Nutrient management in fisheries - sources, effects, and control

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England's recreational fisheries (rivers, canals, lakes, and ponds) provide annual economic benefits exceeding £1.7 billion, through the purchase of fishing tackle, permits and accommodation. These funds provide jobs for around 27,000 full-time equivalent roles, many of which are in rural areas. We license around 1 million anglers every year, equating to over 17 million angling days per year, and the sport is recognised for the numerous wider health and biodiversity benefits it provides. We have a statutory duty to protect, improve and develop these fisheries.

Rod licence income pays for our fisheries service, which includes providing best-practice fisheries management advice to fishery owners, angling clubs, and responsible parties. The advice we provide can, in many instances, be linked to nutrients and the role they play (both good and bad) in fisheries management. Good advice can improve fishery performance, so increasing socio-economic returns, as well as reducing risk of fishery incidents to which we would have to respond.

What are nutrients?

Nutrients are substances that provide nourishment essential for the maintenance of life and for growth. However, nutrient enrichment by nitrogen, phosphorus, and sometimes organic matter, can result in a series of undesirable effects. The significance / loading of nutrients depends on the sources (in no particular order):

- **Shed / rotting leaves** - surrounding trees, overhanging branches.
- **Fishing baits** - higher protein baits are the worst offenders, e.g., boilies, luncheon meat and liquid baits.
- **Ground-baits** - used prior to, and during, fishing sessions.
- **Feed pellets** - including supplementary feeding practices.
- **Fish waste** - the greater the biomass, the more nutrients are contributed.
- **Bird waste** - can particularly be an issue on waters in open public settings, i.e., parks, through visitors feeding ducks and geese etc.
- **Inputs from surrounding land** - nitrogen (N) and phosphorus (P) from agricultural run-off etc.
- **Connected sources** - online water? A flow-through of water can help with maintaining lower temperatures and higher dissolved oxygen levels but can also contribute nutrients… Some fisheries have penstocks in place to control such inputs and only take water as and when they need it - less than 20m3 / day enables abstraction without the need for an abstraction licence, but greater amounts require an abstraction licence.

Fishery types

The fishery type and its location, be it a fast-flowing river, a slow / static drain, or a fully enclosed pond or lake, all influence how nutrients can enter that system, the types of nutrients entering, and the extent of the effects those nutrients can have on that water. The different fishery types are compared below.

Riverine:

The Derbyshire Derwent at Matlock Bath. Whilst occasional inputs further upstream cannot be completely discounted, the notable flow allows scour and transportation of sediments. This limits the build-up of silt, which can store nutrients.

Slow / static drains:

The River Torne, North Lincolnshire. Heavily engineered, slow / static watercourse (a glorified drainage channel). The only time much of it really 'flows' is when the pumping stations are operating. The watercourse is surrounded by intensively managed agricultural land, allowing easy receipt of inputs, and the lack of flow enables a greater deposition of sediments, allowing nutrients to become 'locked up' and transported when the pumping stations move the water. Such watercourses can be particularly prone to dissolved oxygen crashes in the summer due to high temperatures, dry weather (lower water levels), plant and algal activity, and minimalised / static flow.

Stillwater fisheries (ponds / lakes):

An example of a fully enclosed commercial stillwater fishery (no flow-through of water). High input of feed and baits, and the plentiful trees input leaf litter, which decomposes and contributes further nutrients. As is the case with many commercial fisheries, a heavy stocking density means lots of fish waste and over time, a gradual increase in the depth of the silt bed, which locks up nutrients. As silt depth increases, water depth decreases, thus potentially increasing water temperature. Such waters can typically suffer with algal blooms on a yearly basis.

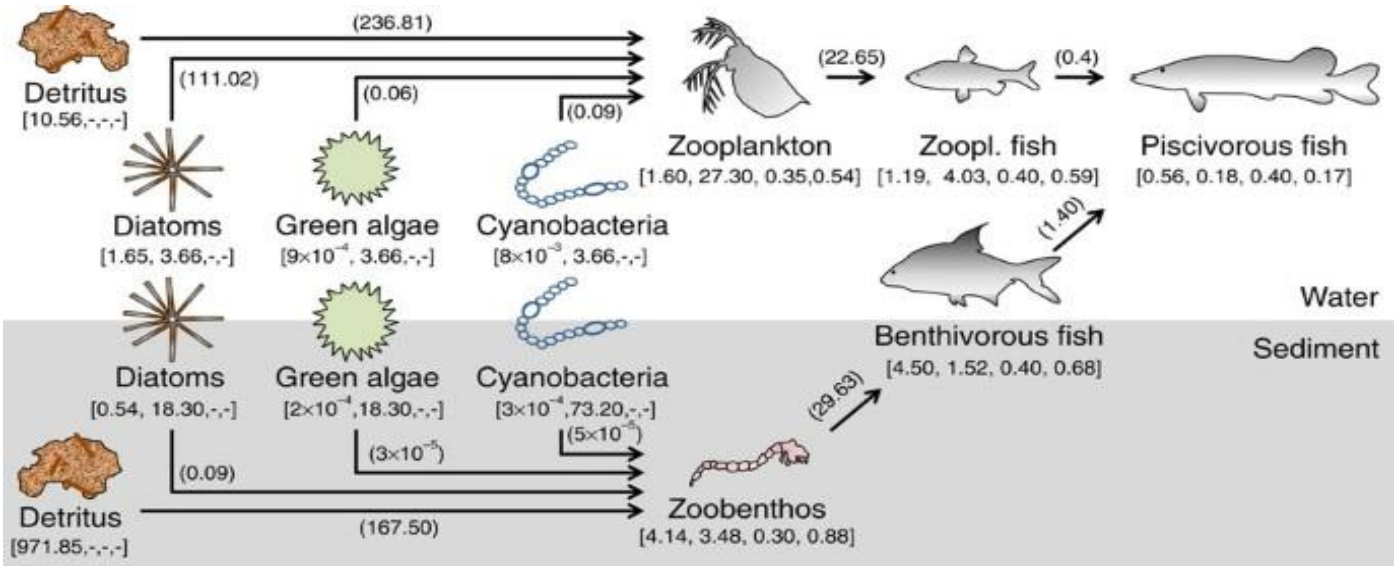
Effects of nutrients

It is important to recognise that nutrients play an essential part in the health and productivity of a fishery. However, 'too much of a good thing' can also cause problems. In this section, we look at the positive and negative effects of nutrients on aquatic ecosystems.

Positives:

- **Sunlight + water + nutrients = algae = food for phytoplankton / zooplankton (natural fish food) - part of a natural food web.**
- **Food (in the form of nitrate) for all aquatic plants and algae, contributing to plant growth and photosynthesis in oxygenating plants - production of dissolved oxygen (DO) - essential for aquatic life.**
- **'Food' for beneficial (nitrifying) bacteria, which grow on underwater surfaces and live in mulm - these convert toxic ammonia (NH3) into a much less harmful substance (nitrate), ensuring the water is healthy for fish.**

So, as we can see, nutrients are part of a natural ecosystem - nutrients feed the algae and plants, which feed the invertebrates, which feed the fish… and some fish eat other fish… A good fishery is a balanced fishery!



Diagrammatic representation of a natural food web.

Negatives:

- **Too many nutrients (+ sunlight) can = overabundance of plants and algal blooms, including blue green 'algae'…**

A species of primitive cyanobacteria ('cyan' means 'blue'), blue green 'algae' obtains its energy through photosynthesis like plants and actual algae. In addition to causing dissolved oxygen and pH fluctuations, high bacterial cell counts in the water column can irritate fish's gills. Some species of cyanobacteria can be toxic to fish, humans, and animals. Pets should be observed, and a vet informed if they have been exposed to blue green algae. Hands should be washed thoroughly! Your Analysis & Reporting (A&R) team can analyse water samples to identify algae (including blue green species), which can assist with the advice given. Provide a letter to the angling club / responsible party and a blue green algae 'warning' sign to educate anglers etc.

Blue green algae (cyanobacteria).

- **Significant swings in dissolved oxygen between night and day = stress…**

In waters with vegetation and algae present, dissolved oxygen levels are lowest at dawn, highest around midday, and begin to drop as the day draws to a close.

Photosynthesis ceases during the night, hence why dissolved oxygen concentration is lowest at dawn, and why this is typically the time fish in distress and / or dead fish are observed. The greater the number of oxygenating plants (and algae) there is, the more significant these 'swings' in dissolved oxygen can be between night and day.

Of course, this links back to the nutrient levels… the more nutrients there are, the greater the plant and algal growth, and the greater significance of these effects on fish.

- **Changes in pH between night and day = stress…**

Carbon dioxide (present in the atmosphere) dissolves in water to form carbonic acid. This 'acid' is absorbed by plants and algae during the day (through photosynthesis) and dissolved oxygen is produced as a useful by-product. This process causes the pH to rise somewhat (become more alkaline). However, the opposite is true at night, i.e., the pH falls somewhat due to the carbonic acid remaining in the water. Again, the greater the quantity of plants and algae, the greater these fluctuations can be, and this influences the extent of stress on the fish.

In waters supersaturated with dissolved oxygen (i.e., exceeding 100% sat) fish respiration slows down as the fish can 'breathe' without frequently moving the gills and / or surfacing for occasional air. This can cause a build-up of carbon dioxide in the blood, which can lower the pH of the blood. During a drop in dissolved oxygen however (due to large diurnal fluctuations, thunderstorms, algal die-off etc.), fish then must breathe quickly to get as much oxygen across the gills as possible, even if this means gulping at the waters' surface. This process expels carbon dioxide from the blood, and thus can raise the pH of the blood. Whilst not typically an issue in 'balanced' waters (i.e., those with minimal fluctuations), large or sudden changes can be very stressful to fish. This can particularly be an issue for fish that are moved between waters with vastly differing levels of dissolved oxygen.

- **Such changes more typical during the summer, further exacerbated by prolonged dry weather (PDW)…**

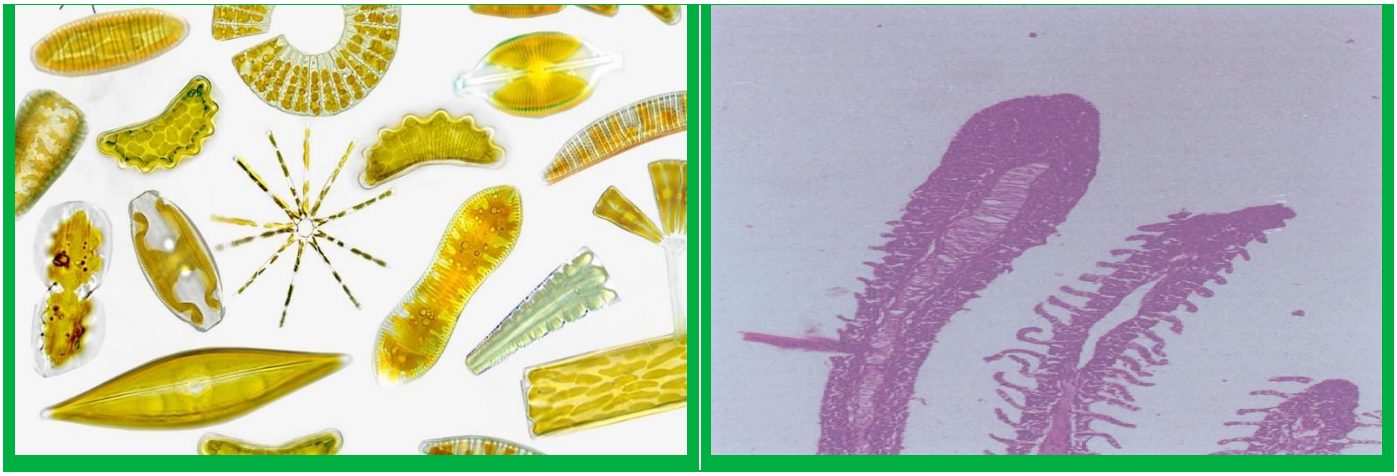
During prolonged dry weather, water levels and volumes can reduce. The less water there is, the more concentrated nutrients become, which can cause wider water quality issues.

- **Algal die-off = dissolved oxygen (DO) crash and degradation of water quality (ammonia spike)**

As a bloom dies off, bacteria in the water 'feed' on the decomposing algae and this process can cause a temporary drop in dissolved oxygen and a spike in ammonia. This will remain until the beneficial (nitrifying) bacteria have multiplied sufficiently enough to be able to consume / convert this ammonia into a much less harmful substance (ultimately nitrate). Oxygen is needed for this process to take place.

- **Diatoms…**

Diatom blooms can occur during the winter / early spring. Unlike algae, diatoms are made from silica, which can irritate the fish's gills, sometimes leading to 'clubbing' / hyperplasia of the gill lamellae and typically increased mucus production. This condition causes the secondary lamellae to clump together, which affects breathing. In extreme instances, the primary and secondary lamellae can clump / bind together, leading to suffocation.



Diatoms (left) and 'clubbing' of the gills / hyperplasia (right), showing the thickening and amalgamation of gill tissue.

- **Stress = reduced immune system = disease = death?**

Fish are most likely to fall victim to a greater burden of parasites and / or disease when stressed. This can further compromise the immune system and their ability to recover, in some cases leading to mortality.

- **Lack of management = greater risk of problems**

Long-term / ongoing management is needed for a healthy, balanced fishery.

Management options

1). Manage nutrients at source:

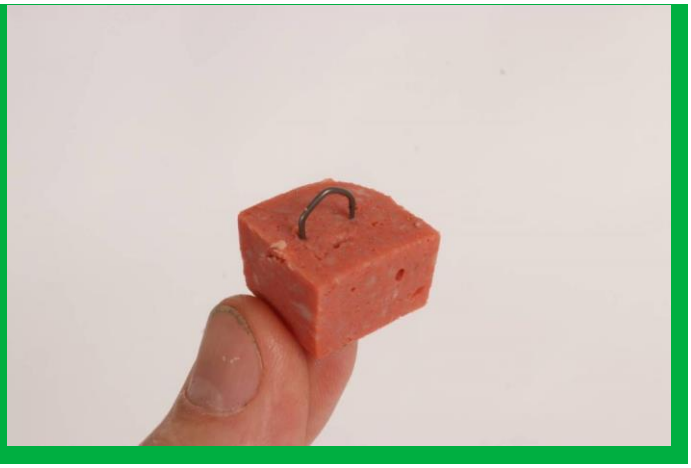
- **Stock management / cropping:**

Crop the silver fish population every 3-5 years. Species such as roach breed prolifically but grow slowly. In unmanaged waters, this can quickly lead to vast numbers of 3-4" (7-10cm) fish that are unable to grow larger due to there being insufficient natural food. These stunted specimens have, in some instances, been aged at 10+ years old! Failure to periodically crop such species can ultimately result in a large fish kill, often exacerbated by a dissolved oxygen crash through abundant algal activity, thunderstorms, and prolonged hot dry weather. This will affect fishery performance, and other fish species present may be unable to reach their growth potential. By periodically cropping the fish, more natural food is available, water quality is improved, fish are more resistant to disease, and they grow better and faster. Remember, if a fishery plans to crop fish (by methods other than rod and line), a Fish Removal (FR2) authorisation is required via our Fish Movements Team (FMT). If fish are moved off site, a supplier permit, and health check may also be necessary.


Roach (*Rutilus rutilus*).

- **Bait management:**

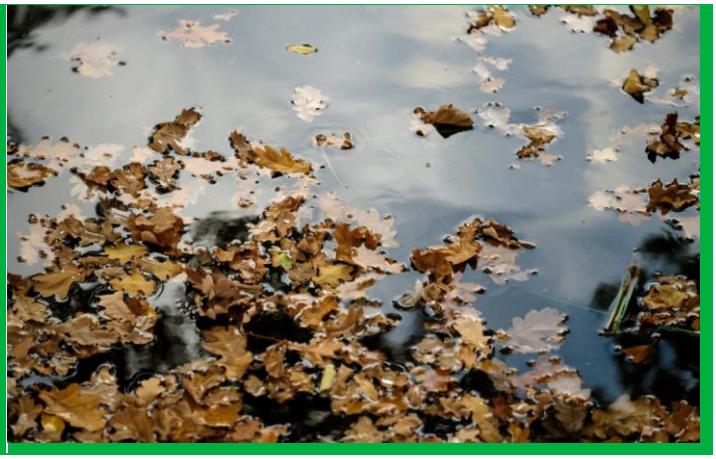
Advise caution regarding the use of too much high protein, oily baits (e.g., luncheon meat, boilies, and liquid baits) - these carry a high Biochemical Oxygen Demand (BOD) and can pollute the water. As such, these types of baits should be used sparingly and other, less nutrient-rich baits, such as sweetcorn etc., should be considered. Any leftover baits from fishing sessions / matches should be taken home or disposed of appropriately, not thrown into the fishery.

Liquid bait (left) and luncheon meat (right).

- **Tree management:**

Tree cover on a fishery is highly valuable, providing shaded areas, habitat diversity where branches enter the water, refuge areas, and locations for increased spawning and feeding opportunities. However, too many trees can input substantial amounts of leaf litter, which breaks down in the water and contributes nutrients. Fewer leaves going in means less leaf-related nutrients, but a balance is important (i.e., amount of marginal cover / shading, verses getting enough wind across the waters' surface).

Overhanging trees (left) and leaf litter accumulating (right).

- **Supplementary feeding:**

Supplementary feeding can be a useful tool for assisting growth in young fish and on waters with typically high stocking densities, e.g., commercial stillwater fisheries. As fish are coldblooded (poikilothermic), they will benefit the most from this practice during the summer months, when higher water temperatures promote appetite and thus growth. The opposite is true during the winter months, with lower water temperatures reducing appetite and the ability to digest food as effectively - this can lead to uneaten and undigested food negatively impacting water quality.

Some fishery owners like to offer a wheatgerm-based feed during the winter (low in protein and easier to digest), but why spend the money? If the fishery is managed correctly, the fish will be healthy and carry sufficient weight to get them through the winter. Skinny fish are not always skinny because they are not eating enough - parasites and / or disease could be responsible… So, only start to offer a supplementary feed when water temperatures reliably rise above 10degC and provide a high-quality diet that is medium-high protein and low in oil.


Examples of feed pellets (33% protein). Easily digested, so less waste.

- **Planting & management:**

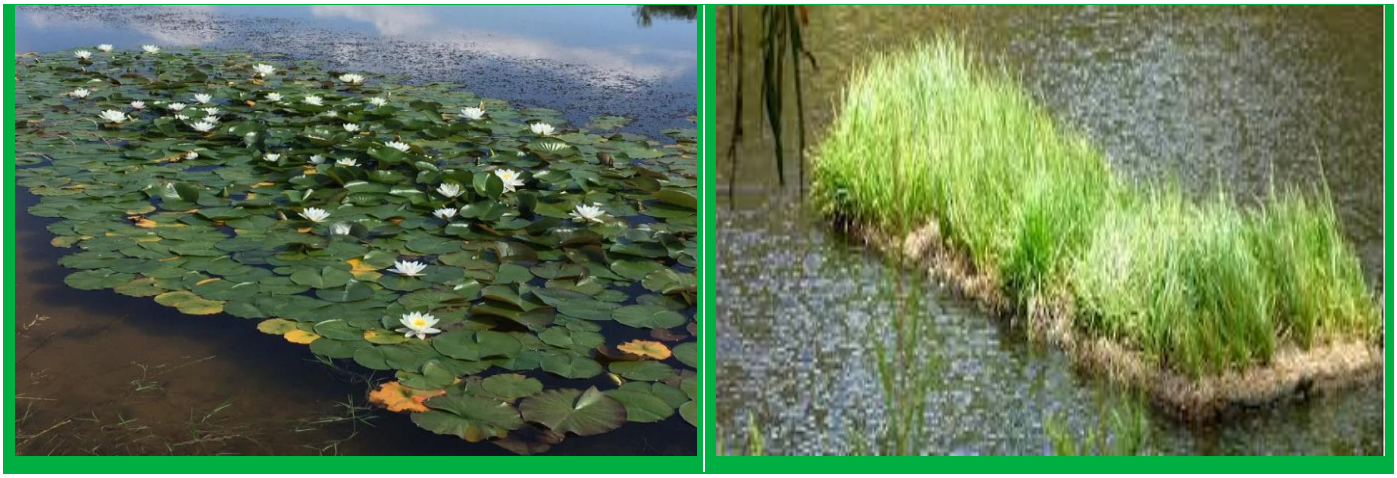
Aquatic plants (and marginals) can be great at mopping up nutrients, plus they provide valuable habitat - shading and shelter from predators, areas for increased feeding opportunities, and 'quiet' areas for when fish want to get out of the way, do not feel like feeding etc. Commercial fisheries typically do not have enough of this valuable habitat. Only native species should be planted - no non-natives (biosecurity)! Only purchase aquatic and marginal plants from reputable suppliers and / or re-seed from existing (native) plants.

Plant consignments entering the UK and EU and moving between member states or within a member state / the UK, now need to carry an official label, physically attached to the consignment. This is officially known as a plant passport.

The approach to managing plant growth can vary depending on the species but managing the source(s) of nutrient inputs will certainly go a long way to helping with all species. A 'little and often' approach with floating types will be easier to manage than leaving them for too long. Pile the plants on the bank, no further back than 1m from bank-top for 24hrs or so, to allow any invertebrates etc. to find their way back into the water. The plants can then be moved elsewhere onsite and allowed to rot down. Hand-pulling / physical removal can be successful for small areas if repeated on a regular basis. A weed razor may be better than using a rake in some instances, as there is less chance of disturbing nutrient-laden silt. Silt is also anoxic (devoid of oxygen), so disturbing it can cause localised drops / crashes in dissolved oxygen. If more 'aggressive' weed maintenance is needed (i.e., if an overgrown / unmanaged fishery has just been taken on), dissolved oxygen levels should be monitored before, during, and after to inform decision-making (i.e., whether to stop, continue with caution, etc.).

Aeration can be used as a mechanical approach to hinder the spread of waterlily pads. Waterlilies prefer to grow in static water, and so surface aerators can disrupt the surface of the water and can limit the growth of these plants. The application of herbicide can help with controlling plant growth, but Glyphosate is the only licensed herbicide that can be used in or near water. Permission must be sought from the Environment Agency, and the herbicide can cause a temporary drop in dissolved oxygen, so caution should be taken if this approach is considered.

Floating reed-beds can be an option for waters where space allows and provide multiple benefits - trailing plant roots underwater suck up nutrients and provide a haven for smaller fish and wider ecology, and terrestrial plant growth up top provides habitat for insects and nesting birds. Fish may also utilise the root systems as a spawning substrate and the reed-bed itself can offer some protection from avian predation. Reed-beds can also be strategically placed at the inlet(s) to online stillwaters to help filter out nutrients from the incoming water. Just ensure that floating islands are well anchored to prevent them from wandering…



Native White Waterlily (*Nymphaea alba*) (left) and a floating reed-bed (right).

Riparian buffer strips can be helpful for protecting fisheries from nutrient inputs. Usually forested, they help shade and partially protect the water from the impact of adjacent land uses.

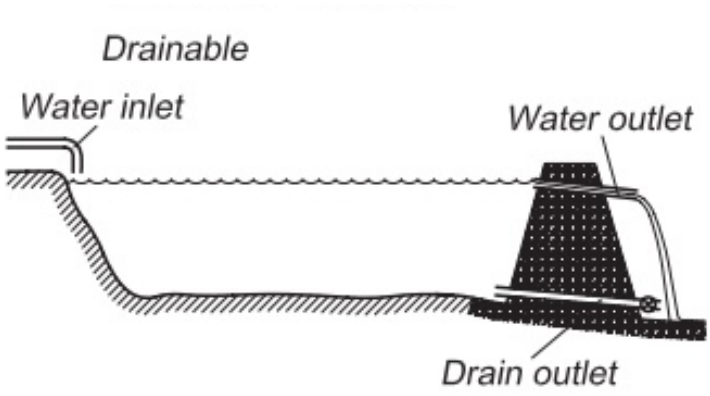
- **Birds:**

Waterfowl, particularly larger species such as Canada geese, can contribute a lot of nutrients through their droppings. For waters in a public setting (parks etc.), any reports should be directed to the local authority. Limiting 'attractants' such as floating bread etc. can help keep them away or help manage their numbers.

Factsheets are available from the RSPCA, and Angling Trust Advisors may be able to help with management options.

- **Drainable ponds:**

Although arguably more typical (and applicable) to fish farming practices, drainable earth ponds offer an effective means of controlling nutrient levels. The advantage with drainable ponds is the possibility for a more effective harvesting process and the ability to control the water level because water can be drained out of the pond. It is simpler to fertilise / feed, and to supply additional air. While non-drainable ponds are normally run extensively, drainable ponds can be run more intensively, depending on the amount and growth rate of the fish. After the fish have been harvested, the ponds are allowed to dry out and the silt bed removed (through mechanical means and / or through the application of hydrated lime) without any risks to water quality and fish.



Drainable pond on a fish farm.

2). Wider / additional control methods:

It is important to emphasise that the following methods are reactive and not preventative, and therefore merely address the symptom, not the cause.

- **Barley straw:**

When applied correctly, barley straw inhibits the growth of algae. The typical dosing period is March-end of October, but as the speed at which it works is dependent on water temperature, it could be added as early as January and left to break down as water temperatures rise. It is essential that: 1). Enough straw is 'dosed' for the size of the water, and 2). The straw is divided up to create as large a surface area as possible through which water can flow (e.g., inside of netting 'sausages'). These can be anchored into the fishery margins, around islands etc., with floats attached to prevent sinking. Do not simply throw in whole straw bales… It is important that barley straw is removed by the end of October, as it will then be 'spent' and if left in situ will rot down and contribute nutrients.

Barley straw is a better option than the extract. Straw rots, working over a longer time and provides habitat for bacteria, fungi, and invertebrates. HSE Biocides have restricted the use of some compounds derived by "processing" a natural substrate, meaning that barley straw is still allowed, but the extract is not.

We now operate our own Biocides regime outside the EU, and it may be that this decision could change in the future. Straw has more advantages over extract anyway - straw rots over an extended period and provides 'habitat'… extract is just a chemical treatment with no biodiversity benefits.

For more information on barley straw and its application, please refer to Barley straw information.

Barley straw (left) in a typical netting 'sausage' and deployed on a pond (right) to allow the maximum flow-through of water.

- **Hydrated lime:**

This product liquifies the silt (accumulation of organics), which can help eliminate the eventual need for invasive mechanical removal of silt. As hydrated lime is an alkaline substance (thus with a high pH), its application can cause a localised increase in pH, and the breakdown process releases nutrients within the silt. For this reason, only 25% of the total area to be treated should be targeted per application. Hydrated lime should only be added during the winter months, as shorter days (and thus less sunlight) reduces the risk of algal blooms occurring. It is important to note that hydrated lime only works on organic silt, and so does not include any sand that has been washed in! Hydrated lime is extremely caustic and can cause serious chemical burns to the eyes and skin. Any application should only be undertaken by trained individuals / professionals in this area.

- **Dye additives:**

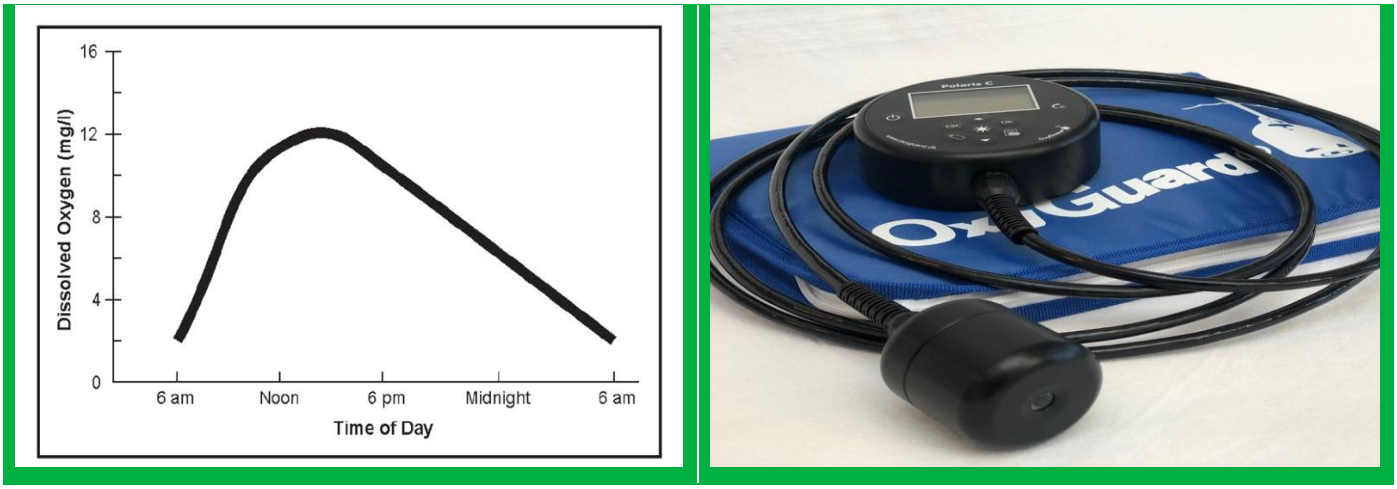
These 'darken' the water, reducing light penetration, which can limit or stop the growth of certain plants and algae. The dose / 'darkness' can be varied depending on the goals of the fishery owner and can be an expensive undertaking on large bodies of water. A lot of aquatic plants provide valuable oxygen, so a balance is needed. It may not be appropriate to dye the water in fisheries with large amounts of tree shading, as its application can kill off, or at least greatly limit, what submerged plants and algae are able to grow in the first place. This can lead to significant dissolved oxygen crashes, which can cause fish mortalities. Less sunlight getting into the water = less plant and algal growth = less invertebrates… this also means less natural food for fish to feed on.

Some dye additives turn the water a dark blue / navy colour, which some find unnatural looking. Such products are also ineffective against floating plants such as duckweed (*Lemna* sp.). All things considered, other management options may be more appropriate for controlling excessive weed and algal growth than going down the route of dyes.

Dye additives - brown to dark blue!

- **Dissolved Oxygen (DO) monitoring:**

In-line with the rhythm of plant and algal photosynthesis, test levels at dawn, around midday, and late afternoon. All waters are different - numbers of fish, management practices, quantity of plants and algae, depth, disturbance of silt etc. all impact dissolved oxygen levels, and so historical monitoring will reveal the 'good' and 'bad' dissolved oxygen levels for a particular water. These readings serve as an 'early warning system', informing the fishery owner when to aerate etc. For people that like / want benchmark figures to go on, aim for minimum levels of 50% (4mg/l) for coarse fish, and 70% (6mg/l) for trout. Ideally, dissolved oxygen levels should be checked at 4+ locations on large waters, including the windward end (highest dissolved oxygen).



Typical dissolved oxygen (DO) diurnal fluctuation in waters with plant and algal activity (left), and an example of a popular electronic DO monitoring probe (right).

- **Mechanical aeration:**

Mechanical aeration can be an invaluable tool during the warm summer months, when higher water temperatures naturally mean lower dissolved oxygen levels. In-line with the rhythm of plant and algal photosynthesis, running aeration equipment through the night into early / mid-morning, can really help in alleviating dissolved oxygen crashes at dawn. This is when levels will typically be at their lowest ebb and thus, the time of day you would typically observe fish in distress. Some fisheries choose to run aeration equipment 24 / 7 during the summer, especially on intensively run coarse fisheries, where very high stocking densities (and the nutrients they contribute) can give rise to abundant algal blooms.

The decision when to deploy aeration equipment (and its duration) should be informed by the climatic conditions (i.e., temperature and atmospheric pressure) as well as the dissolved oxygen readings taken.

There may be instances where dissolved oxygen levels noticeably start falling during the day. This could mean that an algal bloom is dying off (the bacteria that 'feed' off the decomposing bloom consumes dissolved oxygen), and / or a change in atmospheric pressure could be to blame, i.e., thunderstorm. If the fishery in question is online, there could have been an input of something via the feeder stream etc. Again, regularly testing dissolved oxygen levels (3x per day minimum during the summer), will enable informed decisions to be made on when, where, and how long to aerate, and perhaps also the method of aeration / oxygenation most applicable. Numerous types of aeration equipment exist, from electricity-powered paddle-wheel aerators, to solar-powered options, where an electricity source is unavailable.

Diffuse aeration may be a useful aid in some situations, where air is pumped into the water column itself via an air-stone or similar. As the multiple bubbles rise through the water column, they can disrupt the growth cycle of algae, making it harder for a bloom to become established. The positioning of such 'air-stones' should be considered however, as they can disturb anoxic (oxygen deficient) silt, if allowed to sit on the pond bottom, which can cause localised drops in dissolved oxygen and the release of nutrients.

Electricity-powered paddle-wheel aerator (left) and a solar-powered aerator in action (right).

Summary and conclusions

- Almost anything that enters and breaks down in the water contributes nutrients…
- Nutrients can be essential to ensuring a balanced aquatic ecosystem, but be aware of the limitations…
- Various control measures exist for fishery managers / responsible parties, but combined mitigation is likely needed for best results - target the nutrient source(s) first and consider additional control options if necessary / applicable.
- A good fishery is a balanced fishery!