Introducing the
LAKE BIO-ACTIVATOR
Process

using
The Aero-Solar and
Little River Pond Mill
technology

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Table of contents

Introduction

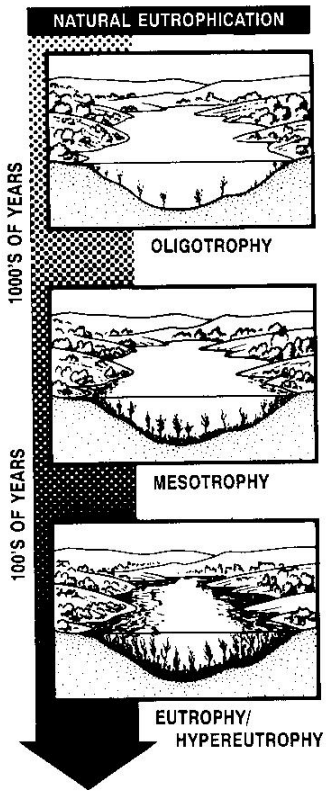
Eco-Guide International was founded by Dany Boudrias in 1996, developing since what has become a unique approach to lake, stream & pond restoration. It was in 1997 that we were first introduced to Little River Pond Mill, a company that targets and manufactures products for the agricultural market. Finding their technology promissing for application in the field of lake restoration, more than 30 lakes now use the **Little River Pond Mill** technology, and since 2000, the solar-powered aerator **Aero-Solar**.

Problems Encountered on Lakes

Eutrophication

The aging process or eutrophication of a lake at it's ***natural state*** is an extremely slow process. It can take many thousands of years for a lake to undergo a transition from oligotrophy to mesotrophy. When the same lake reaches the mesotrophy state and starts to reveal signs of deoxygenation, the aging process accelerates considerably from that point on. Instead of thousands of years, a eutrophic or hypereutrophic state can be reached within only hundreds or even tens of years.

The classical lake succession sequence is usually depicted as a unidirectional progression through the following series of phases (or trophic states):



- Oligotrophy : Nutrient-poor and biologically uproductive. Oxygen rich waters.

Quality : +++

- Mesotrophy : Intermidiate state between oligotrophy and eutrophy. Relative oxygen deficit.

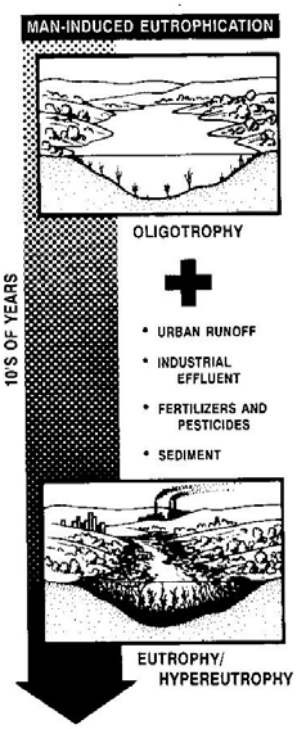
Quality : +

- Eutrophy : Nutrient-rich and biologically highly productive. An oxygen deficit observed at the thermocline.

Quality : -

- Hypereutrophy : Pea-soup conditions ; the extreme end of the eutrophic stage. Severe oxygen deficit. High sedimentation rate.

Quality : - - -



Human activities within the watershed of a lake will increase the nutrient load to a point where problems arising from this human induced eutrophication become visible often in only 10's of years instead of 100's or 1000's in a natural state.

The present figure illustrates the level at which human activities can influence the aging process of a lake.

A watershed management plan is the first step to control point and non-point sources of pollution.

Control measures will often slow down the eutrophication process, but for many lakes, the internal nutrient load will interfere in obtaining better water quality.

For these lakes, it then becomes essential to establish an in-lake restoration plan based on methods that will help re-establish and optimize their natural purification process.

The LAKE BIO-ACTIVATOR Process (LBA)

The overall process was developped by ingeneers and aquatic ecologists based on acquired experience and knowledge from many lake and pond restoration projects in Canada. The LBA process involves using environmentally sound technologies that will greatly increase the lake's natural capacity and its general quality, and therefore improve the trophic status of treated lakes. The goal of this process is to regenerate biodiversity within the lake's capacity.

Technologies used for the LBA process :

- ***Little River Pond Mill – wind powered aerator/mixer***

- ***Aero-Solar***

- ***Lake EcoSOLUTION Bacteria***

Description of technologies used in the LBA process

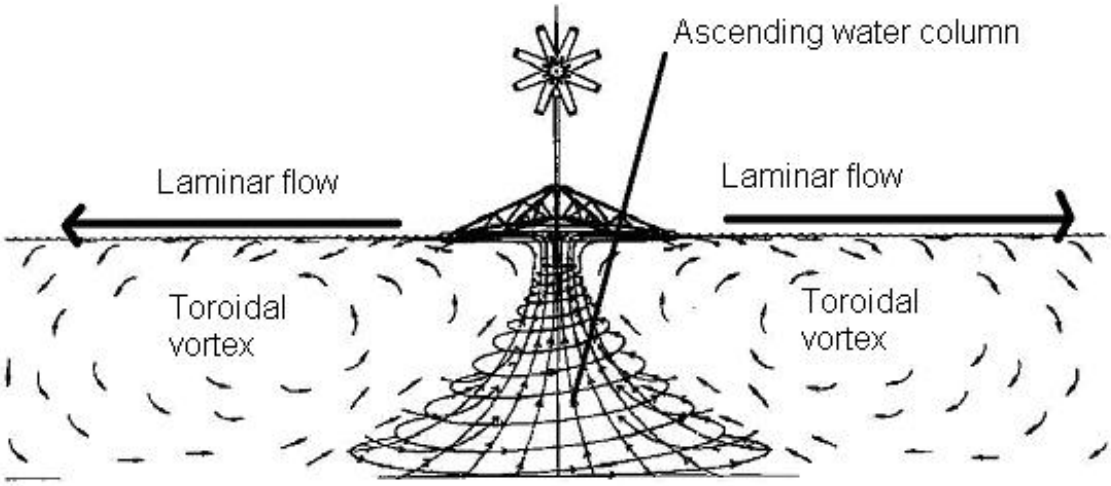
Little River Pond Mill and the toroidal vortex

The Little River Pond Mill offers unique aeration and circulation for environmental management in liquid bodies. Floating on the surface, a windmill-like or electric device turns a submerged impeller. The **direct action of the rotation of the impeller** will be a direct lift of 1,2m water column, pumping approximately 30 000 L per minute to the surface using 50km/h winds, **1/3hp DC solar (Aero-Solar)** or 1/2hp electric motors.

Ascending water current, surface laminar flow, descending water flow and toroidal vortex

The ascending water current will have a tremondous effect on the total water flow measured. This lifting of water will create an outward surface laminar flow outgoing 360^{o} from the center of the machine. The sinking of the laminar flow (as far as 60m from the center of the machine) will induce a beneficial toroidal vortex. Because of the formation of this toroidal vortex, Dr. Bugg from the University of Saskatchewan found that the actual water flow was as high as **9m^{3}sec^{-1}** .

This water flow can, depending on wanted results or actual depth, partially or completely destratify the water column, creating better gas exchanges between sediments and the atmosphere. This induced vertical flow will bring back oxygen in deeper parts of the pond, lake or reservoir.



This toroidal vortex will only take place when having constant rotation of the impeller, meaning that local wind or solar conditions must be taken into account.

This unique waveform will also be called a laminar toroidal vortex. Total Pond or lake Circulation, sometimes called "liquid composting", brings the liquid contents of the pond or lake to the surface several times each hour. Riding on a smooth laminar film that acts as a rotating biological contactor, waste nutrients, beneficial aerobic bacteria and dangerous health pathogens come together at the surface into direct contact with oxygen and sunlight several times each hour. Exposure to UV sunlight kills health pathogens. Direct contact with oxygen builds the aerobic population. Circulation moves the aerobic biomass and dissolved oxygen back down into all parts of the pond or deeper into the lake. Oxygen circulating throughout a pond further prevents anoxic processes and supports aerobic activity that digests waste and reduces sludge.

These different types of water flows induced by either the *Little River Pond Mill* or *Aero-Solar* are the basis of the Lake Bio-Activator process. The ascending and laminar flow will release anoxic gases and transfer atmospheric oxygen into the water. The descending water flow and toroidal vortex will bring back oxygen deeper into the lake. Oxygen produced at the surface by algae and aquatic plants will also be caught with the descending water column to be distributed more uniformly.

In temperate climates, the LBA process occurs naturally during the spring and autumn mixing periods (turnover period). During this period, thermal stratification is non existant (full mixing from top to bottom is possible). This mixing is the only way for deep lakes to naturally bring back high oxygen concentrations at the sediment level. In tropical climates however,deep lakes and reservoirs can never mix completely other than during very violent storms. Thermal or mineral density related stratification occurs and low to no oxygen concentrations can be observed below the thermocline. For eutrophic lakes or reservoirs attributable to cultural eutrophication, a fast build-up of sediments can cause high production of toxic anoxic gases such as hydrogen sulfide.

Using the process in the littoral zone

In any lake or reservoir, the littoral is the most productive zone. When used in shallow areas, the water flow induced by the aeration/mixing systems contributes in maintaining aerobic conditions at the sediment level. This will in turn reactivate beneficial benthic and bacterial populations and bring back biodiversity within the detritus community for better decomposition rates. It is important to know that oxygen is the basis of all animal life and that their loss is directly linked to low oxygen concentrations found in eutrophic or hypereutrophic water bodies. Water circulation is the second most important limiting factor for beneficial bacteria. Creating water currents at the water-sediment level better distributes essential nutrients needed for maintaining their optimal biomass.

A lake management program designed to control cyanobacteria, algae or even macrophyte (aquatic plant) overgrowth like Eurasian Milfoil, must include ways of creating competition for available nutrients. Increasing bacterial and benthic biomass that feed upon the same nutrients as algae or macrophytes through the LBA process is an approach that reflects what occurs naturally in oligotrophic and mesotrophic lakes. Benthic biodiversity and biomass increase will become a food source to other aquatic organisms such as fish as they too are part of the overall LBA process.

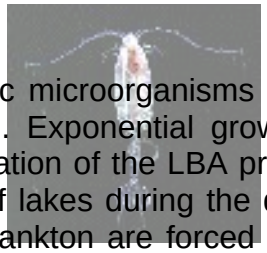
Using the system in the pelagic zone (open water)

This is probably the most distinctive part of our process as it is based on creating an ascending water column **from the surface** where other methods create the ascending water column **from the bottom** (such as bubblers). The LBA process will maintain a partial thermal stratification, thus maintaining a cold layer of water at the sediment level. The multiple advantages are:

- A colder layer of water will maintain populations of aquatic organisms that need colder water for survival
- Nutrients released from the sediment remain trapped below the thermocline and only parts of the nutrients are recycled gradually within the food chain
- Total oxygen concentrations are directly linked to temperature. At saturation we find more dissolved oxygen in colder water than hot water (ex: 20^{o}C = 9,09mg/L ; 30^{o}C = 7,56 mg/L ; 37^{o}C = 6,73 mg/L)

Compressors and air diffusors will be very efficient in eliminating thermal layers. But by doing so, they will cause complete recycling of nutrients and an overall increase in water temperature and evaporation rate (ambiant air compressed at 30^{o}C will result in introducing more than 30^{o}C air in the water because of heat transfer from the compressor). Although some phosphorus might be oxydized with other elements (such as iron), we often find that these elements are rapidly used-up, meaning that phosphorus becomes readily available in a soluble form for new algae growth and macrophytes. Therefore, these systems might aggravate the problem.

Deterioration of water quality when using the LBA process has never been observed because we never recycle all the nutrients at the same time, contrarely to other systems. Recycling part of the available nutrients with the LBA process will not create uncontrollable algae blooms since the double effect of the toroidal vortex and increased oxygen will create optimal conditions for the thriving of beneficial aquatic life forms.

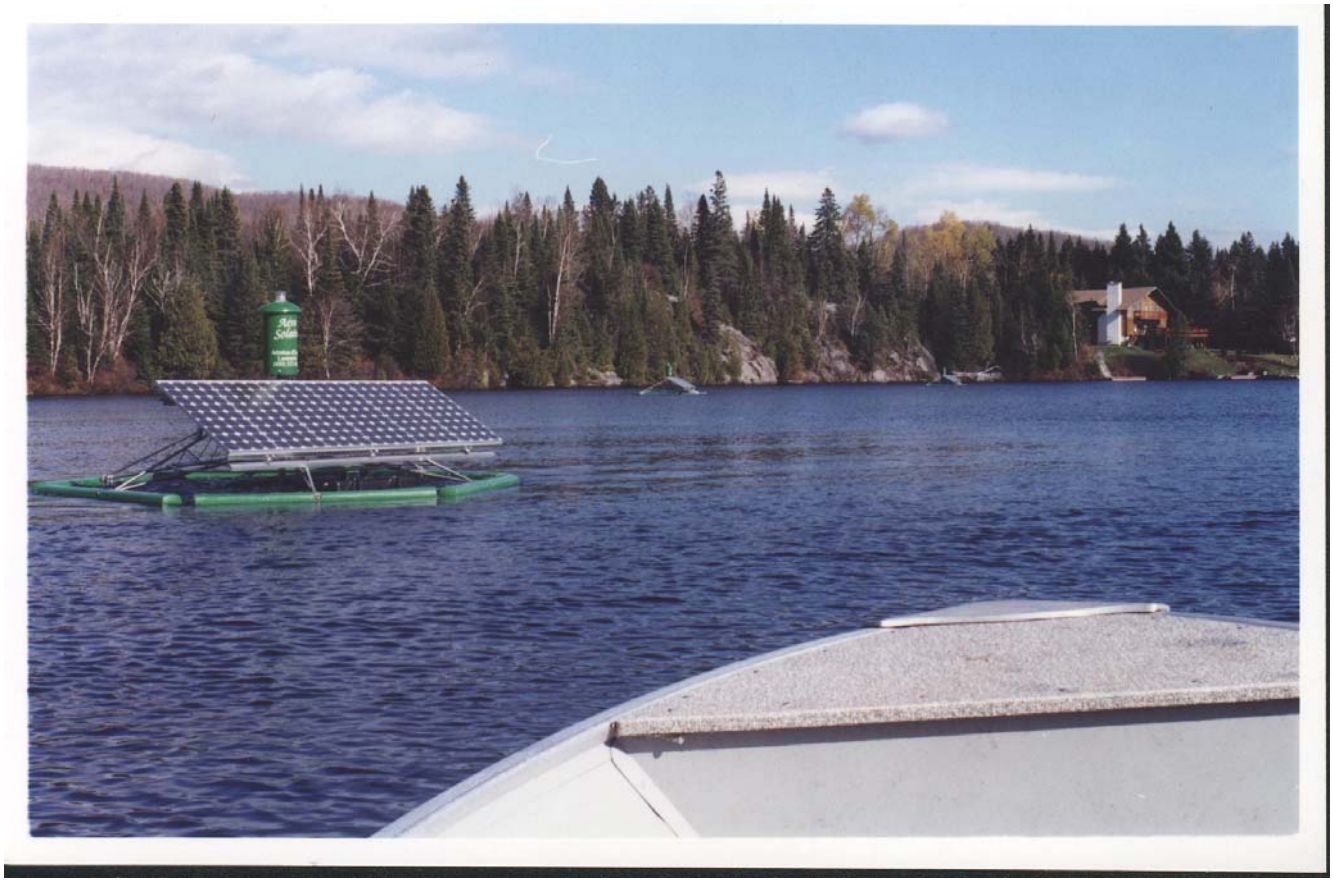


Zooplankton and other metalimnetic microorganisms benefit from the up-welling rich water currents and the return of oxygen. Exponential growth of zooplankton is often observed between 2 to 4 weeks after initialization of the LBA process. Most zooplankton communities migrate to the light limited zones of lakes during the day in order to avoid predation. Being caught in the toroidal vortex, zooplankton are forced to the surface where planktivorus fish and other sightfeeding predators will be able to feed upon them. Consequently, higher predators of the food chain will benefit and their biomass will increase.

Higher animal life biomass = lower algal and macrophyte biomass = increased water transparency and control on macrophyte overgrowth = increase in general biodiversity.

These phenomenons are also well observed in nature. For example, the region of Tadoussac on the St-Lawrence River in Quebec (Canada) is known worldwide for its biodiversity. Due to the marine relief of the region, we find cold and nutrient-rich up-welling currents that mix at the surface. Under sunlight, algae will bloom, and because of high oxygen concentrations crustacea biomass are very high. Many fish will agglomerate around these up-welling currents for feeding. Hundreds of whales, including the great blue whale (biggest mammal on earth), will migrate up into the St-Lawrence each summer for feeding and reproduction. This site acts as a natural Bio-Activator. The ***Little River Pond Mill and Aero-Solar*** are tools to recreate these natural phenomenons.

Technical specifications of the Aero-Solar



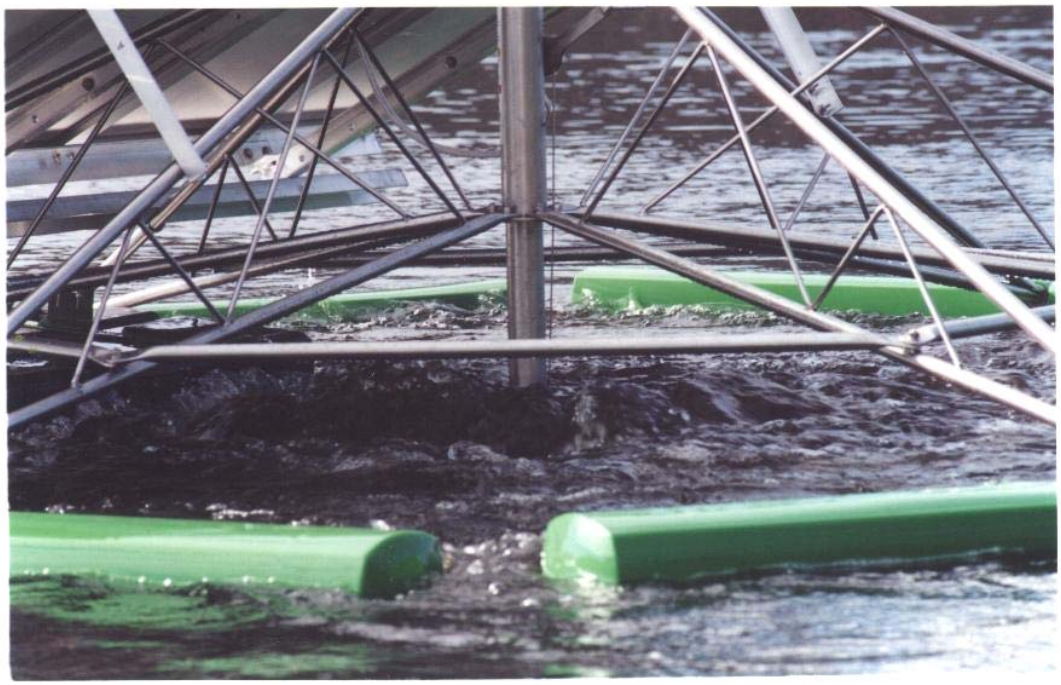
Wind powered aerator/mixer cannot always be used efficiently. It was thus necessary to find other technical solutions for certain lakes where the average wind speeds are below 12km/h. Our multidiciplinary team of experts had to conceive a product that would be applicable in low wind conditions, ecological and still autonomus. Always looking for the right solutions for lake, pond and reservoir restoration, we invented the solar version of the Little River Pond Mill: the **AERO-SOLAR**.

Being the first to use and test the wind operated aerators for lake restoration purposes, we acquired the most experience in this field of expertise. We concluded that the wind powered aerator/mixer was perfect in specific conditions, such as lakes of 8m and less and with a trophic status between mesotrophy and eutrophy. For lakes of more than 8m and/or eutrophic to hypereutrophic conditions, we needed a more powerful technology that would be efficient when lake ambient conditions are at their worst, i.e. low wind and hot sunny days that resulted in algae blooms and macrophyte overgrowth.

With the **AERO-SOLAR**, we now have a machine that is at its best during these critical conditions.

The SOLAR model works at full speed approximately 1hr after sunrise until 1hr before sundown. The 56cm 4 blade impeller turns at 125RPM, which is comparable to using a windmill exposed at constant winds of more than 50km/h.

Typical up-welling current created by an Aero-Solar when exposed to direct sunlight.



Specifications

Motor gear box	D.C. motor brush style with integral gearbox to output motor speed to match optimal impeller speed (125 RPM)
Wiring	Heavy duty, corrosion-resistant, industrial cable with weather and watertight connectors
Solar panels	Six 80 watt panels (total 480 watts) all oriented South for full sunshine and efficiency; Panels with a manufacturer's limited performance warranty of 20 years
Panel mounting	Made of anti-corrosion treated aluminum. The whole structure can be tilted for optimal sunlight angles during different seasons (usually installed at the average yearly inclination)
Steel structure	All structural components and bolts are made of stainless steel
Floatation	8 floats made of high-density polyethylene with UV stabilizing for longer life ; factory tested to be airtight
Linear current booster	Used to control and power the DC motor from a solar panel. The unit prevents stalling of the motor under less than full sun condition. The power of the sun is transformed to the motor running conditions so as the sun goes down the motor slows down instead of stalling. Conversely, or as the sun comes up the motor starts running much earlier instead of staying stalled for hours when it could be running. This translates into more running time of the motor where it spends a lot of time working instead of stalled doing no work.
4 blade impeller	4 blades, lowered 50cm below the surface. Designed to form efficient vortex and be more weed free. Self tightening to drive shaft.
Mast	Contains drive shaft featuring threaded stainless steel stub shaft at bottom and threaded stress proof stub shaft at top. Bearings and seals in top and bottom threaded retainer which screw into mast housing for easy maintenance.
Sealed case for electronic device	All operational electronic and electric components are protected in a sealed case that can be locked by the owner.
Center section	Mast raises and lowers through this assembly using hand operated winch. Stainless steel winch cable.

Anchoring

We usually use three anchoring points on an Aero-Solar chained down to three solid concrete mooring blocks. The lenght of the chain is about 1,5 times the depth of operating site. Anchoring systems can be modified to satisfy the needs of the client or application.

Size and weight

The unit fills a 4,3m diameter and weighs about 190kg.

Maintenance

The D.C. motor uses carbon brushes. It is recommended to change brushes every 2 to 3 years. The motor life span is around 6 years depending on viscosity of liquid. It is recommended to change the bearings and seals every 5 to 6 years. Dust accumulation from pollution can reduce significantly the efficiency of the solar panels. Solar panels must be periodically cleaned with a gentle fiber brush and water.

Additional security measures

We suggess that the owner of an Aero-Solar install personnalized notice signs on the machine.

Optionnal screens can be added between the legs of the Aero-Solar for increased protection against possible injury.

Number of Aero-Solar needed

The number of Aero-Solar per surface area treated can be calculated by determining the actual lake trophic status.

- For mesotrophic lakes or reservoirs: 1 Aero-Solar / 6 to 7ha;
- For eutrophic lakes or reservoir: 1 Aero-Solar / 5 to 6 ha
- For hypereutrophic lakes or reservoirs: 1 Aero-Solar / 3 to 5 ha

For local macrophyte control (depth between 5 to 12 feet), the Aero-Solar can treat an area anywhere between 50 to 150 feet diameter per year, depending on sediment thickness, organic matter content and continuing inputs of nutrient.

Warranty

- *20 years limited performance warranty from solar panel manufacturer*
- *2 years against all defects on structure*
- *1 year on electric and electronic components*

PRICE of AERO-SOLAR

	1 to 3 units	**4 and more units**
CANADIAN DOLLARS	$18,990.00 CAN	$17,950.00 CAN

PRICE of other similar solar powered technology

Price of our competitors using solar powered technology and half the power output of an AERO-SOLAR: *$24,995.00* ***US!!!***

Lake EcoSolution bacteria

Lake EcoSolution is a specially formulated culture of beneficial bacteria that improve rapidly water quality. These micro-organisms use the same nutrients as algae, helping recreating a balanced aquatic ecosystem. **EcoSolution can be used to activate more rapidly the LBA process (but is not compulsary).**

Lake EcoSolution contains…

- Surfactants and bacterial cultures preselectionned and adapted for the acceleration of the regeneration or stabilization of waterbodies
- Non-pathogenous, facultative aerobic and anaerobic
- Bacterial count of 3 billion/gr
- Mix of Bacillus type spores

Stability of product is 2 years if stored in a dry location.

Avantages…

- Biological product, natural and biodegradable
- Non-toxic for living aquatic organisms, fish and humans
- Reduces excess nutrients
- Controls algae growth
- Prevents aquatic ecosystem desequilibrium
- Clears water while neutralising odors
- Reduces drastically infiltration of pathogens
- Compatible with irrigation and aeration products
- Takes action in all aquatic ecosystems where water temperature is superior to 10^{o}C and pH between 5,5 et 8,5

Since the LBA process ocurs gradually in time when using only the Little River Pond Mill and/or Aero-Solar technology, introduction of Lake-EcoSolution bacteria can activate the process more rapidly and more efficiently.

Application rate:

- if more than 1m water transparency, 1kg / 0,5ha
- if less than 1m water transparency, 1kg/ha

PRICE (Canadian dollars)

- If less than 100 kg per order: **$450/kg Can**
- 100 to 200 kg**:$400/kg Can**
- If more than 200 kg: **$350/kg Can**

Oligotrophization of a lake or reservoir with the LBA process

Oligotrophization comes from oligotriphy that reflects poor nutrient conditions, clear water, decomposition rates higher than sedimentation rates, therefore higher concentrations in oxygen at the sediment level. We observed that lakes that use the LBA process show better water quality year after year and that their trophic status decreases; i.e. from hypereutrophy to oligotrophy.

Case study

The best case study on this subject comes from the 26 ha Lake Écho restoration project (in the Laurentides, Quebec). In the initial 1998 study, this lake showed many problems related to eutrophic lakes. This lake, which was recognized by most as one of the most beautiful lakes of the Laurentides, started to suffer from occasional algae blooms during the months of August, when the hypolimnion (deep cold layer of water) was at its lowest oxygen concentrations. This lake was known for its diversity and by fishermen for the presence of speckled trout. Since the beginning of the 1990's, speckled trout disapeared from the lake since optimal conditions (cold layer of water with more than 5mg Dissolved O_2/L) were lost. Indigenous speckled trout was present only up-stream of the main inlet where optimal conditions were still present. The lake trophic status was near **EUTROPHIC,** i.e. a status known where trout populations are usually lost. The objectives of this restoration program were:

- To bring back oxygen and other optimal conditions for trout survival
- Control algae blooms
- Bring down the trophic status from eutrophy to mesotrophy

Because we initially planned a watershed management plan that would take care of non-point source pollution, we decided to use only 4 wind driven Little River Pond Mills (1 Pond Mill / 6.5 ha).The LBA process was initiated in the spring of 1999. It is important to note that little or no watershed management practices were done, but we still obtained great results using only the LBA process as a lake management technique.

RESULTS

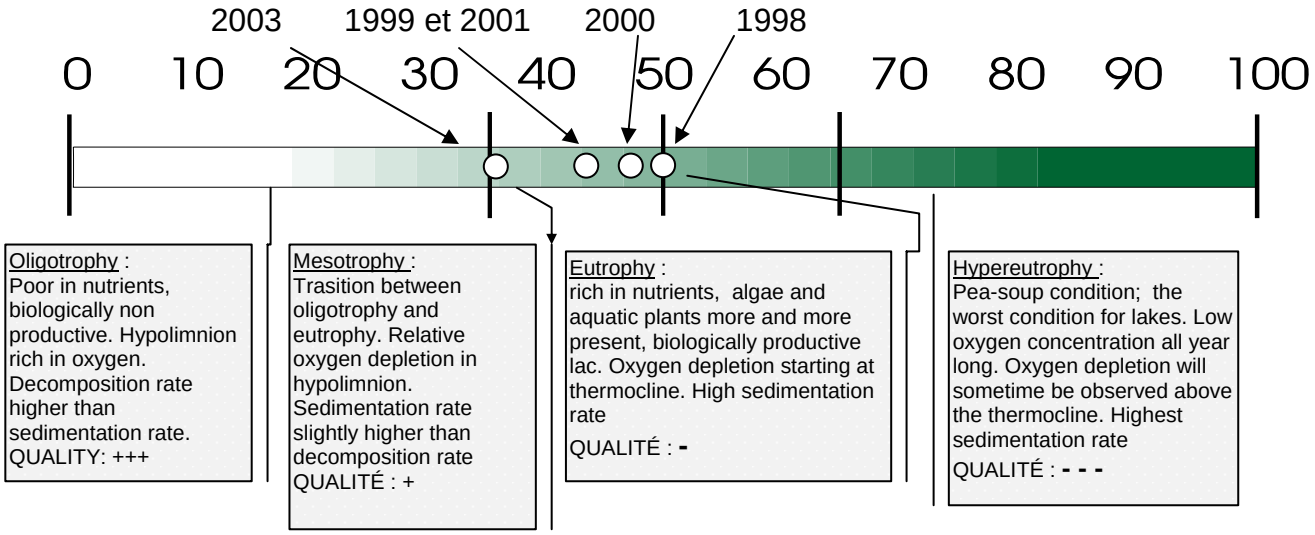
Physico-chimical results before and during the LBA process

Parameters	1998	1999	2000	2001	2003
Total phosphorus	30 µg/L	23 µg/L	17 µg/L	25 µg/L	**15,5 µg/L**
Chlorophyll-a (algae)	9,3 µg/L	3,6 µg/L	8,3 µg/L	3,8 µg/L	**0,75 µg/L**
Transparency	3,1m	4,2m	3,9m	5,0m	**5,0m**
pH	7,2	7,3	7,4	8,1	**7,3**

Data transformed into Carlson's Trophic status index

Parameter	1998	1999	2000	2001	2003
Total Phosphorus	53	50	45	51	43
Secchi Transparency	44	39	44	37	37
Chlorophyll-a (algae)	53	43	52	43	28
AVERAGE	**50**	**44**	**47**	**44**	**36**

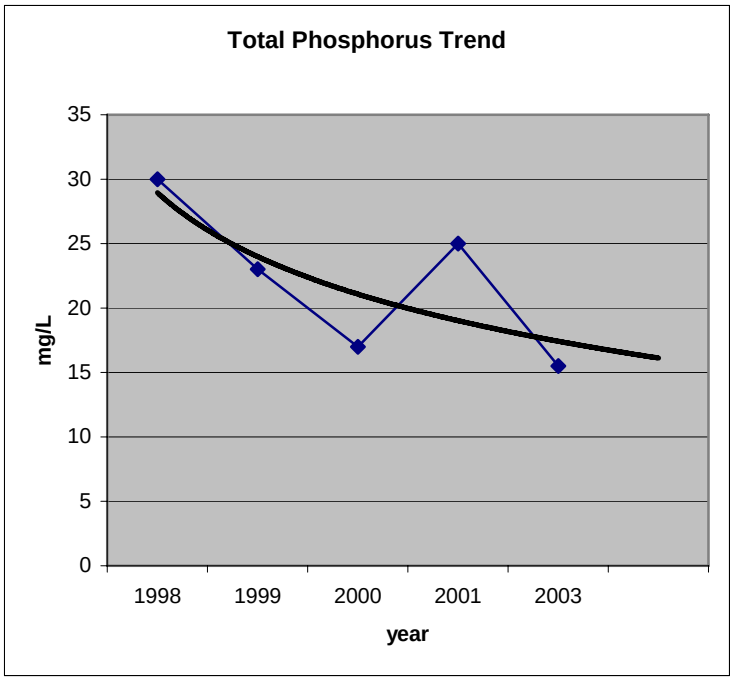
These results are then presented on the Carlson's trophic scale index



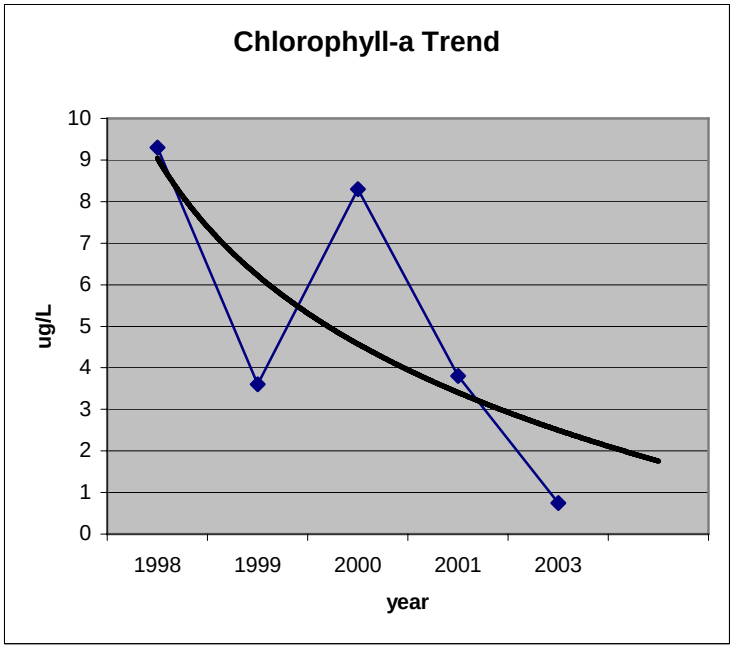
General water quality trends for Lake Echo

After only 5 years, Lake Echo is recovering where little or no watershed management practices are done. The main water quality parameters were used to show the trends. All of them showed that the LBA process helped the recovery of Lake Echo.

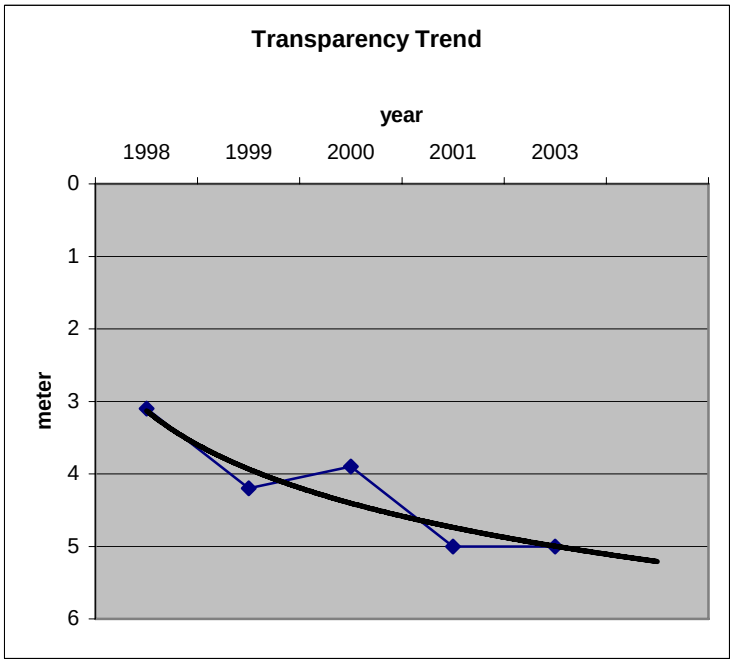
Phosphorus trend



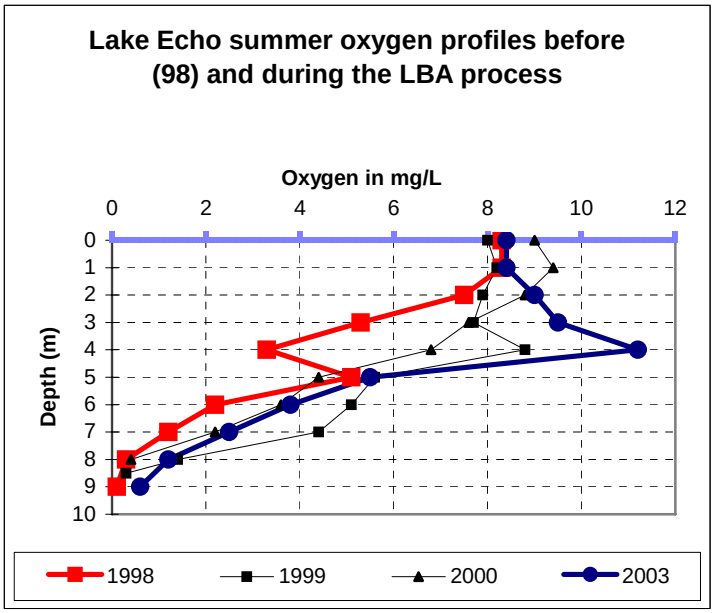
Chlorophyll-a trend (algae)



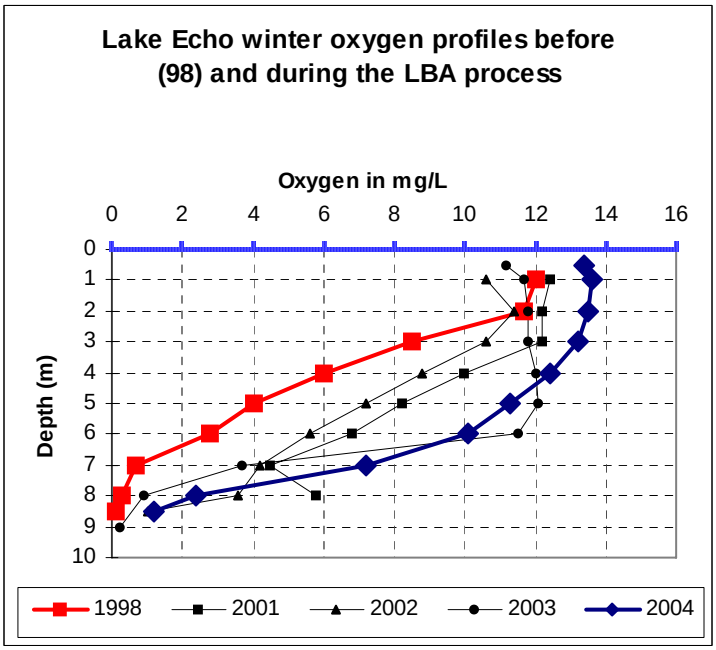
Transparency trend



Summer oxygen profiles



Winter oxygen profiles



In 1999, fishermen started to recapture speckled trout in their lake where it had disapeared for at least 10 years.

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