REDUCING DISCHARGES FROM FISH FARMS

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Recently, I was lucky enough to attend a short training course entitled "Improvement and innovation of aquaculture effluent treatment technology". It was held at the Hotel Legoland in Billund, Denmark as part of the European Commission's AquaEtreat programme. AquaEtreat was set up to "examine the feasibility of developing and implementing cost-effective systems for the treatment of aquaculture farm effluent and the valorisation and reuse of the products and by-products." Valorisation is a 'Commission Speak' word meaning, roughly, 'to increase the value of'. See www.aquaetreat.org for more information on the programme.

Although the treatment of industrial and domestic waste is a huge and well established industry, techniques for the control of the pollution emanating from fish farms are not well developed and those that exist are not in widespread use on European fish farms. A lot of work remains to be done and this field will no doubt see many developments in coming years.

The course trainees came from all across Europe with feed company people and UK trout farmers being particularly well represented. As well as a full programme of presentations we visited 3 'model' fish farms. These trout farms are part of a Danish initiative to "investigate the possibility of an environmentally neutral increase in production from the Danish Aquaculture sector through implementation of new technologies". Each combines recirculation technology with a variety of approaches to waste treatment. In this article I will try and put my experiences in Denmark to good use and will discuss the what, why and how of fish farm waste and its treatment;

- What are the characteristics of fish farm waste?
- Why should it be reduced?
- How can this be achieved?
- What can be done with the resulting sludge?

The final point was high on the agenda in Billund and is clearly an area in which a lot of work still needs to be done.

What is fish farm waste?

At Skretting we ensure that our feed is packed full of useful nutrients and it is the job of the fish farmer to make sure that the maximum amount of these end up integrated within the bodies of harvested fish. However, the process of fish production is not 100% efficient and inevitably a proportion of the nutrients added in the form of food will be lost as waste. Some feed will remain uneaten, some will not be digested and some will be used in metabolic processes rather than being retained in the body of the fish.

A simple 'mass balance' calculation can fairly accurately work out the net amount of various nutrients which will end up as waste. All we need to know is a) how much nutrient is contained in the feed fed to a group of fish and b) how much of that nutrient will stay within the fish. For example, a freshwater salmon diet might contain 1.2% phosphorous (P). If a feed conversion rate (FCR) of 1:1 is achieved then a tonne of feed will grow one tonne of fish. A fish typically contains 0.5% P, so while the tonne of feed contains 12kg of P the tonne of fish contains only 5kg. Therefore 12kg – 5kg = 7kg of P will be wasted and will either be removed during waste treatment or will enter the environment, that is 58% of the P fed. A similar calculation for nitrogen, which is mainly contained in protein, generally shows that a similar proportion is lost, but that the quantities involved are around 5 times higher.

A key part of this equation is the feed conversion rate. If FCR is low, a high proportion of the nutrients contained in feed will ultimately be removed from the system as fish biomass in comparison with a situation where FCR is high. If we use an FCR of 1.5:1 in the above example the difference will be obvious. An FCR of 1.5:1 means that 1.5 tonnes of feed will be required to grow a tonne of fish. This amount of feed will contain 18kg of P and the fish produced will still contain only 5kg. This leaves a net

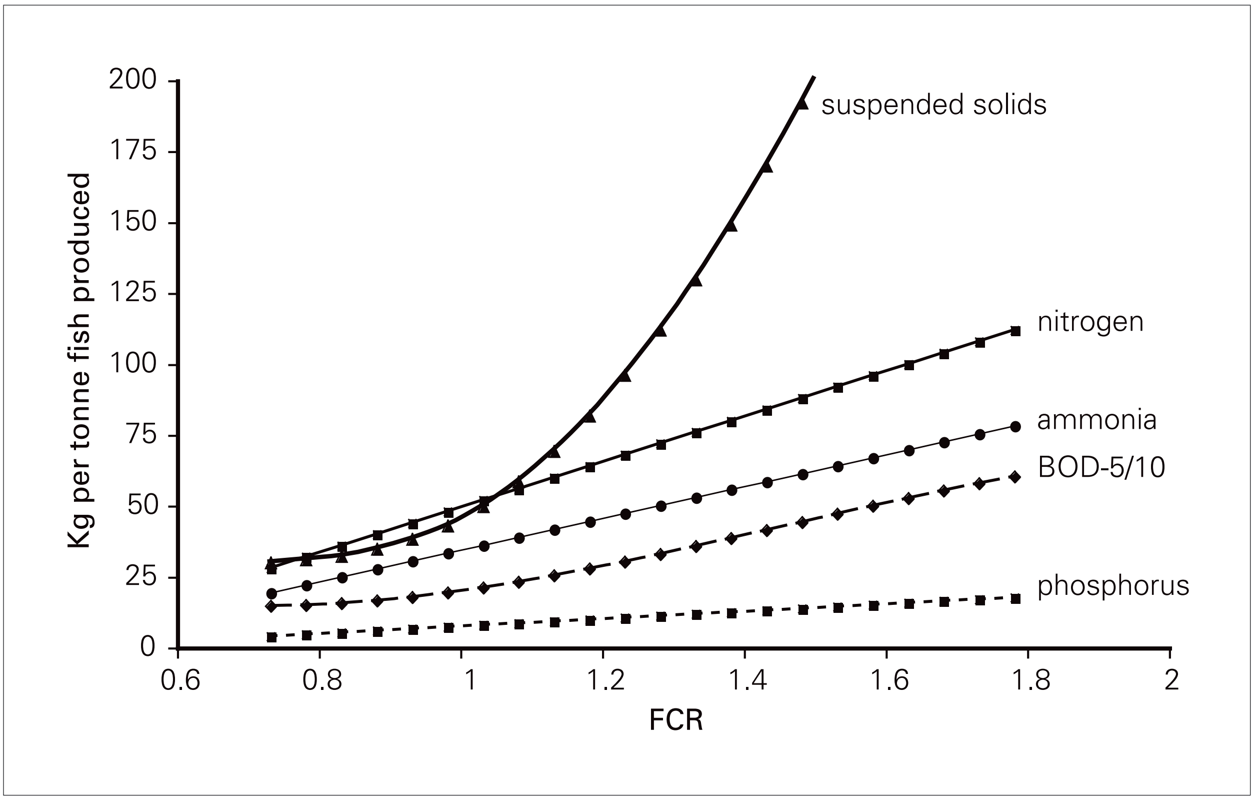

Figure 1: Effect of FCR on nutrient discharges to the environment

amount of 13kg of P which will go to waste, almost twice as much as with a 1:1 FCR, a total in this case of 72% of the P in the feed. The influence of FCR on waste production is shown in Figure 1.

The waste products produced by fish farming are, in the main, either in solid or dissolved form. The solid portion, also known as suspended solids, consists of waste feed and faeces, both of which contain a large proportion of organic matter such as protein, carbohydrate and fat. Faeces contain not only undigested food but also mucous, sloughed intestinal cells and bacteria. Compounds of this type are responsible for most of the Biological Oxygen Demand (BOD) of fish farm waste. BOD is a measure of how much oxygen microorganisms will use up in the process of digesting the organic material in a water sample, usually over the course of 5 hours, and is therefore an indirect measure of the amount of organic matter in a sample. It is usually stated as milligrams of oxygen per litre of water, but the graph shows the total BOD in kilograms produced in the production of a tonne of fish. The solid portion contains the majority of P and organic N in fish waste, a fact which is useful in the treatment of fish farm waste, as will be seen later.

Dissolved waste is mainly ammonia/ammonium which is produced by the fish as a by-product of protein metabolism and released in the urine and through the gills.

Clarke and Phillips (1989) found that a salmon farm produced 40 kg of particulate nitrogen, 7-10 kg of solid phosphorus, and 250 kg of particulate carbon (organic material) per 1000 kg of fish produced. The high organic content of the particulate waste encourages heterotrophic bacteria populations and fungi to grow rapidly. Their metabolism creates high BOD, and the end products of their digestion release ammonia into the water.

In summary, the most important water quality problems produced by fish farms are phosphorous, nitrogen and biological oxygen demand.

Why reduce fish farm waste?

Perhaps the most compelling (literally!) reason to minimise the release of waste to the environment is the law. Many pieces of legislation have an influence on this area including the Control of Pollution Act 1974, the Environment Act 1995, the EU Water Framework Directive (enacted within the Water Environment Water Services Act 2003 in Scotland) and, most directly for fish farms, The Water Environment (Controlled Activities)(Scotland) Regulations 2005. Similar laws are in force throughout the UK. As a consequence fish farms are legally required to be registered, to be assessed for biomass and/or discharge consent and are subjected to regular inspections. Successfully reducing waste outflow may prevent discharge consents being breached and could make an application for increased biomass consent more likely.

The legal framework was set up in order to provide protection for the natural environment. The principle environmental effect of fish farm waste is the nutrient enrichment of the receiving waters, whether river, lake or ground water. In severe cases nutrient enrichment can result in increased plant growth and algal blooms, with the latter having the potential to cause severe oxygen depletion when they subsequently die off. In Scotland there is a principal which states that fish farm wastes should not cause receiving water bodies to change their nutritional status.

There can also be more immediately obvious effects such as oxygen depletion and unsightly sewage fungus, waste feed and fish faeces in rivers. Environmental issues are very high on many people’s agenda today, and it is clearly better for public relations if fish farms are able to show that they are making sincere efforts to reduce discharges.

Where fish farm wastes can be well controlled, particularly if the switch is made from flow through to recirculation systems, it may be possible to dramatically increase fish farm production. This is especially true where water supplies are limiting or where receiving waters are environmentally sensitive. In such cases there can also be strong economic reasons to improve fish farm waste handling, because in their absence the environmental agencies may offer very restricted consents.

How to reduce fish farm wastes?

Prevention is better than cure

The simplest way to reduce fish farm effluent is to reduce production, but this will have adverse economic implications.

As we saw above, a reduction in FCR will result in reduced nutrient discharges. FCR is affected by many factors including feed type, feeding regime, system design and environmental conditions, such as water quality and oxygen level. Many of these aspects are under the control of the farm manager to some extent and it is often possible to reduce environmental impact and to save money at the same time. In a well run farm all these variables will be well controlled and low FCRs will follow as a matter of course.

Fish farm FCRs have fallen considerably over recent years and although many factors may have contributed to this drop, improvements in fish feed are probably the most significant. When we compare the diets of today with those of 20, or even 10, years ago there are huge differences. Today’s fish feeds have benefited from improvements in raw material quality, increased nutrient density and ever greater nutritional know how, all of which have come together to provide fish farmers not only with lower potential FCRs, but with better performance and more economic results.

The easiest way to cause FCRs to rise and to increase wastes is to allow fish feed to go uneaten. A proportion of feed will always be wasted but a well chosen and well-controlled feeding regime will minimise this. It is particularly important to control the timing and rate of feeding and to ensure feed is well distributed. Fish appetite can vary enormously over time, being affected by temperature, oxygen, light level and so on, and so feeding regimes should be flexible enough to take this into account. Ideally there should be a way of knowing when feed is being left uneaten and this knowledge should be used to slow or stop feeding as appropriate. Such feedback systems take many forms ranging from sophisticated detectors with computer control through cameras to a simple basket in the outflow water.