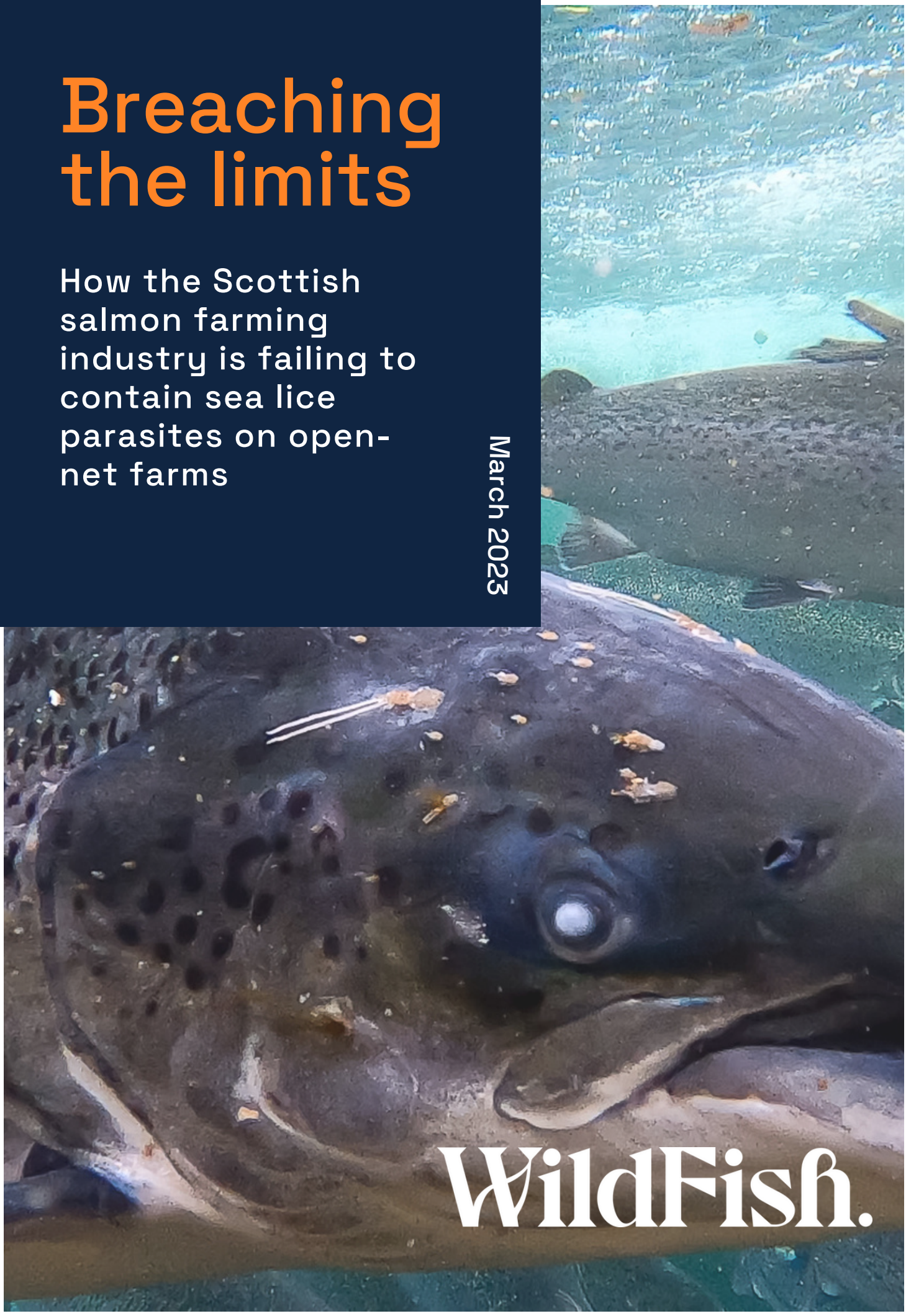
Breaching the limits

How the Scottish salmon farming industry is failing to contain sea lice parasites on open-net farms

March 2023



WildFish.

Executive summary

This report demonstrates how the Scottish fish farming industry is failing to contain sea lice parasites on its open-net farms, with potentially severe consequences for wild Atlantic salmon and sea trout. In 2022, two-thirds of Scottish marine fish farms breached the industry's own Code of Good Practice (CoGP) sea lice thresholds on at least one occasion. The poor compliance comes despite the fact that the CoGP limits are in themselves ***five times*** *more lenient than best global industry practice.*

One in four of the weekly average sea lice counts given during the 2022 sensitive period were above CoGP thresholds; failure to control sea lice during this period risks the health and survival of wild Atlantic salmon smolts in particular. This report demonstrates the severe limitations of the salmon farming industry's self-regulation of sea lice. It highlights a clear need for greater scrutiny of how this code is employed, enforced and used by the industry as a greenwashing tool, and calls for the Scottish Government to introduce an absolute limit on sea lice numbers, in line with the best available science and the precautionary principle.*

The report finds that almost 40% of reported sea lice counts in 2022 were either in breach of the CoGP or not provided. Two thirds of active farms (132 out of 192) were in breach of the CoGP sea lice thresholds at least once. During the "sensitive period" (February to June 2022), breaches were even more common. In this high-risk period for out-migrating wild Atlantic salmon, 1 in 4 of the weekly sea lice counts were above the CoGP thresholds. Concerningly, more than half (56%) of active farms breached CoGP thresholds in one or more of their weekly sea lice counts. One farm, run by Mowi Scotland, recorded levels as high as 8.2 adult sea lice per fish, 16 times higher than the CoGP threshold of 0.5 – and 80 times higher than global best practice.

**Due to their presence in coastal waters for most of the year, sea trout are even more vulnerable to sea lice emanating from marine fish farms*

Contents

This report examines the sea lice levels reported on Scotland's open-net salmon and rainbow trout farms in 2022.

Using industry-supplied, Government-published data, the report examines the frequency at which the industry exceeds CoGP sea lice limits, exposing:

- The true reality of sea lice infestations in the marine fish farming industry in Scotland, with some farms hosting upwards of five million sea lice.
- The inadequacy of government sea lice regulations.
- The lack of industry compliance with its own CoGP sea lice thresholds, despite these being five times more lenient than industry best practice.
- The risk to wild salmonid populations as a consequence of high sea lice levels on marine fish farms.

Loch Duart was the worst-performing company in relation to sea lice in 2022, with over a third (35%) of its reported counts breaching CoGP thresholds. With peaks as high as 5.9 adult sea lice per fish, Loch Duart's average weekly sea lice level during the sensitive period was more than double the CoGP sea lice threshold; additionally, the company breached Marine Scotland's 2.0 limit in 14% of its sea lice counts (excluding "no count").

Levels of sea lice frequently above the industry's own CoGP thresholds also contributed to a 26% increase in emamectin benzoate use in 2022; an in-feed treatment for sea lice, this pesticide can have substantial and persistent negative impacts on the surrounding marine flora and fauna. Given the reported impact this pesticide can have on numerous species, including those of ecological and economic importance, increasing use is of environmental concern.

Sea lice parasites are a serious problem – both from the perspective of farmed fish welfare and impact on wild fish populations. This report details the industry's extensive failure to adhere to its own CoGP, despite the levels stipulated in the industry code being substantially more lenient than best industry practice. In doing so it highlights the true value of the CoGP for sea lice control – a greenwashing tool used by both the industry and third-party certification bodies to give the illusion of strict sea lice management, where the reality does not match up.

Recommendations

- Scottish Government should close open-net salmon and trout farms and encourage alternative aquaculture practices that are less environmentally damaging.
- Scottish Government should immediately introduce absolute limits on sea lice numbers on fish farms, in line with the best available science and the precautionary principle.
- Scottish Government must not rely on industry self-regulation to ensure that marine fish farming is having no negative impact on wild fish populations.
- Scottish Government (and in due course its regulator SEPA) should at a minimum close reporting loopholes and independently verify industry-supplied sea lice data.

Introduction

The wild Atlantic salmon is one of Scotland's most iconic species, migrating thousands of miles across open seas, before returning to spawn in the very same rivers in which they were born. Salmon is part of Scotland's cultural heritage, but its existence is under severe threat. Wild Atlantic salmon are experiencing serious population declines across most of their range, including in Scotland.[1] There are many contributing factors to this decline, one of the most serious of which is the impact of sea lice emanating from marine fish farms.

Sea trout are even more vulnerable to infestations of sea lice from farms as migratory trout remain in coastal waters, where the farms are located, throughout the time that they are at sea (before they return to freshwater to spawn).

The rapid expansion of open-net marine salmon and rainbow trout farming in Scotland in the last 30 years has led to increasing concern about parasitic sea lice infestations on these farms, and the threat these pose to the health and survival of both wild and farmed salmon, and sea trout.[2,3,4] This has been made worse by inadequate regulatory control in Scotland, coupled with regular breaches of industry guidelines on the fish farms.

This report uses industry-supplied data to examine sea lice levels on Scottish marine fish farms between January and December 2022. Through identifying the number of instances in which the industry's own sea lice advisory limits are exceeded (set out in the industry's Code of Good Practice, CoGP), within the context of these advisory limits being up to five times more lenient than best practice, it exposes a worrying picture of an endemic failure to manage and control sea lice in Scotland. The findings of this report highlight the magnitude of risk to migrating wild fish posed by sea lice emanating from marine fish farms, especially when viewed in the context of the estimated 77 million farmed salmon in Scottish waters.

What are sea lice, and why do they matter?

The species of sea lice known as the salmon louse (*Lepeophtheirus salmonis*) is an endemic problem in open-net salmon and trout farming, both in Scotland and globally. A type of marine parasite, the young lice move through the water in search of a salmonid host.

Due to the open structure of the nets used, the free-floating sea lice can move uninhibited into marine open-net cages holding farmed salmon and sea trout.[5] Once attached, the maturing louse feeds on the mucous, skin and underlying tissue of the host, with significant health and mortality implications.[6]

Once present in the farm, the highly intensive nature of marine fish farming provide an optimal breeding ground where numbers can increase rapidly. A single Scottish marine fish farm stocks between 200,000 to 2,000,000 fish, creating the potential for sea lice infestations in the millions.[7]

Once attached to a host, the adult sea lice quickly produce eggs; a single adult louse can produce over 3000 eggs in its lifetime.[8] The free-floating juvenile lice then travel as far as 70km in search of a new host.[9] Scottish open-net salmon and trout farms have been shown to be a much more important contributor than wild fish to the total numbers of sea lice in the Scottish coastal zone.[10] Poor control of sea lice numbers within these sites not only lead to welfare issues in the farmed fish, but also directly increases the number of infective lice in the water surrounding the farms and the number of lice infecting wild salmonids.[11,12,13]

It can take as little as 0.2 sea lice per gram to kill an Atlantic salmon smolt; in practice, this can be just 2 sea lice in a typical wild salmon smolt in Scotland.[14] Lower numbers of attached lice can also cause significant issues, impairing heart function, ability to control blood salts (osmoregulation) and diminishing energy reserves vital for the salmon's (or sea trout's) successful migration and return.[15]

Regulatory background

The Scottish Government has a presumption against setting up new marine fish farms on the north and east coasts, as a precaution to protect migratory fish.[16] Because of this, almost all of Scotland's 200+ open-net marine fish farms are located across the west Highlands and Islands. However, a lack of overall spatial planning for salmon farm development means that open-net marine fish farms are often near, or within, the natural migratory pathways of Atlantic salmon and sea trout. Studies have found a direct correlation to the increased production of farmed salmon and the decreasing populations of wild salmon and sea trout in the west Highlands and Islands.[17,18] As a result of the increased sea lice abundance and location of marine fish farms, infections in wild salmonids due to sea lice emanating from the farms pose a significant risk to survival of both these species.[19,20]

Scottish Government regulation does not take any action on sea lice infestations until a marine fish farm has breached 6.0 adult female sea lice per fish for at least 4 weeks (at 2.0 lice per fish, the Fish Health Inspectorate (FHI) increases surveillance). This is in stark contrast to other salmon farming countries with wild Atlantic salmon populations, where Government limits are as low as 0.1 adult female sea lice.[21] In the UK the 'action' taken after limits are breached is an enforcement notice. This simply requires farms to address the issue, commonly via treatment or harvesting. In contrast, marine fish farms breaching Norway's 30-fold lower sea lice limit are required to carry out more rapid action, including enforced harvesting.

Norway's far lower limits are based on a precautionary approach, anchored in research. As a result of the growing scientific consensus on the potentially hazardous

impacts of farm sea lice on the health of wild salmonid populations in Norway, sea lice thresholds were lowered from 0.5 to 0.1-2 adult female sea lice per fish.[22] This approach from Norway highlights how research from independent national research institutions and organisations can lead to improved sea lice regulation and reduced risk to wild salmonids.

In stark contrast, Scotland relies on industry developed and self-regulated sea lice limits in the form of Industry Code of Good Practice (CoGP). A set of standards developed by the Scottish fish farming industry, the sea lice thresholds stipulated in these standards far exceed Norway's scientifically justified limits (at 0.5–1 adult female sea lice per fish).

Promoting the CoGP as a "world-class" standard, the industry body Salmon Scotland frequently refers to it in the media and on the global stage; it forms an integral part of the Scottish finfish aquaculture industry's global reputation. Additionally, the CoGP is used by third-party certification schemes such as the Aquaculture Stewardship Council (ASC) to determine standards, including those related to sea lice. However, as a voluntary scheme, in reality the CoGP lacks any enforcement, an/or repercussions for companies if limits are exceeded.

Code of Good Practice thresholds

Sensitive period
An average of 0.5 adult female *L. salmonis* per fish during the period 1st February to 30th June inclusive.

Non-sensitive period
An average of 1.0 adult female *L. salmonis* per fish during the period 1st July to 31st January inclusive.

Since March 2021, active marine net salmonid farms have been legally required to report weekly average female sea lice levels. The Scottish Government publishes this industry-supplied, self-reported data. Astonishingly, this data is not independently verified. Recent academic research has found that federal auditing of Canadian salmon farms reported 20% higher levels of sea lice than the industry's self-reporting. Therefore, it must also be questioned whether the true picture of sea lice on Scottish farms is even worse than what is published.[23]

Overview of 2022 data

In a year that saw record mortalities on Scottish marine fish farms, unacceptably high levels of sea lice were reported across the industry. Almost one in five (18.1%) of reported counts showed Scottish farmed salmon and trout suffered sea lice levels above the industry's CoGP; this is equivalent to 1352 instances.

More than two-thirds (130 of the 192) active marine open-net salmon farms breached CoGP sea lice limits on at least one occasion. Only 63.3% of the counts given by the industry in 2022 were within the CoGP limits.

Figure 1 highlights that a significant factor in poor compliance is the high instance of "no counts" – 18.6%. This large data gap, caused by farms failing to submit a numerical sea lice count, is concerning for two reasons:

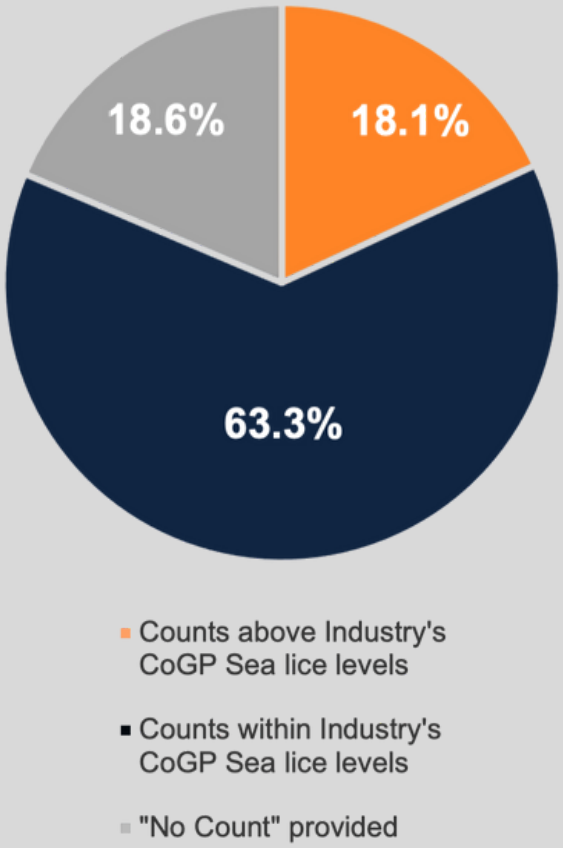
- Under-reporting of sea lice - the majority of "no counts" in 2022 are stated as being linked to either harvesting (slaughter of fish) or veterinary advice (disease, poor water conditions or mortality events) – 30% and 23% respectively. These are both periods during the production cycle when sea lice levels can be extremely high, due to the size of the fish or their immunocompromised state.

- Failure to monitor weekly sea lice trends may result in increasing numbers which risks farmed fish welfare and spread to wild salmon and sea trout.

Over 2/3

of active open-net farms breached CoGP sea lice levels in 2022

Figure 1: **Weekly Sea Lice count performance - Overall 2022**

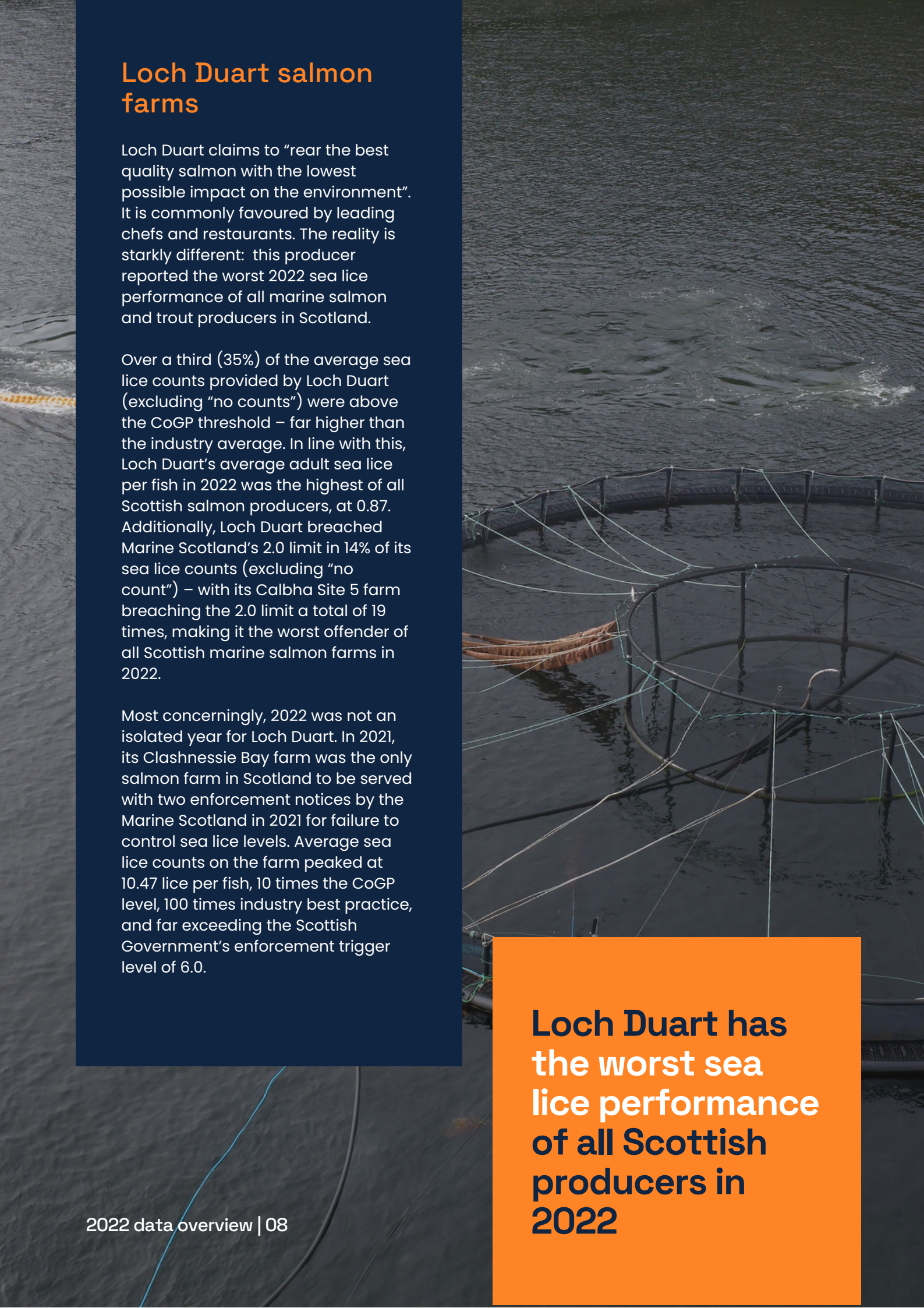


Loch Duart salmon farms

Loch Duart claims to "rear the best quality salmon with the lowest possible impact on the environment". It is commonly favoured by leading chefs and restaurants. The reality is starkly different: this producer reported the worst 2022 sea lice performance of all marine salmon and trout producers in Scotland.

Over a third (35%) of the average sea lice counts provided by Loch Duart (excluding "no counts") were above the CoGP threshold – far higher than the industry average. In line with this, Loch Duart's average adult sea lice per fish in 2022 was the highest of all Scottish salmon producers, at 0.87. Additionally, Loch Duart breached Marine Scotland's 2.0 limit in 14% of its sea lice counts (excluding "no count") – with its Calbha Site 5 farm breaching the 2.0 limit a total of 19 times, making it the worst offender of all Scottish marine salmon farms in 2022.

Most concerningly, 2022 was not an isolated year for Loch Duart. In 2021, its Clashnessie Bay farm was the only salmon farm in Scotland to be served with two enforcement notices by the Marine Scotland in 2021 for failure to control sea lice levels. Average sea lice counts on the farm peaked at 10.47 lice per fish, 10 times the CoGP level, 100 times industry best practice, and far exceeding the Scottish Government's enforcement trigger level of 6.0.



Loch Duart has the worst sea lice performance of all Scottish producers in 2022

Sensitive period

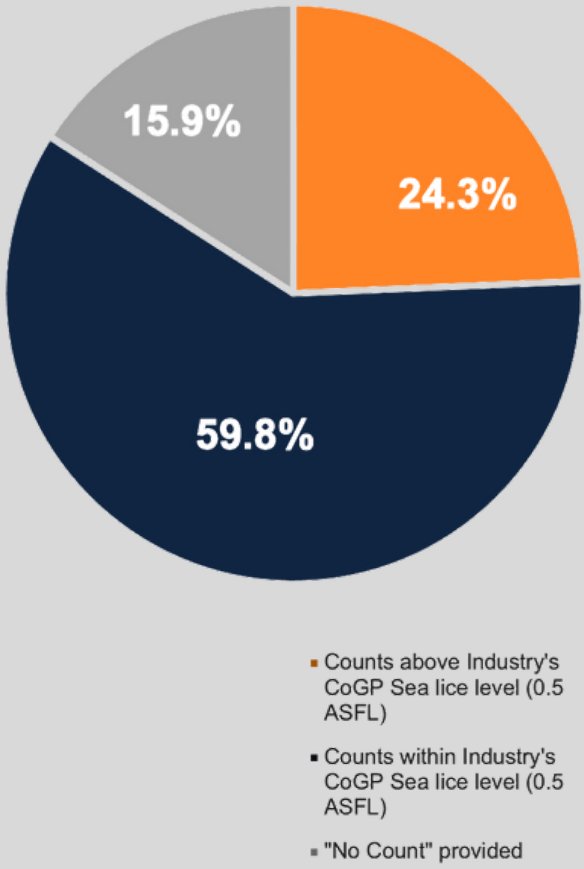
February - June

The "Sensitive Period" runs from 1st February to 30th June, in line with the period in which the majority of wild Atlantic salmon smolts leave Scotland's rivers and begin their migration to sea. In recognition of the risk posed by sea lice emanating from marine fish farms to these out-migrating smolts, the industry CoGP sets a lower sea lice threshold during this period (0.5 average adult sea lice per fish, in comparison with 1.0 during the non-sensitive period.)

Despite recognising the need to restrict sea lice numbers during this period of wild smolt migration, less than 60% of counts submitted during the 2022 Sensitive Period were within the CoGP's 0.5 sea lice limit. The Scottish marine fish farming industry failed to maintain sea lice levels below 0.5 across this entire period, with a minimum of 27 farms in breach each week. Overall, 56% of farms breached the industry threshold at least once during this period.

During the Sensitive Period in 2022, one salmon farm, run by Mowi Scotland (Grey Horse, Channel Outer) recorded levels as high as 8.2 adult sea lice per fish, 16 times higher than the CoGP thresholds. Loch Duart had an average weekly lice count value during the Sensitive Period of more than double the CoGP sea lice threshold (1.1 AFSL).

Figure 2: **Weekly Sea Lice count performance - Sensitive Period**



56%

of farms were in breach at least once across the period

Farm with the most CoGP sea lice level breaches:

Duich, Mowi Scotland Ltd.

Number of CoGP breaches:

19

Farm with the highest weekly average sea lice count:

Grey Horse Channel Outer, Mowi Scotland Ltd.

Average adult sea lice per fish:

8.2

Farm with the highest average across entire sensitive period:

Erisort North Shore West, Mowi Scotland Ltd.

Average adult sea lice per fish:

3.6

Company with the worst performance:

Loch Duart Ltd.

Number of active farms:

9

Number of breaches during sensitive period:

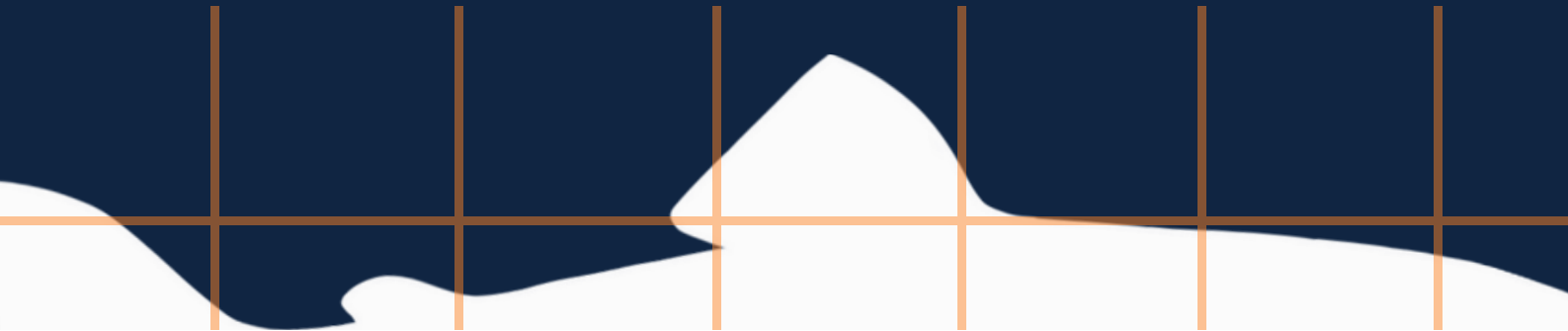
68

Highest company average across entire sensitive period:

Loch Duart Ltd.

Average adult sea lice per fish:

1.1



Non-sensitive period

July - January

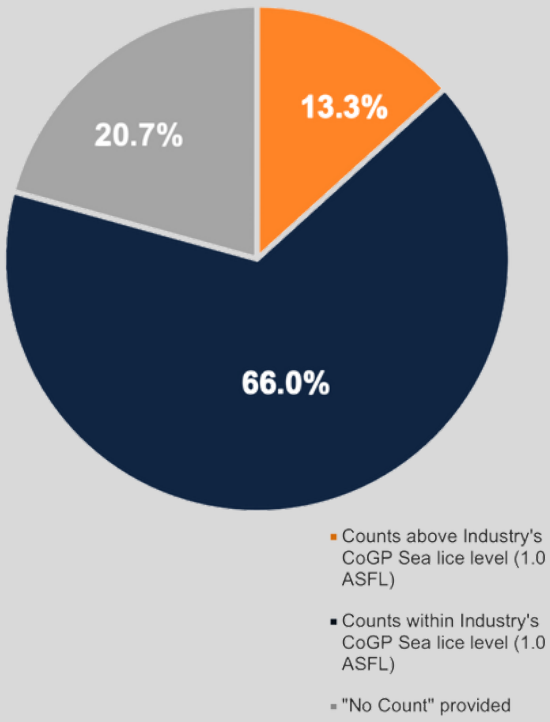
During the non-sensitive period (1 July to 31 January), the CoGP sea lice limit is set at 1.0 adult female lice per fish per fish (double that of the Sensitive Period). In line with this higher limit, average weekly sea lice counts were breached less frequently (13.3% of counts); however, the proportion of "no counts" was higher, at 20.7% (compared to 15.9% during the Sensitive Period).

Across this period (January, and July to December) in 2022, 110 farms breached the CoGP sea lice level, with a minimum of 8 farms reporting weekly average sea lice values above 1.0 every week. The worst performing producer was the rainbow trout producer Dawnfresh Farming Ltd*. As with Loch Duart, 2022 was not an outlier for Dawnfresh; in 2021 sea lice numbers in one instance exceeded 25 sea lice per fish and received multiple warning letters for exceeding Marine Scotland's 6.0 sea lice limit. Dawnfresh reported weekly average sea lice values as high as 17.73 in 2022 - 18 times higher than the CoGP 1.0 limit. Despite only having four active farms during this period, Dawnfresh reported average weekly sea lice counts above the CoGP 1.0 limit on 31 occasions, averaging 1.4 adult sea lice per fish across the non-sensitive period.

Loch Duart, whose farms had performed poorly during the Sensitive Period, also reported high numbers of lice during this period; 25% of the counts provided by Loch Duart (excluding "no counts") were above the CoGP limit.

**Dawnfresh Farming Ltd declared bankruptcy in March 2022. As of February 2023, Dawnfresh is owned by Mowi Scotland.*

Figure 3: **Weekly Sea Lice count performance - Non-sensitive Period**



Highest company average across entire non-sensitive period:

Dawnfresh Farming Ltd.

Average adult sea lice per fish:

1.4

Company with the worst performance:

Dawnfresh Farming Ltd.

Number of active farms:

4

Number of CoGP breaches during non-sensitive period:

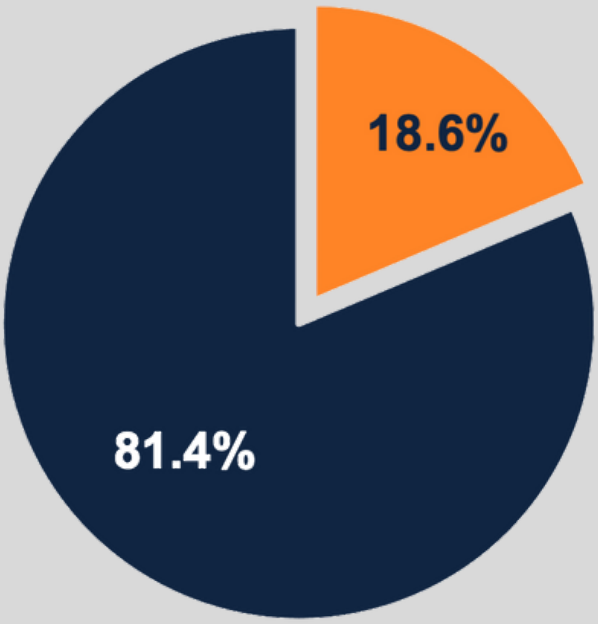
31

Sea lice data gaps

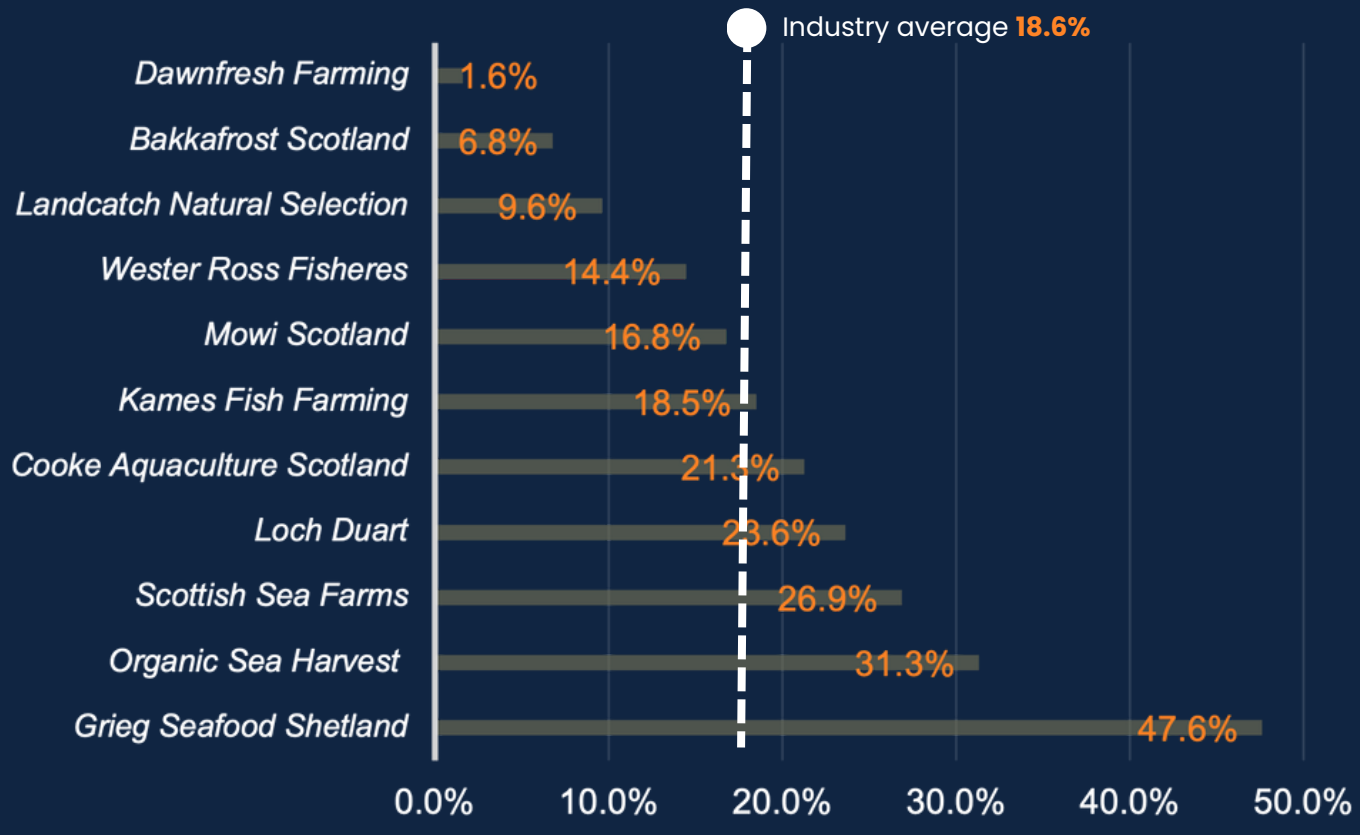
Under the Fish Farming Businesses (Reporting) (Scotland) Order 2020, active marine net salmonid farms are legally required to report weekly average female sea lice levels to Scottish Ministers. Under the current regulation, active farms are permitted to report “no count”, under specific conditions. WildFish research has shown that active farms in Scotland exploit this reporting loophole and fail to submit sea lice counts for as much as one third of the marine production cycle (which is approximately 18 months).[24]

In 2022, Scottish salmonid farms reported “no count” on 1391 occasions, accounting for 18.6% of the total counts provided. This represents a significant data gap. This non-reporting is likely to reflect an underestimation of the volumes of infectious sea lice emanating from Scottish salmon farms, and therefore the risk to wild salmonids. This is particularly concerning as it’s expected that this incomplete data will be used by the Scottish Environment Protection Agency (SEPA) in its forthcoming risk assessment framework for managing sea lice and wild fish interactions.

Figure 4: **Average sea lice counts provided by the industry in 2022**



Graph 1: **"No counts" as a proportion of total counts provided by each company in 2022**



As shown in Graph 1, there is a marked variation in the proportion of “no counts” given by each of the open-net salmon and trout farming companies operating in Scotland.

The frequency of “no counts”, as a proportion of the total counts given by a respective company, ranged from 1.6% for Dawnfresh Farming Ltd, to almost half (47.6%) for Greig Seafood Shetland Ltd. This huge variation suggests some farms are exploiting this reporting loophole, preferring to report "no counts".

In terms of absolute numbers, Scottish Sea Farms submitted a total of 515 “no counts”, far higher than any other producer.

Chemical use

There are two methods that the Scottish fish farming industry administer chemical sea lice treatments to farmed salmon: in-feed treatment or bath treatment (in which fish are submerged). Compared to previous years, 2022 saw an overall industry shift from use of bath treatments to in-feed treatments. The marked reduction in the quantity* of licenced bath treatments used (Azamethiphos and Deltamethrin) is likely to have been driven by the high prevalence of gill health conditions and decreasing efficacy due to increasing drug resistance in sea lice.

Bath treatment can lead to significant morbidity and mortality issues, as well as reduced growth performance. The Scottish salmon farming industry reported record mortality rates in 2022 (16.5 million salmon deaths in total), with conditions affecting gill health reported to be the main driver behind the loss of 11 million salmon on marine open-net farms. It is perhaps then no surprise that bath treatments for sea lice were lower in 2022 than in 2021.[25]

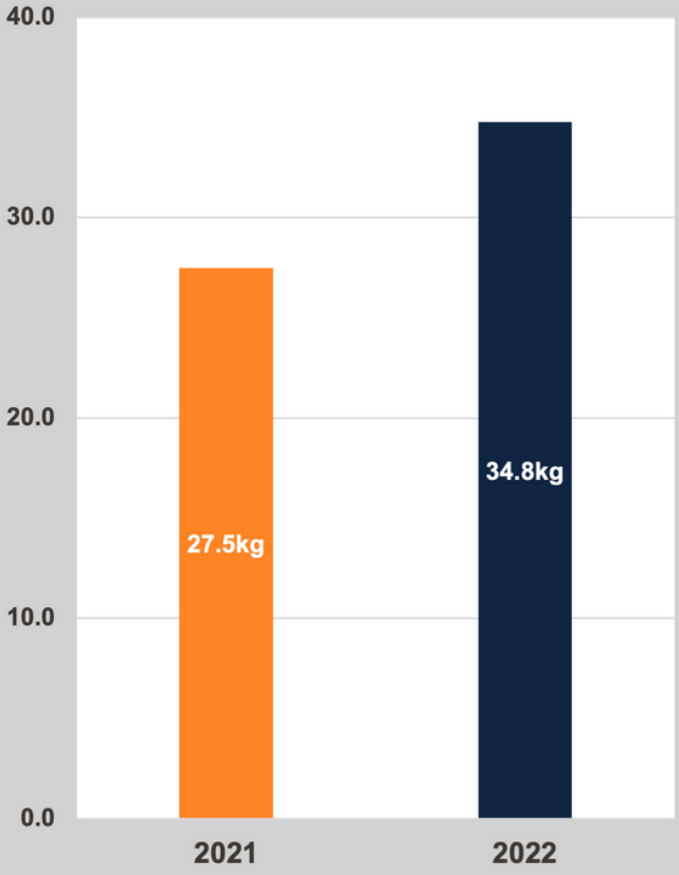
In-feed treatment used on Scottish marine salmon farms increased by 26.4% in 2022** (see Graph 2 to the right). Given as a seven-day in-feed treatment course, this pesticide (emamectin benzoate [26]) is subsequently released into the surrounding environment via excretion in fish faeces and directly as uneaten food pellets.

Once released into the surrounding environment, emamectin benzoate is reported to persist in marine sediment for periods of months to years. An investigation by SEPA found that emamectin benzoate does not break down (degrade) in sediment, suggesting it may persist in the environment indefinitely under certain conditions.[27]

Where present this pesticide negatively impacts a wealth of species, none more so than benthic crustacean communities. This group of invertebrates, including the burrowing types to which emamectin benzoate is especially toxic, play a vital role the health and ecosystem of the seabed. Similar to the role of worms in a terrestrial ecosystem, these invertebrates play an invaluable role in the food chain, break down organic matter and fertilize the seabed; in doing so, significnatly enhancing ecological biodiversity and health.

Given the significant and far-reaching negative impact on the benthic ecology that the use of emamectin benzoate can have, its increasing use within open-net salmon farming is of great ecological concern; no more so than when farms are situated within Marine Protections Areas (MPAs) designed to protect such habitats.

Graph 2: **Kilograms (active ingredient) of emamectin benzoate used on Scottish marine salmon farms**



The data for 2022 is only available for Jan – August (inclusive)
*** grams of active ingredient*
****Compared to the same period in 2021 (Jan – August (inclusive))*

Conclusions & Recommendations

This report demonstrates how the Scottish salmon farming industry is failing to contain sea lice parasites on its open-net farms, with potentially severe consequences for wild Atlantic salmon and sea trout. Almost 40% of the sea lice counts provided by the industry in 2022 were either in breach of the industry's own Code of Good Practice (CoGP), or given as "no count"; more than two-thirds of all active farms breached the CoGP at least once across the year. This is despite the fact that the CoGP thresholds are up to five times higher than those employed by the Norwegian industry as best practice for protecting wild salmonids.

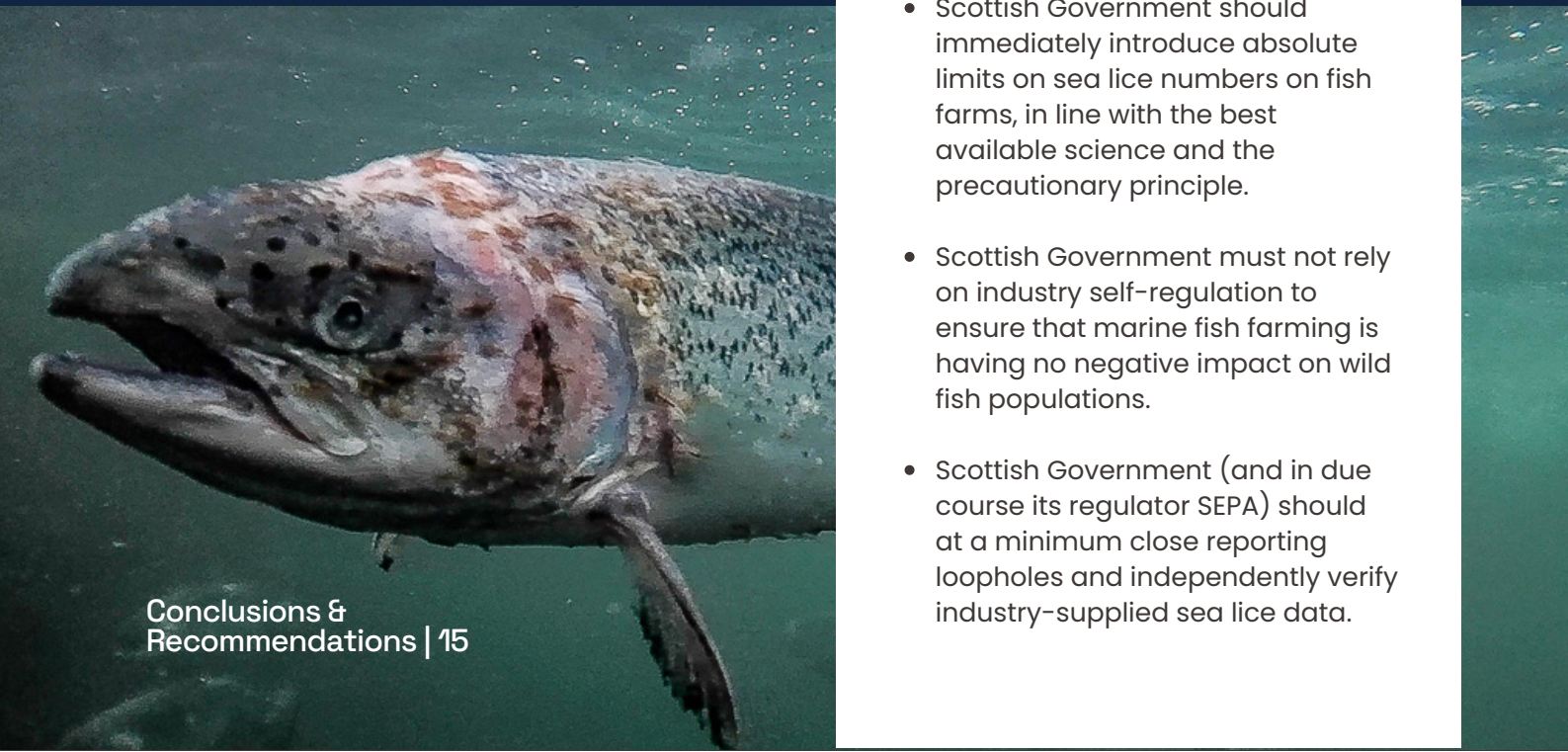
During the Sensitive Period, when the overwhelming majority of wild Atlantic salmon smolts leave Scotland's rivers and begin their migration to sea, at least 27 farms (minimum of 15% of farms) were in breach of the industry thresholds every single week, and more than half (56%) were in breach at least once. In terms of individual producers, Loch Duart performed most poorly overall, with over a third (35%) of the average sea lice counts provided (excluding "no counts") above the CoGP threshold.

Almost one-fifth of data from 2022 is missing, due to "no counts", leaving a significant data gap. In addition, the fact that the data is industry-supplied, and not independently verified, is also problematic in terms of gaining a clear picture of the levels of sea lice infestations on Scotland's salmon farms. Academic research has shown that federal auditing of Canadian salmon farms yields 20% higher numbers than industry-reported data – so the true picture may well be even worse.

Sea lice parasites are a serious problem – both from the perspective of farmed fish welfare and impact on wild fish populations. This report details extensive failure by the industry to adhere to its own CoGP in 2022. In doing so it highlights the true value and sole purpose of the CoGP for sea lice control – a greenwashing tool used by both the industry and third-party certification bodies to give the illusion of strict sea lice management, while its thresholds are both too lenient, and routinely breached.

Recommendations:

- Scottish Government should close open-net salmon and trout farms and encourage alternative aquaculture practices that are less environmentally damaging.
- Scottish Government should immediately introduce absolute limits on sea lice numbers on fish farms, in line with the best available science and the precautionary principle.
- Scottish Government must not rely on industry self-regulation to ensure that marine fish farming is having no negative impact on wild fish populations.
- Scottish Government (and in due course its regulator SEPA) should at a minimum close reporting loopholes and independently verify industry-supplied sea lice data.



References

[1] North Atlantic Salmon Conservation Organization. (2019). State of North Atlantic salmon. Available from https://nasco.int/wp-content/uploads/2020/05/SoS-final-online.pdf

[2] Torrissen O, Jones S, Asche F, Guttormsen A, Skilbrei OT, Nilsen F, Horsberg TE, Jackson D. (2013). Salmon lice impact on wild salmonids and salmon aquaculture. J Fish Dis. pp.171-94. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3675643/

[3] Butler JRA., Watt J. (2003) Wild salmonids and sea louse infestations on the west coast of Scotland: sources of infection and implications for the management of marine salmon farms. Pest Management Science 58, 595-608. Available from: https://pubmed.ncbi.nlm.nih.gov/12138626/

[4] The Guardian. (2023). Salmon deaths on Sco'land's fish farms doube – but are jellyfish to blame? Available from: https://www.theguardian.com/environment/2023/jan/15/salmon-death-scotland-fish-farm-jellyfish-overcrowding

[5] Marine Scotland Directorate. (2021). The Regulation of Sea Lice in Scotland, 2020. Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/ transparency-data/2019/11/fish-health-inspectorate-sea-lice-information/documents/sea-lice-regulation-topic-sheet/sea-lice-regulation-topic-sheet/ govscot%3Adocument/sea%2Blice%2Btopic%2Bsheet.pdf.

[6] Costello MJ. (2006). Ecology of sea lice parasitic on farmed and wild fish. Trends Parasitol, pp 475-83. Available from: https://pubmed.ncbi.nlm.nih.gov/16920027/

[7] Marine Scotland Directorate. (2023). Publication of Fish Health Inspectorate information. Available from: https://www.gov.scot/collections/publication-of-fish-health-inspectorate-information/

[8] Heuch, P.A., Nordhagen, J.R. and Schram, T.A. (2000). Egg production in the salmon louse [Lepeophtheirus salmonis (Krøyer)] in relation to origin and water temperature. Aquaculture Research, 31: pp 805-814. Available from: https://doi.org/10.1046/j.1365-2109.2000.00512.x

[9] Costello, M.J., (2006). Ecology of sea lice parasitic on farmed and wild fish. Trends in Parasitology 22, pp 475–483. Available from: https://doi.org/10.1016/j.pt.2006.08.006

[10] Penston, M.J. & Davies, I.M. (2009) An assessment of salmon farms and wild salmonids as sources of Lepeophtheirus salmonis (Krøyer) copepodids in the water column in Loch Torridon, Scotland. Journal of Fish Diseases 32, pp 75-88. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2761.2008.00986.x

[11] Harte AJ, Bowman AS, Salama NK, Pert CC. (2017). Factors influencing the long-term dynamics of larval sea lice density at east and west coast locations in Scotland. Diseases of Aquatic Organisms 123, pp 181-192. Available from: https://pubmed.ncbi.nlm.nih.gov/28322205/

[12] Pert CC, Fryer RJ, Cook P, Kilburn R, McBeath S, McBeath A, Matejusova I, Urquhart K, Weir SJ, McCarthy U, Collins C, Amundrud T, Bricknell IR. (2014). Using sentinel cages to estimate infestation pressure on salmonids from sea lice in Loch Shieldaig, Scotland. Aquaculture Environment Interactions 5, pp 49-59. Available from: https://agris.fao.org/agris-search/search.do?recordID=DJ20220333006

[13] Salama NKG, Dale AC, Ivanov VV, Cook PF, Pert CC, Collins CM, Rabe B. (2018). Using biological-physical modelling for informing sea lice dispersal in Loch Linnhe, Scotland. Journal of Fish Diseases, 41, pp 901-919. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/jfd.12693

[14] Fjelldal PG, Hansen TJ, Karlsen Ø. (2020). Effects of laboratory salmon louse infection on osmoregulation, growth and survival in Atlantic salmon. Conservation Physiology 8, pp 1-10. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7098368/

[15] Medcalf KE, Hutchings JA, Fast MD, Kuparinen A, Godwin SC. (2021). Warming temperatures and ectoparasitic sea lice impair internal organs in juveniles Atlantic salmon. Marine Ecology Progress Series 660, pp 161-169. Available from: https://www.researchgate.net/publication/347584112_Warming_temperatures_and_ectoparasitic_sea_lice_impair_internal_organs_in_juvenile_Atlantic_salmon

[16] Transforming Planning Scot. (2023). National Planning Framework. Available at: https://www.transformingplanning.scot/national-planning-framework/

[17] Butler JRA. (2002). Wild salmonids and sea louse infestations on the west coast of Scotland: sources of infection and implications for the management of marine salmon farms. Pest Management Science 58, pp 595-608. Available from: https://pubmed.ncbi.nlm.nih.gov/12138626/

[18] Ford JS., Myers RA. (2008). A global assessment of salmon aquaculture impacts on wild salmonids. PLoS Biology, 6(2), e33. Available from: https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.0060033

[19] Thorstad, E.B. & Finstad, B. (2018). Impacts of salmon lice emanating from salmon farms on wild Atlantic salmon and sea trout. NINA Report 1449: pp 1-22. Available from https://brage.nina.no/nina-xmlui/handle/11250/2475746

[20] Marine Scotland Directorate. Impacts of lice from fish farms on wild Scottish sea trout and salmon: summary of science. (2021). Available from: https://www.gov.scot/publications/summary-of-information-relating-to-impacts-of-salmon-lice-from-fish-farms-on-wild-scottish-sea-trout-and-salmon/

[21] Aquaculture Stewardship Council (ASC). (2022). ASC Salmon Standard Version 1.4. Available from: https://www.asc-aqua.org/wp-content/uploads/2022/09/ASC-Salmon-Standard-v1.4-Final.pdf

[22] Aquaculture Stewardship Council (ASC). (2021). Regulatory Processes for Setting Sensitive-Period Sea-lice Thresholds in Major Salmon Producer Jurisdictions: An Evaluation. Available from: https://www.asc-aqua.org/wp-content/uploads/2022/03/Regulatory-Processes-for-Setting-Sensitive-Period-and-Sea-lice-Thresholds-in-Major-Salmon-Producer-Jurisdictions.pdf

[23] Godwin SC, Krkošek M, Reynolds JD, Bateman AW. (2021). Bias in self-reported parasite data from the salmon farming industry. Ecol Appl. Available from: https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.2226

[24] WildFish. (2022). Scottish salmon farming – Harvesting, sea lice and disease. Available from: https://wildfish.org/wp-content/uploads/2022/10/Scottish-salmon-farming_Harvesting-sea-lice-and-disease.pdf

[25] Marine Scotland Directorate. (2023). Publication of Fish Health Inspectorate information. Available from: https://www.gov.scot/publications/fish-health-inspectorate-mortality-information/

[26] SLICE, MSD Animal Health

[27] Scottish Envrinmental Protection Agency (SEPA). (2017). Review of Environmental Quality Standard for Emamectin Benzoate. Available from: https://www.sepa.org.uk/media/299675/wrc-uc12191-03-review-of-environmental-quality-standard-for-emamectin-benzoate.pdf

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