Scientific Backgrounder (September 2018)

Secret Filming Inside Scottish Salmon Farms

- Diseases, Deformities & Wild Fish Interactions

SCOTTISH SALMON WATCH DISEASES

SCOTTISH SALMON WATCH DEFORMITIES

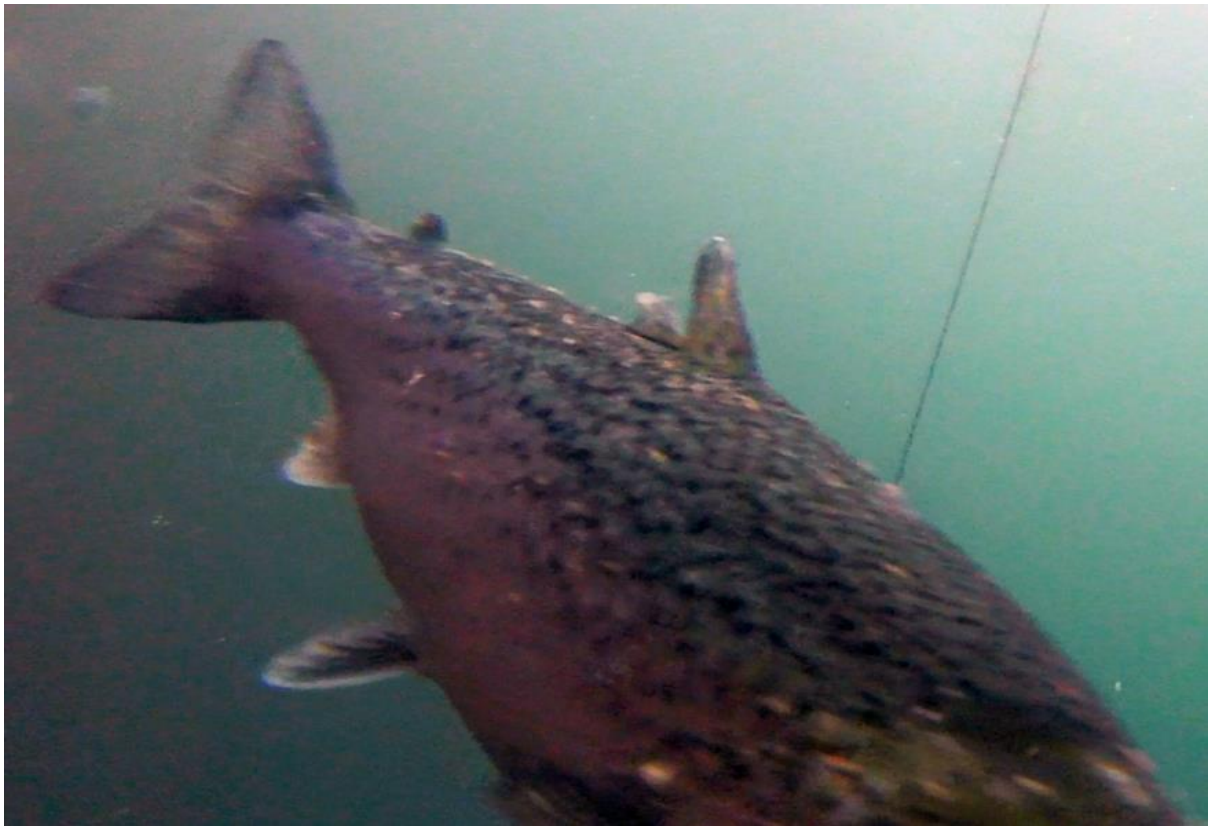
SCOTTISH SALMON WATCH LICE

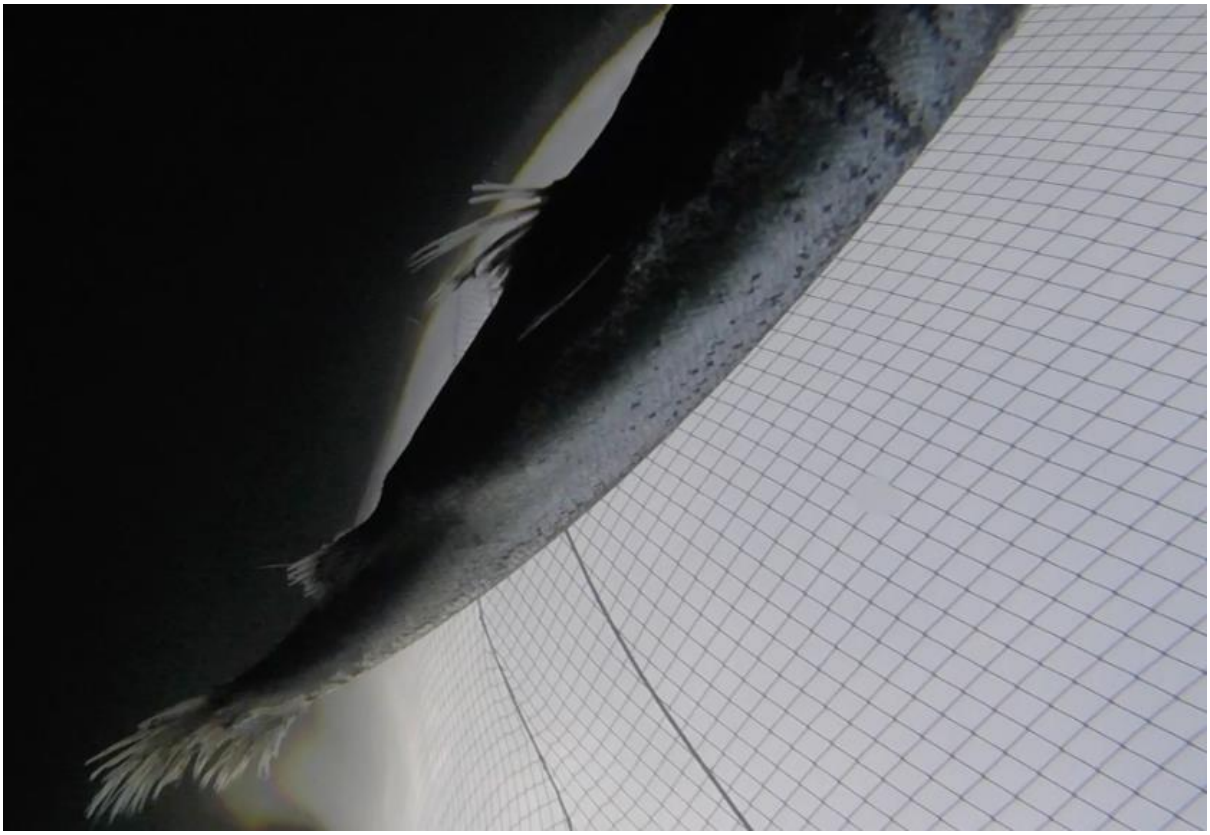
Secret filming inside salmon farms in Scotland during July and August 2018 revealed damning video footage of diseases and deformities in farmed salmon as well as lice-infestation of lumpsuckers (so-called 'cleaner fish') and wild fish such as saithe living inside the cages alongside farmed salmon.

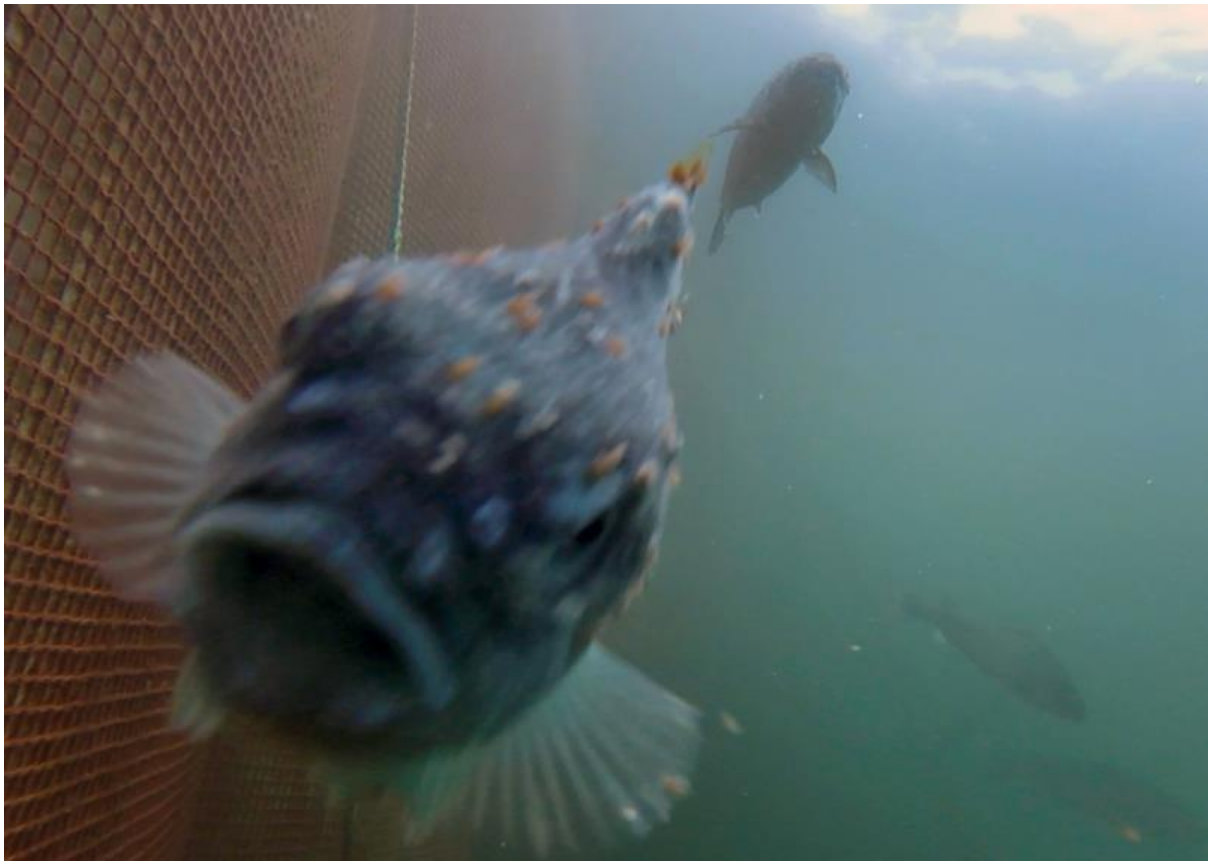
This backgrounder provides further scientific context to the findings.

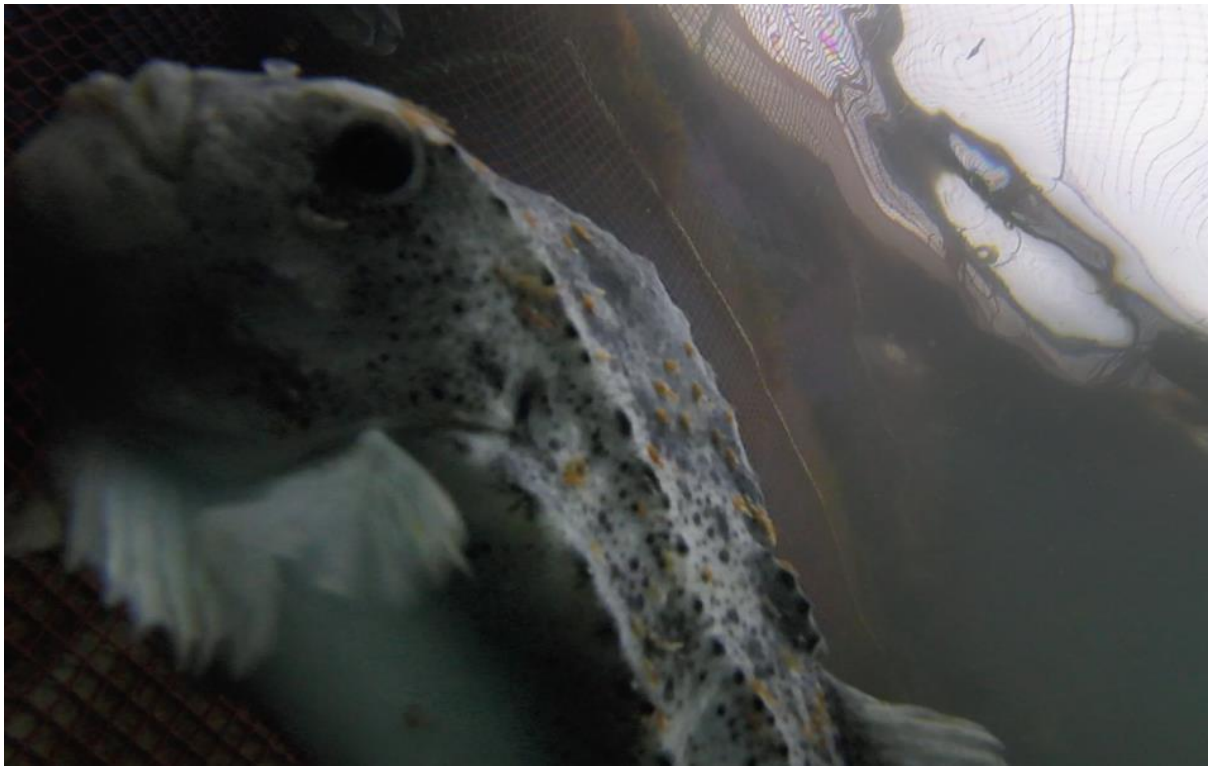
Diseases:

The secret video footage showed farmed salmon (as well as so-called 'cleaner fish') infested with parasites called lice and in poor condition due to unknown disease agents.



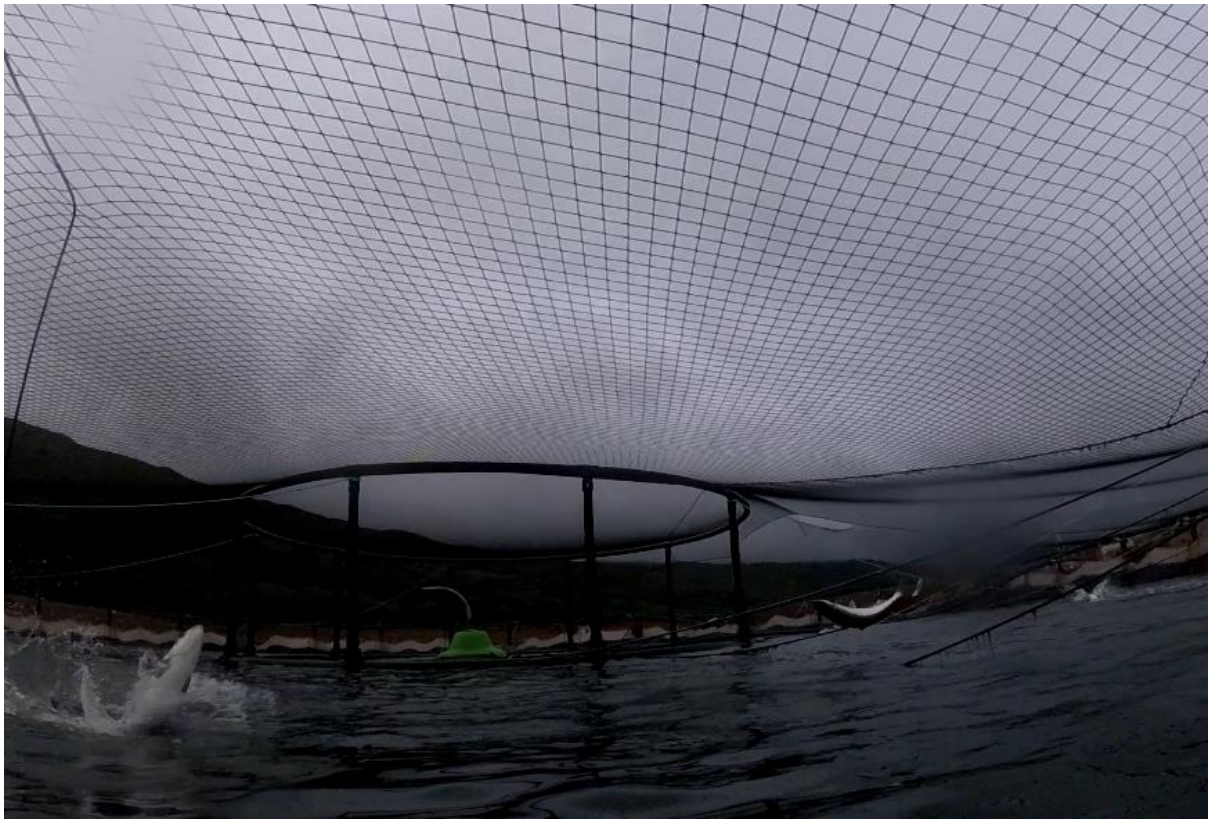


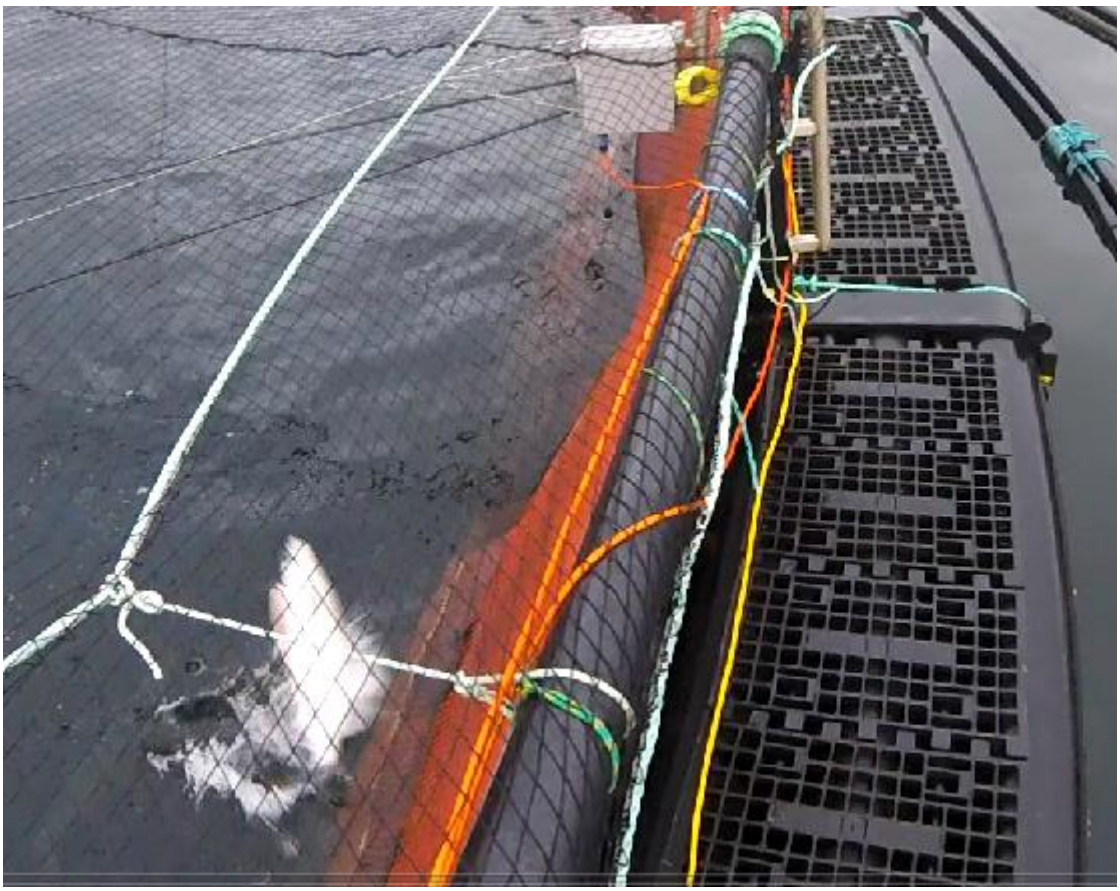




Download high resolution photos [online here]

The secret video footage showed farmed salmon leaping out of the cages - sometimes banging into feed pipes and into the sides of the cages.





Scientific research published in June 2018 revealed that salmon may jump out of water to remove sea lice. The researchers found that, on average, the salmon that were allowed to

leap in the uncovered pen had 22 per cent fewer sea lice compared to those that weren't allowed to leap in the covered pen. The researchers also found that it may take more than 50 leaps for a young salmon to dislodge a sea lice.

Read more via:

"Oust the louse: leaping behaviour removes sea lice from wild juvenile sockeye salmon *Oncorhynchus nerka*" (Journal of Fish Biology, 2018)

The Star Vancouver reported in August 2018:

THE STAR VANCOUVER

Vancouver

Shake it off: it takes young salmon 50 jumps to dislodge one sea louse

By **WANYEE LI** StarMetro Vancouver
Mon., Aug. 13, 2018

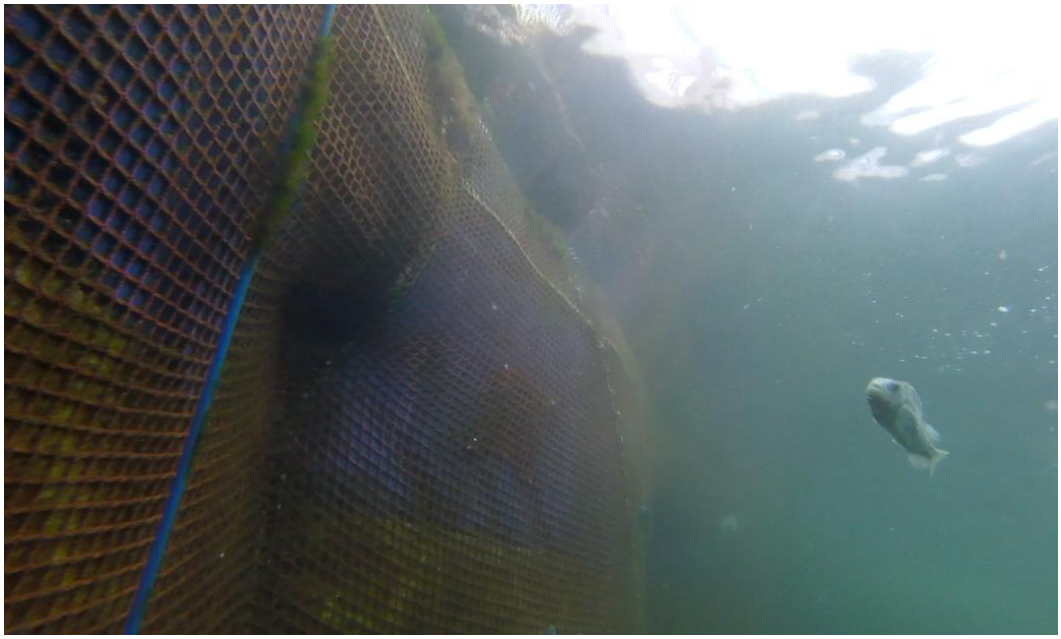
VANCOUVER—Lice can be a stubborn problem to shake off, even for fish.

It takes juvenile salmon an average of 50 leaps out of the waters to dislodge just one sea louse, according to new study from Simon Fraser University.

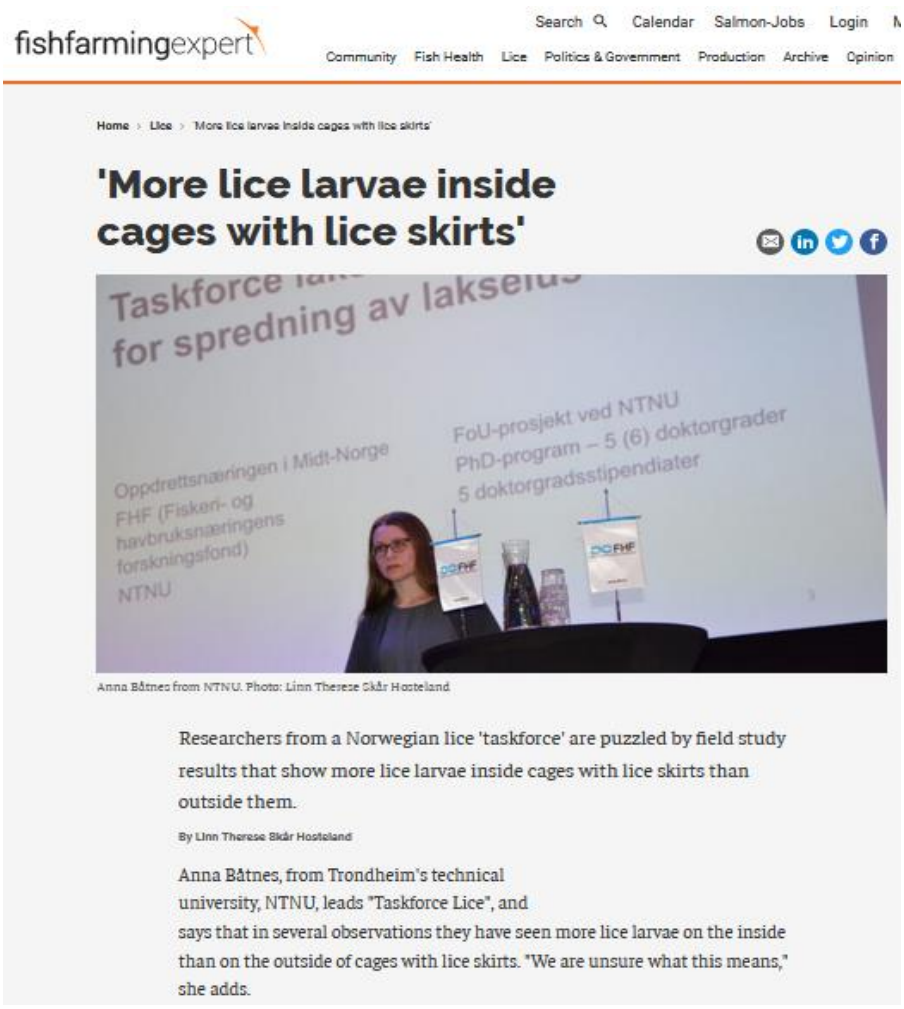
Read more via:

"Shake it off: it takes young salmon 50 jumps to dislodge one sea louse"
"Young salmon may leap to 'oust the louse'"
"Why are these salmon jumping?"
"Can salmon "leap away" their lice?"

The secret video footage showed tarpaulins surrounding the salmon cages in Loch Spelve (Scottish Sea Farms) - perhaps ready for a chemical treatment or so-called 'lice skirts'.



Scientific research in Norway has shown how lice skirts may not be the panacea for lice. Fish Farming Expert [reported in January 2018]():



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Home › Lice › More lice larvae inside cages with lice skirts'

'More lice larvae inside cages with lice skirts'

Anna Båtnes from NTNU. Photo: Linn Therese Skår Hosteland

Researchers from a Norwegian lice 'taskforce' are puzzled by field study results that show more lice larvae inside cages with lice skirts than outside them.

By Linn Therese Skår Hosteland

Anna Båtnes, from Trondheim's technical university, NTNU, leads "Taskforce Lice", and says that in several observations they have seen more lice larvae on the inside than on the outside of cages with lice skirts. "We are unsure what this means," she adds.

Read more via "'More lice larvae inside cages with lice skirts'"

Conversely, other scientific research published in March 2018 reported that:

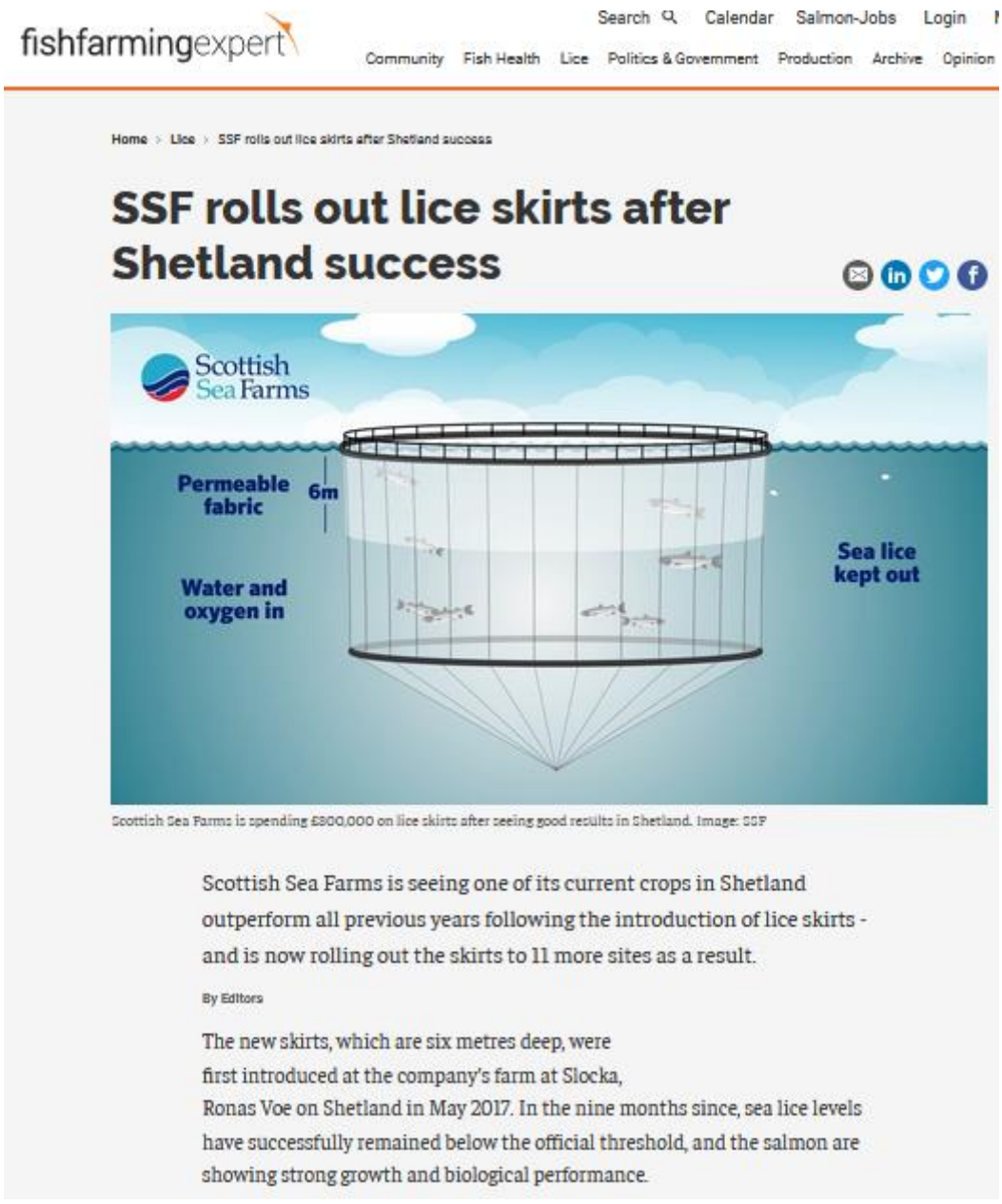
"Skirts around standard sea cages reduced salmon lice infection by 80%".

Read more via "Skirts on salmon production cages reduced salmon lice infestations without affecting fish welfare" (Aquaculture, 2018)

Scientific research published in 2012 reported that: "Putting a tarpaulin skirt around a full scale commercial sea cage may seriously decrease the oxygen saturation levels available for the fish inside the skirt."

Read more via "Skirt around a salmon sea cage to reduce infestation of salmon lice resulted in low oxygen levels" (Aquaculture Engineering, 2012)

Fish Farming Expert reported in February 2018:



> Such has been the effectiveness of the skirts that Scottish Sea Farms has now invested over £800,000 with two Scottish suppliers – William Milne Tarpaulins in Aberdeen and W&J Knox in Ayrshire – in order to roll-out similar protection to 11 of its other farms in Shetland and the west coast.

Read more via:

"SSF rolls out lice skirts after Shetland success"
"Why Scottish salmon farmers love skirts"
"How do environmental conditions affect lice skirts?"

The presence of lice-infested cleaner-fish inside salmon farms raises alarm bells and runs counter to claims by the salmon farming industry that lumpsuckers reduce lice burdens by up to 70 per cent.

Read more via:

"Curious-looking lumpfish proving its worth in fight against sea lice"
"Healthy lumpfish to the rescue of farmed salmon?"
"Cute Little Suckers: Meet the lumpsucker, the adorable fish revolutionizing salmon farming"
"Breeding 'super lice eater' lumpsuckers"
"How Effective are Lumpfish in the Fight Against Sea Lice?"
"New promise in sea lice-eating lumpfish"

A scientific paper published in 2017 reported:

Disease management

As with any new species in aquaculture, the extent and incidence of infectious diseases such as the intranuclear microsporidian, *Nucleospora cyclopteri* (Mullins *et al*. 1994; Freeman *et al*. 2013), and the risks they may pose for Atlantic salmon, need to be addressed. It is not known to what extent lumpfish are susceptible to diseases listed in current aquatic animal health regulations, and this needs to be reviewed as a risk to the developing cleaner fish industry. For example, IPN and VHS have both been detected in farmed lumpfish (Anon 2015a; Towers 2015), and there have been recent instances of atypical Furunculosis, Pasteurellosis, Vibriosis and bacterial gill disease (Cockerill & Wallis 2015). Lumpfish have displayed specific antibodies upon immunization (Haugland *et al*. 2016ba) and shown a significant role for phagocytic B cells in their innate immunity, suggesting that vaccination will likely confer protection against some infectious pathogens (Rønneseth *et al*. 2015). The development of vaccines for certified, disease-free production of juveniles is thus a research priority and some recent progress has been made with autologous vaccines (Cockerill & Wallis 2015; Rønneseth *et al*. 2016) although the highly variable nature of bacterial strains isolated from fish farms may complicate the development of full-scale vaccine trials (Gulla *et al*. 2015). Information on some common diseases of lumpfish is reviewed below.

Fungal infections

Fungal infection is a common disease of adult lumpfish in captivity and can be a major cause of mortality. For example, at a Scottish marine hatchery, fungal infection caused up to 45% losses in hatchery-reared broodstock over 2 years (J.W. Treasurer, pers. comm. 2016). Several species of fungi were probably involved, but those belonging to the genus *Exophiala* appear to be the most common. These cause systemic hyphal growth in the musculature, gills and internal organs, which are often manifested externally by the presence of large, dark lesions. *Exophiala* infection has also been recorded among wild-caught lumpfish, which may need to be quarantined for several weeks. The source of infection, whether in the feed or in the environment, has not been identified. Treatment of *Exophiala* has been attempted via 200 ppm formalin and bronopol baths 25 ppm active for 30 min. However, treatment has not always been successful, and culling of heavily infected fish is recommended. Given the likely future restrictions on the use of formalin in fish farming (CEFAS 2016), control of fungal diseases is expected to become increasingly challenging until new treatments are developed.

Amoebic gill disease

Amoebic gill disease (AGD) is attributed to amoebae of several species, but in salmon and lumpfish, *Paramoeba perurans* is the main species (Adams *et al*. 2012; Powell *et al*. 2015b). Amoebae feed on organic matter on the fish gills, and they can build up to such high numbers that can cause gill necrosis, fusion of lamellae, respiratory distress and eventually mortality through asphyxiation. AGD is common in farmed salmon in northern Europe and also affects ballan wrasse and lumpfish, having caused lumpfish mortalities in the UK (Cockerill & Wallis 2015; Perry & Treasurer 2015) and Norway (Breck 2015). AGD can be controlled with hydrogen peroxide (Adams *et al*. 2012), but this can be very harsh on the fish. At Ardtoe, lumpfish appear tolerant of freshwater exposure, and the administration of freshwater baths for 3–5 h, or the continuous exposure to 15 ppt brackish water over 7–10 days have both been effective (Perry & Treasurer 2015).

Bacterial diseases

Since 2012, lumpfish across hatcheries and deployment sites in Norway have frequently shown signs of systemic bacterial infection, these being characterized by skin lesions, gill haemorrhages, and bacterial aggregations in the heart and spleen (Alarcón *et al*. 2016). The isolates were similar to *Pasteurella* sp. previously associated with systemic infection in farmed Atlantic salmon in Norway and Scotland, posing the possibility that the infection was transmitted from salmon to lumpfish. As the culture of lumpfish expands, other bacterial diseases present in Atlantic salmon and wrasse are also being detected in lumpfish. In addition to *Pasteurella* sp., there have been recent reports of *Vibrio anguillarum*, *Vibrio ordalii*, *Aeromonas salmonicida*, *Pseudomonas anguilliseptica*, *Moritella viscosa* and *Tenacibaculum maritimum* (Poppe *et al*. 2012, 2013; Johansen 2013; Marcos-López *et al*. 2013; Breiland *et al*. 2014; Hjeltnes 2014; Bornø & Lie 2015; Cockerill & Wallis 2015; Alarcón *et al*. 2016; Bornø *et al*. 2016; Gulla *et al*. 2016; Småge *et al*. 2016). The significance of other common bacterial pathogens such as *Aliivibrio logei*, *Aliivibrio wodanis*, *Vibrio tapetis* and *Vibrio splendidus* is unclear (Gulla *et al*. 2015; Bornø *et al*. 2016). As the cleaner fish industry intensifies and the number of lumpfish in close contact with salmon increases, other bacterial pathogens will no doubt be detected.

Sea-lice

Lumpfish appear to suffer from a high prevalence and severity of parasitization by sea-lice, particularly *C. elongatus*, raising potential concerns about transmission to hatchery-reared juveniles, and to farmed salmon after deployment in sea cages. In the North Sea, prevalence of *C. elongatus* among lumpfish was 100% (Boxshall 1974) with a mean of 23 copepods/fish. However, this copepod is a generalist, recorded on 25 of 62 fish species investigated in that study. A more recent study in Norway found that lumpfish was the species most commonly infected with *C. elongatus* (prevalence = 61%, mean 4 copepods/ind.) out of 28 coastal fish species investigated (Heuch *et al*. 2007). Mature lumpfish, caught inshore, had higher levels of sea-lice infestation than immature fish and were infected with *C. elongatus* of exclusively 'type 1' genotype (from mitochondrial cytochrome C oxidase DNA), in contrast to immature lumpfish, which were caught further offshore, and were also infected with *ca*. 10% of 'type II' genotype, which is the type associated with farmed salmon. Lumpfish are thought to act as important reservoirs for type I *C. elongatus*, potentially transmitting it to other species (Øines & Heuch 2005, 2007; Øines *et al*. 2007). However, although not proved conclusively, those studies suggest that deployed lumpfish are unlikely to be the main source of type II *C. elongatus* which precipitates late summer infestations in farmed salmon, although they may pose a transmission risk to farmed cod. Also, wild lumpfish do not appear to be attracted to salmon cages (Mitamura *et al*. 2007, 2012), suggesting there is reduced potential for wild fish to act as disease vectors via horizontal transmission. At CSAR, several steps are taken to minimize the potential risk of transferring *C. elongatus* from wild-caught lumpfish broodstock to hatchery-reared juveniles, including treating incoming broodstock with freshwater baths, quarantining, physical system separation of broodstock and larvae, and the use of targeted medications such as *emamectin*.

Caligus is typically the most common sea-lice present in lumpfish, but several other parasitic copepods may also be present at lower prevalence. For example, Boxshall (1974) found that 36% of lumpfish presented a low abundance (less than 1 parasite/ind.) of the generalist copepod *Bomolochus confusus*. Another sea louse, *Lernaeocera branchialis* ('cod louse'), was commonly observed on the gills of lumpfish, which acted as an intermediate host prior to its two final hosts, the Atlantic cod (*Gadus morhua*) and the Greenland cod (*Gadus ogac*) (Templeman *et al*. 1976). Ranched cod seem to have a high prevalence of *L. branchialis*, apparently resulting from transmission by lumpfish (Khan *et al*. 1990). To our knowledge, there are no records of the salmon louse, *Lepeophtheirus salmonis*, infecting lumpfish.

Read more via "Use of lumpfish for sea-lice control in salmon farming: challenges and opportunities" (Reviews in Aquaculture, 2017)

Scientific research has shown that lumpsuckers (lumpfish) can be infected with the parasitic amoeba *Paramoeba perurans* and develop Amoebic Gill Disease as well as other infectious

diseases such as Pasterellosis and Vibrio.

Read more via:

"Lumpfish (Cyclopterus lumpus L.) develop amoebic gill disease (AGD) after experimental challenge with Paramoeba perurans and can transfer amoebae to Atlantic salmon (Salmo salar L.)" (Aquaculture, 2017)
"Cleaner fish and the risks of transmitting infection to farmed salmon" (Norwegian Scientific Committee for Food & Environment, 2017)
"Pasteurellosis in lumpsucker *Cyclopterus lumpus*, farmed in Norway" (Journal of Fish Diseases, 2015)
"Clinical Vibrio anguillarum infection in lumpsucker Cyclopterus lumpus in Scotland" (Veterinary Record, 2013)

Scientific research in Norway in 2007 reported lice-infestation of wild caught lumpsuckers.

Lumpfish infected with more than 600 sea lice (Caligus elongatus).

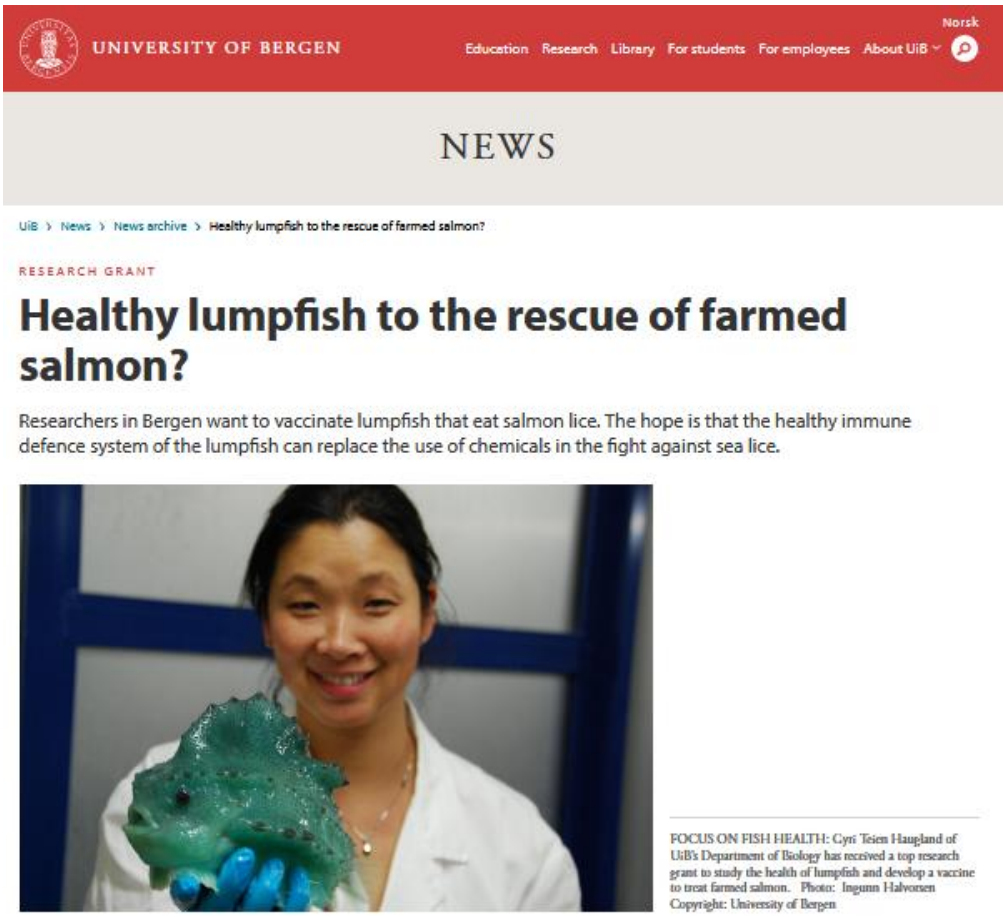
Credit: Photo: Øivind Øines

Øivind Øines has shown in his Ph. D. thesis that the sea louse, a parasitic copepod, is widely distributed among wild fish species along the Norwegian coast. The parasite is found in large numbers in the lumpfish, which is now considered to be one of the primary hosts of the parasite. The lumpfish in turn infects several types of farmed fish when it comes into the coast during the spring months.

Read more via:

"The Sea Louse, A Common Parasite Of Wild Fish"
"En utfordring at lusespiserne selv får lus"
"Mye skottelus på rognkjeks er ikke uventet"

Further scientific research is ongoing in Norway with a project titled "The cleanerfish lumpfish (Cyclopterus lumpus L.) - Immunity, diseases and health". The University of Bergen reported in November 2017:



Swansea University - in conjunction with Marine Harvest - is also investigating lumpfish. "The lumpfish, (*Cyclopterus lumpus*) has recently been noted for its efficacy as a cleaner fish species, particularly in the cold months during winter and spring," claims Swansea University.

A report - "Fish Welfare on Scotland's Salmon Farms" - published by OneKind in August 2018 included:

5.2 Sea lice

Sea lice are natural occuring parasitic copepods (small, water-dwelling crustacea) that feed on the skin, scales, tissues and mucous layer of fish. There are two types of sea lice that infect farmed salmon: *Caligus elongatus* and *Lepeophtheirus salmonis*. The most prevalent type in Scotland is *L. salmonis* - the salmon louse - which currently causes severe problems to farmed salmon.

5.2.1 *How do sea lice compromise the welfare of farmed salmon?*

Through feeding on the skin and tissues, sea lice cause serious damage to the health of salmon and can ultimately cause death.

Sea lice create physical damage to the skin and tissue of salmon, causing the development of lesions, and the loss of scales. So - called "death crowns" can also be created by sea lice, where the flesh on the head of the fish is exposed. For example, Fish Health Inspectorate reports (2017) document seeing fish with *"severe lice damage to their heads"*.

As the skin is an important component of osmoregulation, such damage disrupts water and salt concentrations within the fish. This is because it reduces the efficacy of the skin as a barrier, meaning that a greater amount of water leaks from the fish into the environment (Thorstad *et al.* 2015).

Sea lice can also hinder swimming ability, and act as vectors for transmission of diseases such as Infectious Salmon Anaemia (ISA) (Wagner *et al.* 2003, Nylund *et al.* 1994).

Not surprisingly, because of the damage they cause, high numbers of sea lice can cause high levels of stress. It has been shown that heavy infestation of sea lice leads to increased levels of the stress hormone cortisol, which can last up to three weeks post infestation (Mustafa *et al.* 2000). Chronic stress compromises the welfare of fish by reducing their growth rate and increasing the likelihood of further infection.

Given all these factors, sea lice can be fatal to salmon (Thorstad and Finstad, 2018).

Fish Health Inspectorate

Fish Health Inspectorate

5.3 Disease

Farmed salmon can suffer from a wide range of diseases. This is not surprising given fish farms inevitably create the perfect conditions for diseases to spread, with many fish kept in high densities. Environmental conditions can also increase the prevalence of disease, with warmer waters leading to new and complex gill issues, and reducing generation times for disease and sea lice.

There is now increased understanding of the link between stress and disease, with stressed fish being increasingly susceptible to infection (Tort 2011). Given that salmon farming exposes salmon to a great number of stressors (for example handling, crowding and treatment) it is again not surprising that they suffer from numerous diseases.

Farmed salmon in poor condition Fish Health Inspectore

5.3.1 *Amoebic Gill Disease*

Amoebic Gill Disease (AGD) is caused by a parasitic amoeba Neoparamoeba perurans. Infestation by *N. perurans* can cause an increase in mucous production in the gills of salmon, which causes respiratory problems, and can cause death through asphyxiation. AGD is still a major cause of mortalities in Scotland and has been known to cause up to 50% losses on salmon farms (Scottish Government, 2018). In 2016, at the salmon farm Raineach, 116,551 salmon died over a period of 10 weeks as a result of AGD (Fish Health Inspectorate, 2016).

5.3.2 *Cardiomyopathy Syndrome*

Cardiomyopathy Syndrome (CMS) affects the heart muscle of infected fish, creating heart lesions and consequently reducing their cardiovascular capacity (Garseth *et al.* 2017). This leaves fish fragile and weak and means they are less able to cope with any further stress. CMS has been recorded as the cause for many mass mortalities, including the death of 68,265 salmon, over a period of 17 weeks, on Winna Ness salmon farm (Fish Health Inspectorate, 2016).

5.3.3 *Infectious Salmon Anaemia*

Infectious Salmon Anaemia (ISA) is characterised by severe anaemia and haemorrhage in internal organs. It is a severe disease which currently does not have a cure, meaning that all infected fish must be slaughtered. In March 2018, at Greshornish salmon farm, 6.3% of the salmon on the site died as a result of anaemia. As there were an estimated 430,000 to 2 million fish on this site in this month, this means an estimated 27,000 to 130,000 fish died from ISA (Marine Harvest, 2018b).

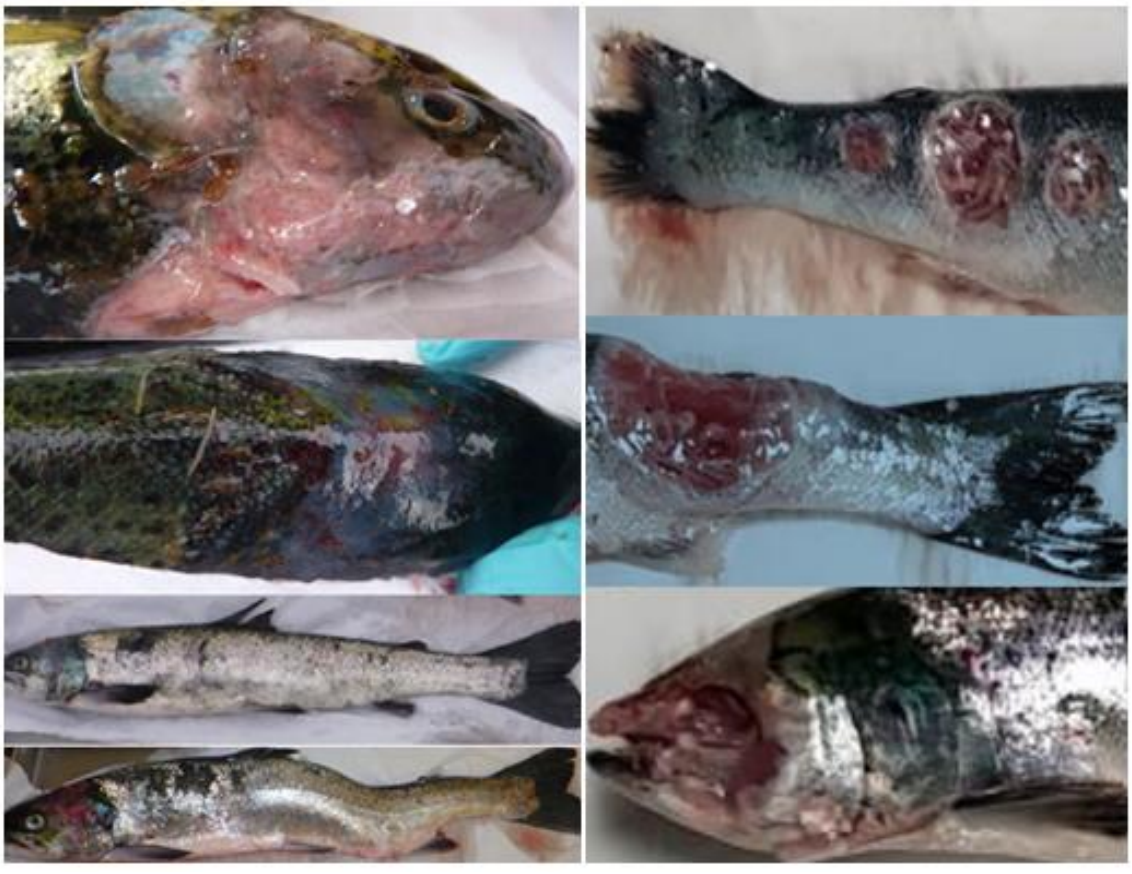
5.3.4 *Pancreas Disease*

Pancreas Disease (PD) is caused by the salmonid alphavirus (SAV) and causes necrosis of pancreatic tissues. Infected fish have been shown to be in poor condition, being thin and lethargic. Kilburn *et al.* (2012) analysed mortalities caused by PD in Scotland and found that there has been an increase in the prevalence of PD in recent years. In 2017 2,000 salmon died as a result of PD on the Plocrapol salmon farm (Fish Health Inspectorate, 2017).

Post-mortem photographs taken by the Scottish Government's Fish Health Inspectorate - obtained by Scottish Salmon Watch via FOI in June 2018 and August 2018 - detail specific disease problems at dozens of Scottish salmon farms since 2015.

The horrific images reveal severe lice infestation eating into the heads of farmed salmon, deformed spines, lesions, adhesions, deformed hearts, anorexia, petechial haemorrhages, enlarged spleens, diseased gills, cataracts and even salmon with no eyes.

Diseases, viruses, bacteria and pathogens reported alongside the photos include Salmonid Alpha Virus, Bacterial Kidney Disease, Pancreas Disease, Cardiomyopathy Syndrome, Heart & Skeletal Muscle Inflammation, Salmon pox virus, Vibrio, Flavobacterium, Moritella viscosa (Winter ulcer), Amoebic Gill Disease, Neoparamoeba perurans, Paranucleospora theridon (syn. Desmozoon lepeophtherii), Parvicapsula pseudobranchicola, Ichthobodo species, Branchiomonas, Costia, Candidatus Syngnamydia salmonis and Pasteurella skyensis.

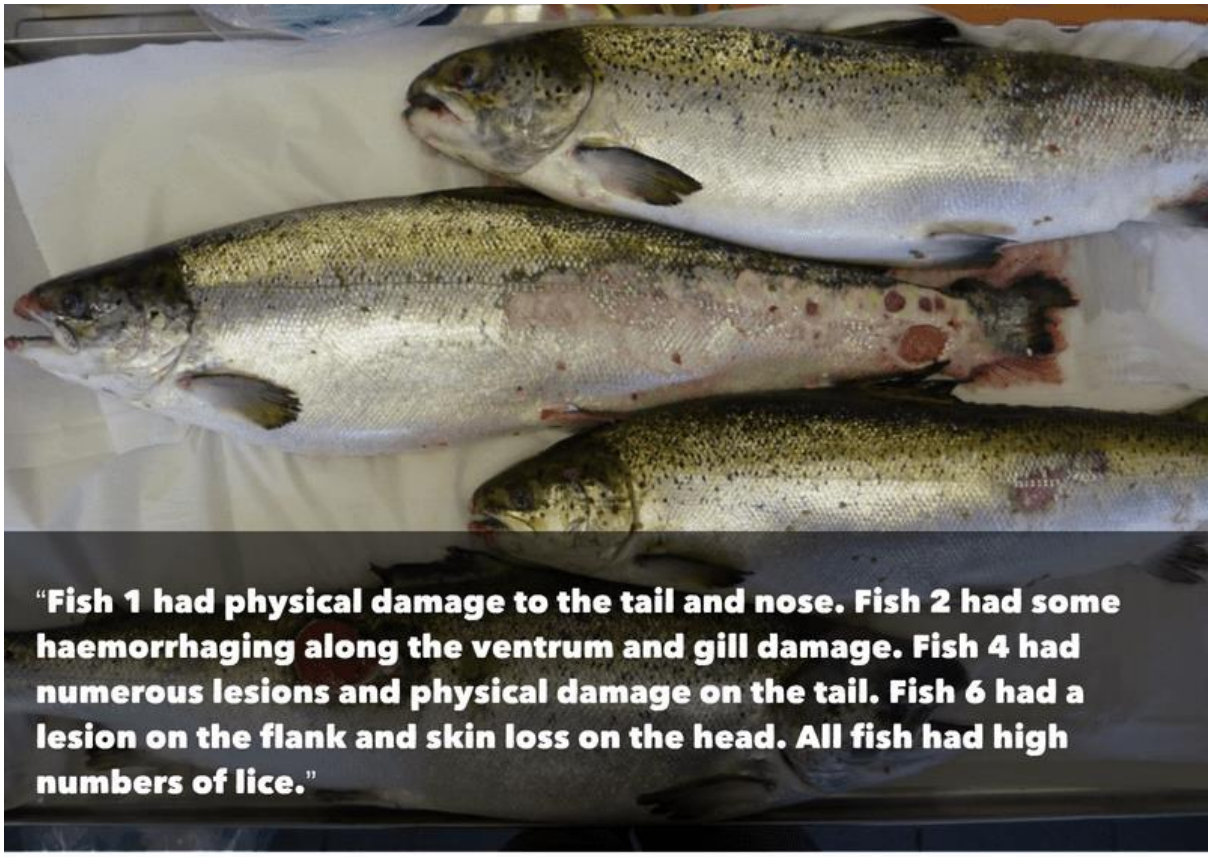


The Ferret reported in June 2018:

Fish Farm: Raineach, East Loch Tarbert, Harris

Company: Marine Harvest
Problems: amoebic gill disease, lice
Fish heath inspection: five fish sampled on 4 October 2016
Case number: 2016-0449

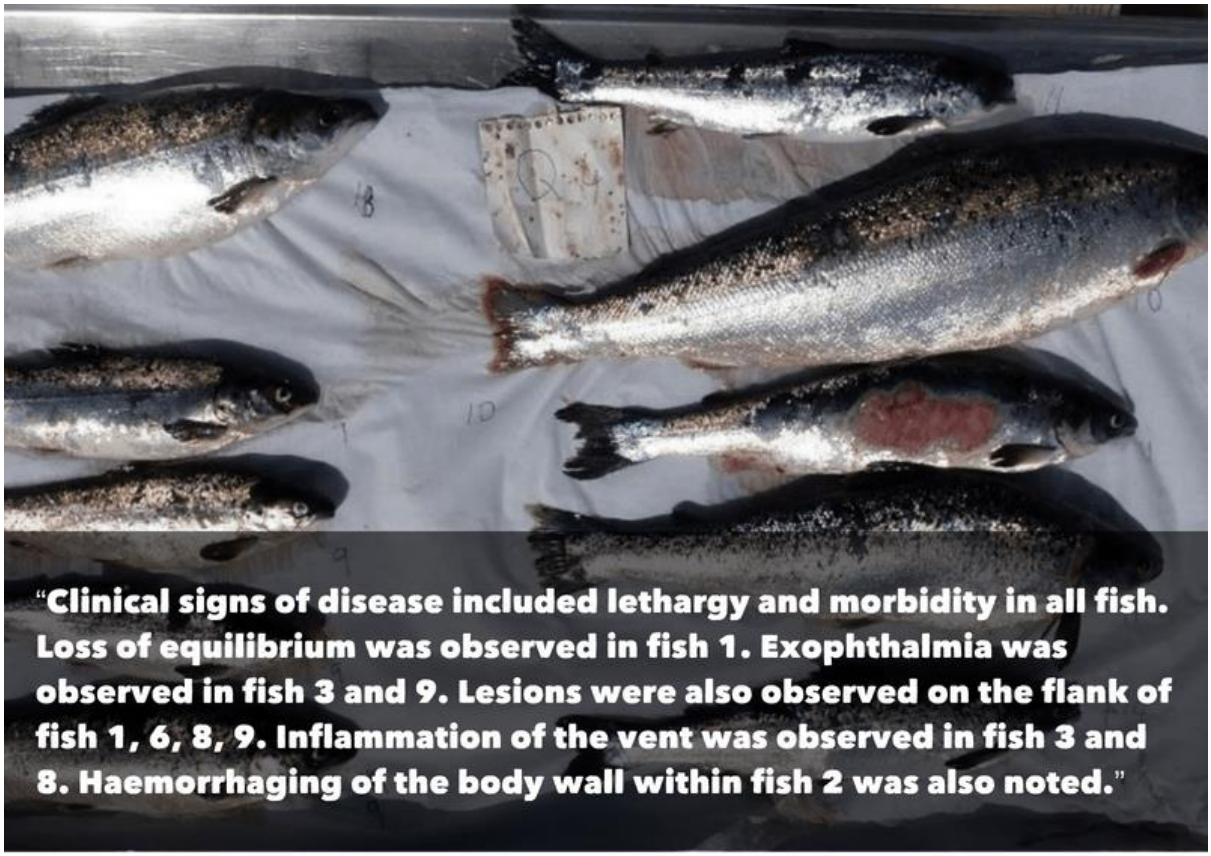
The Ferret



Fish Farm: Ardintoul, Loch Alsh

Company: Marine Harvest
Problems: pancreas disease, lice
Fish heath inspection: Six fish sampled on 5 April 2016
Case number: 2016-0141

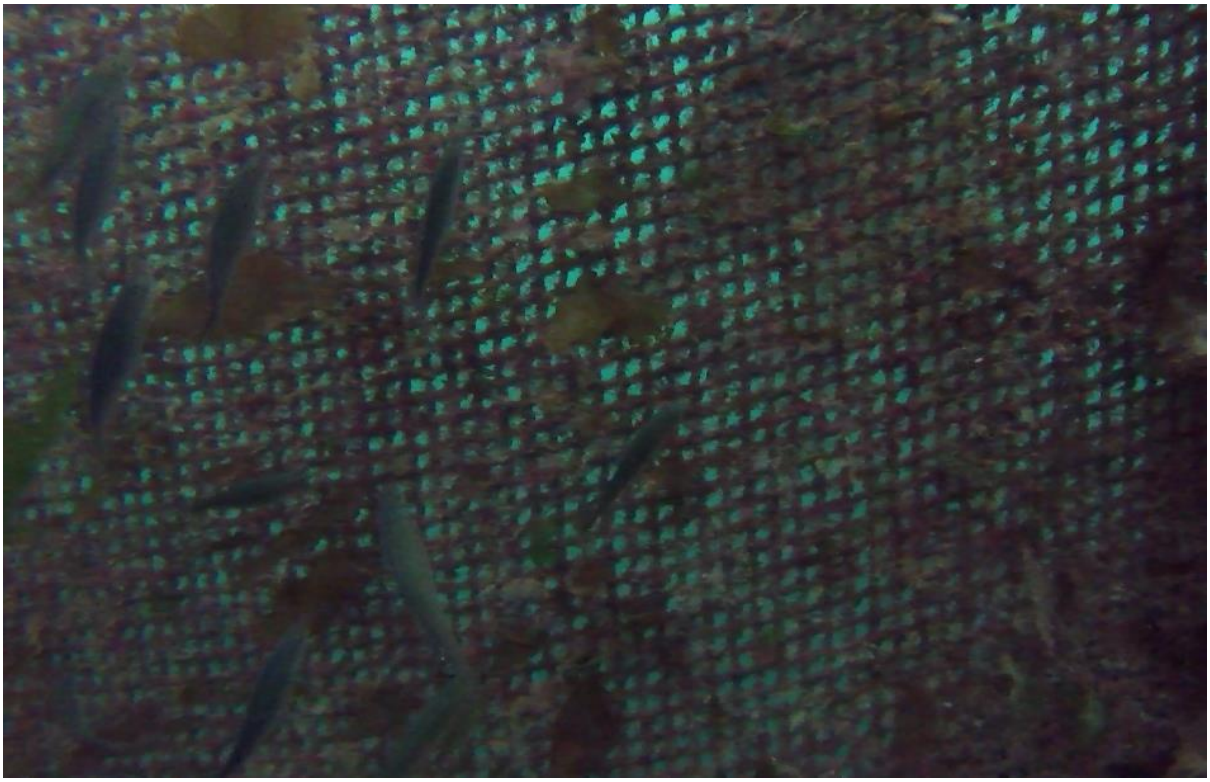
The Ferret

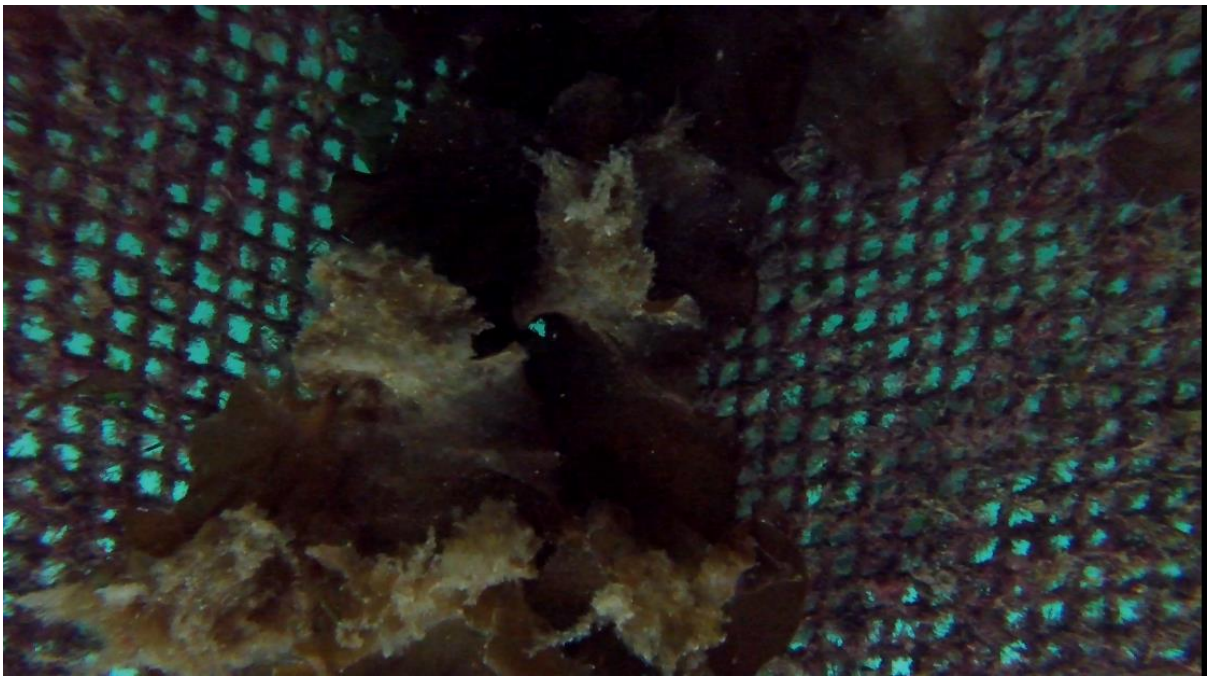


Read more via:

Hard Evidence: Photos of Diseased & Deformed Scottish Salmon (August 2018)
Horror photos of farmed salmon spark legal threat
EXPOSED: Gruesome Photos of Deformed & Diseased Scottish Salmon
Hard Evidence - Photos of Diseased & Deformed Scottish Salmon (June 2018)

The secret video footage showed significant bio-fouling of nets which may represent a response by the industry to new scientific research linking the cleaning of nets with gill diseases.





A scientific study published in 2018 highlighted the potential risks that net cleaning poses to fish welfare with negative impacts on gill health.

Read more via: "Effects of cnidarian biofouling on salmon gill health and development of amoebic gill disease" (PLoS ONE, 2018)

The Fish Site [reported in August 2018]:

"We knew that when we started in situ net cleaning that our gill health started to deteriorate," David reflects. "It's not just cleaning the net – putting high pressure in the water is affecting other things too. Whether it's Japanese skeleton shrimp in the nets, jellyfish on the side of the nets, or jellyfish in the pen itself, they're all getting obliterated and turned into small pieces that can get into the gills."

However, he admits, there may be a large number of different factors at work.

"We can't put all the blame onto net cleaning because it's a hard thing to monitor," he adds. "New things [such as rising sea temperatures] are popping up all the time – we actually don't know why some sites are worse than others for gill health, and it could be the things that we're not seeing that are doing the damage. You can clean nets for three months and it won't be an issue, then suddenly the gills start deteriorating."

Conditions such as amoebic gill disease (AGD) have been increasingly common in recent years
© Hamish Roger, Fish Vet Group

"We've now put them on the three sites that have probably caused us the most issues with gill health over the years. Ornish, on South Uist, has had them since July 2017 and has got a chequered past with gill health; Portnalong has had them since February; and we're going to do Greshornish next year.

There are also a number of other sites that David has earmarked for the new nets.

"Kingairloch is getting them as we speak, and there are plans to install them at Port na Crow and Pol na Ghillie (PNG) shortly too," he says. "PNG's not too bad in terms of gill health, but we believe it will make a difference. At Kingairloch it's more of a cost issue. It's a small site, just eight pens, and it's isolated so it makes perfect sense not to have to use a net cleaner."

And the performance of the sites with the new nets means that Environets are likely to be phased in more widely across the company's marine sites.

Lice-infestation and disease problems in lumpsuckers raises serious concerns about the bio-security and viability of using so-called cleaner fish. Far from reducing the disease and lice burden on salmon farms, cleaner fish may be exacerbating the problem.

A report - "Fish Welfare on Scotland's Salmon Farms" - published by OneKind in August 2018 included:

5.5 Cleaner Fish

Another alternative "treatment" for sea lice that is now prevalent across Scotland is the use of "cleaner" fish – lumpsucker (*Cyclopterus lumpus*) or species of wrasse - to pick off and eat sea lice from salmon. It is recommended that there is one cleaner fish for every 25 salmon (Marine Conservation Society, 2018). The use of cleaner fish began in the UK in the late 1980s but has only become widespread in recent years. It is expected that by 2020 10 million cleaner fish will be used in Scotland and that by 2019 all cleaner fish will be obtained from a farmed source (Marine Conservation Society, 2018).

In 2016, three hatcheries in Scotland produced 118,000 wrasse, and seven hatcheries produced 262,000 lumpsuckers. The remaining cleaner fish used by the industry are wild caught, with inevitable impacts on wild populations and welfare issues relating to how they are caught, handled, and transported, and how well suited they are to captivity.

5.5.1 *Wrasse*

Within Scottish salmon farming, the most common species of wrasse used is the ballan wrasse (*Labrus bergylta*), although others such as goldsinny (*Ctenolabrus rupestris*) and corkwing wrasse (*Symphodus melops*) are sometimes used.
Wrasse exhibit winter dormancy, which means they do not feed below 6oc. This reduces their effectiveness as cleaner fish in the winter months, which partially explains why the industry is shifting towards using lumpsuckers instead.

5.5.2 *Lumpsucker*

Lumpsuckers are also known as lumpfish. They lack a swim bladder, so instead have a suction cup which they use to stick to surfaces. Unlike wrasse, lumpsuckers will feed below 6°c, feeding to 4°c. This makes them preferable to the industry over wrasse, though there is some debate over the effectiveness of lumpsuckers as cleaner fish.

5.5.3 *Welfare of cleaner fish*

As noted by the Farm Animal Welfare Committee (2014a), cleaner fish experience the same welfare issues that farmed fish face. However, there is very little research into their biology and welfare in captivity, though the University of Stirling is starting to research cleaner fish behaviour in captivity (for example see Leclercq *et al.* 2018).

Ballan Wrasse iStock wrangel

Lumpsucker iStock feathercollector

5.5.3.1 *Interactions with other fish*

Salmon are carnivorous, and can show aggression towards cleaner fish, and have been found to consume cleaner fish. Indeed, recommendations, including those of the Royal Society for the Prevention of Cruelty to Animals (RSPCA) Assured standards, state that cleaner fish must only be introduced once salmon are satiated (full), to avoid salmon eating cleaner fish. It has also been shown that cleaner fish compete with salmon for access to food pellets (Imsland *et al.* 2014).

Aggressive interactions can also work the other way around, with cleaner fish causing damage to salmon. In one incident documented in 2010, ballan wrasse caused eye damage to a number of salmon, which resulted in many salmon bleeding to death (Treasurer, 2013). Cleaner fish can also show aggression to each other. For example, reports by the Fish Health Inspectorate show that aggression and cannibalistic behaviour have been documented in farmed lumpsuckers (Fish Health Inspectorate, 2016).

5.5.3.2 *Health*

Cleaner fish on farms suffer from numerous diseases. Ironically, they too can experience severe sea lice loads (Powell *et al.* 2017). Fungal infection is also a common cause of mortality in cleaner fish. Therefore, cleaner fish in salmon farms often have severely compromised health, which can lead to high mortality levels. According to the EU Reference Laboratory for Fish Diseases (2016):

"Cleaner fish mortalities in salmon farms are often high, and very few cleaner fish presumably survive through a full salmon production cycle. Losses of entire batches due to bacterial disease are also occasionally observed in cleaner fish farms".

Further high mortalities of cleaner fish have been seen following disease outbreaks such as the outbreak of Viral Haemorrhagic Septicaemia (VHS), which occurred in wrasse on salmon farms in Scotland, in 2012 (European Union Reference Laboratory for Fish Diseases, 2016).

There is also a suggestion that cleaner fish may transfer disease to salmon, although research into this is limited, with a report by the Norwegian Scientific Committee for Food and Environment (2017) concluding:

"the disease status of wild - caught cleaner fish is, in general, poorly known. Translocations of such fish may result in the introduction of new pathogens to farmed salmonids".

Cleaner fish can also suffer from health problems such as cataracts, with Powell *et al.* (2017) noting that this is likely associated with rapid growth and dietary deficiencies. Fin damage has also been observed to affect cleaner fish, which can lead to the development of fungal infection.

Like salmon, cleaner fish can suffer high mortalities as a result of treatment. Wrasse have been known to die in large numbers following treatment, often as a result of over inflation of the swim bladder because nets to capture fish were raised too quickly (Treasurer, 2013). Lumpsucker can also suffer as a result of treatment. For example, at Caolas A Deas salmon farm, lumpfish were not removed prior to treatment, resulting in the death of 1,500 - 2,000 lumpfish per cage (Fish Health Inspectorate, 2017).

5.5.3.3 *Husbandry*

Cleaner fish have been documented to be easily stressed and can respond negatively to routine aquaculture practices.

It is believed that wrasse are more sensitive than lumpsuckers to handling, though both will suffer when handled incorrectly. Ledrecq *et al.* (2014) found that ballan wrasse exposed to 1-minute air exposure had an increase in cortisol (stress hormone) levels by up to 83.9%, compared to a resting rate. In 2016, at a lumpsucker rearing unit, handling led to the development of furunculosis (swollen areas on the skin caused by a bacterial infection), due to the stress caused by handling (Fish Health Inspectorate, 2016).

In addition to consuming sea lice, cleaner fish need supplementary food. It is also not the case that withdrawing extra food from cleaner fish will cause them to eat more sea lice.

Problems with providing supplementary food to cleaner fish have been documented on salmon farms. Powell *et al.* (2017) noted that around one third of lumpfish died from starvation within a few weeks of being introduced into salmon cages. In 2017, at one salmon farm site it was observed that there was an "increase in lumpsucker mortality as fish were switched onto pelleted food and some of the smaller fish were unable to feed" (Fish Health Inspectorate, 2017).

The Sunday Times [reported in December 2017]():

THE SUNDAY TIMES Today's sections Past six days My articles Times+

Scotland

'Clean fish' bring danger of disease to salmon farms

Julia Horton

December 31 2017, 12:01am, The Sunday Times

Lumpfish and wrasse are seen as a natural solution to sea lice at salmon farms

GETTY IMAGES

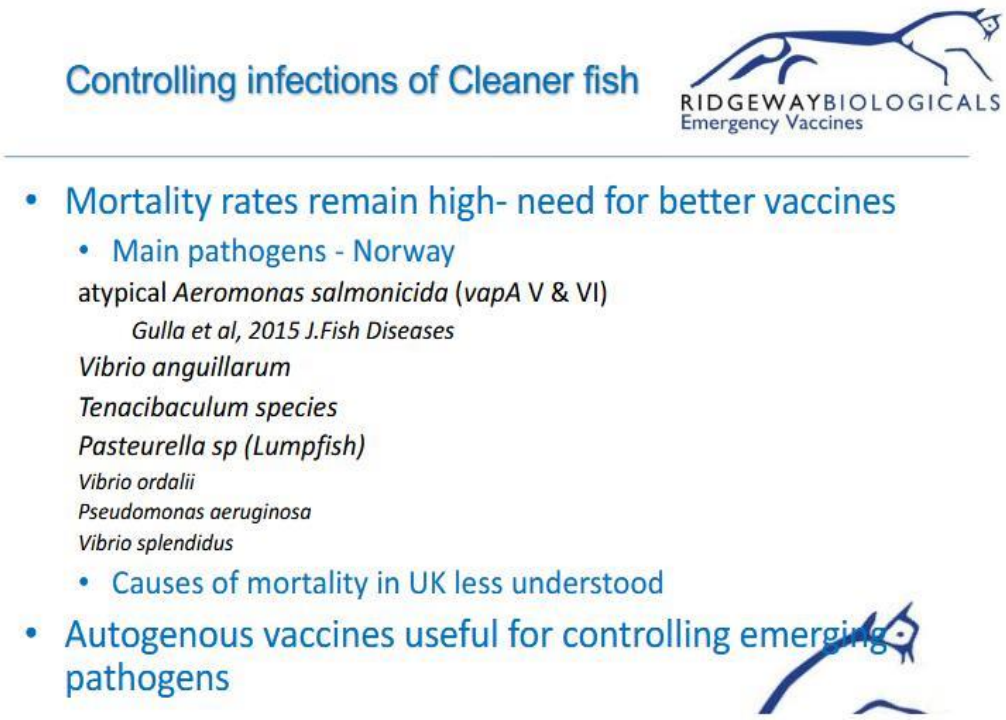
In Norway, diseases in cleaner fish are becoming a big problem. The Norwegian Veterinary Institute reported via [The Health Situation in Norwegian Aquaculture]() in 2017:

Table 10.1 Occurrence (number of diagnosed sites) of selected diseases/agents in cleaner fish investigated by the Norwegian Veterinary Institute

Rensefiskart	Sykdom/agens	Antall positive lokaliteter				
		2012	2013	2014	2015	2016
Rognkjeks	Atypisk *Aeromonas salmonicida*	1	8	5	51	27
	Aeromonas salmonicida subsp. *Salmonicida*	0	0	0	1	4
	Vibrio anguillarum	7	6	8	12	12
	Vibrio ordalii	3	4	1	3	1
	Pasteurella sp.	1	16	8	14	28
	Pseudomonas anguilliseptica	0	0	1	4	8
	AGD	0	0	2	2	8
Leppefisk	Atypisk *Aeromonas salmonicida*	12	13	16	32	18
	Vibrio anguillarum	6	6	6	2	2
	AGD	0	5	2	2	1

An International Cleaner Fish Summit held in Glasgow in May 2017 featured a session on 'Health & Welfare' - including photos of disease-ridden cleaner-fish:

Presentations at the 'Health & Welfare' session included:



Recognised pathogens isolated from Scottish Cleaner fish

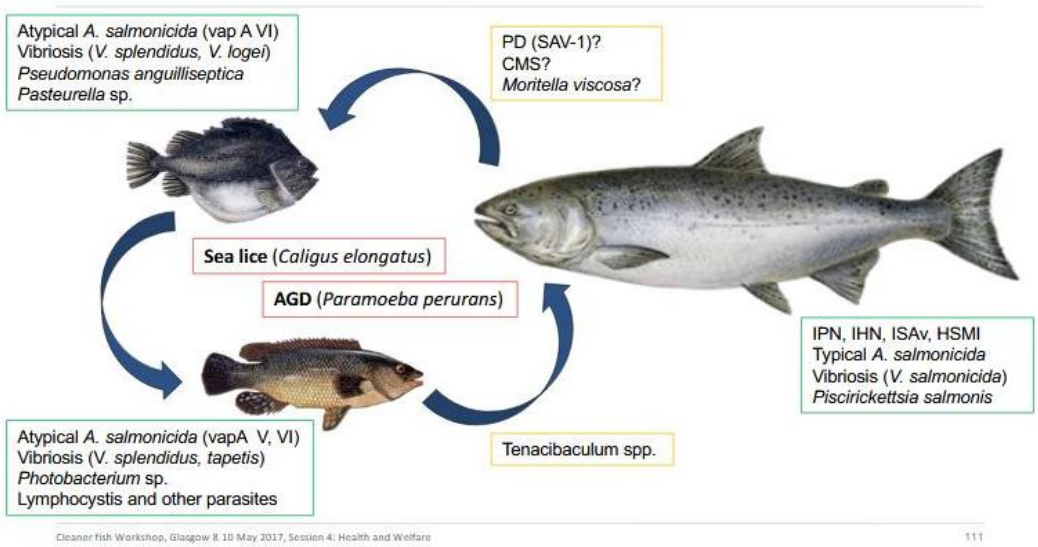
RIDGEWAYBIOLOGICALS
Emergency Vaccines

- atypical *Aeromonas salmonicida*
  - *vapA* types V and VI
  - pathogenic in cleaner fish in Norway
- *Pasteurella skyensis*- like species
  - Related to but distinct to *P.skyensis*
  - Serologically cross-reactive with Norwegian isolates
- *Aliivibrio salmonicida*
  - cold water vibriosis in salmon
- *Vibrio ordalii*

Similar but different to Norway

marineharvest

Disease challenges related to multiple species



Cleaner fish Workshop, Glasgow 8-10 May 2017, Session 4: Health and Welfare 111

Read more via: "[‘Clean fish’ bring danger of disease to salmon farms]"

A scientific paper authored by the Scottish Government in April 2016 included:

"Sea lice are the most damaging parasite of marine salmonids, both economically and in terms of potential impacts on wild fish. An increasingly widely applied control is the use of cleaner fish (CF) such as wrasse that eat lice. However, such CF can carry pathogens that may cause disease in salmon, including the potential emergence of new diseases. This is not just a theoretical risk, as demonstrated by a recent outbreak of viral haemorrhagic septicaemia in wrasse held on salmon farms in Shetland."

Read more via:

"A Modelling Framework for Assessing the Risk of Emerging Diseases Associated with the Use of Cleaner Fish to Control Parasitic Sea Lice on Salmon Farms" (Transboundary & Emerging Diseases, 2016)
"A model of the process of spillover and adaption leading to potential emergence of disease in salmon held with cleaner fish used to control lice" (Aquaculture, 2017)

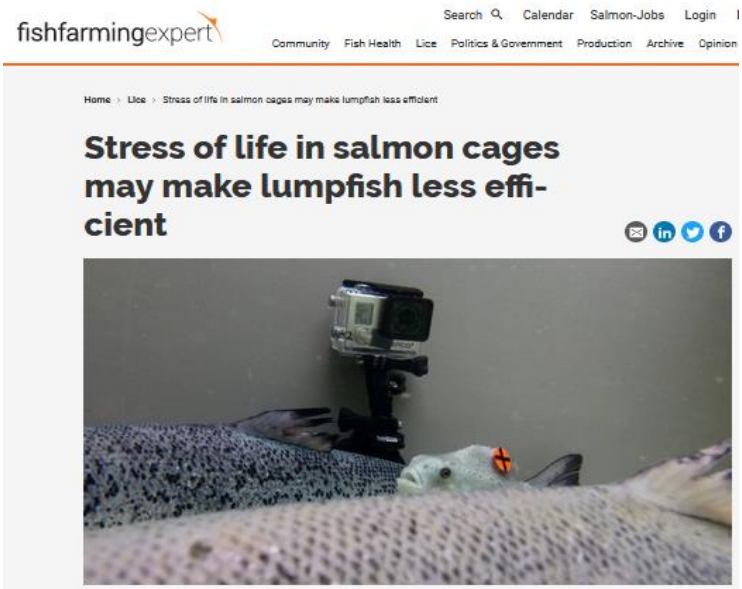
Lumpsuckers have certainly been hit by a wide range of health problems.

"Little is known of the bacterial diseases of lumpsucker," reported a scientific paper published in the Journal of Fish Diseases in 2016. "However, new disease and infectious agents inevitably emerge whenever new species are introduced to aquaculture, and the lumpsucker appears to be no exception to this rule."

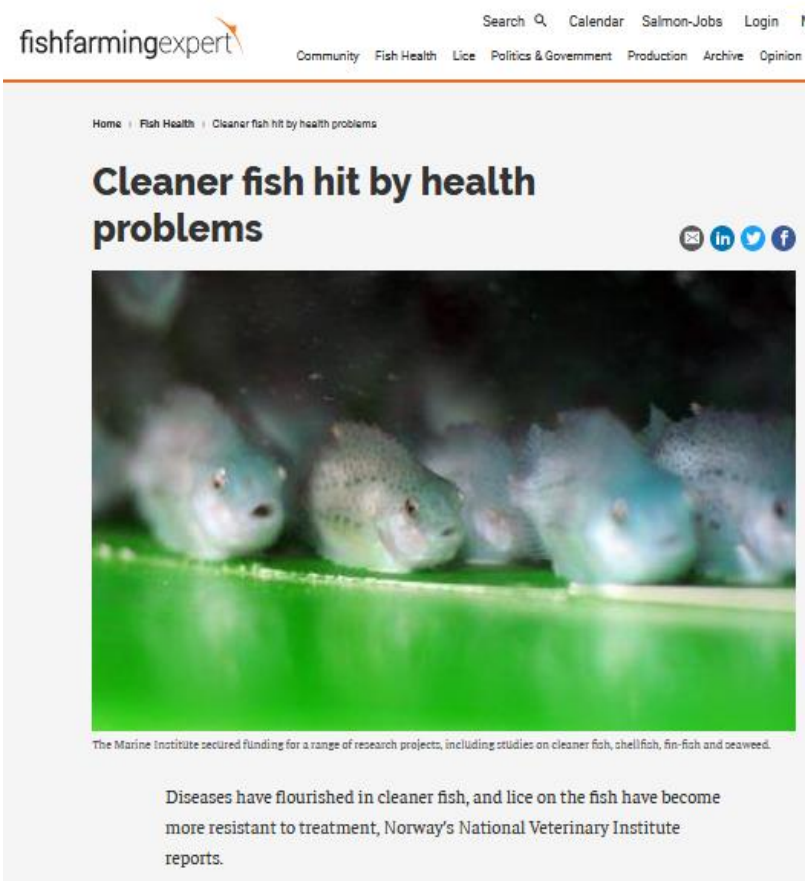
Read more via "Pasteurellosis in lumpsucker *Cyclopterus lumpus*, farmed in Norway" (Journal of Fish Diseases, 2016)

Pasturella skyensis is the disease which killed 125,000 farmed salmon at Marine Harvest in 2017, begging the question: are lumpsuckers giving infectious diseases to farmed salmon and/or farmed salmon to lumpsuckers?

Whatever the answer it is clear that 'cleaner fish' are far from clean and they live a stressful life inside salmon farms. Fish Farming Expert reported in March 2017:



Fish Farming Expert [reported in April 2017]:



fishfarmingexpert

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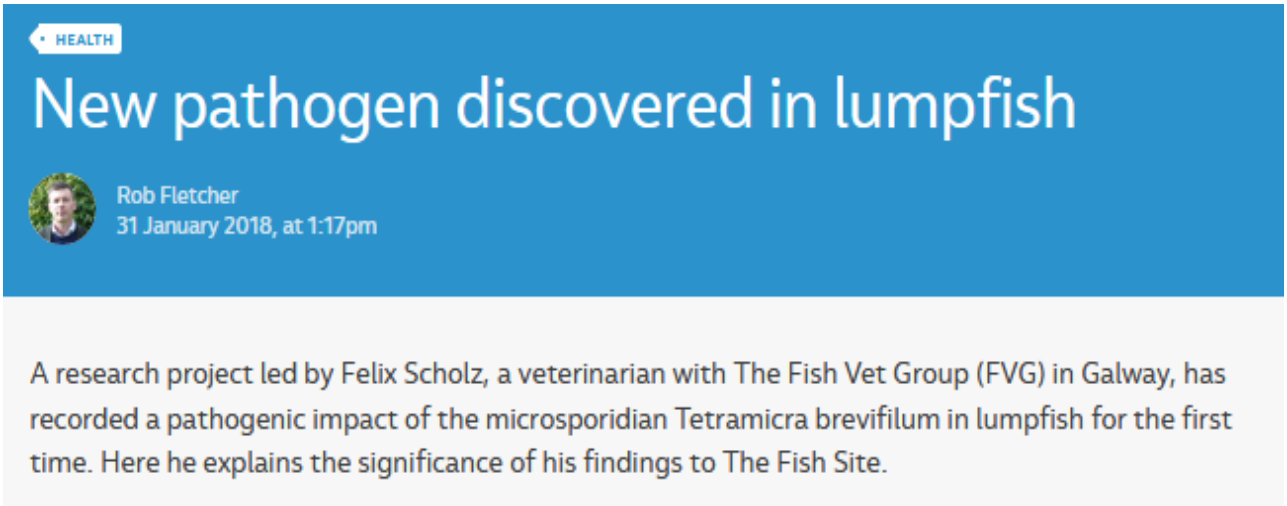
Home › Fish Health › Cleaner fish hit by health problems

Cleaner fish hit by health problems

The Marine Institute secured funding for a range of research projects, including studies on cleaner fish, shellfish, fin-fish and seaweed.

Diseases have flourished in cleaner fish, and lice on the fish have become more resistant to treatment, Norway's National Veterinary Institute reports.

Fish Update [reported in January 2018]:



HEALTH

New pathogen discovered in lumpfish

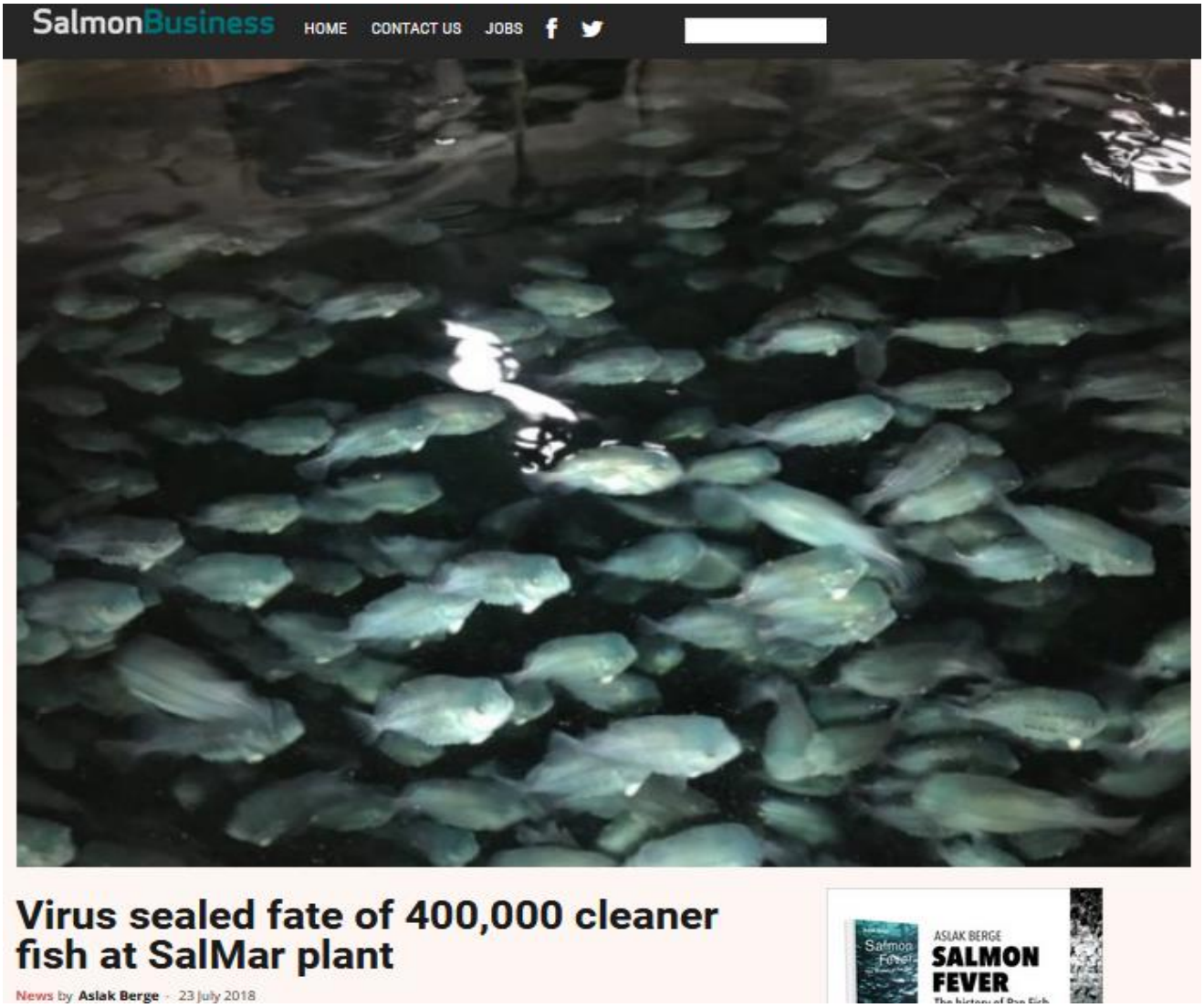
Rob Fletcher
31 January 2018, at 1:17pm

A research project led by Felix Scholz, a veterinarian with The Fish Vet Group (FVG) in Galway, has recorded a pathogenic impact of the microsporidian Tetramicra brevifilum in lumpfish for the first time. Here he explains the significance of his findings to The Fish Site.

T. brevifilum visible as white flocculant material within external cysts and in the eye of this infected lumpfish

Severe systemic infection. Xenomas, partly within cysts, can be seen on all visceral organs and as white nodules in the muscle. Note also the fluid in the abdominal cavity

Salmon Business [reported in July 2018]:



Virus sealed fate of 400,000 cleaner fish at SalMar plant

News by **Aslak Berge** - 23 July 2018

Viral attack at SalMar's Langstein plant in Stjørdal (Mid-Norway).

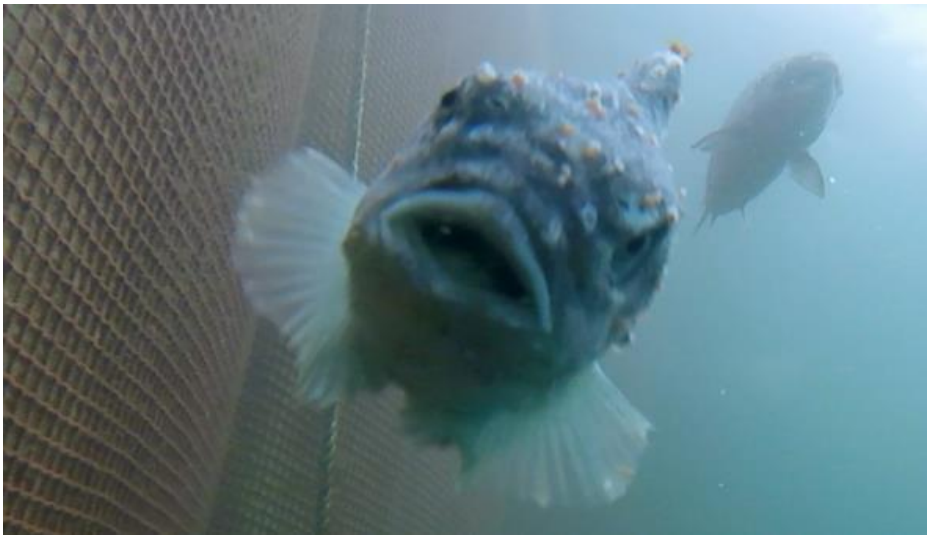
"It's the first time since we started up here in 2015 that we've experienced this. Immediately after discovering the viral attack a few weeks ago, measures were implemented, and the lumpfish in this section were destroyed," Bjørn Hembre, head of fry production at SalMar, told local newspaper Stjørdalens Blad.

Listed salmon farmer SalMar has five separate aquaculture production sections at the Langstein plant, and according to Hembre, each section is hygienically protected from infection separate from the other sections. This means that the four sections that were not affected by the viral attack are in full production.

"How the infection found its way into this particular section is unknown to us – as yet," said Hembre.

The destroyed fish will be pulverised, and probably used for feed at mink farms.

Note that SalMar is co-owner of Scottish Sea Farms (along with Leroy) - the subject of the secret video footage showing lice-infested lumpsuckers at their salmon farm in Loch Spelve.



'Case Information' published by the Scottish Government's Fish Health Inspectorate has reported disease and mortality problems in lumpsuckers. A Fish Health Inspectorate visit in August 2017 reported high levels of sea lice - in excess of 10 adult stages per fish - on lumpsuckers at Marine Harvest's salmon farm in Loch Seaforth:

marinescotland science

The Scottish Government
Riaghaltas na h-Alba

[redacted]
Marine Harvest (Scotland) Ltd
Stob Ban House
Glen Nevis Business Park
Fort William
PH33 6RX
[redacted]

FISH HEALTH INSPECTORATE VISIT REPORT

SUMMARY FOR INFORMATION OF SITE OPERATOR

BUSINESS NO	FB0119	DATE OF VISIT	02/08/2017
SITE NO	FS1042	SITE NAME	Seaforth
INSPECTOR	David Tomlinson	CASE NO	20170310

Section 1: Summary

During a routine inspection it was reported that elevated mortalities were being recorded in the lumpsucker (*Cyclopterus lumpus*) population, five lethargic fish were removed for diagnostic sampling.

At the time of sampling, the lumpsuckers showed high numbers of sea lice (*Caligus elongatus),* these may have attributed to the lesions observed. Histopathology examination revealed skin lesions which may impact on the osmotic balance of the individuals. Bacteria associated with skin tissues were also present in one individual.

Two different *Vibrio* sp. were isolated by bacteriological testing but due to the mixed growth would not suggest bacteria be implicated in fish mortality.

Please contact myself or the duty inspector should you require any further information, have any queries regarding this report or if any problems develop.

Section 2: Case Detail

Observations

During a routine inspection it was reported that increased mortalities were being recorded in the lumpsucker (*Cyclopterus lumpus*) population. On inspection of the pens a number of lethargic lumpsuckers were observed some with white lesions and a high *Caligus elongatus* lice load. Five fish were removed from the pens for further examination and subsequent diagnostic sampling.

All five fish were lethargic, had pale gills and lesions evident on the flanks. The lesions were more prominent on fish 5. Lice loading was in excess of 10 adults stages (*Caligus elongatus*) per fish.

R09
Marine Laboratory, 375 Victoria Road, Aberdeen, AB11 9DB
Tel - 01224 295525 Fax - 01224 295620 Email - ms.fishhealth@gov.scot
Website - www.gov.scot/Topics/marine/science

Another Fisheries Health Inspectorate visit dated July 2017 reported:

FHI 059, Version 10 Issued by: FHI Date of issue: 12/02/2016

Case No:	2017-0281			Date of visit:	24/07/2017
Time spent on site:	2.5 hrs			Main Inspector:	SJD
Site No:	FS0991	Site Name:	Marine Hatchery		
Business No:	FB0374	Business Name:	NAFC Marine Centre		

Additional Case Information:

200,081 lumpsuckers delivered from Sandwick (Icelandic origin).
Early bacterial infection, 2 Vibrio species isolated by vet. Treated with antibiotics.

Shetland News reported in 2013:

Great is the Truth and it will Prevail

Shetland News

Disease forces cull of 10,000 "cleaner" fish

17:16 Thursday, 17 January 2013 | Written by Shetland News

Tweet Recommend 15 Share

A ballan wrasse, almost 10,000 of which have been culled after a disease outbreak

ALMOST 10,000 lice-eating "cleaner" fish have been culled at a Shetland hatchery to help contain the first outbreak of a common virus in the species.

The sea wrasse had been brought into the islands by fish farming giant Scottish Sea Farms from the west coast of Scotland.

The 9,393 fish were in holding tanks at Scalloway's NAFC Marine Centre when the outbreak of marine Viral Haemorrhagic Septicaemia (VHS) virus was found last month.

The wrasse were waiting to be released onto fish farms sites to attack the sea lice that have been causing massive problems on some Shetland fish farms in recent months.

Government fish health inspectors from Marine Scotland have launched an investigation into the source of the outbreak, which has affected other parts of Scotland too.

Controls have been placed on the NAFC and fish farm sites linked by movements of wrasse to minimise the risk of spreading the disease, which poses no threat to human health.

NAFC Marine Centre, Scalloway, where the fish were culled.

Scottish Sea Farms have been experimenting with wrasse to control sea lice for the past two years.

Read more via "Disease forces cull of 10,000 “cleaner” fish"

Read scientific reports more via:

"A survey of wild marine fish identifies a potential origin of an outbreak of viral haemorrhagic septicaemia in wrasse, labridae, used as cleaner fish on marine Atlantic salmon, *Salmo salar* L., farms" (Journal of Fish Diseases, 2015)

"A mortality event in wrasse species (Labridae) associated with the presence of viral haemorrhagic septicaemia virus" (Journal of Fish Diseases, 2015)

A Freedom of Information reply from the Scottish Government in March 2017 also revealed the use of antibiotics on lumpsuckers by Marine Harvest:

With respect to the Marine Harvest Torridon site, information received in July of 2016 says:

Marine Laboratory, 375 Victoria Road,
Aberdeen AB11 9DB
www.gov.scot/marinescotland

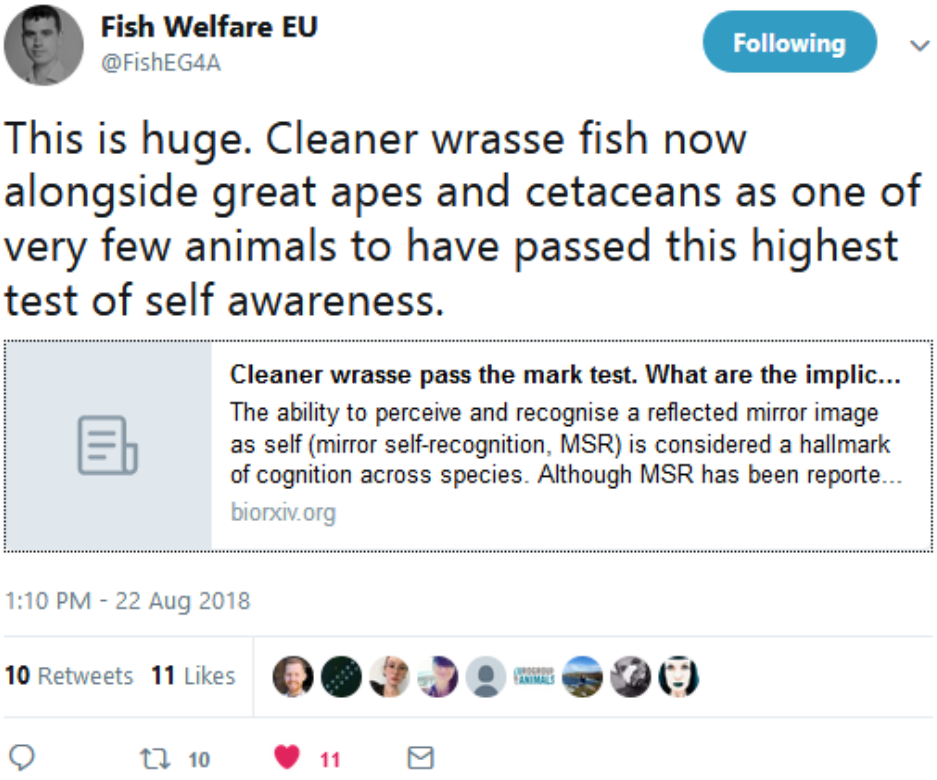
- lumpfish were treated for a presumptive bacterial infection which is being solved with a 21-day-course in-feed Florocol treatment.

In relation to the Marine Harvest sites Gorsten and Torridon, information received in June 2016 says:

- Gorsten – 2015 wild caught wrasse from Invasion Bay showing skin lesions were treated individually with a single dose of oxytetracycline injectable prior allocation into a holding pen, after salmon were harvested.

- Torridon – Increased mortality on lumpsuckers was noticed in two pens due to a presumptive bacterial infection which was solved with a 10-day-course in-feed oxytetracycline treatment.

The poor treatment by salmon farming companies of cleaner fish is all the more disturbing by the recent revelation. Fish Welfare EU Tweeted in August 2018:



Read scientific paper via "Cleaner wrasse pass the mark test. What are the implications for consciousness and self-awareness testing in animals?"

In the context of emerging new diseases and infectious agents, the salmon farming industry's plans to expand lumpfish farming may be a leap too far.

Deformities:

Secret video footage shot inside Scottish salmon farms in July and August 2018 suggests serious spine and skeletal deformities with s-shaped salmon and fish with bulging stomachs:

Without post-mortem analysis and sampling inside salmon farms it is impossible to know what diseases and deformities these farmed salmon are suffering from but they certainly do not look a picture of health.

Download high resolution photos online here

Deformities in farmed salmon have been linked to fast growth, high temperatures in the hatchery and to the use of vaccines.

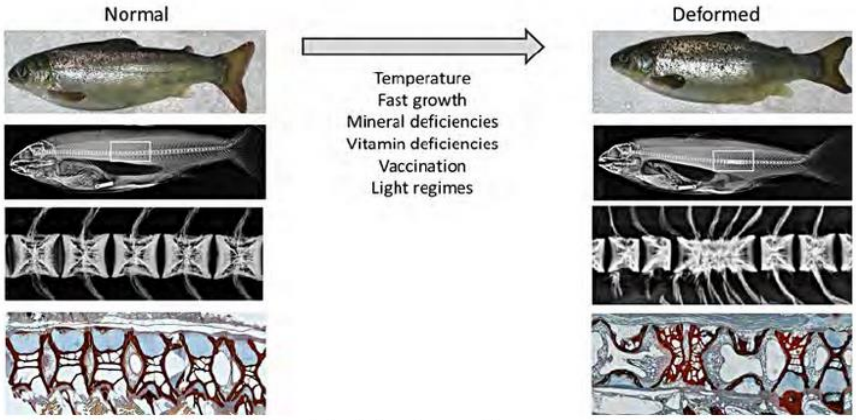


Fig. 9. Normal (left) and deformed (right) Atlantic salmon. From the top: photography of the fish, radiographic image, enlarged radiography, Alizarine red S and Tolouidine blue double staining.

Read more via:

"The Atlantic Salmon (Salmo salar) Vertebra and Cellular Pathways to Vertebral Deformities"

Intrafish reported in August 2018:

Grieg CEO: MSD's vaccine causing 'major damage' to salmon

MSD Animal Health is rejecting the claims, telling IntraFish there is no correlation between its PD vaccine and deformations in salmon.

by Anders Furuset and Joar Grindheim
August 24th, 2018 11:14 GMT Updated August 24th, 2018 12:28 GMT

Andreas Kvame, CEO of Grieg Seafood, said that MSD Animal Health's vaccine against Pancreas Disease (PD) has caused major deformations and damage to its fish in Rogaland, Norway.

MSD Animal Health is rejecting the allegations.

"The seven-component vaccine caused major damage to our fish in Rogaland," Kvame said during the company's quarterly results presentation in Oslo on Wednesday.

NYC Seafood Investor Forum: Benchmark CEO says sea lice solution getting closer

Growth was impacted and the fish still caught PD, despite the vaccination, resulting in deformations, he said.

It's not the first time that the industry has criticized MSD's Aquvac PD7 vaccine. Last fall, a study initiated by farmers within Salmon Group found a correlation between spinal deformations and the vaccine.

Read more

This summer, Grieg Seafood analyzed data around this in order to make a comparison. After those evaluations, the company is strongly criticizing the fish health group.

"It's a big deal for us," Kvame told **IntraFish**, adding the company is in close dialogue with MSD on the issue.

MSD: No correlation between vaccine, deformities

Ingebjorg O. Saevareid, marketing manager at MSD Animal Health, refuted the claims.

"MSD Animal Health has vaccinated more than 190 million salmon with the seven-component vaccine since its launch in 2016," she said. "We have a very good overview of how the fish develop after vaccination.

"We have conducted several studies and none of them show any direct correlation between the vaccine and spinal deformities. And external research has the same conclusion: The seven component vaccine is not the cause of the deformities."

Saevareid said a number of leading salmon producers are using the vaccine today as their main strategy against PD, without deformities occuring.

"The causes of deformations in the spinal column of salmon are complex," she said. "Vaccination can be one of several risk factors."

MSD is nevertheless taking the issue seriously, she said.

Ingebjorg O. Saevareid of MSD Animal Health.

Production growth

Kvame suggested fish currently in the cages in Rogaland have not been vaccinated and are performing well. Kvame nevertheless expects an impact from the issue, which will materialize in the fourth quarter.

The problems in Rogaland mean the company reduced its estimated harvest volumes for 2018 by 5,000 metric tons to 75,000 metric tons. It still stands by its goal to produce 100,000 metric tons of salmon by 2020.

Much of the production growth will therefore come next year.

Marine Harvest, Leroy cagey

Marine Harvest and Leroy Seafood Group also presented their respective quarterly results on Wednesday.

The companies didn't name MSD's PD vaccine, but Leroy did report major problems with deformation at its Leroy Sjotroll operations.

According to the company's quarterly presentation, it achieved lower prices due to a large proportion of deformed fish.

Responding to questions from **IntraFish** regarding whether they have experienced deformations due to the new vaccine, Marine Harvest and Leroy executives said they had not yet reached any conclusions.

"I have not concluded that the seven-component vaccine is the cause of deformities, but we aren't ignoring it, either," Alf-Helge Aarskog, CEO of Marine Harvest, said.

Leroy CFO Sjur Malm said didn't want to speculate to much on the potential link.

"There are several reasons for deformations in salmon," he said.

Read scientific reports on the side-effects of vaccines via:

"Side-Effects of Vaccination" (Fish Vaccination, 2014)
"Vaccinated farmed Atlantic salmon are susceptible to spinal and skull deformities" (Journal of Applied Ichthyology, 2012)
"Manifestations of systemic autoimmunity in vaccinated salmon" (Vaccine, 2010)
"Association of spinal deformity and vaccine-induced abdominal lesions in harvest-sized Atlantic salmon, Salmo salar L" (Journal of Fish Disease, 2008)
"Time of vaccination influences development of adhesions, growth and spinal deformities in Atlantic salmon Salmo salar" (Diseases of Aquatic Organisms, 2006)

Fisheries Health Inspectorate Case Information published by the Scottish Government for March 2016 included a reference to "vaccine adjuvant reaction" at Cooke's Yetts O'Muckart farm:

marinescotland science

The Scottish Government
Riaghaltas na h-Alba

[redacted]
Cooke Aquaculture (Freshwater) Ltd
Crowness Road
Hatston Kirkwall
Orkney
KW15 1RG
[redacted]

FINAL FISH HEALTH INSPECTORATE VISIT REPORT

SUMMARY FOR INFORMATION OF SITE OPERATOR

BUSINESS NO	FB0235	DATE OF VISIT	15/03/2016
SITE NO	FS0371	SITE NAME	Yetts O' Muckart
INSPECTOR	Svenja Elwenn	CASE NO	20160118

Section 1: Summary

During a routine site inspection a moribund fish was observed and removed for diagnostic sampling. Histopathology indicates evidence of kidney necrosis and vaccine adjuvant reaction. Some features resembling haemorrhagic smolt syndrome (HSS) were also observed.

Section 2: Case Detail

Observations

Yetts O' Muckart was visited in accordance with the Aquatic Animal Health (Scotland) Regulations 2009, and to meet the requirements of European Community Council Directive 2006/88/EC. Inspection of the site records indicated mortality levels were not particularly elevated, however approximately 30 mortalities for the site per day were being experienced. The majority of these mortalities were attributed to HSS.

On inspection one moribund fish was observed and was removed for further examination. Externally this fish has an distended abdomen, haemorrhaging on the throat, ventrum and base of the fins and pale necrotic gills. The vent was also inflamed. Internally the fish had ascites and haemorrhaging on the pyloric caeca.

A [FHI Case Information report from 2017] cited "minor peritonitis likely associated with vaccine administration" at Marine Harvest's Loch Alsh farm:

marinescotland science

The Scottish Government
Riaghaltas na h-Alba

[redacted]
Marine Harvest (Scotland) Ltd
Stob Ban House
Glen Nevis Business Park
Fort William
PH33 6RX
[redacted]

FISH HEALTH INSPECTORATE VISIT REPORT

SUMMARY FOR INFORMATION OF SITE OPERATOR

BUSINESS NO	FB0119	DATE OF VISIT	11/10/2017
SITE NO	FS0016	SITE NAME	Loch Alsh (Sron)
INSPECTOR	Joe Triscott	CASE NO	20170444

Section 1: Summary

During a routine inspection of the above site, a number of moribund and lethargic fish were observed. Three fish were removed for further examination and subsequent diagnostic sampling.

Histopathology examination revealed mild gill pathology, mainly lamellar capillary disturbances/damage. Mild multifocal hepatic necrosis was also noted (likely associated with hypoxia). Fish 3 was a poor doing individual and showed a low level of proliferative gill pathology and mild heart inflammation. A minor peritonitis likely associated with vaccine administration was also noted.

The [FHI report (p226) detailed]:

Gut and pyloric caeca: Some fibrous adhesions (likely associated with vaccine administration), lack of abdominal adipose tissue and some cell sloughing noted in F3.
Pancreas: Some fibrous adhesions associated with peri pancreatic adipose tissue (likely associated with vaccine administration) (F1).
Liver: Few scattered nests of hepatocytes showing pyknotic nuclei (F1), mild multifocal hepatocyte necrosis (F2).
Kidney: Increase number of melanomacrophage aggregates (F3).
Spleen: Some fibrous adhesions associated with the splenic capsule (likely associated vaccine administration) (F1), empty ellipsoids noted in F2 and slightly congested in F3.

Signed: [redacted] Date: 17/11/2017
Fish Health Inspector

Another FHI Case Information report for 2017 (North Shore, Marine Harvest) detailed:

Gut and pyloric caeca: Some fibrous adhesions (likely associated with vaccine administration) (F1-F5) and some cell sloughing noted in F1. Mixed bacteria within the lumen of the hindgut (F4).

Pancreas: Few scattered apoptotic cells noted in F3. Some fibrous adhesions associated with peri-pancreatic tissue (likely associated with vaccine administration) (F2).

Liver: Mild focal to diffuse dilation of the sinusoidal space (F2 & F4) and small foci of hepatocyte necrosis (F2). Fibrous adhesion noted on the capsule (F3-F5). Mild diffuse hepatocyte vacuolation noted in F4.

Kidney: Within normal range.

Spleen: Some fibrous adhesions likely associated with vaccine administration (F1-F5), several small distinct structures resembling small granulomas and one or two giant cells associated.

Signed: [redacted] Date: 30/11/2017
Fish Health Inspector

Another FHI Case Information report from 2018 cited "damage in muscle due to vaccine treatments" at Grieg's Girlsta Hatchery:

FHI 059, Version 11 Issued by: FHI Date of issue: 12/09/2017

Case No:	2018-0057	Date of visit:	05/03/2018
Time spent on site:	4.5hrs	Main Inspector:	WJM
Site No:	FS0504	Site Name:	Girlsta Hatchery
Business No:	FB0557	Business Name:	Grieg Seafood Shetland Ltd (Hatchery)

Additional Case Information:

Parr unit currently shut down. Has had a deep clean. Smolt unit to also be deep cleaned once fish moved out.
Units fallowed every 4 months but site never completely fallow
Recent vet report only observing damage in muscle due to vaccine treatments

Another FHI Case Information report from 2018 (Tarbert South, The Scottish Salmon Company) detailed "adhesions likely associated with vaccine administration":

> Gut and pyloric caeca: Adipose tissue showed fibrous adhesions likely associated with vaccine administration (F1-F5), mild to moderate cell sloughing (F1-F5) (likely post mortem artefact).
>
> Pancreas: Fibrous adhesions associated with peripancreatic tissue (likely vaccine administration).

Further FHI Case Information reports for 2018 included reference to "adhesions likely associated with vaccine administration" at Groatay (Marine Harvest) and Meall Mhor (The Scottish Salmon Company):

Groatay (Marine Harvest):

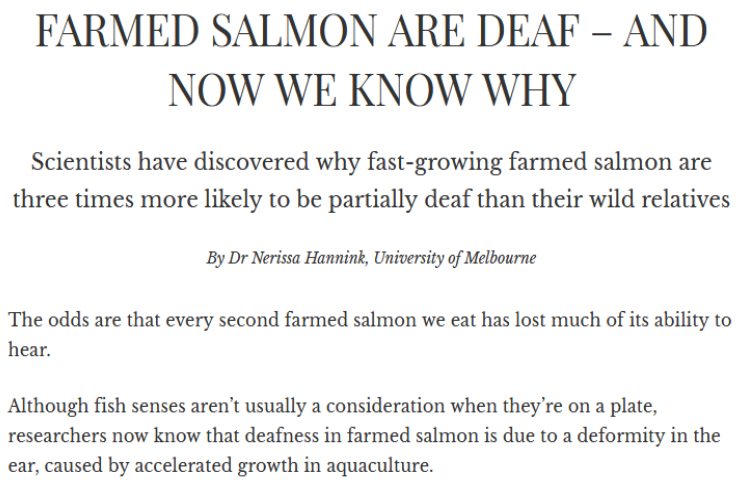
> Gut and pyloric caeca: Adipose tissue showed some fibrous adhesions likely associated with vaccine administration (F2), some to moderate cell sloughing (F1-F2) (likely associated with post-mortem artefact).

Meall Mhor (The Scottish Salmon Company):

> Gut and pyloric caeca: Adipose tissue showed some fibrous adhesions likely associated with vaccine administration (F2) and some cell sloughing noted in F3.

Please note that this is not an exhaustive list of cases (a search for "vaccine" via the FHI Case Information files published since 2013 would yield further details).

Other deformities include deafness with half of the world's farmed salmon part deaf due to accelerated growth rates.



FARMED SALMON ARE DEAF – AND NOW WE KNOW WHY

Scientists have discovered why fast-growing farmed salmon are three times more likely to be partially deaf than their wild relatives

By Dr Nerissa Hannink, University of Melbourne

The odds are that every second farmed salmon we eat has lost much of its ability to hear.

Although fish senses aren't usually a consideration when they're on a plate, researchers now know that deafness in farmed salmon is due to a deformity in the ear, caused by accelerated growth in aquaculture.

Read more via:

"Rapid growth causes abnormal vaterite formation in farmed fish otoliths" (Journal of Experimental Biology, 2017)
"More than 95 per cent of adult farmed fish are deformed" (Daily Mail, 2017)
"Deafness in farmed salmon linked to accelerated growth" (Science Daily, 2017)

No wonder that farmed salmon are "depressed". Oceana reported in 2017:

1. Depression

Up to a quarter of all farmed salmon are what the industry calls "loser fish" or "drop-outs." These deadbeat fish, though otherwise healthy, are sluggish, stunted and uninterested in food. In 2016, researchers examined the losers' brains and found sky-high measures of the stress hormone cortisol. They also discovered that the drop-outs had serotonin levels mirroring those of depressed mammals.

Unusually, the losers in the study didn't respond to the standard method for freaking out a fish — dropping it in a bucket — suggesting that their systems were already so overloaded they couldn't respond to extra stresses.

A healthy salmon (top) dwarfs a depressed "loser fish."

Credit: : Ole Folkedal

The scientists theorized that the overcrowded pens on fish farms are to blame for these bummed-out salmon. Smaller, weaker fish struggle to escape from aggressive neighbors, and may eventually just give up on life. Other unnatural stressors such as vaccination and artificially manipulated water temperatures likely play a role as well.

2. Hearing loss

Can you hear me now? For half of farmed salmon, the answer is "barely." As a 2016 study discovered, 50 percent of all farmed salmon worldwide have deformed ear bones. This deformity, which can cut a fish's hearing acuity in half, is 10 times more common in domestic salmon than wild ones.

Scientists still don't know why hatchery-raised fish are so hard of hearing. But they think that their odd ear bones, or "otoliths" — which are not only essential for hearing but also balance and navigation — may help explain the abysmal survival rates of hatchery-raised salmon released into wild rivers.

3. Scoliosis

Wonky ear bones aren't the only deformity that afflicts farmed salmon. Young salmon, called smolts, often suffer from oddly curved or kinked spines — the fish equivalent of scoliosis. A host of factors have been blamed for "broken back syndrome," from artificial lights and unnaturally warm water used to speed up smolt growth in hatcheries to vitamin deficiencies or exposure to toxins.

Read more via "Deaf, Depressed and Deformed: The Top 5 Reasons Salmon Farming Makes for Unhealthy Fish" (Oceana, 2017)

A report - "Fish Welfare on Scotland's Salmon Farms" - published by OneKind in August 2018 included:

6.2 Health defects

It has been shown that farmed salmon have a range of defects that compromise their health and welfare. Cataracts are relatively common and can be as prevalent as 80% in farmed salmon (Ersdal *et al.* 2001). The causes of cataracts are likely multifactorial, and include nutritional deficiencies, rapid growth and water pollution (Rhodes et al. 2010, Waagbo *et al.* 1998 , Bjerkas et al. 2004). The development of cataracts reduces the ability of salmon to find food, which in turn compromises their development and growth.

Salmon with cataracts Fish Health Inspectorate

et al. 2014). Fish with spinal deformities suffer as they are not able to swim effectively, hindering their ability to obtain food and move away from aggressive interactions (Silverstone and Hammell 2002).

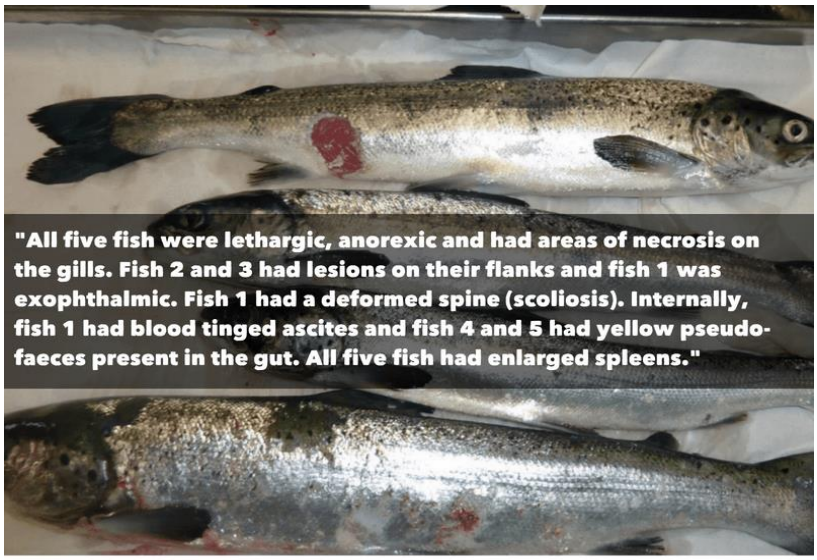
Fish Health Inspectorate reports document many incidents of deformities in farmed salmon, including:

- At Linga (Setterness), some fish were described as having "stunted growth and deformities" as a result of "a very big tidal flow, in combination with severe weather" which "could have pushed fish against the side of the cages". (Fish Health Inspectorate, 2016).
- At North Voe, the main cause of weekly mortality was noted to be "deformity". (Fish Health Inspectorate, 2017).
- At Lismore North, fish were described as having deformed gill covers (Fish Health Inspectorate, 2016).

Other health defects that farmed salmon experience include abnormal swim-bladders and heart shapes (Poppe et al. 1997, Poppe *et al.* 2003). Farmed salmon are also often deaf, as a result of deformed sagittal otoliths, an important component of hearing in teleost fish (Reimer *et al.* 2017). This deformity is likely to be caused by genetic selection for fast growth.

Salmon with a spinal deformity Fish Health Inspectorate

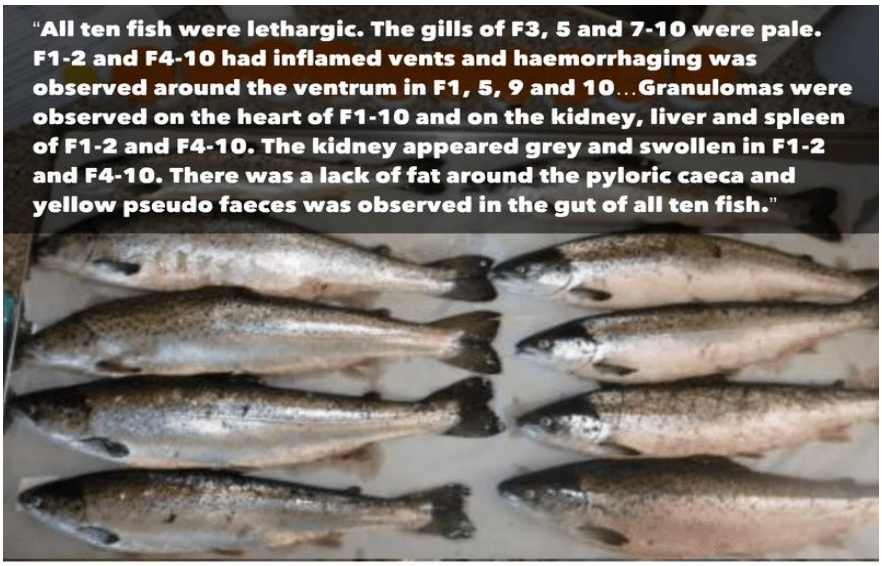
The Ferret reported in June 2018:



Fish Farm: Vuiabeag, Isle of Lewis

Company: Scottish Salmon Company
Problems: amoebic gill disease, poxvirus
Fish heath inspection: five fish sampled on 19 October 2017
Case number: 2017-0467

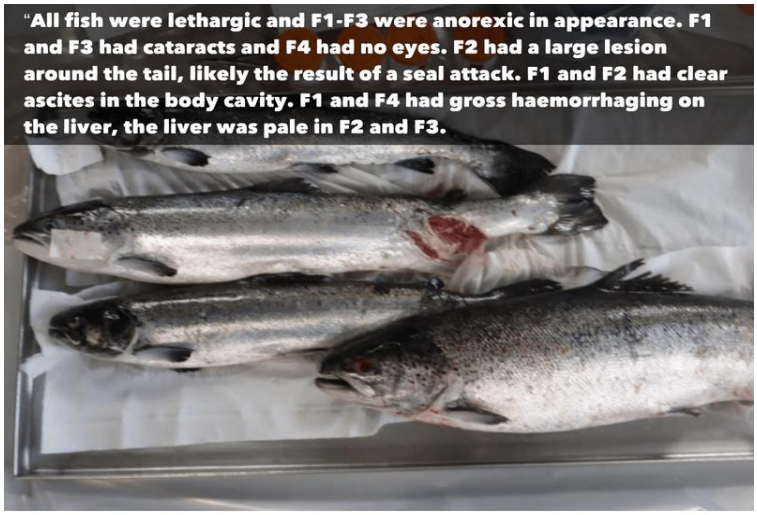
The Ferret



Fish Farm: Torridon, Loch Torridon

Company: Marine Harvest
Problems: bacterial kidney disease
Fish heath inspection: 10 fish sampled on 24 May 2016
Case number: 2016-0202

The Ferret



Read other scientific reports on deformities in farmed salmon via:

"The vertebral column and exercise in Atlantic salmon — Regional effects" (Aquaculture, 2016)
"Multigenic Delineation of Lower Jaw Deformity in Triploid Atlantic Salmon" (PLoS, 2016)
"Unilateral perivertebral fibrosis associated with lordosis, kyphosis and scoliosis (LKS) in farmed Chinook salmon in New Zealand" (Diseases of Aquatic Organisms, 2016)
"The prevalence of vertebral deformities is increased with higher egg incubation temperatures and triploidy in Atlantic salmon Salmo salar L." (Journal of Fish Diseases, 2013)
"Vertebral deformities in farmed Atlantic salmon (*Salmo salar* L.) – etiology and pathology" (Journal of Applied Ichthyology, 2012)
"Spinal deformities in farmed Atlantic salmon" (The Canadian Veterinary Journal, 2002)

Deformities may be the tip of the iceberg in terms of welfare issues for farmed salmon. Suffice to say that there is a growing body of scientific evidence detailing pain in fish. Read more via:

It's Official: Fish Feel Pain: The verdict is in. But will our oceanic friends ever get the same legal protections as land animals?
What a Fish Knows: The Inner Lives of Our Underwater Cousins
Do fish feel pain and why does it matter?
Cognitive evidence of fish sentience
Why human pain can't tell us whether fish feel pain
Fish brains and behaviour indicate capacity for feeling pain
Fish sentience and the precautionary principle
Science Shows Fish Feel Pain, So Let's Get Over It and Do Something to Help These Sentient Beings
Fish Intelligence, Sentience and Ethics
Fish Are Sentient and Emotional Beings and Clearly Feel Pain
Do Fish Feel Pain?

Wild Fish Interactions:

Secret video footage shot on 5 August 2018 at the Scottish Sea Farms salmon farm at Scallastle Bay on the Isle of Mull clearly showed shoals of wild fish (believed to be saithe or pollock or even juvenile cod) swimming amongst the farmed salmon.

In British Columbia, Canada, Alexandra Morton and Sea Shepherd have documented wild herring and capelin swimming inside salmon farms. In May 2018, Alexandra Morton reported via Vimeo:

"We are here to investigate the impacts that salmon farms have on the marine environment and today we saw wild fish trapped inside these farms pens," said Operation Virus Hunter II campaign leader Carolina Castro in 2017. "These fish are not supposed to be there; their valuable populations are already compromised. This is hard evidence of the negative impacts these farms are having on the oceans."

Wild Herring inside farmed Atlantic salmon pen. Photo: George Quocksister Jr

Read more via "[Sea Shepherd Discovers Wild Fish Trapped in British Columbia's Salmon Farm Pens]"

Watch video report [online here]

#OpVirusHunter #Canada #SeaShepherd
Operation Virus Hunter uncovers new impact salmon farms have on the wild.

The Tyee [reported in August 2017]:

A 2014 Norwegian study, for example, found that as many as 17 different species of wild fish came to dine on waste feed from Atlantic salmon feedlots. (Up to five per cent of fish pellets aren't eaten and drop out of the pens to the ocean floor.)

Up to 10 tonnes of wild fish crowd around the nine studied Norwegian fish farms in the summer months, the research found.

As powerful wild fish attractants, fish farms can also spread disease into the wild too. "The little knowledge that exists indicates that the transfer of pathogens from farmed fish to wild marine fish takes place," noted the Norwegian researchers.

They also concluded that "attraction of fish to farms may be negative for local fishermen if it reduces the availability and food quality of the wild fish."

Wild fish congregating around fish farms are exposed to the pathogens that build in the farms, such as sea lice, piscine reovirus and the bacteria *piscirickettsia salmonis*, a growing problem in B.C. salmon farms.

Read more via "Sea Shepherd Documents Wild Fish Trapped in BC Salmon Farm: Studies show fish farms attract wild species, can spread viruses and parasites"

The 2014 Norwegian study - "Impacts of wild fishes attracted to open-cage salmonid farms in Norway" - included:

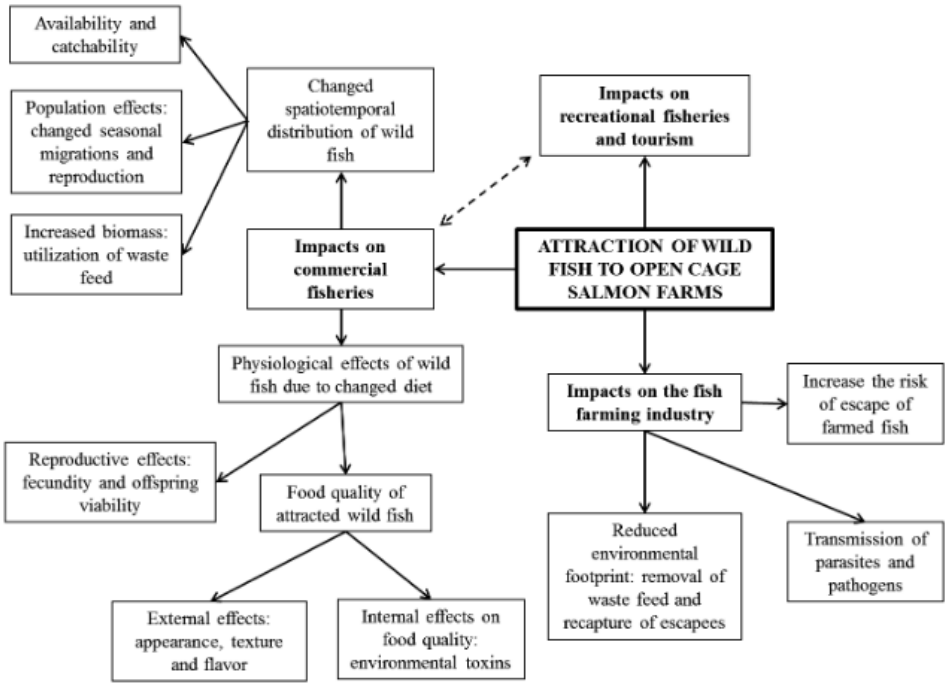


Fig. 1. Conceptual model indicating the potential impacts of wild fish attraction to open-cage salmon farms on the environment and human activities and their interactions in Norway

Table 2. Wild fish species found eating waste feed from fish farms. Fishes (%): percentages of fish that had waste feed in their stomach. Escaped farmed sea bass, sea bream, meagre and pollack *Pollachius pollachius* also eat waste feed (P. Sanchez-Jerez unpubl.)

English name	Latin name	Country	Fishes %	Source
Rainbow trout	*Oncorhynchus mykiss*	Scotland	30–73	Carss (1990)
Saithe	*Pollachius virens*	Scotland, Norway	14–92	Carss (1990), Skog et al. (2003), Bjordal & Johnstone (1993), Dempster et al. (2011), I. Uglem unpubl.
Atlantic cod	*Gadus morhua*	Norway	11–32	Dempster et al. (2011), Sæther et al. (2012)
Atlantic salmon (escaped farm fish)	*Salmo salar*	Norway	80	Olsen & Skilbrei (2010)

Transmission of pathogens

Salmon aquaculture in open sea cages transfers parasites and diseases from farmed salmon to wild salmonids and vice versa, but little is known about the transfer of pathogens to other fish species (Johansen et al. 2011, Taranger et al. 2013). Since the amounts and densities of fish in open sea cages are vast compared to natural situations, not only is a higher local infection pressure due to the high host density likely, but also an increased pathogen virulence as a result of a greater potential for selection (Krkošek 2010, Pulkkinen et al. 2010). Dispersal of pathogens from open-cage aquaculture occurs through ocean currents, transportable equipment and ships, escape of farmed fish and movements of wild farm-attracted marine fish (Johansen et al. 2011, Arechavala-Lopez et al. 2013).

The wild fish might transfer pathogens from farmed fish to other farms or wild fish populations under the assumptions that (1) the wild fish reside close enough to farms for a period of time sufficient for pathogens to be transferred, (2) the wild fish move frequently and far enough among farms and other areas to disperse pathogens and (3) that farmed fish and wild fish are actually carriers of the same pathogens. Wild marine fish may stay in the vicinity of farms for several months and they may move relatively frequently and rapidly among farms and other locations (Uglem et al. 2008, 2009, Dempster et al. 2010, Sanchez-Jerez et al. 2011, Otterå & Skilbrei 2014). In Norway, this is true of Atlantic cod and saithe (Uglem et al. 2008, 2009, Otterå & Skilbrei 2014), and in the Mediterranean for mullets *Liza aurata* and *Chelon labrosus* (Arechavala-Lopez et al. 2010, 2013) and for bluefish *Pomatomus saltatrix* (Arechavala-Lopez et al. 2014). The first 2 assumptions for the transfer of pathogens through wild fish are thus most likely fulfilled. It is, however, unclear to what extent farmed salmonids and wild non-salmonids share the same pathogens, and if these pathogens actually are transferred among species. The little knowledge that exists indicates that the transfer of pathogens from farmed fish to wild marine fish takes place (Heuch et al. 2011, Johansen et al. 2011, Arechavala-Lopez et al. 2013, Taranger et al. 2013). Transfer is more likely amongst closely related species. Recent reviews regarding the possible role of wild fish as vectors for pathogens concluded that the existing knowledge is too sparse for risk evaluations (Johansen et al. 2011, Taranger et al. 2013).

A scientific paper published in 2001 reported sea lice infestation on saithe inside a salmon farm on the West coast of Scotland:

Bull. Eur. Ass. Fish Pathol., 21(2) 2001, 84

Occurrence of gravid salmon lice (*Lepeophtheirus salmonis* (Krøyer)) on saithe (*Pollachius virens* (L.)) from salmon farm cages.

A.R. Lyndon and J.P.G. Toovey

Centre for Marine Biodiversity and Biotechnology, Department of Biological Sciences, Heriot-Watt University, Riccarton, Edinburgh, EH14 4AS, UK.

Abstract

The first record of gravid salmon lice from a non-salmonid host is reported. Five out of twelve saithe (*Pollachius virens*) from inside salmon farm pens were infected with *L. salmonis*. Both gravid females and larval stages (chalimus) were present. These findings have implications for the control of salmon lice in farm situations.

Salmon lice, *Lepeophtheirus salmonis* (Krøyer 1838), are generally considered to have a narrow host specificity, having previously been recorded as reproductive adults only from salmonids of the genera *Salmo* and *Oncorhynchus* (Kabata, 1979). There is one previous record of the occurrence of salmon lice on non-salmonid hosts (saithe, *Pollachius virens* (L.)) in UK waters (Bruno & Stone, 1990), but in this case only pre-adult lice were present. The present note reports the first observation of both chalimus and gravid female salmon lice on saithe at a Scottish marine fish farm site.

During routine counting of salmon lice in connection with other work (see Lyndon & Toovey (2000) for sampling methods), a sample of 12 saithe (mean length = 35 ± 3 cm) was obtained from inside pens at a salmon farm site on the Scottish west coast (Invernessshire). Five were infected with *L. salmonis* (prevalence = 42%; mean intensity = 1.80, range of intensity 1-3; parasitological terms in accordance with Bush *et al.* (1997)) (Table 1), of which 4 carried single gravid (egg-bearing) adult female lice, 2 carried single chalimus stages (1 each of chalimus II and chalimus IV; see Pike & Wadsworth (1999) for details of life history) and 2 carried mobile lice (pre-adults and/or adult males; see Lyndon & Toovey (2000)). The proportion of gravid lice on the saithe was 0.44. In the correspond-

Fish species	n	Abundance of louse stages			Total lice
		Chalimus	Mobile*	Gravid	
Saithe	12	2	3	4	9
Atlantic salmon	20	15	37	25	77

Table 1. Abundance of different stages of salmon lice (*L. salmonis*) on saithe and Atlantic salmon from a Scottish fish farm. * mobiles include pre-adult males and females along with adult males.

ing sample (n = 20) of Atlantic salmon (*Salmo salar* L.) from the same cages, prevalence of salmon louse infection was 95% (mean intensity = 4.05, range of intensity = 1–12) and the proportion of gravid lice was 0.33 (Table 1).

To the authors' knowledge, this is the first report of gravid female *L. salmonis* from a non-salmonid host, with the exception of accidental transfers in aquaria (Kabata, 1979). It is likely, given the close proximity of the saithe to infected salmon within the pens, that these gravid lice represent individuals accidentally transferred from salmon, rather than lice which developed entirely on saithe. The occurrence of mobile lice might also be interpreted in this way (Bruno & Stone, 1990). However, the presence of chalimus stages, which cannot be the result of accidental transfer, leaves open the possibility that *L. salmonis* might be able to complete its life cycle on saithe. In any case, the presence of gravid *L. salmonis* on saithe may represent a significant source of reinfection for salmon, due to their close proximity, with possible implications for the modelling of louse infection under certain circumstances. Furthermore, it also raises the question of whether lice counts on salmon alone will always be an adequate indicator of impending louse loads and, hence, appropriate treatment schedules (Treasurer & Grant, 1997), on sites where the presence of saithe inside, or in close proximity to, pens is significant.

It seems unlikely that infection of saithe inside pens would lead to significant transfer to saithe outside, as previous work has shown that movement of *L. salmonis* from saithe to saithe is far less frequent than from saithe to salmon (Bruno & Stone, 1990). Nevertheless, the development of gravid *L. salmonis* on free-swimming saithe, which are often attracted to the immediate vicinity of fish farm pens (personal observations), cannot be ruled out and should be investigated more thoroughly.

The authors wish to thank the staff at the salmon farm site for assistance in access to the pens and in capture of the samples. JPCT was in receipt of a Heriot-Watt University studentship during this work.

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Aquaculture
Volume 89, Issues 3–4, 15 September 1990, Pages 201-207

The role of saithe, *Pollachius virens* L., as a host for the sea lice, *Lepeoptheirus salmonis* Krøyer and *Caligus elongatus* Nordmann

David W. Bruno, Janet Stone

Show more

https://doi.org/10.1016/0044-8486(90)90125-7

Abstract

The role of saithe, *Pollachius virens*, as hosts for the sea lice *Lepeoptheirus salmonis* and *Caligus elongatus* was investigated. Saithe in the vicinity of sea cages, used for rearing Atlantic salmon, *Salmo salar*, were found to be infested with pre-adult *L. salmonis*. This represents a new host for *L. salmonis*. Only *C. elongatus* was recorded on saithe caught in open sea lochs. In experimental tests *L. salmonis* regularly transferred between saithe and salmon, and to a lesser extent between salmon and salmon. The movement of *L. salmonis* between saithe occurred infrequently. *C. elongatus* also transferred between saithe and salmon, and from salmon to salmon. Moribund salmon and saithe appeared to attract more lice than healthy fish.

Read more via "The role of saithe, *Pollachius virens* L., as a host for the sea lice, *Lepeoptheirus salmonis* Krøyer and *Caligus elongatus* Nordmann"

In 2016, scientists reported that saithe "establish core residence areas close to fish farms".

Read more via "Vertical distribution of saithe (*Pollachius virens*) aggregating around fish farms"

In 2014, scientists reported that "the aquaculture industry is influencing the local saithe distribution". "Large-scale population effects are more difficult to prove, but it is possible that the dynamic relationship between the coastal and oceanic phases has been altered," continued the paper.

Read more via "Possible influence of salmon farming on long-term resident behaviour of wild saithe (*Pollachius virens* L.)"

Scientists reported in 2015:

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

A Metabolomic Approach To Detect Effects of Salmon Farming on Wild Saithe (*Pollachius virens*) Populations

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J. Agric. Food Chem., 2015, 63 (49), pp 10717–10726
DOI: 10.1021/acs.jafc.5b04765
Publication Date (Web): November 24, 2015

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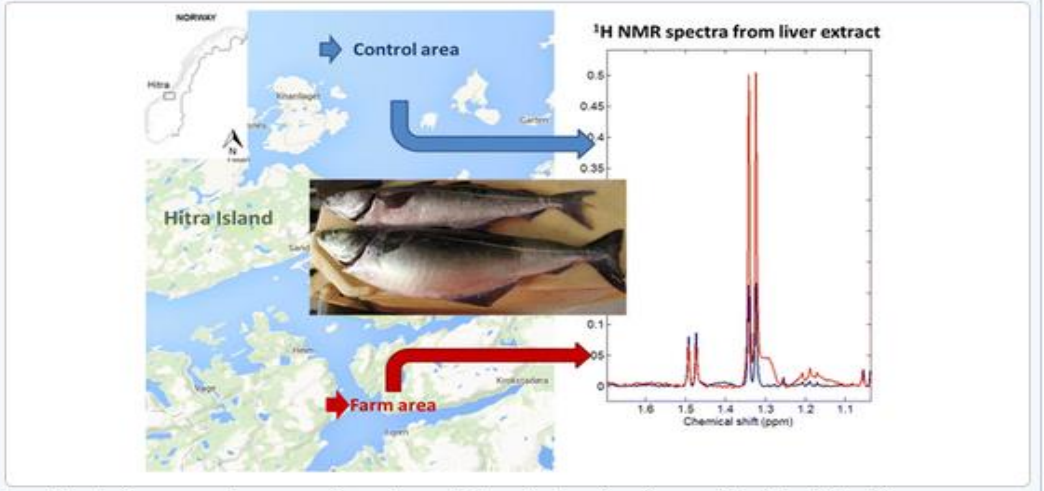
Abstract



A metabolomics approach was used to analyze effects of salmon farming on wild saithe (*Pollachius virens*) populations. Saithe fish were captured at two salmon farms and at two control locations around the island of Hitra, Norway. Changes in diet seem to drive changes in metabolic status of fishes. The liver and muscle tissues, from the fishes captured around the farm, showed higher levels of lactate and certain amino acids (glutamine, glutamate, and alanine) and lower levels of glucose and choline than the fishes captured in the control locations, far from the farm locations. The higher levels of lactate and amino acids could be related to the facility of obtaining food around the farm and the deficit in choline to the deficit of this nutrient in the salmon feed. At each location the fish were captured with either benthic gill nets and automatic jigging machines, and this feature showed also variations in different metabolites.

Read more via "A Metabolomic Approach To Detect Effects of Salmon Farming on Wild Saithe (*Pollachius virens*) Populations"