

insight

The UK Aquaculture industry

Outline

- + Aquaculture is the farming of aquatic animals or plants, but does not include capture fisheries. It can take place in a number of different systems; including freshwater, coastal, onshore and for the cultivation of micro and macro algae.
- + Globally, production from aquaculture is dominated by China and other Asian countries and the EU is a small player. In 2010, Asian countries accounted for 89% of world aquaculture. Total farm gate value of fish production from aquaculture worldwide was estimated to be US \$119.4bn in 2010.
- + The UK imports most of the fish it eats and exports most of what it catches. In 2012, seafood imports amounted to 752 thousand tonnes, worth £2.56bn. Foreign seafood markets greatly value UK species such as langoustine, crab and mackerel, while domestic consumers continue to focus mainly on a small range of species such as cod, salmon and haddock.
- + Fish are an efficient protein source, requiring lower feed inputs than terrestrial animals. This is because water supports the body and also fish are cold blooded, so energy is not required to maintain a high body temperature thereby enabling the feed conversion ratio (the amount of body weight gained for every kilogram of feed consumed) of fish to be higher than for terrestrial animals.
- + In the UK, fish feed for carnivorous fish (which includes salmon and trout) are largely comprised of both fishmeal (dried fish or fish by-products) and fish oil. Fishmeal and fish oil are becoming limiting in supply, so alternative ingredients are increasingly being used in the form of soy bean, protein concentrates and vegetable oils.
- + Technological developments are working to ensure aquaculture remains sustainable and has minimal environmental impacts. Developments include on-land recirculating aquaculture systems, offshore systems, aquaponic systems, advances in modelling of aquaculture impacts and the use of information technology.
- + Fish farms can cause environmental impacts, particularly if nutrients from feed or waste are released into the wider environment, if farmed fish escape or if other users of the coastal zone have to compete with fish farms. Regulations are in place to help prevent environmental impacts.

Global Food Security (GFS) is a multi-agency programme bringing together the main UK funders of research and training related to food. The GFS Insight series provides balanced analysis of food related research, for use by policy-makers and practitioners.



What is Aquaculture?

Aquaculture is the farming of aquatic animals or plants. It does not include capture fisheries, where wild fish are harvested from seas or from fresh water; however some aquaculture may depend, at least in part, on feed derived from wild-caught fish.¹ The total farm gate value of fish production from aquaculture worldwide was estimated to be US \$119.4 billion in 2010¹ and the industry continues to show strong growth, whilst capture fisheries are stagnant or declining. Aquaculture production has been growing faster than the rate of human population increase, and has the potential to contribute towards the increasing need for high quality animal protein to feed a growing world population.

What are the different types of aquaculture?

Aquaculture includes the production of finfish, shellfish and aquatic plants and can take place in the following systems or environments²:

- + **Freshwater systems** include freshwater ponds, tanks and cages. These range from static water ponds to high flow-through tanks.
- + **Coastal systems** include growing finfish in cages and pens, growing shellfish on the seabed, on trestles or suspended on ropes and nets and growing seaweed. The Crown Estate owns the majority of the seabed around the UK out to a 12 nautical mile limit, so fish and shellfish farming operations require a Crown Estate lease.³
- + **Shellfish production** takes place throughout the UK. Mussels and oysters are the principal farmed species, grown on

suspended ropes or racks⁴ and mostly require no feed inputs.²

- + **Onshore systems** include recirculation systems and integrated farming systems. In the UK, land recirculation sea water systems have been used to grow turbot and sea bass⁵ and warm fresh water systems have been used to grow tilapia⁶ commercially. The Scottish salmon sector is seeing increasing interest and investment in the use of recirculation systems, using these to produce freshwater salmon smolts.
- + **Micro and macro algae** cultivation may become increasingly important for bioenergy, food, feed products, nutraceuticals and substitutes for the petrochemicals industry in the future. Current micro algae products on the market include some pigments, omega-3 and -6 fatty acids, speciality food or feed items and for cosmetics. Macro-algae (i.e. seaweed) products include speciality food or feed and fertilisers.⁷

The Aquaculture industry

Globally, aquaculture production is dominated by China and other Asian countries and the EU is a small player.⁸ In 2010, Asian countries accounted for 89% of world aquaculture.¹

In the UK, marine finfish aquaculture is dominated by net-pen production of salmon in Scottish coastal waters, with a total production of 158 thousand tonnes, worth £584.7 million at

farm gate prices in 2011.⁹ In contrast, English finfish aquaculture has not developed to the same level, with only c. 8,000 tonnes of production (principally rainbow trout) in 2009- all from freshwater systems.⁹ Smaller amounts of other species are farmed in England and Wales, including halibut, sea bass, carp, sturgeon and tilapia. Shellfish farming takes place throughout the UK.

The UK imports most of the fish it eats and exports most of what it catches. In 2012, seafood imports amounted to 752 thousand tonnes, worth £2.56 billion.¹⁰ Foreign seafood markets greatly value UK species such as langoustine, crab and mackerel, while domestic consumers continue to focus mainly on a smaller range of species, such as cod, salmon and haddock.¹⁰ The 'Big Five' sea products consumed within the UK are cod, haddock, salmon, tuna and prawns.



The recent expansion of aquaculture

Globally, aquaculture is the fastest growing protein sector, with aquaculture production increasing at an average rate of 8.9% per year since 1970.¹¹ Increasing aquaculture production is in the Scottish Government's draft marine plan (2011) where the target is to increase marine finfish production by 50%, and shellfish by 100%¹² by 2020 from a 2011/2012 baseline. The Welsh Government, although administering a smaller industry, has set similar volume increase targets over the same time period. The UK is currently in the process of producing a Multiannual National Plan (MaNP) for the sustainable development of aquaculture.¹³

The drivers behind the global expansion of the industry have been:

- + The **health benefits** associated with eating fish and shellfish products,¹ such as reducing the risk of heart disease¹⁴, stroke, age related macular degeneration and mental health.¹⁵ The UK Health Departments recommend¹⁶¹⁷ eating at least 2 portions of fish per week, one of which should be oily, although current UK consumption falls short.
- + **Expanding markets** for exporters including, Europe, the USA and emerging economies, such as Brazil, Mexico, the Russian Federation, Egypt, China, Asia and the Near East in general.¹
- + An **increasing world population**. To maintain at least the current level of per-capita consumption of aquatic foods, the world will require an additional 23 million tonnes by 2020, which would have to largely come from aquaculture.¹
- + **Environmental pressures on land and wild fisheries** mean that there is going to be little, or no, new land for agriculture¹⁸ and wild fisheries are also stagnant or in decline.
- + Fish are an **efficient protein source**, requiring lower feed inputs than terrestrial animals. This is because water supports the body and also fish are cold blooded so energy is not required to maintain a high body temperature thereby enabling the feed conversion ratio (the amount of body weight gained for every kilogram of feed consumed) of fish to be higher than for terrestrial animals.¹⁹



Aquaculture policy across the UK

Within the UK, the aquaculture industry is a devolved responsibility, with strategies existing in Scotland²⁰ and Wales²¹. In 2009 a review²² was commissioned by Defra to investigate the potential for aquaculture in the UK to address food security concerns and the UK is also in the process of producing a Multiannual National Plan (MaNP) for the sustainable development of aquaculture.¹³ Defra has outlined aquaculture measures to be supported for funding through the European Maritime and Fisheries Fund (EMFF) in the MaNP.

Aquaculture and the role of research

The aquaculture industry is a relatively new industry in the UK. Trout farming expanded in the 1960's and 70's with salmon farming growing rapidly since the 1980's. The industry is diverse, both in the types of species grown and business operation. It is however highly technical, and sometimes fragmented, with varied research needs as outlined below.

Fish nutrition

In the UK, fish feeds for carnivorous fish (which includes salmon and trout) are largely comprised of both fishmeal (dried fish or fish by-products) and fish oil. Fish oil is necessary to satisfy the nutritional requirements of both the fish and consumers. Both fishmeal and fish oil are finite resources and, with the expanding aquaculture sector, their supply is becoming increasingly limited and subsequently unsustainable.

Alternative ingredients are now being used in the form of soya bean, protein concentrates and vegetable oils. Fish nutrition is a growing research area and research programmes have included:

- + **Improving the digestibility of diets to maintain the welfare of fish.** When carnivorous species are fed on vegetable diets there is some evidence suggesting that this may impact on fish health. For example, unrefined soybean can induce enteritis in salmon.²
- + **Oilseed crops** that contain fish oil omega-3 fatty acids in their seeds have been developed²³. The plant *Camelina sativa* has been genetically modified with algal genes to produce fish oil omega-3 fatty acids that can be put into fish feed. Nutritional trials on Atlantic salmon are currently taking place.²⁴
- + **"Beans4feeds"** is a £2.4 million industry led project, investigating whether a low cost process can separate faba (broad) beans into a protein concentrate for salmon feeds and a starch concentrate for use in pig and poultry feeds²⁴. Faba beans may be able to replace a significant proportion of imported soybean products, increasing environmental sustainability.

Disease and health management

Disease can be a major problem for aquaculture, because these systems tend to hold high numbers of animals in relatively open systems. Water movement can provide a route for disease transmission between wild and farmed fish. There



have been many technological advances during the relatively short period of time aquaculture has been in development and these have included:

- + **Vaccines** have been very effective for bacterial pathogens, where they have almost eliminated the need for antibiotics, but they are more limited for viral pathogens. Methods include injection, immersion, spray and oral vaccination.²⁵
- + **Wrasse and lumpsuckers** are cleaner fish which naturally predate parasites on the skin surface (e.g. sea lice) and remove them. Scottish salmon producers and scientists have been awarded £2.1m co-funding from the Technology Strategy Board (TSB), to develop technologies to breed and grow commercially viable numbers of wrasse.²⁶
- + **Functional feeds**, such as different feed ingredients, probiotics and prebiotics may be used to enhance fish welfare by enhancing the fish immune systems and thereby improving disease resistance, growth performance and body composition, reducing malformations and improving gut microbial balance.^{27,2}

Breeding programmes

As aquaculture is a relatively young industry, the majority of aquaculture production comes from wild or recently domesticated stocks and desired traits have therefore not been selected over long periods. Selective breeding programmes have been shown to improve traits, such as growth, disease resistance and delays in the onset of sexual maturation.²

The following are examples of research and development to improve breeding programmes and fish traits:

- + **Trait selection for fast growth** has been taking place in the trout sector for at least four decades and more recently, strain selection has occurred in the salmon sector. Many salmon companies have selection programmes for fast growth.
- + **Genetic chips** can detect variations in the genetic make-up of individual fish, making it possible to identify genes that are linked to desirable traits, such as growth rate or resistance to diseases. In 2014 a chip was developed which carries over twenty times more genetic information than previous chips and can be used easily by salmon farmers by taking a sample of fin tissue.³⁵

- + **Triploid induction** (fish with three sets of chromosomes instead of two) has been used to produce sterile fish, which pose no threat to wild fish by interbreeding if they escape. It is carried out by exerting either temperature or pressure shocks on the eggs. This is a non-chemical, non-GM method of producing sterile fish (reducing the risk posed by escapees) and can have additional benefits such as lowered disease risk, larger size and wider harvest windows.³⁴
- + **Genetically modified salmon** in the US have been developed to grow twice as fast as unaltered salmon.³⁷ The Food and Drug Administration (FDA) has declared 'AquaAdvantage'³⁸ salmon safe to eat and the company is now seeking to approval to sell the salmon in the US.

Top disease threats in UK Aquaculture

Some of the major diseases affecting the aquaculture industry in the UK include:

- + **Sea lice**, which, if uncontrolled, can damage the skin of fish and compromise welfare. Medicines and wrasse can be used as control methods and vaccination has been proposed, although none have currently been licensed.²⁹ A £1.5m four-year project is currently being funded by the TSB for a consortium to develop a vaccine.³⁰
- + **Infectious salmon anaemia (ISA)** is an infectious viral disease of Atlantic salmon. ISA occurred on 2 separate occasions in the UK. In 1998 and 2008. In both occasions the disease was eradicated and the UK, is free of ISA disease. ISA is a notifiable disease in the UK, with no treatments or licensed vaccines in the EU.³⁰
- + **Infectious pancreatic necrosis (IPN)** is an infectious viral disease that affects numerous species of fish. Recently, vaccines have been developed against IPN.
- + **Amoebic gill disease (AGD)** is a parasite which causes the cell layer on the gill surface to thicken, reducing the amount of oxygen the fish can take up. There are no current veterinary medicines for this condition although treatment with fresh water or hydrogen peroxide both have some efficacy. Avoiding stress can also mitigate the effects of gill disease.³²
- + **Shellfish** can pose a human health risk as they can carry a number of diseases, including Norovirus.^{31 32}

Environmental impacts of Aquaculture

Aquaculture based fisheries can have detrimental ecological impacts, although regulations are in place to minimise this.² Potential detrimental environmental impacts include:

- + **Nutrients released from fish farms** (nitrogen and phosphorus from feed and waste) can enhance the growth of marine plants. Feed and faeces can also collect on the sea bed under fish pens, impacting on the sea floor environment⁴⁴, however models are used to predict such impacts and the size of the site is restricted accordingly. Increasingly fish farms are being moved to more exposed coastal waters, where any impacts can be more effectively managed.
- + **Escaped farmed fish** which compete for territory and food with wild fish may also alter the wild fish gene pool, although this is species specific (i.e. valid for Atlantic salmon but not rainbow trout). There will also be a flow of parasites between farmed and wild fish, which can detrimentally effect the environment.⁴⁴ In Scotland, the Aquaculture and Fisheries (Scotland) Act (2007) requires the reporting of escapes and the implementation of measures to contain fish and control sea lice.
- + **Competition with other users** may occur in coastal zones, such as boating and navigation, recreation, preservation of seascape scenery and protection of wildlife. In Europe, these issues are considered during the licensing process or increasingly through the development of coastal zone plans.²

Climate change is likely to lead to changes to the marine environment over the next 50 years, although there is currently little evidence of impacts on aquaculture that can be attributed to climate change⁴⁵. Higher water temperatures may lead to enhanced growth rates or thermal stress for some species. New species may also be able to be grown in UK waters, such as sea bass, bream and abalone. Harmful algal blooms may increase in frequency, with the risk that toxins could enter the food chain. Pathogens may also become a concern, because of changes to water temperature and more torrential rain and storm flow events causing discharge from land to enter aquaculture farms.¹ Ocean acidification associated with climate change may have impacts on shellfish farming by influencing shell formation.

Advances in technology

To ensure that aquaculture remains sustainable and has minimal negative environmental impact, the aquaculture sector is increasingly developing specialist new technologies.²

- + **Recirculating aquaculture systems (RAS)** are land-based systems which use tanks or raceways supplied with flowing water that replenishes oxygen and removes metabolic wastes and uneaten feed. In RAS, some or all of the water is reused after treatment. In the UK, tilapia⁶, sea bass⁵ and juvenile freshwater salmon are currently being produced using RAS.
- + **Offshore systems** operate at more than 2 km from shore and compared to near-shore systems, can minimise negative visual and environmental impacts, resolve issues of space constraints and reduce predation or disease risks.² Challenges include large ocean swells, winds, reduced physical accessibility and the need for remote monitoring.²
- + **Integrated multi-trophic aquaculture (IMTA)** systems recycle the by-products from one species (i.e. unused food, nutrients and energy) to become inputs for another, so that a range of species are being farmed at the same site (for example, seaweed, shellfish and finfish). Pilot projects have been developed in Scotland: the most extensive is in Loch Fyne.³⁷



- + **Aquaponic systems** are increasing in popularity in developing countries, where small scale systems are being developed. These systems combine freshwater aquaculture in a recirculated system, with hydroponic horticulture, usually herbs and salad vegetables. The horticultural crop is mostly fertilized by the nitrogen waste from fish culture.²

- + **Information technology** advances are leading to improved monitoring and control systems and better

Recirculating technology – the Danish model

In Denmark, many traditional fish farms have been rebuilt into farms that use recirculation technology. Currently around 50% of the Danish production of trout in fresh water takes place using these systems.⁴⁷ The benefits of these farms include lower water intake per Kg fish produced, as well as reduced environmental impact.⁴⁷ The driving force behind changes in the strategy for Danish production of rainbow trout, is strict environmental legislation and implementation of the EU Water Framework Directive, which sets water quality standards. Future research could indicate whether existing trout farms in the UK could be converted to recirculation⁴⁸.

real time information for managers. The development of micro-sensors combined with electronic tags is opening up possibilities for data collection from individual fish within an aquaculture environment.²

- + **Modelling the impacts** of traditional net-pen aquaculture in coastal zones is a requirement for obtaining a consent from the Scottish Environmental Protection Agency (SEPA) (using DEPMOD and AutoDEPOMOD)³⁸ to ensure that farms operate within environmental carrying capacity.
- + **Micro-algae** for high value chemicals (e.g. fuel, plastics and health products), may be cultivated in land-based ponds or photobioreactors (a type of translucent tube, fed with nutrient rich water and carbon dioxide, with a light source). PBRs are not currently commercially viable, but research programmes are being developed towards this goal.³⁹
- + **Macro-algae** cultivation (such as the seaweed kelp) for food and industrial chemicals is a major industry in parts of Asia. For example, Japanese kelp is reported⁴⁰ to be China's top aquaculture species (over 4 M tonnes in 2005). The Crown Estate has an on-going programme to develop macroalgae production across the UK and the Scottish Association for Marine Sciences is leading a consortium to develop technology to farm two species of seaweed.⁴¹

References

- 1 FAO. The State of World Fisheries and Aquaculture 2012. (2012).
- 2 Bostock, J. et al. Phil. Trans. Royal Soc. B 365, 2897-2912, doi:10.1098/rstb.2010.0170 (2010).
- 3 The Crown Estate, Aquaculture, www.thecrownestate.co.uk/coastal/aquaculture/, (2014).
- 4 Cefas. Shellfish News. (2012).
- 5 Anglesey Aquaculture. Fish Farm Technology, www.angleseyaquaculture.com/fish-farm-technology/, (2014).
- 6 Jeffery, K., et al. FES220L A review of the land-based, warm-water recirculation fish farm sector in England and Wales. (2011).
- 7 BBSRC. Algal Research in the UK. (2011).
- 8 STECF. The Economic Performance of the EU Aquaculture Sector -2012 exercise (STECF - 13 -03). (2012).
- 9 Cefas. English marine finfish project: aquaculture operators being sought. (2013).
- 10 SEAFISH, Market summary, www.seafish.org/research--economics/market-insight/market-summary#retail-sector, (2014).
- 11 FAO. State of World Fisheries and Aquaculture. Rome.(2004).
- 12 Scottish Government. Scotland's National Marine Plan Pre-consultation draft. (2011).
- 13 Defra. United Kingdom Multiannual National Plan for the Development of Sustainable Aquaculture. (2014).
- 14 Mozaffarian, D. & Rimm, E. B. Jama-Journal of the American Medical Association 296, 1885-1899, doi:10.1001/jama.296.15.1885 (2006).
- 15 Peet, M. & Stokes, C. Drugs 65, 1051-1059, doi:10.2165/00003495-200565080-00002 (2005).
- 16 Sacn. Advice on fish consumption: benefits and risks. Joint report by the Scientific Advisory Committee on Nutrition and Committee on Toxicity. (2004).
- 17 NHS choices. Fish and Shellfish, www.nhs.uk/Livewell/Goodfood/Pages/fish-shellfish.aspx, (2011).
- 18 Foresight. The Future of Food and Farming. (2011).
- 19 Ytrestoyl, T., et al. Use of resources in salmon production compared to other livestock production. Fish farming xpert 4 (2012).
- 20 The Scottish Government, A Fresh Start: The renewed Strategic Framework for Scottish Aquaculture. (2009).
- 21 Welsh Assembly Government. Wales Fisheries Strategy. (2008).
- 22 Defra. UK Aquaculture R&D Database Strategic Summary 1999 - 2009. (2009).
- 23 Ruiz-Lopez et al. The Plant Journal 77, 198-208 (2014).
- 24 Bell, J. & Tocher, D. Novel Ingredients for aquafeeds to improve sustainability and security of supply. Fishfarming xpert 4 (2012).
- 25 McLoughlin, M. Fish Vaccination - A brief overview, www.imb.ie/images/uploaded/documents/Fish%2520Vaccine%2520Overview.pdf&sa=U&ei=drpCU5j3JeSU7QaklYDQCw&ved=0CCoQFjAD&usg=AFQjCNG8LZiVw3y28VOWWMy8btimIU_A (2014).
- 26 Univeristy of Stirling. Farmed wrasse as a "green" sustainable sea lice control solution for Scottish farmed salmon. (2011).
- 27 Merrifield, D. et al. Aquaculture 302, 1-18 (2010).
- 28 The Fish Site Sea Lice, www.thefishsite.com/diseaseinfo/9/sea-lice, (2014).
- 29 Harvey, J. Zoetis sea live vaccine project as 'Holy Grail'. Animal Pharm News (2013).
- 30 The Fish Site, T. F. Infectious Salmon Anaemia (ISA), www.thefishsite.com/diseaseinfo/5/infectious-salmon-anaemia-isa, (2014).
- 31 Cefas. Norovirus, www.cefas.defra.gov.uk/our-services/testing-services/cefasshellfish-testing/norovirus.aspx, (2011).
- 32 Public Health England, Shellfish consumption and the risk of norovirus infection, www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/Norovirus/oysterconsumptionnorovirus/, (2011).
- 33 Houston, R. et al. Development and validation of a high density SNP genotyping array for Atlantic salmon (*Salmo salar*). (2014).
- 34 Migaud, H., et al. Sterile salmon: toward a more sustainable and eco-friendly industry. Fish Farmer (2008).
- 35 Ledford, H. Nature 497 (2013).
- 36 AquaBounty Technologies. AquaBounty Technologies, <<http://www.aquabounty.com/>> (2014).
- 37 LochFyne. Integrated Aquaculture, www.lochfyne.com/about/integrated-aquaculture/ (2014).
- 38 SAMS. DEPOMOD, www.sams.ac.uk/kenny-black/depomod, (2014).
- 39 University of Greenwich. www2.gre.ac.uk/about/news/articles/2013/a2816-algae-research-gives-hope-for-renewable-carbon-negative-source-of-food-and-medicines, (2014).
- 40 FAO. Aquaculture in China and Asia fact sheet. (2007).
- 41 BBSRC. £4M for Agricultural Innovation, www.bbsrc.ac.uk/news/food-security/2014/140328-pr-4m-for-agricultural-innovation.aspx, (2014).
- 42 Jokumsen, A. & Svendsen, L. Farming of Freshwater Rainbow Trout in Denmark. (2010).
- 43 Jeffery, K. An Overview of English Aquaculture (Cefas, 2011).
- 44 Marsden, K. SPICe Briefing 12/68, (2012).
- 45 Gubbins, M. et al. MCCIP Science Review, 318-327 (2013).
- 46 Shellfish Association of Great Britain, EFF Project - Shellfish Aquaculture in Welsh Offshore Wind farms - Co -location Potential, (2012).
- 47 Addison, J. & Bannister, C. Re-stocking and enhancement of clawed lobster stocks: A review. Crustaceana 67 (1994).
- 48 The National Lobster Hatchery. The National Lobster Hatchery, www.nationallobsterhatchery.co.uk/, (2014).



Partners



Affiliates



This review has been prepared by the science writer for the GFS programme, Theresa Meacham, and provides a representation of the current state of knowledge in a particular area. The review will help to inform policy and practice, which is based on a wide variety of factors, including evidence from research. The review does not necessarily reflect the policy positions of individual partners.

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