FISH POND TOOLKIT

Fish pond practices promoting extensive and sustainable fish production based on natural resources

This guide for fish farmers provides a presentation of knowledge on important ecological processes regulating the productivity of fish ponds based on natural resources.

It describes some key parameters that allow basic monitoring of ponds. Eight variables are interpreted under four different scenarios to illustrate how key ecosystem processes can be assessed and improved to enhance biodiversity friendly fish production in ponds.

For each scenario, management practices are proposed to optimize fish production by enhancing the productivity of the system, while simultaneously aiming at relatively high levels of biodiversity.

KU LEUVEN
biodiversa
AGENCE NATIONALE DE LA RECHERCHE ANR
isaralyon
Une école d'ingénieurs au cœur de la vie

The food web in ponds and productivity of ponds

The food web structure in fish ponds is grounded on photosynthesis by primary producers, including aquatic plants and algae. Photosynthesis is based on the availability of three major sources: carbon, light and nutrients (Figure 1).

In general, carbon is available as carbon dioxide in the water, whereas light and nutrients can be limiting factors for photosynthetic cells. Light becomes particularly limiting when water turbidity is high and reduces light penetration in the water column (for example due to water brownification by organic matter, suspension of sediments or strong development of algae).

The rate of photosynthesis in the water regulates the productivity of higher food web levels, such as macro-invertebrates (e.g. insects, snails, worms), zooplankton, amphibians, fish and birds), and is strongly determined by the ratio between submerged aquatic plants and phytoplankton.

Large datasets on major ecosystem variables, including nutrient concentrations, water transparency, and the biomass of algae and aquatic plants, are needed to assess the food web structure and functioning in fish ponds Monitoring programs need to take into account the fact that small waterbodies are not stable over time. Indeed, multiple parameters can show high temporal variability. Appropriate monitoring should therefore include bi-monthly sampling for selected parameters.

Monitoring and subsequent data analyses allow a good diagnosis of the food web structure. In addition, it facilitates detailed analysis of the diversity and abundance of different aquatic organism groups (plants, algae, zooplankton, invertebrates, fish...).

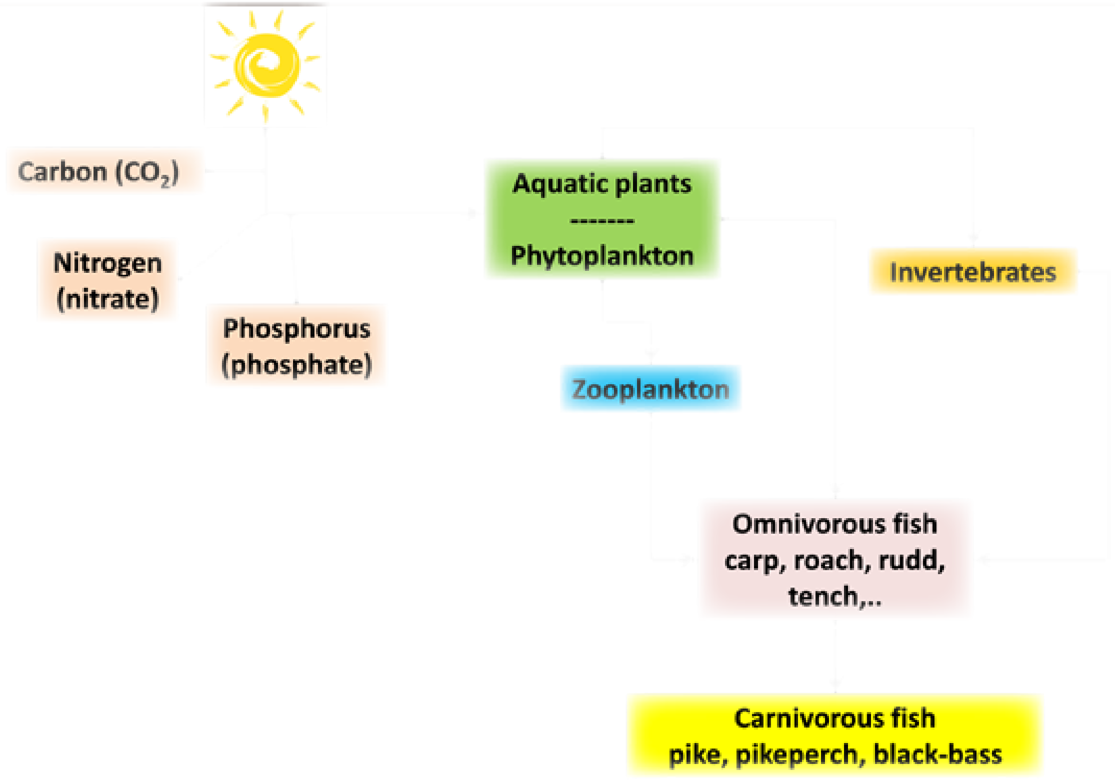


Figure 1. Simplified representation of the trophic food web in a fish pond: in light brown, variables allowing the biomass production in the system. In green, primary producers in competition. Balance between phytoplankton and aquatic plants will affect the productivity of the higher other compartments.

Food web structure and fish

Figure 2. A fish pond in the Dombes, France

The structure of the food web has major effects on fish productivity (Figure 3) and thus also affects the economic performance of fish farming activities.

On the top and bottom part of the figure below, fish ponds are not in a good ecological state to produce fish as they are either dominated by phytoplankton (algae) or aquatic plants. These ponds need a better balance between these two species groups. Excessive development of phytoplankton (bottom) or plants (top left) can lead to lower biomass of zooplankton and benthic invertebrates compared to balanced plants/ algae systems.

On the right, the fish yield is good, with a balanced food web structure favouring biodiversity. Fish farming practices such as liming and corrective fertilization - ideally their combination – promote fish production, provided that these practices are applied moderately with low inputs and regularly.

There is a significant link between fish yield and zooplankton biomass, confirming that the fish production is related to ecosystem productivity, with important fish food resources provided by zooplankton and invertebrates.

However, if phosphate concentrations and productivity are too high, this may have detrimental effects as macrophytes will disappear due to algae blooms and fish kills may occur because of oxygen depletion. Optimal fish biomass production can be obtained when the balance between algae and plants is established and maintained.

Figure 3. Correlation circle presenting the major relations between fish pond parameters. In blue, parameters linked to pond monitoring. In red, parameters linked to fish farming activity. Note the antagonism between aquatic plants linked to transparency and phytoplankton linked to phosphate concentration.
The productivity of zooplankton and fish is linked to fish farming practices, and also to the balance between phytoplankton and aquatic plants.

Tools for monitoring the food web structure in fish

We propose eight parameters for the monitoring of fish ponds. Each of them has been selected based on their relevance with regard to different ecosystem states or processes:

We propose eight parameters for the monitoring of fish ponds. Each of them has been selected based on their relevance with regard to different ecosystem states or processes:

- **Calcium concentration in water:** calcium promotes nutrient recycling in the pond, and is the main source for skeleton growth (for vertebrates).

- **Nitrate concentration in water:** nitrate is the main source of nitrogen involved in the photosynthesis processes.

- **Phosphate concentration in water:** phosphate is the main source of phosphorus for photosynthesis.

- **Water transparency:** this parameter is a good indicator for the light availability in the water column.

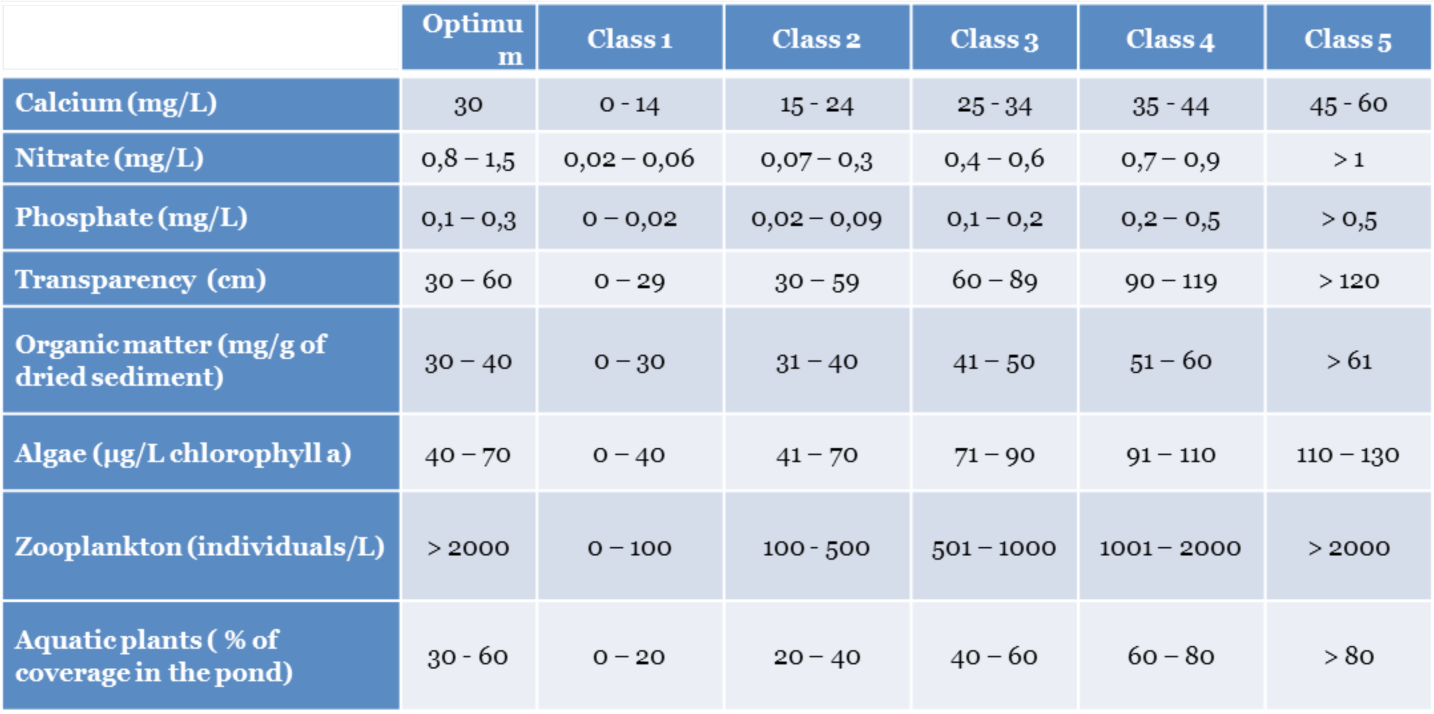
- **Organic matter in sediment:** this parameter provides information on nutrient recycling processes in the pond. When organic matter accumulates at the sediments, nutrient recycling is not good, and nutrient depletion (nitrate, phosphate) can then be observed.

- **Algae biomass:** this represents the density of phytoplankton and is measured as chlorophyll a concentration.

- **Aquatic plant abundance:** is determined by estimating the percentage of pond surface covered with aquatic vegetation.

- **Zooplankton density:** the number of zooplankton individuals per liter.

Figure 4. A fish pond at Midden-Limburg, Belgium



	Optimum	Class 1	Class 2	Class 3	Class 4	Class 5
Calcium (mg/L)	30	0 - 14	15 - 24	25 - 34	35 - 44	45 - 60
Nitrate (mg/L)	0,8 – 1,5	0,02 – 0,06	0,07 – 0,3	0,4 – 0,6	0,7 – 0,9	> 1
Phosphate (mg/L)	0,1 – 0,3	0 – 0,02	0,02 – 0,09	0,1 – 0,2	0,2 – 0,5	> 0,5
Transparency (cm)	30 – 60	0 – 29	30 – 59	60 – 89	90 – 119	> 120
Organic matter (mg/g of dried sediment)	30 – 40	0 – 30	31 – 40	41 – 50	51 – 60	> 61
Algae (µg/L chlorophyll a)	40 – 70	0 – 40	41 – 70	71 – 90	91 – 110	110 – 130
Zooplankton (individuals/L)	> 2000	0 – 100	100 - 500	501 – 1000	1001 – 2000	> 2000
Aquatic plants (% of coverage in the pond)	30 - 60	0 – 20	20 – 40	40 – 60	60 – 80	> 80

Figure 5. Fluorescence probe for algal biomass measure (algae torch, BBE, Germany)

Figure 5. Fluorescence probe for algal biomass measure (algae torch,BBE, Germany)

New generation devices for rapid and reliable monitoring of aquatic systems have been developed recently. This is particularly the case with electronic probes measuring multiple chemical parameters in water and portable fluorometers for measurement of phytoplankton densities.

These new field tools have several advantages. With the exception of sediment organic content, the variables presented above can be measured directly in the field. In addition, these probes allow a more efficient control of the spatiotemporal variability of the parameters in the pond ecosystem as measurements can be repeated over time in different pond zones, without a significant increase in financial costs. Added to conventional tools routinely used by fish farmers, they allow a global assessment of the pond directly in the field.

Assessment of the fish pond system

Radar plots are well suited for overall assessments of the ecological status of fish ponds as they simultaneously visualise information of different variables.

The figure below presents the optimal values of each variable, according to the classes presented in table 1. The numbers (1 to 5) refer to the number of the optimal class with the grey values mentioned in the table.

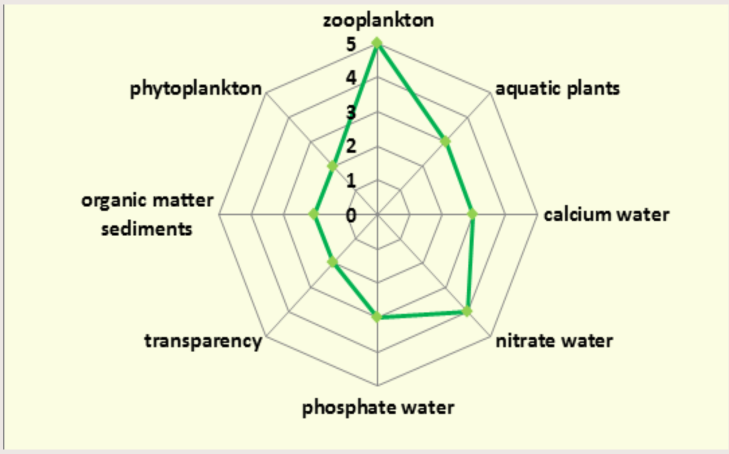


Figure 6. Radar plot presenting the optimal class of each variable, according to the classes (1 to 5) and values presented in Table 1.

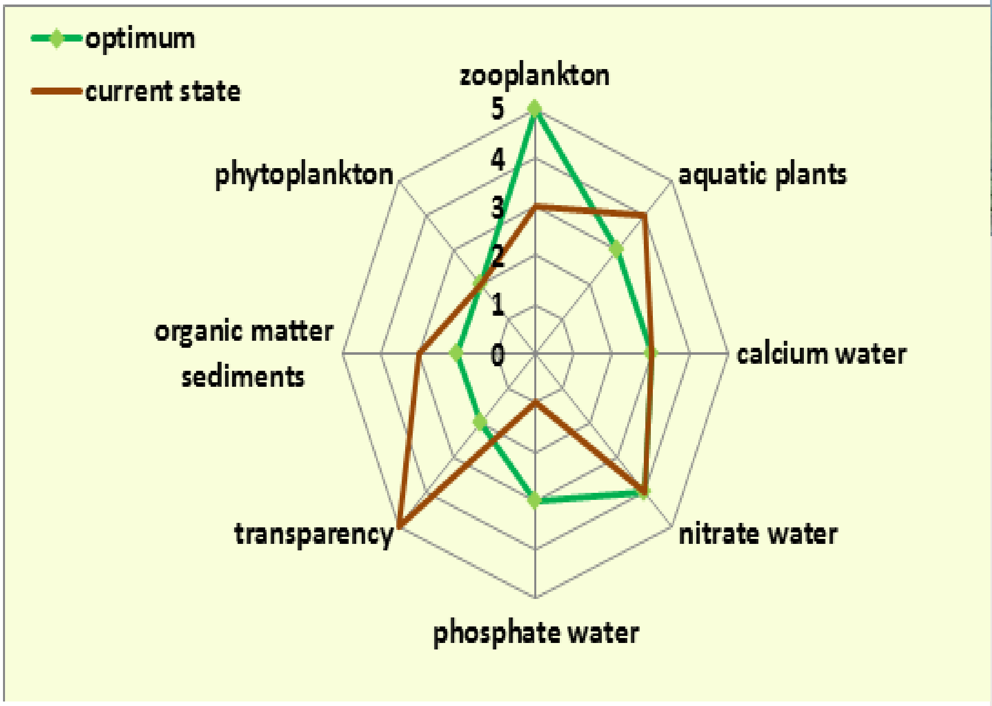
In addition to the optimal values, the radar can be complemented with data on the current condition of the pond (see case 1). This allows visualising the deviation of the current state of the pond from the optimum for fish production. Such analysis is thus useful for planning future management actions.

Radar plots are based on agroecological fish pond management practices, increasing the natural productivity of the pond, valorising biodiversity, maintaining resilience, and improving fish yield. It is based on the need of aquatic plants for extensive fish production in ponds. Submerged aquatic plants enhance the abundances of natural food sources for fish, and can also promote the diversity of multiple other aquatic species groups. The occurrence of aquatic vegetation is also crucial for the pond resilience, in other words its ability to stay or return to the original state.

Intensification of fish farming practices, which includes the use industrial fish feeds and high nutrient inputs, is not sustainable as it reduces biodiversity of fish ponds. Moreover, intensification drastically reduces the resilience of the system: phytoplankton blooms are a good example of the consequences of the intensification in fish ponds, causing instability of the system.

As an example, we present four different cases to illustrate some remediation practices when optimal conditions for maximizing extensive fish production are not met.

Case 1



Case 2

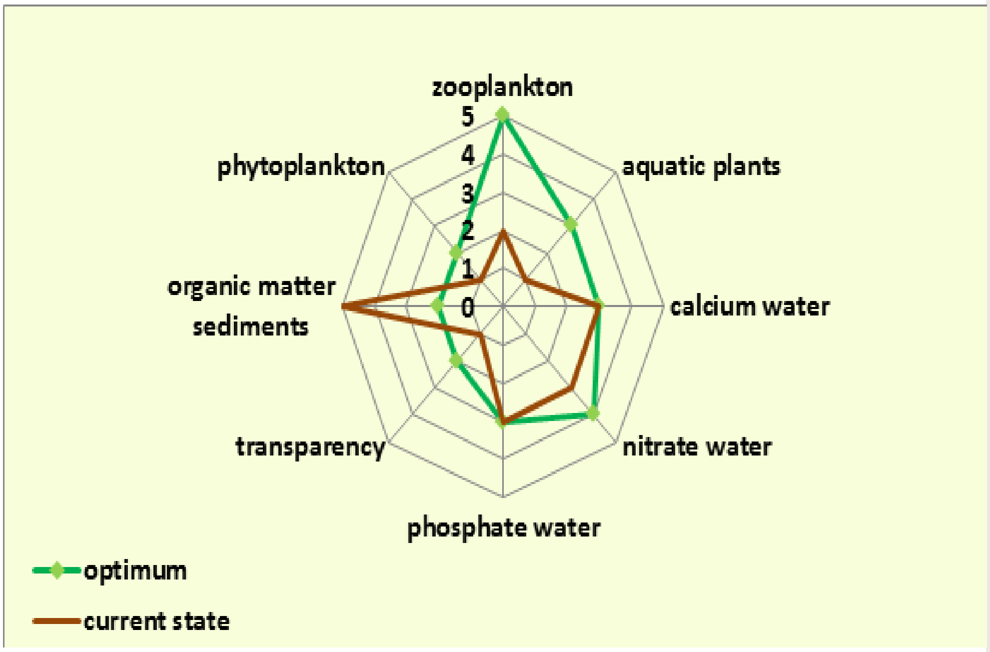


Figure 7. Fish pond with a good balance of plants and algae.

Figure 8. Cyanobacteria bloom in a fish pond, reducing fish yield and biodiversity.

In this pond, the water transparency and nitrate concentration are relatively high, whereas the phosphate concentration is rather low.

Such conditions may results in an overdevelopment of aquatic plants and inversely low phytoplankton biomass. The productivity of zooplankton is consequently low.

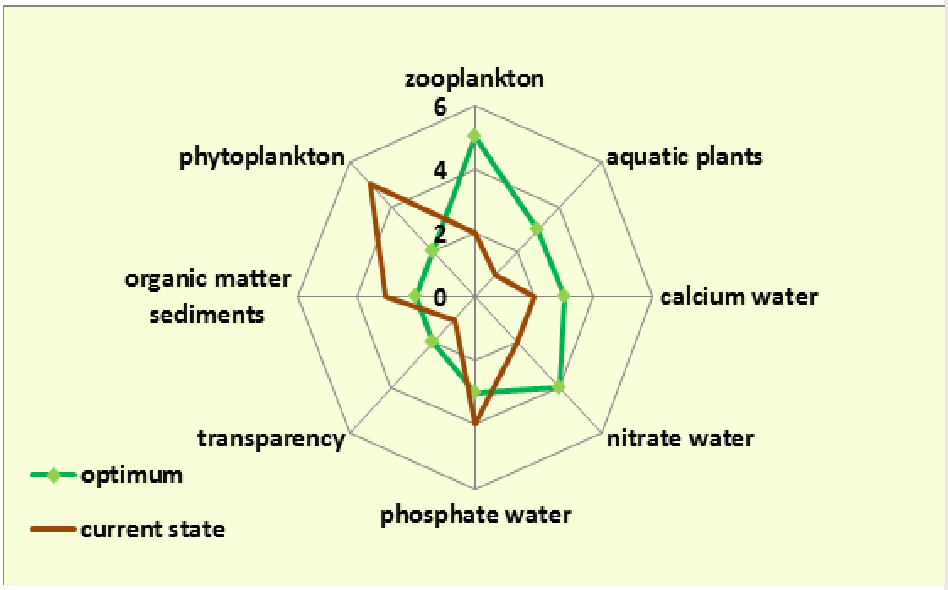
The proposed remediation aims to increase the water turbidity during aquatic plant development (in May) to improve the ratio algae/aquatic plants (reach 40-60% coverage of aquatic plants, but also have a bit more phytoplankton biomass).

Water mixing with a hydro-ejector and consequently resuspension of sediment matter can limit the light penetration during spring and enhance the development of algae.

Despite the good values for the chemical parameters nitrate, phosphate, and calcium, the phytoplankton biomass and the aquatic plant coverage are too low. This lack of primary productivity can likely be due to high concentrations of organic matter in the sediment and low water transparency.

One potential solution is liming the pond in earl spring (April). The application of calcium oxide has two benefits: (1) a flocculation of suspended matter in the water which increases the water transparency allowing the development of plants and algae, and (2) a stimulation of the mineralization of sediments by chemical oxidation processes.
Another solution is pond drainage and a subsequent temporarily dry period (several weeks or months) to activate the mineralization processes.

Case 3



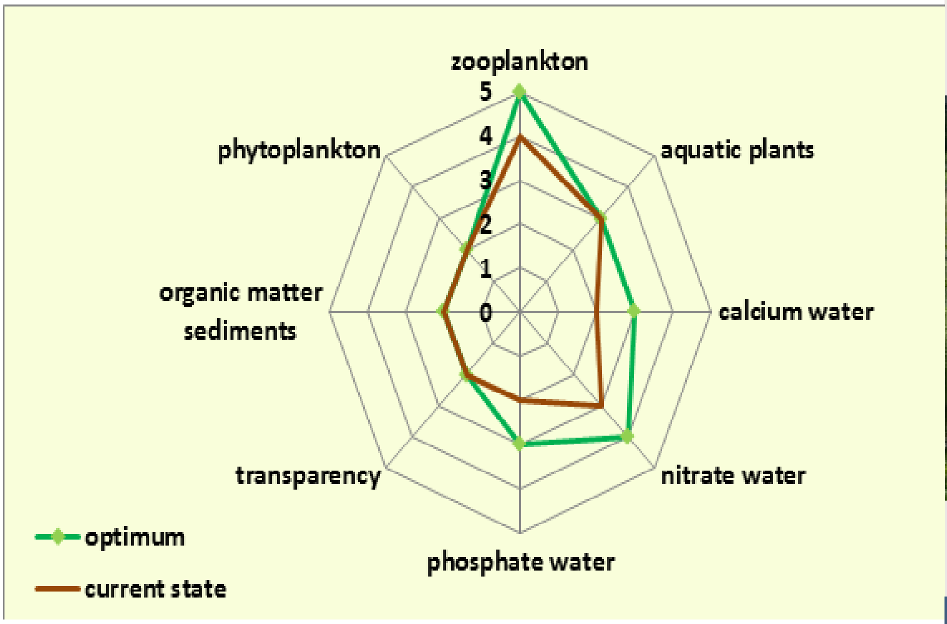
This pond is too rich in phosphate and relatively poor in nitrate. This unbalanced mineral N:P ratio can cause high phytoplankton biomass development (especially cyanobacteria blooms) at the expense of aquatic plants.

The transparency is too low to allow a good penetration of light into the water. Overall, the system is unbalanced and the productivity of the higher trophic levels, such as zooplankton and fish, is potentially low. Both fish yield and the biodiversity are potentially low.

If it is not possible to reduce phosphate concentrations rapidly, a potential alternative is to conduct a corrective nitrate fertilization at a moment when it can be expected to be limited (generally May or June).

In this case, the addition of small amounts of nitrate (7 to 10 kg/ha of ammonitrate in solution) can promote the production of green algae, whiling limiting cyanobacteria blooms which easily develop under low N:P ratio (typically below 7).

Case 4



The different parameters are relatively good. In this case, we propose maintenance practices, such as liming with calcium oxide or calcium carbonate. Liming promotes the recycling of organic matter by mineralization.Calcium also increases pH values in water and regulates the pH level during the season due to its buffer capacity.

Finally, higher calcium concentration in the water increases the overall productivity of the aquatic system.

Figure 9. A fish pond used for crop cultivation (in the background) during an annual dry period.

Figure 10. Liming of the pond ground during the dry period.

Conclusions

A good equilibrium between aquatic plants and phytoplankton in cover and diversity permits good fish production and species conservation at the same time. Phytoplankton density should be not too high to allow the development of aquatic vegetation.

Management practices such as prolonged dry periods after fish harvest, dry years after 3-5 years of fish production, liming, corrective fertilization and development of heterogeneous ponds allow production of fish and persistence of a high number of aquatic plant species.

ACKNOWLEDGMENTS

This research was funded by the ERA-Net BiodivERsA, with the national funder Agence National de la Recherche (ANR), France, part of the 2012 BiodivERsA call for research proposals.
We acknowledge also the support of Région Rhone-Alpes, Conseil Général de l'Ain, and Conseil Général de la Loire.

Creation K.LATTI - Communication department - com@isara.fr

www.isara.fr

ISARA-Lyon - AGRAPOLE
Alexander WEZEL (awezel@isara.fr) or
Joël ROBIN (jrobin@isara.fr)
23 rue Jean Baldassini - 69364 Lyon CEDEX 07 -
FRANCE
Tel: +33 (0)4 27 85 85 50

isaralyon
Une école d'ingénieurs au cœur de la vie