrophication and silting-up. (It is not coincidental that the 750th anniversary of Berlin and the 750 years of lake eutrophication match up. This confirms the theory of the relatively young field of Cultural Ecology as regards the inevitability of correlation between cultural development and damage occurring to the environment.)

Interference in the aquatic environment by commercial fishing

As with farming, which became a determining factor regarding soil erosion and the appearance of the face of the earth, the routined relationships within aquatic biocenoses changed basically with the advent of planned catching and stocking; this change was not always for the best, as can be seen from some of the documents taken from reports of the fishing associations. As early as the beginning of the 20th Century, the side-effects of intensive fishing in lakes and rivers were being discussed.

Selective catching of certain fish species led to a large population of the unwanted species, especially true of the low-quality silver-scaled fish.

This effect was strengthened foolishly in that the "fish-enemies", the natural predators, were annihilated. Species which had very little influence on fishing such as the black stork or the otter had bounties on their heads and these rare species were fought despite pleading not to do so.

Aquatic farming aimed at the maximum fish yield without taking into consideration the prognoses regarding the adverse development of the water quality and the resulting adverse effects on the fishing industry itself.

Unfortunately, this way of thinking about the waters of the world has not changed fundamentally since that time. The abundance of fish is still the ultimate criteria of evaluating the quality of a body of water, from the fishing industry's point of view, which is understandable, as well as from the point of view shared by the public and politicians, which is not so understandable. The following examples show the extent to which this way of thinking contradicts reality, nature and the demands on their environment by the fish.

Trout is regarded as the fish coming from clean and clear streams, its natural ecological niche. The fact that at least 90% of all trout in Central Europe is the result of trout farming in ponds should not lead to the misconception that the water quality of these ponds is anywhere near that of a clear stream.

Most of the waters with an abundance of fish have been stocked with fish larvae. The fish do not go there on their own, nor do they breed there. Parallels may be drawn to other types of farming, the soil which is the substrate for the intensive growing of non-indigenous plants (also by destroying all competition) or for producing fast growing wood. In the long term, both types of farming have become useless in order to allow natural and well balanced biotic systems to develop.

Community water management policies from 1850 up to the present day as a cause for the rapid ageing of lakes

Waste water management of the urbanised and industrialised areas, using sewer systems, has resulted in subjecting flowing bodies of water to catastrophic changes in the last century. Observations make by Kolkwitz and Marsson at the turn of the century concerning flowing bodies of water in and around Berlin served as the basis for the sabrobic system established to classify water biologically, according to the burden of biodegradable or biologically functional substances. Publications from the early part of the 20th century describe changes in aquatic biogenoses resulting from tipping waste water - the conditions observed today were caused a hundred years ago. Further degeneration in the future may be considered as gradual changes which speed up the ageing and destabilisation processes.

The sewage burden placed on many flowing bodies of water inevitably causes a corresponding reaction in static waters which are fed by these rivers and streams. This can be seen in the lakes of Greater Berlin and especially in the series of lakes formed by the rivers Spree and Havel, and their tributaries. Having obtained their present size either naturally or by having been dammed up.

Strategy to conquer waste was developed for Berlin almost a hundred years ago. First of all, the untreated sewage was deposited on a sewage farm. Integrating nutrients into agricultural products was an ecological start in the true sense of the word. In order to avoid overburdening the sewage farms, the amount of water deposited was approximately the same as the annual precipitation. Unfortunately, the sewage farms were not enlarged proportionately to the amount of sewage, and after a few years the absorption capacity of the soil had been exceeded totally with 10m3/m2. The final attempt to solve Berlin's sewage problems was started in the 1920's. It was planned to spread biologically treated sewage on the agriculturally used heights at Barnim and Teltow. Using the available knowledge of that period regarding fertiliser requirements of crops and absorption capacity of the soil, it was calculated that such a project would require several hundred square kilometres. Unfortunately, this concept was never put into practice due to political and economic mismanagement of the following years.

2. DEVELOPMENT OF THE DECISION-MAKING PROCESS IN THE FIGHT AGAINST EUTROPHICATION

The autrophication of the static bodies of water was presented to the public in the 1960's as the result of using laundry detergents containing phosphates, based on a coincidence factor.

Mounds of foam floating on the flowing bodies of water burdened with sewage were contributed to tipping detergents along with domestic sewage.

The Detergents Act, which went in effect in the mid-60's, was the first legal regulation of handling identifiably chemical environmental hazards.

The increase in population density in the urbanised areas, in the number of sanitary facilities and in the use of laundry detergents came about the same time as did the public and political awareness of the increase in eutrophication problems. This caused the misconception which preserves to this day, i.e. that the eutrophication did not only become apparent at the same time as the above-mentioned factors but was actually caused by them.

This mistake was strengthened by scientific experiments concerning eutrophication and the generalised sewage-caused changes in the surface waters.

Exact knowledge of the life requirements of the cyanophycae (blue algae) taught us that nitrogen-fixing cyanophycae were able to become dominant in a system limited by nitrogen after phosphate ceased to be a limiting factor due to increasing the amount added.

Various scientist were of the opinion that the eutrophication process could only be limited by elimination the growth-limiting factor in the body of water concerned. This misconception confronts us again today in evaluating the eutrophicating process in the North Sea and in the Baltic. The correct procedure here would be the same as in the case of the eutrophicating of inland water ways; that is, after many years of disrupting ecology by adding nutritive substances, to create a condition by either replacing the natural limiting factor or employing one, which according to the present state of the art, we could expect to serve as a regulator after many years of disrupted ecology. According to scientific studies in anthropo-genically over-fertilised lakes, it is usually necessary to reinstate a phosphate limitation system, independent of the fact that large loads of ammonia are just as much a burden to the oxygen supply in the coastal waters as in the flowing bodies of elimination of nitrogen from domestic sewage or from illegally tipping liquid manure from animal husbandry into the surface water.

During the 1960's, a scientific controversy developed as regards carbon, nitrogen of phosphate being the limiting factor of algae growth in eutrophication bodies of water. This argument moved increasingly in the direction of accepting the phosphate hypothesis. The scientific verification of the phosphate hypothesis, i.e. the eutrophication model creation by Vollenweider became the basis for evaluating the permissible phosphate load for static waters.

We encounter many possible points of view which are defended by the "correct strategy" for overcoming the eutrophication of the lakes. Only very few clear scientific positions have been taken regarding the eutrophication of the flowing bodies of water as well as concerning the eutrophication of coastal waters. Both of these areas are lacking in fundamental scientific information which would permit a comparable intensive treatment as is the case with static waters. Therefore, the following material is virtually limited to the problems encountered in static inland waterways.

The present state of the art concerning the problems of eutrophication offers a great deal of supporting evidence which would enable us to make correct decisions.

The acceleration of the ageing process in lakes by tipping nutrients from the surrounding areas may be correlated with the start of intensive agriculture and extensive land clearing which started in and around Berlin and Brandenburg during the first half of the 13th century. The supporting evidence comes from pollen analyses conducted on drill logs consisting of sediment.

We have access to observations of the eutrophication of static waters, influenced by human behaviour, which were written in the middle of the last century, such as "water blooms" of Aphanizomenon flos-aquae and Microcystic aeruginosa in Tegler See; Anklamm, 1878.

Scientific investigations conducted in the period between 1900 and 1940 verify the fact that the conditions fo the lakes worsened due to agricultural measures, i.e. amelioration and the use of agrochemicals, and due to the expansion of the sewage systems. Some scientist and fishing experts pledged to improve the amount of fish caught by pumping nutrient-enriched sewage into the lakes used for fishing (Demoll's proposal for Lake Constance from 1923), other scientists from the up and coming field of limnology rejected this and referred to the declining catch and the economic damages resulting from an uncontrolled tipping of nutrients into lakes; they also recognised fertilising measures as being totally senseless (Wundsch, 1940).

In 1953 Ohle described the "rapid ageing process of lakes" in Holstein based upon the observations of changed ecology in various lakes over the past fifty years. After exceeding a certain amount of phosphate in the lakes, internal processes accelerate the ageing process due to a higher primary production and an increased load on the oxygen supply, independent of a further increase or of a gradual decrease of the added nutrients.

There is a lot of speculation on the possibilities of decreasing the use of phosphate, in order to avoid damage instead of repairing it. In most of those cases, the minimal amount of phosphate generated by every living individual is underestimated. The request to avoid phosphate as a food additive was articulated, which is possibly correct for other reasons but not for physiological ones. The urine of a healthy human has a mean value of 750 mg phosphate per litre. This buffer is replenished from the calcium phosphate reserves of the skeleton if a phosphate deficiency should occur. Healthy humans receiving sufficient nutrition eliminate about 1.1 to 1.3 g of phosphate daily in their urine. If we are to keep our presently existing concept of municipal sewage disposal via a system without any alternative plan, we will have to contend with an amount of phosphate making its elimination from sewage compulsory.

Improvements in sewage treatment by utilising biological treatment facilities are not taking the burden off the bodies of water, due to the fact that inorganic nutrients are retained in the treatment plant only in a small amount. This is the case for all dissolved phosphate compounds regardless of whether they were produced by human metabolism or by laundry detergents. This is the basis of the call for advanced treatment, i.e. the chemical or biological elimination of phosphate.

Before the discussion gets involved as to whether politically motivated opinions are called for, the scientific theses should be tested for their validity.

Both of the following premises can be found in scientific works conducted in the last few decades.

1. Phosphate was or is the natural limiting factor of most of the static bodies of water in Central Europe
2. Excessive addition of phosphate increases the primary production and leads to eutrophication.

A second group of findings is based on knowledge of the composition of laundry detergents and of the situation of communal water management.

1. Modern all-purpose laundry detergents contained phosphates, at least up until 1986.
2. Using laundry detergents containing phosphate increases the amount of phosphate tipped into bodies of water.

It is possible to draw the following conclusions from these premises based on historical coincidence.

1. Phosphate from laundry detergents cause eutrophication.
2. Forbidding phosphates from being put into laundry detergents would help fight eutrophication.

In the Federal Republic of Germany, this incorrect conclusion has led to legislation dictating a highest legal concentration of phosphate and has cost more than an entire decade of scientifically unnecessary work trying to fight against the acceptance of such unscientific postulates.

Due to the fact that we are thoroughly successful in finding eutrophic bodies of water in which it can be proven that the eutrophication did not result from the influence of phosphates contained in laundry detergents, we are therefor able to disprove the general validity (and with it the general usefulness) of such a conclusion. If however, it is not possible for us to find a body of water which has become oligotrophic due to forbidding phosphates in laundry detergents, i.e. a body of water which has reacted with a reversed development to return to its earlier state, the conclusion is not scientifically acceptable. We can only accept a scientific theory as a basis for our actions when it is the based on an unacceptable and disaprovable conclusion, as it is here.

The questionability was articulated by experts in this field during consultations in the Federal Republic on phosphate policies. In focusing on the detergent industry as a contributor to the problem, they wanted to conform with the positive experience made as regards the Detergents Act. In his closing remark at a symposium on advanced sewage treatment, Malz stated "that solving the problems with surfactants is basically the job of industry which has solved it brilliantly", on the other hand "solving the problem with phosphate is essentially the job of sewage technology, definitely involving relevant industry and agriculture".

The scientific material is supposed to serve as a basis for decision making and there is no moral obligation connected to possessing this knowledge concerning environmental policy. Our form of government provides for a separation of powers which has two different effects. It is not enough just to put scientists in their place when they use their expert knowledge to give them an automatic commission to put research results into practice. Politicians are required to make decisions based on expert knowledge and are responsible for any difficulties from a wrong decision because they did not sufficiently consider the available knowledge. Both sides have made unnecessary mistakes in the past as regards environmental protection which can be traced to confusing responsibilities. Frequently, the politician was not informed extensively enough as to which of the possible decisions he ad to choose from would have what effects on the general public. There is not enough emphasis placed on the limitations concerning the moral acceptance (but sometimes low) degrees of plausibility from scientific studies.

An example of the aviodability of such mistakes is found in the Swiss phosphate policies. Opponents to our water conservation policies who want to limit solving the eutrophication problem by banning phosphate in laundry detergents are often told that the Swiss cannot have been totally out of contact with reality. In Switzerland, after making a political decision based on the options offered by the scientists, they are concerned with the political goal of identifying agriculture as the main remaining cause in this cause in this case and of forcing it to take necessary measures. The package "more effective sewage treatment plus phosphate stop" has been used successfully to put an end to the game of shoving the blame from one party to the next. In cases in which the weight of evidence of certain scientific information or of common sense is not sufficient, political tactics become an essential element in environmental policy. It must also be clear that this tactic can be directed against the environment and society as well. In that case the demand is placed upon the scientist to work for better fundamentals and their application.

3. CONCEPT FOR THE RESTORATION OF BERLIN LAKES

It was recognised that one of the goals of lake restoration was that the rapid ageing of the lakes had to be stopped or slowed down and that the foreseeable uses with demands on the functionability of the lakes' ecosystem had to be put in line with natural conditions.

This recognition was the basis for a restoration concept with reinstating the limiting factor, phosphate, as a goal. Of course, the isolated situation of the City of Berlin (FRG) played an important role in instituting this plan.

There are no alternatives for supplying drinking water.

There is a large demand for local recreation areas which are fairly well intact.

The Berlin lakes are used for a multitude of purposes, ranging from gaining bank filtrate to recreational fishing and discharging sewage.

The Vollenweider phosphate loading concept from 1968 as the basis of the concept for dephosphorisation

From 1968 Vollenweider's eutrophication model was the first in which a relationship between the phosphate load in a lake and its tropic level had been calculated. Using this as a reference, the phosphate burden from external sources acceptable for the Berlin lakes could be put into figures. This requires a reduction in the phosphate content of the major sources of influx by more than 99%. This is the stumbling block which starts up the controversy between the expects as to whether or not such a comprehensive elimination is feasible at all. Experiments with models on a technical scale have shown that by treating the water from Nordgraben (one of the main tributaries of the Tegeler See) which has an extremely high nutrient content, the process combination of flocculation, sedimentation and filtration reduced the total phosphate content from more than 10 mg per litre to 10 mg per litre (Hasselbarth, 1977; Grohmann, 1982). Due to the fact that we have to reckon with more sources of nutrient, such as the recycling of phosphate from sediment, or phosphate in precipitation, the phosphate elimination plants have been constructed in such a manner that there is a residue of less than 10 mg per litre of total phosphate after plant treatment. The data in the following survey show that this would result in 0.11 g/m2* a for Schachtensee and in 0.25 g/m2* a for Tegeler See when seen in a relationship of influx from the main tributaries to the surface areas. This lies clearly under the permissible total phosphate load.

Drinking water, recreational areas and restoration planning

The aspects which trigger lake restoration (aside from the obvious changes in depth visibility and the macrophyte vegetation) are the demands for the supply of drinking water, influenced by the water quality of bank filtrate from the lakes and interference with the use of swimming areas. This is not only an aesthetic interference, but also has an impact on health, as demonstrated by the presence of allergens and toxins produced by the predominant cyanobacteria in the summer.

Accordingly, the demands placed on the restoration's efficacy are to be in total concordance with the requirements of this most sensitive kind of use, whereby the slowest possible ageing process should be obtained. It has never been planned nor is there any danger of establishing more or less sterile drinking water reservoirs in the open country around Berlin as they have in America. The present load and other external and internal nutrient sources cause us to fear that the goal we have set will start to become visible for the first time years after the restoration processes have been started. Nevertheless, highly eutrophic lakes have already started to make poor use of nutrients. The fish population and its multiplication is supposed to be positively influenced due to the fact that long-term eutrophication-related dominance of the white-scaled fish which is of "inferior quality as seen from a fisherman's point of view" is not a situation we wish to maintain, neither from a fisherman's point of view nor from an ecological one. Let us not forget that the fishing associations are major cause of this situation, due to their rigorous fight against the so-called enemies of the fish and because of their selective fishing.

Process engineering concept for phosphate elimination

The procedures to follow for phosphate elimination were being discussed up to a few years ago, especially with respect to more comprehensive sewage treatment, however, with considerably fewer requirements. The requirements usually drew to a close at a level which could be obtained fairly easily without seriously interfering with the existing biological treatment plans. However in restoring lakes we have to contend with a concentration range which can only be attained by technology suited to produce drinking water. We also have to filter out the colloids which are not sedimentable and the particle-bound phosphor. When producing portable water by treating surface water, we have to use these generally recognised rules of technology, i.e. the necessary filtration. This has been ignored by the sewage technicians when working out water conservation measures. These conditions were the basis for the process technology described by Grohmann in 1982 in which he eliminated phosphor to less than 10 mg per litre phosphate.

Secondary measures

Other measures, aside from reducing the main influx, were taken into consideration. They were supposed to support the restoration process because of the high degree of preliminary burden. Some of these thoughts were directed at nutrient-enriched hypolimnetic water and sediment. In the pertinent publications in this field, there are several procedures used to stabilise sediment:

- in-situ precipitation with aluminium of water;
- hypolimnetic aeration;
- aerating by circulation the entire body of water;
- treating sediment by injecting nitrate and iron salts;
- withdrawing the hypolimnetic water, rich in nutrients.

Based on the situation in Schlachtensee, the only measure felt to be essential and helpful was pumping out the hypolimnion; pumping in water for Wannsee was considered to support the chemical precipitation. This was used each year in late summer, and it began in August 1981, the year before the phosphate elimination plant was started up. This was performed in order to avoid, at least in part during the full circulation in October, the recalculation of the nutrients which had accumulated in the hypolimnetic water. Due to the pool morphology, to the relative small importance of the hypolimnion and to the varying degree of stability in the lake's strata, aeration does not have any prospect of succeeding.

Treating the sediment with Ca-nitrate is an involved measure which has only been used up to now in small shallow lakes. From 1982 to 1983, the release of phosphate was reduced by employing several tonnes of Ca-nitrate. Further use is not planned, due to the fact that the sediment is stabilising itself, even without any help because the influx of nutrients has been reduced.

An important plan for ensuring the long-term success of the restoration is keeping the storm water away from the lakes. Only after reducing the total phosphate load, did it become visible that the nutrients coming from precipitation and storm water, especially during the summer, improved phytoplankton's development. Diverting storm water coming from the communities surrounding the lake would, however, cost about 20 million Deutche Marks. As part of the total scheme of reducing the load in the South-Berlin lakes, rivers and streams, it is in the plans to divert the water resulting from precipitation in the communities surrounding Schlachtensee to a so-called rain-water-collection-and-treatment pool.

Expectations and success predictions at the start of restoration

Controversies among the experts arose even as clearly as the process-engineering planning stage as regards the attainability of high quality/quantity purification. Even great differences in opinion concerning the expected development of the lake resulted in public and scientific discussions. Due to the fact that several of the arguments frequently came up in similar form, we are going to list them here, grouping them in pro and contra.

CONTRA	**PRO**
Due to the many years of over-fertilising, no success can be expected at all without first eliminating or treating the sediment.	The enrichment of hypolimnetic water will be stopped with the reduction of the nutrient input into the production zone.
The productivity of the algae will not have been checked enough to stabilise the oxygen budget.	After an exchange phase of a few years, the level of primary production will also permit an increase in the oxygen content in the hypolimnetic water.
The fish population will increase. or The fish-population will suffer.	The stock of high-quality fish will improve when the white-scaled fish are put in check. The stock is perhaps less in quantity but higher in quality.
The Vollenweider - OECD - model cannot be applied to lakes the size and depth of those in Berlin.	The OECD study, "Shallow Lakes and Reservoirs", tends to give load limits in the same dimension as would apply to deeper lakes.
Phosphate elimination with a chemical water treatment are no measures to be applied to the source. Furthermore, environmental protection should employ natural methods.	The inevitable phosphate load, resulting from human nourishment, forces us to eliminate phosphates as much as possible from waste water, sewage or surface water. The required surface area for natural phosphate elimination processes is larger than the total surface area of Berlin itself. Of late, there are promising initial results for eliminating phosphate biologically using the activated sludge process.

4. TEST PROGRAM AIDING THE PROCESS OF RESTORATION

Two years prior to the planned commencement of the phosphate eliminating plant in Beelitzhof, an in-depth research program was started to determine the status quo, conducted over a period of almost eight years and it has provided for a comprehensive answer to the pressing questions.

Can phosphate be eliminated to this large degree, from more than 1 mg per litre down to less than 10 per litre total phosphate content, on the long term with a reasonable amount of effort?

Would such strongly over-fertilised ecosystems which have been in this state for such a long while, as is the case with Schlachtensee and the Krumme Lanke, show reactions to the reduction of the nutrient load within the near future?

How and within which period of time would the ecological characteristics of the lakes change?

Which changes of the phytoplankton and zooplankton populations can be traced back to a reduction in the phosphate influx?

Due to the fact that Schlachtensee and the Krumme Lanke are fed with water directly from the phosphate elimination plant, we would expect to see the first reaction here. Therefore, it is legitimate for us to limit ourselves to these two lakes, although the Grunewaldsee is fed with water from the Krumme Lanke via the pumping station, Paulsborn, but is changed to a certain extent by first passing through the Riemeisterfenn. This marshy idea includes an area occupied at one time by the marsh lake which dried up when the ground water level dropped; nowadays there are only a few sloughs and ponds, either left over or newly created by pumping water into the area. To what extent the water resulting from precipitation flowing into the Grunewaldsee from the urbanised areas via the precipitation small chain of lakes in the Grunewaldsee area influences the ecosystems than further on "downstream" with the low-nutrient water from the Krumme Lanke will be seen in the next couple of years. Further studies are planned.

Information-gathering network and periods of testing

Because of its oblong form and its division into independent reactors, three permanent information-gathering centres were established in Schlachtensee and two in the Krumme Lanke. Water samples were taken here once a week from the epilimnion (1-m depth), once a month the sample taking included a logbook entry which was supposed to reflect the subsurface chemical, physical and biological parameters. This temporal gridwork made it possible during the two years before starting up the phosphate elimination plant and over the three following years, to the end of 1984, to sufficiently characterise the basic limnological conditions. Afterwards, and for reasons of cost, sample taking was limited to once a month at one station in each lake. However Station III remained in use in Schlachtensee during the summer in order to evaluate the varying conditions in the strata.

5. RESULTS UP TO PRESENT

The phosphate elimination plant has now been in operation for more than five years. In that time, Schlachtensee has shown definite positive results which prove that the restoration concept was correct and that the technology which was used is in fact effective. With a bit of delay, the Krumme Lanke has started to stabilise on the level of a reduced tropic condition.

Reaction of the phosphate dynamics

The phosphate content in the lakes has been reduced very quickly, with a reduction of the total phosphate influx flowing from Wannsee into Schlachtensee from originally 1500 kg per year (1980/1981) to about 30 kg per year in 1986. During the first summer, the surface water contained almost no more solute phosphate available to algae. The mean value of the total phosphate content (determined with the total water column and over a period of 1 year) lies at about 30 mg/l phosphate only slightly over the goal of about 30 mg/l phosphate based upon about 600 mg/l before the restoration. Proportionately to the reduction in the body of water, the phosphate enrichment in hypolimnetic water was reduced to such an extent that refluxing the nutrients form the depths does not pose a danger to the restoration.

Influences on the fish population

With delay of two to three years the nutrients were reduced in the lakes and a redistribution of the algae population took place. Interfering water blooms made of blue-algae masses which had become common in Berlin lakes have not appeared since 1984. The total reduction in algae development allowed visibility of up to seven meters in spring 1985 and 1986. Water of this clarity had never been documented for any natural lake in Berlin.

Development of phytoplankton

Of course, such a drastic influence in ecology and in the possibilities of plankton development will influence the feeding conditions of the fish in the restored lakes. Consumers of algae such as small crabs and the larvae of insects are in the food chain. They were no longer in a position to decimate the algae effectively because they were the prey of the white-scaled fish, due to the fact that the population of the white-scaled fish adapted itself to the availability of large amounts of zooplankton. Therefore, an elimination of algae always meant a collapse in the white-scaled fish population. Unfortunately, this happened with an unexpected efficiency during the spring of 1983 which caught everybody concerned by surprise. The press attacked the planners and operators of the phosphate elimination plant. However, neither the unusual selectivity in the fish which died (only old, malformed and "used" breams) nor examination of the fish and the lakes gave any evidence that the phosphate elimination had poisoned the water. Because we had reckoned that the remainder would die off gradually, we had not taken any measures to get rid of these fish beforehand. However the stock of bream and others was reduced to a tolerable amount for the lakes during the winter of 1983/84.

6. EVALUATING THE EFFECTS OF RESTORATION

The results of restoration work carried out in the lower lakes in the Grunewald area were presented at international congresses. The Berlin Concept is by far the most demanding in phosphate elimination of any restoration measures taken up to now in the whole world. It is also the most advanced as regards the effects achieved by restoration as expressed by the phosphate concentration in the lakes and the development of algae (qualitatively by changing the population to more favourable species and quantitatively by reducing the biomass of algae).

We may regard the unfortunate situation of our city being walled in as a positive factor in getting scientific knowledge put into practice so rapidly. In other places, as experience has shown in the past, other possibilities could be found where the water was not polluted and from which drinking water could be drawn and which could be used for recreational purposes. However, in closing we do not want to cover up the fact that even seen from an economic point of view the basically expensive measures carried out in the Berlin lakes is a gain in the end. According to Evers, there is at least a 30-million Deutche Marks profit as opposed to the 20-million Mark cost of running the phosphate elimination plant which has been started up in Tegel.

In view of the development in water quality as well as with respect to the economical justification we are going to work towards instituting further ecological measures with this degree of significance.

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