Aquaculture techniques and technology:

Marine and Freshwater environments

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Acknowledgements

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1. INTRODUCTION

1.1 The aquaculture industry

Aquaculture is a fast expanding farming industry and is practiced by some of the poorest farmers in developing countries, and by multinational companies (FAO, 2017). A range of freshwater and marine fish are cultivated, as well as shellfish, and aquatic plants. Farming technology to suit both freshwater and marine aquatic life is evolving constantly and new developments in the Re-circulating Aquaculture System (RAS) and the area of aquaponics are being investigated. This is to ensure we can achieve a sustainable future for fish farming, both economically and environmentally.

As part of my travel grant I visited HAKI, a research institute in Hungary to learn about freshwater fish farming and the technologies they use to keep costs low and increase yields. I also visited two freshwater fish farms while I was in Hungary; Szarvas-Fish Kft, a North African catfish farm, and Hortobágyi Halgazdaság Zrt which is a common carp farm. It was an eye-opener to see both species of fish stocked in tanks at such high densities, with low mortality rates. I also visited NOFIMA, a research institute in Norway to learn about marine fish cultivation. The Re-circulating Aquaculture System (RAS) technology being investigated for marine fish is highly sophisticated and requires a huge amount of space and staff are highly experienced and dedicated to the running of the systems. I was able to speak to staff working in the biological and genetic side of fish farming; investigating breeding techniques and fish deformities. I also visited one very large marine fish farm while I was in Norway; Lerøy Belsvik, an Atlantic salmon farm in Hitra. The sheer size of the fish farm and the sophisticated technology was breath-taking. The control of disease was also very interesting.

My travel grant also enabled me to visit Sparsholt College in Winchester, UK where an aquaculture course is currently running. I was keen to understand the course structure and investigate whether I could potentially create and run such a programme at Writtle University College in the future. I was very impressed with the aquaculture facilities at Sparsholt College and the expertise of the lecturers delivering the course.

1.2 Aim of my study/objectives

- To speak to the world leading experts in aquaculture research and learn about the expanding area of fish farming in both freshwater and marine environments
- To explore the new sustainable technologies that are being implemented worldwide
- To investigate the potential for creating an aquaculture course at Writtle University College

2. AQUACULTURE SPECIES

2.1 North African catfish (*Clarias gariepinus)* (FRESHWATER)

Fig. 2.1 North African catfish (*Clarias gariepinus*)
Source: Life.In.A.Tank

North African catfish (*C. gariepinus*); simply referred to as 'African catfish' (Fig. 2.1) is a freshwater fish with a pan-African distribution. They are also native to the streams in Jordan and Israel, and it is an introduced species to some rivers of Turkey (FAO Factsheet). The fish have slender eel-like bodies, with flat bony heads and four pairs of barbels. African catfish are found in lakes, streams, rivers, swamps and floodplains, many of which have low water levels or are subjected to drying in hot months. According to the IUCN (2017), it is not a threatened species.

The African catfish is highly resilient to diseases (Edward et al., 2010), and has accessory breathing organs which allow it to survive during dry seasons (FAO Factsheet 1), and during my trip to Hungary I observed that stocking density was so high that the water was barely covering the fish. The fish are naturally adapted to live comfortably during draughts when water is scarce (Edward et al., 2010), and this also enables fish farmers to use less water which is much more cost effective and environmentally friendlier. African catfish are considered to be one of the most important and sought after tropical freshwater fish species, producing high yields in the aquaculture environment (Dada and Wonah, 2003). *C. gariepinus* has a high fecundity rate, tolerates high stocking densities (Fig. 2.2) along with environmental extremes, and accepts a varied diet of both natural and artificial food (Bruton, 1979).

Fig. 2.2 African catfish stocked at high density
Source: AgriFarming

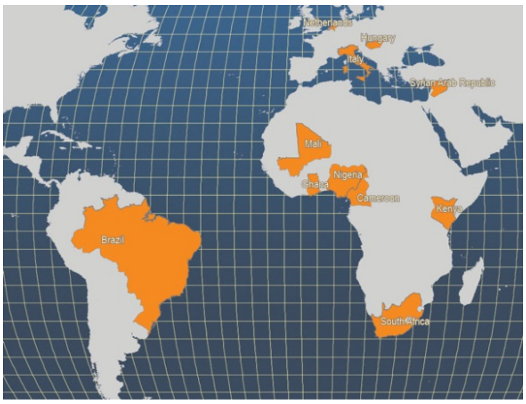

Fig. 2.3. Main producer countries of North African catfish (*C. gariepinus*)

Nigeria is by far the largest producer of catfish according to FAO statistics, but the Netherlands, Hungary, Kenya, the Syrian Arab Republic, Brazil, Cameroon, Mali and South Africa also produce significant volumes (Fig. 2.3) (FAO, 2017). Many local recipes in African regions use catfish species in soups, curries and stews, and in south east Asia catfish is often deep fried and served rice and salad.

2.2. Common Carp (*Cyprinus carpio*) (FRESHWATER)

Fig. 2.4 Common Carp
(*Cyprinus carpio*)
Source: Department of Primary Industries

Common carp (*Cyprinus carpio*) (Fig. 2.4) are a brownish-green colour on the back and upper sides, and are golden ventrally. They have an elongated and compressed body, and thick lips (FAO Factsheet 2). The common carp has one long dorsal fin with hard and soft rays. They are found in a large temperature range of 3 -35C, and the optimal water temperature for growth is between 20–25 ^{o}C (Froese and Pauly, 2011). According to Freyhof and Kottelat (2008), wild common carp are listed as 'vulnerable', and this may be due to rivers drying out. Although carp prefer to live in shallow waters, they require flooded areas to spawn. Common carp in the wild normally feed on worms, snails and insects. They are distributed in European lakes and rivers, however it has been widely introduced to North America, Southern Africa, New Zealand, Australia and Asia. In the wild, common carp live in sections of rivers where the water is shallow (just a few meters deep) and where the substrate is muddy (FAO Factsheet 2).

Common carp (Fig. 2.5) is the third most widely produced freshwater fish species in the world (FAO, 2013), after grass carp and silver carp. Common carp is rarely produced in tanks or cages owing to the lower value of carp itself and the high costs in obtaining protein-rich foods like worms and snails. Therefore, most commercially farmed carp is produced in fish pond systems, and this is much more cost effective for producers (FAO, 2013).

Fig. 2.5. Farmed common carp
Source: Flickr

Fig. 2.6. Main producer countries of common carp (*C. carpio*)

Asia accounts for more than 90% of common carp aquaculture production (Fig. 2.6), and China alone contributed 77% of the world's aquaculture production of common carp in 2009 (FAO, 2013). Carp is often deep fried, or baked and served with lemon and chips.

2.3. Atlantic salmon (*Salmo salar*) (MARINE)

Fig. 2.7. Atlantic salmon
(*Salmo salar*)
Source: SeaMaxGlobal

The Atlantic salmon (*Salmo salar*) (Fig. 2.7) has a laterally compressed body form and dorsal adipose fin (Webb et al., 2007). Atlantic salmon spend their juvenile life in rivers. Those that are anadromous will migrate to sea, and later return as adults to their natal stream to spawn. In many rivers, the species is already extinct (IUCN, 2017). Its demise can largely be attributed to human activities, yet paradoxically it remains abundant owing to its importance to humans as a successful aquaculture species (Verspoor et al., 2007). Existing wild stocks of Atlantic salmon are distributed around the east coast of North America, Europe and Baltic regions.

Most of the research into salmon farming is undertaken in Northern European producing countries (Fig. 2.8), and tends to focus on developing economies, reducing unit production costs, and protecting profit margins. It seems likely that future production surges will occur in Chile, where costs of production tend to be lower, owing to lower cost of labour and raw materials (FAO, 2017). Disease susceptibility is a major problem for Atlantic salmon farmers. In fact, it can be the cause of very high mortality rates in the aquaculture environment at all stages of the salmon life cycle. Many research groups are investigating genetic resistance to diseases, vaccines, and effective breeding programs to increase productivity.

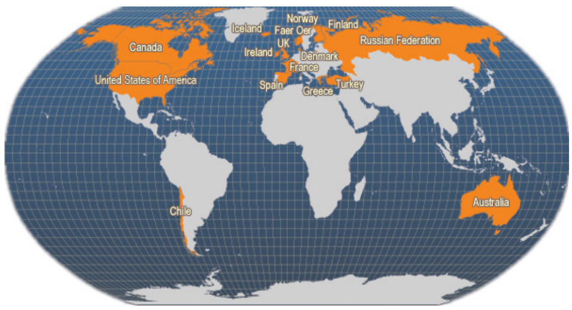

Fig. 2.8 Main producer countries of Atlantic salmon (*Salmo salar*)
Source: FAO, 2017

Fig. 2.9 Farmed Atlantic salmon steak. The flesh tends to be fattier and paler than wild salmon
Source: atlanticcanadaexports

The farmed salmon industry has grown significantly in the last 40 years; today around 60% of the world's salmon production is farmed (Global Salmon Initiative, 2017). More than 2,200,000 tons of farmed salmon were produced 2015, in comparison to around 880,000 tons of wild-caught salmon (Marine Harvest, no date). The largest markets for farmed Atlantic salmon are Japan, the European Union, and North America (FAO, 2017), and are sold fresh (Fig. 2.9) and frozen. Baked salmon is a popular dish in Europe and America, but it is common to see salmon eaten raw as part of a sushi dish in Asian countries.

3. TRIP TO HUNGARY

3.1 Aquaculture in Hungary

Hungary is a landlocked country (Fig. 3.1), and is known for its long-standing tradition of fish farming. The first fish farms in Hungary were established in the 1890s. The geographical, water and climatic conditions in Hungary are favourable for traditional pond fish husbandry. Pond aquaculture is benefited by the sheer volume of highly experienced professionals who have passed knowledge down to generations for centuries. Also, Hungary is fortunate to receive rich geothermal water, which reduced energy demands and can also be used to support a range of exotic species with high export potential. These exotic species are resilient and thrive in recirculation systems (European Commission, 2017).

Hungarian aquaculture possesses some special characteristics, for example, its worldwide reputation in carp breeding. The total area covered by fish ponds in Hungary is approximately 28,000 ha with the majority species farmed being common carp (*Cyprinus carpio*). Hungary's carp production is the third largest in Europe and represents 74% of the total fish production in Hungary. More than 10% of production comes intensive fish farming of mainly European catfish, sturgeon species, and some pikeperch. Around 7% of production comes from geothermal intensive water systems, in which the major species farmed is the North African catfish (*Clarias gariepinus*) (FAO, 2017).

Fig. 3.1 Hungary, showing the location of the research station (lower circle) and carp farm (upper circle). Source: TES

3.2 HAKI

Many areas of research carried are out at HAKI; Aquaculture system development, fish nutrition, immunology, fish biology, freshwater fisheries, genetics, and water ecology. Current projects include genotyping and maintaining live and frozen fish gene banks, and investigating the prevention and treatments of fish diseases. Some of the first experiments investigating the growth rate and larval rearing in African catfish were conducted at HAKI in the 1980s. Researchers at the institute also found that Pikeperch grow faster in intensive indoor conditions as compared with less intensive, outdoor pond rearing.

3.3. Recirculating Aquaculture System (RAS): closed indoor system

I was very happy to be able to see a Recirculating Aquaculture System (RAS) during my trip to HAKI. It is amazing how an entire fish production system can exist in just one large area and be controlled very simply. The tanks in this system contained common carp, grass carp and sterlet (Fig. 3.2), and often attracted visiting farmers from African countries to see the set up and learn how to develop their own systems. The farm consists of tanks containing water and the fish which are fed by the farmers (Fig. 3.3). The water is closely monitored so that oxygen levels may be maintained at safe levels. Equipment to dissolve O_2 is installed outside each tank. The catfish are stocked at a high density and I was able to observe them being fed.

Fig. 3.2 The Recirculating Aquaculture System (RAS) at HAKI, Hungary

Fig. 3.3 Tanks containing common carp, grass carp, and sterlet stocked at high density

The whole set up of the RAS is fascinating. Since it is a recirculating system, a vast majority of water is reused, therefore it needs to be cleaned after each cylce. A small fraction of water is lost after each cycle through bio-filtering and removal of waste, therefore a small fraction of water is added to the tanks in each cycle. The cycle starts with the water in the tanks (Fig. 3.3) containing the fish. The water then leaves the tanks and passes through a mesh filter drum to remove large waste particles (Fig. 3.4). Often this waste product can be used as a fertiliser for plants or aquaponics systems. Once the water has passed through the mesh filter, it then enters tanks which contain biofilters (Fig. 3.5).

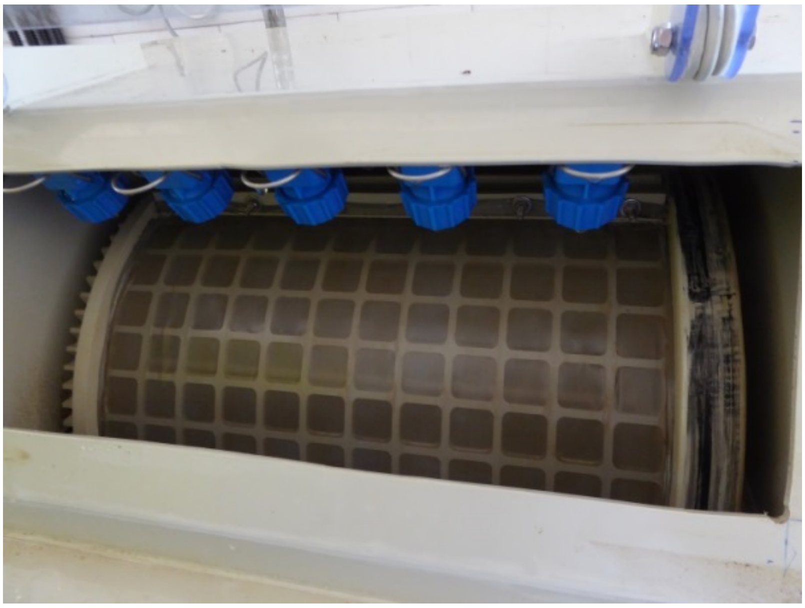

Fig. 3.4 Mesh filter drum

Fig. 3.5 Biofilter tank, HAKI

These biofilters are look a little bit like pasta shapes to me! (see Fig. 3.6). The biofilters are placed into a compartment in which water which has passed from the first drum filter, to be filtered again via the biofiltration system. This is where toxins are removed from the water before entering the fish tanks where the recirculating water cycle starts again.

The whole RAS is controlled by a panel installed by the door (Fig. 3.7) so that farmers do not need to enter far into the farm, thus reducing any risk of contamination.

Fig. 3.6 Biofilter close up, HAKI

Fig. 3.7 RAS control panel

3.4. African Catfish Farm (Szarvas-Fish Kft)

Fig. 3.8 African catfish farm, enclosures house size-specific fish

The African catfish farm (Szarvas-Fish) I visited is one of two sites. African catfish at the farm are housed in enclosures which support specific sized-ranged fish. They are fed with pellets, and the water is not recirculated (Fig. 3.8). The propagation methods and hatchery processes take place at the other site. Propagation takes place 4-5 times a year. The fish arrive at this site at around 40-50g. There are different size groups ranging from around 50g to 3-4kg, hence the number of different enclosures seen in Fig. 3.8.

Fig. 3.9 Trickling tower is installed to remove CO_2 from the water

The water is sourced by naturally occurring thermal springs, and trickling tower is installed to remove CO_2 from the water (Fig. 3.9). The water temperature is around 22-28C. It takes 11 months from the larvae stage to market size which is around 1.5 – 2.5 kilos. Cannibalism is common, but only at the juvenile stage. Survival of larvae is 20%, but the survival of adults is 90-95%. Around 2000 tons of fish is produced a year, but since the fish farm is located in two sites, it generates a total of around 4000 tons per year. This farm supplies 10.15% of the total Hungarian fish production.

Fish are stocked at a density of 300kg per cubic meter. The catfish require no health treatment as the species has no known viruses, or genetic diseases. Gastrointestinal issues can occur occasionally due to feeding, but is not of great concern. It is a closed aquaculture system, and the water comes straight in from the ground and into each tank, then straight back out again. Each tank is independent of one another so no disease-borne bacteria/viruses can be transmitted between tanks, if a disease were to break out.

Fig. 3.10 Sorting a range of marketable-sized fish into crates

The farmers use crane-like equipment to haul large volumes of African catfish from the enclosure. Fish which are within marketable-size are sorted into crates (Fig. 3.10), ready to bring to another part of the farm for processing. Some buyers/consumers prefer fish that are smaller, others prefer the fish of a larger size. Fish are often sold as fillets ready for cooking.

Fig. 3.11 Waste sediment is drawn out from the water

Fig. 3.12 Catfish outdoor enclosure

Water is filtered when it leaves the tanks (Fig. 3.11), and large particles including food debris and algae is removed before it moves into the outdoor enclosures where African catfish are farmed at a lower density (Fig. 3.12) and receive food which is controlled by a timer (Fig. 3.13). The effluent water runs through a constructed wetland system, which purifies the water before it is led to surface waters.

Fig. 3.13 Outdoor reared fish: Controlled Feeding

3.5. Carp Farm (Hortobágyi Halgazdaság Zrt)

The carp farm (Hortobágyi Halgazdaság) I visited is owned by a very large company which contains many systems. The farm consists of 6 units, and the pond areas span 3075 hectares in total. The pond is only 120cm in depth which is very shallow, but it is the average depth for this type of fish farmed in Hungary. If the water is shallower, the fish are reported to be less tasty because the fish are too close to the muddy sediment. The water enters the ponds through channels from the River Tisza which is one of the biggest rivers in Hungary. The water passes through the ponds, then through different channels to other fish farms, before returning to the River Tisza. The entire carp production cycle takes 3 years from propagation to marketable-sized fish. Fish are processed at a location not far from the farm. Fish is sold fresh or frozen depending on the consumer's choice.

Larvae is sourced from other locations independent from the fish farm. In 162 hectares of pond area, 300 tons of market-sized fish is produced per year (Fig. 3.14). The ponds are flooded in the Spring by rain and overflow from channels and streams. At the end of the first season, fish reach around 50-100g. At the end of the second season fish weigh in at around 400-600g (Summer). By the end of the third season (Autumn), fish have gained a significant amount of weight and are around 2.5kg and are harvested. It is normal at the end of the first season for the fish farmers to record a 90% loss. At the end of the second season a 50% is often seen, but by the end of the third season it plummets to a 10-20% loss. Loss of biomass/production is due to the fish not feeding for 2-3 weeks, therefore grain is given to supplement their natural diet.

Fig. 3.14 162 hectares of pond area producing 300 tons of fish per year

Fish feed on naturally occurring organisms like worms and larvae. Additional feed (grain) is provided so that the farmers can maximise production (Fig. 3.15). The boat has an opening at the bottom which allows the farmer to distribute the feed in a controlled manner (Fig 3.16). Around 8-10 tons of manure is distributed per hectare - it encourages flies and worms to appear and therefore seems to enhance the pond environment and the production of fish. No antibiotics are used. The farm appears to maintain a totally natural system. Everything that enters the farm must be verified so that it can be used in this 'bioproduction' system. The price of "biofish" and normal/non-biofish is the same, but in time the hope is that Hungarian consumers will favour naturally farmed fish bioproduced fish, over other more intensive methods of farming fish.

Fig. 3.15 Grain feed

Fig. 3.16 Boat used to distribute grain

3.6. Research experiments at HAKI

Fig. 3.17 Outdoor carp feeding experiment

Several experiments were being undertaken during my visit to HAKI with study sites close by to the institutes. Groups of carp were closely fed and watched over time - a researcher uses a boat to move to each enclosure so that the fish can be fed and survival and condition index can be monitored (Fig. 3.17). A water composition study was also being undertaken at an oxbow near to HAKI (Fig. 3.18). The oxbow takes the effluent water from the catfish farm to surface waters. The study was to monitor the water quality, and I was able to assist the researchers in a boat to collect data for this study.

Fig. 3.18 Oxbow. Water composition study site

4. TRIP TO NORWAY

4.1 Aquaculture in Norway

Fig. 4.1 Norway, showing the location of the research station (lower circle) and salmon farm (upper circle) Source: Welt-atlas

Aquaculture in Norway specialises in marine fish since it is surrounded by the North Sea and the Atlantic ocean (Fig. 4.1). Farming of Atlantic salmon is the most important activity, and accounts for more than 80% of the total Norwegian aquaculture production (FAO, 2017). Salmon are anadromous species, having a freshwater and saltwater phase in their life cycle. Salmon hatch as alevins, develop into parr (during which vertical ‘parr’ markings are visible). They then enter the smolt stage (salmon develop a silvery appearance and physiological adaptation to the marine environment). These life phases occur in onshore freshwater tanks. On-growing to market size takes place in offshore marine cages/open sea cages.

4.2 NOFIMA

NOFIMA has several research stations. I was based at a research station at Sunndalsøra where the NOFIMA Centre for Recirculating Aquaculture System is located. Research areas investigated at NOFIMA include breeding and genetics, fish heath, food safety and quality, and seafood processing. There are also x-ray facilities to view abnormalities in the formation of the spine in fish. Fish deformities can be caused by exposure to too much phosphorus and high water temperatures.

4.3 Salmon Hatchery

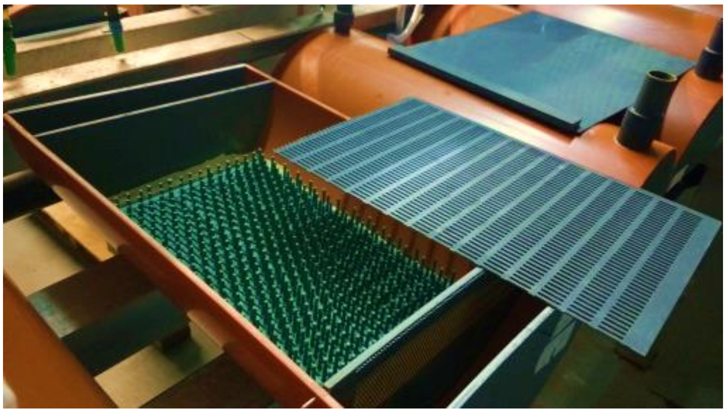

Fig. 4.2 Salmon hatchery tank with artificial gravel

The salmon hatchery tank consists of two parts: a green, structured, removable layer that mimics gravel, and a perforated tray which sits atop the gravel and offers both shelter and a means for water flow creating a riffle effect as you would find in natural river systems (Fig. 4.2). Salmon eggs are distributed in the gravel layer and then the perforated tray is positioned on top. Finally each individual tank is covered with a lid to offer protection from light and the open air, thus limiting spread of disease.

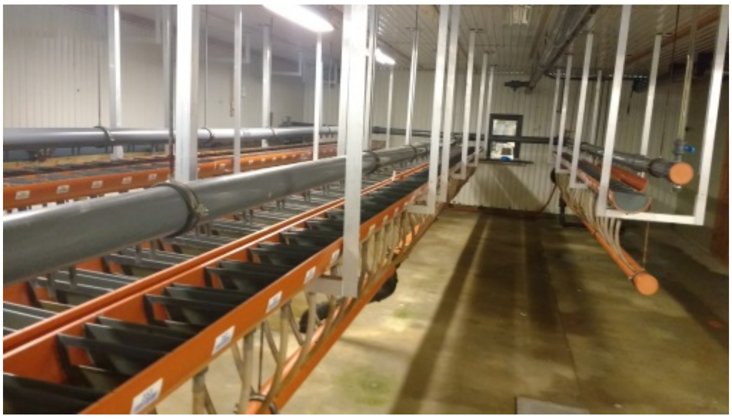

Fig. 4.3 Salmon hatchery tanks with pipes

Each hatchery tank is provided with its own water source via the large pipe running along the row of tanks (Fig. 4.3). Once the water passes through the layers (mentioned above), it passes through a pipe at the bottom of the tank and back out into the river.

Fig. 4.4 Salmon hatchery tank with own water supply

In this way water does not pass from one tank to another, thus the eggs in each tank are not exposed to any diseases, nor odour cues from any other tanks (Fig. 4.4). This system is used to investigate the effect of water quality and disease resistance on the eggs from different family groups, hence the interaction between genetics and the environment can be examined, and kinship studies are also possible with this experimental structure.

4.4 Juvenile salmon food trails

Fig. 4.5 Salmon feeding trials I

In the tanks used for feeding trials, water enters through the top large pipe running along above all the small individual enclosures (Fig. 4.5). Each enclosure receives water from the large pipe by opening the small red tap to fill the tank to the desired water level. The water after passing through each enclosure, passes through a pipe which extends from the enclosure into the ground. In this way, water does not pass between enclosures, thus studies on kinship, and water contamination are possible.

Fig. 4.6 Salmon feeding trials II

Juvenile salmon parr, family groups were held in separate tanks and were provided with food which differed from tank to tank (Fig. 4.6). This type of investigation enables food manufacturers to test which food is more favourable to juvenile salmon. The delivery of a measured volume of food is controlled by automated equipment which can be set by a timer. Food might differ in the amount of nutrients, protein, colour, size and shape.

Fig. 4.7 Kinship studies

Researchers manipulated juvenile salmon parr into sibling groups with isolated sibling groups fed a different type of food and then growth rate measured over time (Fig. 4.7). This useful information provides fish farmers with an understanding of growth rate, and food preference depending on the suitability of the type of food for particularly family strains.

4.5 Processing Fish

Fig. 4.8 Processing unit

A processing room contains the equipment needed to measure and identify fish (Fig. 4.8). In this room there is a weighing scale and measuring platform to record growth rate of fish. There is also a hand-held tool which allows the user to accurately insert a Passive Integrated Transponder (PIT) tag into the fish more accurately than using traditional methods (which previously involved making an incision in the fish and inserting the PIT tag by hand). This accurate technique promotes a higher welfare for the fish as well as lowering mortality. PIT tags are small capsules containing a barcode to help identify individual fish. A PIT tag reader is also connected to the weighing scales so that fish may be identified while being simultaneously weighed. This allows the scientists to collect different data at the same time and reduces the amount of time the fish is handled.

4.5 Recirculating Aquaculture System

Experiments are carried out on Atlantic salmon in Recirculating Aquaculture Systems (RAS) to understand the optimal conditions required to maximise growth rate and obtain good quality marketable salmon. RAS for Atlantic salmon farming is a relatively new area since the salmons' life history is complex, and their environmental requirements are very specific. Research is still needed to understand how to increase biomass and lower the incidence of mortality, while considering the welfare of the fish. I was impressed with the size of the RAS at NOFIMA (Fig. 4.9) and mostly how efficiently the researchers were monitoring the fish and maintaining the entire system.

Fig. 4.9 Re-circulating Aquaculture System (RAS), NOFIMA Norway

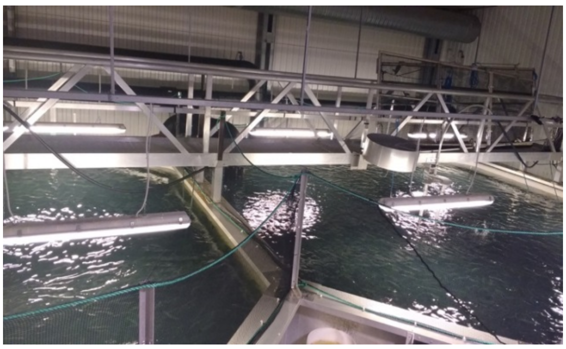

Fig. 4.10 Re-circulating tanks

The tanks of the recirculating system (Fig. 4.10) are much larger and deeper in comparison to the tanks used in the RAS in Hungary for catfish (compare with Fig. 3.3). The stocking density of Atlantic salmon is much lower, and they require much deeper waters, whereas catfish can survive in very shallow water and even droughts. The size of the tanks, and sheer volume of water, not to mention the temperature sensitivity and disease susceptibility of Atlantic salmon, are attributes that drive up the cost of farming Atlantic salmon.

4.6 Salmon fish farm (Lerøy Belsvik)

Fig. 4.11 High speed boat to Hitra

A high-speed boat was used to travel to Lerøy Belsvik (Fig. 4.11) to visit one of the biggest fish farms in the world. This was my first time on a boat going at such a high speed so I was both excited and nervous about the whole experience! The site has large living quarters for on-site staff who attend to the outdoor fish areas.

Fig. 4.12 Indoor salmon hatchery farm

The sheer size of the fish farm is quite breath-taking. There are so many areas for fish of different life stages and sizes and just when you think you've seen it all, you walk down a corridor to find another huge part of the fish farm. Most of the fish farm was in an enclosed environment and could only be viewed from platforms behind windows (Fig. 4.12). I assume much of this was to limit disease spread. What was so incredible was the way in which the farm was set up. A whole enclosed area would be dedicated to salmon at the juvenile stages. Juveniles would be sorted in order of their size. So I observed many different tanks dedicated for salmon of a specific size range. As mentioned before, the salmon life history is so complex. Since it spends its juvenile stages in freshwater, the indoor tank environment is very suitable, however salmon do go through a 'smoltification' stage during which they undergo physiological changes as preparation for life in the marine environment as adults. The smoltification process is often mediated by length of day and a gradual adaptation to salt water. Therefore, there are also dedicated areas within the indoor part of the fish farm that are solely for rearing salmon 'smolts', and light is regulated during this stage so that they may be fully prepared for the marine environment outdoor sea cages (I will talk about this later).

Fig. 4.13 biofilter tank, Hitra

My most interesting find at Hitra were the biofilters that are used to clean the recirculating water (Fig. 4.13). The biofilters used in Norway were of a different shape and size the biofilters I observed in Hungary (compare with Fig. 3.6), although I learnt that the surface area is what is of most importance – so that a larger amount of space is available to support and larger volume of bacteria that convert ammonia to less-toxic nitrate (Fig. 4.14).

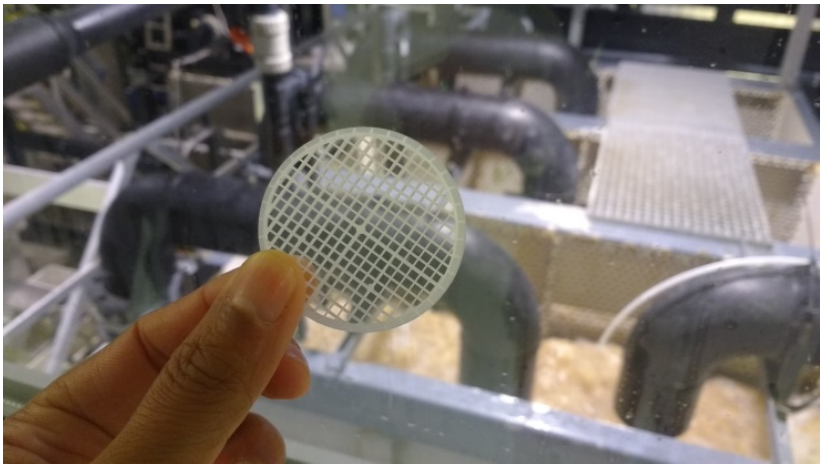

Fig. 4.14 Biofilter close up, Hitra

The biofilter is a key component of the filtration process of the RAS. Fish excrete ammonia (NH_3), which is toxic to the fish and is an environmental stressor – therefore it can reduce appetite and growth rate, and increase mortality rates. Naturally occurring bacteria oxidize the ammonia and convert it to Nitrite which is also toxic to fish, therefore further oxidization is necessary to remove the toxic form of nitrogen. Bacteria from the *Pseudomonas* spp. is cultivated on the surface area of the biofilters. The biofilters are designed to be compact units with as much surface area as possible so that they can hold large volumes of *pseudomonas* spp. These bacteria metabolize and oxidize the nitrite, and convert it to nitrate(NO_3), thus maintaining a clean and viable environment for the farmed fish.

The open sea cage at Lerøy Belsvik consists of a rigid circular structure which sits on the surface of the ocean (Fig. 4.15). This rigid structure holds a mesh cage which is submerged in the ocean, and contains the fish. Unlike a Recirculating Aquaculture System (RAS), the fish in the open sea cage are completely exposed to the ocean water flowing in and out of the cage, and this creates a natural environment for the fish. This renders the fish at high risk of contracting infections either viral, or parasitic (discussed later). Fish farmers can experience huge losses of fish due to disease, and this is one of the major problems of salmon aquaculture in the marine environment. Underwater technology is being created in order to detect sea lice infestations as early as possible so that parasite load can be determined and be controlled more efficiently.

The fish are fed, and vaccines are administered into the cage, so waste products and uneaten feed falls through the bottom of the cage onto the bottom of the ocean. This is clearly an environmental concern, so outdoor recirculating systems are being considered for the future of marine salmon fish farming, but we are still at the early stages of experimentation.

Fig. 4.15 Outdoor sea cage

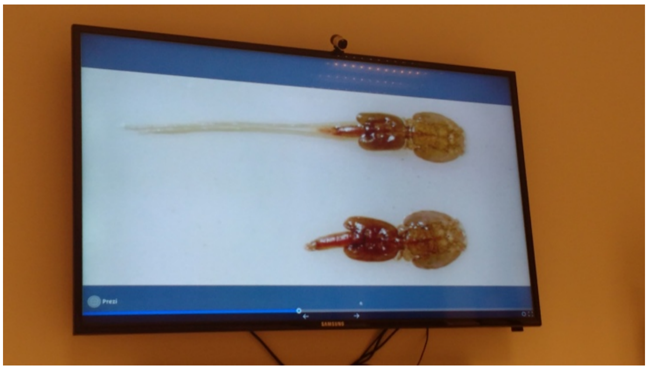

Fig. 4.16 Sea Lice

While I was at Lerøy Belsvik, I had the pleasure of attending a lecture about the evolution of fish farming techniques and technology. What interested me the most was the prevalence of disease and its management. Sea lice (*Caligus* spp.) is one of the major ectoparasites that fish farmers are most concerned about, particularly in open sea cages where fish are completely exposed to water from the ocean entering and leaving the cage constantly.

The females are significantly larger than the males (see top parasite in Fig. 4.16) The parasites attach themselves to salmon (the host), and the feeding of the parasites causes changes in mucus consistency and damage to the epithelium of the fish, which can result in blood loss. The sea lice detach from salmon when they enter the freshwater environment (when they migrate to their natal stream). They are also intolerant of warmer water temperatures, so fish farmers use a system to move salmon from open cages through a pipe filled with warmer water where the salmon are deloused, before returning to the sea cage (Fig. 4.17)

Fig. 4.17 Sea Lice warm water treatment

5. POTENTIAL AQUACULTURE COURSE DESIGN

5.1 Visit to Sparsholt College

I visited Sparsholt College to meet Adrian Love, a former recipient of the Farmers Club Education award, and course manager of the aquaculture course at Sparsholt. Adrian was able to talk to me about the course content, assessments and offsite placements undertaken with industries that the college has links with. I was also able to look around the college facilities and was very impressed with the Aquatic Research and Conservation Centre which houses catfish, carp and tilapia as well as ornamental varieties. I was also able to view the Salmonid Rearing and Trial Centre where fish feed trials are undertaken and students can conduct a variety of experiments for their dissertation. Sparsholt also has its own natural pond located just outside the labs and indoor aquaria. It really is fascinating how well equipped they are for running such a course and students are lucky to have these facilities on their doorstep!

During this trip to Sparsholt, I realised the vast amount of space and expertise that I would need to consider prior to potentially creating an aquaculture course at Writtle. It would take time to develop links with industries, acquire space and funding for aquaculture technology, and acquire experienced lecturers with sound knowledge of fish farming and techniques. None the less, it is a course that I feel could potentially attract many interested students since aquaculture is a fast expanding industry worldwide.

5.2 Aquaculture lectures at Writtle

On my return to Writtle, I was able to design a suite of aquaculture lectures incorporating a lot of what I learned during my trips to Hungary and Norway. The lectures were received by students very well and I found most students in the year opted to answer my aquaculture essay questions and exam questions. They would often quote the techniques used at HAKI and NOFIMA. Below are a sample of PowerPoint slides from one of my lectures.

5.3 Aquaculture lecture samples

Hungary and Norway

- Hungary, Szarvas
- Research Institute for Fisheries and Aquaculture (HAKI)
- Freshwater fish (river fish)
- Research station, Fish farms on site (but visited an independent one too)
- Fish processing

- Norway, Sunndalsøra
- Norwegian Institute of Food, Fisheries, and Aquaculture research (Nofima)
- Marine/diadromous fish (saltwater fish)
- Research station, no fish farms on site (travelled to Hitra to visit biggest fish farm in Europe)
- New camera technology

Research Institute for Fisheries and Aquaculture (HAKI)

African catfish
(*Clarias gariepinus*)

- Catfish
- Carp
- Freshwater
- Easier to maintain stocks
- Cheap to run farm
- Low incidence of disease and spread
- Usually import outside Europe
- Train breeders to set up their own fish farm

Common carp
(*Cyprinus carpio*)

Norwegian Institute of Food, Fisheries, and Aquaculture research (Nofima)

Atlantic salmon
(*Salmo salar*)

Parr

Alevins

- Salmon
- Cod
- Diadromous/Marine
- Expensive to maintain stocks
- High risk of disease, expensive to treat
- Import salmon worldwide
- Sophisticated technology

Salmon experiments: food

Salmon parr (experiments with different feeds)

6. CONCLUSION

The Farmers Club Educators Award enabled me to travel to HAKI in Hungary and NOFIMA in Norway to speak to the experts in the field of aquaculture learn about new research and technology emerging in the field. The grant enabled me to visit a catfish and carp farm in Hungary, and a salmon farm in Norway, therefore I was able to observe the difference between fish farming in the freshwater and marine environment in two different countries. The grant also allowed me to visit Sparsholt College where an Aquaculture course is being run, thus I have been able to look at the facilities and course content, and explore the potential development of an aquaculture course at Writtle University College.

With regards to my three project objectives, I have fulfilled the first two. However, the third objective; my idea to design a new Aquaculture course at Writtle, would be something that would require a huge amount of thought and funding to set up (see pg. 28 for more of my thoughts about this). This is more of a long-term goal. None-the-less, as short-term goal I have been and will continue to educate my students and the staff at Writtle on the topic of aquaculture. Therefore, I have partially fulfilled objective three, by introducing aquaculture to a variety of modules on the Animal Science and Animal Management degree programmes (see pg. 28-30 for samples of lecture slides). I was also able to deliver a lecture about my trip to staff in my department, and this was received very well, with enthusiasm and numerous questions following my talk. I hope to instil the passion for fish farming in the lecturers I work with so that even on modules that I do not teach, they will continue to teach aquaculture as part of their own module specifications. After all, as educators of animal science and management programmes it is in our hands to enlighten people about the fascinating and alternative methods of producing fish worldwide for our growing population, and we need to develop people's knowledge and enthusiasm to become experts to support the fast expanding industry of aquaculture.

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