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Restoring Lakes in Sweden

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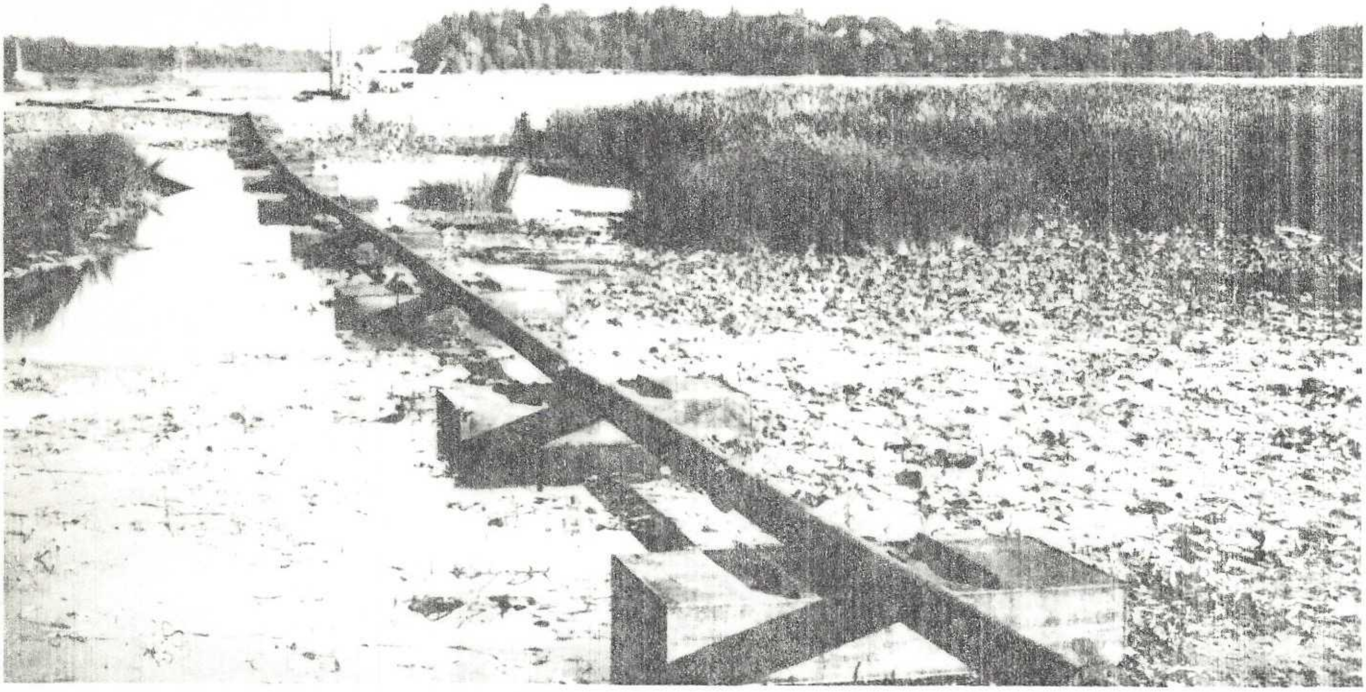
The town of Växjö in southern Sweden stopped pouring sewage into Lake Trummen in 1958 when it became obvious that the 1 km.^{2} body was overexploited. The upper photograph shows the unrecovered lake 11 years later—no oxygen, no fish, no underwater vegetation, little human use. The problem mainly was one of a rapidly increasing black muddy sediment fed by decaying plankton. Starting in 1970 the sediment was sucked out and deposited into settling ponds; runoff water was freed of phosphorus and returned to the lake. Lake Trummen is now in good health (lower photograph) and a recreational asset.



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Restoring Lakes in Sweden

Since lake restoration research is a very young field, ecologists need opportunities to test their ideas, to apply their theories in nature, to provide concrete examples of ecologically sound methods of tackling the problems created in lake ecosystems by man.

However, responsibility for the restoration of lakes does not rest solely with ecologists. A cooperative effort with public administrators, politicians and technicians is necessary.

There are very few cases on record, to date, where these interests have joined forces to save a damaged lake.

This article presents four lake restoration projects, three in Sweden and one in Tunisia, that prove such cooperation is possible. The great interest displayed by the concerned governments in initiating projects such as these to improve the human environment is most encouraging. Two of the projects are completed, and work is progressing on the other two. Each project is an educational experience and provides further knowledge of the structure and function of lake ecosystems.

The four projects were undertaken by a team of limnologists at the University of Lund in Sweden as part of a lake restoration program that has been going on for several years. Now that the initial phase of the program is finished, news of the ideas and methodology is travelling quickly to other parts of the world, and due to a lack of funds for nonroutine limnologic investigations in Sweden, trained limnologists will probably follow.

The aims of the lake restoration research program at the University of Lund can be summarized as follows:
—To obtain methods of solving some of the severe environmental problems that Man has created.
—To restore certain lakes judged to be of high environmental value.
—To train limnologists and other ecologists so that they are capable of solving practical problems in applied water management.
—To contribute additional knowledge to theoretical ecology.

As each water is unique, each one must be investigated and given a tailor-made limnological treatment. It must be stressed that it is impossible to establish a standardized treatment. The lakes investigated in this program represent a wide variety of conditions.

The three Swedish lakes included in the program are of different types: shallow Lake Trummen and deep Järla Lake—both old receivers of sewage and industrial waste water—and shallow Hornborga Lake, where the water level had been drastically lowered. Thus three different sets of methods had to be worked out to correct the balance of the three different lake ecosystems. This meant that, among other things, the equilibrium between production and mineralization had to be restored.

A total of about 20 research workers from the Institutes of Limnology, Microbiology, Plant Ecology, Animal Ecology, and Quaternary Geology have been active in the project, and there has been close cooperation with technological experts.

The Hornborga Lake project began in the late fall of 1967, the Lake Trummen project in the late winter of 1968, and the Järla Lake project in the late winter of 1969. The former is still in progress, and the latter two have been completed.

Some of the knowledge gained from the Swedish experiment is now being applied in a project to restore the Lake of Tunis in Tunisia. Plans for this restoration are being formulated under the auspices of the Tunisian Government, Tunis city administrators, and fishery administrators. These authorities are anxious to see the lake transformed from the environmental mess it is today to the environmental asset it can be tomorrow. This can be a fairly simple operation if carried out in the ecologically correct way. The Tunisia project is described later in this article, following a presentation of the Swedish pilot projects.

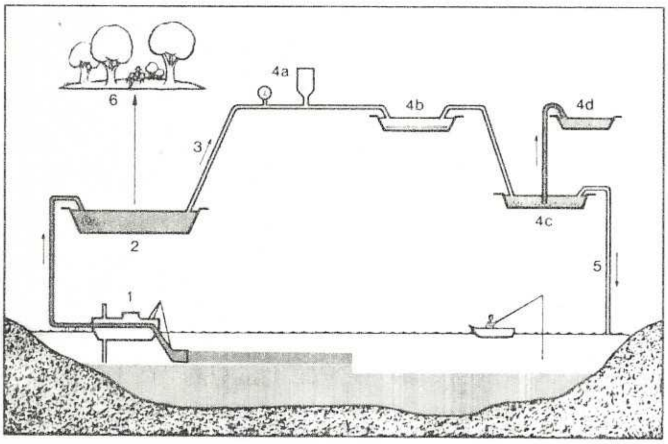
Lake Trummen

The inland town of Växjö (ca. 60,000 inhabitants) is surrounded by lakes. Of these, Lake Trummen and Växjö Lake became the first recipients of the town's sewage. When these eventually became overexploited, the waste water was diverted to another, South Bergunda Lake. For the past 20 years or so, the sewage has gone through a two-step treatment. A third step, treatment with aluminum sulfate was added in 1972. At this time, however, South Bergunda Lake is also overexploited. Nearby North Bergunda Lake is therefore being considered as the potential fourth recipient of Växjö's waste water.

Helga Lake, which lies north of Växjö, became polluted by waste water from a paper pulp plant and is blacklisted because of the high mercury content there.

Originially, Trummen, Växjö and South Bergunda were low-productivity lakes, but the inflow of waste water eventually converted them into water bodies

Lake Trummen was virtually dead when the sewage inflow was cut off. It did not recover for 12 years. Then a restoration project, based on removal of sedimentary ooze, brought the lake dramatically to life again.



Lake Trummen's tailor-made treatment: (1) suction dredger designed to operate with minimal turbidity and mixing; (2) settling pond; (3) runoff water; (4) precipitation of phosphorus and suspended matter with aluminum sulfate; [(4a) automatic dosage, (4b) aeration, (4c) sedimentation, (4d) sludge pond], and (5) clarified runoff water. (6) The dried sediment is used as fertilizer for parks and lawns.

containing concentrated nutrient solutions and maintaining an enormous growth of algae in the summer.

Lake Trummen (1 km.^{2}, maximum depth 2 m. until 1969) was well fed with sewage, especially from 1936 to 1958. From 1941 to 1957, the lake received waste water from a flax factory. Prior to that, only small quantities of waste water were discharged into the lake. The lake was utilized as a water supply source, at least to some degree, until the 1920s. During that time the bathing places were frequently utilized.

From a water conservationist's point of view, it is a remarkable and important fact that Lake Trummen did not recover after the inflow of waste water was cut off in 1957—1958. This meant that the lake maintained the characteristics of an overexploited recipient during the 1960s. In the soup of blue-green algae, the summer transparency in 1969 was only about 20 cm., reeds and water lilies spread and the total oxygen deficiency in the winter killed off the fish. There was no underwater vegetation at all.

Substantial investments are made in sewage treatment plants in order to improve the environment. In Sweden, about 300 million Swedish kronor (ca. US $60 million) are invested per year in plants (not including pipes to these). During periods with high unemployment the investments are much larger.

It is common knowledge that waste water treatment methods are still fairly stereotyped, and that very few plants use original combinations of methods specially tailored to the ecosystem of the specific receiving body of water. The efficiency of the treatment is commonly expressed in relation to the raw sewage.

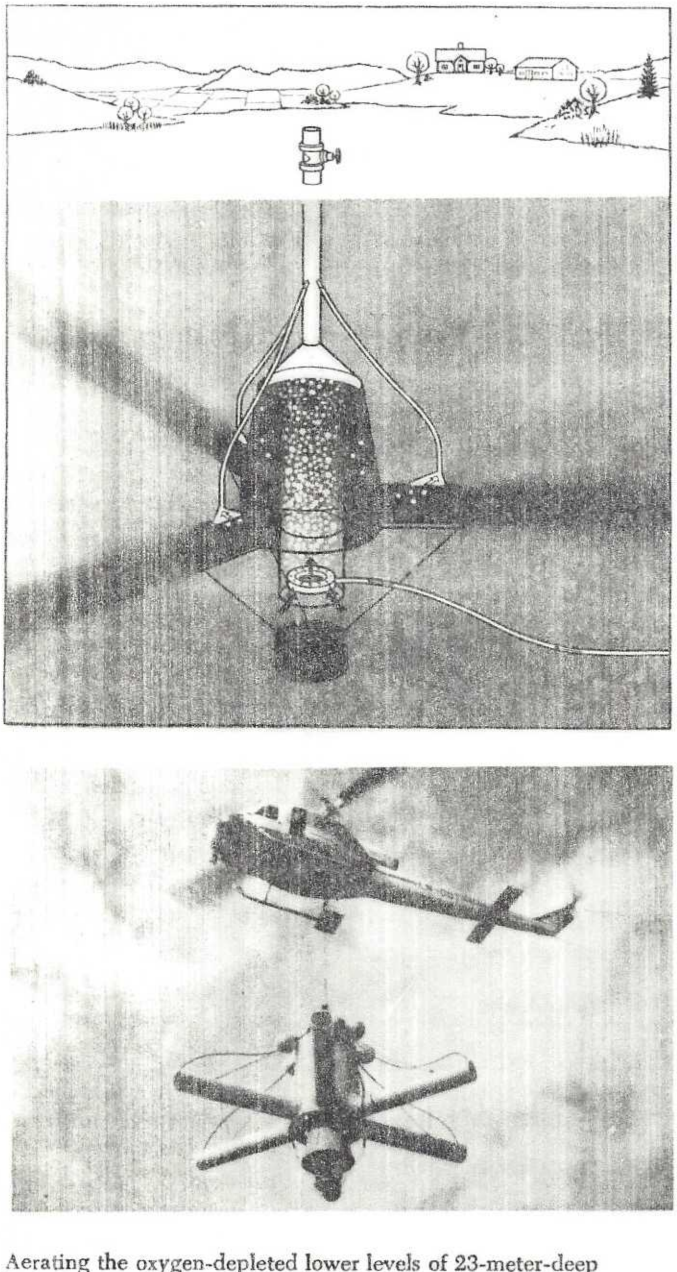
When dealing with a receiving lake's ecosystem, single-factor data are given, e.g., supply of phosphorus or nitrogen per ha./yr. Figures such as these can be evaluated in agriculture when fertilizers containing a few elements are added to monocultures growing in extremely well-known soils. However, no two lake ecosystems are alike, neither with respect to environment nor to organism communities. Furthermore, the lake ecosystems undergo successive changes as they undergo exploitation, which means that this kind of evaluation is hardly relevant to the measuring of the loading of lakes.

In treatment plants as well as in lakes, physical and chemical parameters are easily recorded automatically. Within the biological sector we must confess that we have great difficulties, even in identifying the organisms chiefly involved in the treatment process and responsible for the variations in the recipients' ecosystems. An enormous investment is necessary if we are to have, decades from now, enough trained limnologists within the biological sector, microbiologists, planktonologists, etc.

The fact that there are great variations in nature means there are also great variations in the influence of different treatment plants on different lakes. Some receiver lakes are exploited to the point where the damage is irreversible: even when the source of pollution is cut off, the lake cannot recover on its own. Other exploited lakes have the capacity for self-recovery, at least to some extent.

In the case of Lake Trummen the damage was irreversible.

Just before Trummen became a recipient of waste water, the sediment growth rate was 0.4 mm./yr. The onset of pollution and the consequences thereof caused an increase in the growth rate to 8 mm./yr. The difference in the quality of the two sediments is striking. During the lake's recipient period, the accumulation per m.^{2} of phosphorus was up to 20 times higher and the accumulation of zinc was up to 65 times higher than before the waste waters started pouring in.



Aerating the oxygen-depleted lower levels of 23-meter-deep Järla Lake without disturbing thermal stratification. The compressed-air oxygenation (250 kg./day) is done internally in the submerged unit so that bubble-free water may be dispersed over a large bottom area. The photograph shows the installation of a specially developed hypolimnio aerator, which restored the oxygen level of the deep waters without causing eutrophaction at the upper levels.

The irreversible situation in Lake Trummen was due to the deposition of the loose black "cultural layer" covering the well-consolidated brown sediment of the pre-recipient years. The black mud layer was from 0.2 mm. to 0.4 m. thick, and the nutrient leakage from this layer caused the high productivity in the spring and summer. Plankton and macroscopic plants grew, died, settled and decayed, maintaining the rapid growth rate of the sediment and supplying it with releaseable nutrients.

The limnological plan for the restoration of Lake Trummen was focused on the sediment problem. It was decided that the black cultural mud had to be pumped from the lake up into settling ponds on land. From these, the run-off water would go through a simple treatment plant for phosphorus removal before being discharged back into the lake.

The project was carried out with very stimulating co-operation between the ecologists, town authorities and technological experts. For the sediment-removal part of the project, a suction-dredging method was used. The limnologists requested a nozzle which would make it possible to suck in the sediment without making the lake water turbid and with very little mixing of lake water. The engineers of the Swedish company Skanska Cementgjuteriet constructed this nozzle.

In 1970 about 0.5 m. of sediment was removed, and in 1971 another 0.5 m. Altogether about 600,000 m.^{3} of mud and 300,000 m.^{3} of lake water were pumped to the settling ponds. The ponds were constructed in an arable land area from which the topsoil had first been removed, exposing a poor moraine suitable for pond dikes. The sediment pumping ended in October 1971. The dried sediment is now being used as a fertilizer for lawns and parks in the rapidly growing town of Växjö.

The run-off water from the settling ponds was a mixture of lake and interstitial (sediment) water. Its high fertilizing effect was checked by means of bio-assay with algae. The total phosphorus content in the water in Trummen before the restoration was ca. 600 μg/1 in the summer, and in the untreated run-off water from the settling ponds, a further increase was brought about by the addition of interstitial water. However, aluminum sulfate was used for precipitation of suspended matter and phosphorus, and thus in the treated water returned to the lake the total phosphorus content was only about 30 μg/1.

The littoral zone of Lake Trummen is fairly rich in stones and boulders. In the landward part, the dense vegetation growing in sediments overlying the stoney bottom had to be removed by a dragline. The elimination of the vegetation exposed the original shoreline to view. In 1972, the first year after the restoration, a distinct rinsing of the shores [took] place, thanks to the revived water movements. Until the sedimentation limit has stabilized, a detritus turbidity will be noticeable in the water. The invasion of underwater vegetation and bottom fauna will help to keep the detritus particles confined to the bottom.

Follow-up investigations in Lake Trummen will continue until the summer of 1980. Information will be collected on water and sediment chemistry, phytoplankton, macrophytes, zooplankton, bottom fauna and fish populations.

As was foreseen, the changes in Trummen's ecosystem have been dramatic. The transparency has increased but [was], in 1972, still limited by plankton and is highly dependent on the amount of detritus whirled up by the wind, especially from the littoral zone. The phosphorus content has decreased, as has the nitrogen content. During the late winter period which had in the past been the critical time, the oxygen conditions were excellent after the black sediment had been removed. The heavy waterbloom of *Microcystis spp.* (blue-green algae) disappeared, while *Pediastrum spp.* (green algae) and *Anabaena flos aquae* (blue-green alga) were the characteristic summer plankters of 1971 and 1972, respectively.

Lake Trummen is now accessible for fishing and bathing, and it can be considered to be a valuable recreational asset.

The total cost of bringing Lake Trummen back to health was Sw. kronor 2.5 million (U.S. $500,000). The cost of adding the third step to the Växjö treatment plant was Sw. kronor 20 million (U.S. $4 million).

Now that it has been brought back to health, Lake Trummen is being attacked from another angle. A proposal to build a new motorway across the lake and along the southern shore has been made. None other than the National Swedish Road Administration would be responsible for the realization. It is a remarkably short-sighted proposal, an example of the kind of "progress" envisaged by the forces of exploitation. Another motorway is already being built close to the western shore. This new encroachment on the Lake Trummen area would, of course, be an irremediable mistake. The lake has been restored, yes. But if Trummen is to be framed in by motorways, one could well ask, restored for what? And for whom?

Järla Lake

Situated near Stockholm, Järla Lake has an area of 1 km.^{2}, is 23 m. deep at its deepest point, and has a distinct thermal stratification in the summer. It is an old recipient for sewage and industrial waste water. Before the restoration project, the oxygen content in the lower water layers was reduced to zero during stagnation periods.

Although it is possible to increase the oxygen content of some lakes by means of artificial total circulation during the natural stagnation periods, this method was not advisable in the case of Järla Lake. Artificial total circulation would have brought about the transport of nutrients from the bottom water layer and their dispersal in the illuminated superficial water layer—thus increasing the productivity—and the cultural sediments would have been warmed up, bringing about an increased consumption of oxygen.

The goal of the Järla Lake project was to increase the oxygen content of the lower water layers in a limnologically correct way, i.e. without disturbing the thermal stratification. A collaboration between limnologists and technological experts from the Central Laboratory of Physics at the Atlas Copco Company resulted in the ingenious technical solution shown on p. 55.

In brief, this equipment now makes it possible to increase the oxygen content in deep recipients to the desired degree. In a lake of the Järla type, the earlier anaerobic water layers could easily to kept at an oxygen level of, say, 7 mg./1.

Because of lack of funds, it has not been possible to carry out long-term studies of limnological changes accompanying the improved oxygen conditions of Järla Lake. However, after three months' aeration (June—August), the sediment surface was oxidized, the concentrations of phosphate phosphorus and ammonium decreased, and the nitrate concentration increased. In spite of the short experimental period, an invasion of bottom animals was hoped for, but they failed to appear. A search conducted to determine the causes of this and the consequences of the aeration of the sediment led to the discovery that the cultural sediment layer was partly impregnated by oil, which made it impossible for certain organisms to survive.

Experiments are now being carried out in West Germany in which inert phosphate-adsorbing substances are added in connection with the aeration.

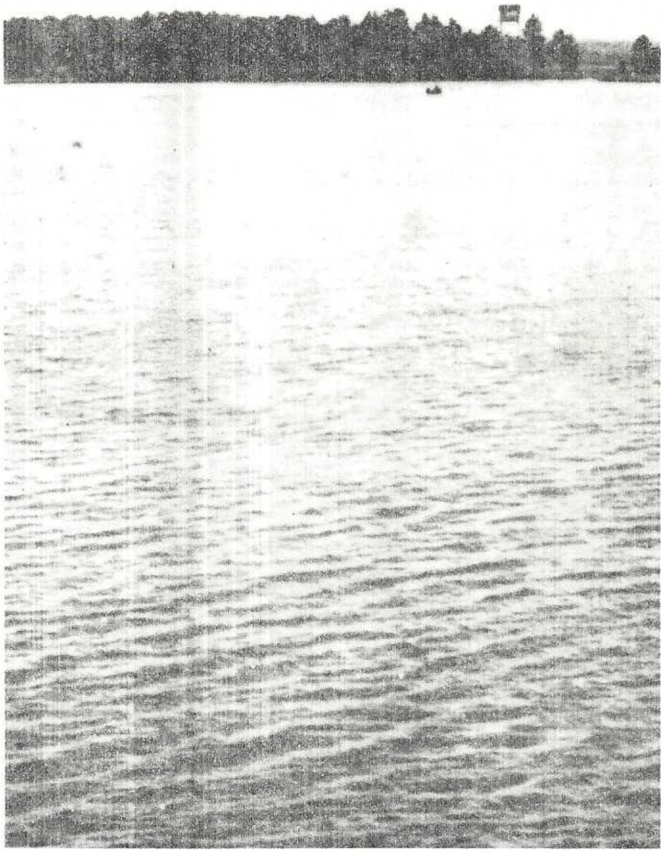
In Sweden, the effect of the so-called "bubble-method" has been checked in a 7 m.-deep lake in which a thin layer of bottom water was depleted of oxygen during calm periods. In this lake the proportions between the volumes of water with and without oxygen made it possible to use artificial total circulation. With this method compressed air bubbles out from plastic hoses distributed in a rib pattern in the deepest part of the lake. Anaerobic conditions can thus be avoided. As soon as the oxygen content of the lake starts to decrease, the compressor is started and operates until the oxygen deficiency is eliminated.

Aeration and bubbling are two ways of making recipients more effective and for speeding up the recovery process in old recipients. Irreversible damage can in this way be prevented until a modern treatment plant is built.

Hornborga Lake

Hornborga Lake is a shallow, drained lake. Until man interfered with the well-organized system of components that functioned within this lake, it maintained a rather high degree of productivity without suffering from rapid aging. That is quite remarkable for a lake of this size (30 km.^{2}) and shallowness (3 m. at the deepest point). Most of the lake was much shallower. A constellation of such factors as rapid water renewal, well-situated inlets and outlets, strong water movements, and strong ice movements prevented the lake from becoming overgrown and provided a good system for transporting matter from the lake.

Since 1802 the lake has been lowered five times in attempts to obtain arable land. The last big failure, in 1932—1933, resulted in a bottom that was drained in



Sweden's 30 km.^{2} Hornborga Lake was lowered five times in futile attempts to gain arable land, the last in 1933. The result was a large area covered with reeds, sedge, and willow bushes. Restoration work was started in 1968 using amphibious and floating machinery for mowing, cutting, harvesting, and cultivating. The goal for the restoration was to transform 11 km.^{2} of reed area into open water and to keep 18 km.^{2} sedge-covered as a substitute for the original marshy areas. By 1970 the new open water area was becoming repopulated with desirable underwater vegetation and bottom fauna.

the summer, and which consisted largely of calcareous mud. A hilly land area of about 616 km.^{2} drains into the lake. This area needs the big reservoir Hornborga Lake to catch rainwater and melted snow that rush down the hills to the plain below.

From a nature conservancy point of view, the lake had a very high value before it was lowered, especially as a nesting site and resting place for waterfowl. After the last lowering, the lake ecosystem's structure and function were definitely destroyed. Monocultures of *Phragmites communis* (common reed), *Carex acuta* (sedge) and *Salix spp.* (willow bushes) crept in and nearly covered the lake area until 1967.

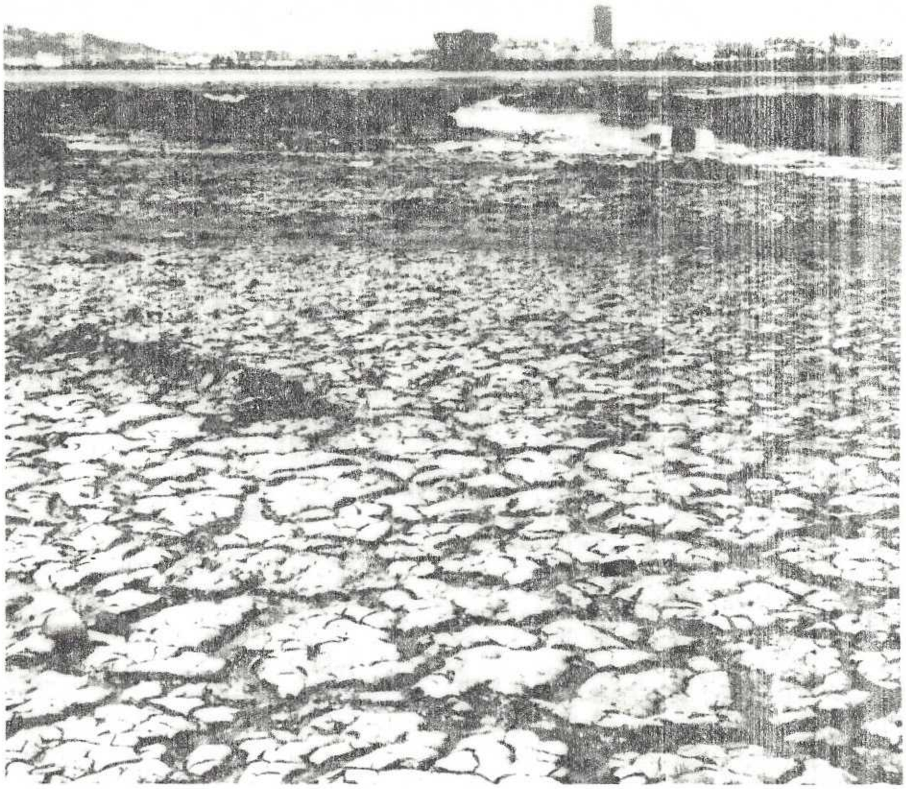
The National Swedish Environment Protection Board, after being ordered by the Government to investigate the possibilities of restoring Hornborga to the status of a waterfowl lake, organized a broad study of the complex of man-made problems concerning the lake. One year of limnological studies made it quite clear—theoretically—that the lake could still be restored. Large-scale field experiments were begun in 1968 to work out practical methods of correcting the irreversible damage. This was made possible because of the cooperation between the National Environment Protection Board, the National Labour Market Board, the National Board of Forestry, Seiga Harvester Co. (manufacturer of amphibious machines), and the Institute of Limnology at Lund.

As the water level had been lowered, emergent vegetation had invaded the colonizable areas and the upper sediment layer had become interwoven by roots. With the two plant species *Carex acuta* and *Phragmites communis* covering the main area of the southern and northern parts of the lake, respectively, the sedge had developed a thick, tough and resistant root felt. The sedge root felt posed a problem, as it was impossible to remove. However, the reed root felt could be cut by the amphibious rotor cultivators that were constructed for this project. The development of amphibious and pontoon-equipped machines for the restoration of lower lakes is continuing, and rotor cultivators strong enough to cut the sedge root felt will be constructed.

The project goal for Hornborga Lake is to transform the reed areas to open water (about 11 km.^{2}) and to keep the sedge-covered part (about 18 km.^{2}) for emergent vegetation as a substitute for the originally marshy areas around the lake.

The restoration plans for Hornborga Lake include a raising of the water level for a maximum depth of 1.9 m. or, even better, 2.4 m. It should only take one spring to fill the lake with water, as Hornborga Lake is flooded

Raw sludge deposits in the Lake of Tunis contribute mightily to the stench afflicting the city of Tunis. Experienced in tailoring lake restorations in their own country, Swedish limnologists and engineers are using sediment pumping, aeration, and vegetation removal techniques in a plan to bring the salty 29.5 km.² northern part of the lake back to health.



every year after the melting of the snow. When the water level has been raised, the sedge root felt will float to the water surface. This well-known phenomenon is caused by the gas (mainly methane) that forms in and under the root felt, through which the gas bubbles cannot penetrate. The floating root felt will rapidly be colonized by *Phragmitis, Schoenoplectus* (bulrush) and *Carex.*

By means of amphibious excavators, it is possible to break up the monotony of the sedge-covered areas—where the root felt will float up after the water level is raised—and to create a mosaic of open water and biotopes safe for nesting and attractive to birds.

The procedure for achieving the change from production of emergent vegetation to production of submerged vegetation in the reed areas is as follows:

In the winter the dry stems are cut by amphibious harvesters and burned on the ice. In the spring the stubble mats are shortened to about 40 cm. by pontoon-equipped mowers. During the low water period in the summer and autumn, amphibious machines are again utilized, first for cutting the green shoots and then for rotor cultivating the stuble mats and root felts. The requisite time per hectare is 8—10 machine hours. Enormous masses of accumulated coarse detritus are loosened from the bottom and transported by the spring high water to the shores where they are burned in the summer.

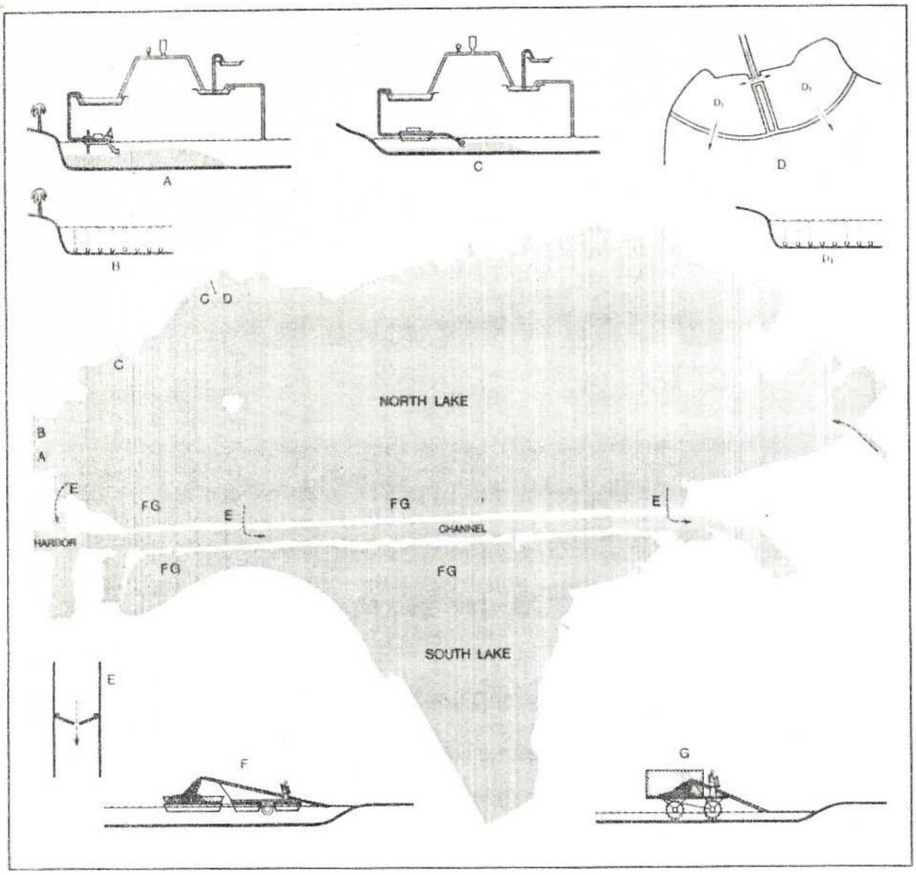
With the detritus out of the way, the consolidated mud again becomes the bottom and the reed monoculture is replaced by an underwater vegetation of *Chara* (charophytes,) *Potamogeton* (pondweeds) and *Myriophyllum* (water milfoils). A rich bottom fauna, microbenthos and periphyton is also reestablished.

Altogether, the biotope changes during the experimental period have resulted in a very obvious improvement of the waterfowl fauna. Of the nesting species, 70 per cent have increased in number. *Larus ridibundus* (the black-headed gull) increased from 5,000 to 8,500 couples, *Podiceps cristatus* (the great crested grebe) from 5 to 50 and *Aythya ferina* (the pochard) from 20 to 110 couples. These are results of the limited, experimental activity that has taken place in a small diked area of the lake where the maximum summer water depth is 80 cm. A definitive raise of the water level must include the whole lake area.

The Lake of Tunis

Experiences gained in the Swedish restoration projects—with sediment pumping, aeration and vegetation removal—were all useful in drawing up plans for the restoration of the Lake of Tunis. The city of Tunis has long suffered from the bad breath of the polluted lake. The stench is most repelling close to the population center, and it is there that the Tunisian authorities want to create an attractive environment. The planning of the Lake of Tunis restoration project has been organized and sponsored by the Tunisian Government in cooperation with the Swedish International Development Authority (S.I.D.A.) and the Institute of Limnology at Lund.

The Lake of Tunis is divided into the north and south lakes. Increasing volumes of raw sewage and increasing amounts of industrial waste water have been discharged into the north and south lakes, respectively. The north lake is the object of the restoration project dealt with here. It has an area of 29.5 km.², but contains only 27.6 million m.³ of water. Tunis is surrounded by



Plan for restoring the Lake of Tunis: (A) Suction-dredging of sewage sludge from the basin nearest the city; treatment of runoff water. (B) Aeration of basin until sludge is removed. (C) Sludge dredging at the Montplaisir and Cherguia sewage outlets; runoff treatment. (D) Collection of waste water from the Cherguia plant in two ponds until the outfall sludge is removed; (D_1) pond aeration. (E) Lock-controlled intake of water from the Mediterranean Sea (to right on map) into north lake, then into harbor and out to sea via the channel. (F&G) Removal of floating masses of algae using pontoon and amphibious skimmers.

very shallow, highly saline lakes. As the Lake of Tunis is connected with the Mediterranean, it does not dry up as the other lakes do. The water level, however, is dependent upon that in the sea.

The north lake is still receiving raw sewage (the westernmost part) and effluent from a treatment plant (the northwestern part). Thanks to the high salinity of the lake water (specific conductivity ranges from about 45 mS_{20} in early June to about 65 mS_{20} in early August), the coagulation and precipitation of particles is good. The sewage sludge deposits are, therefore, concentrated to restricted areas.

The self-purification capacity of the lake is still extremely good. This is apparent from the compressed zonation and steep gradients of environmental conditions and organism communities east of the outlets. In the summer the turbid zones of bacteria and phytoplankton can be very narrow in the western part, while the water in the rest of the lake is clear. In the clear area, luxuriant meadows of *Ulva* (sea lettuce) cover the bottom from shore to shore (*Enteromorpha* is also common), with the exception of the eastern part where brown algae are numerous, and there are open bottom areas that consist of pure shell gravel. Reefs of *Mercierella enigmatica* (tube worm) are common. The reefs are problematic from a hydrological point of view. However, the animals perform a filtration function, and thus play an important role in the lake's self-purification process.

The direct discharge of nutrients and the release of nutrients from the sewage sludge deposits speed up the growth of *Ulva* and other algae in the warm, shallow lake, and conditions are similar to those prevailing in a very effective algal culture. Due to the efficient photosynthesis, gas bubbles form in *Ulva* leaves, and large amounts of *Ulva* are set afloat. Thus, green mats of loosened algae periodically cover vast areas of the water surface. When the weather is warm and the water stagnant, the crop of *Ulva* and other algae decomposes and the water becomes oxygen-deficient. As the consequences of primary and secondary pollution, a nasty stench of raw sewage and hydrogen sulfide is apparent, and fish kills can occur. At times the waters of the Lake of Tunis become wine-red, and it looks as though the lake has been visited by one of the "seven plagues". This wine-red color is caused by the mass development of planktonic micro-organisms, a common phenomenon in salines and highly saline lakes in North Africa.

According to present plans, the sewage will be diverted from the north lake when a more effective treatment plant is completed. The preliminary aims of the project are to eliminate the most disturbing effects of the pollution, to break the trend toward progressively worsening conditions, and at the same time to prepare for the final restoration. In line with these aims, a working program has been presented to the concerned authorities.

The ca. 20-hectare water basin closest to the beautiful palm-lined Avenues Mohammed V and Curtelin is filled with sewage sludge and the water sparkles with gas convection. Within the areas around the sewage outlets of Montplaisir and Cherguia, the situation is about the same. In laboratory tests it was found that the release of NH_4-N is 500-900 and of PO_4-P 25—30 mg./m.^{2}/day from the sewage sludge sediment to the water. The corresponding figures from Lake Trummen were 75 and 15 mg./m.^{2}/day, respectively.

The method used in the restoration of Lake Trummen can be adopted for use in the Lake of Tunis project. Land areas perfectly suited for sediment deposition are available close to the parts of the lake where the sewage sludge is concentrated. Until now, these land areas, enveloped in the evil-smelling gas from the polluted lake, were considered to be a no-man's-land.

The run-off water from the sediment ponds will be a highly concentrated nutrient solution. It must therefore be treated in a simple plant before being discharged into the lake, and experiments are presently being carried out with different coagulents.

When the restoration project is finished and the western and northwestern parts of the lake are accessible, the dewatered sludge should be quite useful when parks and gardens are laid out in the land areas adjoining the lake.

Until the new treatment plant is finished, sewage will continue to be discharged into the lake. In order to overcome the problems presently caused by anaerobic conditions in the water nearest the population centers, and in order to keep the fertilizing effect of the sewage at a minimum during the construction period, it has been proposed that the following measures be taken:

Sewage sludge should be removed from the Esplanade basin, leaving a water depth of 2.0 m.—2.5m. "Bubble" equipment should be installed here to aerate the well-defined basin. At Montplaisir and Cherguia, the outlets in the northwest, simple ponds should be constructed in the littoral zone of the lake. These ponds should also be aerated.

Nutrients transported to the lake are efficiently concentrated in the large-leaved algae *Ulva* and *Enteromorpha.* After some alterations, the equipment designed to deal with the vegetation in Hornborga Lake should be used to skim off floating algae at different water depths in the Lake of Tunis. This activity would result in losses in nutrients and gains in oxygen for the lake.

Longer-range plans for the lake's restoration ought to include the creation of a water inflow at Khereddine and an outflow to the harbor at Tunis Marine. This should not be considered solely as a hydromechanic undertaking, but should be seen as a means of achieving a nutrient budget suitable for the lake.

By making use of short-term, wind-caused water level variations of at least 50 cm. at Tunis Marine, a large-scale export of nutrients could be secured from the lake to the harbor, to the canal and finally to the Mediterranean, bringing about self-purification. In July—August 1972, for example, nutrient-loaded water with 400—700 μg PO_4-P/l rushed out from the north lake at Tunis Marine, and then the same water, with an addition of oil from the harbor, flowed back the same way into the north lake. At Khereddine, the proposed intake of water for the north lake, there was at the time only about 20 μg PO_4-P/l.

In its present unbalanced state, the Lake of Tunis ecosystem represents an interesting case of illness. After active therapy it will be a marvelous water. At present, it is understandable that most visitors don't pay much attention to the large flocks of flamingos that can be seen in the lake, very close to the capital. However, when the lake has been restored to health, the malodorous pollution barrier will be down, and I am sure that the scene of water and flamingos set against the picturesque ruins in the island of Chekli and the sun-drenched mountains beyond will become an attraction.

Sven Björk, Ph.D., is Professor of Limnology at the University of Lund's Institute of Limnology. This article was reprinted with permission from *Ambio*, a publication of the Royal Swedish Academy of Sciences that concentrates on the interrelations of environmental management, technology, and the natural sciences.