BVA British Veterinary Association | Policy statement

BVA policy position on UK sustainable finfish aquaculture

Introduction

As the world population continues to grow, global consumption of animal-derived food is rapidly increasing[1]. This provides challenges in protecting the welfare of all animals involved and minimising the impacts of our food production on the environment, climate change, habitat loss and waste. In response to this challenge, BVA launched its position on UK sustainable animal agriculture in 2019. This position now seeks to provide a similar vision for finfish aquaculture in the UK.

With wild stocks of many species declining and capture fisheries around the world at their limit, aquaculture plays a significant role in meeting growing demands for fish protein to feed the global population. It represents a major part of meeting the United Nations sustainable development goals. In 1975 just 10% of global fish consumption came from aquaculture, but there has since been a major cultural shift away from wild caught fish. Aquaculture now produces 50% of the fish consumed, and this is predicted to increase to 70% by 2050. Fish by-products are also used to feed farmed animals, including pigs and poultry, though it is most often an ingredient in the diets of other farmed fish species[2].

Despite this rapid growth, estimates suggest there will be a 7 million tonne deficit in fish protein production by 2050. To meet this demand, many nations will need to develop robust aquaculture industries, and it is important this happens sustainably. There will also need to be a cultural shift, as many of those who accept fisheries as a means of obtaining food are slower to accept aquaculture as a concept. It will also be important to promote the benefits of sustainable consumption properly valuing quality animal-derived products, as well as the concept of "less and better" to help ensure the demand itself is more sustainable.

The 2022 UK Government Food Strategy recognised seafood as "another potentially lower-carbon and healthy source of protein which can grow sustainably to fulfil its potential within the food sector". It committed to invest £100 million in the UK Seafood Fund, and noted that innovations in aquaculture will "help us boost production in the seafood sector without adding to pressure on fish stocks"[3].

There have been questions raised as to whether aquaculture can ever truly be considered sustainable. This is a complex question, and as in any food production sector, on land or in water, there are many wide-reaching environmental, ethical and economic considerations to take into account. There are also many knowledge gaps, and aquaculture covers a wide array of sub-sectors focused on production of hugely varied taxa in similarly diverse production systems. Therefore, this position focuses on making recommendations for improvement, with the aspiration of encouraging the sector to become more sustainable whilst research into key challenges is undertaken.

Definitions

Aquaculture means "the farming of aquatic organisms including fish, molluscs, crustaceans, and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies

[1] Food and Agriculture Organisation of the United Nations (FAO) 2023. Livestock and the environment. www.fao.org/livestock-environment/en/ Accessed March 2023
[2] Miles, R.D., and Chapman, F.A. (2021) FA122: The Benefits of Fish Meal in Aquaculture Diets, *Fisheries and Aquatic Sciences Department, UF/IFAS Extension*. Original publication date November 2005. Reviewed March 2021 https://edis.ifas.ufl.edu/publication/fa122 Accessed March 2023
[3] UK Government (2022) Government food strategy www.gov.uk/government/publications/government-food-strategy/government-food-strategy Accessed March 2023

individual or corporate ownership of the stock being cultivated, the planning, development and operation of aquaculture systems, sites, facilities and practices, and the production and transport"[4].

Sustainable aquaculture can be defined as aquaculture carried out in a way that meets the needs of the present without compromising the ability to meet the needs of the future[5]. Sustainable aquaculture should be undertaken in a way that is environmentally, ethically, and economically acceptable for consumers, producers and wider society. As part of this, animal health and welfare should not be unnecessarily compromised to address human need and in order to be considered sustainable, aquaculture systems must work towards the positive health and welfare of all fish raised within them.

UK aquaculture

Aquaculture is one of the UK's key strategic food production sectors, helping to underpin sustainable economic growth, both in rural and coastal communities and in the wider economy. The UK is the 8th largest producer of finfish from aquaculture globally, and worth an estimated £1.4billion, contributing significantly to the UK economy. It is particularly important in Scotland, providing essential jobs in remote and rural communities. A study showed that the Scottish aquaculture sector supported 11,700 jobs, generated £885 million gross value added, and paid £94.1 million in taxes in 2018[6].The sector is expected to grow faster than the UK economy over the next 10 years[7]. Scottish salmon farming, specifically Atlantic salmon (*Salmo salar),* dominates UK aquaculture production, representing 95% of the industry by value and 90% by volume. In 2021, 51.1 million smolts (young fish, after the parr stage) were transferred to sea, producing 205,393 tonnes of salmon in total[8]. Although 30% of the fish eaten in UK is farmed salmon, nearly half of salmon produced in the UK is exported. The largest percentage goes to France, and a significant proportion is flown across the Atlantic.

The salmon aquaculture industry is relatively new, the first output being Unilever in 1970. The sector has since grown very rapidly but has recently plateaued as site development became a limiting factor. There has also been a consolidation of the companies involved, with just seven companies now responsible for the c.200 salmon sea farms in Scotland, including four international companies. Despite the huge scale of the sector, the total pen area measures just 168ha, representing an area smaller than Edinburgh Airport. This impacts an estimated 120 to 125 square miles of seabed. To compare, 24,000 square miles of Scotland is designated as agricultural area[9].

Trout is the next most significant UK aquaculture output, with around 17,000 tonnes of rainbow trout (*Onchorynchus mykiss*) being produced each year[10]. There are around 290 registered trout farms across the UK, most of which are small to medium sized businesses and often owner operated, and the sector employs approximately 1,050 people. The majority of farms and hatcheries are based in England, and trade is focussed on the domestic market. The UK does not have sufficient hatcheries to supply the market, so imports large number of eggs from overseas, monitored by the agencies of UK and devolved administrations to control disease risk.

The trout sector started around the 1870s, initially driven by the need to restock fisheries for fishing clubs. Rainbow trout was first introduced to the UK from the USA around 1885, but serious production began in the 1950's with the establishment of Wansford Fish Farm by a Danish entrepreneur. Large companies and hatcheries began to appear in the 1970's. The main species farmed in the UK are rainbow trout and brown trout (S*almo trutta*).

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[4] Food and Agriculture Organisation of the United Nations (2023). Fisheries and Aquaculture https://www.fao.org/fishery/en/aquaculture Accessed March 2023
[5] This definition is based on that used in the BVA Position on UK sustainable animal agriculture
[6] Biggar Economics (2020) Estimation of the Wider Economic impacts of the Aquaculture Sector in Scotland. A report to Marine Scotland. www.gov.scot/publications/estimation-wider-economic-impacts-aquaculture-sector-scotland/pages/1/ Accessed 21/03/23
[7] Department for International Trade (2019) Presentation on High Potential Opportunity Sustainable Aquaculture. www.dorsetlep.co.uk/userfiles/files/IID/Brochures/HPO%20Aquaculture%20Proposition%20FINAL%20Dec%202020.pdf Accessed March 2023
[8] Scottish Government (2021) Scottish Fish Farm Production Survey 2021 www.gov.scot/publications/scottish-fish-farm-production-survey-2021/pages/2/ Accessed March 2023
[9] Brand, A. (2023) Land use and rural policy: subject profile https://digitalpublications.parliament.scot/ResearchBriefings/Report/2021/8/19/fd352596-863e-4e0f-9a5e-84af26856d74-1 Accessed March 2023
[10] British Trout Association (2019) Trout farming in the UK and its history https://britishtrout.co.uk/about-trout/trout-farming/ Accessed March 2023

Other aquatic species farmed in the UK in much smaller numbers include Arctic char (*Salvelinus alpinus*), carp (*Cyprinus spp.*), sea bream (*Pagellus centrodontus*), tilapia (*Oreochromis spp.*), Pacific oysters (*Magallana gigas*) and mussels (mainly blue mussels, *Mytilus edulis*). Cleaner fish, such as ballan wrasse (Labrus bergylta) and lumpfish (Cyclopterus lumpus), are also farmed to be used within other aquaculture systems.

Globally there has been a trend for growth in the freshwater species sector, and especially significant growth and interest globally in the faming of tilapia. These trends have not yet been seen in the UK, with the trout industry appearing to have remained static, and tilapia not currently being a significant part of the UK market.

Key concerns

The aquaculture industry attracts much public attention, with many concerns being regularly highlighted. According to the RSPCA[11], some of the most commonly raised concerns from the public are in relation to:

- mortality levels on farms
- shooting of seals to protect salmon
- inadequate fish welfare
- sea lice levels and treatments
- farmed fish as potential incubators of disease
- use of antibiotics
- damage to the natural environment, including from sourcing fish feed

This position will discuss each of these issues and make recommendations where relevant.

Position focus

All forms of aquaculture are important for feeding the growing population, however there is a huge variety in the requirements and issues associated with each species. Since salmon and trout farming are the most significant sectors in the UK aquaculture industry, this position focuses on finfish. Most of the evidence and information included refers to these two types of fish, but many of the recommendations should also be applied to other finfish species being farmed in the UK. Many of the principles discussed will be relevant to other species farmed in aquaculture systems around the world, including cephalopods and decapods, but there will also be key differences which are not covered in this position. The position will be reviewed over time and updated as the UK aquaculture industry evolves.

We are aware that questions exist around the suitability of species being farmed. One concern is that salmon are migratory species, and this behaviour is prevented in captivity. However, there is currently a lack of understanding of why salmon migrate, beyond the physiological need to move into a saltwater environment, and whether these needs could be met in captivity, assuming that fish are slaughtered before they experience the motivation to return to freshwater (eg to breed). Given the lack of clear evidence, this position takes a pragmatic approach, focusing on recommendations for improvement rather than questioning the choice of species.

This position seeks to discuss the main sustainability challenges facing the aquaculture sector in the UK and make recommendations for how it may develop more sustainably. The role of this position is not to defend all aspects of current practice, and it will make recommendations for improvements where they are needed.

Recommendations

Recommendation 1: Sustainable aquaculture should be undertaken in a way that is environmentally, ethically, and economically acceptable for consumers, producers, and wider society.

[11] Pers. comm. - raised during a BVA Sustainable Aquaculture Working Group meeting

Recommendation 2: BVA should monitor any new research or evidence of new and emerging aquaculture systems in the UK, and consider developing additional positions on sustainable aquaculture for those species as appropriate.

Animal health and welfare as a key sustainability objective

In order to be considered sustainable, aquaculture systems must work towards the positive health and welfare of all farmed animals raised within them. To have a 'good life', and at least a 'life worth living', animals must have the opportunity to have positive experiences. Over time, positive experiences should outweigh negative experiences. This should encompass the whole of an animal's life. Animal health and welfare should not be unnecessarily compromised to address human want or need.

There has been growing research and evidence to show that fish feel pain, though different species have varying responses, so pain indicators have to be quantified on a species by species basis[12]. For example, studies showed koi carp to move away from noxious stimuli and their response decrease when lightly anaesthetised[13], rainbow trout learn to avoid an area where an electric shock is given[14], and Atlantic salmon decreased swimming and suspended feeding after experiencing abdominal peritonitis due to vaccination[15]. Their status as sentient beings was enshrined into law in the Animal Welfare (Sentience) Act 2022[16], along with all other vertebrates. Industry fully accepts that fish are sentient beings, with most fish farm workers receiving training in fish pain, welfare, and husbandry.

Despite this progress, there remain improvements to be made in public understanding of fish sentience[17]. Fish are also not included in the definition of an animal in older pieces of legislation, including the Veterinary Surgeons Act which defines "animals" as including birds and reptiles, but does not include fish. We support the definition used in the Veterinary Medicines Regulations 2013 where "animal" means all animals other than man and includes birds, reptiles, fish, molluscs, crustacea and bees. In the Animal Welfare Act 2006 "animal" means a vertebrate other than man[18]. Defining the term appropriately in the Veterinary Surgeons Act would help to protect the welfare of farmed fish and ensure the relationship between vets and fish is not open to interpretation.

To be considered sustainable, aquaculture systems must provide for the five animal welfare needs, positive health outcomes and adhere to World Organisation for Animal Health (WOAH) standards for animal health and welfare. Systems should aspire to offer stimulating environments to allow for the performance of highly motivated behaviours; opportunities for positive welfare outcomes, such as comfort, pleasure, interest and confidence; and excellent health outcomes. It is challenging to balance the health, welfare and sustainability aspects of keeping fish, and there are still major evidence gaps in relation to factors which positively or negatively influence fish welfare, which are discussed in the welfare outcomes section below. Further research is needed to support all those caring for fish.

As well as the moral imperative to care for the farmed fish, poor fish health and welfare can reduce growth rates, require more expensive interventions (eg medicines), and make it difficult to comply with legal requirements. This impacts on the environmental sustainability of the sector, including through increased waste and medicines, and reduces the profitability of the business. It is therefore in everyone's interests to strive for the best fish health and welfare in the aquaculture sector.

An overview of some of the major health and welfare issues affecting farmed fish is included below.

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[12] Sneddon, L. U., Elwood, R. W., Adamo, S. A., & Leach, M. C. (2014) Defining and assessing animal pain. *Animal behaviour*, 97, 201-212.
[13] Stockman, J., Weber, E. S. P., III, Kass, P. H., Pascoe, P. J., & Paul-Murphy, J. (2013) Physiologic and biochemical measurements and response to noxious stimulation at various concentrations of MS-222 in Koi (*Cyprinus carpio*). *Veterinary Anaesthesia and Analgesia*, 40, 35e47
[14] Dunlop, R., Millsopp, S., & Laming, P. (2006) Avoidance learning in goldfish (Carassius auratus) and trout (Oncorhynchus mykiss) and implications for pain perception. *Applied Animal Behaviour Science*, 97, 255e271
[15] Bjørge, M. H., Nordgreen, J., Janczak, A. M., Poppe, T., Ranheim, B., & Horsberg, T. E. (2011). Behavioural changes following intraperitoneal vaccination in Atlantic salmon (*Salmo salar*). *Applied Animal Behaviour Science*, 133, 127e135.
[16] UK Government (2022) Animal Welfare (Sentience) Act 2022 https://www.legislation.gov.uk/ukpga/2022/22/enacted Accessed March 2023
[17] In 2022, the RSPCA Animal Kindness Index (figure 20) showed that only 52% of respondents thought that carp were sentient, less than lobsters and just more than bees. https://www.rspca.org.uk/whatwedo/latest/kindnessindex/report#nation Accessed March 2023
[18] British Veterinary Association (2021) BVA and BVNA response to RCVS Legislative Reform consultation www.bva.co.uk/media/4038/response-to-rcvs-legislative-reform-consultation-final-11-march-2021.pdf Accessed March 2023

Mortality rates

One major challenge is the mortality rate on fish farms. High levels will have serious impacts on the ethical, economic and environmental sustainability of fish farms, so it is vital that they are addressed.

Fish have a very different reproductive strategy to mammals and birds, usually producing thousands of eggs at a time rather than a few offspring a year or single egg a day. This strategy is designed to cope with high mortality rates at all stages of the natural lifecycle, as a low percentage of wild fish survive to adulthood. Only a very small proportion survive to reproduce, with most of the mortalities occurring in the early life stages.

Mortality rates for more developed fish are of greatest concern to the industry. Salmon Scotland publishes monthly stock mortality rates, and in 2020 reported average monthly losses of 1.3% of post-smolt farmed salmon, compounding to 14.5% over the year. The Scottish salmon farming sector is the only UK farming sector to publish monthly stock mortality rates[19]. Gathering meaningful data is challenging for the trout sector due to its small size and high levels of variation between farms, but mortality rates are thought to be low once fish have developed beyond the early stages. Mortality rates may be higher if there is a significant event, eg a disease outbreak, oxygen depletion event, or jellyfish bloom.

The aquaculture sector is constantly working to reduce mortality rates, but more efforts are urgently needed to improve the survival rates of farmed fish. Identifying and mitigating existing risks and staying aware of emerging threats will be a vital part of this. This position discusses some of the major risks to fish health and welfare which directly contribute to mortality.

Stress and handling

Stress is an important factor in managing fish health and welfare, as it reduces resilience to disease and other threats. If an infection is present in the background and a stressful event occurs, it may lead to a sudden increase in mortality shortly afterwards.

Handling fish can cause significant stress, so must only be conducted when necessary and well managed to minimise harm. Where possible handling is avoided, but it is sometimes necessary and important, eg for vaccinations, controlling size variation, health checks and treatments. In these situations, stress should be controlled as much as possible, with measures such as limiting the number of fish in nets, corralling them slowly, and monitoring oxygen levels and fish behaviour.

Automated processes are becoming more common, including for vaccinating fish. These can remove some of the operator errors which can cause stress and can also speed up processes. For example, in some trout farms, a fish pump and grading machine transfers fish into graded tanks in less than one minute, with the impacts of stress noticeably reduced.

It can be very difficult to capture individual fish, especially in large systems. Capturing an individual may require crowding and handling of a large proportions of the population, therefore, treating or euthanising an individual fish can often only be achieved at the expense of stress to a large number of fish. Innovative methods or technology to identify and capture individuals with poor health and welfare without causing stress to others would be hugely beneficial.

Gills, skin, and fins

The health of fish gills is important to consider, as they are highly adapted organs and are involved in a number of critical functions such as gas exchange, osmoregulation, acid-base balance, excretion of nitrogenous wastes and immune function. However, they are easily damaged, which can have a significant impact on fish health and welfare. Gill health impacts the needs of fish in relation to water chemistry, especially in terms of oxygen and carbon dioxide concentrations. The efficacy of treatments used to control a range of diseases will be impacted by gill health, with some treatments having a negative effect if the gills are compromised, eg hydrogen peroxide treatments when fish have been exposed to Harmful Algal Blooms (HAB). Handling fish with compromised gills can also result in significant mortalities.

[19] Salmon Scotland (2023) Mortality rates in Scottish salmon farming www.salmonscotland.co.uk/facts/fish-health-welfare/mortality-rates-in-scottish-salmon-farming Accessed March 2023

It is important to pay attention to gill condition and manage the needs of fish accordingly. A number of factors can affect gill health. Amoebic gill disease (AGD) is a significant challenge, especially for any fish transferred into the sea in autumn – see section on disease below. Thermal treatments, which can be an effective treatment for removing sea lice, can also be damaging to gills and the integument, especially if they are overused. There are currently no specific controls on their use, and unlike medicinal treatments, they do not require veterinary involvement. In practise, veterinary professionals are usually involved in decisions regarding these treatments, but as they have the ability to cause harm, they should always be managed as part of a welfare assessment structure, with veterinary advice. Gills can heal rapidly, and may recover if fish are moved into a less challenging environment, for example from one marine farm to another with an absence or lower numbers of harmful environmental organisms, and this may form the basis of gill health management plans.

Fish skin has living cells and a mucous layer rather than a keratinised epidermis, and this provides a barrier to the environment, infections, and pathogens. Alongside the gills, skin plays an important role in osmoregulation, allowing fish to maintain the careful balance of salts and water within their cells compared with the external environment. Any disruption to this delicate layer due to disease, handling or trauma can result in significant health and welfare issues.

Fins are important for movement and many behaviours, and contain blood vessels, nerves and probably nociceptors. The impacts depend on age and level of damage, but can be significant. Studies have found evidence that damage to the fin leads to adverse behaviour, indicating that fin erosion contributes to negative welfare[20]. Damage to the fins can also lead to health problems through increased susceptibility to disease[21], reducing production performance and welfare[22]. Damage can be from many sources, including inter-fish aggression, handling, predators, and feed withdrawal which results in biting.

Disease and biosecurity

Management of disease and parasites is vital for maintaining fish health, and prevention is always preferred over the need for treatment.

Many of the tools used in terrestrial farming to maintain biosecurity cannot be applied in an aquatic environment, so although there have been lessons to share, the sector has needed to develop its own specific prevention methods. Communication and awareness of risks in an area is important, since the flow of water means diseases and parasites could spread from one farm to another.

The most significant bacterial conditions affecting fish include ulcerative skin diseases and septicaemias. The main challenges for rainbow trout in the UK are enteric redmouth (*Yersinia ruckeri)*, proliferative kidney disease (PKD) and *Flavobacteria psychrophilum*. For salmon, the most common pathogens involved include *Aeromonas salmonicida*, *Pasteurella skyensis*, *Listonella/Vibrio anguillarum*, *Vibrio salmonicida* and *Moritella viscosa*. There is no evidence of diseases affecting farmed salmonids being zoonotic, and many can be managed or vaccinated against.

In the Scottish salmon industry, there is currently a good level of communication between companies working in each area. A benefit of big businesses is also that they can make a significant impact through investment, and they have largely been able to consolidate farms geographically. All farms in one sea loch are usually owned by the same company, with several having swapped farms in order to achieve this. This helps to synchronise production cycles, and allows for a more holistic approach to disease challenges in the area, making disease control more manageable than in the early years of the sector's development.

Disease Management Areas have been established in Scotland to create separation distances around active farms, taking into account tidal excursions and other epidemiological risk factors. Farms with overlapping separation distances will usually be within the same disease management area. All

[20] Noble C, Jones HAC, Damsgård B, Flood MJ, Roque, A., Sæther, B.S. and Cottee, S.Y. (2012) Injuries and deformities in fish: their potential impacts upon aquacultural production and welfare. *Fish Physiol Biochem* 38: 61−83
[21] Turnbull JF, Richards RH and Robertson DA (1996) Gross, histological and scanning electron microscopic appearance of dorsal fin rot in farmed Atlantic salmon, *Salmo salar L., parr*. *Journal of Fish Diseases* 19: 415−427
[22] Stien, L.H., Bracke, M.B., Folkedal, O., Nilsson, J., Oppedal, F., Torgersen, T., Kittilsen, S., Midtlyng, P.J., Vindas, M.A., Øverli, Ø. and Kristiansen, T.S. (2013) Salmon Welfare Index Model (SWIM 1.0): a semantic model for overall welfare assessment of caged Atlantic salmon: review of the selected welfare indicators and model presentation. *Reviews in Aquaculture* 5: 33−57

sites in the management area will follow the same stocking strategy to minimise the impact of disease, with synchronised stocking and harvesting. Fish farmers are encouraged to carefully consider management areas before stocking a site, and to consider not re-stocking sites if this would create a "fire break", splitting one of the larger disease management areas into two smaller areas. New sites which would bridge two existing areas together are avoided. There have been huge investments and advances made in area management, and this has been highly effective at improving health management. As our understanding of water flow and dynamics has improved, this could be reviewed and further improved, potentially helping with additional welfare issues, eg the control of sea lice.

Parasites

While endoparasites do not appear to be a significant health risk in UK finfish farming, there are many ectoparasites which affect salmon, trout and some cleaner fish. There are also concerns that the build-up of parasites on farms increases the risks of wild populations being negatively affected by them, so this is a key welfare and sustainability issue for the industry.

Sea water parasites

Sea lice (*Lepeophtheirus salmonis* and *Caligus elongatus*) pose a significant health threat in sea-based aquaculture systems, causing extensive skin damage, stress and increasing susceptibility to disease. Lice would naturally be present, so fish can cope with a few and do so in the wild, but on farms the number of lice can build up to harmful levels and spread quickly. The damage caused comes at significant cost to industry, so there is a financial incentive to control sea lice as well as the ethical imperative to protect welfare. Regulations are in place, with the Fish Farming Businesses (Reporting) (Scotland) Order 2020 requiring Businesses in Scotland that farm fish (other than in freshwater sites) to report the average number of adult female sea lice (*L. salmonis*) counted per fish per site each week to Scottish Ministers. Sites will be monitored closely when reported averages reach 2 or above, and any site with an average of 6 or more will be required to take immediate action[23]. Since October 2021, the Scottish Environment Protection Agency (SEPA) have been managing wild fish and farmed fish interaction in relation to sea lice, on behalf of Scottish Government. There are also international obligations for businesses to consider.

How sea lice are managed and treated will be a significant sustainability issue going forwards. There is a limited choice of medicinal therapy available, and there are concerns regarding their potential impact on the natural environment (see section on “Water pollution, effluent, and medicines in the environment” for more information). Emamectin as in-feed medication is sometimes used to target juvenile lice. Historically bath treatments have been used, including deltamethrin, azamethiphos and hydrogen peroxide. However, the development of resistance and the resulting reduction in efficacy in some compounds has led to a decline in reliance on medicinal treatments, and the emergence of non-medicinal lice control options. Although vital for protecting the environment, regulations can sometimes complicate treatments, as controls on discharge levels may mean farmers can only treat one pen on a farm at a time. This results in higher volumes of parasiticide use, as lice travel between pens when they are treated in succession instead of simultaneously. Expert vets working in the sector believe that medicinal treatments would be more effective if whole farms could be treated simultaneously. Thermal and mechanical treatments can also be successful, but come with drawbacks, for example, some can strip the protective mucus off fish skin.

In the past decade, there has been a very significant increase in the number of cleaner fish, species such as wrasse and lumpfish which feed on the parasites, being introduced for sea lice control. This can be very successful, but as the cleaner fish have different needs to the farmed salmonids, their welfare needs must be considered. There has been an increase in the understanding of and interest in cleaner fish welfare needs, and wrasse fishery regulations have now become mandatory. Where they are sourced from is also important. Wild wrasse continue to be caught to be used in aquaculture systems, as they are often more effective at sea lice control than farmed wrasse. They are captured by approved individuals during permitted periods, using specially modified pots which ensure only the right size and species are retained. These fish are cared for in line with the RSPCA standards, and humanely harvested at the end. Annual consumption of wrasse is estimated at 40 tonnes for salmon

[23] Scottish Government (2021), Fish Health Inspectorate: sea lice information. Accessed 07/02/23 https://www.gov.scot/publications/fish-health-inspectorate-sea-lice-information/

farms, compared with 3,454 tonnes by seals and 400 tonnes by otters[24]. Further research is being conducted into wild wrasse fisheries to ensure they are sustainable[25].

A combination of methods may be needed to treat an outbreak of sea lice. Integrated sea lice-management can include: a fallow period to break lice lifecycle, lice shields to prevent early settlement, in-feed medication to target juvenile lice, bath treatment to target mobile lice on small salmon, cleaner fish to target adult lice, physical treatments to target mobile lice on larger fish, and in-feed or bath treatment to target seasonal *Caligus*.

Treating and managing sea lice is an urgent and important issue for the aquaculture industry. More research into treatment options is needed, and if cleaner fish continue to be used then further research into their welfare needs will also be required. Research into potential preventative methods is also needed. Work in Norway has shown that moving farms offshore, away from other farms and/or into deeper water can potentially help to manage sea lice and reduce infection pressures. However, this brings rougher conditions and other challenges to consider, such as the technology and pens needed to withstand the conditions. Genetic solutions are also being implemented, as some studies have shown resistance to the lice is heritable, meaning it is possible to selectively breed for this trait.

Vets in the sector are concerned about the unintended consequences of regulations designed to limit sea lice numbers on farmed fish. These will sometimes require keepers to treat fish with intercurrent health issues, which might be exacerbated by the sea lice treatment. This is especially concerning if the treatment is ultimately ineffective. As advocates for animal health and welfare, it would be useful for veterinary professionals to continue to play a key role in the development of novel treatments and interventions, and in fish health or medicines laws and policies. Vets can help to ensure these developments do no harm, and where relevant, that appropriate controls are in place. While enforcement of sea lice management policy in relation to fish health sits is the responsibility of Scottish Government's Fish Health Inspectorate, a new risk-based framework is being developed by SEPA, with the aim of improving management sea lice interactions between farmed and wild fish.

Another significant challenge is Amoebic gill disease (AGD), which is caused by *Neoparamoeba* parasites. AGD leads to plaque-like lesions on the gill filaments, which can affect their functions including respiration and the removal of metabolic waste, plus damage to gill tissue frequently causes haemorrhage. Whilst the main cause is *(Neo)Paramoeba perurans,* it rarely occurs alone, and is commonly seen as complex gill disease with environmental factors and a range of other pathogens including *Branchiomonas cisticola*, *Desmozoon lepeophtherii* and the salmon gill pox virus. Severe cases of gill disease may result in significant mortalities of up to 50%, with cleaner fish also impacted.

AGD is a seasonal disease related to water temperature, being most challenging in autumn and early winter. Amoebae may proliferate following environmental change, so it is possible that climate change will result in increased risks from AGD. Research is being undertaken to look at how risk of disease is related to environmental factors, including water temperature and presence of sediment under the pens.

There are no medicines authorised specifically for use against AGD, so treatment generally involves freshwater or hydrogen peroxide baths. Gill disease may be intercurrent with other health threats, especially lice infestation and viral cardiac myopathies, which can make control and treatment especially challenging.

To monitor and diagnose issues with parasites, farmers take a sample of fish from pens on a weekly basis, anesthetise them, count the number of lice present, score the gills, score for AGD, and take gill swabs. This is a stressful event for the fish, so diagnostic tools which require less handling would be beneficial in the management and treatment of parasites.

[24] Based on Marine Scotland 2018 figures
[25] Scottish Salmon Producers Organisation (SSPO) are partnering with Marine Scotland on a PHD study into the sustainability of wild wrasse fisheries

Freshwater parasites

In freshwater, a wide range of protozoan and other parasites affect gills, skin and fins, causing irritation and general morbidity. One of the most significant challenges parasites cause for rainbow trout is PKD, which was once a huge constraint on the industry, though the worst impacts can now be reduced through stock management. External protozoan parasites are diagnosed via wet scrapes direct to a microscope slide, though fish jumping and rolling, called flashing, is also a sign of itchiness and likely infection.

Although not technically a parasite, the mould-like *Saprolegnia* species are the most significant health problem in freshwater species, affecting maturing broodstock, their eggs, alevin and smolts. Although authorised treatments are available, they are not always effective, so control is usually maintained through good hygiene, water management and careful husbandry measures. For salmon, transferring fish to sea water can be helpful, but this is not always possible if they are not at the correct physiological status. Saltwater bathing, at lower concentrations than seawater, may also be helpful.

Medicines and treatments

Medicinal treatments are not widely available for use on fish, as the relatively small market appears unattractive to many pharmaceutical companies. The use of medicines in aquaculture is also challenging due to the aquatic setting and there are concerns regarding their potential impact on the natural environment (see section on “Water pollution, effluent, and medicines in the environment” for more information).

Antibiotics are important medicines when treating any animal affected by bacterial pathogens, but they must be used responsibly to prevent resistance developing. The most commonly prescribed antibiotics in aquaculture are *oxytetracycline* and *florfenicol*. These are usually added to feed, though some injections are used on high value individuals. Bath treatment for small numbers in contained systems are also possible, but rarely used.

There is a misconception amongst some members of the public that farmed fish are ‘full’ of antibiotics, which may be due to historic usage levels. Antibiotics were used much more frequently in the 1980s, when a lack of vaccines meant they were required more often, but their use has since declined dramatically and is now much lower than in most terrestrial farming systems. The latest Responsible use of Medicines in Agriculture Alliance (RUMA) targets taskforce report showed that over 90% of freshwater and marine salmon farms were not using any antibiotics, and no critically important antibiotics have been used for several years[26]. Similarly the report shows that usage of antibacterials has fallen in the trout sector and is well within the sector target.

Many of the medicines licensed for fish are specifically for salmon, so have to be used under the cascade for trout. This means longer withdrawal periods, effectively limiting them for use on smaller fish only. The trout sector currently relies on the use of oxolinic acid, a critically important antibiotic, for treating diseases such as furunculosis and enteric redmouth. Usage levels are low and for targeted treatments only, but due to concerns around resistance, it is now a restricted medicine. Resistance is so far thought to be restricted to a single farm and in *Aeromonas spp.*, but this has been seen over multiple years. As there are a lack of medicinal options available, if the industry were to stop using oxolinic acid it is likely that there would be an overall increase in the use of antibiotics, since others would need to be used in larger quantities to be effective. The trout sector is actively working to find solutions, such as developing a system to detect changes in bacterial levels of rivers and predict disease outbreaks, and the BugBank project[27] which aims to sample disease outbreaks, monitor antibacterial resistance and to help develop autogenous vaccines.

In recent years the use of antimicrobials increased in the salmon sector due to a number of reasons, including a rise in bacterial outbreaks at sea. This is concerning, and this trend will need to be closely monitored and reversed for the sector to be considered sustainable. It is important to put any

[26] RUMA (2022) RUMA Targets Task Force 2: Two Years On www.ruma.org.uk/wp-content/uploads/2022/11/RUMA-TTF-Report-2022-FINAL-FINAL.pdf Accessed March 2023

[27] Pers. comm. - raised during a BVA Sustainable Aquaculture Working Group meeting. The BugBank project has been launched by the BTA, Biotope, Skretting, Ridgeway Biologicals and CEFAS. CEFAS is collating isolates of bacteria, checking ID, and carrying out in depth antibacterial resistance assessments to see if or how they have changed. Isolates of *Yersinia ruckeri* and *Aeromonas salmonicida* are then passed to Ridgeway to build a library. This will enable farms to have organisms from their farm on file which autogenous vaccines can be made from.

percentage increases or decreases into context of overall usage levels. Levels of antibiotics use remain low and significantly below use in terrestrial production systems, and treatments are restricted to a relatively small number of farms (8.5% and 4.9% of freshwater and marine farms, respectively)[28]. However, as with other areas of food production, we are encouraging the ongoing replacement, reduction and refinement of antimicrobial use in the aquaculture sector. Rapid diagnosis is crucial for providing effective treatment, so improved diagnostic tools will be important for reducing antibiotic use in the future. Alternative methods of prevention and treatment must also be sought.

Other medicinal treatments available for fish include a range of medical baths, such as bronopol, formaldehyde, benzalkonium chloride and Chloramine T. For some health issues, non-medicinal therapeutic treatments may also be used, including salt and freshwater bathing, or thermal and physical treatments. These may come with their own risks to fish health and welfare, and any handling increases stress, so they should also be managed as part of a welfare assessment structure with veterinary advice. Further research is needed into these non-medicinal options.

Whilst every effort must first be made to prevent disease and reduce the need for medicines, continued access to pharmaceuticals in order to treat diseases is important for the welfare of farmed fish. A greater range of medicines is needed, and this is likely to require a level of corporate social responsibility amongst pharmaceutical companies to continue and increase production, and a dynamic relationship between Governments, regulators and pharmaceutical companies will be required to ensure medicines are able to be used.

Vaccines

Vaccination is used wherever possible to prevent disease, and is an effective tool against many common pathogens. On salmon farms, parr (juvenile fish) are vaccinated before smoltification and sea transfer. Salmon will be vaccinated against furunculosis (*Aeromonas salmonicida*), most against Infectious Pancreatic Necrosis (IPN) and Pancreas Disease (PD), and some against other bacterial diseases. Fish are anesthetised first, and the majority are now machine vaccinated. Other species of fish destined for sea water production are also vaccinated against these diseases.

On freshwater trout farms, fish are vaccinated against enteric redmouth and sometimes Furunculosis. They are usually crowded in a pond, anesthetised and then netted, before being individually injected by hand. Personnel vaccinating fish must have undertaken appropriate training, should wear appropriate PPE, and should use a needle with safety guards, however, there remains a risk of accidental self-injection. Some trout farms are starting to use machines for vaccinations, but only the largest farms can afford this option.

Fish cannot be vaccinated for notifiable diseases. The underlying reason for this legislation is related to export checks, but the rule applies even if they are not for the export market. The problem lies with difficulty in differentiating between a vaccinated and infected fish, but if this could be established via the use of DIVA vaccines, then the vaccines for notifiable diseases would be very useful.

As with medicines, there is a lack of vaccines available for use on fish, and those available tend to be aimed at the salmon sector. The lack of available options also reduces competition, meaning vaccines are becoming more expensive. As a result, some smaller farms are no longer able to afford routine vaccinations, especially in the trout sector. Husbandry measures are used to try to prevent diseases, but farms are finding it is more affordable to treat for diseases if they occur. The sector is investigating the use of bacteriophages as an alternative.

A greater range of vaccines at affordable prices are needed to provide options for fish farmers to care for the needs of their fish, and failure to improve this could result in significant welfare issues. This will require pharmaceutical companies to continue and increase production, potentially as part of their social responsibility efforts, with support from Government and the Veterinary Medicines Directorate (VMD) to ensure ongoing availability. As part of global efforts to improve accessibility to vaccines, BVA provided input into the FVE FishMedPlus Coalition on the availability of vaccines for aquaculture, which helped to increase awareness of routes for pharmaceutical companies to gain reciprocal recognition of fish medicines and vaccines across member states, and of routes for fish vets to use medicines and vaccines licensed in other member states under mutual recognition arrangements.

[28] RUMA (2022) RUMA Targets Task Force 2: Two Years On www.ruma.org.uk/wp-content/uploads/2022/11/RUMA-TTF-Report-2022-FINAL-FINAL.pdf Accessed March 2023

Following this, the European Medicines Agency (EMA) agreed to maintain a centralised list of licensed medicines and vaccines for fish.

Governments, regulators, and pharmaceutical companies should address the issue of availability of vaccines and medicines for farmed fish, taking their role in social responsibility into account. Development of novel technologies and approaches should be encouraged. Currently new treatment approaches such as bacteriophages are prevented from coming to market as there are no simple regulatory mechanisms to support this. Regulations should be streamlined and made more dynamic to enable these to be considered, whilst maintaining their ability to safeguard animal health and welfare, and the environment.

Stocking density

It is often assumed the lower stocking density, the better this will be for fish welfare. Stocking densities that are too low or too high can have negative impacts on welfare, but lowering the stocking density will not always have a positive impact, especially if other factors are contributing to poor welfare. The ideal density depends on numerous factors, including the system, life stage, water source and species[29]. It is it therefore difficult to set minimum and maximum stocking density levels that will protect welfare. Stocking density is only indirectly related to welfare and cannot be used to accurately predict or control welfare[29, 30, 31, 32, 33].

Regulation or guidance directly limiting stocking density alone is unlikely to be effective, and monitoring for acceptable levels of other indicators is more likely to support fish welfare, eg water quality, health, nutritional condition and behavioural indicators[34]. However, stocking density limits are useful to ensure that production needs are not able to take priority over welfare needs, and to reduce the risks if monitoring is not effective, so they have a place in assurance schemes and industry guidance. Further research on the impact of stocking density is needed, and thresholds included in current guidance should be reviewed where appropriate.

Keeping fish in larger pens is likely to have a positive impact, even if the stocking density remains the same, each fish then has a larger overall volume of water to move around in. This may also allow fish to move away from predators more easily, reducing direct risks and stress levels.

Water quality

The quality of the water in which they live has a direct and significant effect on the health and wellbeing of farmed fish. There are many chemical, biological, and physical parameters to consider in relation to water quality, including dissolved gasses (particularly oxygen, nitrogen, and carbon dioxide levels), pH, salinity, temperature and water flow. Particulate matter (suspended solids) can be a significant factor, eg if input water is affected by floods or if the seabed is disturbed by storms. The natural flora and fauna of water bodies are also important elements, with a range of phytoplankton, zooplankton and jellyfish known to be detrimental to fish; significant mortality events have been associated with the presence of harmful marine organisms.

Water quality requirements vary between fish species, with salmonids generally being more sensitive to poor quality, and the parameters differ with location and system. Low ambient oxygen levels can be a feature of some water bodies, while the likelihood of harmful algal blooms (HABs) has varying levels of predictability.

There is a complex inter-relationship between water quality parameters (chemical, physical and biological) and fish farms and human activities and other natural events; for example, the application

[29] Turnbull JF, North, B.P., Ellis, T., Adams, C.E., Bron, J., MacIntyre, C.M. and Huntingford, F.A. (2008) Stocking density and the welfare of farmed salmonids. *In: Branson EJ, editor. Fish Welfare.* Oxford: Blackwell Publishing. p. 111–20.
[30] Adams, C., Turnbull, J.F., Bell, A., Bron, J. & Huntingford, F.A. (2007) Multiple determinants of welfare in farmed fish: stocking density, disturbance and aggression in salmon. *Canadian Journal of Fisheries and Aquatic Science*. 64, 336-344.
[31] North, B.P., Ellis, T., Davies, J. & Turnbull, J.F. (2006) Stocking density practices of commercial UK rainbow trout farms. *Aquaculture*. 259, 260-267.
[32] North, B.P., Turnbull, J.F., Ellis, T., Porter, M.J., Migaud, H., Bron, J. & Bromage, N.R. (2006) The Impact of stocking density on the welfare of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*. 255, 466-479.
[33] Turnbull, J.F., Bell, A., Adams, C., Bron, J. & Huntingford, F.A. (2005) Stocking density and welfare of cage farmed Atlantic salmon: application of a multivariate analysis. *Aquaculture*. 243, 121-132.
[34] Saraiva JL, Rachinas-Lopes P and Arechavala-Lopez P. (2022) Finding the “golden stocking density”: A balance between fish welfare and farmers’ perspectives. *Frontiers in Veterinary Science*, p.1099

of nitrogen-based fertilisers on river-side agricultural farms can, via run-off, promote phytoplankton blooms which threaten fish farms. Changes in any one parameter can also affect the toxicity of others, which can have consequences for fish health. Significant knowledge and expertise are needed to understand how all the parameters interact. There is a limited network of support services to analyse, monitor and advise on water quality issues, so it would be helpful for any advisors, including vets, to be trained in water quality, recirculation systems and related topics.

The ability of fish farmers to influence the environment in which their stock live is very variable. In tank-based systems, particularly Recirculating Aquaculture Systems (RAS), very tight control may be possible and, indeed, essential. However, water quality in the sea can rarely be controlled, and this may have an impact on fish welfare. While mitigation measures against the effects of harmful water quality parameters are possible in many circumstances, some threats may not be possible to resolve and so the impact on welfare of farm locations must be considered.

Note that the issue of *Water pollution, effluent and medicines in the environment* is discussed later in this document.

Slaughter

Slaughter processes should result in a humane death for fish, minimising avoidable pain, distress, fear, and suffering. Species-specific needs should be considered at all stages of the slaughter process, and all animals, including farmed finfish, should be effectively stunned before slaughter.

Traditionally, wild caught fish are left to suffocate after being removed from the water, resulting in a protracted death. This method would not be permitted under legislation regulating UK aquaculture, or under the welfare codes the majority of farms have signed up to.

Many trout farms do not kill their fish, as a large proportion are destined to transported to rivers and lakes for anglers to catch, and others are transported to a processor. Farms which do slaughter their fish on site commonly use a priest (weighted stick), or on bigger farms an electrical device is used to stun and slaughter. There may be significant risks to lone-workers in the use of electrical stunners particularly as, to reduce stress prior to and during slaughter, trout are often killed in the early hours of the morning when fish are naturally calmer. There must also always be someone monitoring the receiving vessel to check for stun efficiency (signs of life), so farms need to have sufficient staff available to use this method. A small proportion of fish are slaughtered using Ikejime, a Japanese method to destroy the spinal cord, which is cleaner and quicker when used properly and with adequate training, but the time taken per fish makes this impractical for most farms. Carbon dioxide and iced slurry methods were previously used, but are no longer considered humane. Except for some of the larger fish, table trout are not usually bled, and most farms will send them to a processing site to be prepared for sale.

In the salmon sector, fish may be slaughtered on site, but the majority are transferred by wellboat into dedicated facilities. Care is taken to control conditions such as temperature to keep fish calm during these transfers. At a harvesting facility, fish are first stunned, most commonly with a percussive blow, before they are bled to death. Much of the process is automated with staff members checking at every stage, and secondary stun given to any fish if there is a suspicion they have not been correctly stunned, which works effectively for the majority of fish, but anomalies can have a significant impact on the welfare of individual fish. Facilities must control the number of fish being processed and ensure sufficient time for human checks at every stage to ensure fish are stunned and slaughtered as humanely as possible. Blood is captured and contained so it does not contaminate the environment.

There are several key stages during the pre-slaughter harvesting process that can impact on fish welfare[35], these are:

- feed withdrawal – we support RSPCA standards and Humane Slaughter Association guidance that stipulates a maximum of 72 hours withholding of food to completely empty the gut while minimising any negative welfare implications. Any circumstances that require a longer period of food withdrawal should only be done with guidance from a veterinary

[35] FAWC (2014). Opinion on the welfare of farmed fish at the time of killing. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/319331/Opinion_on_the_welfare_of_farmed_fish_at_the_time_of_killing.pdf Accessed March 2023

surgeon. Before feed withdrawal takes place, it is also important that the welfare of cleaner fish is taken into account eg the risk of predation. Protective measures, such as the potential removal of cleaner fish from pens at this stage, should be specifically addressed in the farm's veterinary health plan

- crowding – should be managed to reduce the risk of distress and injury
- handling and removal from water – this must only be carried out when absolutely necessary
- transportation from pen to harvesting station – any transport should be in accordance with general safe transport guidance as set out in RSPCA standards and The Code of Good Practice from Scottish Finfish Aquaculture

We encourage all those involved in the harvesting of fish to familiarise themselves with, and adhere to, best practice to promote positive fish welfare during harvesting. the BVA position on the welfare of animals at slaughter provides useful guidance.

Technology is increasingly being used to improve automated processes, with cameras and apps now being used throughout to continually check everything is working correctly and the number of fish being processed is at a safe level. The automated process is also being used during vaccination, so any progress on technology to improve this will be helpful at several important stages of a farmed fish's life. After many years of development, electrical stunning has recently become possible, to be used before or as an alternative to percussive stunning, offering potential improvements to welfare at slaughter. This will be especially useful for stunning larger fish and where there is significant variation in the size of fish being stunned, as percussive stunning systems are set up for a specific range of sizes and variation can make the process less effective. Electrical stunning eliminates the need for fish to be within a specific range of sizes.

These large, expensive, automated stunning and slaughter machines are unaffordable for many smaller farms, so a lot of work has been going into finding other humane slaughter methods that can be used in these scenarios, particularly for trout and non-salmonids. Cost-effective tools are being developed which aim to make slaughter quicker, safer and more humane, which will be especially beneficial in the trout sector.

Slaughter processes have improved dramatically in the last 20 years to the benefit of fish welfare, and industry has driven real innovation around stunning and slaughter techniques. As well as a moral obligation to consider fish welfare, health and safety and commercial reasons also drive improvements, and the sector has adopted several industry-led codes of practice and assurance scheme standards which protect fish welfare at slaughter, including The Code of Good Practice from Scottish Finfish Aquaculture and RSPCA Assured scheme for salmon and trout. However, there is currently no detailed legislation to protect the welfare of farmed finfish at slaughter, with provisions for farmed finfish in UK and EU legislation limited to key principles, as opposed to detailed protections. Given the number of fish harvested in UK aquaculture each year, the UK Governments should introduce specific legislative protections for the welfare of farmed fin fish at the time of killing to reinforce existing good practice by the aquaculture industry.

We support the principles of humane slaughter as set out in the Animal Welfare Council[36] opinion:

- all personnel involved with slaughter or killing of animals have a duty of care and must be trained and competent
- only those animals that are fit and healthy should be caught, loaded and transported to the slaughter site
- any handling of animals prior to slaughter must be done with consideration for the animal's welfare
- in the slaughter facility, only equipment that is fit for the purpose must be used
- prior to killing an animal, either it must be rendered unconscious and insensible to pain instantaneously or unconsciousness must be induced without pain or distress

[36] The Farm Animal Welfare Council became the Animal Welfare Council in 2019. The principles of humane slaughter predate the change of name.

- animals must not recover consciousness until death ensues

For more information, refer to BVA and FVS response to the AWC call for evidence on farmed fish killing and the BVA position on the welfare of animals at slaughter.

Recommendations

Recommendation 3: Animal health and welfare should not be unnecessarily compromised to address human need. Aquaculture systems must work towards the positive health and welfare of all fish raised and used within them.

Recommendation 4: The definition of "animal" in the Veterinary Surgeons Act should be updated to "all animals other than man", to bring it in line with more recent legislation.

Recommendation 5: To be considered sustainable, aquaculture systems must provide for the five animal welfare needs, positive health outcomes and adhere to WOAH standards for animal health and welfare.

Recommendation 6: Practical and scientific research should be urgently undertaken to support keepers in being able to provide systems which offer stimulating living environments and allow for the performance of highly motivated behaviours; opportunities for positive welfare outcomes, such as comfort, pleasure, interest and confidence; and excellent health outcomes.

Recommendation 7: Urgent efforts should continue to be made to reduce the mortality rates of farmed fish, identifying and mitigating existing risks and staying aware of emerging threats.

Recommendation 8: Innovative methods or technology to identify and capture individuals with poor health and welfare without causing stress to others should be researched and developed.

Recommendation 9: To prevent potential harm to fish, thermal and physical treatments for lice should only be used within a welfare assessment structure and with veterinary advice.

Recommendation 10: Further research should be carried out to improve prevention and treatment options for all common parasites and diseases affecting the aquaculture sector.

Recommendation 11: Governments, regulators and pharmaceutical companies should address the issue of availability of vaccines and medicines for farmed fish, taking their role in social responsibility into account. Development of novel technologies and approaches should be encouraged, and regulatory mechanisms should be made more dynamic to enable these to have a clear and safe route to market.

Recommendation 12: Fish farmers should consider all aspects of fish health and welfare, to ensure a balanced approach, acknowledging that many complex diseases require a toolkit of control measures used in dynamic, strategic and planned ways. All treatments and interventions should be considered and managed through a veterinary health and welfare plan, ensuring appropriate advice is taken into account.

Recommendation 13: Veterinary professionals should develop their skills and knowledge to play a more active role in supporting fish welfare. Organisations such as BVA and FVS have a role to play in providing education and CPD, as well signposting to useful information. Veterinary schools and the Veterinary School Council should work to include more information on aquaculture as part of the veterinary curriculum.

Recommendation 14: All those involved in the harvesting of fish should familiarise themselves with, and adhere to, best practice to promote positive fish welfare during harvesting. the BVA position on the welfare of animals at slaughter provides useful guidance.

Recommendation 15: The UK Governments should provide specific legislative protections for the welfare of farmed finfish, including at slaughter. The UK Welfare of Animals at the Time of Killing regulations should include the stunning of farmed fish (including detailed requirements of key parameters), alongside general welfare protections at slaughter.

Recommendation 16: Innovative stunning technology should be further developed and used as widely as possible to improve welfare at slaughter.

Sustainable resource management to protect and conserve species, habitats and biodiversity

As a health-centred profession and key stakeholder in the One Health agenda, the veterinary profession also recognises that policies relating to sustainable aquaculture must address the use of natural resources, protection and conservation of wild species, habitats and biodiversity in order to better protect the environment which both humans and animals share and reduce the ecological footprint of animal agriculture as a whole.

With natural fish populations under pressure globally, the shift towards aquaculture could be vital for protecting remaining stocks, enabling consumption to continue without additional pressure on the wild populations. With a growing human population relying on protein from fish, it is unlikely that commercial fisheries alone will be able to keep up with demand in a sustainable way, and thus aquaculture must be considered as part of the solution.

Although it reduces reliance on wild fish species intended for human consumption, aquaculture has the potential to impact wild stocks in other ways, as well as other species and the wider environment. An overview of some of the biggest challenges and concerns about the sector are included below.

Fish feed sourcing

One of the biggest pressures in terms of sustainability of the sector is where feed for fish is sourced from[37].

The feed for most farmed species comes in the form of pellets made from fishmeal, fish oil, by-products, plants, and other sources. These pellets are very sophisticated, and so food conversion efficiency is often as good as 1.1. There is already a strong focus on making sure all ingredients currently being used in feed are sourced responsibly, and on checking compliance. Some retailers require a full traceability audit which includes the source of fish food. Certification processes are in place, eg the Aquaculture Stewardship Council (ASC) food standard, which requires that feed mills meet strict environmental and social requirements, source ingredients from socially responsible suppliers and use environmentally responsible raw materials[38]. Feed used in the UK aquaculture sector comes from certified sources. The sector has also been making significant efforts to increase the percentage of raw ingredients sourced from within the UK, which will reduce the carbon footprint associated with transport of products.

However, the fishmeal and fish oil elements of feed often come from marine sources, usually from small, pelagic species not commonly caught for human consumption, eg Peruvian anchovies or Chilean sand eels. These species are low in the trophic pyramid, so are often critical to the health and productivity of the ecosystems in which they exist, which has created concern over their extraction[39],[40]. With depleted stocks and growing awareness of our impact on natural populations, it is important for the sector to move away from harvesting wild fish for aquaculture feed. The sector is therefore working to improve this, with vegetable proteins and added amino acids making up an increasingly large proportion of the content, and a greater proportion of fishmeal coming from fish waste (ie aquaculture by-products)[41]. Research is underway to support this, and alternative feed ingredients could include:

- a wider array of different algae
- single cell protein – these are limited by legislation until there is further evidence that it is safe to use

[37] Kuempel, C.D., Frazier, M., Verstaen, J., Rayner, P.E., Blanchard, J.L., Cottrell, R.S., Froehlich, H.E., Gephart, J.A., Jacobsen, N.S., McIntyre, P.B. and Metian, M., (2023) Environmental footprints of farmed chicken and salmon bridge the land and sea. *Current Biology,* 33(5), 990-997.
[38] ASC (2023) Feed www.asc-aqua.org/what-we-do/our-standards/feed-standard/#feed-standard-documents Accessed March 2023
[39] Tacon A.G. and Metian M. (2009) Fishing for feed or fishing for food: increasing global competition for small pelagic forage fish. *Ambio* 38: 294– 302.
[40] Siple M.C., Essington T.E., Plagányi É. (2019) Forage fish fisheries management requires a tailored approach to balance trade-offs. *Fish and Fisheries*. 20: 110– 124.
[41] FAO (2022). The state of world fisheries and aquaculture. *Opportunities and challenges. Food and Agriculture Organization of the United Nations*. https://doi.org/10.4060/cc0461en

- vegetable sources, including pea protein, and chickpea protein – these are expected to be a popular option
- insect protein - this is a growing research area, attracting high levels of investment. In aquaculture, the short-term use is likely to be as a diet additive, with a view to switching feed if further studies show animal welfare and nutritional benefits. It is also possible they could bring added benefits in relation to infection control, and the production of insect protein can be carbon neutral

Continued research into alternative feed sources is needed to reduce the pressure of wild stocks, but this must not be at the expense of farmed fish welfare. Fish meal and fish oil contain the perfect balance of nutrition for fish, which needs to be taken into account when looking for alternative feed sources. It is also important to consider any impacts on fish faeces, which in many systems will be deposited in the natural environment, so the use of non-aquatic feed sources may have unintended consequences. A One Health approach will be required when researching the most sustainable diets to be used, as it will need to balance the needs of people, animals, plants and their shared environment. It will also be important to consider the circular economy, eg use of waste products from other sectors.

Predator control

Predators of salmon include birds and otters, but predation by seals is the key issue for the salmon sector. Grey seal (*Halichoerus grypus*) populations in Scotland are healthy and growing, so salmon farms present an enticing source of food leading them to attack nets and find ways of getting into sea pens. Anecdotal evidence suggests that seals are becoming less scared of humans, with many now hauling themselves onto walkways and into sea pens. Up to 500,000 fish could be lost through seal attacks each year, with 80-92% of Scottish farms affected[42], making it one of the most significant fish welfare issues facing the industry.

Seals present a serious welfare issue for salmon, as attacks can cause death or serious injury to any fish caught, as well as considerable stress for all fish in the net, contributing to reductions in growth, feeding and increased susceptibility to disease. Salmon show a strong behavioural response to the presence of seals, and research[43] has also shown that heart rates remain raised over long periods when predators are known to be present, even if they are not visible. Evidence from other species also suggests that chronic stress occurs in prey animals when exposed to the constant or frequent presence of a predator. Damage caused by attacks to the nets also mean salmon are more likely to escape, which could be detrimental to their welfare, increase the risk they will interact with wild fish, and reduce profitability. Predation is therefore an issue which can affect fish welfare, wildlife and economic sustainability.

Preventing seal attacks is crucial and has always been the preferred option for the industry since it reduces stress and fish mortality. Acoustic deterrent devices (ADDs) had previously been popular for discouraging seals from approaching nets. However, evidence suggests that ADDs can harm cetaceans and seals, causing hearing loss and affecting their habitat use[44,45]. These species have European Protected Species (EPS) status, and The Conservation (Natural Habitats, &c.) Regulations 1994[46] makes it an offence to deliberately or recklessly capture, injure, kill, harass or in particular circumstances, disturb a wild animal with EPS status in Scotland. It also makes it a specific offence to deliberately or recklessly disturb any dolphin, porpoise or whale (cetacean). The term ‘disturbance’ is not defined and so may potentially include stimuli that cause a change in behaviour indicating a negative experience[47]. Scottish Government has clarified that all currently available devices can only

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[42] Scottish Government (2022) Scottish Animal Welfare Commission - proximity of seals to farmed fish: response to Marine Scotland https://www.gov.scot/publications/scottish-animal-welfare-commission-proximity-of-seals-to-farmed-fish-response-to-marine-scotland/pages/outcomes-of-the-investigations/ Accessed March 2023

[43] Hjelmstedt, P., Brijs, J., Berg, C., Axelsson, M., Sandblom, E., Roques, J.A.C., Sundh, H., Sundell, K., Kiessling, A. and Gräns, A. (2021) Continuous physiological welfare evaluation of European whitefish (Coregonus lavaretus) during common aquaculture practices leading up to slaughter. *Aquaculture* 534: 736258.

[44]Götz T. and Janik, V.M. (2013). Acoustic deterrent devices to prevent pinniped depredation: efficiency, conservation concerns and possible solutions. *Marine Ecology Progress Series* 492: 285-302.

[45] Lepper, P.A., Gordon, J., Booth, C., Theobald, P., Robinson, S. P., Northridge, S. & Wang, L. (2014). Establishing the sensitivity of cetaceans and seals to acoustic deterrent devices in Scotland. *Scottish Natural Heritage Commissioned Report* No. 517.

46 UK Government (1994) The Conservation (Natural Habitats, &c.) Regulations 1994 www.legislation.gov.uk/uksi/1994/2716/regulation/39 Accessed March 2023

47 Scottish Government (2022) Scottish Animal Welfare Commission - proximity of seals to farmed fish: response to Marine

be used under licence, otherwise evidence that they do not disturb European Protected Species must be provided to Scottish Government. Currently no licences are in place. More research is needed into the level and type of disturbance caused by these devices, as the frequency, design, and use of ADDs may have an impact. With new technology, including AI and cameras to detect when seals are approaching, it may be possible for some ADDs to be used to protect farmed fish welfare in the future.

The Scottish Animal Welfare Commission (SAWC) working group was specifically asked to consider the welfare of farmed fish, wild seals and cetaceans. They recommended that alternative strategies to deter seals should also be used wherever possible, but agreed that the use of ADDs may be justifiable in some situations when there is no satisfactory alternative, as their use appears to be effective in some situations and contexts. They recommended the application of the international consensus principles of wildlife control in the management of seals to ensure that this is continually evaluated in each situation, and when ADDs must be used, they should be reserved for critical periods or as part of a suite of controls that can be used at different times. Appropriate measures to reduce the possibility of harm to cetaceans should also be implemented as far as possible[48].,

In addition to the research on ADDs, the sector is actively working on methods to prevent seal attacks and mitigate their impacts, including:

- changes to the net design, to make it harder for them to reach the salmon. For example, the industry is moving towards high-density polyethylene (HDPE) nets, with better tensioning arrangements
- larger pens, to allow fish to move away from seals when they are outside, reducing stress
- seal blinds and seal protection nets, to further separate seals from fish to make them less appealing. For example, the Huon fortress pen being used in Tasmania which has inner sections with conventional netting for fish, then outer netting to keep predators away and raised posts with netting over the top
- research into the distribution of the two seal species to understand when they are more likely to predate on fish, eg studies suggests that pregnant or lactating females are more likely to attack. Research into what causes seals to attack specific farms will also be useful

Predation is a significant issue and the industry is willing to make changes to prevent this, but there is currently no clear solution or direction of travel. Any of these changes could bring benefits, but may also have other unintended consequences, so must be carefully thought through. For example, larger pens could impact on use of medicines as more may be needed to treat the stock, and stronger nets could hurt fish swimming into them. These new systems also require large investments, in terms of both time and money, so evidence is urgently needed to ensure the chosen measures are going to be safe and effective. In addition, a more supportive planning process is urgently required, taking welfare and predation risks into account when assessing applications for new sites or alternative pen systems for the benefit of both fish and predator welfare. The sector, Scottish Government, veterinary professionals, and industry experts must work together to decide on how best to manage seals in the future. Further research on the impacts the presence of predators has on fish health and welfare, and how to mitigate this, is also needed.

Once a seal is in a sea pen, it can be very difficult to encourage it to leave. Up until 2021, fish farms could lethally remove seals under licence for the protection of the health and welfare of farmed fish or to prevent serious damage to fisheries or fish farms and so seals which could not be enticed to leave could be shot under licence. Around 60 to 80 were killed each year, with training and controls in place to ensure this was done correctly and humanely. Aside from ethical issues associated with killing them, seals in Scotland represent a large proportion of the UK population and thus lethal control could negatively impact the species' future, though population dynamics were taken into account by regulators when considering applications. Licensed shooting of seals to protect the health and welfare of farmed fish or to prevent serious damage to fisheries or fish farms ended in 2021 when USA import requirements changed, preventing any country allowing the use of lethal control to protect fisheries

Scotland www.gov.scot/publications/scottish-animal-welfare-commission-proximity-of-seals-to-farmed-fish-response-to-marine-scotland/pages/acoustic-deterrent-devices-and-legislation/ Accessed March 2023

48 Scottish Animal Welfare Commission (2023) Report on the use of acoustic deterrent devices (ADDs) in salmon farming to control predation by seals and their wider effects on wildlife. https://www.gov.scot/publications/report-use-acoustic-deterrent-devices-adds-salmon-farming-control-predation-seals-wider-effects-wildlife-scottish-animal-welfare-commission/pages/1/ Accessed March 2023

from trading with them. This poses a challenge to the aquaculture sector of how to handle seals in pens, as they can now only legally be shot to relieve their suffering but cannot be ignored due to the serious welfare harms they cause to the salmon. Vets can euthanise an animal which is suffering, so are likely to be involved in these cases. Anesthetising a seal in a sea pen is not usually an option, since it is unsafe for the animal and humans involved[49,50,51].

On some trout farms, threat of predation comes from otters, mink, and birds such as herons, cormorants, egrets and more rarely, osprey. Bird netting and specialist electric fences can help to keep predators away from fish, and Natural England may sometimes grant licences to shoot fish-eating birds[52].

There is a balance to be struck between fish welfare and the welfare of their wild predators. As with all wildlife control, the first consideration should be measures to deter and prevent access, before any control measures are taken. The industry should aspire towards future measures that best protect both fish and predator welfare, utilising the best mitigations currently available until new measures are developed and become widespread.

Escapes and interactions with wild populations

The potential interactions between farmed fish and wildlife greatly concern members of the public.

Many farmed fish, especially in the trout sector, are deliberately released into the wild, as they are purposely bred to restock angling sites. Brown trout are bred in captivity for stocking rivers and lakes, though some are sold for human consumption. Rainbow trout, a non-native species, are also released, but so far do not appear to establish populations in most areas and so are not thought to be a significant threat to wild fish. However, there is evidence of rainbow trout establishing themselves in an area of Derbyshire, and the factors enabling this to happen are unclear.

Even for fish not destined to be released, if they are farmed in the sea or rivers rather than closed tanks on land, there is potential for escapees to directly interact with wild populations. It is not clear how well escaped individuals can survive in the wild, so escaping also represents a risk to their welfare. Escapes can happen when nets are damaged by erosion, extreme weather conditions or predator attacks.

Commercially farmed species living in the wild cause concern because there are fears they would outcompete the natural population, and potentially spread diseases or parasites which have been able to build up above natural levels in the fish farm environment. Farmed fish have been selectively bred over a number of years and will now show some genetic difference to those in the wild, so if they were to breed with wild fish, this could affect the genetic make-up of the natural population and potentially reduce diversity. There is little scientific evidence available to show the impacts of this, with a recent study found no indication that an escape event resulted in significant interbreeding of escaped farm fish with wild stocks in the months immediately after the escape, though longer-term impacts were not assessed[53].

Further research on the impact of escaped or released fish on natural populations is needed, and all efforts should be made to prevent unintended escapes where possible. Wild salmon populations in the North Atlantic have been declining in recent years, with aquaculture and escapes being cited alongside overfishing, climate change, pollution etc as one of the many factors involved[54]. Research is therefore needed into the reasons for the decline in natural populations and to assess any impact aquaculture may be having on these.

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[49] Haulena, M. and Schmitt, T., (2018) Anaesthesia, in F.F.D. Gulland, L.A. Dierauf & K.L. Whitman (eds.), CRC handbook of marine mammal medicine, 3rd edn., pp. 567-606, Taylor & Francis, Boca Raton, FL

[50] Baylis, A.M.M., Page, B., Staniland, I., Arnould, J.P.Y. and McKenzie, J.(2015) Taking the sting out of darting: Risks, restraint drugs and procedures for the chemical restraint of Southern Hemisphere otariids, *Marine Mammal Science* 31(1), 322-344

[51] Geschke, K. and Chilvers, B.L., 2009, Managing big boys: A case study on remote anaesthesia and satellite tracking of adult male New Zealand sea lions (*Phocarctos hookeri*), *Wildlife Research* 36(8), 666-674.

[52] UK Government (2022) Bird licences www.gov.uk/government/collections/bird-licences Accessed March 2023

[53] Gilbey, J., Sampayo, J., Cauwelier, E., Malcolm, I., Millidine, K., Jackson, F., and Morris, D.J. (2021). A national assessment of the influence of farmed salmon escapes on the genetic integrity of wild Scottish Atlantic salmon populations. *Scottish Marine and Freshwater Science,* 12(12).

[54] Morris, O., Morris, O., Barquín, J.O.S.É., Belgrano, A.N.D.R.E.A., Blanchard, J.U.L.I.A., Bull, C.O.L.I.N., Layer-Dobra, K.A.T.R.I.N., Lauridsen, R.A.S.M.U.S., O'Gorman, E., Guõbergsson, G.U.Õ.N.I. and Woodward, G. (2022) New strategies for sustainable fisheries management: A case study of Atlantic salmon. http://hdl.handle.net/10044/1/95364 Accessed March 2023

Water pollution, effluent, and medicines in the environment

A major concern associated with aquaculture is the potential impact of medicines, faeces and food waste on the seabed and water quality in and around farms.

In sea-based systems, and especially the salmon industry, waste such as faeces and excess food falling through the nets is a concern. The build-up of waste can directly damage the seabed, and it may contain pathogens, making it a potential source of disease to other marine life. It may also contain medicinal residues if the fish have been treated, which could contribute to an increase in resistant bacteria or parasites in the environment. Fish feeding regimes are usually designed to reduce the potential for waste, since this would also be an unnecessary cost for the business, with developments in technology and monitoring methods supporting continued improvement. Environmental regulators also have strict restrictions on the levels of waste which can be produced.

In pond systems, and especially the trout industry, water is taken from rivers, used in the farms, and then returned to the river further downstream once any waste has been removed and the required standards met. Solid waste (food and faeces) is settled out, and there is some removal of other contaminants, such as bacteria and ammonia. This may happen in a settling pond, through a long outlet channel, in large swirl separators, or other system depending on the individual farm, but all discharged water must reach standards required by the environmental regulator consents. This process can take several years, and the environmental regulator monitors the water quality, including for medicinal waste.

A potential development for the trout sector is the Danish Model 3 recirculation farm, which could provide opportunities to improve their ecological footprint. This model replaces 10-15% of the water each day, meaning 95% of the water used can be recirculated, with only 5% discharged back into the environment. To protect their rivers, the Danish government has funded all major farms to replace their systems with this method. One site in the UK is trialling this system, and the sector is currently monitoring the profitability of making the change without Government funding. It is also important to note that this system uses more electricity, so a cost-benefit assessment will be needed to determine its true sustainability credentials.

Due largely to concern for the environment, the use of medicines is a highly regulated area, and treated differently to land-based sectors. There are two key pieces of legislation to consider in relation to medicines in aquaculture:

- the Veterinary Medicinal Products (VMP) guidelines. These are EU-wide requirements, though the EU has approved updated requirements since the UK left. The requirements were originally written for terrestrial animals, and so are not always appropriate for aquaculture
- the Water Framework Directive is important to consider when looking at use of medicines in water, as well as the use of biocides and other chemicals not included in medicines regulations

The VMD first approve medicines for use on fish, then the environmental regulator decides whether it can be used on a specific fish farm. SEPA is the principal environmental regulator in Scotland, working to ensure environmental and human health are protected, regulating and advising on a wide range of environmental activities. The Environment Agency (EA) have a similar role in England, and are responsible for providing consents for medicinal use and monitoring discharge thresholds are met on fish farms. Similar roles are carried out by Natural Resources Wales and the Northern Ireland Environment Agency (NIEA).

The requirements being considered by separate agencies can sometimes mean they are contradictory, affecting how they are used and sometimes having unintended consequences. For example, in Norway evidence suggests that low thresholds for the volume that can be used has led to increased resistance and lower efficacy[55]. The regulations would benefit from improved harmonisation to ensure both fish welfare and environmental health are always considered. It has also been suggested that monitoring discharge rather than use would be helpful, as this would focus on the impacts and potentially enable more efficient use of medications. We advocate for the need for regulation of the use of veterinary medicines, vaccines and other products, but the regulatory

[55] Overton, K., Dempster, T., Oppedal, F., Kristiansen, T.S., Gismervik, K. and Stien, L.H. (2019). Salmon lice treatments and salmon mortality in Norwegian aquaculture: a review. *Reviews in Aquaculture*, 11(4), pp.1398-1417.

framework needs to be proportionate, streamlined, evidence-based, and dynamic to reflect the speed of change in the industry and the needs of the fish.

Continued access to pharmaceuticals and control of disease are key issues globally for the aquaculture industry. Vaccines or medicines without a discharge are usually considered safe to use, and those which break down quickly are less likely to pose a threat to the environment. However, medicines which persist for a long time and can have long term cumulative effects are difficult to monitor and regulate, and less likely to be approved for use.

Where medicines are used, the environmental regulators have various mechanisms to make sure activities are carried out within the given license, aiming to protect natural wildlife underneath and close to the pens. Any impacts of medicine use should be minimal and rapidly reversable. For example, SEPA expect to see biological conditions being close to background conditions at the edges of their designated 100m 'mixing zone'. However, in order to accurately measure the impact of medicines and other chemicals, there needs to be a greater understanding of what a biologically or ecologically significant effect is, and agreement on what level of protection is acceptable. In terrestrial system extinction rates may be measured, but this is challenging in the aquatic environment since there is constant recruitment of individuals from other areas. More research is needed to establish clear and measurable maximum levels for environmental contamination, and to improve methods of marine water quality monitoring, particularly for marine organisms including plankton, jellyfish and hydrozoans.

SEPA currently focuses on monitoring compliance with the medicines requirements, but plans to play a bigger role in encouraging improvements in the future and raising awareness of environmental issues. This will involve understanding consumer demands, working with organisations such as NGOs to take individual sites beyond compliance.

As well as regulatory reform, new technologies could change the way medicines are used in aquaculture, potentially reducing the risk of medicines leaking into the natural environment and impacting wildlife. Technology has already been developed which could enable keepers to use the parasiticide imidacloprid to treat for sea lice, allowing fish to be treated and then the water cleaned and returned to the sea, and has been approved for use in Norway, but not in the UK. The ability to decouple fish health and environmental constraints could make this a highly effective tool for fish farmers in the UK, but more research and development is needed to establish safety and efficacy in UK production systems. Within any such system it would be critical to ensure that medicine discharge levels can consistently be below safe threshold levels, and that excretion levels from the fish themselves is considered and does not contribute to significant residues in water. Parasiticide products are coming under increasing scrutiny as their use in other sectors is thought to be affecting invertebrate populations in rivers, so any additional use of these compounds must be thoroughly evaluated. Other innovations include phage technologies, which could provide an alternative to antibiotics, but would be difficult to regulate under current legislation. As new approaches are found, it will be important for legislation to remain dynamic, and for suitable systems and controls to be in place to ensure they are used safely.

With many animal health and welfare issues to treat, the cost-benefits of any medicines used in fish production will need to be carefully considered and their use monitored. Veterinary professionals will always advocate for non-medicinal and preventative measures to be used first, but it is also important to look at how to tackle immediate problems whilst long-term improvements are made. Should any medicines become available for use, either through improved understanding of their impacts, regulatory reform, or through use of new technologies, research must continue to look for solutions which prevent welfare issues and reduce the need for medicines, eg through genetics or management factors. The veterinary profession could play an important role in helping the industry to continually assess and improve, and to communicate the advantages or risks of any new systems.

The aquaculture sector is also working to mitigate impacts through work to improve biodiversity around sea farms. Current studies include looking at the potential of fallow farm recovery, multi-trophic farming to enhance water quality, regeneration using natural oyster settlements, and seabed recovery using sea cucumbers. Experiments with growing seaweed and other plants are also being conducted to see how these can help protect the local environment, whilst ensuring this does not have unintended consequences.

It is important to consider that there are numerous sources of pollutants which can have negative environmental effects in our water systems. The relative impact of these must be understood such that critical risks can be mitigated in each and every sector.

Policy, legislation and planning permission

The sustainable development of aquaculture will be heavily influenced by international, UK and devolved nation legislation, policies, agreements and obligations. Climate change and biodiversity loss are major drivers for policy change globally, so the environmental impact of aquaculture will continue to be a key focus.

Scottish Government have significant environmental ambitions, including creation of more marine protected areas, an ambition to achieve net Zero by 2045, and a drive to increase the number of wind farms, so the Blue Economy strategy will play an important role in the future of the Scottish aquaculture industry. Across the UK, the Marine Strategy, Food Strategy, and the Environment Act could impact the future of the industry.

These policies and laws will have a particularly significant impact on which sites are approved for development, and how they are allowed to operate. The location of a fish farm is important to consider, in terms of suitability for the fish being farmed, impact on the environment and social license. Planning permission is required for any new sites and can only be attained through a lengthy process involving several key bodies. It also has an impact on infrastructure, such as the type of sea pens that can be used, which effects the level of welfare protection that can be provided for the fish (eg protection from predators).

For salmon farms in Scotland, five different consents from four separate bodies are required to build on a new site. The bodies involved are Marine Scotland, SEPA, Crown Estate Scotland and the relevant local council. Nature Scotland do not issue licenses but provide advice during the process. When planning a site, all impacts should be identified and mitigated where possible, and the consenting bodies will consider:

- biology and health of the fish
- hydrography of the location
- environment, including impact of any organic waste, eutrophication, wellboat discharge, medicines and chemicals, and interactions with wild populations (including escapes, diseases, and parasites)
- Seabed, water quality and cumulative impacts (complex modelling)
- natural heritage
- protected areas (eg marine protected areas, priority marine features, special areas of conservation etc.)
- predator management plans
- visuals, practicality, and neighbours
- communities and stakeholder consultation results

This process is very expensive and time consuming, in addition to the costs associated with site development. Consents are largely focussed on assessment of the environmental impacts, so there are concerns that the health and welfare of the farmed fish rank low in the decision-making process. In 2022, the “Griggs” review for Scottish Government[56] concluded that the planning and consenting system needs to become more streamlined, recommending having a single licensing body but with all current organisations continuing to be involved in the process. It also recommended having a central science and evidence base which could advise everyone involved in the process. This would make the consenting system more efficient, and science led, supporting the industry to develop more sustainability.

[56] Scottish Government (2022) Aquaculture regulatory process: review www.gov.scot/publications/review-aquaculture-regulatory-process-scotland/ Accessed March 2023

Whilst environmental issues will undoubtedly play a central role in the development of the sector, other issues also needing to be factored in will include health and food security, plus current affairs or market forces such as the impact of the crisis in Ukraine.

Carbon footprint

An important part of the sector's sustainability will be to consider its carbon footprint for the entire supply chain.

At the start of the chain, and as outlined earlier in this position, the food given to fish is a significant contributor to aquaculture's carbon footprint. Efforts are being made to improve this, including research into more sustainable raw ingredients, and by sourcing more from the UK. Further increasing the food conversion efficiency will also support the sector in reducing its carbon footprint. Refer to the section on *Fish feed sourcing* for more information.

Improving efficiency and increasing the use of green energy is another key focus for the sector, including by increasing the use of hybrid power, linking farms to mains power, generating renewable energy on-site, and tracking greenhouse gas emissions. In recent years, there has been an increase in the use of land-based facilities for the freshwater stage of salmon production, using Recirculating Aquaculture Systems (RAS). These tanks are sealed off from the environment and replace the natural flow of water with a filtration and recirculation system. Water is reused after waste products are removed, helping to maintain water quality conditions for the fish and minimising the volume of water needed. RAS can reduce transport and fuel requirements by concentrating activities into one area, and enable any effluent to be treated before discharge, limiting the risks of chemicals or waste leaking into the aquatic environment. With RAS, the electricity to power the system becomes the highest contributor to its carbon footprint, but this can be mitigated through use of green energy. The sector is also looking at how to extend the time fish can stay in this controlled environment, and whether reducing the time spent in the marine stages will improve overall sustainability.

Land-based aquaculture systems have received a lot of attention globally, but are not considered to be practical or commercially viable for the seawater stage. As fish are much bigger by this stage, the size of pens required would be prohibitively large, with few locations which would be suitable, and the energy use would be significantly higher than with current practises. They could also have welfare implications, with high stocking densities required and fish being moved further away from their natural environments. There would also be societal impacts, since the industry would likely move away from the coastal locations currently reliant on the sector. A more viable alternative is the current trend to consolidate farming activities in fewer, larger pens, maintaining the same stocking densities whilst potentially improving efficiency. This can also bring welfare benefits, with fewer pens and a greater focus on each improving husbandry, plus a greater area for fish to use and swim away from nearby predators.

Transport and travel also contribute to the sector's carbon footprint. In the production stages, the remote locations of many farms make access to mains power and use of electric vehicles challenging, but greener vehicles and hybrid vessels and feed barges are being developed to help the sector reduce fuel consumption. Once a product is ready for consumers, the majority is transported by road to European markets, so development of greener road haulage vehicles will also benefit the sector.

Approximately 25% of Scottish salmon products are flown internationally, to supply a high-end market. As this market expects fresh fish which has never been frozen, transport by boats takes too long, leading to wasted fish, and is not yet commercially viable. Long term, the sector aims to extend the shelf-life of fish so it can be transported by sea. In the meantime, any products that cannot be transported by road and sea are shipped in the hold of passenger planes. Although this is important to consider, the carbon footprint of fish feed is a more significant and urgent challenge, so research is focussed on this. It is questioned whether supplying the luxury international market could ever truly be considered sustainable, but as shown throughout this position, the sustainability of the sector is far more nuanced than this. With feed sourced from raw materials across the globe, UK animal products cannot truly be considered "local", and as the vast global value chain they support brings many benefits to rural communities with few other sustainable income choices, socioeconomics must also be considered as part of the sustainability of the sector[57]. However, we would support industry led

[57] Newton, R.W. and Little, D.C., (2018) Mapping the impacts of farmed Scottish salmon from a life cycle perspective. *The International Journal of Life Cycle Assessment,* 23, pp.1018-1029.

efforts to consider the range of species farmed in the UK, with a view to improving sustainability through diversification.

As well as considering mitigations to help prevent global warming, the sector must also consider potential impacts from the warming that will take place and any adaptations it will need to make. Sea water temperatures are rising, although these are not predicted to have a significant direct impact on aquaculture in Scotland within the next 50 years[58]. The current increase in algae blooms is thought to be connected to the climate, which farms will need to manage carefully since these can lead to mass mortalities. The greatest impacts are potentially going to come from the land-based impacts of climate change, such as flash flooding in coastal areas having consequences for sea farms in the area. The sector will need to thoroughly risk assess these threats and develop adaptation plans to remain sustainable in the future.

Waste

Another key focus for the industry is to reduce waste, both in terms of fish by-products and non-organic waste.

The sector is working to make sure all fish by-products are fully utilised. There are already very low levels of wastage, with a high proportion of flesh being used as the main product, and markets available for most other parts. For example, there is a strong market for fish heads in China, and other parts can be used in pet food. With a view to creating a sustainable, circular economy, some organic waste is now used to produce fertiliser to use on land, and biogas made from animal waste is being developed. It is important to note that one of the most effective ways to reduce animal waste is to keep the fish healthy and alive for as long as possible, which can only be achieved with good animal health and welfare.

Farms have strict polices on dealing with waste, especially plastics. As the sector improves and upgrades infrastructure, the pens can be repurposed and re-used. Old pens may be suitable for seaweed or shellfish aquaculture, or for use in agriculture, eg as polytunnels. Through a programme of beach cleans and marine litter recovery programmes, the sector is also working to clear up historical debris, regardless of its original source.

Once fish have been slaughtered, they have traditionally been transported to markets in polystyrene boxes, with ice to keep them cool. This combination is effective at protecting the product and reducing waste of the fish itself, but does lead to wastage. In recent years, the UK sector has been moving towards the use of reusable bulk bins for the local supply chain, which reduce waste and the amount of ice needed, as they are more efficient at keeping the product chilled. It is estimated that for every 1kt of salmon, switching to bulk bins saves 44,512 polystyrene boxes, 1,368 single use pallets, 137 tonnes of ice, and 14,178kW of energy associated with producing ice, 73 tonnes of carbon dioxide emissions[59]. However, these are not suitable for international trade, so further alternatives to the polystyrene boxes are being sought.

Recommendations

Recommendation 17: Policies relating to sustainable aquaculture must address the use of natural resources, protection and conservation of species, habitats and biodiversity in order to better protect the environment which humans, domestic and wild animals share, and reduce the ecological footprint of aquaculture as a whole.

Recommendation 18: Research into alternative feed sources should continue to reduce the pressure of wild stocks, but this must not be at the expense of farmed fish welfare. A One Health approach is required.

Recommendation 19: Any ingredients used in fish feed must be sustainably sourced, including, but not limited to, those currently coming from wild marine environments.

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[58] Black K. and Hughes A. (2017) Future of the Sea: Trends in Aquaculture. A review commissioned as part of the UK government's Foresight Future of the Sea project. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/635209/Future_of_the_sea_-_trends_in_aquaculture_FINAL_NEW.pdf Accessed March 2023

[59] Pers. comm. - Statistics provided by Scottish Sea Farms in a presentation to the BVA Sustainable Aquaculture Working Group

Recommendation 20: To progress towards being a key stakeholder in the production of insects as a food source, the veterinary profession should develop further understanding and specific expertise in relation to insect rearing health and welfare issues, husbandry systems and assuring food safety for human consumption.

Recommendation 21: Methods to control seals and other predators must carefully balance fish welfare and the welfare of the predators. As with all wildlife control, the first consideration should be measures to deter and prevent access, before any control measures are taken. Further research into all possible methods of prevention should be urgently undertaken to allow the sector to work towards an agreed direction of travel. Planning policies should support use of sea pens which prevent seals accessing pens. The aspiration is to eventually find solutions that best protect fish welfare without unnecessary welfare harms to wild predators such as seals. Humane destruction of predators that do become trapped in pens and cannot escape or be safely removed should however be available as a last resort to prevent them suffering and to protect the welfare of the farmed fish.

Recommendation 22: Further research should be conducted to fully understand the impacts the presence of predators has on fish health and welfare, and how this can be mitigated.

Recommendation 23: Keepers should make all reasonable efforts to prevent fish from escaping, embracing new innovations which are shown to reduce the likelihood. Where escapes do occur, they must be reported and mitigated as much as possible.

Recommendation 24: Research should be conducted to establish any role aquaculture may be playing in the decline of natural fish populations.

Recommendation 25: Medicines regulations should be reviewed and harmonised, to ensure animal health and welfare, human health and environmental health concerns are all appropriately considered. This should include all regulatory bodies and must be robust, transparent and evidence based.

Recommendation 26: The industry should look to embrace innovation which makes incremental improvements in existing systems/practices in the immediate term, whilst also considering more fundamental approaches with new or very different systems/practices which will make a bigger impact. Innovative solutions of providing medicines without discharge should continue to be developed and researched.

Recommendation 27: More research is needed to establish clear and measurable maximum levels for environmental contamination, to develop a coherent view of what a biologically or ecologically significant effect of medicines discharges may be.

Recommendation 28: The cost-benefits of various medicines used in fish production needs to be carefully considered and use monitored. Consideration should be given to fish welfare, environmental impacts and public opinion. Whilst closed land-based treatment systems may have some advantages, these will need to be carefully controlled. The use, advantages and disadvantages of such systems will need to be properly communicated to the profession and general public.

Recommendation 29: Planning regulations and farm licensing procedures should be proportionate, streamlined, evidence-based, and dynamic, with the environment and fish health and welfare both being central to decision making.

Recommendation 30: The aquaculture sector should continue to reduce its carbon footprint and to produce less waste. New innovations, methods and technology should be embraced, and any potential for diversification considered, but all changes must be fully considered to ensure they do not negatively impact on animal welfare.

Recommendation 31: Individual farms and the wider aquaculture sector should ensure they can identify areas impacting their carbon footprint and focus efforts on where they can make the most significant reductions. They should also develop risk assessments and adaptations plans to respond to the threats climate change is likely to pose.

The role of the veterinary profession

Historically, veterinary professionals have not been as closely involved in the UK aquaculture sector as they are with terrestrial farming systems. They may only have been involved when prescription for a specific medicine was needed, rather than full work up of a clinical case. This is largely due to fish not being included in the Veterinary Surgeons Act, combined with the unique way in which aquaculture has developed.

All vets receive university training in caring for small animal and farmed species, but most will graduate with little experience or understanding of how to care for fish. To work in the sector, a vet must complete additional qualifications or learn from other experienced professionals on the job. As a result, there is a significant shortage of vets with the correct expertise to provide useful guidance to the aquaculture sector. For example, the large majority of trout farms and all hatcheries in England are covered by a single expert veterinary surgeon. The remaining small holdings either do not use medicines, or seek advice from their local veterinary practice. If local veterinary practices do not have the knowledge or appropriate contacts to treat fish, it may be difficult for the fish farmer to get the assistance they need. The low number of veterinary surgeons involved in the sector also raises concerns for future accessibility to expertise.

There is a deficit in aquatic animal health specialists in general, including veterinary professionals and the non-veterinary DEFRA and Marine Scotland fish health inspectors. For the aquaculture industry to be sustainable, a One Health approach with advice from different specialists will be needed. As advocates for One Health, veterinary professionals could be well placed to provide much needed advice on complex animal health and welfare needs. The veterinary profession as a whole should work to increase visibility of aquaculture within the veterinary industry, particularly for students at university, and encourage all vets to improve their understanding of the sector.

Vets are essential in the sector for prescribing medicines and completing export health certifications. Since leaving the EU, the requirements for veterinary checks have increased, making their role even more important for trade. Ensuring enough vets are trained and supported in aquaculture roles is essential for the sustainability of the sector. Feeling valued is an important factor in vets choosing to stay in a role, so to retain and attract them, there is a need to tackle the view that they are only needed to write prescriptions, to make sure they are listened to and their views acknowledged.

Further, as an evidence-based, scientific profession, the veterinary voice is also valued by both producers and consumers as an ‘honest-broker’ of information about animal-derived food. With this in mind, the profession has a role to play in informing and educating the public as to the provenance, pricing and value of food, as well as dispelling common misconceptions about how production systems and new technologies impact on animal health and welfare. They could also potentially be a helpful voice in the regulatory bodies. All veterinary surgeons would therefore benefit from having a good level of knowledge in these areas and be able to articulate the contributions that the profession can make to the sustainable aquaculture agenda; for example, at the levels of individuals (communicating directly to animal keepers and owners), communities (eg veterinary practices serving as credible and informed animal welfare hubs) and nationally (eg veterinary associations developing and advocating policy).

BVA usually advocates for veterinary professionals to work as part of a vet-led team, but it is important to recognise the different role vets have in the aquaculture sector. Vets play an important role in improving fish health and welfare and are well placed to engage in actions to reduce the environmental impact of the profession, wider industry, and the communities they serve, bringing a great mix of experience and knowledge to conversations around sustainability. The profession should work to improve its knowledge of sustainable aquaculture systems and play an even more active role in aquaculture as part of a vet-inclusive team.

Recommendations

Recommendation 32: Veterinary professionals should play an active role in aquaculture, as part of a vet-inclusive team.

Recommendation 33: All veterinary surgeons should be able to articulate the contributions that the profession can make to the sustainable aquaculture agenda; at the levels of individuals (communicating directly to animal keepers and owners), communities (eg

veterinary practices serving as credible and informed animal welfare hubs) and nationally (eg veterinary associations developing and advocating policy).

Recommendation 34: The veterinary profession should ensure there is increased visibility of aquaculture within the veterinary industry, particularly for students at university, and encourage all vets to improve their understanding of the sector.

Welfare outcome assessment

BVA recognises that from an animal health and welfare point of view, it is not sufficient to carry out a tick-box exercise in terms of inputs. BVA supports welfare outcome assessment in assurance schemes as a tool to drive continuous improvement of animal management and husbandry practices (including welfare at slaughter and food hygiene), in turn promoting high animal health and welfare.

The standardised assessment of welfare outcomes should provide a practical and scientifically informed method of assessment that aims to provide a more objective, accurate and direct picture of animal welfare.

A welfare outcomes approach also contributes to informed considerations of the advantages and disadvantages of different production systems, assisting producers and consumers to consider how well a production system holistically meets all of an animal's health and welfare needs.

The majority of aquaculture in the UK is covered by RSPCA Assured schemes. These are generally regarded as world leading and provide useful, detailed guidance. However, their limit is their need to be auditable, which is a challenge with some elements of welfare assessment.

FishWell have developed guidance[60] which goes beyond the auditable standards, providing information on what could be used to improve welfare, in addition to what should be done as standard. It also includes scoring indices, including a poster with various negative welfare indices which has made a positive impact. These indices can be used to check welfare during weekly lice counts.

Monitoring health and resources

Welfare assessment for fish currently relies principally on looking at health and resource indicators. Resource indicators include infrastructure, environment, keeper training and management. When these resources are sufficiently in place, they reduce the risk of the fish having poor welfare, so are useful for predicting and preventing issues. Health indicators include mortalities, damage, productivity, weight, and behaviour. These provide clear signs of poor welfare and allow keepers to make suitable interventions to help.

Whilst both resource and health indicators are useful, they are usually measured across a whole group rather than looking at individuals, and focus only on the absence of poor welfare. Collecting the data often requires handling, which is stressful for the fish, so monitoring data which does not require any handling is preferred. Fish are also highly resilient, so can appear to be healthy until they are seriously compromised.

There is a strong public focus on indicators of negative welfare in farmed fish, such as skin lesions. Monitoring of health and resources shows there have been major improvements in the sector in recent years, and that this is continuing, but further improvements are urgently needed. The industry needs to look at potential short-term improvements as well as long-term ones.

The welfare needs of cleaner fish introduced to pens to control sea lice must also be considered and monitored. For example, provision of enrichment (often in the form of faux kelp), and supporting acclimatisation to sea-cage conditions can positively improve and encourage more natural behaviours, including diurnal rhythms and the establishment of home ranges[61]. The RSPCA welfare

[60] Noble, C., Gismervik, K., Iversen, M.H., Kolarevic, J., Nilsson, J., Stien, L.H., Turnbull, J.F. and AS, N. (2018). Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welfare 351pp

[61] Brooker, A.J., Davie, A., Leclercq, E., Zerafa, B. and Migaud, H., (2020) Pre-deployment acclimatisation of farmed ballan wrasse (*Labrus bergylta*) to sea-cage conditions promotes behaviour analogous to wild conspecifics when used as cleaner fish

standards for farmed Atlantic salmon also include standards for care of cleaner fish. Further research is needed to ensure we understand the husbandry needs of all cleaner fish species, and how best to measure their welfare outcomes.

Monitoring behaviour

The importance of good husbandry, and of the competence of fish farmers in recognising positive and negative welfare indicators in their stock cannot be over-emphasised. We support the further development of training in welfare assessment, with vets playing a key role in developing and delivering such training.

Measuring behaviour is important for assessing welfare, but is particularly challenging in fish as:

- the aquatic environment makes access and visibility difficult
- large numbers in pens provide a challenge for monitoring individuals
- fish naturally move away from anyone attempting to assess them, but crowding them to make this easier can cause stress
- some species, including salmon, do not exhibit many inquisitive behaviours which can be easily assessed
- there is huge diversity of species, so one species' needs are not going to be the same as another's. Even those of a similar size and anatomy can have hugely different needs

Welfare assessments which account for large numbers and do not interfere with fish are urgently needed. Divers carrying out routine procedures such as net checks can be helpful if they also pay attention to fish behaviour, but this is not a practical tool for daily assessment. Technology is improving the ability to observe and assess fish, with videos and AI increasingly being used by the industry. However, understanding the data this provides remains a challenge, so qualitative assessment methods are being researched.

Positive welfare

Animal welfare science is an evolving social concern, and fish welfare should align to modern standards, reflecting the latest scientific understanding of animals' needs, preferences, pleasures, and pains[62].

As well as checking for absence of disease and abnormal behaviour, those involved in keeping and safeguarding fish would ideally monitor for positive welfare indicators, to ensure they have a life worth living. To have positive welfare, an animal needs:

- nothing harmful or damaging in the environment
- an environment that is mostly predictable, but with some unpredictability within the fish's adaptive range
- the capacity for positive emotions or experiences

Fish sentience has only recently been recognised in law, and it is different to that of other animals, so more work is needed to understand what positive welfare means for each fish species.

More research is urgently needed to better understand the behavioural needs of fish, and how important each one is. However, there has been significant work over the past twenty years to improve our understanding, which can already be used to make improvements. It is likely their needs will be related to choice, social interaction, exercise, rest, food, stimulation, and enrichment. There is evidence fish responses are not all pre-programmed[63], indicating that a sterile environment will remove the need for fish to think, but a highly unpredictable one could induce fear and anxiety. There

in Atlantic salmon (*Salmo salar*) farms. *Aquaculture*, 520, p.734771.

[62] In line with BVA's Animal Welfare Strategy, available at https://www.bva.co.uk/take-action/our-policies/animal-welfare-strategy/

[63] Eg Schuster, S., Wöhl, S., Griebsch, M. and Klostermeier, I., (2006). Animal cognition: how archer fish learn to down rapidly moving targets. *Current Biology*, 16(4), pp.378-383.

is also evidence of affective states[64,65], where the behaviours can be rewarding as well as the outcomes, eg the act of hunting providing an adrenaline rush before the reward of the kill, so preventing rewarding behaviours may lead to frustration.

As the aquaculture sector rapidly develops, and farmed species become more genetically distant from their wild counterparts, our understanding of fish behavioural needs must also quickly improve. For example, the question of what motivates salmon to migrate, and how these needs can be met beyond the transfer from freshwater to saltwater urgently needs to be answered to decide how or whether their needs can be met in captivity. We would welcome further research into fish behaviour and positive welfare, with a view to developing animal welfare metrics across species so that indicators of positive welfare, emotional and behavioural states are incorporated into welfare outcomes assessment and lifetime welfare assessment where possible. In the meantime, keepers should improve welfare assessment through practical implementation of the existing knowledge on welfare, using the best available evidence and expert opinions where this is lacking.

Recommendations

Recommendation 35: To avoid oversimplification when considering how different production systems address animal health and welfare needs, animal health and welfare outcome assessments should form part of production system key performance indicators.

Recommendation 36: The welfare needs of cleaner fish introduced to pens must be considered and monitored. Further research is needed to ensure we understand the husbandry needs of all cleaner fish species, and how best to measure their welfare outcomes.

Recommendation 37: Further research should be undertaken to better understand fish welfare needs and what a good life represents. This should be a high priority for the sector.

Recommendation 38: Development of new and improved monitoring techniques should be encouraged, including those which reduce the need for handling fish. Welfare assessments which account for large numbers and do not interfere with fish are urgently needed.

Recommendation 39: BVA would welcome the further development of animal welfare metrics across species and sectors where they do not currently exist so that indicators of positive welfare, emotional and behavioural states are incorporated into welfare outcomes assessment and lifetime welfare assessment where possible. In the meantime, keepers should improve welfare assessment through practical implementation of the existing knowledge on welfare, using the best available evidence and expert opinions where this is lacking.

Emerging trends: breeding, technology, and innovation

The aquaculture industry has so far shown itself to be highly innovative, meaning it has been able to rapidly progress in recent years. This has supported a growth in the industry as well as improvements for animal health and welfare. For example, the use of well boats has revolutionised what can be achieved at sea, and improvements to feed mean producers can now expect a better than 1.1 conversion rate, improving efficiency.

Innovation is an important part of tackling sustainability challenges. Examples of emerging trends and future possibilities include:

- precision automated vaccination systems
- electrical stunning for humane slaughter
- stronger sea pens and mooring fixtures which can operate in open oceans rather than sea lochs
- new technology to allow for better collection of waste, such as semi-closed floating systems[66]

[64] Huntingford, F., Rey, S. and Quaggiotto, M.M., (2020) Behavioural fever, fish welfare and what farmers and fishers know. *Applied Animal Behaviour Science*, 231, p.105090
[65] Cerqueira, M., Millot, S., Castanheira, M.F., Félix, A.S., Silva, T., Oliveira, G.A., Oliveira, C.C., Martins, C.I.M. and Oliveira, R.F. (2017) Cognitive appraisal of environmental stimuli induces emotion-like states in fish. *Scientific reports,* 7, 13181.
[66] Eg BBC (2022) Scotland's first 'enclosed' salmon farm to open on Loch Long www.bbc.co.uk/news/uk-scotland-glasgow-

- new diagnostic tools, including biochemistry, swabs, and non-lethal testing
- improved monitoring methods, collection and use of data
- increased use of AI, robotics, and sensor technology
- water purification systems which could allow medicines to be used without discharge into the environment
- use of land-based recirculating aquaculture systems (RAS) for commercial production
- the Danish Model 3 recirculation farm
- research into key areas such as gill disease, fish feed sources and the likely impacts of climate change on fish farms

BVA supports the research and use of new technologies and innovative methods which improve the sustainability of the sector. It is important that these are employed carefully, with sufficient checks to ensure they do not compromise animal welfare. Veterinary professionals could play a vital role in ensuring welfare is protected as methods progress, so should educate themselves on new technologies to enable them to play a role in communicating them to the public, correcting misunderstandings and highlighting any risks.

Genetics and breeding

Domestication of UK aquaculture species is relatively recent and ongoing, with most of it happening within the last 100 years. There is a huge potential for genetic improvement in all fish species, and this is already a key part of sustainable production with the potential to have a huge impact on efficiency.

Global aquaculture is based on a diverse range of species compared with terrestrial systems, with tailored breeding programmes and technology needed for each species. High fecundity and predominately external fertilisation provides easy opportunities for managing genetics, and innovative genomic tools have led to significant progress for selection in all major species over the last decade. Almost all farmed salmon globally are derived from large and well-managed breeding programs which focus on balanced selection goals, eg targeting growth and robustness traits, and focussing on specific resistance to certain pathogens. Selective breeding has played a key and demonstrable role in improving fish welfare, for example via improved disease resistance, improving welfare directly and by reducing the need for stressful treatments.

Breeders can select for desirable traits from fish in different families, helping to maintain a greater range of genetic diversity within and across family groups, and allowing them to select for multiple traits to improve at the same time. Some commons traits that are selected for include:

- growth rate - as with terrestrial systems, most programmes target growth as this increases efficiency. They have been highly effective, for example, the growth rate for Tilapia has increased by 130% in 12 years whilst maintaining broad genetic variation
- disease resistance - especially for those which have no vaccine or treatment available. An early example of genetics being used to mitigate the impact of disease is Infectious Pancreatic Necrosis (IPN) in Atlantic salmon[67]. It was noted that a single allele of disease resistance provided sufficient protection, so all aquaculture companies quickly bred for this allele. This was the main factor in reducing mortality of fish from IPN. However, most disease resistance is affected by multiple alleles, making the process more complicated. Several studies have shown resistance to the main species of sea lice is moderately heritable, and many production companies are now using genetic selection as part of their toolkit to tackle this
- production efficiency including food conversion, adaptation to more sustainable diets, sterility and monosex populations are also important target traits

west-60156103 Accessed March 2023

[67] Houston R. and Bishop S. (2021) J: Genomics-enabled breeding for disease resistance prevents mortality and improves welfare in aquaculture. Impact case study for University of Edinburgh/Scotland's Rural College. www.ed.ac.uk/sites/default/files/atoms/files/uoa6_ics_j_salmon_genetics.pdf Accessed March 2023

- cross breeds and colour morphs may be bred, mainly for the fishing sector

This process is effective but gradual and has some limitations. New innovations offer intriguing possibilities, for example, non-invasive methods to identify, test and record desirable traits are being developed, which will enable breeding programmes to progress more quickly and make it possible to see how individuals with selected characteristics interact on a farm level. Selective breeding and genetic improvement could play a key role in tackling major sustainability challenges, but, as with any new innovations, it will be vital to proceed carefully to ensure development do not compromise fish welfare.

In addition to genetic improvement through selective breeding, there is growing interest in the concept of gene editing. This would involve an intervention to change the genomic sequence of an early-stage embryo, and could be used in one of three ways:

- increasing frequency of, or fixing desirable alleles
- introgression of desirable alleles from different populations or species
- creation of *de novo* alleles with desirable effects based on biology of traits

The regulatory environment around gene editing is evolving rapidly, and some tests can be conducted in a controlled environment to establish whether or not this is a useful tool. Research projects are taking place using all three approaches, with a major focus on disease prevention. A particular area of interest is the work to understand the methods by which some salmon species develop their resistance, eg Coho salmon (*Oncorhynchus kisutch*) and Pink salmon (*Oncorhynchus gorbuscha*), and to then use gene editing on a shortlisted set of genes to test if it improves resistance in Atlantic salmon.

This technology is still in its infancy and will require significant research to make it viable. It could potentially be a useful tool for tackling major sustainability issues in the future, but will first require public acceptance and changes in legislation. Researchers will need to show that the process does not have any negative impacts, including if genetically edited fish escaped and interacted with wild populations, and that it has demonstrable benefits to animal welfare before any progress can be made.

As with any new tools and technology, this must never be used as a substitute for good health and welfare. The veterinary profession should keep up to date with any new technologies in order to ensure they are used to benefit animal welfare rather than prop up poor systems.

Recommendations

Recommendation 40: Whilst BVA recognises the role of new technologies and innovative methods, particularly in the aquatic environment, in monitoring animal health and welfare outcomes, addressing animal health and welfare conditions and optimising the contribution of each fish to aquaculture systems, automatic systems should not replace either the regular assessment of welfare and behavioural needs by skilled veterinary professionals and keepers, or appropriate human interventions.

Recommendation 41: New technologies and innovative models used to improve the contribution of animals, be that in terms of the production of food, animal feed or environmental goods, must not compromise the welfare needs of the animals in question.

Recommendation 42: Members of the veterinary profession should educate themselves on new technologies to enable them to play a role in communicating them to the public, correcting misunderstandings and highlighting any risks.

Recommendation 43: Further consideration should be given to how breeding and genetics can be used in an ethically responsible way to improve animal health and welfare within sustainable aquaculture

Recommendation 44: BVA should highlight the benefits and risks of gene editing for animal welfare, to support evidence-based decisions over its potential future use.

Recommendation 45: Rigorous research should be undertaken to assess the safety of any new technologies which may benefit fish health and welfare or sustainable production.

Consumers and sustainable consumption of animal-derived products

As mentioned previously, there is significant public concern regarding the aquaculture industry, meaning the sector has often been criticised in recent years. Aquaculture is also a relatively new food production sector, and so societally is not as widely accepted as other forms of producing food may be.

Whilst there are undoubtedly many areas in which the sector needs to make improvements, as highlighted in this position paper, there have also been significant improvements in recent years which are often not well known outside the sector. This lack of understanding around aquaculture operations and the progress being made can be unhelpful. The aquaculture sector has become more transparent and collaborative in recent years, but still needs to improve communication with the public to dispel misconceptions, and engage with stakeholders on initiatives to tackle the challenges that exist. Veterinary professionals and organisations also have a role to play in educating others on current UK standards and advances in farmed fish welfare.

Though many environmental and welfare legal requirements impact aquaculture, one major concern is the current lack of clear regulation and legal baseline requirements designed to specifically protect fish being farmed in the UK. Existing regulations applicable to the sector are disjointed and need streamlining to improve sustainability, balancing social, economic and environmental aspects. Regulations also need to be sufficiently dynamic to reflect the best available evidence and stimulate innovation. Improved regulation would better protect both fish welfare and the environment, ensure all keepers reach a minimum level, drive improvements, and provide much needed reassurance to the public on how the industry operates.

We recognise that the UK aquaculture sector has adopted several industry-led codes of practice and assurance scheme standards to protect fish welfare[68,69,70], including The Code of Good Practice from Scottish Finfish Aquaculture and RSPCA Assured scheme for salmon and trout. Nearly all farmed salmon and a majority of trout producers adhere to voluntary standards, driven largely by demand from retail and consumers. The RSPCA welfare standards are generally accepted to be the best welfare standards currently available and therefore have been copied by organisations around the world. It is important to note that RSPCA and RSPCA Assured can, and do, investigate issues on accredited farms and can remove accreditation if there are significant welfare concerns, or serious breaches of the standards or scheme guidelines. The introduction of minimum legal standards would enable farm assurance schemes to offer standards above and beyond those requirements, which could further encourage producers to go above and beyond the minimum requirements in order to market their products.

Farmed fish as part of a sustainable human diet

Vets are a key stakeholder in food production and a key driver in the One Health agenda. As such, the profession has a role to play in influencing discussions around sustainable, healthy consumption and assessing the sustainability of demand-led production models. BVA notes and supports the Farm Animal Welfare Committee (FAWC)'s observations in this regard:

> "Rather than entailing ever-increasing production to satisfy consumer demand, consideration of sustainability should call into question demand-led developmental models. The per capita consumption and production of meat and animal products would need to fall, or at the very least, the rate of increase in their consumption and production would need to reduce, if these are to be sustainable, especially in the context of a growing global population. In this context, governments have a role in influencing consumer behaviour"[71].

[68] FAWC, (2014) Opinion on the welfare of farmed fish at the time of killing. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/319331/Opinion_on_the_welfare_of_farmed_fish_at_the_time_of_killing.pdf Accessed March 2023

[69] All members of the Scottish Salmon Producers Organisation (SSPO)_subscribe to The Code of Good Practice from Scottish Finfish Aquaculture

[70] RSPCA Assured state that around 70% of total Salmon production in Scotland is RSPCA Assured.

[71] FAWC (2016). Sustainable agriculture and animal welfare. www.gov.uk/government/uploads/system/uploads/attachment_data/file/593479/Advice_about_sustainable_agriculture_and_farm_animal_welfare_-_final_2016.pdf Accessed March 2023

It is important to recognise that fewer healthier and happier animals with better productivity have less of an impact at all levels compared to numerous animals with poorer health and welfare outcomes. Considering sustainable consumption and production together can therefore have a positive impact on animal welfare and provide an opportunity to drive consumer demand for high animal welfare products.

Within the context of One Health, the veterinary profession should promote the benefits of sustainable consumption, coupled with properly valuing quality animal-derived products, where quality encompasses good animal health and welfare, food safety, environmental protection, and fair returns for producers. In this way, the concept of "less and better" sees some citizens reducing consumption while maintaining proportional spend and directing this spend towards higher health and welfare products.

In many ways, aquaculture compares favourably with agriculture on sustainability metrics, with lower greenhouse gas emissions, use of nitrogen, phosphorus and fresh water, and land use per tonne of edible weight[72]. However, there is still room for improvement, such as around the sourcing of fish feed. Given the many differences it may be unwise to compare and contrast the aquaculture and agriculture sectors, but it is advisable to include both sectors when looking at how to sustainably feed the growing population. The language used and types of conversations taking place for the agriculture sector should also be used when considering aquaculture. Consumers should consider the fish they eat alongside other animal derived products as part of the "less and better" approach.

Recommendations

Recommendation 46: The aquaculture sector needs to improve communication with the public to dispel common misconceptions, and engage with stakeholders on initiatives to tackle the challenges that exist. Veterinary professionals and organisations also have a role to play in educating others on current UK standards and advances in farmed fish welfare.

Recommendation 47: UK governments urgently need to introduce clear, streamlined legislation which standardises the conditions in which fish can legally be farmed and provides confidence to consumers on minimum standards. Farm assurances schemes should then produce standards which go above and beyond the legislation and further improve conditions for fish and the environment.

Recommendation 48: Within the context of One Health, the veterinary profession should promote the benefits of sustainable consumption and the concept of "less and better", which sees some citizens reduce consumption of animal derived products, whilst maintaining proportional spend on high animal health and welfare products. The role of farmed fish should be considered as part of this sustainable diet.

Recommendation 49: The veterinary profession should promote the benefits of properly valuing quality animal-derived products, where quality encompasses good animal health and welfare, food safety, environmental protection and fair returns for producers.

[72] Poore, J. and Nemecek, T. (2018) Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), pp.987-992.