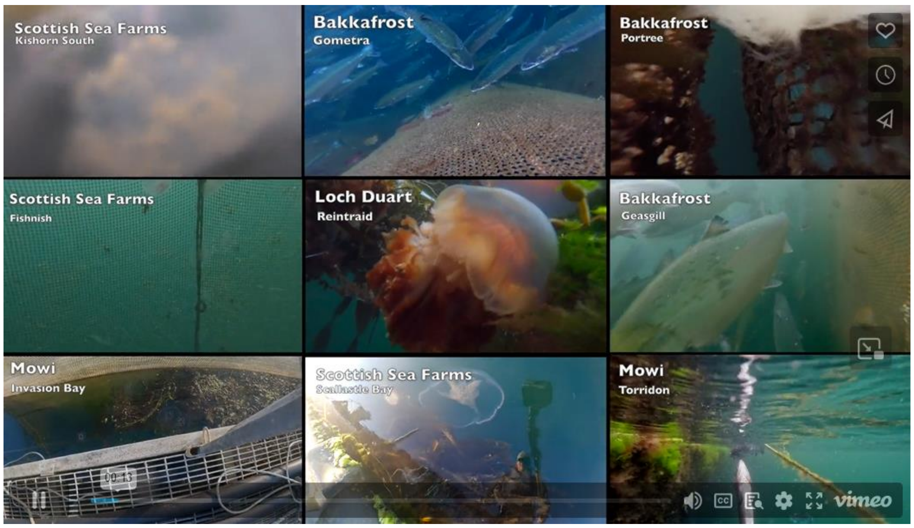
**$camon $cotland, 4 October 2023**

**Scottish Salmon's Silent Sting!**
**– Video evidence of jellyfish, microjellies & medusa monsters suffocating Scottish salmon!**
**- Scientist warns salmon farms exacerbate jellyfish via a 'vicious cycle': "It's a self-inflicted wound – it's the Sorcerer's Apprentice" says Dr Lisa-ann Gershwin, author of 'Stung'**

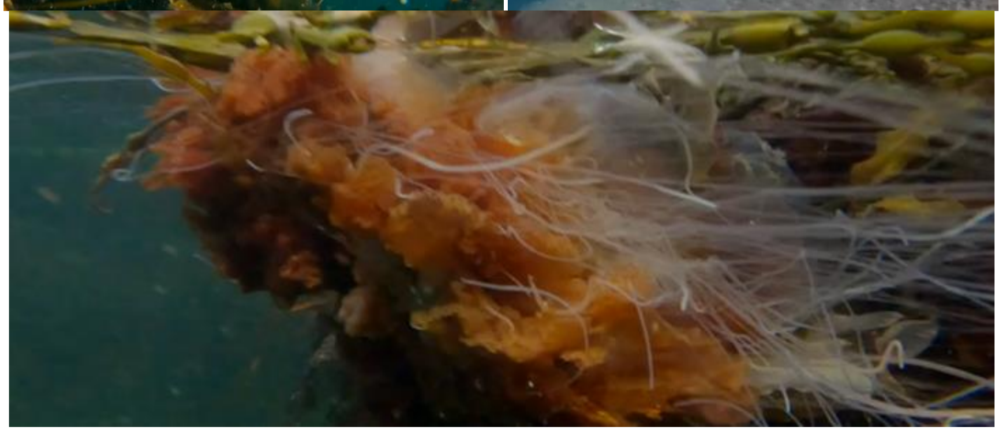



**- Published data on farmed salmon mortalities shows the scale of the jellyfish problem**
**- Warming water & jellyfish are the 'death knell' for salmon farming in Scotland**

Video evidence shot this year inside and outside salmon cages exposes how swarms of jellyfish and microjellies are plaguing fish farms around Scotland. Footage was shot at over a dozen salmon farms including Bakkafrost (Geasgill, Gometra, Portree & West Strome); Scottish Sea Farms (Scallastle Bay, Fishnish, Fiunary & Kishorn); Mowi (Torridon & Invasion Bay); Loch Duart (Reintraid) and Wester Ross (Corry & Ardmair). Watch 'Silent Sting' online here

Jellyfish can kill and injure farmed salmon via suffocation and de-oxygenation of the water as well as clogging the gills causing Amoebic Gill Disease and exacerbating other gill health problems.  In video footage shot between May and August 2023, larger jellyfish species such as Lion's Mane and Moon Jellyfish are clearly visible with their tentacles stinging through the nets.





Microscopic jellyfish – dubbed 'microjellies' by salmon farmers - are by definition much more difficult to see.  A jellyfish expert has identified Pleurobrachia pileus (sea gooseberry) – which can clog the gills of farmed salmon and Pandeidae – it has bell-shaped medusa and threadlike tentacles – from the video footage.   'Mortality Event Reports' and 'Case Information' published by the Scottish Government has cited Obelia, Muggiaea Atlantica, Solmaris and Sarsia tubulosa. Further sampling and identification under a microscope is required to identify particular species.

Data published by Salmon Scotland in September 2023 cited 10 cases where jellyfish/plankton – along with gill health and viral disease - caused mortalities at salmon farms in July 2023 (by comparison with the same time last year, there were no mortality incidents citing jellyfish in July 2022):

**Monthly Mortality Rate: July 2023**

**Published:** September 1st, 2023

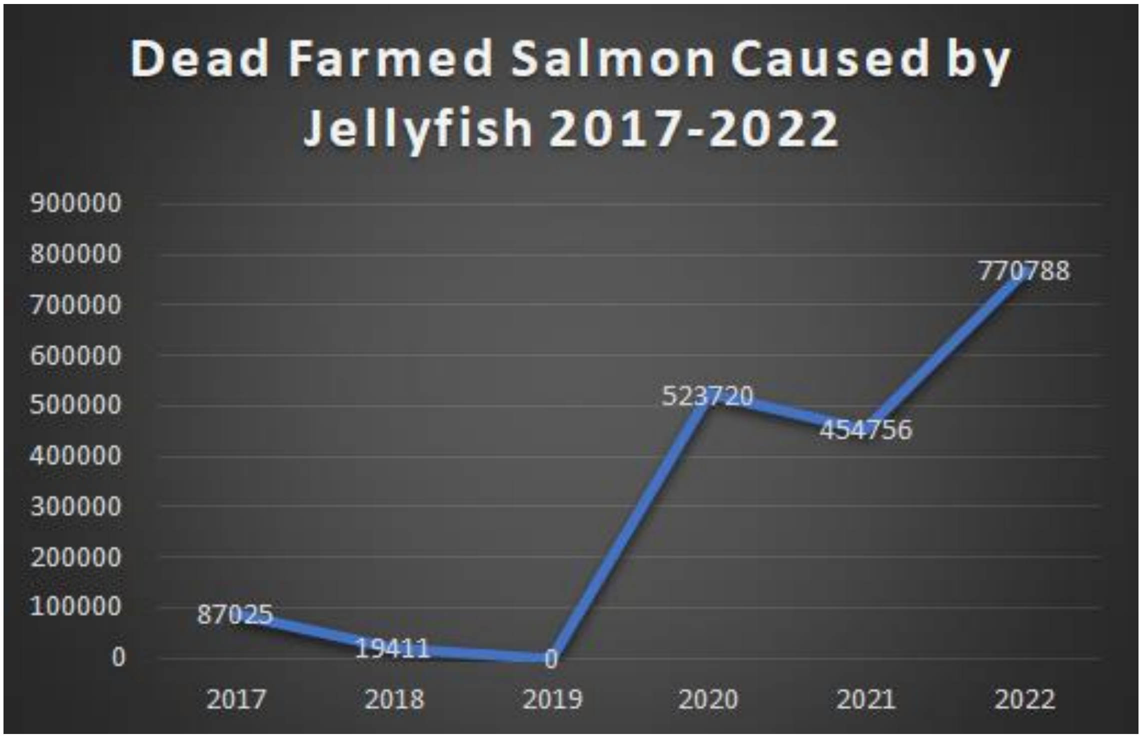
Salmon SCOTLAND

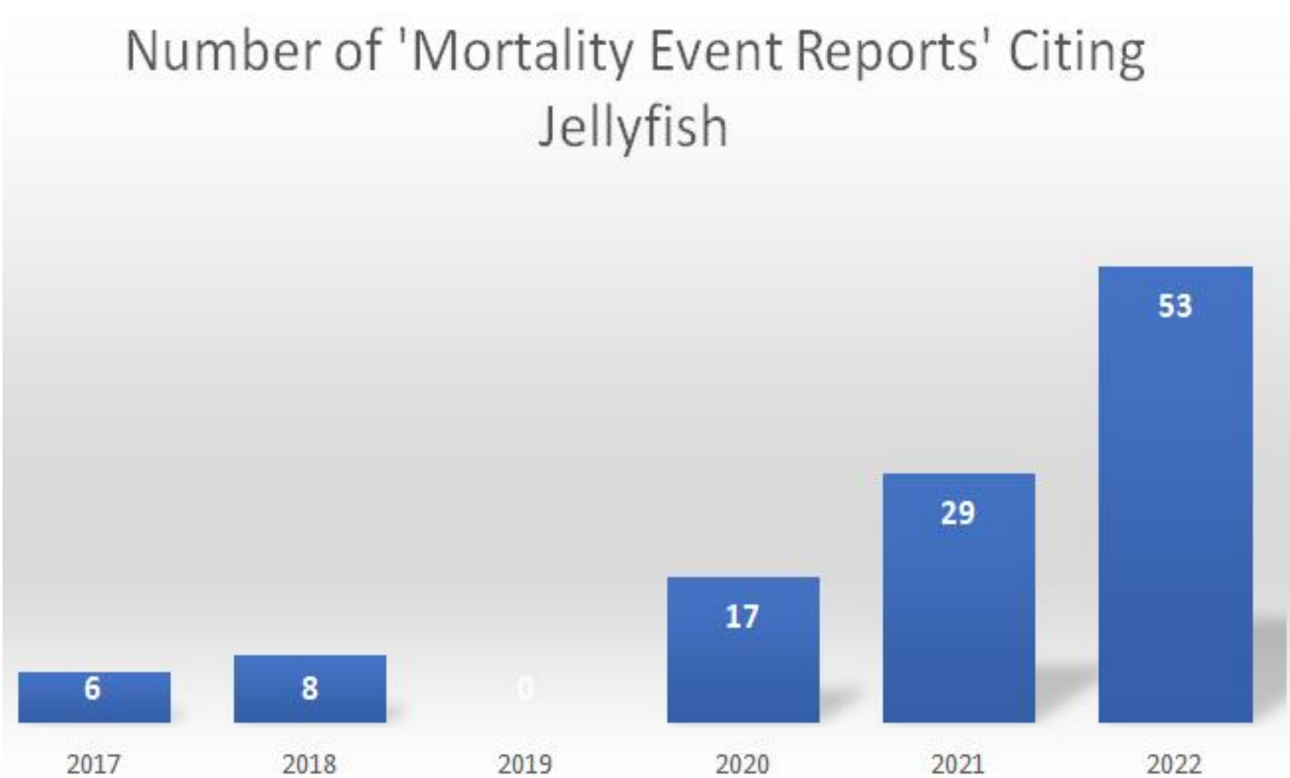
| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Bakkafrost Scotland | Geasgill | 23.7 | Jellyfish / plankton, Gill health related, Viral disease | In production |
| Bakkafrost Scotland | Gravir Outer | 22.6 | Jellyfish / plankton, Gill health related, Viral disease | In production |
| Scottish Sea Farms Ltd | Kishorn C (West) | 16.2 | Jellyfish / plankton, Gill health related | In production |
| Scottish Sea Farms Ltd | Kishorn A (South) | 15.2 | Jellyfish / plankton, Gill health related | In production |
| Bakkafrost Scotland | Lamlash | 13.8 | Jellyfish / plankton, Gill health related, Viral disease | In production |
| Scottish Sea Farms Ltd | Kishorn B (North) | 11.3 | Jellyfish / plankton, Gill health related | In production |
| Scottish Sea Farms Ltd | Lober Rock | 9.5 | Jellyfish / plankton, Gill health related | In production |
| Bakkafrost Scotland | Gometra | 4.6 | Jellyfish / plankton, Gill health related | In production |
| Scottish Sea Farms Ltd | Hunda | 4.1 | Jellyfish / plankton, Gill health related | In production |
| Scottish Sea Farms Ltd | Westerbister | 3.9 | Jellyfish / plankton, Gill health related | In production |

No jellyfish-related mortalities were reported by Salmon Scotland between January and June 2023 (the previous citation of jellyfish was in November 2022). The salmon farming industry has published monthly data on mortalities since January 2021 – including 22 cases in 2022 where 'jellyfish' are cited as a cause of mortality (spiking in September 2022 with 13 cases including 56% mortality at Loch Duart's RSPCA Assured Loch Carnan salmon farm and 38% mortality at Mowi's RSPCA Assured Stulaigh salmon farm) and 9 cases in 2021. The month of May was the earliest report of jellyfish problems in any year with the month of September accounting for 16 of the 22 cases in 2022 and 2021 **[1]**.

Mortality data published by the Scottish Government's Fish Health Inspectorate on 3 July 2023 (data up to the end of May) detailed 115 'Mortality Event Reports' totaling 1.86 million farmed salmon where jellyfish or microjellyfish were cited as 'explained reasons'. Cases citing jellyfish or microjellyfish increased with 770,788 morts reported in 2022 via 53 incidents compared to

454,756 morts via 29 incidents in 2021; 523,720 morts via 17 incidents in 2020; zero reported in 2019; 19,411 morts via 8 incidents in 2018; and 87,025 morts via 6 incidents in 2017.



Dr Lisa-ann Gershwin – author of Stung! – On Jellyfish Blooms and the Future of the Ocean – told $camon $cotland via a Zoom call from Tasmania:

“Salmon farming makes jellyfish worse and jellyfish kills salmon so it’s a vicious cycle where salmon farming is exacerbating this problem that’s actually a problem for themselves. They’re kind of doing themselves in – suffering from their own success. It’s a self-inflicted wound - it’s the Sorcerer’s Apprentice.”

“It’s insane. If you formed a committee to help jellyfish flourish and you white-boarded this with all the experts in the world the salmon farming system is what you’d come up with.”

“Jellyfish love warming water – you haven’t seen anything yet. They love warm water – the jellyfish go into super-amped up mode. Global warming is a dream come true for jellyfish.”

“If you want to talk about animal welfare: the acute mortalities from jellyfish are probably the kindest to the farmed salmon: shocking to the workers watching - they suffocate, but at least it’s quick. The salmon which die of Amoebic Gill Disease are in prolonged agony – you wouldn’t wish it on anyone.”

“I believe there's every probability that aquaculture is making the jellyfish problem worse,” said Dr Lisa-ann Gershwin in an interview with ABC News in 2019. “We do have good data from places overseas that shows aquaculture stimulates the growth of the very organisms that cause problems for the aquaculture industry. It's a vicious cycle, where the aquaculture is making the problem worse.” [Read more via a scientific submission by Dr Lisa-ann Gershwin to a salmon farming inquiry in Tasmania in November 2019].

Mortality data published by the Scottish Government on 2 October 2023 (information up to early September 2023) details 16 ‘Mortality Event Reports’ where jellyfish or microjellyfish are cited since 1 August 2023 involving 362,244 dead salmon. The mass mortalities are headed by Bakkafrost’s Portree salmon farm off the Isle of Skye with a staggering 175,115 deaths “as a result of suspected Solmaris jellyfish bloom”. Other cases include Bakkafrost’s West Strome salmon farm in Loch Carron which reported "high levels of Muggia Atlantica and Solmaris"; Bakkafrost's Gometra salmon farm off the Isle of Mull which reported "gill damage the result of microjellies" and "large numbers of jellyfish reported" and Mowi's Loch Greshornish salmon farm off the Isle of Skye which reported: "Mortality occurring from Jellyfish stings to the gills. Blooms of Jellyfish are present currently and causing persistent issues, the site are planning to move their stock to Maol Ban (FS0519) to avoid further jellyfish damage":

| Mortality Event No | Reporting Business Name | Site Name | Date reported | Mortality % | Explained reasons | Mort #s | Additional information | Action taken by FHI |
|---|---|---|---|---|---|---|---|---|
| MRT04376 | Bakkafrost Scotland | Portree | 11/09/2023 | 31.14 | Gill Health Related | 175115 | FW week 35 and mort removal. Site experienced significant environmental challenge as a result of suspected Solmaris jellyfish bloom. Pens with elevated mortality are currently on harvest plan. Wk 36 mortality reduced significantly -3.1%. | Business correspondent contacted. First report this cycle. Site inspection scheduled. APHA informed and will accompany FHI. |
| MRT04286 | Mowi Scotland Ltd | Loch Greshornish | 24/08/2023 | 5.73 | Jellyfish | 46077 | Site now fallow | No further action - site fallow. |
| MRT04381 | Bakkafrost Scotland | Portree Outer | 12/09/2023 | 3.34 | Gill Health Related | 20188 | FW week 35 and mort removal. Site experienced environmental challenge as a result of suspected Solmaris jellyfish bloom. Wk 36 mortality reduced below threshold. | Business correspondent contacted.Site inspected 02/08/2023 and diagnostic taken (gill health issues identified). FHI to monitor. |
| MRT04328 | Mowi Scotland Ltd | Creag an T'Sagairt (Loch Hourn) | 31/08/2023 | 2.76 | Gill infections / CMS | 19089 | | Targeted harvesting ongoing, issue with early maturation and gill health from jellyfish, mortlities will continue but will improve as biomass is reduced, FHI to monitor. |
| MRT04228 | Bakkafrost Scotland | West Strome | 14/08/2023 | 1.99 | Gill Health Related | 10082 | Site contacted for further information, Gill health related issues from a recent enviromental insult, high levels of muggia altlantica and solmaris identified from routine plankton checks. The majority of mortality onsite has been confined to cage one, which was harvested out on 14/08/23. | FHI to monitor. |
| MRT04325 | Scottish Sea Farms | Westerbister | 31/08/2023 | 3.9 | Environmental; Gill Health | 18415 | CGD; low DO | FHI visit carried out on 15/08/2023 (case number: 2023-0352). No clinical signs of disease observed so no samples taken for diagnostic analysis. Poor gill health was reported to be exacerbated by low DO and the presence of microjelly fish. Company biologist has been in attendance routinely to take histology and blood samples. Fish appeared in good health during inspection. Fish removed for routine residue samples appeared healthy externally and internally. |
| MRT04291 | Mowi Scotland Ltd | Bagh Dail Nan Cean | 24/08/2023 | 10.28 | Treatment losses | 17382 | Business contacted - fish moved from MacLeans Nose due to jellyfish issues. | Business contacted. FHI to monitor. |
| MRT04308 | Bakkafrost Scotland | Gometra | 28/08/2023 | 3.39 | Gill Health Related | 14944 | FW Week 33 | FW treatment was completed in week 33, gill damage the result of microjellies. This has resulted in the ongoing issues. Large numbers of jellyfish reported, Mortalities have reduced but still above the reporting threshold (2.2%) . FHI to monitor. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| MRT04228 | Bakkafrost Scotland | West Strome | 14/08/2023 | 1.99 | Gill Health Related | 10082 | Site contacted for further information, Gill health related issues from a recent enviromental insult, high levels of muggia altlantica and solmaris identified from routine plankton checks. The majority of mortality onsite has been confined to cage one, which was harvestered out on 14/08/23. | FHI to monitor. |
| MRT04253 | Mowi Scotland Ltd | Loch Greshornish | 17/08/2023 | 1.22 | Jellyfish | 9969 | Site contacted for further information, Mortality occuring from Jellyfish stings to the gills. Blooms of Jellyfish are present currently and causing persistant issues, the site are planning to move their stock to Maol Ban (FS0519) to avoid further jellyfish damage. | FHI to monitor. |
| MRT04329 | Mowi Scotland Ltd | Loch Greshornish | 31/08/2023 | 2.55 | Jellyfish | 7724 | Site now fallow | Site fallow. |
| MRT04331 | Mowi Scotland Ltd | Scalpay | 31/08/2023 | 1.13 | Jellyfish | 7609 | | Gill issues the problem. Depending on availability FW may be used next week but a peroxide treatment for AGD may be administered if FW not available. FHI to monitor. |
| MRT04295 | Cooke Aquaculture | Chalmers Hope | 25/08/2023 | 1.91 | Gill issues, Jellyfish | 4432 | Not provided | Historic event picked up during routine inspection. Business reminded of requirement to report mortality events that exceed the reporting thresholds. NFA. |
| MRT04251 | Mowi Scotland Ltd | North Moine | 02/08/2023 | 1.26 | Gill issues, Jellyfish | 3686 | Environmental gill issues caused by micro jellyfish. Reduced feeding approved by vet and increased health monitoring of stock | Unreported event from 2022 picked up during inspection in 2023 (case no. 2023-0333). Mortality numbers had reduced the following week. Manager reminded to report such events to FHI |
| MRT04250 | Mowi Scotland Ltd | North Moine | 02/08/2023 | 1.01 | Gill issues, Jellyfish | 3474 | Environmental gill issues caused by micro jellyfish. Reduced feeding approved by vet and increased health monitoring of stock | Unreported event from 2022 picked up during inspection in 2023 (case no. 2023-0333). Mortality numbers had reduced the following week. Manager reminded to report such events to FHI |
| | Cooke Aquaculture | Chalmers Hope | 25/08/2023 | 1.19 | Gill issues, Jellyfish | 2725 | Not provided | Historic event picked up during routine inspection. Business reminded of requirement to report mortality events that exceed the reporting thresholds. NFA. |
| MRT04294 | Mowi Scotland Ltd | Ardnish | 24/08/2023 | 1.81 | Jellyfish / Gill infections | 1333 | | First report this cycle. FHI to monitor. |

## Information to download

- mortality information - correct at the time of data extraction - 2 October 2023
- mortality notification form and guidance

**Mortality information - until end August 2023**

Excel document | 713.8 kB

"Warming seas around Scotland and jellyfish plagues are suffocating disease-ridden Scottish salmon," said Don Staniford, Director of $camon $cotland who has kayaked out to a dozen salmon farms so far this year. "It is crystal clear from video footage shot inside and outside salmon cages that big jellyfish like the lion's mane and 'microjellies' are killing off the King of Fish. Factory farms around the coast of Scotland are not just growing Atlantic salmon but they are also farming lethal jellyfish. The summer of 2023 will be looked back on as the last nail in the coffin of Scottish salmon – killed by a deadly cocktail of climate change, swarms of jellyfish, gill diseases and plagues of parasites. Jellyfish are not just the sting in the tail of Scottish salmon – they are covert killers and invisible assassins. The silent sting of the sea will be the death knell for salmon farming in Scotland."

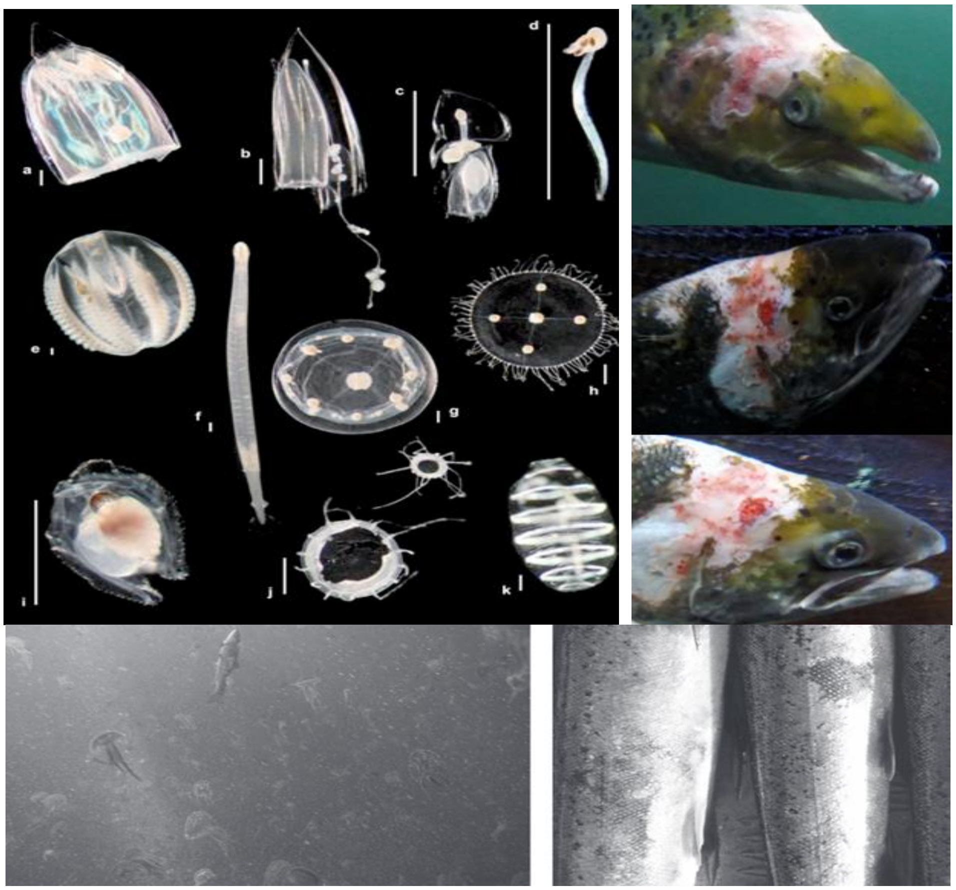

"Untreated sewage wastes from salmon farms and the cage structures themselves provide unlimited food and a breeding ground for jellyfish," continued Staniford (dubbed the 'Kayak Vigilante' by The Times). "The toxic soup inside a salmon cage is a recipe for disease disaster and a welfare nightmare for millions of suffering Scottish salmon. Relocating sick salmon away from jellyfish blooms in wellboats – as Mowi have done in Loch Greshornish – may transfer infectious diseases and exacerbate problems with microjellies and gill health. Mowi, Bakkafrost, Scottish Sea Farms, Loch Duart, Wester Ross Fisheries, Cooke, Kames and Organic Sea Harvest farming salmon in warming waters should shut down their entire Scottish operations. In the hothouse of the 21st century, Scotland is simply not a safe or suitable place to farm Atlantic salmon. This is a dying industry on life-support with oxygen pumped into cages prolonging the suffering of tens of millions of RSPCA Assured Scottish salmon on death row. Scottish salmon is dead in the warming water."

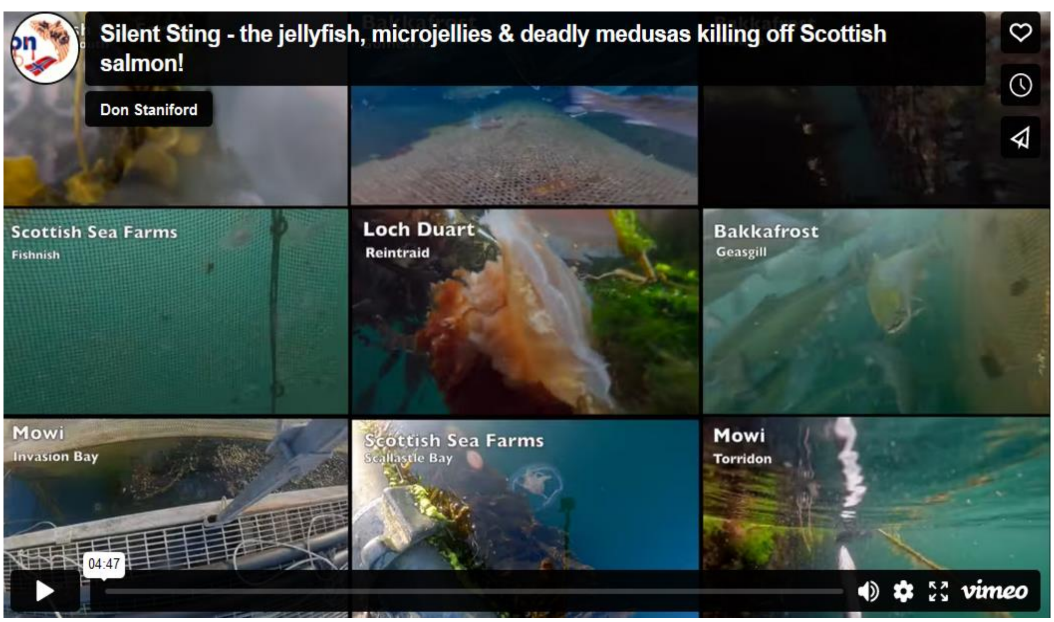
**Contact:**

Don Staniford: 07771 541826 (salmonfarmingkills@gmail.com)

**MEDIA BACKGROUNDER (October 2023):**

# SILENT STING
# – SCOTTISH SALMON IS DEAD IN THE WARMING WATER!





Mortality data published by the Scottish Government on 5 September 2023 (information up to the end of July 2023) detailed 15 'Mortality Event Reports' citing jellyfish during 2023:

| Mortality Event No | Reporting Business Name | Site Name | Date reported | Mort % | Explained reasons | Mort #s | Additional information |
|---|---|---|---|---|---|---|---|
| MRT04149 | Mowi Scotland Ltd | Invasion Bay | 25/07/2023 | 2.11 | Gill infections | 4,426 | Site is positive for AGD, PGD and CMS. Site was impacted by jellyfish last year 2022. Harvesting is ongoing. Current plans are to be fallow by August. |
| MRT04132 | Mowi Scotland Ltd | Creag an T'Sagairt (Loch Hourn) | 19/07/2023 | 6.16 | Gill infections / CMS | 49,907 | Site is positive for HSMI and CMS. Site is also positive for AGD and PGD, with also jellyfish damage being observed. Handling of fish has exacerbated mortality. Due to sealice increasing on site, intervention via FW and FLS conducted in WK 28. Targeted harvestes scheduled for WK30. In addition, weekly health visits with diagnostic sampling has been occurring. |
| MRT04133 | Mowi Scotland Ltd | Invasion Bay | 19/07/2023 | 3.05 | Gill infections | 7,035 | Site is positive for AGD, PGD and CMS. Site was impacted by jellyfish last year 2022. Harvesting is ongoing. Current plans are to be fallow by August. |
| MRT04093 | Mowi Scotland Ltd | Creag an T'Sagairt (Loch Hourn) | 11/07/2023 | 2.87 | Gill issues - jellyfish | 24,436 | |
| MRT04080 | Mowi Scotland Ltd | Creag an T'Sagairt (Loch Hourn) | 06/07/2023 | 2.78 | Gill issues - | 18416 | |
| MRT04069 | Scottish Sea Farms | Kishorn West | 05/07/2023 | 6.2 | Gill Health | 20341 | AGD; Destocking through harvest; Business contacted: FW treatement 6/10 pens wk26, pausing further treatments due to increased mortality, Obelia (jellyfish) issues in the area for 10/14 days but now resolved. Site planned fallow September 2023. |
| MRT04073 | Scottish Sea Farms I | Kishorn A (South) | 05/07/2023 | 2.4 | Gill Health | 8407 | AGD; Destocking through harvest; Business contacted: Obelia (jellyfish) issues in the area for 10/14 days but now resolved. Site planned fallow September 2023. |
| MRT04074 | Scottish Sea Farms I | Kishorn B (North) | 05/07/2023 | 1.1 | Gill Health | 5140 | AGD; Destocking through harvest; Business contacted: Obelia (jellyfish) issues in the area for 10/14 days but now resolved. Site planned fallow September 2023. |
| MRT04058 | Mowi Scotland Ltd | Creag an T'Sagairt | 30/06/2023 | 1.45 | Gill Issues - jellyfish | 14082 | Business contacted: This year seems to be mostly Obelia (jellyfish), which is different from previous years. Have also started to see increased level of concussion on site through a sudden influx of adult Caligus, which are susppected to have come in with wild fish as previously no juvenile stages of Caligus have been observed on site. |
| MRT04059 | Mowi Scotland Ltd | Linnhe | 30/06/2023 | 3.01 | HSMI | 28394 | Business contacted: Antibiotic treatment for secondary bacterial infection has concluded. The bacterial load seems to have decreased. Fish also suffer with CMS and gill insult by jellyfish and plankton. HSMI is seen as main cause for mortality but issues are multi factorial. |
| MRT04029 | Bakkafrost Scotland | Gravir | 19/06/2023 | 1.74 | Viral Disease (PD); Environmental | 13085 | Monitor - minimise stress and manage feeding around blooms. Jellyfish causing gill issues but have now cleared. Species not identified. |
| MRT03811 | Cooke Aquaculture : | South Cava | 14/02/2023 | 1.04 | Gill Health/ Viral Disease | 3843 | Business correspondent contacted. Gill issues are related to the previous jellyfish issues they've had on site. CMS on site. Site is currently harvesting out the affected fish. Site visited w/b 06/02/2023. FHI to monitor. |
| MRT03704 | Scottish Sea Farms I | Score Holms | 06/01/2023 | 1.8 | Gill Health Related | 12404 | Site contacted for further information. Source of gill issues is thought to have been from a jelly fish bloom which occured late last year. The site are planning to thin out stock in the worst affected cage and start treating the site with peroxide in week 2. FHI to monitor. |
| MRT03712 | Scottish Sea Farms I | Easter Score Holms | 06/01/2023 | 2 | Gill Health Related | 13470 | Site contacted for further information. Source of gill issues is thought to have been from a jelly fish bloom which occured late last year. The site are planning to thin out stock in the worst affected cage and start treating the site with peroxide from the start of next week. FHI to monitor. |
| MRT03695 | Cooke Aquaculture : | Chalmers Hope | 03/01/2023 | 1.22 | Gill Damage | 5143 | Site contacted for further information. Gill damage as a result of a previous jellyfish insult. Two weeks worth of morts collected due to poor weather the previous week. FHI to monitor. |

The ten biggest 'Mortality Event Reports' - as published by the Scottish Government's Fish Health Inspectorate in September 2023 – that blame jellyfish is headed by Mowi's Marulaig Bay salmon farm which reported 139,023 dead fish in September 2022. Other cases include over 200,000 dead fish at Grieg's Leinish salmon farm in Loch Dunvegan in August and September 2020; and 42,602 at Bakkafrost's West Strome salmon farm in September 2021:

| Mortality Event No | Reporting Business Name | Site Name | Date reported | Explained reasons | Total mortality during event |
|---|---|---|---|---|---|
| MRT03320 | Mowi Scotland Ltd | Marulaig Bay | 29/09/2022 | Gill infections / Jellyfish | 139023 |
| MRT01754 | Grieg Seafood Shetland Ltd | Leinish | 18/08/2020 | Complex gill disease and jellyfish | 107700 |
| MRT01822 | Grieg Seafood Shetland Ltd | Leinish | 08/09/2020 | Complex Gill Disease / Jellyfish | 81247 |
| MRT03319 | Mowi Scotland Ltd | Stulaigh | 29/09/2022 | Gill infections / Jellyfish | 65332 |
| MRT01792 | Grieg Seafood Shetland Ltd | Corlarach | 01/09/2020 | Complex Gill Disease / Jellyfish | 53177 |
| MRT02447 | Mowi Scotland Ltd | Rum | 04/10/2021 | Gill disease and microjellyfish bloom | 52598 |
| MRT02456 | Mowi Scotland Ltd | Rum | 04/10/2021 | Gill disease and microjellyfish | 49282 |
| MRT01839 | Grieg Seafood Shetland Ltd | Leinish | 15/09/2020 | Complex Gill Disease / Jellyfish | 48245 |
| MRT03529 | Cooke Aquaculture Scotland Ltd | Meil Bay | 15/11/2022 | Jellyfish/Gill Damage | 44781 |
| MRT02396 | The Scottish Salmon Company | West Strome | 20/09/2021 | Jellyfish/Plankton, Gill Health Related | 42602 |

The vast majority of the 'Mortality Event Reports' involving jellyfish and microjellyfish occurred in the Autumn with 43 incidents reported in September; 21 in October; 20 in November; 17 in August; 4 in December; 3 in July; 3 in June and 1 in May (no cases were reported between January and April) **[2]**.

'Case Information' published by the Scottish Government's Fish Health Inspectorate in September 2023 reported on inspections to salmon farms in July 2023 – including the following cases where jellyfish were cited as the cause of mortalities:

| | | | |
|---|---|---|---|
| Case No: | 2023-0292 | Date of visit: | 05/07/2023 |
| Time spent on site: | 7 Hrs | Main Inspector: | [redacted] |
| Site No: | FS0248 | Site Name: | Loch Duich |
| Business No: | FB0119 | Business Name: | Mowi Scotland Ltd |

Main cause of current mortalities has been via runts and gill issues via increased numbers of micro jellyfish on site.

| | | | |
|---|---|---|---|
| Case No: | 2023-0314 | Date of visit: | 18/07/2023 |
| Time spent on site: | 3.5hrs | Main Inspector: | [redacted] |
| Site No: | FS0804 | Site Name: | Kishorn B (North) |
| Business No: | FB0125 | Business Name: | Scottish Sea Farms Ltd |

Reduced feeding combined with the presence of AGD/CGD on site has resulted in the entire Loch now being placed on a harvest plan, with all Kishorn sites expected to be fallow in the coming months.

Attributed to poor gill health and AGD/CGD combined with the prolonged presence of jellyfish in the area.

| | | | |
|---|---|---|---|
| Case No: | 2023-0315 | Date of visit: | 18/07/2023 |
| Time spent on site: | 3hrs | Main Inspector: | [redacted] |
| Site No: | FS1274 | Site Name: | Kishorn West |
| Business No: | FB0125 | Business Name: | Scottish Sea Farms Ltd |

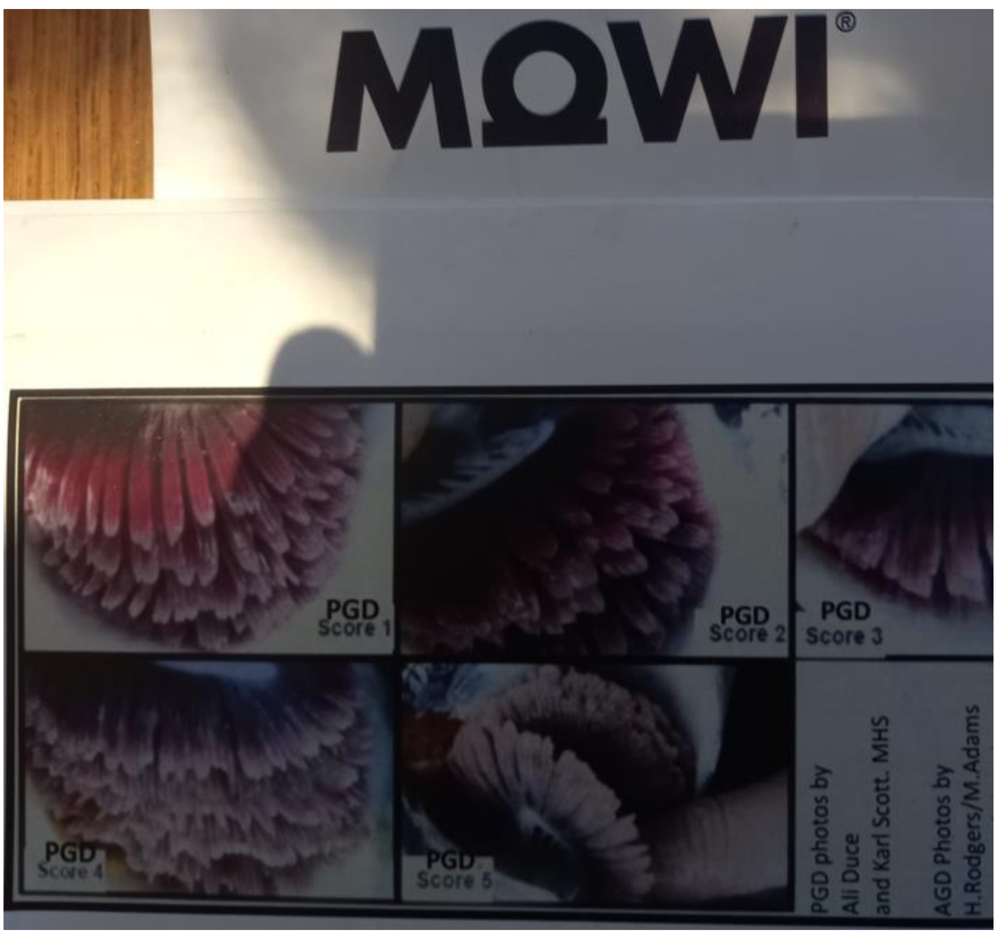
AGD/CGD on site has been attributed to elevated mortality in recent weeks. Attributed to poor gill health and AGD/CGD combined with prolonged presence of jellyfish.

| | | | |
|---|---|---|---|
| Case No: | 2023-0318 | Date of visit: | 20/07/2023 |
| Time spent on site: | 4hrs | Main Inspector: | [redacted] |
| Site No: | FS0245 | Site Name: | Ardintoul |
| Business No: | FB0119 | Business Name: | Mowi Scotland Ltd |

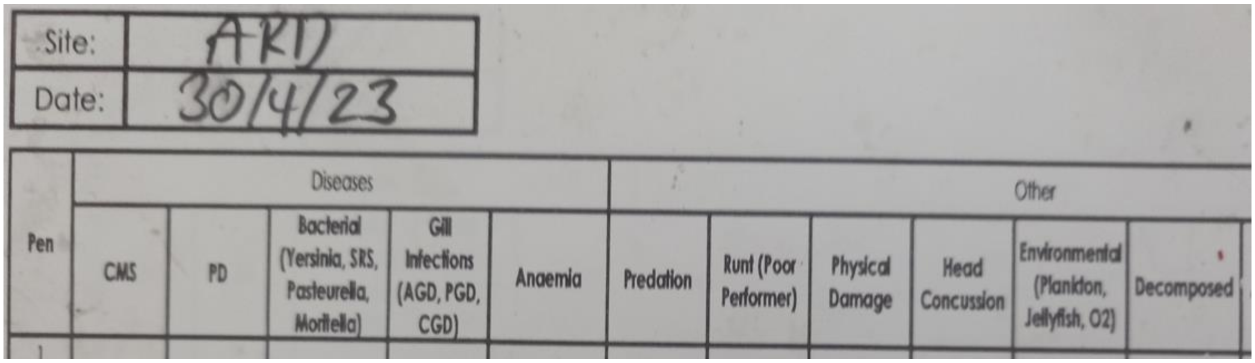
Micro jellyfish were present in the water from June until last week so feeding was reduced to avoid interaction. Feeding increased again once volume of jellies had reduced.

When $camon $cotland visited Mowi's Ardintoul salmon farm in June 2023 we filmed mortalities piled up in bins and a macerator unit for disposing of dead fish with Formic Acid:


A Mowi 'Mort Book' – found at Ardintoul salmon farm - includes photos of gill disease with different scales of damage:



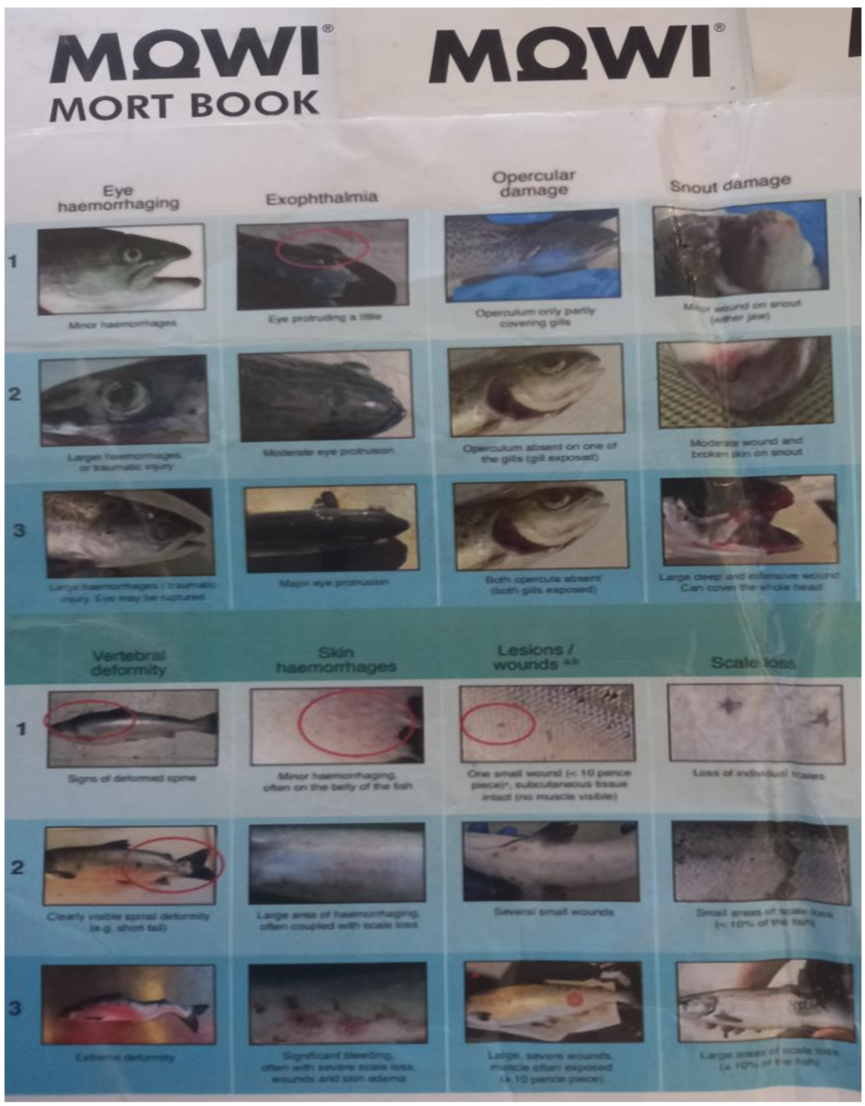
Mowi’s ‘Mort Book’ for the Ardintoul salmon farm – and presumably other Mowi salmon sites - contains various mortality factors including ‘Environmental’ (Plankton, Jellyfish, O2):



| Site: | ARD |
|---|---|
| Date: | 30/4/23 |

| Pen | Diseases | | | | | Other | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CMS | PD | Bacterial (Yersinia, SRS, Pasteurella, Moritella) | Gill Infections (AGD, PGD, CGD) | Anaemia | Predation | Runt (Poor Performer) | Physical Damage | Head Concussion | Environmental (Plankton, Jellyfish, O2) | Decomposed |
| 1 | | | | | | | | | | | |

A photographic guide details examples of disease and welfare problems causing mortalities – including lesions, scale loss and skin haemorrhages which may be caused by jellyfish:



‘Case Information’ published by the Scottish Government’s Fish Health Inspectorate on 21 July 2023 detailed an inspection report from Bakkafrost’s West Strome salmon farm in May 2023 (Case 20230205):

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Case No: | 2023-0205 | | | | | | | Date of visit: | 17/05/2023 | | |
| Time spent on site: | 2h | | | | | | | Main Inspector: | [redacted] | | |
| Site No: | FS1342 | Site Name: | West Strome | | | | | | | | |
| Business No: | FB0169 | Business Name: | Bakkafrost Scotland | | | | | | | | |
| Case Types: | 1 DIA | 2 REP | 3 | 4 | 5 | 6 | | | | | |
| Water Temp (°C): | 9.8 | Thermometer No: | T173 | | | FHI 045 completed | | | | | |
| Observations: | | Region: | HI | Water type: | S | CoGP MA | M-20 | | | | |
| Dead/weak/abnormally behaving fish present? | Y | If yes, see additional information/clinical score sheet. | | | | | | | | | |
| Clinical signs of disease observed? | Y | If yes, see additional information/clinical score sheet. | | | | | | | | | |
| Gross pathology observed? | Y | If yes, see additional information/clinical score sheet. | | | | | | | | | |
| Diagnostic samples taken? | Y | | | | | | | | | | |

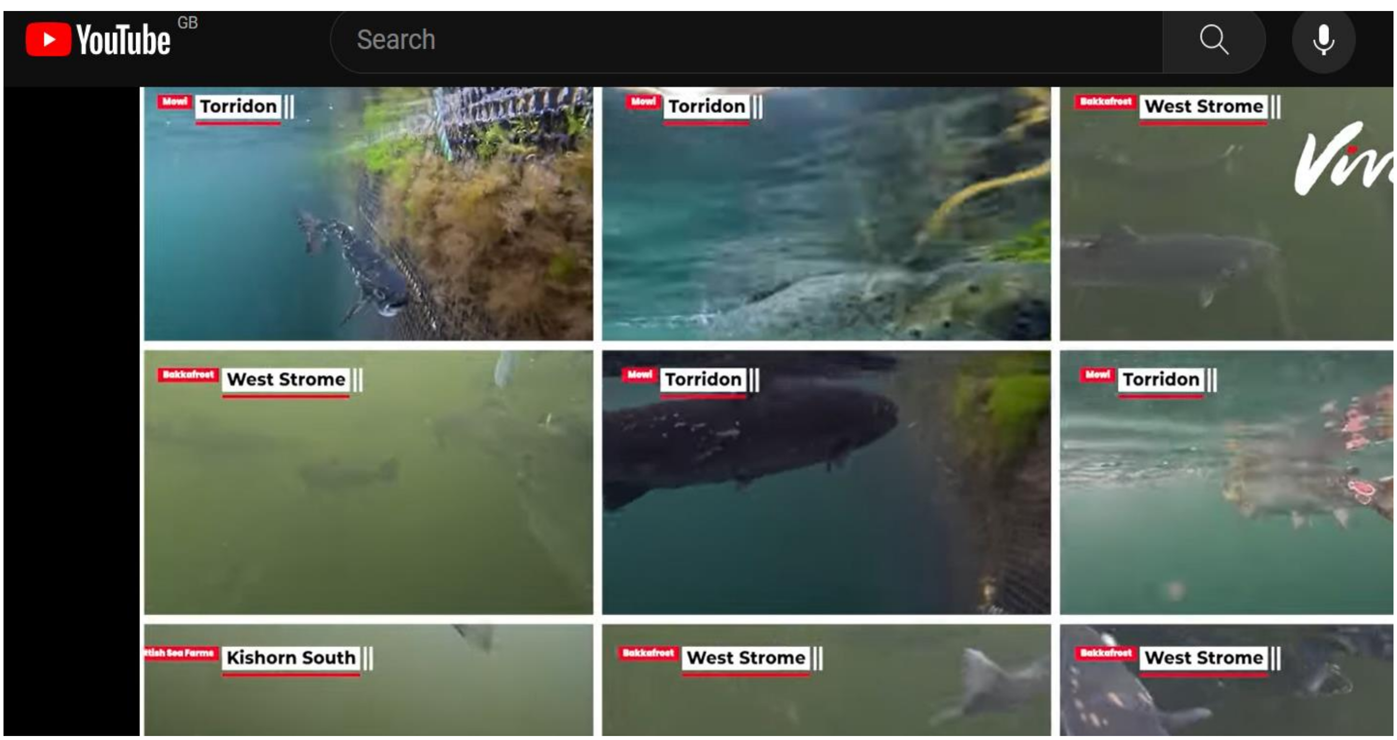
A novel species of jellyfish had been observed in the area suspected to be Sarsia tubulosa, it is unsure if this is part of the increased mortality

Covert filming inside Bakkafrost’s West Strome salmon farm in May 2023 may have captured Sarsia tubulosa [see **Note 3** for further details]:

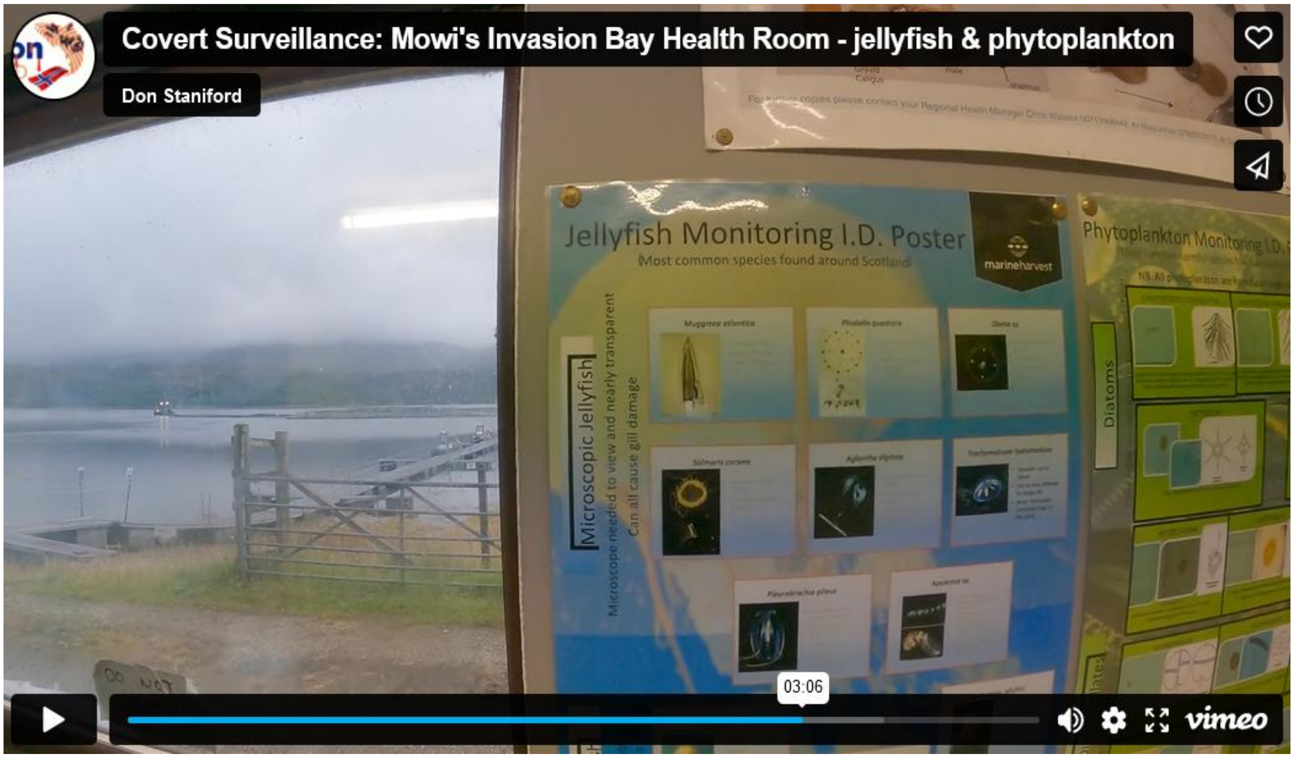
Video footage shot in June 2023 at Bakkafrost’s West Strome salmon farm – published by Viva in September 2023 – may also have captured Sarsia tubulosa and other microjellies:

A salmon at Bakkafrost farm in West Strome where lice were caught on film. Photograph: Viva!

Watch Viva’s video footage [online here]

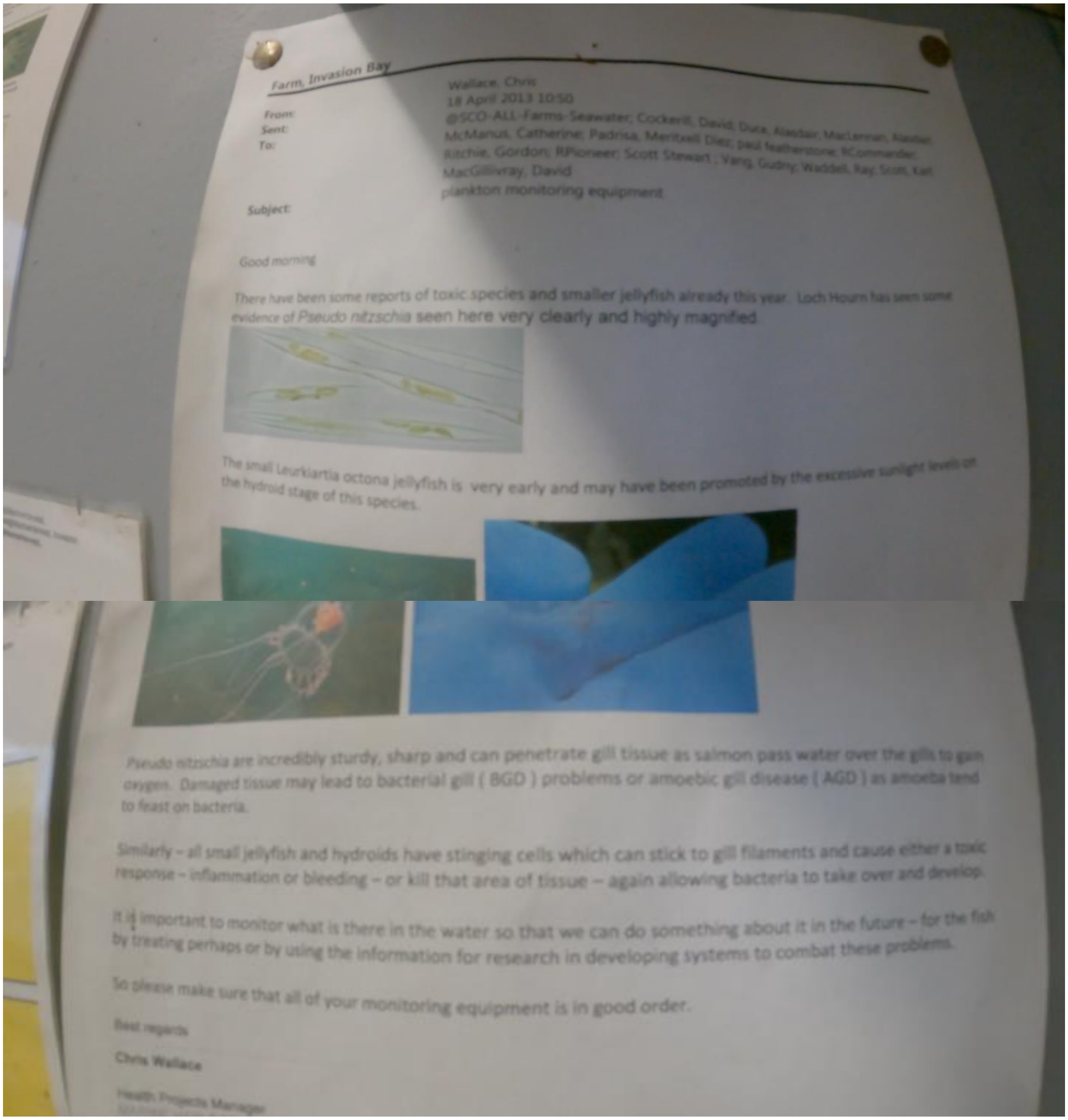


When $camon $cotland visited Mowi's Invasion Bay salmon farm in Loch Sunart in August 2023 we saw warnings of jellyfish, microjellies and plankton on the walls of the 'Health Room':




Mass mortalities and oxygen tanks were found outside Mowi's Invasion Bay salmon farm:

Emails from 2013 warning about jellyfish were found inside Mowi's 'Health Room' at Invasion Bay:



Farm, Invasion Bay

From: Wallace, Chris
Sent: 18 April 2013 10:50
To: @SCO-ALL-Farms-Seawater; Cockerill, David; Duce, Alasdair; MacLennan, Alasdair; McManus, Catherine; Padrisa, Meritxell Diez; paul featherstone; RCommander; Ritchie, Gordon; RPioneer; Scott Stewart ; Yang, Gudny; Waddell, Ray; Scott, Kari; MacGillivray, David
Subject: plankton monitoring equipment

Good morning

There have been some reports of toxic species and smaller jellyfish already this year. Loch Hourn has seen some evidence of *Pseudo nitzschia* seen here very clearly and highly magnified.

The small Leurkiartia octona jellyfish is very early and may have been promoted by the excessive sunlight levels on the hydroid stage of this species.

Pseudo nitzschia are incredibly sturdy, sharp and can penetrate gill tissue as salmon pass water over the gills to gain oxygen. Damaged tissue may lead to bacterial gill ( BGD ) problems or amoebic gill disease ( AGD ) as amoeba tend to feast on bacteria.

Similarly – all small jellyfish and hydroids have stinging cells which can stick to gill filaments and cause either a toxic response – inflammation or bleeding – or kill that area of tissue – again allowing bacteria to take over and develop.

It is important to monitor what is there in the water so that we can do something about it in the future – for the fish by treating perhaps or by using the information for research in developing systems to combat these problems.

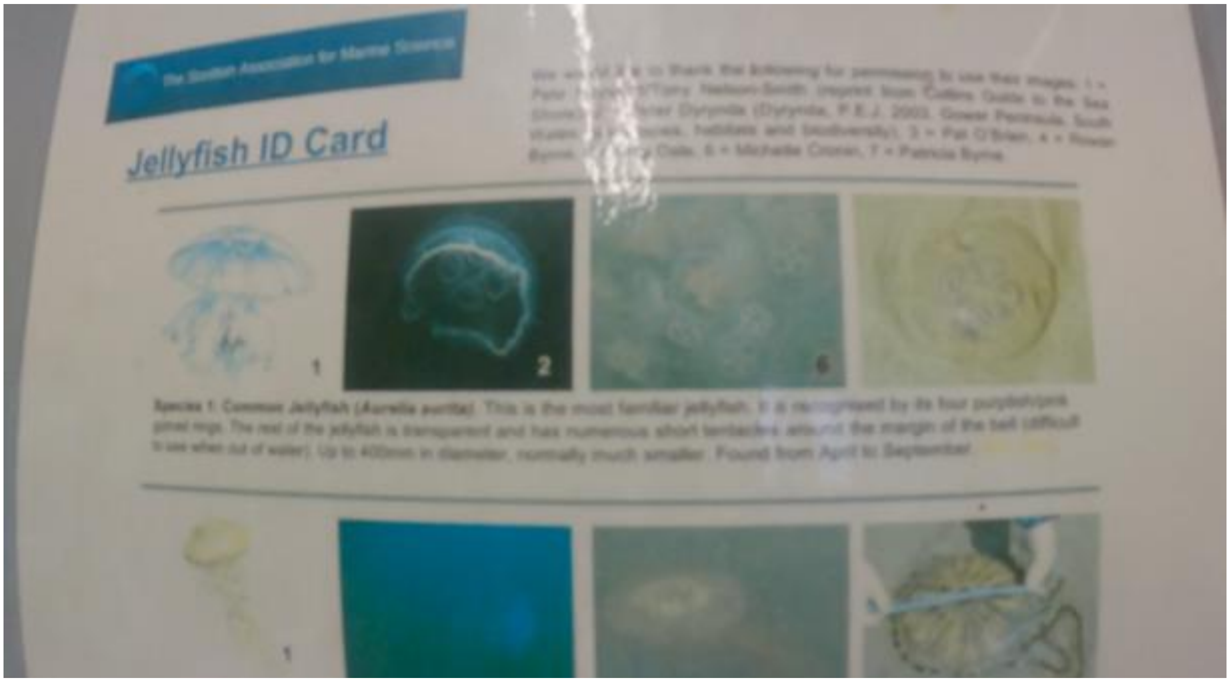
So please make sure that all of your monitoring equipment is in good order.

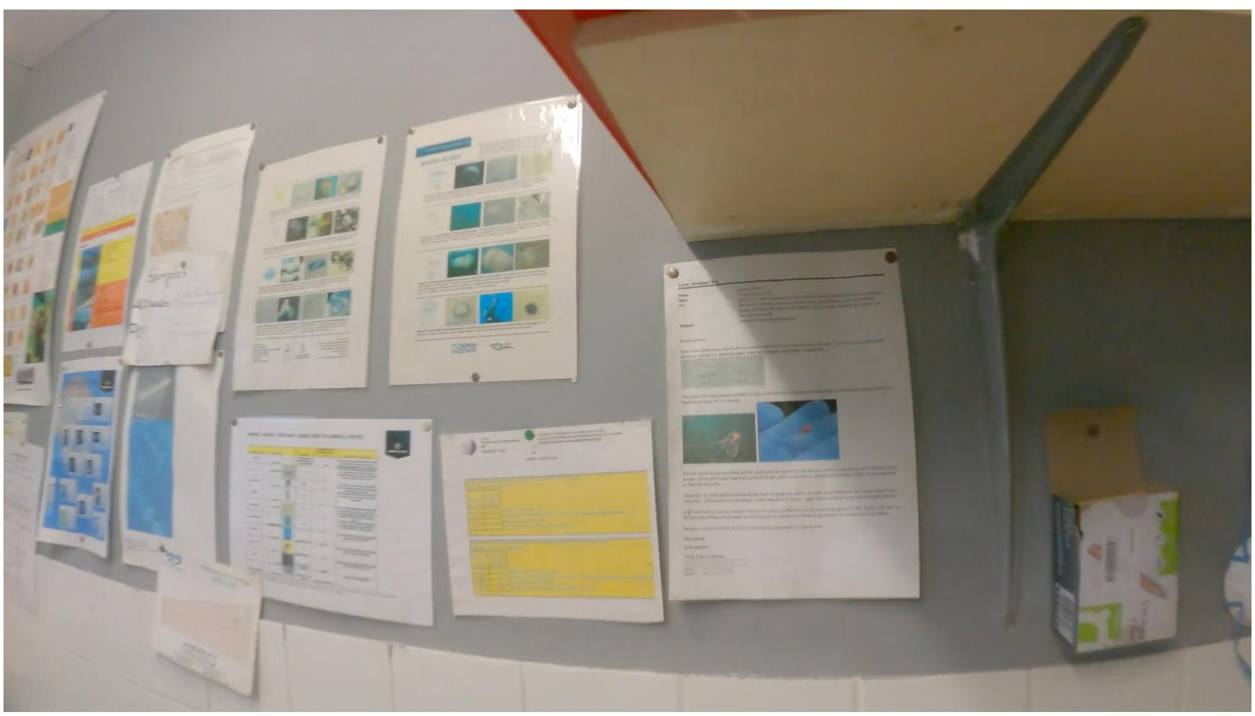
Best regards

Chris Wallace

Health Projects Manager

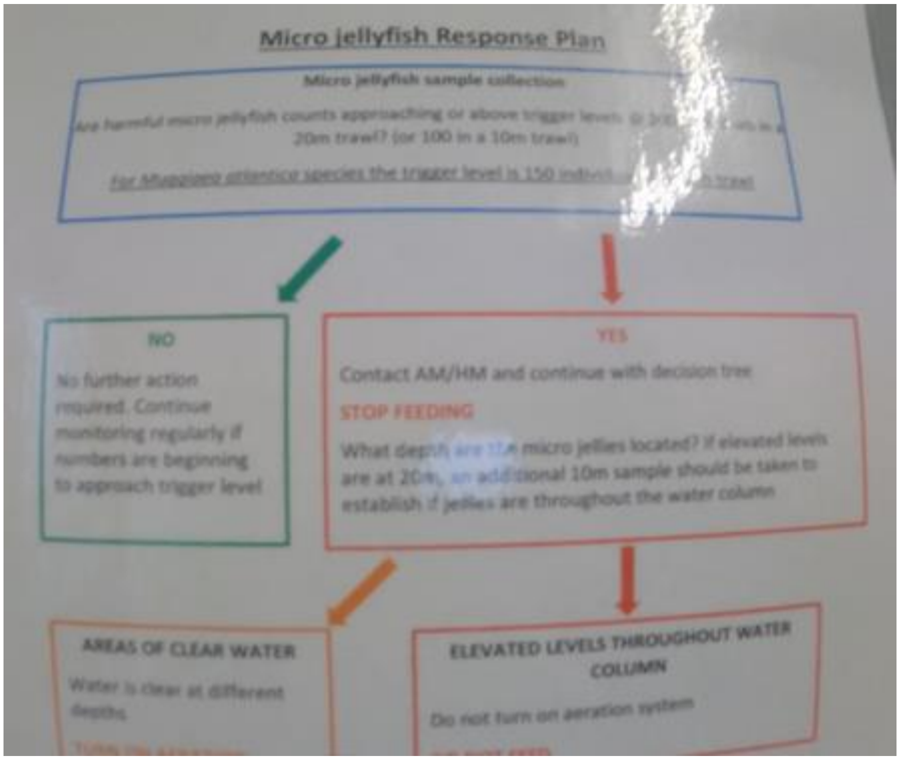
The video footage shot inside Mowi's 'Health Room' at Invasion Bay shows a 'Jellyfish ID Card' published by the Scottish Association of Marine Science, the Scottish Salmon Producers Organisation (Salmon Scotland) and the Crown Estate in 2010:

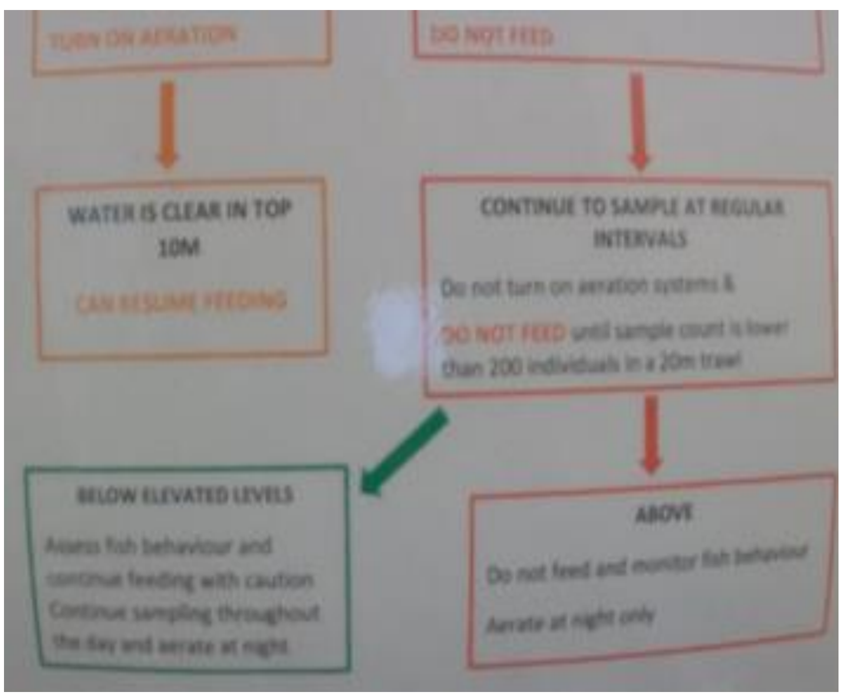


[See **Note 4** for more details]

Mowi’s ‘Health Room’ at Invasion Bay in Loch Sunart had a copy of a ‘Micro Jellyfish Response Plan’ on the wall:

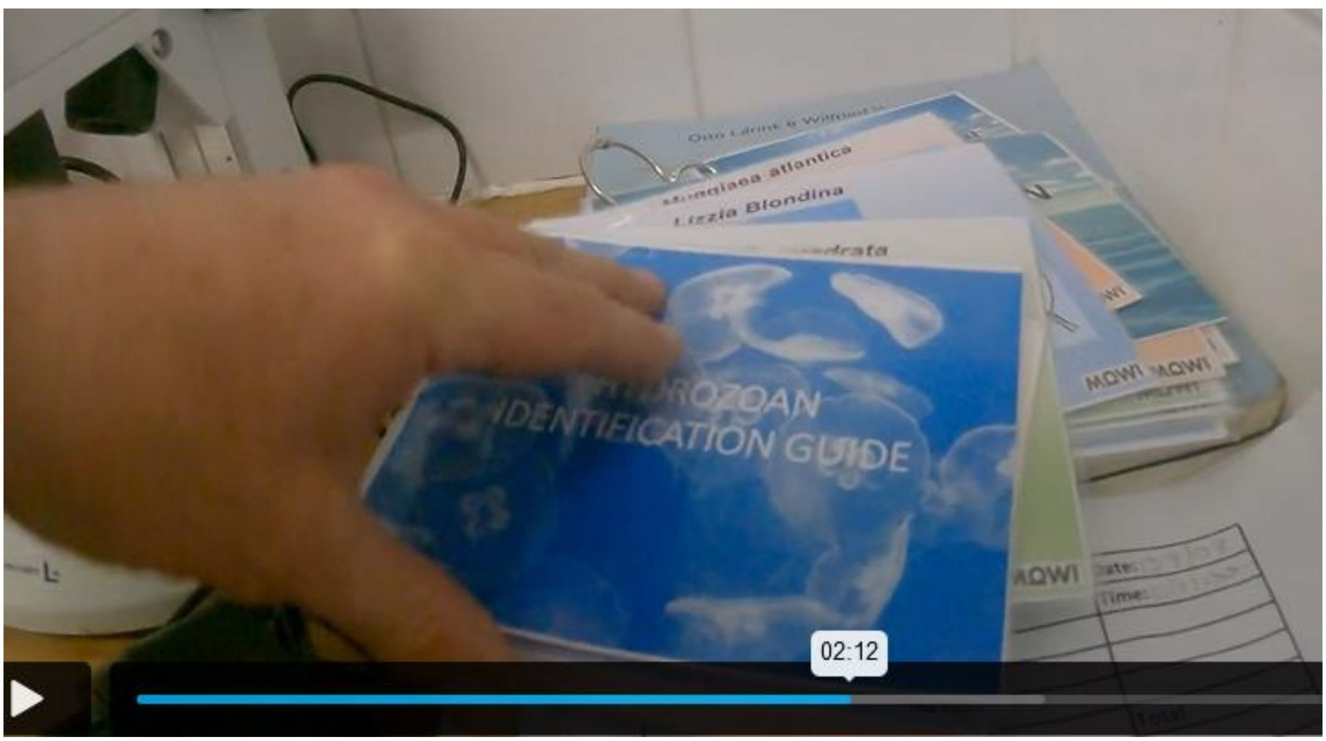



The [video surveillance](#) in Mowi’s Invasion Bay ‘Health Room’ found various guides on jellyfish and phytoplankton:

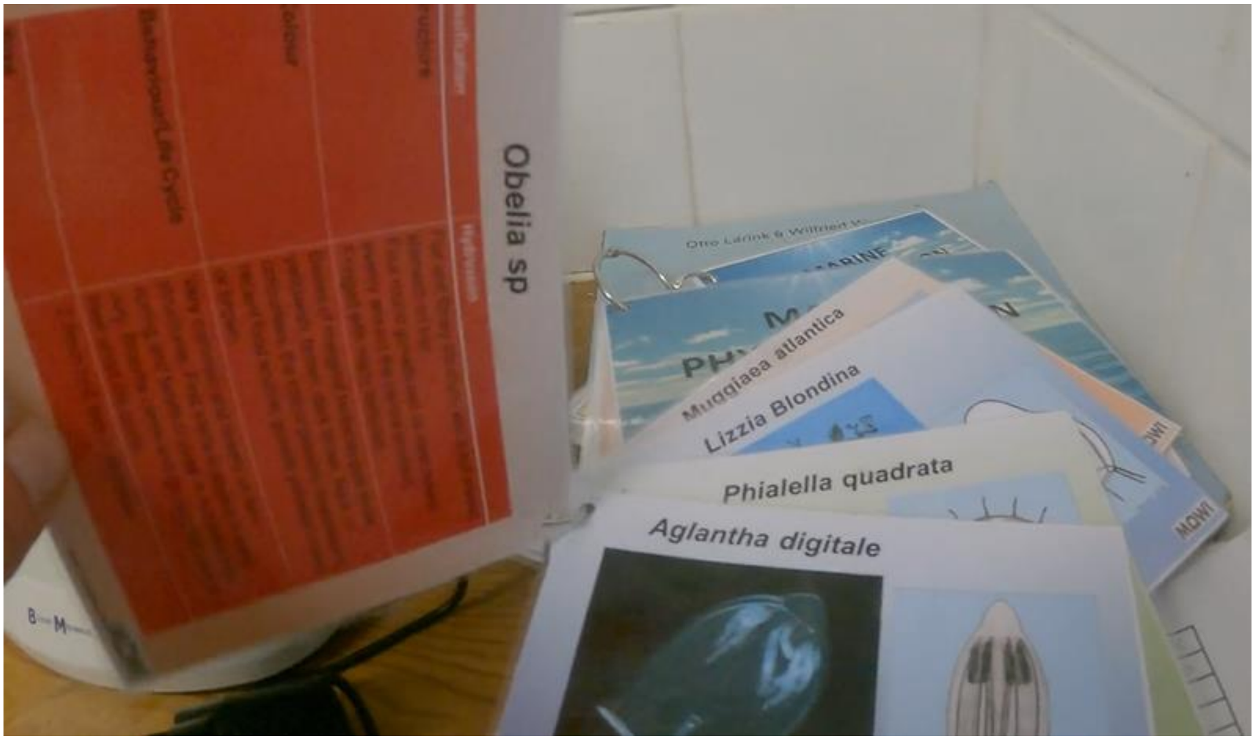


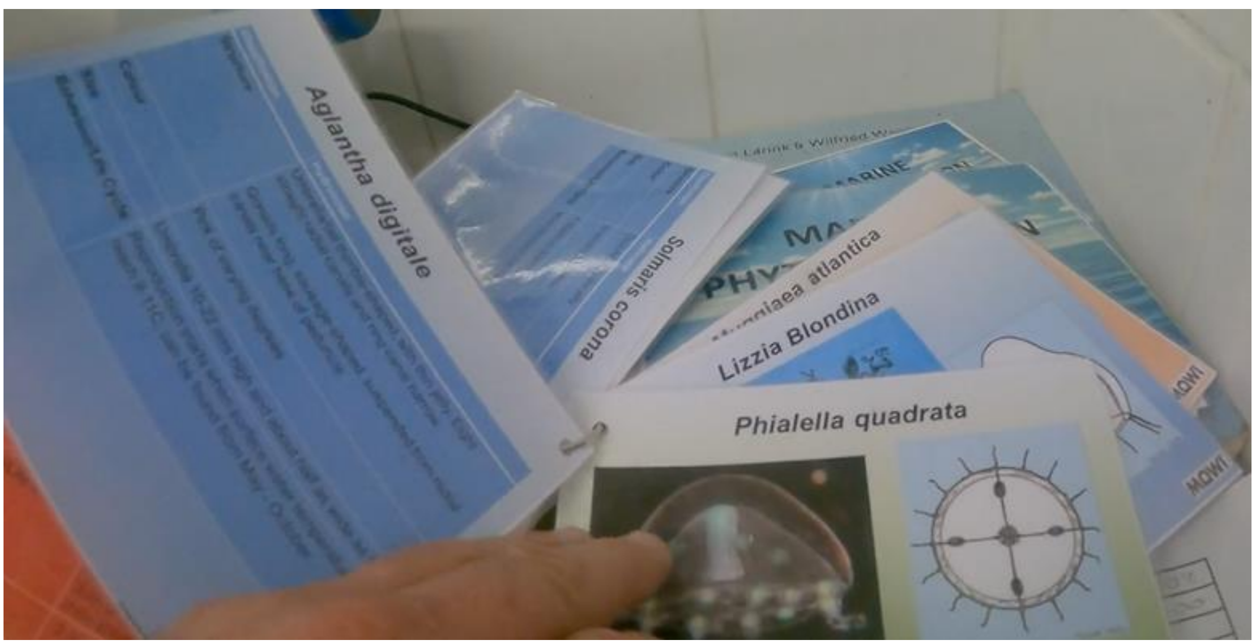
A ‘Hydrozoan Identification Guide’ published by Mowi – found in the ‘Health Room’ at Mowi’s Invasion Bay salmon farm in Loch Sunart in August 2023 – details various jellyfish including Solmaris corona, Obelia spp, Phialella quadrata,  Aglantha digitale, Lizzia Blondina, Muggiaea atlantica:

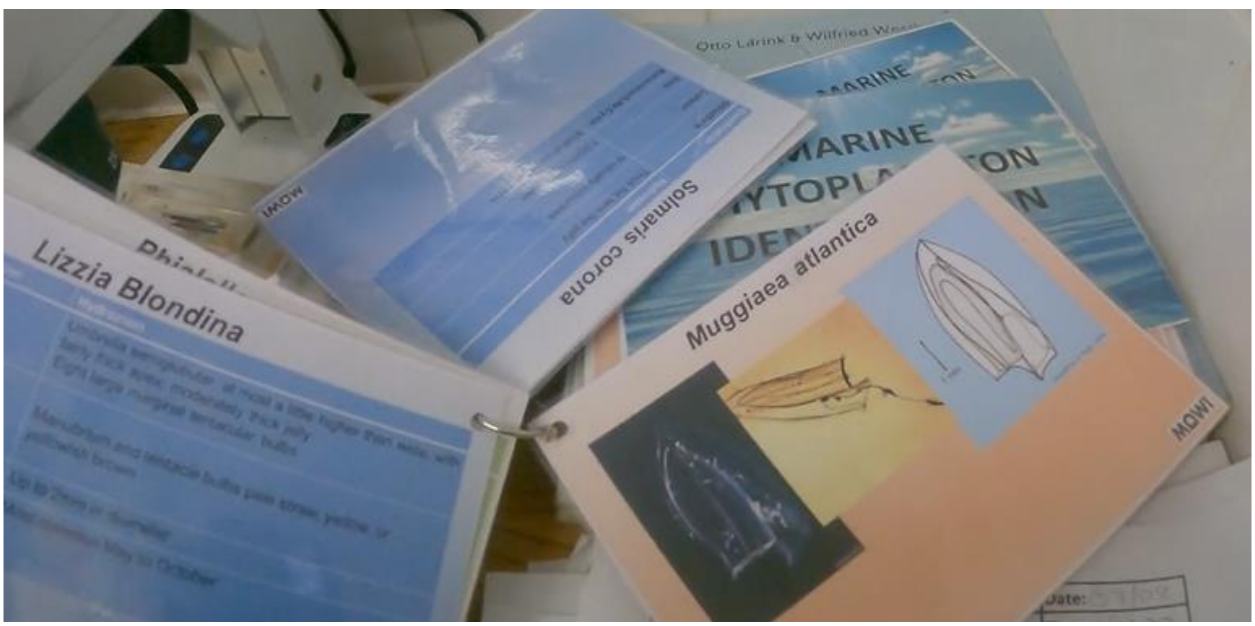



Muggiaea atlantica
Lizzia Blondina
Phialella quadrata
Solmaris corona
MOWI

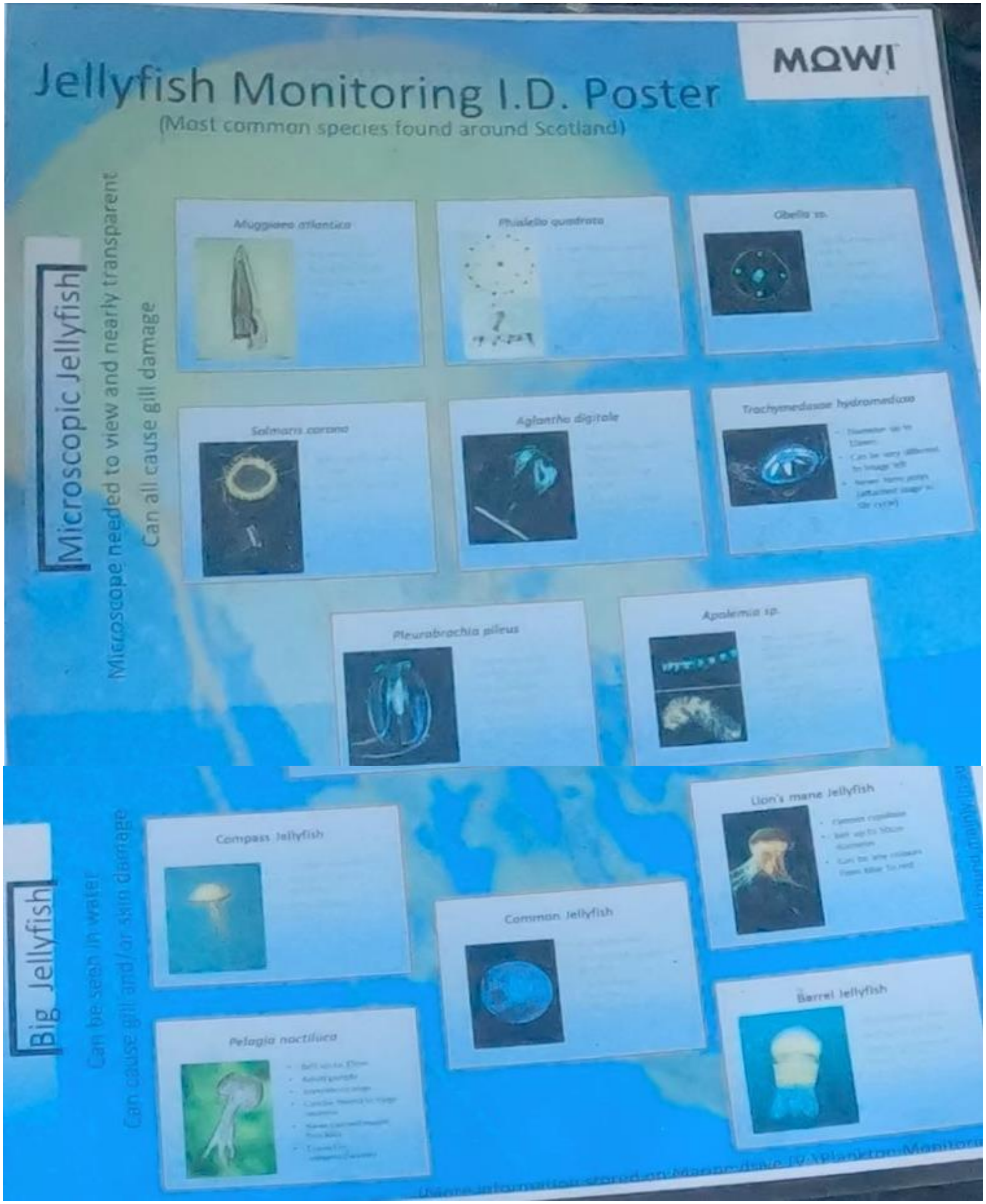

Solmaris corona
Muggiaea atlantica
Lizzia Blondina
Phialella quadrata
Obelia Spp
MOWI


Obelia sp
Muggiaea atlantica
Lizzia Blondina
Phialella quadrata
Aglantha digitale
MOWI


Aglantha digitale
Solmaris corona
Lizzia Blondina
Phialella quadrata
MOWI


Here is a copy of Mowi's 'Jellyfish Monitoring I.D. Poster' which features 'microscopic jellyfish' and 'big jellyfish':

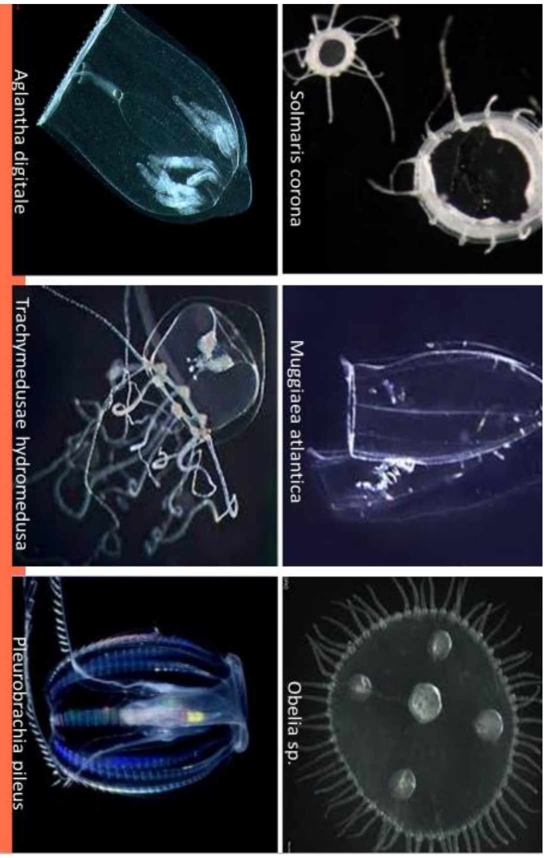



A Mowi 'Salmon Health Training' report dated May 2023 – authored by Mowi Scotland's Alistair Duff - references six microjellyfish including Obelia, Solmaris corona and Muggiaea atlantica and listed symptoms of toxic phytoplankton and hydrozoan species including head shaking, gasping, suffocation and cardiac paralysis:

# NON-INFECTIOUS PATHOGENS

- PGD (Proliferative gill disease)
- Phytoplancton (see training module)
- Zooplancton (see training module)

May 2023 – Health team




Many of the toxic phytoplankton and hydrozoan species produce the following symptoms in fish:

- Scale sloughing
- Head shaking
- Loss of appetite
- Stacking up , facing current
- Gasping
- Disorientation
- Fin reddening
- Reddening of iris
- Fluttering gills
- Mucus build up on gills
  Brownish/reddening gills
- Destruction of gill tissue
- Suffocation
- Respiratory and cardiac paralysis
- Can also cause rashes and swelling to human skin- some, esp *Karenia sp.* can produce aerosols which cause respiratory problems in humans

In Ireland, Norwegian giant Mowi (the world's largest salmon farming company – and the largest in Ireland and Scotland) announced job losses in September 2023 citing higher sea temperatures as well as zooplankton and phytoplankton blooms.

Mowi's Q2 2023 report – published in August 2023 – flagged up "higher than normal" seawater temperatures and the "increased presence of plankton, algae and jellyfish" which could reduce production later this year:

"Biological performance was relatively stable in Scotland whilst seawater temperatures were higher than normal throughout the quarter which may impact biological performance in the second half of 2023." (p5)

"Biological performance in the quarter was relatively good, especially taking into consideration the record-high seawater temperatures. However, the high temperatures caused some feeding issues due to the challenges of storing and handling feed in such high air temperatures. The high temperatures also led to more challenging environmental conditions related to increased presence of plankton, algae and jellyfish." (p10)

Referring to Ireland, Mowi's Q2 2023 report stated:

"The cost increase came as result of previous issues with micro-jellyfish and SRS in the second half of 2022." (p13)

Mowi's Q1 2023 report – published in May 2023 – included in relation to Scotland:

"Incident-based mortality of EUR 1.0 million (EUR 4.9 million) was recognised in the quarter related to winter sores and AGD. Sea water temperatures have shown slower seasonal decline than in most previous years and consequently AGD has remained challenging during the winter months. Although still higher than normal for the season, seawater temperatures declined during the winter and this led to an improved marine environment." (p10)

Mowi's Q4 2022 report – published in February 2023 – cited "significant issues with micro-jellyfish in the aftermath of a record warm summer" and "relocation to inshore sites during the jelly fish bloom":

"Harvest volumes in Scotland dropped slightly compared with the fourth quarter of 2021, which was below guidance. Supply was negatively impacted by adverse biological issues related to SRS following significant issues with micro-jellyfish in the aftermath of a record-warm summer." (p5)

"Salmon which were relocated to inshore sites during the jelly fish bloom, recovered well and were harvested at the end of the fourth quarter, with some stocks being deferred for harvesting into the first quarter." (p10)

Mowi's Q3 2022 – published in November 2022 – cited how "micro-jellyfish impacted growth and harvest volumes" leading to relocation to other sites and "accelerated harvesting":

"Harvest volumes in Scotland dropped slightly compared with third quarter of 2021, which was below guidance. Biological issues related to gill health and effects from micro-jellyfish impacted growth and harvest volumes." (p5)

"Non-seawater costs were significantly impacted by incident-based mortality of EUR 7.6 million (EUR 1.5 million), or EUR 0.52/kg, related to micro-jelly fish blooms around Skye and the Western Isles causing elevated mortalities in some of our farms. As a response to these challenges several fish groups were relocated to other sites with good results." (p10)

Mowi's Q3 2022 report stated in relation to Ireland:

"Earnings were significantly impacted by gill pathology issues due to micro-jellyfish." (p13)

Mowi's Q3 2022 report cited "elevated mortality costs in Scotland and Ireland caused by issues with micro-jellyfish":

"Results within Farming were good in the quarter due not only to strong prices and record-high volumes, but also relatively stable farming costs compared to the previous quarter, despite elevated mortality costs in Scotland and Ireland caused by issues with micro-jellyfish." (p20)

Mowi's Q2 2022 report – published in August 2022 – cited in relation to Scotland:

"Incident based mortality losses in the quarter amounted to EUR 2.8 million (EUR 1.5 million) mainly related to gill issues, treatment mortality and predators. In addition to the issues related to stocks grown from externally sourced eggs, the biological situation has been negatively impacted by gill issues, including AGD, algae and jelly fish." (p10)

In June 2023, covert filming at Mowi's Loch Torridon salmon farm captured footage of microjellyfish and a toxic soup of zooplankton and phytoplankton:

Further video footage shot at Mowi's Loch Torridon salmon farm in June 2023 found microjellyfish near dead and dying farmed salmon:

And video footage shows farmed salmon swimming in a microjellyfish and zooplankton toxic soup (the nets may act as a nursery/spawning area for microjellies to multiply):

Mowi's 'Salmon Farming Industry Handbook 2023' – published in July 2023 – included (p99):

Salmon Farming Industry Handbook 2023

MOWI

# Risk Factors

## 12.2 Most important health risks to salmon

**Gill Disease (GD):** GD is a general term used to describe gill conditions occurring in sea. The changes may be caused by different infectious agents; amoeba, virus or bacteria, as well as environmental factors including algae or jellyfish. Little is known about the cause of many of the gill conditions and to what extent infectious or environmental factors are primary or secondary, how they interact, and causes of disease.

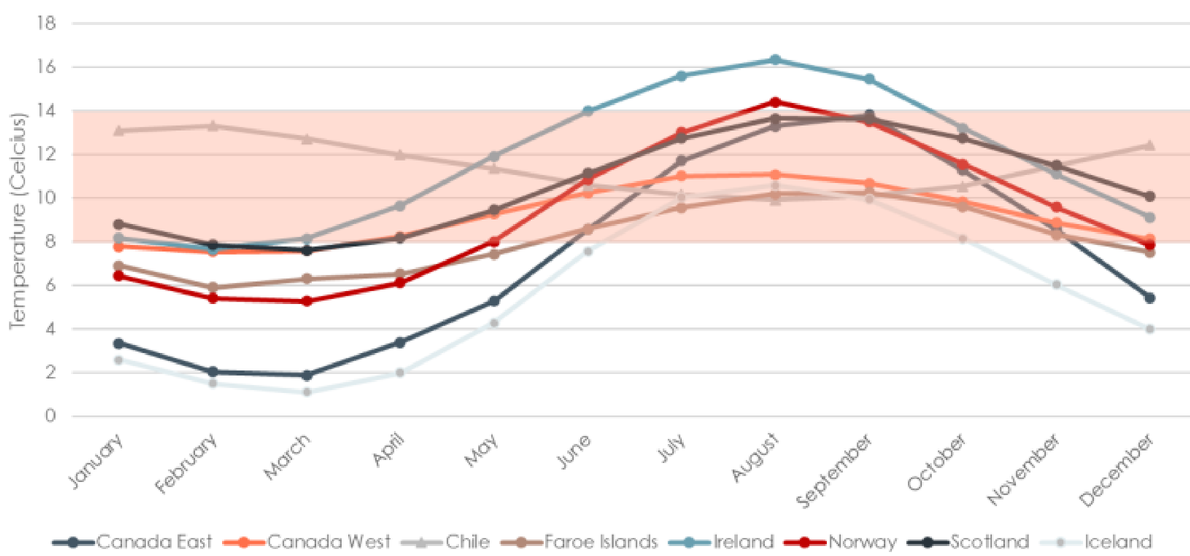
Mowi's 'Salmon Farming Industry Handbook 2023' includes (p28):

"The optimal temperature range for salmon is between 8 and 14 degrees C".

Mowi's 'Salmon Farming Industry Handbook 2023' includes (p54):

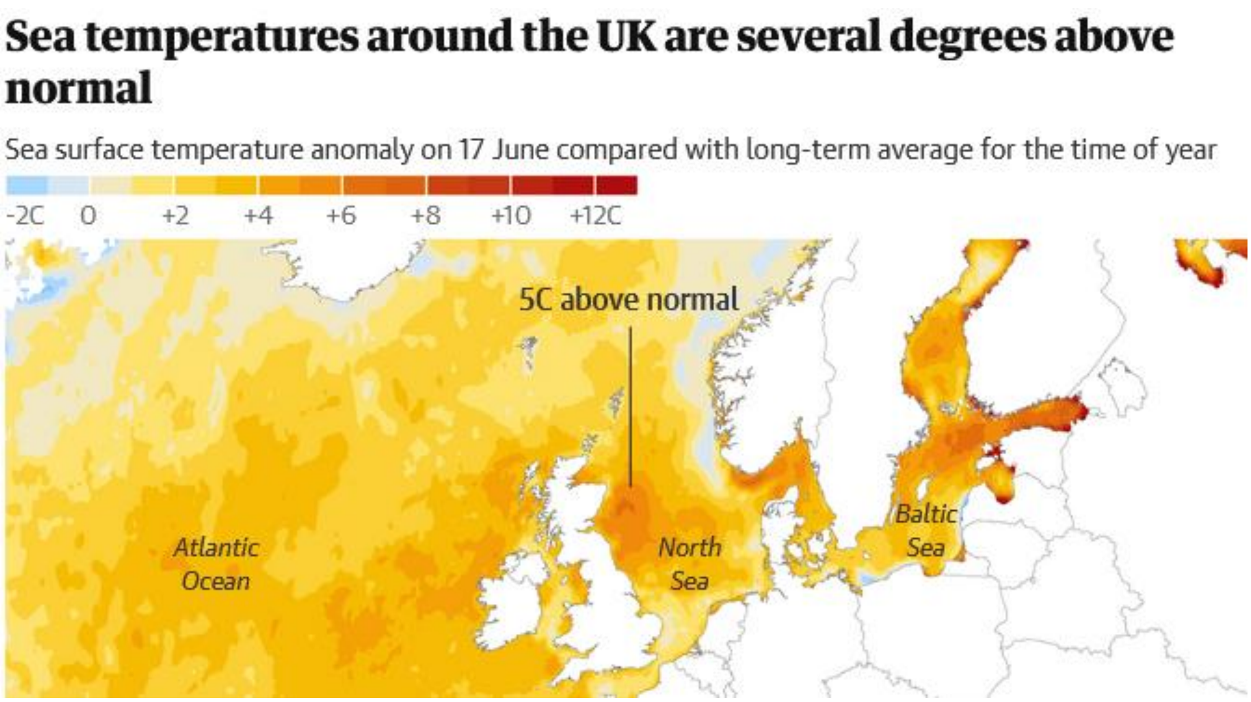
# Salmon Production and Cost Structure

## 8.3 Influence of seawater temperature



> Seawater temperatures vary considerably throughout the year in all production regions. While the production countries in the northern hemisphere see low temperatures at the beginning of the year and high temperatures in autumn varying by as much as 10°C, the temperature in Chile is more stable varying between 10ºC and 14°C. Chile and Ireland have the highest average temperature of 12°C, and the four other regions have an average temperature of about 10°C, except from Iceland which have the lowest average temperature of 6 °C.
>
> As the salmon is a cold-blooded animal (ectotherm), water temperature plays an important role in its growth rate. The optimal temperature range for Atlantic salmon is 8-14°C, but they thrive well from 4-18°C. Temperature is one of the most important natural competitive advantages that Chile has compared to the other production regions as production time there has historically been shorter by a few months.
>
> With high seawater temperatures the risk of disease increases, and with temperatures below 0°C, mass mortality becomes more likely, both of which cause the growth rate to fall.

Temperatures in Scotland – as published by the Scottish Government's Fish Health Inspectorate – have reported temperatures in excess of 14 degrees C with 14.8 degrees C reported at Bakkafrost's East Tarbert Bay salmon farm off the Isle of Gigha in August 2022; 16.8 degrees C off Islay in August 2022; 14.3 degrees C in Loch Broom in August 2022 and 14.2 degrees C in Loch Kanaird in August 2022. Data for the summer of 2023 – to be published online here - may report even higher temperatures in view of an "unheard of" marine heatwave.



EuroNews reported in September 2023:

euronews. My Europe World Business Sport Green Next Travel Culture Video

**Since March 2023, Scotland's waters have been gripped by an unprecedented Category 4 marine heatwave, causing mass marine mortalities.**

For some of Scotland's salmon farms the staggering **five degree temperature increase** has led to a proliferation of sea lice infestations.

euronews. My Europe World Business Sport Green Next Travel Culture Video

But there are other threats that come from rising sea temperatures that are threatening salmon.

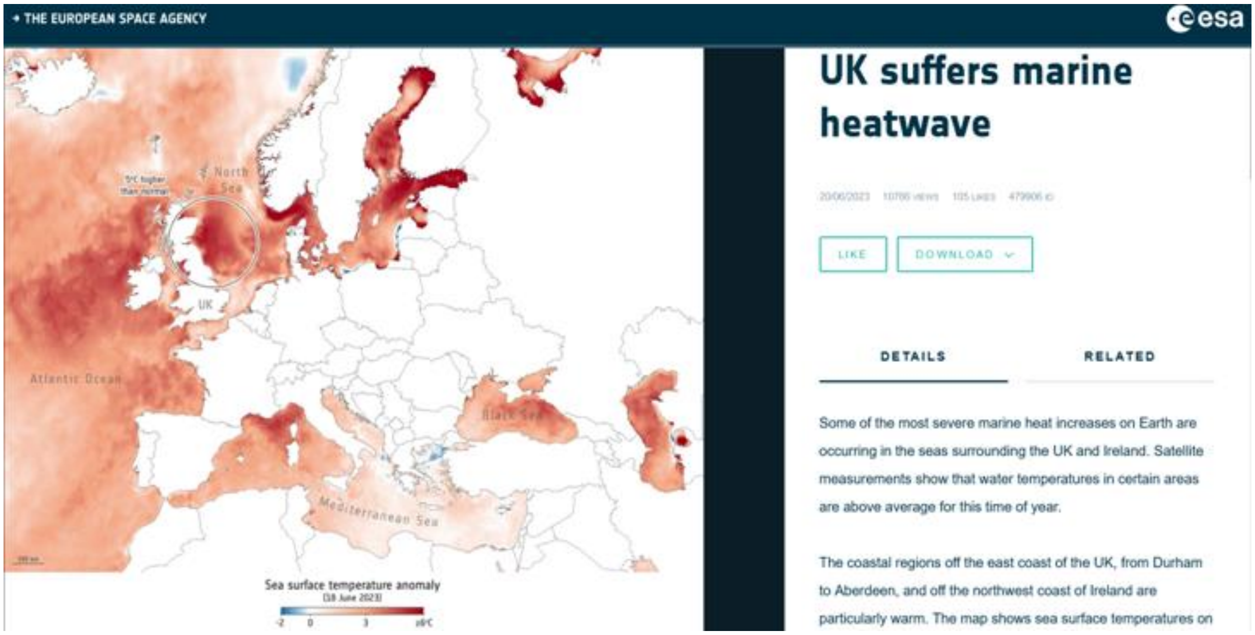
Jellyfish thrive in warmer waters and they can both sting the salmon and block their gills.

Across Europe and the world rising sea temperatures in 2023 have tested marine ecosystems and aquaculture.

"Any rise in temperature is an extra stress, and any sudden big rise that gets beyond what the animals are used to can cause stress to the point where they will die," Dr Sevrine Sailley, an ecosystem modeller at Plymouth Marine Laboratory, said.

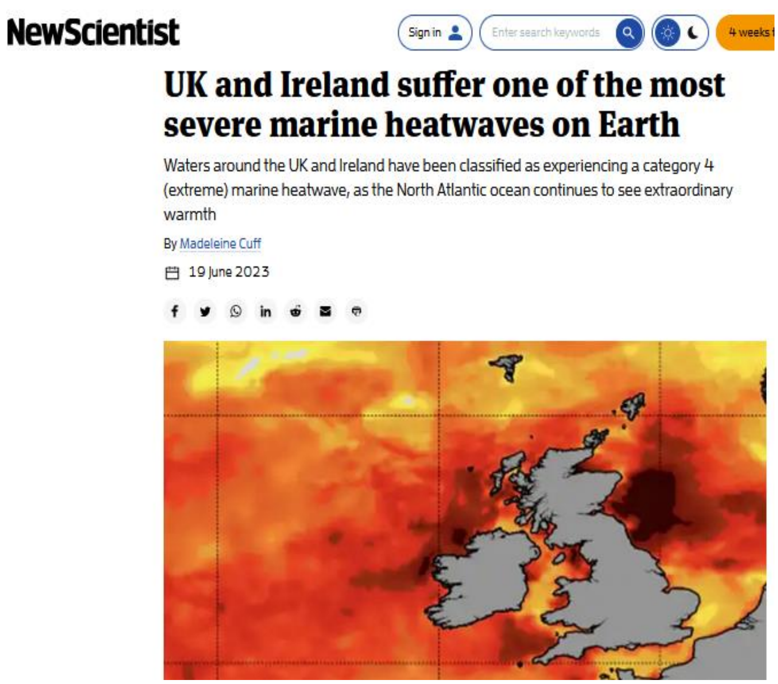
"We could see mass mortality of aquaculture whether they be fish or shellfish," she added.

The European Space Agency reported in June 2023:




Craig Donlon told the ESA: “Extreme Marine Heatwaves are not an everyday event in UK waters. Satellite data, together with data on the ground, will allow us to document the impact of this marine heatwave including stress on the marine ecosystem, the impact on industries such as aquaculture and fisheries, modification of local wind patterns and potential rainfall events that may emerge later.”

New Scientist reported in June 2023:



Video evidence of jellyfish attacking salmon farms is stacking up as water temperatures crank up the heat. When $camon Scotland visited Fishnish salmon farm operated by Scottish Sea Farms (Norskott Havbruk) in the Sound of Mull in August 2023 we found Lion's Mane jellyfish swarming outside a cage and their stinging tentacles encroaching inside the net:


When $camon $cotland filmed at Wester Ross Fisheries (Mowi) in Loch Broom in June 2023 we saw jellyfish surrounding the cages at the Corry salmon farm:

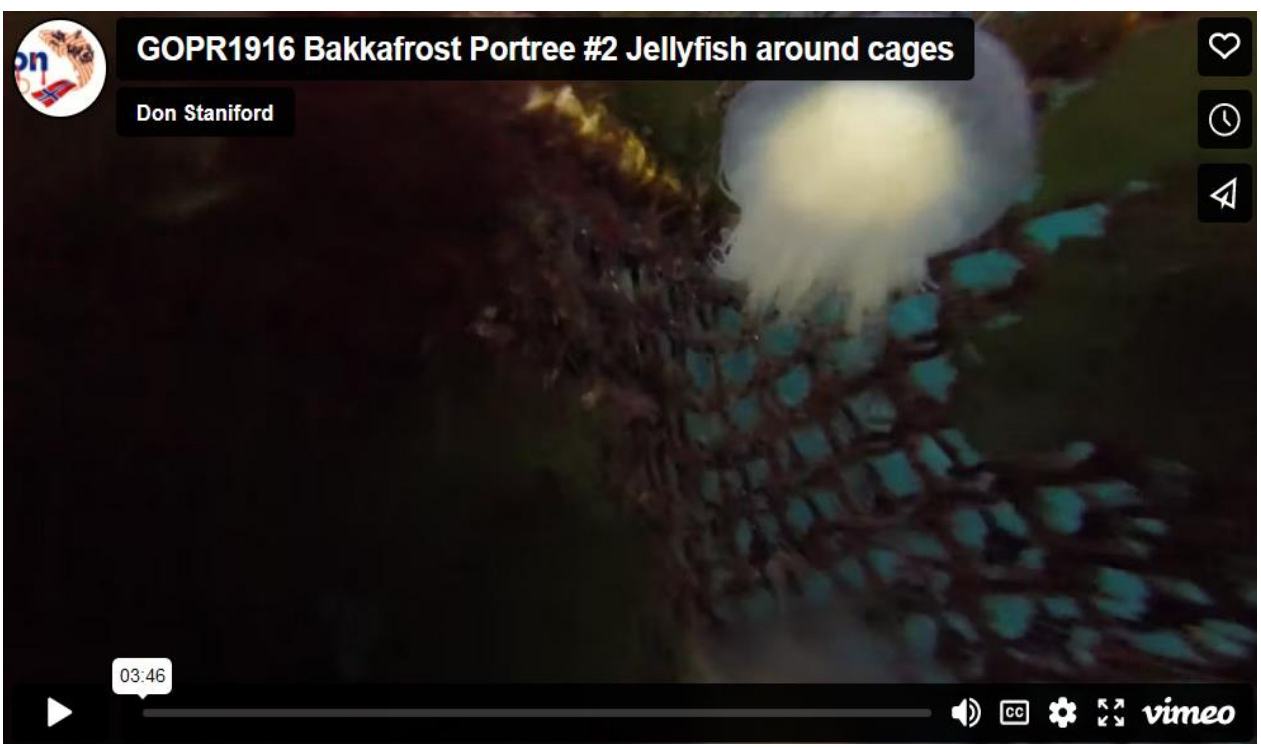

At the land base operated by RSPCA Assured Wester Ross Fisheries near Ullapool we filmed mass mortalities piled up in bins:

When $camon $cotland visited Ardmair salmon farm operated by Wester Ross Fisheries (Mowi) in Loch Kanaird in June 2023 we saw swarms of jellyfish but the farm had just been harvested out (a week later the site was restocked with fish moved from Loch Broom):


In June 2023, [covert filming at Scottish Sea Farms (Norskott Havbruk) in Loch Kishorn (Kishorn South)]() found moon jellyfish swarming around the cages:

Video footage shot at Scallastle Bay salmon farm operated by Scottish Sea Farms (Norskott Havbruk) in the Sound of Mull in June 2023 shows jellyfish stuck on the outside of the net and a toxic soup of microjellies and zooplankton:


In this video footage shot at Bakkafrost's Portree salmon farm off the Isle of Skye in late June 2023 you can see jellyfish congregating outside the salmon cage with the tentacles of one medusa reaching out into the net where the farmed salmon are swimming:



Two months later in early September 2023, Bakkafrost's Portree salmon farm suffered a horrific mass mortality event (175,115 deaths "as a result of suspected Solmaris jellyfish bloom" were reported to the Scottish Government on 11 September 2023 with a mortality rate of 31%). The Sunday Mail reported (24 September 2023):

CAMPAIGNER'S FEARS OVER ANIMAL WELFARE AT FARM SITE

# Salmon horror is off the scale

## Drone footage shows thousands of dead fish

■ Dawn Thompson

**The deaths of thousands of salmon at a controversial fish farm have been exposed by shocking drone footage.**

The images of the RSPCA Assured site off Skye shows thousands of dead fish being extracted from cages for disposal.

The surveillance pictures of the Bakkafrost Scotland farm outlines large containers packed with lifeless salmon being offloaded on to the 73m well boat Bakkanes for removal.

Dead fish are seen floating in a cage as a live trapped salmon struggles to free itself from a net across the top.

Secret underwater filming at the same site – previously revealed by the Sunday Mail – showed horrific images of "zombie salmon" swimming around, despite missing large chunks of flesh.

The firm have blamed jellyfish for the deaths, with Scottish Government inspectors being called in to investigate.

Campaigner Don Staniford said the images raise concerns over animal welfare and biosecurity at Bakkafrost Scotland's Portree site.

Last night, he said: "Salmon farming is a welfare nightmare and must be immediately closed down to save tens of millions of fish.

"The ethically and environmentally bankrupt salmon farming industry is dead in the water as warming summer temperatures make Scotland no place to farm salmon.

"This is an estimate but, having watched events from onshore and having reviewed the footage, there is a credible argument to say we could be talking 500 tons of dead fish in this single incident. It could be over 1000.

"The images show some 30-40 tons at one moment in time and the response to whatever caused this incident took place over at least four days. The Bakkanes can transport 600 tons.

"Consumers should avoid RSPCA Assured Scottish salmon like the plague. A deadly cocktail of warming water temperatures, swarms of jelly-fish, gill problems, infectious diseases, plagues of parasites and toxic algal

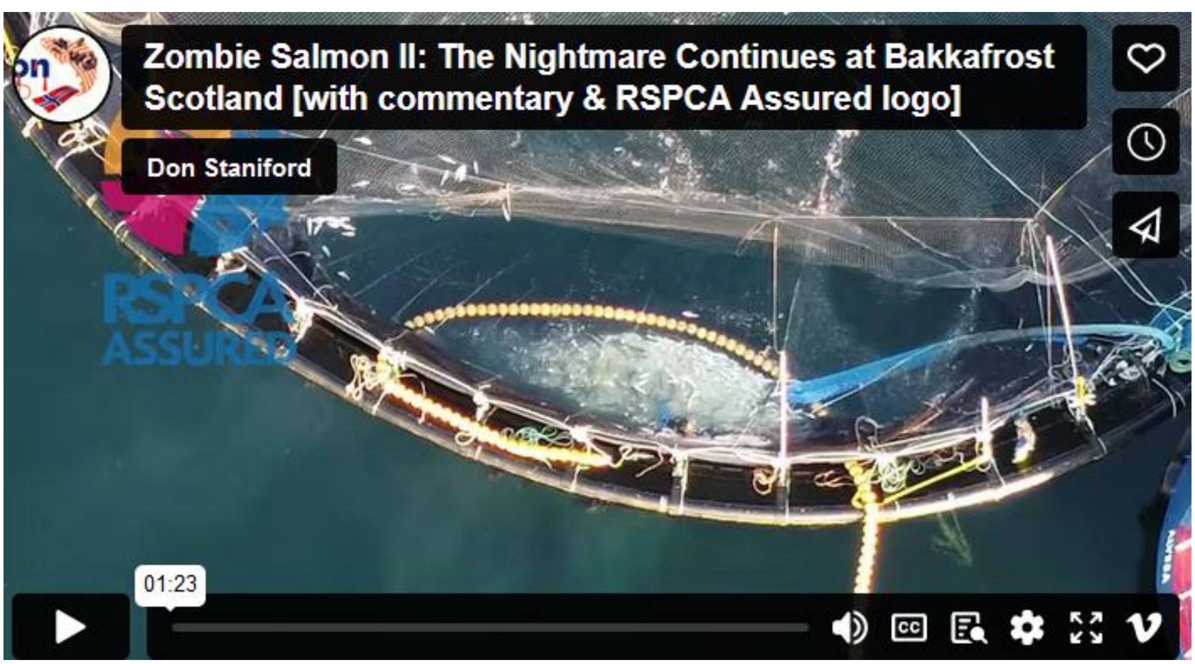
"There could be over 500 tons of dead fish in this single incident

**SHOCK** Footage of 'zombie salmon'

**EXPOSED** Fish are extracted from cages for disposal

**OPERATION** Drone footage reveals how tons of dead salmon were transferred on to the well boat Bakkanes for removal from Portree site

and the natural environment. We would strongly disagree with any suggestion our team has operated in



The Sunday Mail [reported (24 September 2023)]:

Daily Record  Bookmark

Iain MacIntyre, director of marine operation at Bakkafrost Scotland, admitted to an issue with its salmon and blamed jellyfish.

He said: "Salmon farming takes place in the natural environment and can face unique and difficult biological challenges, particularly when the water is warmer.

"This has been the case at Portree when, following a prolonged period of hot weather, a jelly fish bloom moved through the area. We immediately deployed additional resources and equipment to resolve the issue and the relevant authorities were notified.

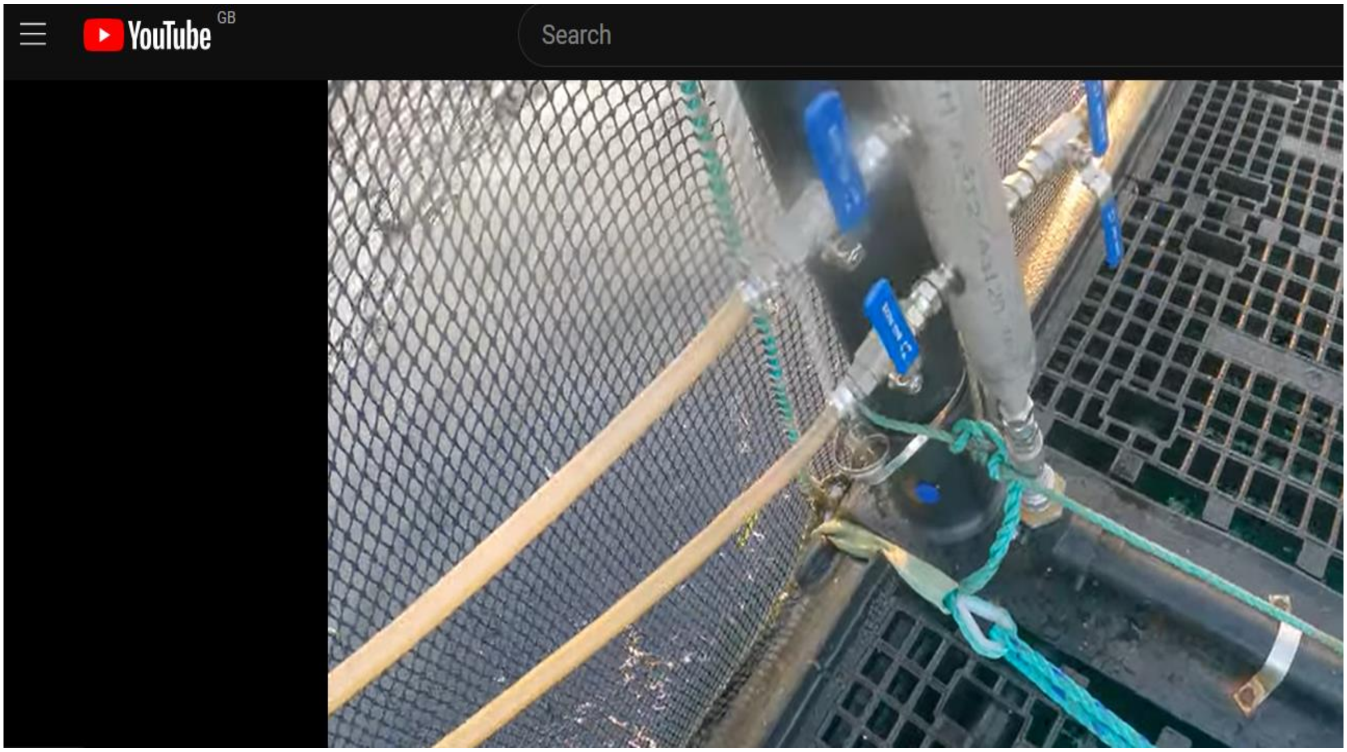
"Our staff worked diligently and went above and beyond to manage a challenging set of circumstances and deal with the problems caused by the jelly fish bloom.

"This was carried out in a matter of days and the jelly fish bloom has now passed through the site and the incident-based mortality has ceased.

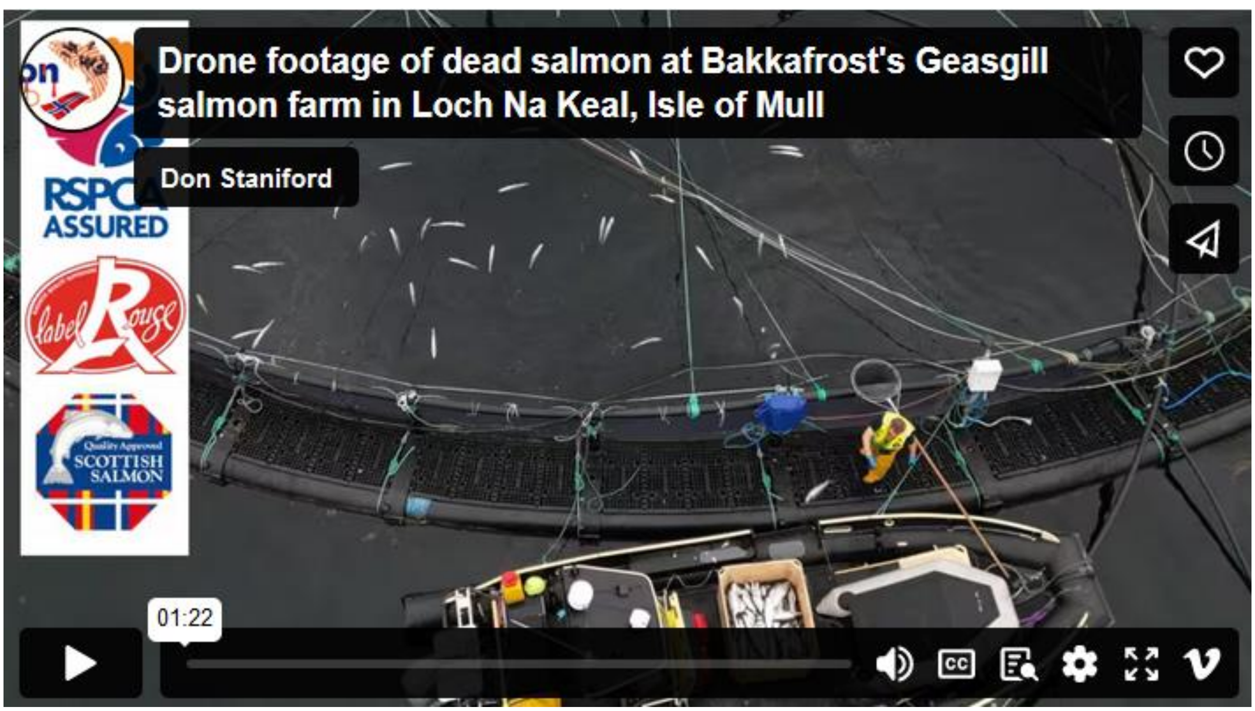
Daily Record  Bookmark

"Consumers should avoid RSPCA Assured Scottish salmon like the plague. A deadly cocktail of warming water temperatures, swarms of jellyfish, gill problems, infectious diseases, plagues of parasites and toxic algal blooms has killed off millions of Scottish salmon this summer."

When $camon $cotland visited Bakkafrost's Geasgill salmon farm in Loch Na Keal off the Isle of Mull in late June 2023 we found swarms of jellyfish and a toxic soup of microjellies and zooplankton with oxygen being pumped into the cages:


Weeks later in late July and early August 2023, Bakkafrost's Geasgill salmon farm suffered mass mortalities with a staggering 24% mortality just in the month of July 2023 (data for August 2023 is expected in early October 2023).



Data published by Salmon Scotland in September 2023 cited 10 cases where jellyfish/plankton – along with gill health and viral disease - caused mortalities in July 2023 including 23.7% mortality at Bakkafrost's Geasgill salmon farm with jellyfish problems also cited at Bakkafrost's Gometra salmon farm off the Isle of Mull. When $camon $cotland visited Bakkafrost's Gometra salmon farm in August 2023 we captured evidence of microjellies inside and outside the cages along with dead fish floating on the surface:


[Note the Scottish Government's Fish Health Inspectorate reported on 2 October 2023 that Bakkafrost's Gometra salmon farm suffered "gill damage the result of microjellies" with "large numbers of jellyfish reported" and 14,994 dead fish in late August 2023]

Bakkafrost's 2022 Annual Report does not specifically cite jellyfish but referenced microalgae, hydrozoa and other plankton species (which includes jellyfish and microjellyfish) :

ANNUAL REPORT 2022

# Risk Management

BAKKAFROST

ESTABLISHED 1968

**Climate change**

Climate change may have negative impact on fish health and increase the risk of harmful species. Elevated sea temperatures may lead to episodes of oxygen depletion, increased blooms of harmful algae and other plankton species, as well as more extreme weather events.

Bakkafrost has close surveillance at the site with online oxygen monitoring implemented and monitoring sea temperature at farming sites. Algae and patogens monitoring is implemented, and the assessment and procedures for physical demands for equipment have been improved.

**Algae, hydrozoa, and other plankton living species**

Microalgae, hydrozoa, and other plankton species may harm fish and cause mortalities either by causing oxygen depletion, releasing toxic substances or causing gill damage. Current knowledge on the prevalence of algae and hydrozoa is limited. Recent studies on salmon on one of our sites have indicated an inflammatory response on gill health at algae levels typically found at our farming sites. Further effort ought to be put into a survey of the prevalence of plankton living species and their effect on fish health.

Surveillance of algae and other plankton living species is implemented, and Bakkafrost is working in collaboration with researchers to gain a better understanding of the occurrence of hydrozoans and other species. Bakkafrost also samples and analyse nutrients level preparing for further knowledge and possibilities of a modelling and predicting.

Bakkafrost's 2021 Annual Report – published in October 2022 - references the "deadly cocktail" of micro-jellyfish and reduced gill health:

BAKKAFROST

ESTABLISHED 1968

**ANNUAL REPORT 2021**

In Scotland, we had severe mortality in Q3 and Q4, with a total of 262 mDKK in exceptional mortality costs. The underlying issue was linked to the reduced gill health the fish develops due to the extended growth cycle in the marine environment, up to 22 months, due to the small average smolt size on release. The fish are exposed to hazards that impair their gills during this period. Late in Q3 and into Q4, there was a significant bloom of hydrozoans and micro-jellyfish, which deteriorated the gill health even more and led to very high mortality across several sites. In short, the micro-jellyfish bloom on top of reduced gill health was a deadly cocktail.

The farming operation in Scotland has been very challenged in this quarter. The main root-cause of the mortality in Scotland is compromised gill health in combination with secondary complications, such as blooms of micro-jellyfish/hydrozoans and fish handling during necessary treatments. Late in the quarter, the situation stabilised on somewhat elevated mortality rates, which for a few sites remained until end of January 2022.

**September**

- Bakkafrost announced a 6.2 billion DKK investment program for 2022-2026 on the Capital Market Day in the Faroe Islands
- Farming supply vessel M/S Bakkanes commenced its operation in Scotland
- Sudden bloom of hydrozoans and micro-jellyfish in Scotland cause beginning mass-mortality

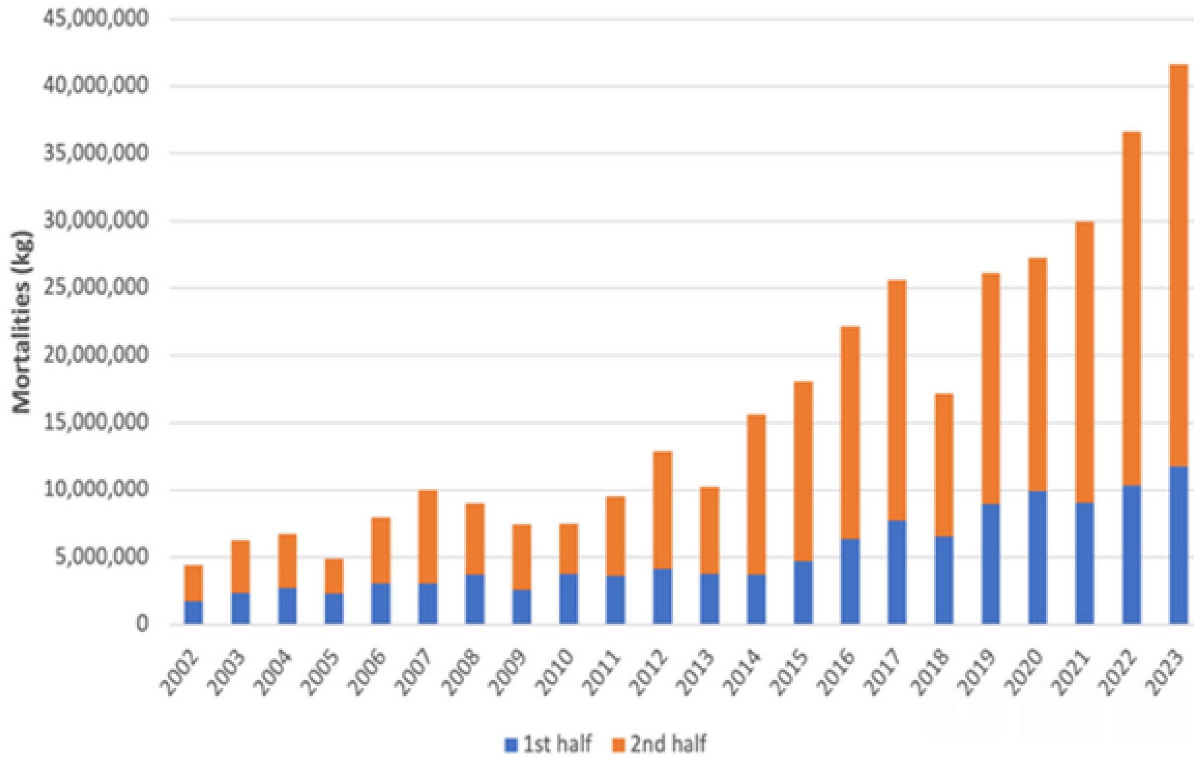
Read more via: Bakkafrost is Dead in the Water in Scotland - 2021 Annual Report Details "Deadly Cocktail"!

In Norway, jellyfish problems are increasing too although not on the scale of Scotland's. The Norwegian Fish Health Report 2022 – published by the Norwegian Veterinary Institute in March 2023 - cites jellyfish in relation to four 'welfare-related incidents' in 2022. Injuries inflicted by jellyfish on farmed salmon may be indirect (e.g. blocking of nets leading to low oxygen levels) or direct (e.g. blockage of mouth or operculae, or the toxic effect of stinging nematocysts) **[5]**.

Zooplankton damage from Muggiaea atlantica with erosion of gill rakers and Tenacibaculum sp. colonisation of damaged tissue obvious as yellowish colouration on damaged tissue.

The physical injuries and painful deaths caused by jellyfish and microjellyfish are detailed in scientific research from Ireland **[6]**.

Mortalities on salmon farms in Scotland in 2023 are shaping up to be the worst ever with a record 11,761 tonnes of morts reported in the first six months of this year and 41,623 tonnes predicted by the end of 2023.




Read more via: Scottish Salmon is Dead in the Warming Water (2 October 2023)

Mass mortalities at Scottish salmon farms – and jellyfish blooms - could increase even further during 2023 if the marine heatwave has accelerated mortality (satellite data from the European Space Agency in June 2023 showed sea surface temperature more than 5°C higher than the average during this time of year).

Increases in mortalities on salmon farms have been correlated with rising water temperatures. “At salmon farms, a strong link between milder winter temperatures, disease and increased fish mortality has been identified,” reported a ‘Marine Climate Change Impacts Partnership’ paper co-authored by Marine Scotland Science and the Institute of Aquaculture in Stirling published in November 2022. “We have statistical evidence of an existing association of salmon mortality with milder winters and evidence of the emergence of amoebic gill disease in UK waters in association with warm summers and persistence with mild winters.”

Read more via a Freedom of Information disclosure by the Scottish Government in September 2023 **[7];** scientific research by the University of Stirling on the impact of climate change on salmon farming **[8]**; media coverage **[9]**; industry perspectives **[10]** and an overview **[11].**

**Notes to Editors:**

**[1]** Data published by Salmon Scotland:

# November 2022

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Cooke Aquaculture (Scotland) | South Cava | 4.6 | Gill health related, Jellyfish / planton | In production |
| Loch Duart Ltd | Loch Carnan | 8.4 | Jellyfish / plankton | In production |

# October 2022

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Loch Duart Ltd | Loch Carnan | 26.5 | Jellyfish / plankton | In production |
| Mowi Scotland Limited | Hellisay | 15.6 (Farm fallowed in Oct.) | Jellyfish / plankton | 23.0 |
| Mowi Scotland Limited | Loch Alsh | 6.0 | Jellyfish / plankton | In production |
| Organic Sea Harvest Ltd | Invertote | 12.8 | Jellyfish / plankton, Gill health related | In production |

# September 2022

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Cooke Aquaculture (Scotland) | Lyrawa Bay | 4.3 | Jellyfish / plankton, Gill health related | In production |
| Loch Duart Ltd | Loch Carnan | 55.9 | Jellyfish / plankton | In production |
| Mowi Scotland Limited | Harport | 9.7 | Jellyfish / plankton | In production |
| Mowi Scotland Limited | Hellisay | 13.9 | Jellyfish / plankton | In production |
| Mowi Scotland Limited | Loch Alsh | 5.0 | Jellyfish / plankton | In production |
| Mowi Scotland Limited | Marulaig Bay | 21.7 | Jellyfish / plankton | In production |
| Mowi Scotland Limited | Muck | 23.9 | Jellyfish / plankton | In production |
| Mowi Scotland Limited | Rum | 25.2 | Jellyfish / plankton | In production |
| Mowi Scotland Limited | Stulaigh | 38.0 | Jellyfish / plankton | In production |
| Organic Sea Harvest Ltd | Invertote | 10.7 | Jellyfish / plankton, Gill health related | In production |
| Wester Ross Fisheries Ltd | Ardessie A | 7.6 | Jellyfish / plankton | In production |
| Wester Ross Fisheries Ltd | Ardessie B | 8.6 | Jellyfish / plankton | In production |
| Wester Ross Fisheries Ltd | Ardmair | 4.7 | Jellyfish / plankton | In production |

# August 2022

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Wester Ross Fisheries Ltd | Ardessie A | 10.4 | Jellyfish / Plankton | In production |
| Wester Ross Fisheries Ltd | Ardessie B | 4.0 | Jellyfish / Plankton | In production |
| Wester Ross Fisheries Ltd | Ardmair | 18.2 | Jellyfish / Plankton | In production |

# May 2022

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Mowi Scotland Limited | Loch Alsh | 4.9 | Jellyfish / plankton | In production |

# December 2021

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Mowi Scotland Limited | Loch Alsh | 10.6 | Jellyfish / plankton | In production |

# November 2021

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Mowi Scotland Limited | Loch Alsh | 4.2 | Jellyfish / plankton | In production |

# October 2021

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Wester Ross Fisheries Ltd | Ardessie A | 9.2 | Jellyfish / plankton | In production |
| Wester Ross Fisheries Ltd | Ardmair | 4.7 | Jellyfish / plankton | In production |

# September 2021

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Wester Ross Fisheries Ltd | Ardessie A | 24.9 | Jellyfish / plankton | In production |
| Wester Ross Fisheries Ltd | Ardessie B | 31.0 | Jellyfish / plankton | In production |
| Wester Ross Fisheries Ltd | Ardmair | 16.4 | Jellyfish / plankton | In production |

# August 2021

| Company | Farm | Monthly mortality (%) | Notes | Cumulative mortality over full production cycle (%) |
|---|---|---|---|---|
| Mowi Scotland Limited | Harport | 7.8 (Farm fallowed in Aug.) | Jellyfish/Plankton | 17.3 |
| Mowi Scotland Limited | Sconser Quarry | 7.1 | Jellyfish/Plankton | In production |

Mortality data for August 2023 is expected to be published by Salmon Scotland in early October 2023.

**[2]** Here is a list* of 'Mortality Event Reports' which cited jellyfish or microjellyfish – highest to lowest (download Excel spreadsheet online here) – sourced from the FHI data downloaded in July 2023:

| Mortality Event No | Reporting Business Name | Site Name | Date reported | Explained reasons | Total mortality during event |
|---|---|---|---|---|---|
| MRT03320 | Mowi Scotland Ltd | Marulaig Bay | 29/09/2022 | Gill infections / Jellyfish | 139023 |
| MRT01754 | Grieg Seafood Shetland Ltd | Leinish | 18/08/2020 | Complex gill disease and jellyfish | 107700 |
| MRT01822 | Grieg Seafood Shetland Ltd | Leinish | 08/09/2020 | Complex Gill Disease / Jellyfish | 81247 |
| MRT03319 | Mowi Scotland Ltd | Stulaigh | 29/09/2022 | Gill infections / Jellyfish | 65332 |
| MRT01792 | Grieg Seafood Shetland Ltd | Corlarach | 01/09/2020 | Complex Gill Disease / Jellyfish | 53177 |
| MRT02447 | Mowi Scotland Ltd | Rum | 04/10/2021 | Gill disease and microjellyfish bloom | 52598 |
| MRT02456 | Mowi Scotland Ltd | Rum | 04/10/2021 | Gill disease and microjellyfish | 49282 |
| MRT01839 | Grieg Seafood Shetland Ltd | Leinish | 15/09/2020 | Complex Gill Disease / Jellyfish | 48245 |
| MRT03529 | Cooke Aquaculture Scotland Ltd | Meil Bay | 15/11/2022 | Jellyfish/Gill Damage | 44781 |
| MRT02396 | The Scottish Salmon Company | West Strome | 20/09/2021 | Jellyfish/Plankton, Gill Health Related | 42602 |
| MRT01774 | Grieg Seafood Shetland Ltd | Leinish | 25/08/2020 | Complex gill disease and jellyfish | 40260 |
| MRT03305 | Scottish Sea Farms Ltd | Nevis B | 29/09/2022 | Environment; Gill Health Related post jellyfish bloom | 40041 |
| MRT00354 | The Scottish Salmon Company | Loch Tuath | 11/09/2017 | AGD, Algal bloom, Complex gill issues, Jellyfish | 36422 |

| | | | | | |
|---|---|---|---|---|---|
| MRT00354 | The Scottish Salmon Company | Loch Tuath | 11/09/2017 | AGD, Algal bloom, Complex gill issues, Jellyfish | 36422 |
| MRT03277 | Scottish Sea Farms Ltd | Nevis C (Ardintigh) | 22/09/2022 | Environment; Gill Health Related post jellyfish bloom | 35990 |
| MRT03309 | Scottish Sea Farms Ltd | Nevis C (Ardintigh) | 29/09/2022 | Environment; Gill Health Related post jellyfish bloom | 35875 |
| MRT03425 | Cooke Aquaculture Scotland Ltd | Pegal Bay | 18/10/2022 | Jellyfish/Gill Damage | 35678 |
| MRT02482 | Mowi Scotland Ltd | Rum | 11/10/2021 | Gill disease and microjellyfish | 34444 |
| MRT01741 | Grieg Seafood Shetland Ltd | Corlarach | 11/08/2020 | CMS/ Complex Gill Disease / Jellyfish | 34300 |
| MRT01794 | Grieg Seafood Shetland Ltd | Leinish | 01/09/2020 | Complex Gill Disease / Jellyfish | 33802 |
| MRT02417 | The Scottish Salmon Company | Portree | 27/09/2021 | Jellyfish/Plankton, Gill Health Related | 29321 |
| MRT03388 | Mowi Scotland Ltd | Hellisay | 14/10/2022 | Gill infections / Jellyfish | 29280 |
| MRT03322 | Mowi Scotland Ltd | Hellisay | 29/09/2022 | Gill infections / Jellyfish | 27616 |
| MRT03370 | Mowi Scotland Ltd | Hellisay | 07/10/2022 | Gill infections / Jellyfish | 27065 |
| MRT01864 | Grieg Seafood Shetland Ltd | Leinish | 24/09/2020 | Complex gill disease/jellyfish | 27055 |
| MRT01693 | Mowi Scotland Ltd | Stulaigh | 10/07/2020 | Harmfull Algae Bloom and Jellyfish during last weekend | 26556 |
| MRT02397 | The Scottish Salmon Company | Portree | 20/09/2021 | Jellyfish/Plankton, Gill Health Related | 25482 |
| MRT02619 | Mowi Scotland Ltd | Loch Alsh (Sron) | 19/11/2021 | Jellyfish bloom and HSMI | 23459 |

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|---|---|---|---|---|---|
| MRT02383 | The Scottish Salmon Company | West Strome | 13/09/2021 | Jellyfish/Plankton, Gill Health Related | 22440 |
| MRT03310 | Scottish Sea Farms Ltd | Nevis A | 29/09/2022 | Environment; Gill Health Related post jellyfish bloom | 19385 |
| MRT03554 | Cooke Aquaculture Scotland Ltd | Meil Bay | 21/11/2022 | Jellyfish/Gill Damage | 19302 |
| MRT02384 | The Scottish Salmon Company | Portree | 13/09/2021 | Jellyfish/Plankton, Gill Health Related | 18687 |
| MRT03315 | Mowi Scotland Ltd | Loch Harport | 29/09/2022 | Gill infections / Jellyfish | 18244 |
| MRT00561 | Cooke Aquaculture Scotland Ltd | Stead of Aithness | 22/12/2017 | Jelly fish bloom | 17774 |
| MRT02418 | The Scottish Salmon Company | Portree Outer | 27/09/2021 | Jellyfish/Plankton, Gill Health Related | 16817 |
| MRT03500 | Mowi Scotland Ltd | Loch Alsh (Sron) | 08/11/2022 | Gill infections / Jellyfish | 16711 |
| MRT01698 | Mowi Scotland Ltd | Stulaigh | 16/07/2020 | Effects of Harmful Algae Bloom and Jellyfish during previous weekend. | 16652 |
| MRT03426 | Cooke Aquaculture Scotland Ltd | Lyrawa Bay | 18/10/2022 | Jellyfish/Gill Damage | 16078 |
| MRT01753 | Grieg Seafood Shetland Ltd | Corlarach | 18/08/2020 | complex gill disease/jellyfish | 15250 |

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|---|---|---|---|---|---|
| MRT02322 | Mowi Scotland Ltd | Caolas A Deas | 30/08/2021 | Jellyfish and Freshwater Extended treatments. | 15051 |
| MRT02416 | The Scottish Salmon Company | West Strome | 27/09/2021 | Jellyfish/Plankton, Gill Health Related | 14485 |
| MRT02398 | The Scottish Salmon Company | Portree Outer | 20/09/2021 | Jellyfish/Plankton, Gill Health Related | 14443 |
| MRT02413 | The Scottish Salmon Company | Kyles Vuia | 27/09/2021 | Gill Health Related, Jellyfish/Plankton, Sea Lice Related | 14046 |
| MRT01712 | Mowi Scotland Ltd | Stulaigh | 24/07/2020 | Effects of Harmful Algae Bloom and Jellyfish. | 13712 |
| MRT02321 | Mowi Scotland Ltd | North Shore | 30/08/2021 | Salmosan and thermolicing treatments. Jellyfish bloom on site | 13620 |
| MRT03441 | Cooke Aquaculture Scotland Ltd | Lyrawa Bay | 24/10/2022 | Jellyfish/Gill Damage | 13084 |
| MRT00353 | The Scottish Salmon Company | Loch Tuath | 11/09/2017 | AGD, Algal bloom, Complex gill issues, Jellyfish | 12919 |
| MRT00562 | Cooke Aquaculture Scotland Ltd | Stead of Aithness | 22/12/2017 | Jelly fish bloom | 12910 |
| MRT01731 | Grieg Seafood Shetland Ltd | Corlarach | 04/08/2020 | CMS/ Jellyfish | 11975 |
| MRT03442 | Cooke Aquaculture Scotland Ltd | South Cava | 24/10/2022 | Jellyfish/Gill Damage | 11347 |
| MRT00775 | Loch Duart Ltd | Loch Laxford | 11/09/2018 | Gill issues, algae, AGD, low O2, jellyfish | 11293 |

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|---|---|---|---|---|---|
| MRT02385 | The Scottish Salmon Company | Portree Outer | 13/09/2021 | Jellyfish/Plankton, Gill Health Related | 11202 |
| MRT03273 | Scottish Sea Farms Ltd | Nevis B | 22/09/2022 | Environment; Gill Health Related post jellyfish bloom | 10611 |
| MRT03321 | Mowi Scotland Ltd | An Camus | 29/09/2022 | Gill infections / Jellyfish | 10448 |
| MRT02980 | Mowi Scotland Ltd | Loch Alsh (Sron) | 09/06/2022 | Jellyfish | 10086 |
| MRT02351 | Mowi Scotland Ltd | Hellisay | 03/09/2021 | Jellyfish Bloom | 9975 |
| MRT02978 | Mowi Scotland Ltd | Loch Alsh (Sron) | 03/06/2022 | Jellyfish | 9251 |
| MRT02352 | Mowi Scotland Ltd | Caolas A Deas | 03/09/2021 | Yersinia +S2339and Jellyfish Bloom | 9211 |
| MRT03427 | Cooke Aquaculture Scotland Ltd | South Cava | 18/10/2022 | Jellyfish/Gill Damage | 8676 |
| MRT03367 | Mowi Scotland Ltd | Stulaigh | 07/10/2022 | Gill infections / Jellyfish | 8553 |
| MRT03556 | Cooke Aquaculture Scotland Ltd | South Cava | 21/11/2022 | Jellyfish/Gill Damage | 7741 |
| MRT03523 | Mowi Scotland Ltd | Loch Alsh (Sron) | 14/11/2022 | Gill infections / Jellyfish | 7613 |
| MRT03484 | Cooke Aquaculture Scotland Ltd | South Cava | 07/11/2022 | Jellyfish/Gill Damage | 7030 |
| MRT03443 | Cooke Aquaculture Scotland Ltd | Chalmers Hope | 24/10/2022 | Jellyfish/Gill Damage | 6956 |
| MRT03440 | Cooke Aquaculture Scotland Ltd | Pegal Bay | 24/10/2022 | Jellyfish/Gill Damage | 6486 |
| MRT02379 | The Scottish Salmon Company | Kyles Vuia | 13/09/2021 | Gill Health Related, Jellyfish/Plankton | 6386 |
| MRT03369 | Mowi Scotland Ltd | An Camus | 07/10/2022 | Gill infections / Jellyfish | 6289 |

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|---|---|---|---|---|---|
| MRT01838 | Grieg Seafood Shetland Ltd | Corlarach | 15/09/2020 | Complex Gill Disease / Jellyfish | 6056 |
| MRT03368 | Mowi Scotland Ltd | Marulaig Bay | 07/10/2022 | Gill infections / Jellyfish | 5927 |
| MRT03364 | Mowi Scotland Ltd | Loch Harport | 07/10/2022 | Gill infections / Jellyfish | 5925 |
| MRT00563 | Cooke Aquaculture Scotland Ltd | Stead of Aithness | 22/12/2017 | Jelly fish bloom | 5750 |
| MRT03541 | Mowi Scotland Ltd | An Camus | 18/11/2022 | Gill infections / Jellyfish | 5748 |
| MRT02262 | Mowi Scotland Ltd | Loch Harport | 09/08/2021 | Micro jellyfish bloom | 5564 |
| MRT02265 | Mowi Scotland Ltd | Loch Harport | 09/08/2021 | Jellyfish Bloom (updated 17/8/21 AZM) | 5377 |
| MRT03314 | Mowi Scotland Ltd | Loch Alsh (Sron) | 29/09/2022 | Gill infections / Jellyfish | 5259 |
| MRT03363 | Mowi Scotland Ltd | Loch Alsh (Sron) | 07/10/2022 | Gill infections / Jellyfish | 5205 |
| MRT02394 | The Scottish Salmon Company | Kyles Vuia | 20/09/2021 | Gill Health Related, Jellyfish/Plankton | 5190 |
| MRT03946 | Scottish Sea Farms Ltd | North Papa | | Environment; Algae & Jellyfish; Virus disease | 5179 |
| MRT03335 | Cooke Aquaculture Scotland Ltd | Lyrawa Bay | 03/10/2022 | Jellyfish/Gill Damage | 5079 |
| MRT03351 | Cooke Aquaculture Scotland Ltd | Pegal Bay | 06/10/2022 | Jellyfish/Gill Damage | 4971 |
| MRT03278 | Scottish Sea Farms Ltd | Nevis A | 22/09/2022 | Environment; Gill Health Related post jellyfish bloom | 4649 |
| MRT03387 | Mowi Scotland Ltd | Marulaig Bay | 14/10/2022 | Gill infections / Jellyfish | 4524 |
| MRT01863 | Grieg Seafood Shetland Ltd | Corlarach | 24/09/2020 | Complex gill disease/jellyfish | 4382 |

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|---|---|---|---|---|---|
| MRT03540 | Mowi Scotland Ltd | Marulaig Bay | 18/11/2022 | Gill infections / Jellyfish | 4142 |
| MRT02289 | Mowi Scotland Ltd | Sconser Quarry | 16/08/2021 | Jellyfish Bloom | 3889 |
| MRT03352 | Cooke Aquaculture Scotland Ltd | Lyrawa Bay | 06/10/2022 | Jellyfish/Gill Damage | 3705 |
| MRT03385 | Mowi Scotland Ltd | Loch Alsh (Sron) | 14/10/2022 | Gill infections / Jellyfish | 3244 |
| MRT03334 | Cooke Aquaculture Scotland Ltd | Pegal Bay | 03/10/2022 | Jellyfish/Gill Damage | 3141 |
| MRT03318 | Mowi Scotland Ltd | Grey Horse Channel | 29/09/2022 | Gill infections / Jellyfish | 2677 |
| MRT03229 | Scottish Sea Farms Ltd | Tanera | 15/09/2022 | Gill Health Related post jellyfish bloom | 2635 |
| MRT03542 | Mowi Scotland Ltd | Hellisay | 18/11/2022 | Gill infections / Jellyfish | 2468 |
| MRT02288 | Mowi Scotland Ltd | Maol Ban | 16/08/2021 | Jellyfish Bloom | 2336 |
| MRT00881 | The Scottish Salmon Company | Plocrapol | 21/11/2018 | Post Jellyfish (pelagia notoluca) Damage during November 2014, reduced feeding and burnt marks so didn't handle bath treatments well | 2206 |
| MRT01772 | Grieg Seafood Shetland Ltd | Corlarach | 25/08/2020 | Complex gill disease and jellyfish | 2172 |
| MRT02316 | Mowi Scotland Ltd | Sconser Quarry | 30/08/2021 | Salmosan Treatment and Jellyfish Bloom | 1970 |
| MRT02301 | Mowi Scotland Ltd | Loch Harport | 20/08/2021 | CMS and Jellyfish Bloom | 1861 |

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|---|---|---|---|---|---|
| MRT02302 | Mowi Scotland Ltd | Maol Ban | 20/08/2021 | Jellyfish Bloom and Yersiniosis | 1742 |
| MRT02303 | Mowi Scotland Ltd | Sconser Quarry | 20/08/2021 | Jellyfish Bloom and Yersiniosis | 1665 |
| MRT03471 | Cooke Aquaculture Scotland Ltd | Lyrawa Bay | 01/11/2022 | Jellyfish/Gill Damage | 1630 |
| MRT03270 | Scottish Sea Farms Ltd | Tanera | 22/09/2022 | Environment; Gill Health Related post jellyfish bloom | 1630 |
| MRT02349 | Mowi Scotland Ltd | Sconser Quarry | 03/09/2021 | Jellyfish and Hydrolicer treatments | 1611 |
| MRT03948 | Scottish Sea Farms Ltd | Lismore West | | Gill Health; Algae & Jellyfish | 1608 |
| MRT00882 | The Scottish Salmon Company | Plocrapol | 21/11/2018 | Post Jellyfish damage to gills so didn't handle bath treatment well | 1434 |
| MRT00564 | Cooke Aquaculture Scotland Ltd | Stead of Aithness | 22/12/2017 | Jelly fish bloom | 1250 |
| MRT01821 | Grieg Seafood Shetland Ltd | Corlarach | 08/09/2020 | Complex Gill Disease / Jellyfish | 1179 |
| MRT00885 | The Scottish Salmon Company | Plocrapol | 21/11/2018 | Post Jellyfish damage to gills so didn't handle bath treatment well | 1075 |
| MRT02996 | Mowi Scotland Ltd | Loch Alsh (Sron) | 15/06/2022 | Jellyfish | 1028 |
| MRT00883 | The Scottish Salmon Company | Plocrapol | 21/11/2018 | Post Jellyfish damage to gills so didn't handle bath treatment well | 1025 |

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|---|---|---|---|---|---|
| MRT00884 | The Scottish Salmon Company | Plocrapol | 21/11/2018 | Post Jellyfish damage to gills so didn't handle bath treatment well | 1005 |
| MRT03302 | Scottish Sea Farms Ltd | Fada | 29/09/2022 | Environment; Gill Health Related post jellyfish bloom | 932 |
| MRT00886 | The Scottish Salmon Company | Plocrapol | 21/11/2018 | Post Jellyfish damage to gills so didn't handle bath treatment well | 890 |
| MRT03269 | Scottish Sea Farms Ltd | Fada | 22/09/2022 | Environment; Gill Health Related post jellyfish bloom | 592 |
| MRT03560 | Mowi Scotland Ltd | Loch Alsh (Sron) | 23/11/2022 | Gill infections / Jellyfish | 567 |
| MRT03303 | Scottish Sea Farms Ltd | Tanera | 29/09/2022 | Environment; Gill Health Related post jellyfish bloom | 538 |
| MRT00887 | The Scottish Salmon Company | Plocrapol | 21/11/2018 | Post Jellyfish damage to gills so didn't handle bath treatment well | 483 |
| MRT02963 | Mowi Scotland Ltd | Loch Alsh (Sron) | 26/05/2022 | Jellyfish | |

* 2 cases were undated and 1 case did not provide numbers of morts (only cases where jellyfish were cited under 'Explained Reasons' are included – see below for more details)

Download the Excel spreadsheet online here

The vast majority of the 'Mortality Event Reports' involving jellyfish and microjellyfish occurred in the Autumn with 43 incidents reported in September; 21 in October; 20 in November; 17 in August; 4 in December; 3 in July; 3 in June and 1 in May (no cases were reported between January and April).

'Mortality Event Reports' published by the Scottish Government's Fish Health Inspectorate which cite additional information on jellyfish include:

“Only 4 pens still on site and complex gill disease a result of Muggia sp. bloom in 2022” (Kerrera B, Scottish Sea Farms) – April 2023

“Gill issues are related to the previous jellyfish issues they've had on site. CMS on site. Site is currently harvesting out the affected fish” (South Cava, Cooke Aquaculture) – February 2023

“Gill damage as a result of a previous jellyfish insult. Two weeks worth of morts collected due to poor weather the previous week” (Chalmers Hope, Cooke Aquaculture) - December 2022

“Fish were subject to mico jelly Muggiea Atlantica exposure causing gill isues, morts are attributed to AGD, FHI to monitor” (North Papa, Scottish Sea Farms) – December 2022

“High levels of Muggiaea atlantica (jellyfish) have been identified during plankton counts” (Dunstaffnage, Scottish Sea Farms) – November 2022

“The site has been subject to a recent environmental gill insult, thought to have been brought on by a jellyfish bloom” (Shuna Point, Scottish Sea Farms) – October 2022

“Environmental insult from a bloom of jellyfish has compromised gill health onsite” (Strondoir Bay, Bakkafrost) – October 2022

“Waterbourne insult from premused microjellies 4 weeks ago. AGD escalated quickly since then with necrosis on gills. Trial pens treated with 6hr FW and settled mortality and amoeba reduced. Therefore all pens on site treated with FW. Weekly health visits have occurred since insult began. Low level PRV on site but not clinically expressed. Some physical wounds  from handling and low level Tenacibaculum diagnosed. Histology has not revealed any bacterial infection” (Lamlash Bay, Bakkafrost) – September 2022

“Mortality largely related to jellyfish damage to gills, freshwater treatment has been conducted and they are monitoring stock” (Ardcastle, Bakkafrost) – July 2022

“Aeration has been deployed to reduce the number of jellyfish entering the cages and to increase water exchange. Feeding was also suspended during the bloom and mortality appears to have decreased this week, although there is still a high number of jellyfish in the area” (Tanera, Scottish Sea Farms) – July 2022

“Complex gill disease confirmed and microjellies present” (Mowi, Loch Alsh/Sron) – December 2021

“On-going issues with gill health from jellyfish bloom in the summer and recently CMS on site” (Portree Outer, Bakkafrost) – December 2021

“Historic levels of AGD due to jellyfish bloom during the summer” (Portree, Bakkafrost) – December 2021

“Historic levels of AGD due to jellyfish bloom in the summer” (Portree Outer, Bakkafrost) – December 2021

“Prev issues on site with Yersinia ruckeri and jellyfish bloom” (Caolas a Deas, Mowi) – October 2021

“Gill issues have been exacerbated by jellyfish/plankton blooms. Some cages have been harvested to reduce biomass on site and fish are scheduled to undergo a FW treatment in the coming weeks to try and improve gill health on the site” (Portree, Bakkafrost) – September 2021

“Gill issues have been exacerbated by jellyfish/plankton blooms. Some cages have been harvested to reduce biomass on site and fish are scheduled to undergo a FW treatment in the coming weeks to try and improve gill health on the site” (Portree Outer, Bakkafrost) – September 2021

“High mortality levels due to jellyfish and plankton bloom resulting in gill issues” (West Strome, Bakkafrost) – September 2021

“Gill issue exacerbated by jellyfish/plankton blooms” (Portree, Bakkafrost) – September 2021

“Mortalities exacerbated by jellyfish/plankton blooms” (Portree Outer, Bakkafrost) – September 2021

“Health report sent through which highlights severe jellyfish bloom. Anaemia is cause for mortalities, and exacerbated by PGD” (Kyles Vuia, Bakkafrost) – September 2021

“Stress of treatment exacerbated by jellyfish bloom increased mortalities. Specifically, gill issues as a result of jellyfish” (Sconser Quarry, Mowi) – August 2021

“Mortalities exacerabted by jellyfish bloom and stress of treatments” (North Shore, Mowi) – August 2021

“Mortalities exacerbated by severe jellyfish bloom and stress of treatment” (Caolas a Deas, Mowi) – August 2021

“Continuing jellyfish bloom from Saturday to Monday. Aeration switched on during the day. Mortalities have started to reduce. Company vet visit in wk31 to check if there is any gill pathology” (Sconser Quarry, Mowi) – August 2021

“It was a week of increased mortalities, and with the health visit on 13/08/2021 determined that it was due to microjellies” (Bagh Dail Nan Cean, Mowi) – August 2021

“Mortality event has been attributed to the presence of phytoplankton and jellyfish in the water around the site, exacerbated by lice treatments. Net cleaning has been increased and oxygen is being used during treatments” (Kishorn B, Scottish Sea Farms) – July 2021

“Mortalities attributed to increased gill damage due to environmental insult/jellyfish. Blooms of small ctenophore jellyfish have been observed on site, coinciding with the increase in mortalities. Further testing is ongoing to determine if there are any other causes. Harvesting begun yesterday on the worst affected pens and will continue until mortality has reduced or the site becomes fallow” (North Voe, Grieg Seafood) – December 2020

“Gill health has been deteriorating with AGD and environmental/jellyfish issues resulting in complex gill disease” (North Voe, Grieg Seafood) – September 2020

“Spate of jellyfish and poor water quality. Bath treatments for gills combined with PGD resulting in mortality” (Vuia Mor, Bakkafrost) – September 2020

“Contacted the Fish Health Technician, a high density of lions main jellyfish resulting in toxic reaction on the gills and also internally. AGD has been confirmed in the stock but this was not considered to be contributing to the mortality, no treatments have been administered. FVG have been on site conducting sampling. The site will be fallowed as soon as possible but likely to be in three to four weeks time” (Corlarach, Grieg Seafood) – August 2020
“Ongoing sea lice treatments aplha max and peroxide treatment, histos come back with complex gill disease. Large swarm of jellyfish came through last week and increased mortality. Half of site been treated, treated cages have stabilised, treatments should be finished by Friday. Freshwater treatment planned” (Corlarach, Grieg Seafood) – August 2020

“Large swarm of jellyfish came through w/b 27/08/2020. Increasing mortality as well as post treatment losses from alphamax treatments. Whole site is to be treated with freshwater next week. Site manager expects some post treatment mortality from FW treatments, but overall improvement after completion of treatments” (Corlarach, Grieg Seafood) – August 2020

“Fish have been diagnosed with AGD, pox virus, branchiomonas and damage on gills from jellyfish and plankton also observed. Further treatments have not been performed due to poor gill condition - accelerated harvest, hope to be fallow by end of August” (Bay of Vady, Cooke Aquaculture) – August 2018

“Post Jellyfish damage to gills so didn’t handle bath treatment well” (Plocrapol, Bakkafrost) – June 2015

“Post Jellyfish (pelagia notoluca) Damage during November 2014, reduced feeding and burnt marks so didn’t handle bath treatments well” (Plocrapol, Bakkafrost) – February 2015

Download mortality information online here

**[3]** 'Case Information' published by the Scottish Government's Fish Health Inspectorate on 21 July 2023 detailed an inspection report from Bakkafrost's West Strome salmon farm in May 2023 (Case 20230205):

| | | | | | |
|---|---|---|---|---|---|
| Case No: | 2023-0205 | | | Date of visit: | 17/05/2023 |
| Time spent on site: | 2h | | | Main Inspector: | [redacted] |
| Site No: | FS1342 | Site Name: | West Strome | | |
| Business No: | FB0169 | Business Name: | Bakkafrost Scotland | | |
| Case Types: | 1 DIA | 2 REP | 3 | 4 | 5 6 |
| Water Temp (°C): | 9.8 | Thermometer No: | T173 | FHI 045 completed | |
| Observations: | | Region: HI | Water type: S | CoGP MA | M-20 |
| Dead/weak/abnormally behaving fish present? | | | Y | If yes, see additional information/clinical score sheet. | |
| Clinical signs of disease observed? | | | Y | If yes, see additional information/clinical score sheet. | |
| Gross pathology observed? | | | Y | If yes, see additional information/clinical score sheet. | |
| Diagnostic samples taken? | | | Y | | |

A novel species of jellyfish had been observed in the area suspected to be Sarsia tubulosa, it is unsure if this is part of the increased mortality

At the time of inspection, the site was stocked with 563,298 Atlantic salmon at an average weight of 1.44kg. Mortalities had been low until week 19 when levels had increased.

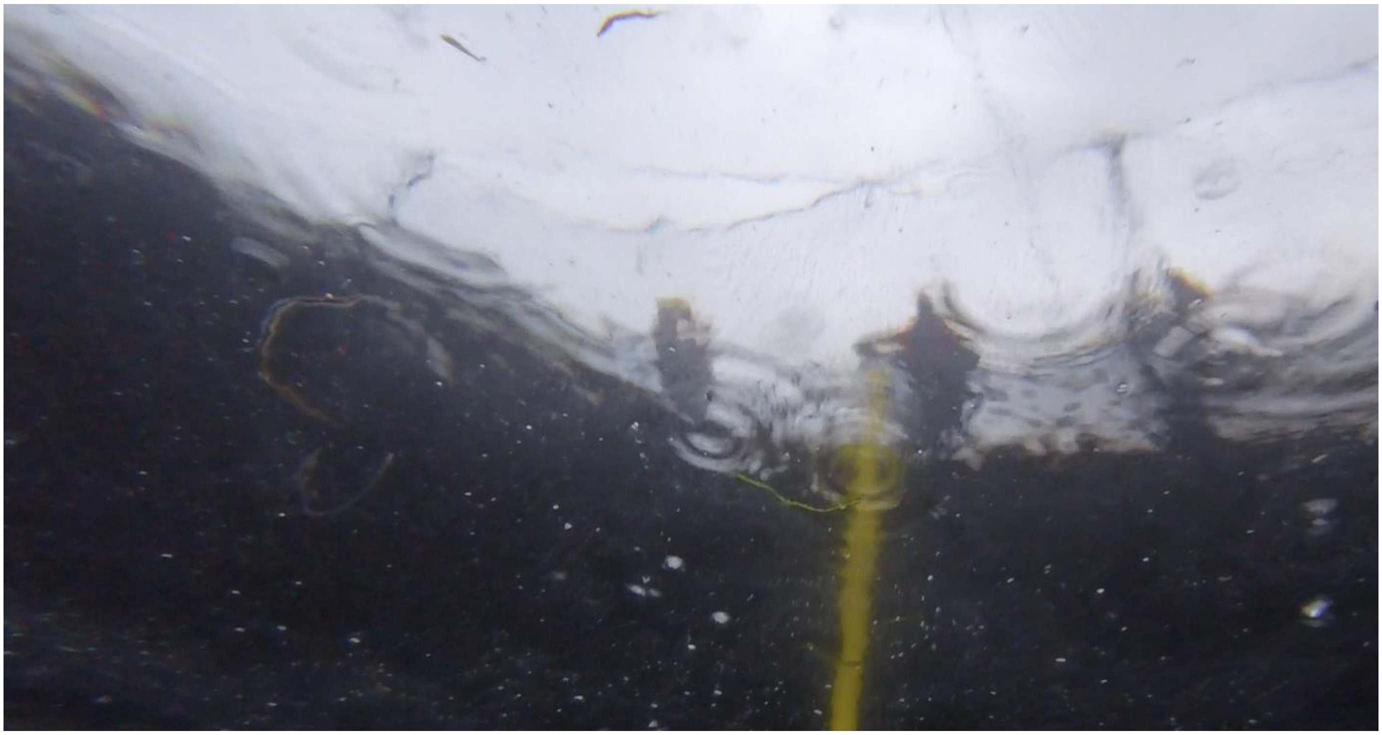
On inspection of pen four ~100 fish were observed swimming slowly below the surface, some were lethargic and moribund others were aimless and some spiralling was also noted. A number of fish had eye damage and some bi-lateral exophthalmia was also observed. Three were removed from the pen for diagnostic sampling.

F1-F3 were moribund and lethargic with a loss of equilibrium, F3 also displayed spiralling behaviour, the body of F2 was notable distended.

Gill: F3 displayed mild lamellar epithelial hyperplasia and haemorrhage. Occasional several basophilic epithelial inclusions (likely epitheliocystis) observed in all fish. Few aneurysmal dilation/telangiectasia and cell debris with bacteria among gill filaments (F2-F3).

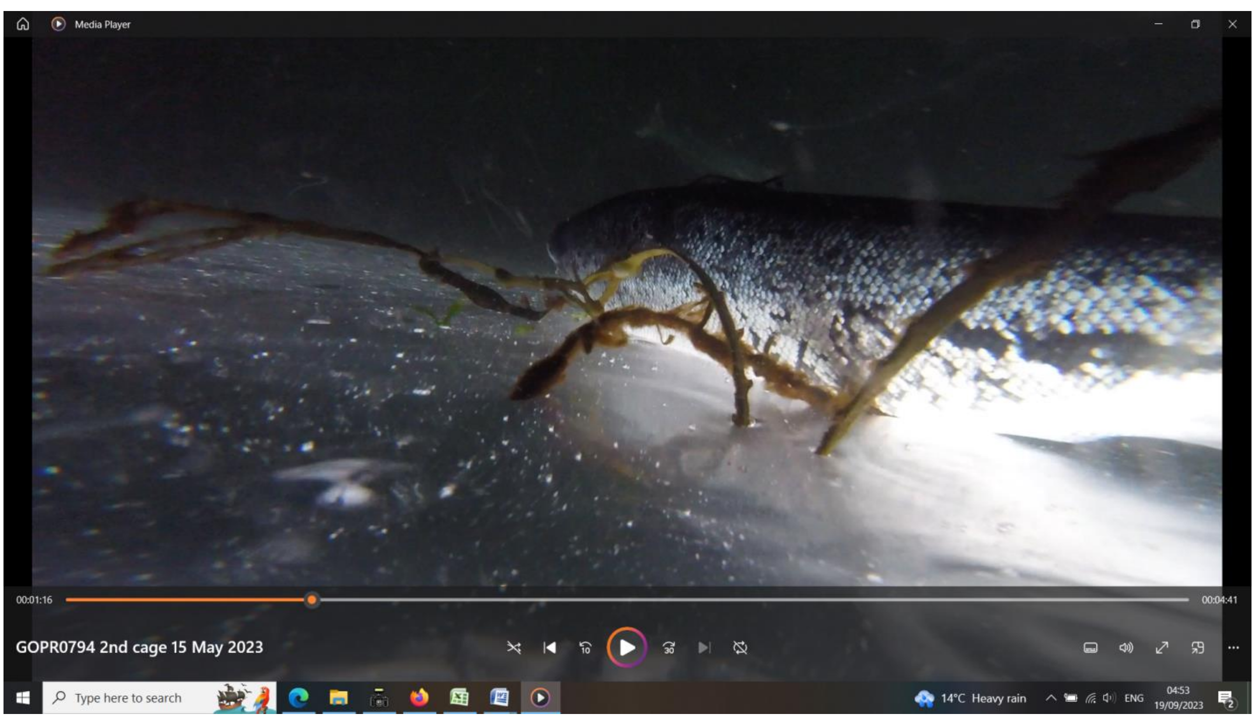
Video footage shot at Bakkafrost's West Strome salmon farm as the light got better on 15 May 2023 shows microjellies living inside the cages:

Filming at Bakkafrost's West Strome salmon farm in May 2023 found dead salmon floating on the surface of cages – with a toxic soup of phytoplankton and microjellies:

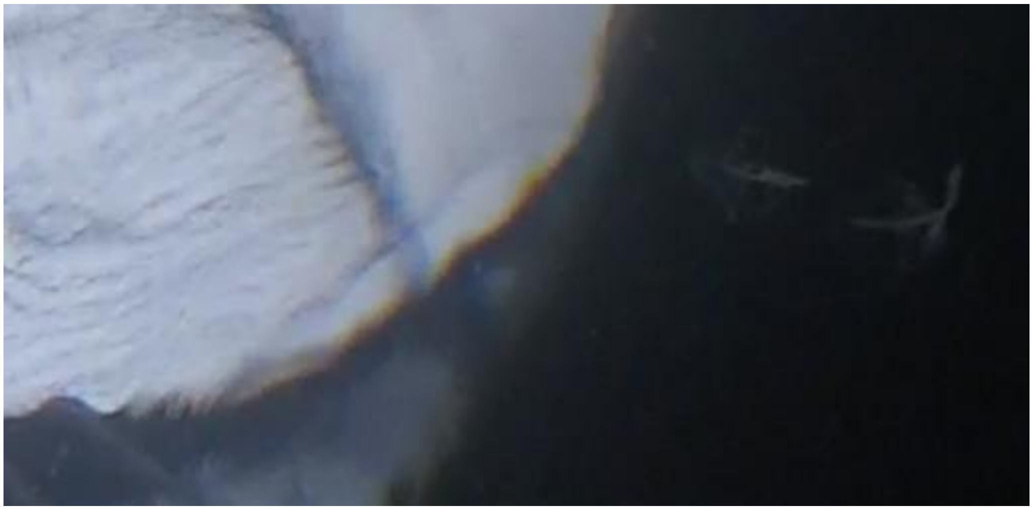


Above via GOPR0793 1st underwater filming 15 Ma...

Filming at Bakkafrost's West Strome salmon farm in May 2023 captured evidence of a microjelly and phytoplankton ecosystem in the surface layer of the water – with the carcasses of dead salmon floating nearby:

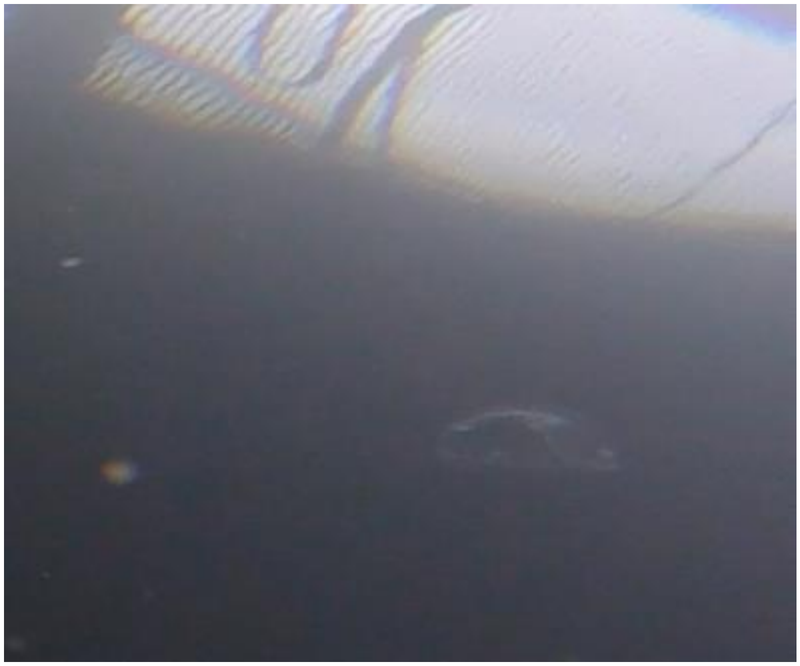


There is video evidence of microjellies in the surface layer:

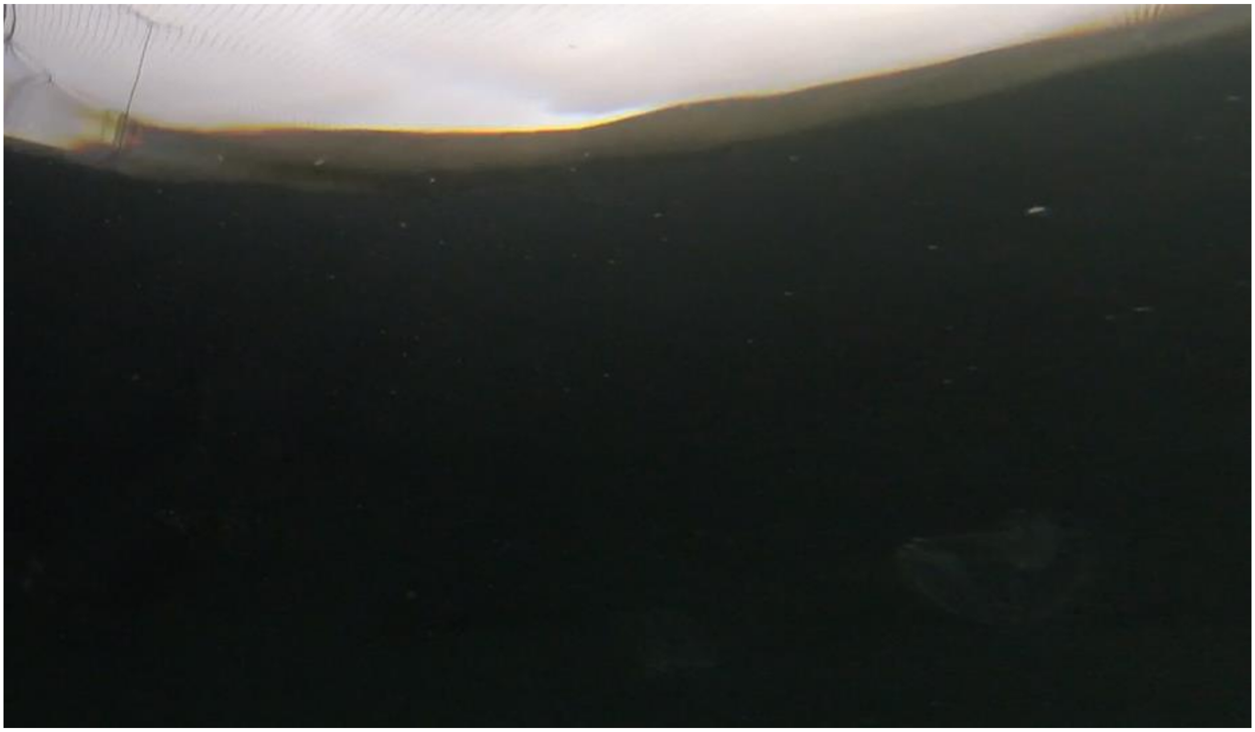


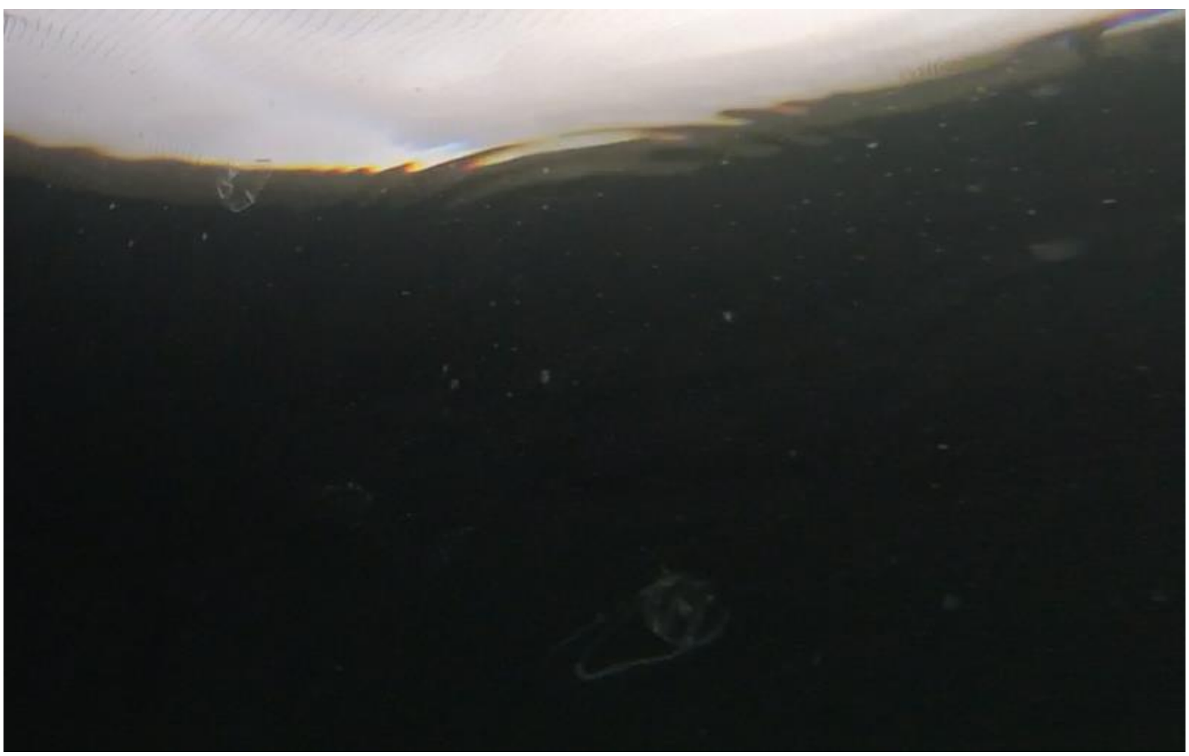
Above via: GOPR0802 3rd cage 15 May 2023 15/05/2023 06:23

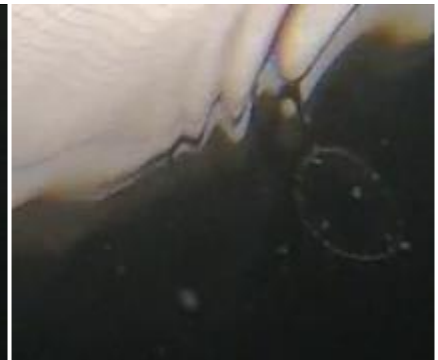
Despite the morning gloom and poor light, microjelly UFOs are clearly visible:



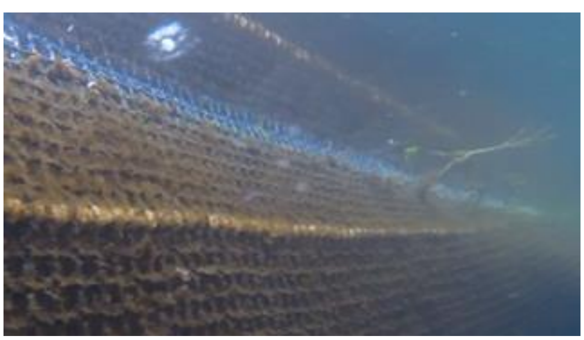
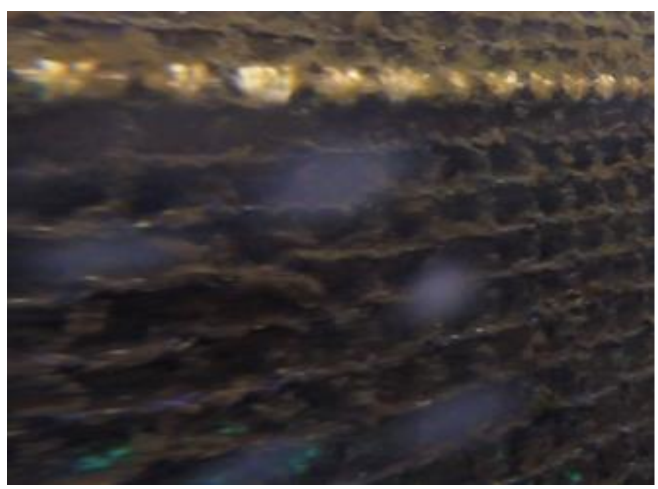
Above via: GOPR0805 Last cage 15 May 2023 15/05/2023 06:42

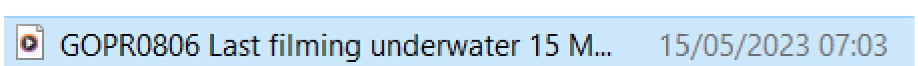





The nets appear to be home to microjellies too:

Above via: 

‘Case Information’ published by the Scottish Government’s Fish Inspectorate includes:

“A bloom of Muggiaea atlantica (micro jellyfish) compromised gill health in early October, along with seasonal AGD and most recently diagnosed with CMS…. White circular lesions were observed on the fish as well as some 'boils'/raised scales on a few fish both observed on site and during sampling….Gill condition in fish removed for sampling, showed ragged and pale gills, with some white lesions observed on the tips” (Easter Score Holmes, Scottish Sea Farms – January 2023: Case 2023-0009)

*Figure 8 Lesion on Fish 3*

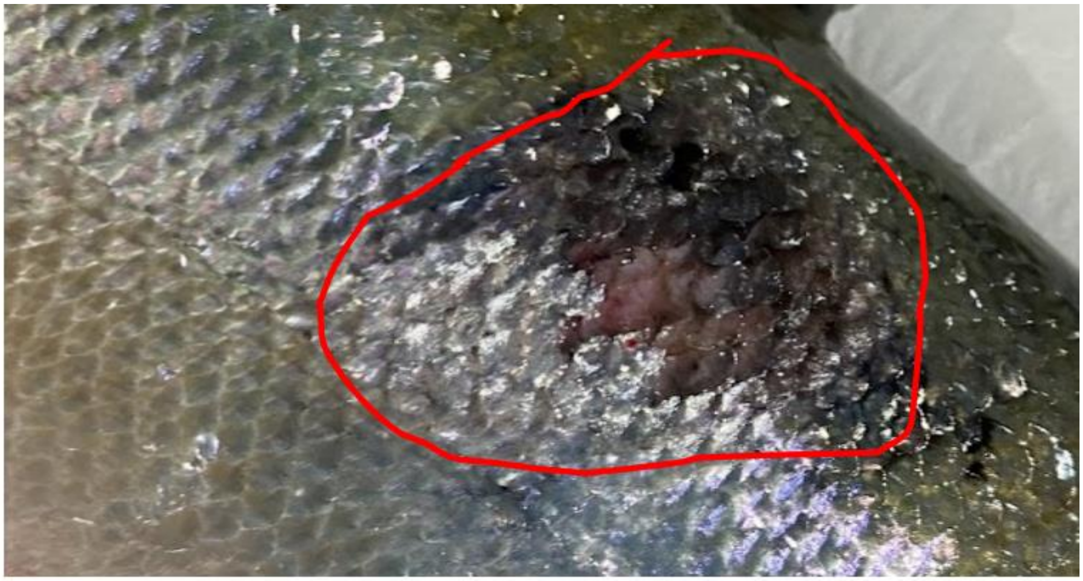
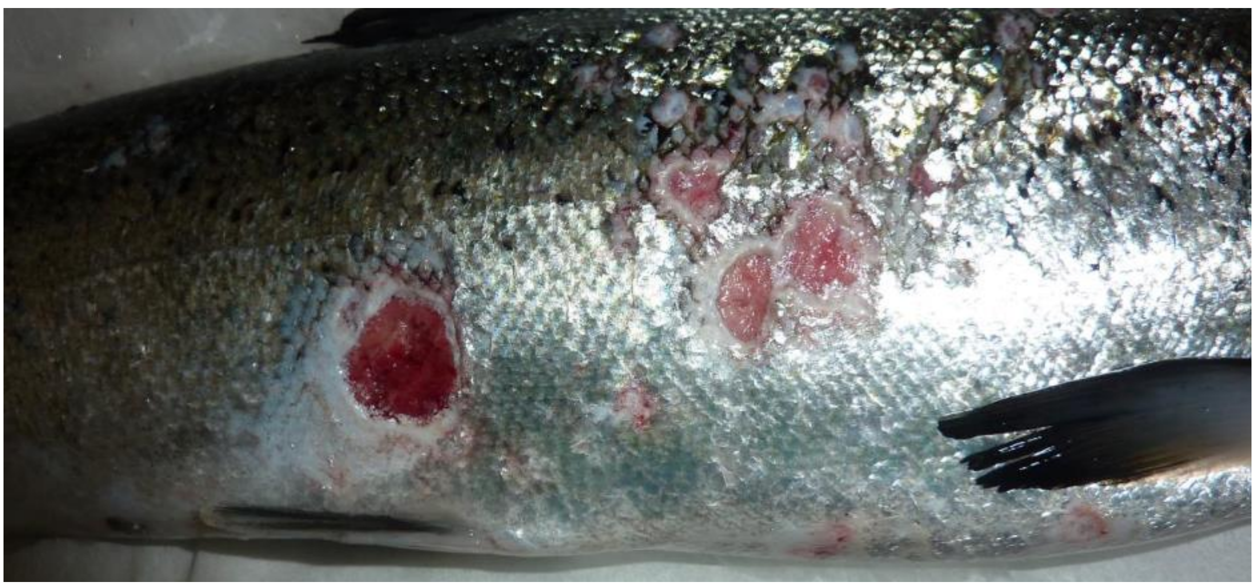


*Figure 11 Picture of 'boil-like lesion on Fish 4*

“Micro jellyfish bloom during September, confirmed as Muggiaea atlantica. No morts directly attributed but some damage to gills likely. AGD reported to be an issue with P4 being worst affected….Chronic AGD confirmed by gill swabs….” (Culnacnoc, Organic Sea Harvest – November 2022: Case 2022-0483)

“Poor gill health attributed to micro jellyfish - gill health improving…..From health reports; primary cause of gill health challenge during this period starting August, and continues to be present today albeit in much lower concentrations. The main species identified is Muggeia atlantica, a hydrozoan species…..Population of poor doers continues to cause increased mort levels…..Branchial disease suggestive of chronic gill damage possibly 2ndry environmental factor” (Ardifuir, Mowi – November 2022: Case 2022-0542)

“Mortality attributed to poor gill health - AGD confirmed and the site is reporting high counts for PGD. High levels of Muggiaea atlantica (jellyfish) have been identified during plankton counts….On inspection moribund fish observed in pen margins. Lesions observed on many fish, some single deep lesions and some fish with many lesions all over body surface. Lesions appeared in August prior to mort issues and bloom. Mortalities generally incinerated on site but with increased mortalities incinerator unable to manage. Morts are been taken whole and stored at the shore base in Loch Spelve as this site is currently not stocked, is the only site in the disease managements area and Dunstaffnage does not have a suitable shore base” (Dunstaffnage, Scottish Sea Farms – November 2022: Additional Case 2022-0541)



“Gill health, jellyfish insult although nothing observed over trigger levels….The gills from the fish removed for sampling were observed to be very pale with shortened and ragged filaments ….The site was inspected due to sustained mortality reports above the reporting criteria attributed to gill issues and a suspected jellyfish bloom” (Marulaig Bay, Mowi - October 2022: Case 2022-0481)

“AGD and anaemia, micro-jellies as precursor…..Haemorrhaging of gills in F3. F1 & F2 gills pale and clumped with some haemorrhaging. F3 internal adhesions...The gills were necrotic in fish 1 and 2….Gill lesions also displayed features that could potentially be associated with environmental factors/water insult" (Ardgadden, Bakkafrost – October 2022: Additional Case 2022-0485)

* Fish 1 – Pale clumped gills with necrosis

"The site has a touch of AGD and CGD following a bloom of micro jelly fish in early October. Mortality remains low despite the environmental insult. Water temperature is decreasing and the site is hopeful that this will aid gill recovery" (Setter Voe, Scottish Sea Farms – October 2022: Case 2022-0528)

"Health reports suggest fish exposed to water borne insult, potentially harmful plankton bloom or stinging jellyfish. Routine water sampling hasn't identified any harmful plankton or jellyfish…. Gill pathology - indicative of plankton bloom or jellyfish" (Tarbert South, Bakkafrost – October 2022: Additional case 2022-0500)

"Seasonal AGD, CDG bloom of Muggiaea Atlantica….There was a bloom of muggiaea atlantica (micro jellyfish) confirmed at the site in early October which has compromised gill health along with a touch of seasonal AGD. Staff have been monitoring the site daily for plankton levels and has confirmed that jellyfish counts in recent weeks have decreased. With the water temperature on site decreasing the site is hopeful to see an improvement in gill health in the coming weeks ….Moderate to severe, acute to chronic gill damage reported by Vet" (Easter Score Holmes, Scottish Sea Farms – October 2022: Additional case 2022-0529)

"Gill issues - AGD and anaemia, micro jellies as a precursor….Mortality rise since late July/early August - average of 2-3% for site per week. No other peaks. Lost 19% - 77,500 fish since last visit. Majority of mortality occurring since August….SAV PCR positive by blood serum; IPN, PD / SAV, CGD, HSMI, Moritella viscosa through histology ; PRV, IPN, AGD, SAV, Tenacibaculum maritimum - PCR" (Gob a Bharra, Bakkafrost – October 2022: Additional Case 20220488)

"Micro jelly bloom occurred in the week of input, which agitated gills primarily. Then the arrival of Lion's mane jellyfish exacerbated gill issues on site further. Mild AGD observed in gills of fish…..Sampled fish were moribund and lethargic. In addition, signs of loss of equilibrium…. Osmoregulatory issues and poor water quality due to micro jellies and lion's mane jellyfish" (East Tarbert Bay, Bakkafrost – August 2022: Case 2022-0342)


*Figure 3 Closer view of external observations on fish 4 and 5. Fish 4 exhibits lesions on the belly/flank on fish 4. Extra bacteriology and histology samples taken from lesion.*

"Fish appeared in good physical health but were observed jumping a lot due to an increased presence of jellyfish on site over the last few days. Many were observed in the water during the inspection" (Kerrera B, Scottish Sea Farms – June 2022: Case 2022-0200)

"Some sort of environmental damage possibly jellyfish or plankton bloom at some point. Gills damaged PGD in September/October, then issues with AGD which were thought to be improving until situation started to deteriorate again in December with complex gill disease causing large level of mortality (all reported). Water temperature still fairly high for the time of year around 9C" (Ardintoul, Mowi – January 2022: Case 2022-0001)

"Chaetoceros convolutes identified and can be very dangerous for gill health. Biologist also suspects a micro jellyfish event although nothing has been observed by site staff. TSSC currently trying to role out [sic] a jellyfish surveying programme to all site in Scotland in an attempt to understand what micro jellyfish are in which areas and adjust stocking plans accordingly" (Gometra, Bakkafrost – November 2021: Case 2021-0492)

| | | |
|---|---|---|
| 2. Any increased mortalities? (since last inspection.) | | Y |
| If yes, detail: | Gill scores increased mostly due to PGD. AGD detected by swab but no clinical signs. Site is exposed, so rarely any plankton, this cycle seems to be different. Daily trawls done for plankton. Chaetoceros convolutus identified and can be very dangerous for gill health. Biologist also suspects a micro jellyfish event although nothing has been observed by site staff. TSSC currently trying to role out a jellyfish surveying programme to all site in Scotland in an attempt to understand what micro jellyfish are in which areas and adjust stocking plans accordingly. | |

"Increased mortalities at site due to jellyfish, plankton and associated gill health issues….Gill issue exacerbated by jellyfish/plankton blooms….Some cages have been harvested to reduce biomass on site and fish are scheduled to undergo a FW treatment in the coming weeks to try and improve gill health on the site…..Reporting; Zooplankton, sea gooseberries, moon, crystal and lions mane jellyfish, cyanea sp and phialedla and other hydrozoa. Blooms have been observed onsite for many weeks starting in August and only clearing now….Recent increase morts have required Fergusons uplift….Increased mortalities had been attributed to gill health, jellyfish/plankton blooms, AGD and CMS…..All fish sampled were moribund and lethargic. All gills were slightly pale, and also mildly necrotic in fish 3 and 4. A lesion was present on the flank of fish 1 and there were abrasions on the belly of fish 4" (Portree, Bakkafrost – October 2021: Case 2021-0383)

"Increased mortalities had been attributed to gill health, jellyfish/plankton blooms, AGD, a period of low dissolved oxygen and treatment losses…..All fish sampled were moribund. All gills were slightly to moderately pale in colour. The body of F4 was moderately anorexic and the opercula of F1 were shortened. F3 displayed exophthalmic eyes and F5 had a moderate cataract. Lice numbers ranged between 9-20 per individual" (North Shore, Mowi – October 2021: Case 2021-0411)

"Gill disease and micro jellyfish bloom…..CGD was on-going on site, background AGD, gill checks were seeing anaemic fish, fish bleeding out during lice counts. Heavy stocked pens were seeing high mortality - Dips in oxygen at night time and late afternoon. High biomass pens took largest hit at first. Large amounts of jellyfish observed in water at time of mortality event. Mortality attributed to poor gill health and enviromental insult. P. pileus and Aglantha sp identified from water sampling. Uplifts moved onto site to remove excess mortality - extra boats and bins brought in to deal with mortality. After test treatment was conducted, it was decided to remove all fish from site, crowds sustaining high mortality….Being transported by Aquascotia to Shetland" (Rum, Mowi – October 2021: Case 2021-0415)

marinescotland science

Scottish Government Riaghaltas na h-Alba gov.scot

# FISH HEALTH INSPECTORATE VISIT REPORT

**SUMMARY FOR INFORMATION OF SITE OPERATOR**

| | | | |
|---|---|---|---|
| **Business No** | FB0119 | **Date of Visit** | 14/10/2021 |
| **Site No** | FS1317 | **Site Name** | Rum |
| **Case No** | 20210415 | **Inspector** | [redacted] |

**Passive Surveillance Inspection**

A notification of mortality levels above the reporting criteria was received by the Fish Health Inspectorate for the period of 13/09/2021 to 17/10/2021.

A passive surveillance inspection was conducted by telephone to gather information in accordance with the Aquatic Animal Health (Scotland) Regulations 2009. Information was also gathered in accordance with the Aquaculture and Fisheries (Scotland) Act 2007, as amended, with respect to section 3 regarding parasites (sea lice).

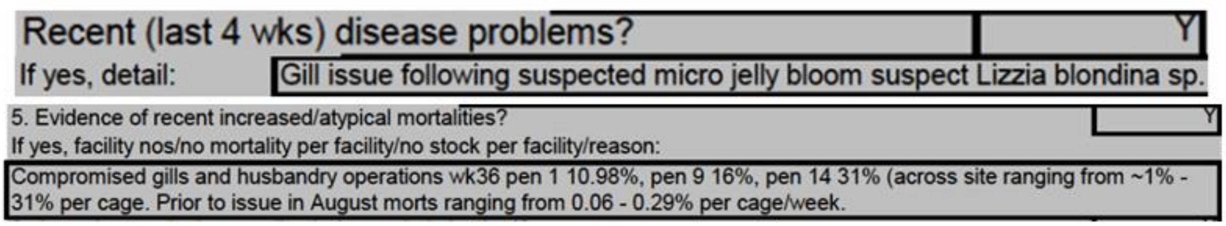
The site had suffered significant mortality attributed to gill health and jellyfish plankton blooms. The presence of jellyfish species *P. pileus and Aglantha* sp were identified through water sampling during the event. The company attempted the treat the fish for gill health issues, but due to significant post treatment mortality the decision was made by the company to remove the affected fish from the site by harvesting. All affected fish have now been harvested out from the site.

"PGD and AGD - Significant environmental damage from Jellyfish…..Operator fed through jellyfish bloom, July/August. Caused significant damage to gills. Potential for whole site to be harvested. Boat brought in to help with mortality disposal, being taken to Shetland. Fresh water treatments concluded 14th of September. Fish took treatments fairly well considering poor gill health….Likelihood that whole site will be harvested out will be quite high…Site has been affected by environmental gill insult which has caused a prolonged period of increased mortality" (Muck, Mowi – October 2021: Case 2021-0431)

"Additional peaks in mortality: 2021, Wk. 29 1904 (0.75%), Wk. 30 1866 (0.74%), Wk. 31 1277 (0.51%) Wk. 32 1769 (0.71%) attributed to jellyfish/environmental….Some jellyfish observed in a couple of pens" (Kirk Noust, Cooke Aquaculture – October 2021: Additional case 2021-0365)

"Moribund fish were near the surface and particularly in pen corners. A number of fish were also observed gasping on the surface or working their opercula. Pens were being aerated. Lions Mane jelly fish observed on site and some fish were seen to have signs of interaction with jellyfish tentacles. Upon inspection of the gills of the fish removed, evidence of mild gill damage was observed, attributed to PGD by site staff. Site began H2O2 treatment on the day of inspection based on veterinary advice" (Wester Ross Fisheries, Ardessie B – September 2021: Additional case 2021-0331)

"Received veterinary advice in early September to conduct a treatment to combat sea lice accepting the potential mortality in fish which had been affected by the suspected micro jelly bloom which occurred in mid-August. Moribund fish present in all cages with cages 10 and 11 currently the worst affected. These cages are to be harvested out in week 38. Rest of cages will receive a Hydrolicer treatment. Pens are also receiving aeration….Clinical signs of disease included morbidity and lethargy present in all 5 fish sampled. All five fish also had haemorrhaging on the ventrum and pale gills. There was also zonation of the gills of fish 2, 4 and 5" (West Strome, Bakkafrost – September 2021: Additional case 20210258)



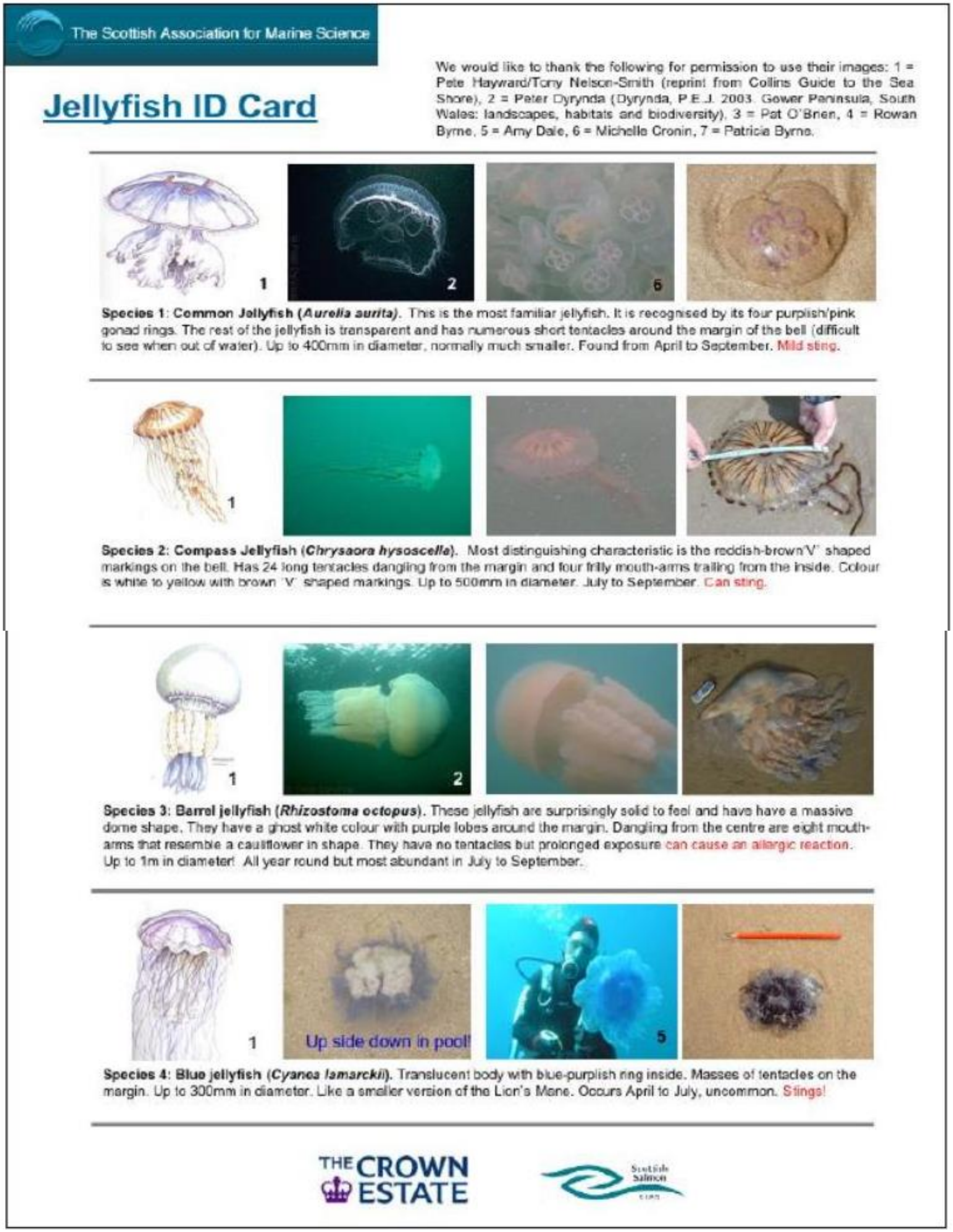
| | |
|---|---|
| Recent (last 4 wks) disease problems? | Y |
| If yes, detail: | Gill issue following suspected micro jelly bloom suspect Lizzia blondina sp. |
| 5. Evidence of recent increased/atypical mortalities? | Y |

If yes, facility nos/no mortality per facility/no stock per facility/reason:

Compromised gills and husbandry operations wk36 pen 1 10.98%, pen 9 16%, pen 14 31% (across site ranging from ~1% - 31% per cage. Prior to issue in August morts ranging from 0.06 - 0.29% per cage/week.


Data in more detail online via FHI Jellyfish Data 2021 to 2023

**[4]** Here's a better copy of the 'Jellyfish ID Card' – published by the Scottish Association of Marine Science, Crown Estate and Scottish Salmon Producers Association in 2010:


The Scottish Association for Marine Science

Jellyfish ID Card

We would like to thank the following for permission to use their images: 1 = Pete Hayward/Tony Nelson-Smith (reprint from Collins Guide to the Sea Shore), 2 = Peter Dyrynda (Dyrynda, P.E.J. 2003. Gower Peninsula, South Wales: landscapes, habitats and biodiversity), 3 = Pat O'Brien, 4 = Rowan Byrne, 5 = Amy Dale, 6 = Michelle Cronin, 7 = Patricia Byrne.

**Species 1: Common Jellyfish (*Aurelia aurita*).** This is the most familiar jellyfish. It is recognised by its four purplish/pink gonad rings. The rest of the jellyfish is transparent and has numerous short tentacles around the margin of the bell (difficult to see when out of water). Up to 400mm in diameter, normally much smaller. Found from April to September. Mild sting.

**Species 2: Compass Jellyfish (*Chrysaora hysoscella*).** Most distinguishing characteristic is the reddish-brown 'V' shaped markings on the bell. Has 24 long tentacles dangling from the margin and four frilly mouth-arms trailing from the inside. Colour is white to yellow with brown 'V' shaped markings. Up to 500mm in diameter. July to September. Can sting.

**Species 3: Barrel jellyfish (*Rhizostoma octopus*).** These jellyfish are surprisingly solid to feel and have have a massive dome shape. They have a ghost white colour with purple lobes around the margin. Dangling from the centre are eight mouth-arms that resemble a cauliflower in shape. They have no tentacles but prolonged exposure can cause an allergic reaction. Up to 1m in diameter! All year round but most abundant in July to September.

Up side down in pool!

**Species 4: Blue jellyfish (*Cyanea lamarckii*).** Translucent body with blue-purplish ring inside. Masses of tentacles on the margin. Up to 300mm in diameter. Like a smaller version of the Lion's Mane. Occurs April to July, uncommon. Stings!

THE CROWN ESTATE

Scottish Salmon




**Species 5: Lion's Mane Jellyfish (*Cyanea capillata*):** Can reach a bell diameter of 2 meters, normally much smaller. Bell margin divided into 8 lobes and 8 clusters of up to 150 tentacles each. Tentacles are longer than the oral arms. Colour varies from deep red to yellow individuals. Warning! These jellyfish sting severely.

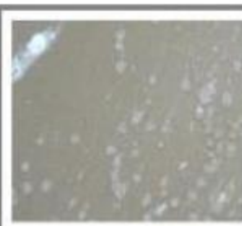



**Species 6: *Pelagia* jellyfish (*Pelagia noctiluca*):** Bell has warts or bumps on it. Very small jellyfish, about the size of a closed fist, up to 10cm in diameter. Has only eight tentacles. Occurs autumn/winter. Similar to the common jellyfish, however they occur at different times of the year. Warning: Can sting




**Species 7: By-the-wind-sailor (*Velella velella*).** Not a true jellyfish, but a close relative. Bluish oval disk reaching 8cm in length. Equipped with a 'sail' that projects above the surface of the water to catch the wind and aid their dispersal. Around the margin of the float is a ring of tentacle-like fishing appendages. Can occur all year round. Mild sting


**Species 8: Portuguese Man O'War (*Physalia physalis*).** Again not a true jellyfish but related. Large & conspicuous float up to 30cm long & 10cm wide. Float is silver-blue with red/pink tinging.rest of colony is blue purple. WARNING! Inflicts severe stings.




**Species 9: Sea gooseberry (*Pleurobrachia pileus*).** Not a jellyfish at all but a Ctenophore. Shaped like a gooseberry and is transparent. Up to 20 mm long. If you look close you can see 8 ciliary plates or comb rows. No sting.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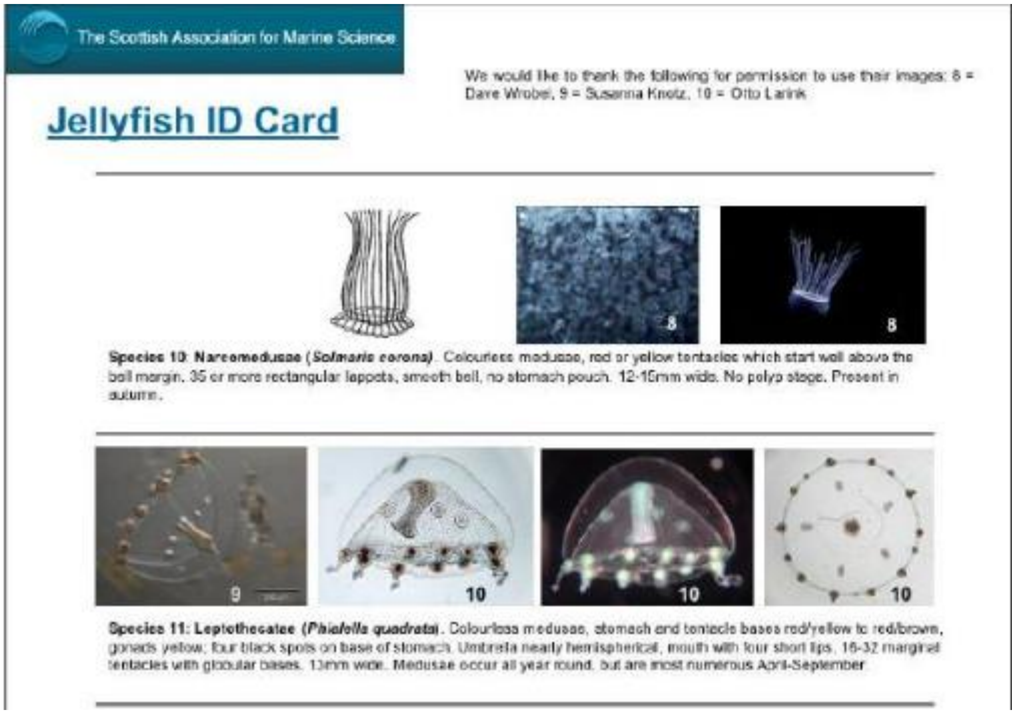


The 'Jellyfish ID Card' was sent out to salmon farmers in Scotland along with a questionnaire:

## 2 Work Package 1: Industry survey

### 2.1 WP1 Methods

To attempt to identify the extent of jellyfish incidents in the Scottish aquaculture industry, a questionnaire was compiled with the aid of the Scottish Salmon Producers' Organisation (SSPO). The questionnaire is reproduced below:

SAMS Jellyfish Survey

SCOTTISH ASSOCIATION for MARINE SCIENCE

Objectives:

- To produce a map of areas affected by jellyfish blooms
- To identify the time of year of worst impact
- To identify areas at greatest risk of jellyfish blooms

Questions

1. What is the name and location of your farm?
2. Has your site been affected by jellyfish?

| Density (estimate number per $m^3$) | Month/Year | Species from the ID sheet |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

3. Did the incident(s) cause mortalities or some lesser effect?
4. If there were mortalities, how many?
5. Were there any days lost feeding or a starvation period following the incident?
6. What density of jellyfish do you think would pose a problem to your farm?
7. Are there specific weather conditions that would prove the most problematic to you? eg. wind from a certain direction?
8. Would a forecast of a likely jellyfish bloom be of use to you?
9. How many days warning period would be of most use in the event of a bloom?
10. Would you be willing to pay for an early warning service?

Please return this questionnaire to:

Dr Thom Nickell
Ecology Department,
Scottish Association for Marine Science (SAMS),
Scottish Marine Institute, Oban, Argyll PA37 1QA
Scotland, UK
T: (+44) (0)1631 559261 (direct)
F: (+44) (0)1631 559001
E: tdn@sams.ac.uk

Furthermore, to ensure the widest possible dissemination to the producers the questionnaire was distributed *via* the SSPO, who were asked to send it to all of their farm managers for completion. Along with the questionnaire, a jellyfish identification chart was distributed (see overleaf):

However, only 9 out of 257 salmon farms returned the questionnaire with six jellyfish species were identified as being involved in incidents (Cyanea capillata, Aurelia aurita, Phialella quadrata, Solmaris corona, Apolemia uvaria and Pelagia noctiluca) and the gelatinous ctenophore (Pleurobrachia pileus) with three species (Apolemia uvaria, Pelagia noctiluca and Solmaris corona) responsible for mortalities:

### 2.2 WP1 Results

The most recent data available from 2008 show 257 active Atlantic salmon farm sites in Scotland (Figure 2.1) (Marine Scotland Science, 2008). The SSPO's membership (16 companies)[2] accounts for roughly 95% of the total salmon production in Scotland (J. Smith, SSPO, pers. comm). The questionnaires were disseminated *via* the SSPO but only nine farms made returns. Of these, 66% reported serious jellyfish incidents (defined as causing loss of feeding as a minimum). A total of six jellyfish species were identified as being involved in these incidents (*Cyanea capillata*, *Aurelia aurita*, *Phialella quadrata*, *Solmaris corona*, *Apolemia uvaria* and *Pelagia noctiluca*) and the gelatinous ctenophore (*Pleurobrachia pileus*); of these, three species (*Apolemia uvaria*, *Pelagia noctiluca* and *Solmaris corona*) were responsible for mortalities. Three farm sites had experienced mortalities and one estimated losses of 65%.

The 2010 Crown Estate report and proposed jellyfish monitoring program failed to develop or secure further funding (although it seems that salmon farming companies set up their own monitoring):

From: **Don Staniford** <salmonfarmingkills@gmail.com>
Date: Fri, Jul 21, 2023 at 12:33 PM
Subject: Jellyfish data?
To: <clive.fox@sams.ac.uk>

Dr Fox,

I was reading: https://www.fishfarmingexpert.com/biological-hazards-on-the-rise/1180559

And your 2010 report – 'Developing the capacity to monitor the spatial and temporal distributions of jellyfish in western Scottish waters' - published by the Crown Estate.

Do you know anyone in Scotland currently researching jellyfish and salmon farms?

I am looking for a map/database of salmon farms affected by jellyfish.

Best fishes,

Don

From: **Clive Fox** <Clive.Fox@sams.ac.uk>
Date: Mon, Jul 24, 2023 at 9:38 AM
Subject: RE: Jellyfish data?
To: Don Staniford <salmonfarmingkills@gmail.com>

Dear Don

I'm not aware of anyone currently monitoring jellyfish although some of the salmon farms might be doing some local monitoring.

Unfortunately our funding ran out after the initial money from the Crown Estate and we were not able to continue with a more comprehensive monitoring program.

Dr Clive Fox FHEA

Senior Lecturer Fisheries Ecology (SAMS)
Head of Postgraduate Researcher Development (UHI)

Scottish Association for Marine Science
Dunbeg, Oban PA37 1QA
email: clive.fox@sams.ac.uk
tel: +44 (0)1631 559423

SAMS Scottish Association for Marine Science
UHI
uhi.ac.uk

From: **Don Staniford** salmonfarmingkills@gmail.com
Date: Mon, Sep 18, 2023 at 1:18 PM
Subject: Re: Jellyfish data?
To: Clive Fox Clive.Fox@sams.ac.uk

OK - thanks.

Is there anyone in Scotland doing jellyfish research (following up your 2010 Crown Estate work)?

I can share lots of video footage of jellyfish inside and outside salmon farms in Scotland during 2023 if you're interested.

From: **Clive Fox** Clive.Fox@sams.ac.uk
Date: Mon, Sep 18, 2023 at 2:07 PM
Subject: RE: Jellyfish data?
To: Don Staniford salmonfarmingkills@gmail.com

As far as I know there is nothing systematic going on for monitoring jellyfish in Scotland although some of the farms I think are doing their own monitoring.

From: **Don Staniford** salmonfarmingkills@gmail.com
Date: Mon, Sep 18, 2023 at 2:30 PM
Subject: Re: Jellyfish data?
To: Clive Fox Clive.Fox@sams.ac.uk

Surely the Scottish Government should be co-ordinating monitoring of jellyfish - and microjellies - at salmon farms given the increasing mortality problems?

Do you know which companies are doing their own monitoring?

From: **Clive Fox** Clive.Fox@sams.ac.uk
Date: Mon, Sep 18, 2023 at 3:37 PM
Subject: RE: Jellyfish data?
To: Don Staniford salmonfarmingkills@gmail.com

Hi Don

You'd have to ask individual companies for that information.

One of our recommendations from the Crown Estate work (in the report) was that it would be useful to establish routine monitoring and reporting of jellyfish so that larger patterns could be investigated, but this was never implemented in a co-ordinated manner.

As far as I know there is no statutory duty to report jellyfish counts.

**[5]** The latest annual report – Norwegian Fish Health Report 2022 – published by the Norwegian Veterinary Institute in 2023 cites jellyfish in relation to four 'welfare-related incidents' in 2022 (download report as a PDF online here):

Table 4.7.3. The distribution of welfare-related incidents reported to the Norwegian Food Safety Authority based on incident type. Data from the Norwegian Food Safety Authority as registered in their electronic reporting system (MATS), applicable to ongrowing/broodstock fish.

| Number reported welfare related incidents ongorwing/broodstock fish | 2018 | 2019* | 2020* | 2021* | 2022 |
|---|---|---|---|---|---|
| Non-medicinal delousing with handling | 629 (61%) | 906 (61%) | 873 (54%) | 774 (48%) | 752 (42%) |
| Undetermined mortality | 196 (19%) | 251 (17%) | 282 (17%) | 270 (17%) | 332 (19%) |
| Other | 112 (11%) | 178 (12%) | 312 (19%) | 384 (24%) | 445 (25%) |
| Handling | 40 (4%) | 60 (4%) | 78 (5%) | 71 (4%) | 93 (5%) |
| Medicinal delousing with handling | 40 (4%) | 55 (4%) | 19 (1%) | 38 (2%) | 86 (5%) |
| Grading/pumping | 7 (1%) | 18 (1%) | 16 (1%) | 15 (1%) | 14 (1%) |
| Natural forces | 0 | 9 (1%) | 25 (2%) | 23 (1%) | 31 (2%) |
| Medicinal delousing without handling | 9 (1%) | 9 (1%) | 6 (0%) | 10 (1%) | 7 (0%) |
| Non-medicinal delousing without handling | 3 (0%) | 3 (0%) | 9 (1%) | 31 (2%) | 17 (1%) |
| Jellyfish | | | 3 (0%) | | 4 (0%) |
| Reduced susceptibility/resistence | 1 (0%) | 0 | 0 | 1 (0%) | 0 |
| Total | 1037 | 1489 | 1623 | 1617 | 1781 |

* Minor changes from the Fish Health Report 2021 are due to delayed reporting/updated figures.

The report includes:

> Health issues caused by algae and jellyfish is still a challenge at individual plants, but there are no
>
> major regional problems with toxic algae blooms as in 2019. For 2022, however, jellyfish are ranked higher as a health problem in the survey than previously, and this year's chapter contains a more detailed description of damages that can occur when salmon are exposed to jellyfish.

*Gill disease*

Gill disease may affect farmed salmon and rainbow trout throughout the whole life cycle from yolk sac larvae to brood fish and represents a significant welfare challenge. Gill injuries may result from poor production routines, poor water quality, algae, jellyfish or disease causing agents such as viruses, bacteria, fungus or parasites. When the barrier of the gill is damaged, susceptibility to infection increases.

In the spring and summer months there is generally a considerable bloom of algae and jellyfish in the sea and several species may irritate or damage the gills, see Chapter 9.7 Algae, jellyfish and fish health. Fouling organisms growing on the nets within a sea farm may have a similar effect when released during net cleaning operations. Hydroids are a type of stinging organism closely related to jellyfish and often dominate the population of fouling organisms on fish farm cages (Figure 9.1.1). When nets are cleaned in the water, the hydroids are crushed, the stinging cells become spread in the water and may result in irritation and gill injury. Secondary bacterial infections caused by environmental bacteria such as *Tenacibaculum* spp. commonly follow such events. Bacteria that cause systemic infection and necrosis e.g. *Pasteurella*, can also result in gill damage.

# 9.7 Algae, jellyfish and fish health

*By Alf Seljenes Dalum, Stefanie Wüstner, Martin Huun-Røed, Even Thoen (Patogen), Trine Dale (NIVA) and Geir Bornø*

## Algae and jellyfish

There are many thousands of species of algae. Of these, around 300 are known to cause algal blooms, while only 80 or so have the ability to produce potent toxins, and even fewer are recognised as injurious for fish. Of the jellyfish capable of damaging fish, four groups are particularly dominating i.e. the Sycphozoa, Hydrozoa, Siphonophora and the Ctenophora. The injuries inflicted by jellyfish on farmed fish may be indirect (e.g. blocking of nets leading to low oxygen levels) or direct (e.g. blockage of mouth and operculae, or the toxic effect of stinging nematocysts (not Ctenophora which lack nematocysts)). The effect of toxic algae, eaten by jellyfish, which in turn have been eaten by fish, has also been discussed as a possible mechanism.

## *The Health Situation in 2022*

### The annual survey

Based on responses from fish health personnel and Food Safety Authority inspectors to the annual questionnaire, algae do not appear to have been a serious cause for concern in 2022. However, losses of 20 percent over the course of a few days were reported from individual farms, illustrating that the consequences can be serious in some cases.

Eight of 52 respondents considered jellyfish to represent one of the most important increasing problems in 2022. Algae and jellyfish were also considered challenging in relation to welfare and reduced growth. Fish health personnel also consider current surveillance for algae, jellyfish and other zooplankton inadequate.

### *The jellyfish situation*

Throughout the autumn and winter of 2022, fish health personnel have reported significant numbers of jellyfish during routine farm visits, particularly the increased prevalence of the string jellyfish Apolemia uvaria, a member of the Siphonophora. The geographical extent of the area affected has not been systematically mapped, but reports have been received from large areas of the coastline. Previous investigations have identified string jellyfish as far north as Finnmark.

Read more via:

IntraFish Latest News Salmon Whitefish Shrimp Aquaculture Fisheries Markets IntraFish.no

**Jellyfish that caused mass farmed salmon deaths making a troubling return to Norway**

**[6]** A PISCES presentation – ‘Detrimental impacts of jellyfish on finfish aquaculture: insights from the North East Atlantic’ – published in 2012 included:

## Jellyfish that cause ‘mass mortality events’


- There are four species that have caused major salmon fish kills in the past
  - The mauve stinger (*Pelagia noctiluca*)
  - *Muggiaea atlantica* (siphonophore)
  - *Apolemia uvaria* (siphonophore)
  - *Solmaris corona*



## Other mass mortality events…


- >100,000 farmed salmon in Norway caused by the siphonophore *Muggiaea atlantica* (Fosså et al. 2003)
- This species was also a suspected causative agent of over 1,000,000 salmon killed off northwest Ireland in 2003 (Cronin et al. 2004)
- The siphonophore *Apolemia uvaria*, the oceanic hydromedusa *Solmaris corona* and the neritic hydromedusa *Phialella quadrata* have also been previously implicated in fish kill events (Bruno & Ellis 1985, Båmstedt et al. 1998)

## Characteristics of jellyfish that cause mass mortality events

- Most are oceanic or shelf species (i.e. they need to be carried into an aquaculture site)
- Some of them can multiple very rapidly (3-4 weeks)
- Can occur in very high densities e.g. 100s – 1000s individuals $m^{-3}$
- Can occur in enormous aggregations 10s – 100s $km^{-2}$ spatial extent


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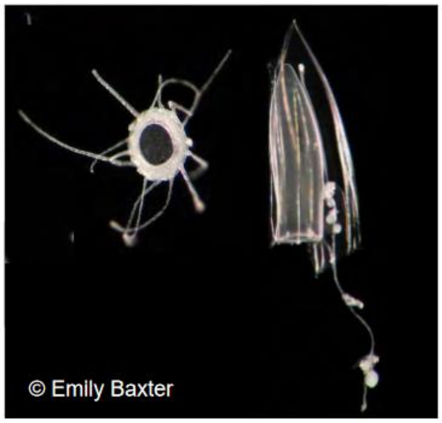
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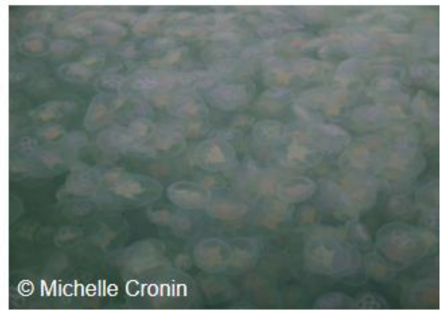
## Gill disorders in salmon aquaculture

- Gill disorders may be multi-factorial with 1□ damage caused by jellyfish and then 2□ infection by bacteria or parasite
- Between 2003 and 2006 Irish farms suffered an average of 12% mortality due to gill disorders (Rodger & Mitchell 2005)


© Hamish Rodgers

## What species cause gill disorders?

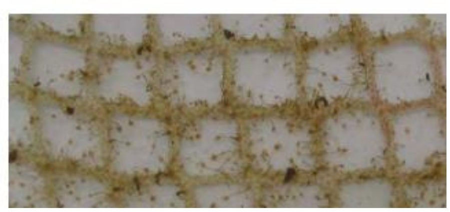
- All jellies that cause mass mortality events (e.g. *Pelagia, Muggiaea, Solmaris*)
- Many small jellyfish species (e.g. *Phialella quadrata*) may cause background mortalities but also many large scyphomedusae e.g.
    - The common jellyfish (*Aurelia aurita*)
    - The Lion's Mane (*Cyanea capillata)*

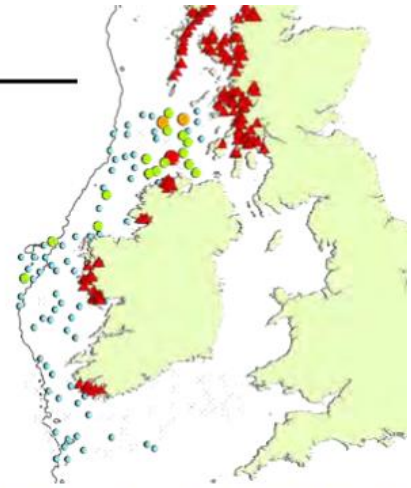

Baxter et al (2011) Plos One; Baxter et al (2011) Aquacult Environ Interact

## Characteristics of jellyfish that cause gill disorders

- No unifying characteristics but some generalisations can be made:
    - Occur in lower densities
    - Many are local species (home grown)
    - Hydrographic factors or behaviour may led to local aggregations

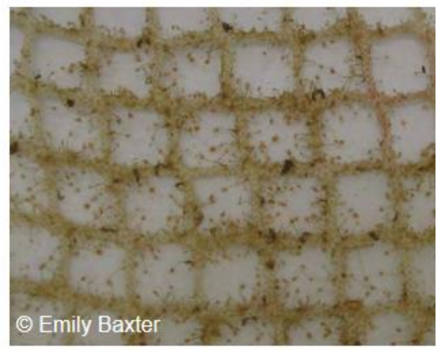



## So what are the real threats?



- Mass mortality event at a single farm:
  - *The Mauve stinger (Pelagia)*
  - *Muggiaea*

- Gill disorders at a national level:
  - At a single farm losses of 5-10% may seem acceptable, but when widespread such losses add up

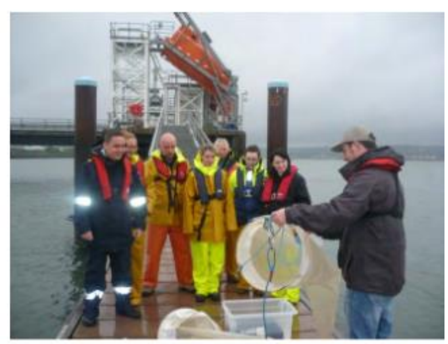



Bastian et al (2011) ICES J of Mar Sci and Baxter et al (2012) Fish Veterinary Journal

## Development of an early warning system

- It would help if we knew when a jellyfish bloom is going to occur

- However, this is only part of the solution e.g. what do farmers do if they know a large bloom of *Pelagia* is heading their way?



A scientific paper – '[Jellyfish Impacts on Marine Aquaculture and Fisheries]' - published in 2021 included:

**Table 1.** Reported jellyfish species interfering with fishery and aquaculture sectors worldwide.

| Fishery sector | Aquaculture sector |
|---|---|
| **SCYPHOZOA** | |
| *Aurelia* spp. | *Aurelia* spp. |
| *Pelagia noctiluca* | *Pelagia noctiluca* |
| *Cyanea* sp. | *Cyanea capillata* |
| *Chrysaora* spp. | *Chrysaora plocamia* |
| *Rhopilema nomadica* | *Phacellophora camtschatica* |
| *Rhizostoma pulmo* | |
| *Phyllorhiza punctata* | |
| *Cotylorhiza tuberculata* | |
| *Nemopilema nomurai* | |
| *Phacellophora camtschatica* | |
| *Periphylla periphylla* | |
| *Lychnorhiza lucerna* | |
| *Crambionella orsini* | |
| *Sanderia malayensis* | |
| **HYDROZOA** | |
| *Velella velella* | *Aequorea coerulescens* |
| *Aequorea* sp. | *Phialella quadrata* |
| *Olindias sambaquiensis* | *Porpita porpita* |
| | *Solmaris corona* |
| | *Ectopleura larynx* |
| | *Ectopleura crocea* |
| | Hydrozoans (unidentified) |
| | **Siphonophores:** |
| | *Muggiaea atlantica* |
| | *Apolemia uvaria* |
| **CUBOZOA** | |
| *Chiropsoides quadrigatus* | |
| **CTENOPHORA** | |
| *Mnemiopsis leidyi* | |
| *Beroe cucumis* | |

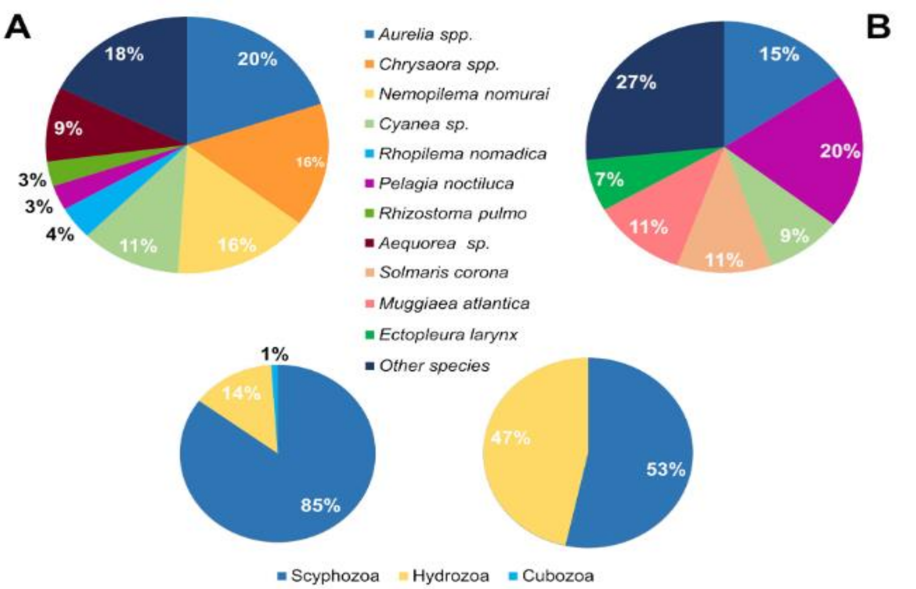



**Figure 2.** Percentage of reports where every jellyfish species and cnidarian class have been involved: (A) for fishery; (B) for aquaculture sector.

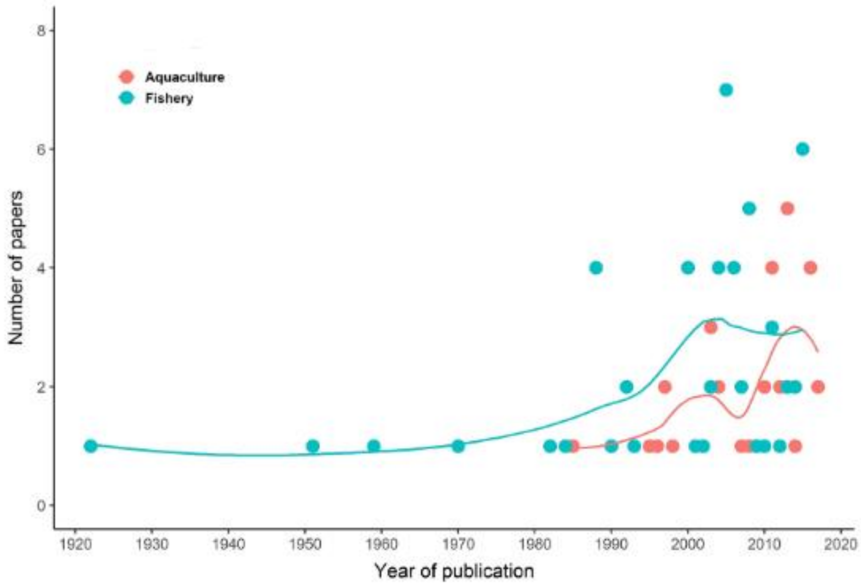
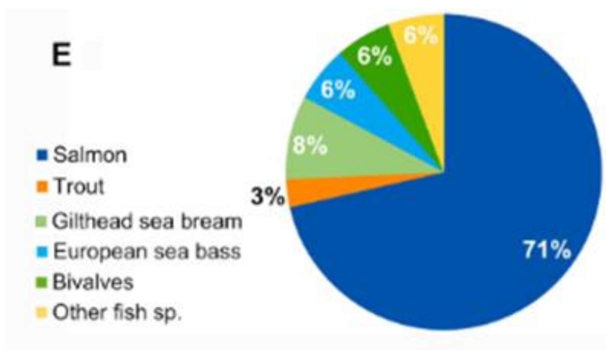



**Figure 1.** Temporal trend of published papers including reports on jellyfish interference with fishery (blue) and aquaculture (red) sectors.



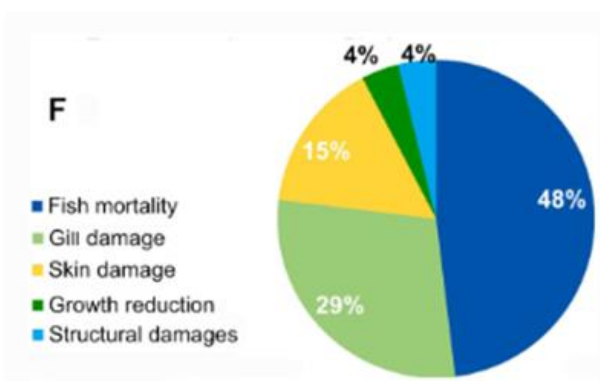




**Figure 3.** Percentage of reports related to: interactions between jellyfish and fishing activities by area :
most affected farmed species or group by jellyfish blooms occurrence
on worldwide marine aquaculture facilities (E); jellyfish direct impacts on farmed species health and facility structures (F).

### *Jellyfish and aquaculture interactions*

Out of 35 papers, a total of 45 events were found related to jellyfish interfering with aquaculture activities in the scientific literature: the majority of cases involved 5 jellyfish taxa (Figure 2B): three scyphomedusae (*Pelagia noctiluca*, *Aurelia* sp., *Cyanea capillata)*, one hydromedusa (*Solmaris corona*), and one siphonophore (*Muggiaea atlantica*). Whereas jellyfish interfering with fishery are mostly scyphozoans, nearly 50% of gelatinous zooplankton affecting fish farming activities are represented by hydrozoan taxa (Figure 2B). Their polyp colonies are indeed a dominant component of the biological fouling of cages and other submerged structures (e.g., floating pontoons, piers, anchors, buoys, ropes) and can impact farmed fish in different ways (Baxter et al. 2012; Fitridge et al. 2012): the reduction of water flow through net occlusions; the seasonal budding of free-living propagules, such as medusae, medusoids, or larvae of progenetic hydroids (e.g., *Tubularia* spp.), all well equipped with stinging cells; or by direct contact of fish with the large polyp colonies growing on the inner border of the cages.

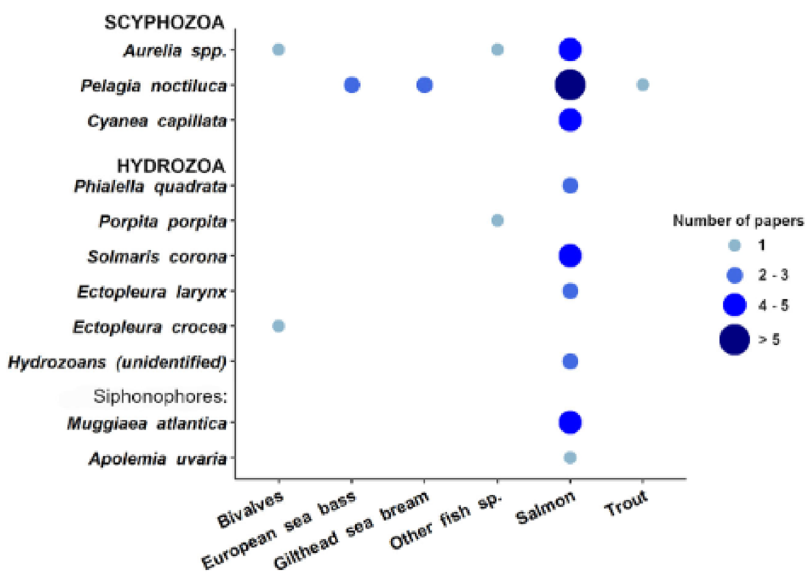



**Figure 8.** Number of reports related to impact of different jellyfish taxa (including polyp stages) on different farmed organisms.

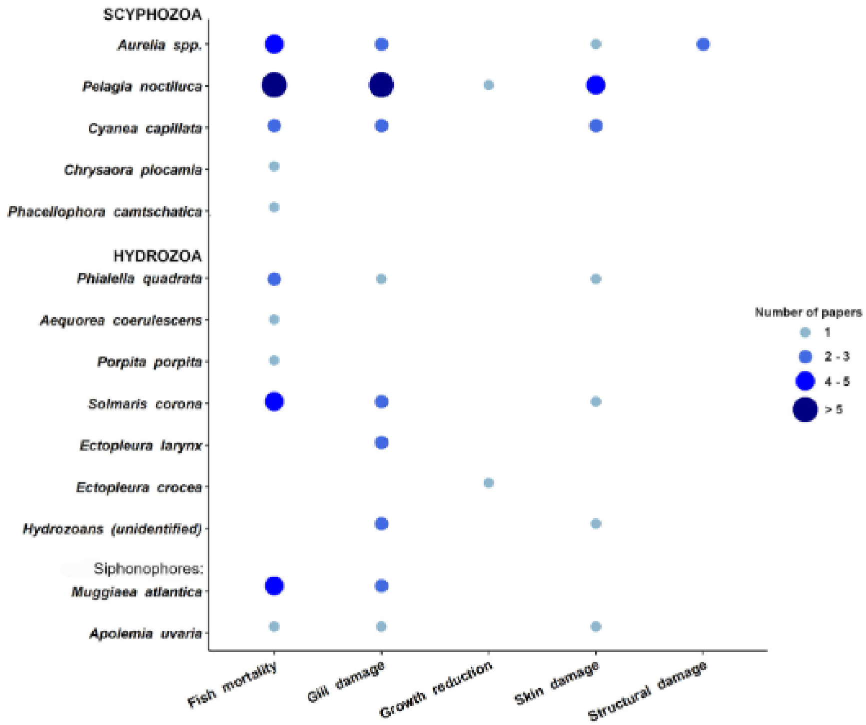



**Figure 9.** Number of reports relative to different jellyfish species and type of impacts caused on farmed organisms health and facility structural integrity.

## *Direct impacts of jellyfish blooms on marine aquaculture*

A significant difference was detected in the type of damages caused to farming activities ($X^2 = 36.65$, *p*-value $= 2.12^{-07}$). The most common negative impacts of jellyfish on fish farming concerned fish mortality (74% of reports), macroscopic damage on gill epithelia (44%), and skin ulcerations (24%) (Figure 3F).

Complex gill disorders have become one of the most serious causes of mortality in marine farmed salmon in Ireland, with average losses of 12% per year (Baxter, Rodger et al. 2011; Marcos-López et al. 2016; Herrero et al. 2018). Jellyfish nematocyst discharge and venom injection usually lead to local inflammatory response, cell toxicity and histopathology (Helmholz et al. 2010; Rodger et al. 2011; Marcos-López et al. 2016). Prolonged nematocyst discharges in fish tissues may often cause secondary bacterial infections and associated systemic reactions, including respiratory and osmoregulatory distress, altered behavior, and death (Bruno and Ellis 1985; Seaton 1989; Baxter, Sturt et al. 2011; Rodger et al. 2011). In addition, some jellyfish species can act as vectors of *Tenacibaculum maritimum*, the causative agent of tenacibaculosis (Småge et al. 2018), or as potential reservoirs of *Neoparamoeba perurans* (Downes et al. 2018), the causal agent for amoebic gill disease. Both major pathogens affect fish farming worldwide and may heavily exacerbate the impacts of jellyfish injuries (Ferguson et al. 2010; Delannoy et al. 2011; Floerl et al. 2016; Clinton et al. 2020).

Some records reported also on fish reduced growth rate (Baxter, Albinyana et al. 2011; Fitridge and Keough 2013; Bosch-Belmar et al. 2016) (Figure 9). Interference of functioning or damage of facility infrastructures was also reported: Mitchell et al. (2013) described the blockage of boat pumping system in a salmon farm in northwest Ireland clogged by hundreds of adults and juvenile ephyrae of *Aurelia* sp.; Bosch-Belmar, Azzurro et al. (2017) reported on two different finfish mariculture farms along the Spanish Mediterranean coast whose nets had to be replaced after *P. noctiluca* swarms were smashed by currents against the fish cages. Similar episodes have been repeated in these farms during 2016 and 2018 (Bosch-Belmar pers. comm).

The number of reports related to jellyfish interactions with marine aquaculture increased in the last years, and several events were detected across web-based blogs and digital media, gray literature, also reported as "personal communications" from aquaculture facilities staff (Table 2). This new information integrates and updates the table of reports provided by Purcell et al. (2013).

**Table 2.** Records of jellyfish blooms interference with aquaculture farming activities found in the web media (not previously reported in scientific literature).

| ID | Year | Date | Location | Country | Jellyfish sp. | Farmed fish sp. | Damages to aquaculture | Economic losses | Source |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1998 | November | Stewart Island | New Zeland | *Aurelia* spp. | salmon | > 65,000 individuals killed | NA | (Zaid 2018) |
| 2 | 2002 | March | Quemchi area | Chile | NA | salmon | 120,000 – 45,000 salmon killed | NA | (IntraFish 2012) |
| 3 | 2010 | November | Stewart Island | New Zeland | *Aurelia* spp. *Cyanea capillata* | salmon | > 2000 salmons killed | NA | (Zaid 2018) |
| 4 | 2013 | October | Clare Island | Ireland | *Pelagia noctiluca* | salmon | 20,000 individuals killed | NA | (Siggins 2013) |
| 5 | 2013 | November | Glenarm Bay in Co Antrim | Ireland | *Pelagia noctiluca* | salmon | 100,000 salmons killed | > US$ 1.3 million | (Practical 2014) |
| 6 | 2014 | November | Red Bay | Ireland | *Pelagia noctiluca* | salmon | 1,500 smolt salmon lost | NA | (Practical 2014) |
| 7 | 2014 | NA | North Uist (Western Islands) | Scotland | *Pelagia noctiluca* | salmon | 300,000 salmons killed | US$ 1.9 million | (BBC 2014) |
| 8 | 2017 | September | Galway, Mayo and Cork regions | Ireland | *Pelagia noctiluca* *Muggiaea atlantica* | salmon | >200,000 salmons killed = 80% production lost in 4 facilities | NA | (O'Sullivan 2017) |
| 9 | 2018 | November | Tasmania's Huon River and D'Entrecasteaux Channel | Tasmania | *Aurelia* spp. | salmon | Thousands of salmons killed | US$ 7.1 million | (Ford 2019) |

A chapter – 'Jellyfish as products and problems of aquaculture' – published in Advances in Aquaculture Hatchery Technology in 2013 included:

# Jellyfish as products and problems of aquaculture

J.E. Purcell, ... V.L. Fuentes, in
Advances in Aquaculture Hatchery Technology, 2013

## Hydromedusae

Hydromedusae are a diverse group (> 800 species worldwide), most of which are < 1 cm in size and transparent, thereby going mostly unnoticed by humans. Because of their small sizes, they can pass through the nets and some directly into the opercula of the fish. Many of the species produce medusae asexually from the hydroid stage, which lives attached to hard surfaces, including aquaculture structures. Other species lack an attached, benthic stage (holoplanktonic) (e.g., *Solmaris corona);* still other species (e.g., *Ectopleura larynx* syn. *Tubularia larynx)* produce swimming larvae, but not medusae (Fig. 13.6).

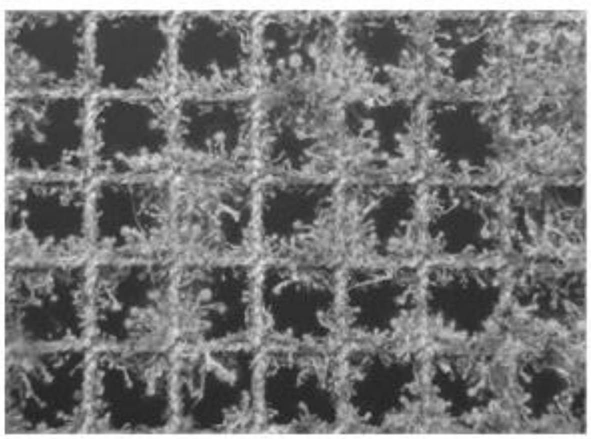


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Fig. 13.6. *Ectopleura larynx* hydroids fouling aquaculture netting.

(courtesy of Jana Guenther)

A bloom of holoplanktonic *S. corona* (~0.5–20mm) medusae was implicated as the causative agent in the mortality of ~900000 salmon at Scottish aquaculture sites in August/September 1997 (Båmstedt *et al.*, 1998) and again in 2002 when there were around 650000 mortalities in two days (Rodger *et al.*, 2011a). This species has also been recently linked to more chronic mortalities and severe gill damage at a salmon farm in Ireland (Baxter *et al.*, 2011a).

The neritic medusae of *Phialella quadrata* have been implicated in fish kill events and as a vector of bacterial gill disease. In the 1980s 1500 salmon died at farms on the Shetland Isles, Scotland. Histopathological examination revealed severe epithelial stripping and necrosis of the lamellae amongst other damage and some of the fish were reported to have up to 40 *P. quadrata* in their stomach contents (Bruno and Ellis, 1985). Recent research has identified *P. quadrata* as a potential vector for the bacterial pathogen *Tenacibaculum maritimum*. These filamentous bacteria were found on both the manubrium of *P. quadrata* and on the gills of salmon from a Scottish salmon farm (Ferguson *et al.*, 2010). This bacterium is common to farmed fish and has also been found on parasitic sea lice (Barker *et al.*, 2009); however, importantly it may have the potential to exacerbate jellyfish-induced gill damage (Rodger, 2007) as it has been shown to be a secondary opportunistic pathogen (Handlinger *et al.*, 1997).

A scientific paper – ‘Epidemiology of marine gill diseases in Atlantic salmon (Salmo salar) aquaculture: a review’ - published in 2020 included:

## Zooplankton (cnidarian nematocyst)-associated gill disease

Gelatinous zooplankton (referred to hereafter as jellyfish) occur in oceans worldwide and can be associated with high mortality rates in open-pen salmonid aquaculture. Examples include a study in Ireland in which 70% of mortality of all fish was due to occasional bloom events (Ruane *et al.* 2013; Marcos-Lopez *et al.* 2016), and a study in Scotland which found that around 60% of all fish mortalities due to plankton between 1999 and 2005 were associated with jellyfish (Scottish Government 2018a). Jellyfish abundance has been correlated to daily mortality rates with a lag of one to seven days (Baxter *et al.* 2011a), and blooms can lead to increased operational cost and insurance fees (Lucas *et al.* 2014).

Zooplankton damage from Muggiaea atlantica with erosion of gill rakers and Tenacibaculum sp. colonisation of damaged tissue obvious as yellowish colouration on damaged tissue.

Most zooplankton-associated gill disease is due to stings of free-living jellyfish. Cnidarian jellyfish have stinging cells which contain nematocysts that can cause mechanical and toxic insults to the fish gills and epithelia (Marcos-Lopez *et al.* 2016). In open net pens such as used in salmon aquaculture, small and transparent cnidarian jellyfish enter the fish pens intact, whereas larger jellyfish are broken up against the net mesh (Marcos-Lopez *et al.* 2016). Both of these cases can lead to nematocyst damage. Additionally, avoidance behaviour of the fish, such as excessive jumping, may result in more mechanical damage (Båmstedt *et al.* 1998). It has been proposed that jellyfish may serve as reservoirs or vectors for pathogens such as *Tenacibaculum* spp. (Ferguson *et al.* 2010; Fringuelli *et al.* 2012; Småge *et al.* 2017), which can cause disease in the fish.

Sessile jellyfish, hydrozoans, can foul aquaculture structures so that water flow and quality is reduced. To counter this, nets can be cleaned using pressure washers, but fish in cages have been observed to exhibit avoidance behaviour from the dense clouds of debris that come off the nets during the cleaning process. Experimental challenges showed that this debris can cause pathological changes in the gills, such as epithelial sloughing, necrosis and haemorrhaging (Baxter *et al.* 2012; Bloecher *et al.* 2018).

Clinical signs associated with presence of or damage caused by jellyfish include lethargic behaviour, fish swimming high in the water column close to the water surface and increased jumping behaviour (Marcos-Lopez *et al.* 2016). Sometimes zooplankton can still be seen in the gills both macroscopically and microscopically. Macroscopic signs include skin erosions, scale loss, swollen or haemorrhagic lesions on the skin with ulcers, see Figure 3. Microscopically, the gill damage observed can consist of hyperplasia, lamellar fusion, occasional presence of giant cells and bullae-like formations at the edges of filaments in chronic lesions with necrosis, haemorrhages, congestion, infiltration, oedema, lamellar epithelium sloughing and loss of tissue inflammation (Baxter *et al.* 2011a, 2011b; Ruane *et al.* 2013; Marcos-Lopez *et al.* 2016). Microscopic and/or macroscopic signs are not always observed during a jellyfish bloom (Småge *et al.* 2017). A yellow-brown colour associated with skin and gill lesions from jellyfish could indicate aggregations of *Tenacibaculum* sp. (Rodger *et al.* 2011a; Marcos-Lopez *et al.* 2016).

Risk factors for jellyfish blooms are warm weather (Marcos-Lopez *et al.* 2016), and there is some evidence that processes like overfishing, eutrophication, climate change, translocations and habitat modification may lead to more jellyfish blooms (Richardson *et al.* 2009). Fish have been treated with antibiotic, such as oxytretracycline in some cases in the past, after a jellyfish encounter to reduce the impact of secondary bacterial infections (Marcos-Lopez *et al.* 2016).

Jellyfish damage has been observed simultaneously with *T. maritimum* (Ferguson *et al.* 2010; Delannoy *et al.* 2011; Rodger *et al.* 2011b; Ruane *et al.* 2013; Marcos-Lopez *et al.* 2016) and *T. finmarkense* (Småge *et al.* 2017). See Table 1.

For a review on this topic, see Purcell *et al.* (2013).

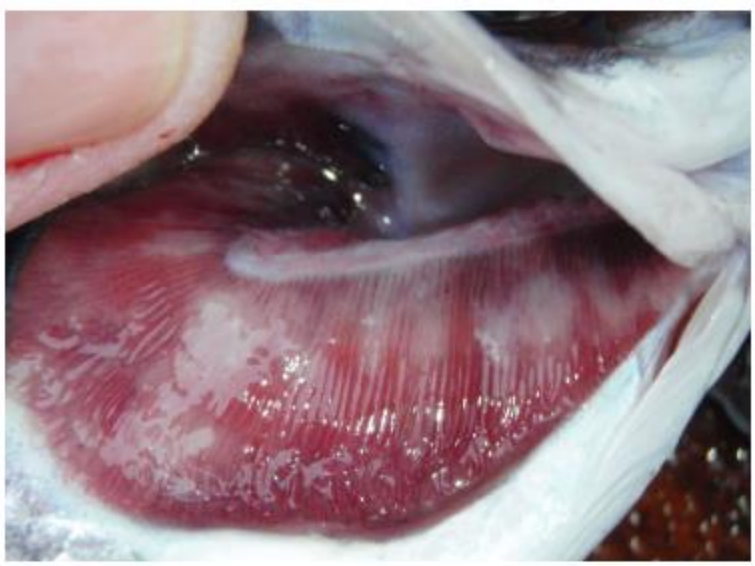
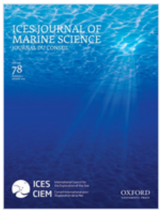


**Figure 2** Severe amoebic gill disease (AGD) lesions.

ICES Journal of Marine Science reported in 2021:




Volume 78, Issue 5
August 2021

JOURNAL ARTICLE

### Impacts of jellyfish on marine cage aquaculture: an overview of existing knowledge and the challenges to finfish health FREE

Morag Clinton ✉, David E K Ferrier, Samuel A M Martin, Andrew S Brierley

*ICES Journal of Marine Science*, Volume 78, Issue 5, August 2021, Pages 1557–1573, https://doi.org/10.1093/icesjms/fsaa254

**Published:** 02 April 2021 **Article history ▾**

## Abstract

Gelatinous plankton present a challenge to marine fish aquaculture that remains to be addressed. Shifting plankton distributions, suggested by some to be a result of factors such as climate change and overfishing, appear to be exacerbated by anthropogenic factors linked directly to aquaculture. Fish health can be negatively influenced by exposure to the cnidarian hydrozoan and scyphozoan life stages commonly referred to as "jellyfish". Impact is particularly pronounced in gill tissue, where three key outcomes of exposure are described; direct traumatic damage, impaired function, and initiation of secondary disease. Cnidarian jellyfish demonstrated to negatively impact fish include *Cyanea capillata*, *Aurelia aurita*, and *Pelagia noctiluca*. Further coelenterates have also been associated with harm to fish, including sessile polyps of species such as *Ectopleura larynx*. An accurate picture of inshore planktic exposure densities within the coastal environments of aquaculture would aid in understanding cnidarian species of concern, and their impact upon fish health, particularly in gill disease. This information is however presently lacking. This review summarises the available literature regarding the impact of gelatinous plankton on finfish aquaculture, with a focus on cnidarian impact on fish health. Present strategies in monitoring and mitigation are presented, alongside identified critical knowledge gaps.

The study of gelatinous plankton and their impact on fish health has emerged recently as an important field of research. Gelatinous plankton include Ctenophora (commonly known as "comb jellies"), salps, and Cnidaria such as the pelagic stages of Hydrozoa and Scyphozoa commonly referred to as "jellyfish". As concern grows regarding the underlying causes of mixed gill pathologies such as proliferative gill disease in fish (Król *et al.*, 2020), the potential impact of cnidarian jellyfish is of particular interest. Jellyfish are hypothesised to act as waterborne irritants (Downes *et al.*, 2018), initiating or potentiating disease. Jellyfish are also associated with fish mortality events in the aquaculture industry, with reports of loss of thousands of fish across the globe, including in Ireland (Cronin *et al.*, 2004), New Zealand (Zaki, 2018) and Tasmania (Ford, 2019). By one estimation, in Scotland between 1999 and 2005, 2.9 million marine-stage mortalities of Atlantic salmon (*Salmo salar*) were attributable to planktonic organisms (Hay and Murray, 2008). Although also implicated in harmful events to fish, Ctenophora are documented less frequently as a challenge to the aquaculture industry (Rodger *et al.*, 2011a).

A scientific submission by Dr Lisa Gershwin to a salmon farming inquiry in Tasmania in November 2019 included:

## POSITIVE FEEDBACK LOOP BETWEEN JELLYFISH & SALMON FARMING

Dr Lisa-ann Gershwin
Director, Australian Marine Stinger Advisory Services Pty Ltd

*Executive summary*

Salmon farming is exacerbating jellyfish blooms, which are in turn impacting ecosystem stability and industry viability. Peculiarities of the jellyfish life cycle mean that two quite different life forms are both threatening the health of salmon and other species. Threats from jellyfish include direct stinging, suffocation by mucus, gill damage leading to necrosis, hydroid seeding whereby the pest problem is multiplied each time the holding pens are cleaned, adding to the nutrient load, and legacy degradation of the ecosystem. I make this submission to the Fin Fish Farming in Tasmania Inquiry out of great concern over a worsening ecological problem that is already influencing long term viability of the industry; my concerns specifically address all the Inquiry's terms of reference.

*Background*

*"Huon Aquaculture have felt the sting of a jellyfish bloom that resulted in a 64 per cent drop in full-year profit…"* (AAP 2019). These opening words in a media story portray the devastating effects of a fish kill and its knock-on losses. An estimated million and a half fish were killed, either acutely by stinging and suffocation, or slowly by gill disease and necrosis that infected the survivors.

As shocking as a 64 per cent loss is, the more serious part is that this is not the first time it has happened, and probably not the last. In fact, all evidence points to current salmon farming practice making the jellyfish problem worse, with increasingly bigger losses over the last several decades.

While some may argue that a company has a right to lose money and may even assert a right to destroy the natural resources on which its future viability depends, I argue that this right does not extend to destruction of publicly owned property and native species downstream. These increasingly destructive jellyfish blooms fueled by salmon farming are causing legacy environmental damage that will likely never return to normal.

Jellyfish and salmon farming interact in four main ways, as outlined below, creating a positive feedback loop, with no positive outcome. My points of concern relate to all three Terms of Reference (TOR), as detailed in each section.

**1. Medusa threats**

Depending on medusa size, they either get stuck onto the outside of the nets, similar in principle to how a plastic wrapper gets sucked into a pool filter screen, or if small enough or fragmented enough, they penetrate the cages. Some people have speculated that if enough jellyfish are stuck on the cages, this could block the flow of oxygenated water, suffocating the fish; I have not seen data to substantiate this, but it seems theoretically possible.

The more accepted mechanism of fish kills happens with a combination of mucus and nematocysts (microscopic stinging cells). When jellyfish are stressed, such as when they are caught up in a net or a cageful of frantic fish, they exude copious amounts of mucus, which contains countless nematocysts. Stings to the gills panic the salmon, so they breathe faster, inhaling more mucus. The mucus coats the surface of the gills, preventing oxygen uptake. Simply, the salmon suffocate. A typical fish kill event is over and done with in a half hour or so, leaving hundreds of thousands of fish dead.

For the surviving fish, it's not over. Nematocysts in the gills cause microscopic injuries, which often lead to gill disease (Baxter et al. 2012; Bosch-Belmar et al. 2017). Moreover, some types of jellyfish actually carry bacteria associated with gill disease, such that the jellyfish may act as vectors or their stings may act as threat multipliers (Ferguson et al. 2010; Småge et al. 2017).

The impacts on salmon due to jellyfish blooms also impact native species and other aquacultured species in the same ways, as well as in additional ways detailed below.

**TOR 1b**. The cramped pens characteristic of salmon farming act as both incubators and feeder sources for jellyfish blooms, which is a **biosecurity issue** for other species. A biosecurity plan should include not only effects of pest species on farmed salmon stock, but also the effects on native fish and invertebrate species, as well as other aquacultured species.

**TOR 2c**. Jellyfish blooms harm not only salmon, but they also permanently **degrade the environment** and affect the native species that live there. Although in theory the legislation governing salmon farming can address adverse environmental sequelae, these laws (notably the Marine Farming Planning Act 1995 and the Living Marine Resources Management Act 1995) have not been implemented robustly and the industry has been allowed to expand in defiance of concerns from local communities and environmental scientists. To ensure that the industry is regulated at arm's length without conflicts of interest, the Commonwealth should assume responsibility for regulation of fish farms in coastal waters.

## 2. Polyp threats

Experiments on jellyfish polyps have demonstrated that they prefer artificial surfaces (Bloecher et al. 2013; Holst and Jarms 2007). The infrastructure associated with salmon farms, therefore, offers an ideal habitat for jellyfish to flourish in.

### *A. Hydroid colonies on nets affect the fish*

Hydroid colonies growing on nets sting fish as they swim by. Lesions on the skin make the fish less saleable, and there is the possibility for toxic contamination or infection of flesh. There is also high potential for clouds of nematocysts or debris to form as fish bump into them; nematocysts and debris have been shown to cause gill disease and necrosis (Bosch-Belmar et al. 2017). Hydroid colonies can also impede water circulation, and can add to drag of the nets in currents. Thus, the hydroids must be cleaned away regularly.

### *B. Net cleaning debris causes gill necrosis*

The primary threat from polyp stages comes from debris generated by net cleaning activities. Cleaning is accomplished by high pressure water blasting, or by manual brushing or scraping of the nets. Debris consists of stingy and abrasive components, both of which lead to gill injuries, amoebic gill disease, necrosis, and mortality (Bloecher et al. 2018; Bosch-Belmar et al. 2017).

As bad luck would have it, hydroid regrowth is stimulated by the mechanical action of net cleaning (Guenther et al. 2010). Laboratory experiments have demonstrated that tiny bits of hydroids left on the nets after cleaning are sufficient to regrow entire colonies, and the more frequent they are cleaned, the faster they reproduce.

Hydroid seeding can be compared to the broom scene in the Disney film *Fantasia*, where each effort to destroy the brooms simply resulted in more brooms. Downstream hydroid seeding is a serious issue affecting farmed and native species alike. In the short term, it leads to a higher biomass of medusae stinging the salmon and native species, and in the long term, the extra biomass permanently alters the function of the ecosystem.

**TOR 1b, 2c 3**. Hydroid seeding downstream beyond the farms is a serious biosecurity issue and environmental hazard for other industries and natural habitats, with knock-on effects back to the farms in terms of increased bloom impacts; the biosecurity plan must consider this.

**3. Impacts on native species**

I've alluded above to effects of jellyfish blooms on native species. Just like jellyfish and hydroids affect salmon gills, so too they affect native fish. These native fish, however, do not have the benefit of veterinary care, antibiotics, or freshwater bathing to kill gill pathogens. Moreover, some of these infected fish may be caught by recreational fishers; the effect of gill diseased fish on food safety and human health has not been investigated to my knowledge, but should be.

Likewise, the gills of bivalves like scallops, oysters, mussels, and clams are damaged by jellyfish and hydroids too. To my knowledge, the negative effects from salmon farming are poorly researched for these species, but should be considered.

Jellyfish blooms also impact native invertebrate species like bryozoans and sponges through polyps outcompeting these other species for settling space.

One of the biggest impacts, however, that jellyfish blooms have on native species is by consuming their eggs and larvae, as well as the plankton that the larvae would eat. This double whammy of predation and competition can keep other species from replenishing by continuing to consume any eggs and larvae they produce. In this way, jellyfish effectively "flip the ecosystem" to being dominated by themselves, and once flipped, these ecosystems are highly resilient against switching back to what we would consider healthy.

Besides being a hazard for salmon, other farmed species, and native species, jellyfish also negatively impact recreational fishing through reducing biodiversity, and boating by getting sucked into boat motors, causing all sorts of problems.

**TOR 1a, 2c**. There is no question that salmon farming is **affecting native species**; the unresearched questions are how badly and how permanently. The Act should mandate independently-conducted research and monitoring on these questions. The environmental impact and assessment processes in the existing legislation are too short-term in their scope to capture long-term environmental changes from fish farming.

**TOR 1b.** Fish farms attract and incubate opportunistic pests because of their artificial nature; this presents a chronic biosecurity risk to the fish. Likewise, from the point of view of native species, salmon farming presents a **biosecurity risk**, because farms breed pathogens and degrade water quality. Tasmania's new Biosecurity Act 2019 should be implemented to ensure that biosecurity plans and regulations extend beyond protection of the salmon from invading pathogens, to include the role of farms in threatening the health and habitats of native species.

## 4. Nutrients making it worse

Astonishingly, the take-home message from salmon farming all over the world, including Tasmania, is that the current business model of high stocking densities in coastal waters is making the jellyfish problem worse, which is in turn impacting the salmon and the habitat they require. The plan for "offshore farming" is probably not offshore enough to prevent this problem. Storm Bay is not offshore; it is a bay, which hydrologically means that the residence time of the water is longer than if it were the open ocean. And in bays, the water re-circulates, so there is some residual buildup of contaminants.

The problem comes down to nutrients. Salmon farming produces an excess of waste from excrement and uneaten food. This waste acts as fertilizer, stimulating phytoplankton (plant plankton like diatoms and dinoflagellates). An abundance of phytoplankton provides a buffet for small consumers like copepods and larvae of just about everything. These small organisms in the water column are collectively referred to as zooplankton, or animal plankton; these are the primary food of jellyfish. So the more nutrients → the more phytoplankton → the more zooplankton → the more jellyfish. And unfortunately, not many things eat jellyfish, so they typically bloom into super-abundances then die off, and when they do, they add to the nutrient load, which keeps the cycle going. Therefore, there is a positive feedback loop between jellyfish and nutrients, which is aided by salmon farming. Jellyfish swarms, therefore, are not only a visible indicator of imbalance, they are also a driver to speed the ecosystem to a much worse state.

**TOR 2c, 3**. Jellyfish blooms are an integral part of a positive feedback loop, together with nutrients and algae, that causes legacy damage to the environment. Jellyfish and algae blooms are normal, but not in the frequency, densities, and duration created by current fish farming practices. This is unsustainable to both the long-term viability of this industry and to the environment in the broader sense.

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A scientific paper published in Aquaculture in 2020 reported:

ELSEVIER

Aquaculture
Volume 518, 15 March 2020, 734801

Short communication

## Molecular identification of potential aquaculture pathogens adherent to cnidarian zooplankton

Morag Clinton [a b 1], Anna H. Kintner [a 1], Christian M.J. Delannoy [c], Andrew S. Brierley [a], David E.K. Ferrier [a]

### Abstract

Cnidarian jellyfish are pest species of marine aquaculture, with their acute impacts well documented in farmed fish, particularly affecting the delicate gill tissue. Less is known about subsequent consequences of exposure, including their association with secondary bacterial infections. The aim of this study was to identify whether potentially pathogenic bacteria were present as part of the adherent microbial populations of three medusozoan jellyfish species; *Obelia geniculata*, *Neoturris pileata* and the Lion's Mane jellyfish *Cyanea capillata*. A number of potential pathogens of commercial aquaculture were identified, including Aeromonas salmonicida, Vibrio splendidus and Vibrio alginolyticus. These findings suggest that jellyfish must be considered not just agents of direct trauma to fish in aquaculture, but also potential reservoirs and vectors of bacterial disease. Since jellyfish may be increasing in the coastal waters where marine aquaculture occurs, the role of jellyfish in bacterial outbreaks has implications for marine aquaculture globally.

Including:

> The results of this study show that potentially harmful bacteria are present on the surface of the cnidarian species investigated, jellyfish which can and do come into contact with aquaculture production. Whilst disease initiation is a multifactorial process and the in vivo pathogenicity of bacteria isolated is as yet unconfirmed, their presence is confirmed in the adherent microbial communities of these jellyfish, in sufficient densities to be culturable. Our results imply that exposure of fish to the jellyfish species studied here also risks exposure to potentially pathogenic bacteria capable of proliferating in the gills. Of particular concern is exposure of unvaccinated species such as the cleaner fish employed in Atlantic salmon production. Bacterial disease appears to be associated with the high losses of these species that can be experienced by producers, with bacterial disease one of the most common clinical findings in mortalities of these fish (Nilsen et al., 2014; Bornø and Lie Linaker, 2014; Gulla et al., 2016).

A multitude of factors impact the onset and progression of bacterial infection, but jellyfish are considered a strong predisposing factor of bacterial gill disease (Rodger et al., 2011). Potentially providing the perfect delivery mechanism for pathogens, discharge of stinging nematocysts causes physical trauma and impairs immunity of epithelial tissue. This trauma can facilitate the growth of pathogenic bacteria within wounds or may even allow entry across epithelial surfaces for systemic bacterial effects such as septicaemia (Dror et al., 2006; Gomez et al., 2013; Handlinger et al., 1997). The diseases furunculosis and vibriosis are both promoted by removal of the mucus layer and tissue trauma (Balebona et al., 1998; Dror et al., 2006) such as occurs during jellyfish exposure. These diseases cause erosive tissue damage similar to *T. maritimum*, the proteolytic fish pathogen already linked to vector transmission by jellyfish (Delannoy et al., 2011; Ferguson et al., 2010).

Sample size and limited geographical area of collection preclude conclusions regarding presence of these bacteria in the core microbiome of the jellyfish species investigated. However, this study does demonstrate the ability of jellyfish to host bacteria with disease-causing potential within their microbiomes. With that in mind, we suggest there may be appreciable risk to fish following exposure to the three common cnidarian species studied here, which the aquaculture industry should bear in mind as it moves towards improved treatment and prevention of bacterial disease. Outbreaks of bacterial disease in marine aquaculture production units preceded by jellyfish blooms may well be due to vector transmission of infective bacteria, however, current under-reporting and lack of routine monitoring of jellyfish populations limits linking outbreaks of clinical bacterial disease in farmed fish to jellyfish exposure.

A scientific paper in the Journal of Fish Diseases in 2018 reported:

JOURNAL OF
FISH DISEASES

ORIGINAL ARTICLE

**Acute lion's mane jellyfish, *Cyanea capillata* (Cnideria: Scyphozoa), exposure to Atlantic salmon (*Salmo salar* L.)**

M D Powell, Å Åtland, T Dale

First published: 18 January 2018 | https://doi.org/10.1111/jfd.12771 | Citations: 9

## Abstract

Jellyfish-induced gill pathology relies upon occasional diagnostic observations yet the extent and impact of jellyfish blooms on aquaculture may be significant. Idiopathic gill lesions are often observed in apparently healthy fish. This study exposed Atlantic salmon (*Salmo salar* L.) smolts to macerated *Cyanea capillata* at 2.5 and 5 g/L for 2 hr under controlled laboratory conditions. Blood chemistry and gill histopathology were examined over a subsequent 4-week period. Fish showed an acute response to the presence of jellyfish, including characteristic external "whiplash" discoloration of the skin and acute increases in blood electrolytes and $CO_2$ concentration; however, these were resolved within 4 days after exposure. Histopathologically, gills showed first an acute oedema with epithelial separation followed by focal haemorrhage and thrombus formation, and then progressive inflammatory epithelial hyperplasia that progressively resolved over the 4 weeks post-exposure. Results were consistent with the envenomation of gills with cytotoxic neurotoxins and haemolysins known to be produced by *C. capillata*. This study suggests that many focal hyperplastic lesions on gills, especially those involving focal thrombi, may be the result of jellyfish stings. Thus, the presence of jellyfish and their impact may be severe and understated in terms of marine fish aquaculture and fish welfare.

PLOS ONE reported in 2017:

PLOS ONE

PLoS One. 2017; 12(11): e0187476.
Published online 2017 Nov 2. doi: 10.1371/journal.pone.0187476

PMCID: PMC5667831
PMID: 29095885

## Concurrent jellyfish blooms and tenacibaculosis outbreaks in Northern Norwegian Atlantic salmon (*Salmo salar*) farms

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### Abstract

Go to: ▸

Tenacibaculosis is an increasing problem in the Norwegian Atlantic salmon aquaculture industry causing significant economic losses. In September 2015, two separate outbreaks of suspected tenacibaculosis occurred at two Atlantic salmon farms in Finnmark County in Northern Norway. The events resulted in major losses of smolts newly transferred into seawater. Prior to, and during the outbreaks, large numbers of small jellyfish, identified as *Dipleurosoma typicum* (Boeck) were observed in the vicinity of the farms and inside the net-pens. This study investigates the possible link between the jellyfish, *Tenacibaculum* spp. and the tenacibaculosis outbreaks. Bacteriology, histology, scanning and transmission electron microscopy, and real-time RT-PCR screening were performed on both fish and jellyfish samples. Based on the findings, *Tenacibaculum finnmarkense* was found to be the dominant bacteria associated with the tenacibaculosis outbreaks at both sites and that *D. typicum* is unlikely to be a vector for this fish pathogenic bacterium. However, results do show that the jellyfish caused direct damage to the fish's skin and may have exacerbated the bacterial infection by allowing an entry point for bacteria.

## Introduction

Go to: ▸

Jellyfish blooms are a rising concern to the marine aquaculture industry because they have been associated with an increasingly large number of mortality events in Atlantic salmon farming, which have resulted in economic losses and fish welfare issues [1,2]. This phenomenon is not fully understood but is possibly due to changing ocean conditions, including anthropogenic causes, and/or that production is now occurring in areas with naturally high occurrences [3–5]. High levels of *Pelagia noctiluca* in Northern Ireland have been linked with several mortality events with Atlantic salmon exhibiting skin and gill lesions, as well as abnormal behaviour such as increased jumping [2,6,7]. This species has also been linked to a mortality event in Atlantic Coastal France [8]. In Scotland and Norway, mass mortality events showing mainly gill lesions have been linked to blooms of *Phialella quadrata* [9,10]. Mortality events in Norway have also been associated with blooms of: *Aurelia aurita*, *Muggiaea atlantica*, *Apolemia uvaria*, and *Bolinopsis infundibulum* [11–13]. Some of these jellyfish (e.g. *Aurelia aurita* and *Pelagia noctiluca*) have been experimentally shown to cause gill and skin damage to marine-farmed fish without the need for other stressors or pathogens [14,15].

The ability of jellyfish (in this paper, members of Phylum Cnidaria are referred to as "jellyfish") to form blooms under favourable environmental conditions is due to them having both asexual and sexual reproduction [4]. All jellyfish have the potential to be toxic due to having cnidocytes mainly found on the tentacles, which contain stinging nematocysts [16]. These are highly specialised organelles that fire a venom containing structure when triggered in response to a chemical or physical stimuli such as contact with a fish's skin [17,18]. There are variations in the composition of the venoms between jellyfish species and some have been shown to be cytotoxic or haemolytic [15,19]. The severity of mechanical and toxic injury caused by jellyfish is exacerbated by certain factors such as increased temperatures and exposure [15].

Studies have shown that many environmental bacteria, including pathogenic ones such as *Tenacibaculum* spp. (Family Flavobacteriaceae) and *Moritella viscosa* (Family Moritellaceae) are found on jellyfish and these could therefore act as vectors [10,20–22]. *Tenacibaculum* spp. are found worldwide with some species causing tenacibaculosis in marine aquaculture; a disease mainly characterised by ulcerative lesions, frayed fins and mouth erosion [23–27]. The bacteria have also been linked to gill lesions [28,29]. Tenacibaculosis has been reported with increased frequency in the last few years in the Norwegian salmon farming industry [30,31]. In Norway, affected fish most commonly have mouth erosion, frayed fins (pectoral, pelvic and anal), and tail rot and these lesions have been associated with *Tenacibaculum finnmarkense* [25]. Lesions are often characterised by skin ulcers with yellow margins that are surrounded by wide areas of scale loss (personal observations). Similar lesions have been associated with jellyfish mortality events [6]. The literature would therefore suggest that such mortality events are a result of the direct damage by the jellyfish, as well as associated filamentous bacterial infections [2,13,32].

During the sampling, large blooms of small (approximately 10 mm) transparent jellyfish (Fig 2) were present in and around the net-pens at both sites, as well as throughout the surrounding fjords. In certain areas aggregations of the jellyfish gave a greyish cloudy appearance to the sea. The individual jellyfish were found to be very friable thus hampering the sampling. Fish in the net-pens showed abnormal behaviour, including swimming high in the water column and increased jumping activity. Moribund fish showed signs of tenacibaculosis: frayed fins, scale loss, and skin ulcers and mouth erosion with yellow pigmentation of the margins (Fig 3). Some fish had eyes with a cloudy appearance. No gross pathology was observed internally.

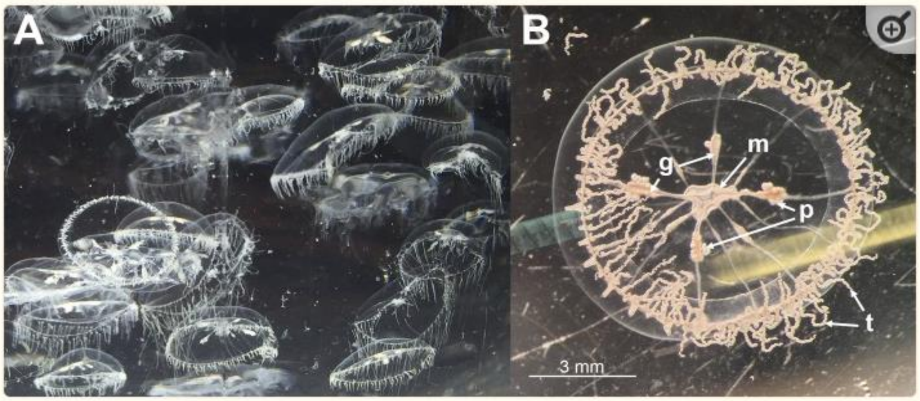



Fig 2

**Jellyfish morphology.**

(A) A water sample collected outside one of the net-pens at site 1. A high concentration of *D. typicum* was present in the sample. (B) One of these specimens under a stereomicroscope showing the characteristics typical for this species [40,41]. m: the mouth, t: tentacles, g: gonads, p: planula larva (Note: the planula larva was found to be ciliated and highly motile, which differs from previous descriptions given for this species).

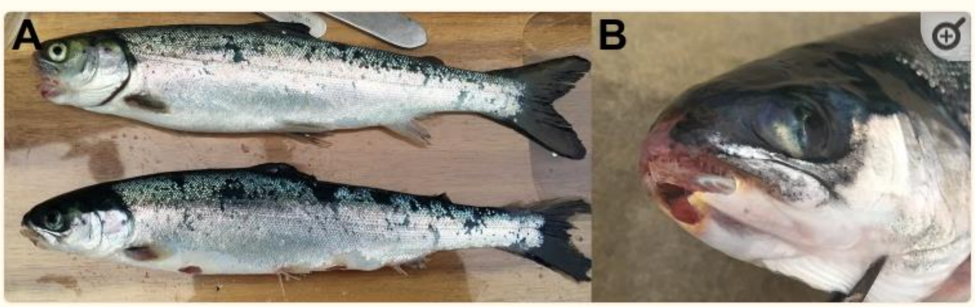



Fig 3

**Moribund fish showing signs of tenacibaculosis.**

(A) Fish representing moribunds from both site 1 and 2. Skin lesions have the typical scale loss and yellow margins seen with tenacibaculosis. Frayed fins are also clearly visible. (B) A close up of an affected head showing a mouth lesion that has the typical yellow margin associated with tenacibaculosis.

There is a complex relationship between bacterio-, phyto- and zooplankton and jellyfish communities in the environment, which make determining the reservoirs and vectors of pathogenic bacteria difficult. Flavobacteriaceae levels, including *Tenacibaculum*, have been shown to be associated with elevated levels of organic material (e.g. phytoplankton blooms) in the environment due to their ability to decompose complex molecules [59–61]. Phytoplankton blooms frequently occur in the Barents Sea (the sea surrounding the Northern most part of Norway) [62–65]. This was also the case in 2015 when a phytoplankton bloom occurred in close proximity to the sites approximately one month prior to the mortality events (NASA Worldview, https://goo.gl/oq8Sb3). As a result, levels of Flavobacteriaceae present around the farm sites are expected to be high during these blooms when there is a high organic load in the water [59,61,66,67]. Different clades of Flavobacteriaceae will dominate at different times of the phytoplankton bloom cycles [59,60,66,68,69], and *Tenacibaculum* spp. tend to be later in the cycle when the plankton are decomposing [70]. The timeline of these cycles match what was seen in this study with the tenacibaculosis outbreaks starting 4 to 6 weeks after the onset of the phytoplankton blooms.

Jellyfish levels also react to organic load, and blooms often occur as a result of increased levels of zooplankton which generally lags that of phytoplankton blooms by a month [3,71,72]. All known described jellyfish in Phylum Cnidaria from the Barents sea forage on zooplankton [72]; it is therefore likely to be the case for *D. typicum*. It is also shown that jellyfish blooms can have an effect on the bacterial community composition in the vicinity of the bloom; as was shown in a study where the presence of the jellyfish *Mnemiopsis leidy* was associated with increased levels and prevalence of Flavobacteriaceae [73].

The earliest recorded bloom of *D. typicum* was near the British Isles in the late 1800s and the presence of the species has been reported in much of the boreal-circumpolar region [40,41]. The presence of *D. typicum* in Northern Norwegian waters may not be a new finding, but with new areas being used for salmon aquaculture their presence could be a rising issue. The ability of *D. typicum* to rapidly propagate and cause massive blooms is due to its ability of repeated transverse fission [40].

*D. typicum* is described as being friable [41], which was confirmed during field sampling, and can therefore easily break up into pieces that are still capable of stinging fish [6]. This might be a concern in saltwater semi-enclosed and closed systems, which generally pump in saltwater that may contain pieces or whole jellyfish as was described by Hosteland [74]. The jellyfish may be accompanied by pathogens, in particular some members of Flavobacteriaceae that are expected to be high in times of blooms, which could further exacerbate the situation. The introduction of pathogens into a closed system has already been noted for *Tenacibaculum* [75]. This is likely to be an issue for well-boat fish transports as well.

## Conclusions

Go to: ▸

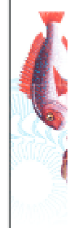
Based on the findings of this study, *D. typicum* is unlikely to be a vector for the fish pathogenic species *T. finnmarkense*. However, these jellyfish are likely to cause enough damage physically through their nematocytes to result in a route of infection for pathogenic environmental or opportunistic skin bacteria.

Smolts go through an intense transition when transferred to saltwater, linked to a shift in skin microbiota, making them more susceptible to environmental stressors; therefore, increased knowledge is needed as to when and where to transfer fish into saltwater. Possible options, such as closed post-smolt facilities using treated saltwater could be a mitigation tool for outbreaks like the ones described in this study.

A short communication published in the Journal of Fish Diseases in 2014 included:

Journal of Fish Diseases 2014

doi:10.1111/jfd.12267



Short Communication

**Pathology and mortality associated with the mauve stinger jellyfish *Pelagia noctiluca* in farmed Atlantic salmon *Salmo salar* L.**

**M Marcos-López, S O Mitchell and H D Rodger**

Vet-Aqua International, Oranmore, Co. Galway, Ireland

Significant numbers of jellyfish were observed within the affected cages prior to presence of the gill and skin lesions. Therefore, the reported pathology was directly associated to the jellyfish presence. Affected fish showed respiratory distress, loss of appetite, lethargy and/or increased jumping behaviour. On the most severe cases, up to 80%

of the fish examined presented signs of jellyfish damage. Macroscopically, fish exhibited damage in the skin and gills. Gross skin lesions were mainly present in the flanks and ranged from mild focal (<1 cm) skin erosions, scale loss, swollen and/or congested/haemorrhagic lesions to extensive skin ulcers (>5 cm) (Fig. 1b). Gill damage, mainly noted in the filaments but with the occasional gill arch affected, comprised of focal to multifocal necrosis, haemorrhage and/or loss of tissue. Some

lesions showed a yellow-brownish colour suggesting bacterial infection.

Increased eutrophication due to anthropogenic activities and other human activities (e.g. overfishing) may favour jellyfish multiplication. Floating aquaculture structures also provide a suitable surface for polyp settlement (Purcell, Uye & Lo 2007).

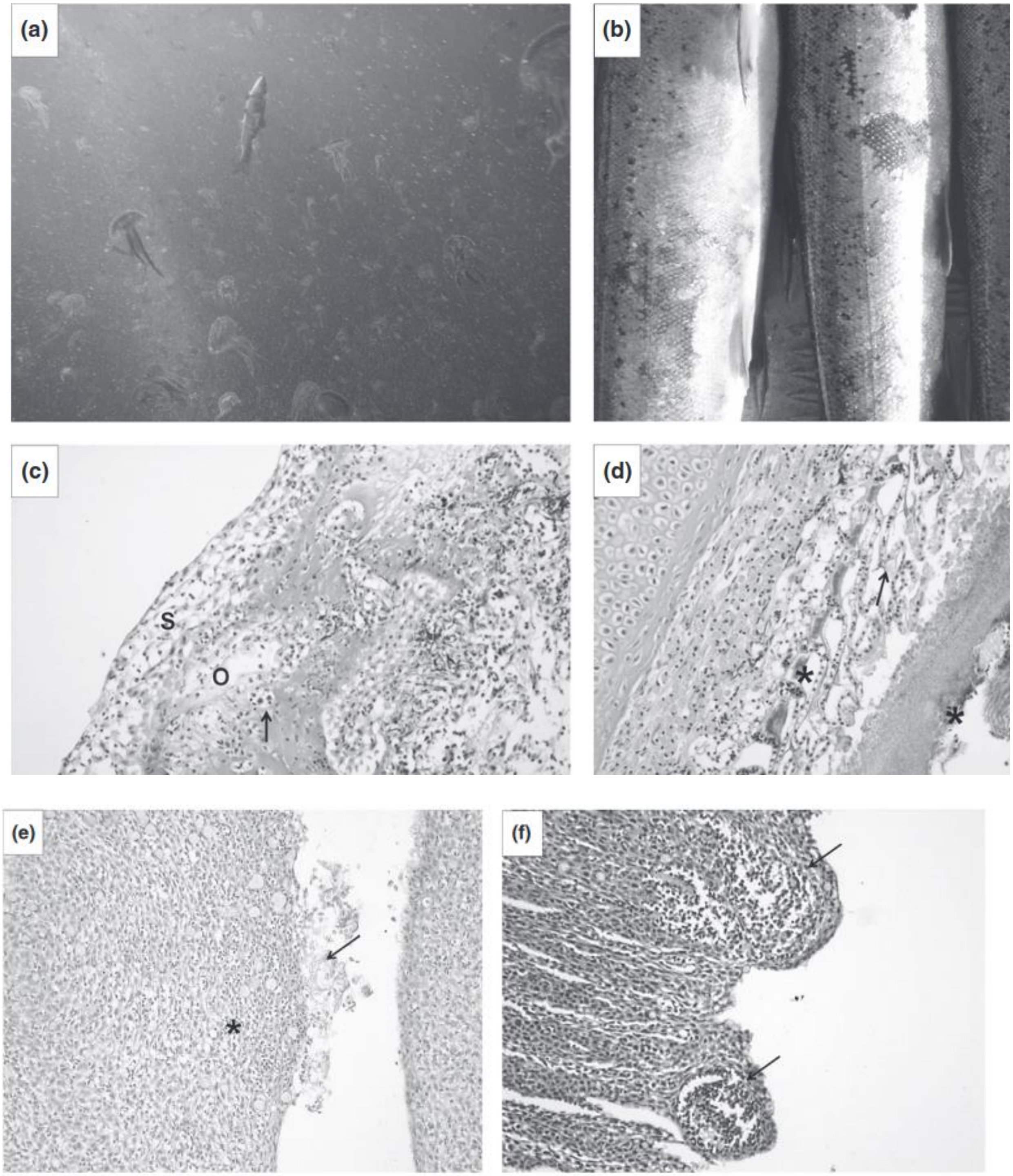



**Figure 1** (a) Numerous *Pelagia noctiluca* jellyfish inside marine Atlantic salmon pen. *Picture courtesy of Pete McDonagh.* (b) Flank skin lesions in farmed Atlantic salmon caused by contact with *P. noctiluca.* (c) Skin pathology caused by *P. noctiluca.* Note dermal necrosis (N), cell infiltration (arrow), oedema (O), and epidermal spongiosis (S). (×20) H&E. (d) Severe gill pathology caused by *P. noctiluca.* Note lamellar epithelium necrosis (arrow) and secondary colonization with filamentous bacteria (*). (×20) H&E. (e) Jellyfish contact point in lamellar gill epithelium. Note cell infiltration in affected epithelium (*) and remains of jellyfish tissue at the epithelial surface (arrow). (×20) H&E. (f) Bullae-like lesions at the edge of proliferated affected lamellar epithelium (arrows). (×20) H&E.

A scientific paper published in 2011 detailed:

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# Gill disorders in marine-farmed salmon: investigating the role of hydrozoan jellyfish.

| | |
|---|---|
| Title | Gill disorders in marine-farmed salmon: investigating the role of hydrozoan jellyfish. |
| Publication Type | Journal Article |
| Year of Publication | 2011 |
| Authors | Baxter, EJ, Rodger, HD, McAllen, R, Doyle, TK |
| Journal | Aquaculture Environment Interactions |

ABSTRACT: Jellyfish have been implicitly linked to a number of fish kill events in marine-farmed finfish over recent decades. However, due to insufficient data, it is difficult to identify small hydrozoan jellyfish as the causative agents of the more common and chronic problem of gill disorders. Gill disorders (physical, pathogenic or parasitic damage to the gills) can be caused by a number of waterborne agents and are an increasing though poorly understood problem for the aquaculture industry. Hence, the first year-long monitoring programme to study hydrozoan jellyfish, other gelatinous zooplankton, phytoplankton and fish health was initiated at 2 aquaculture sites on the west coast of Ireland. At the southern site, 2 jellyfish species previously implicated in aquaculture fish kill events (*Muggiaea atlantica* and *Solmaris corona*) occurred at high abundances (combined density of ~450 jellyfish $m^{-3}$, an order of magnitude lower than during previous mass mortality events). The fish at this site exhibited clinically significant gill damage throughout the peak in jellyfish abundance. Analyses revealed a significant positive correlation between daily fish mortality and the abundance of these jellyfish but not with any other factors. At the northern site, there were low abundances of jellyfish; nevertheless, gill damage due to the protozoan parasite *Trichodina* sp. was observed over a shorter time period. As the European aquaculture sector experiences annual economic losses due to gill disorders, these findings raise concerns for the expected growth of the industry, especially as jellyfish populations are predicted to increase in some areas. Therefore, mitigation methods need to be developed and implemented.

The scientific paper included:

> The development of significant gill disorders in the salmon from the Bantry Bay farm was evident during late summer/autumn. Histological examination of the gill tissues showed a clear increase in gill damage from

a state of low level damage to gross gill damage (i.e. represented by lamellar fusion and necrosis of the epithelium, Fig. 5a,c). This coincided with the peak in harmful jellyfish abundance (September to November, abundance: ~450 ind. $m^{-3}$) (Fig. 6a). This level of gill damage would have had a significant clinical impact of the fish's health and ability to survive. Importantly, a highly significant, positive correlation between the abundance of harmful jellyfish (*Muggiaea atlantica*, *Phialella quadrata* and *Solmaris corona*) and the average daily fish mortalities was identified (Fig. 7). The results suggest that *M. atlantica* and *S. corona* were the causative agents of the gill disorders identified and may also have had an impact on the observed mortali- ties.

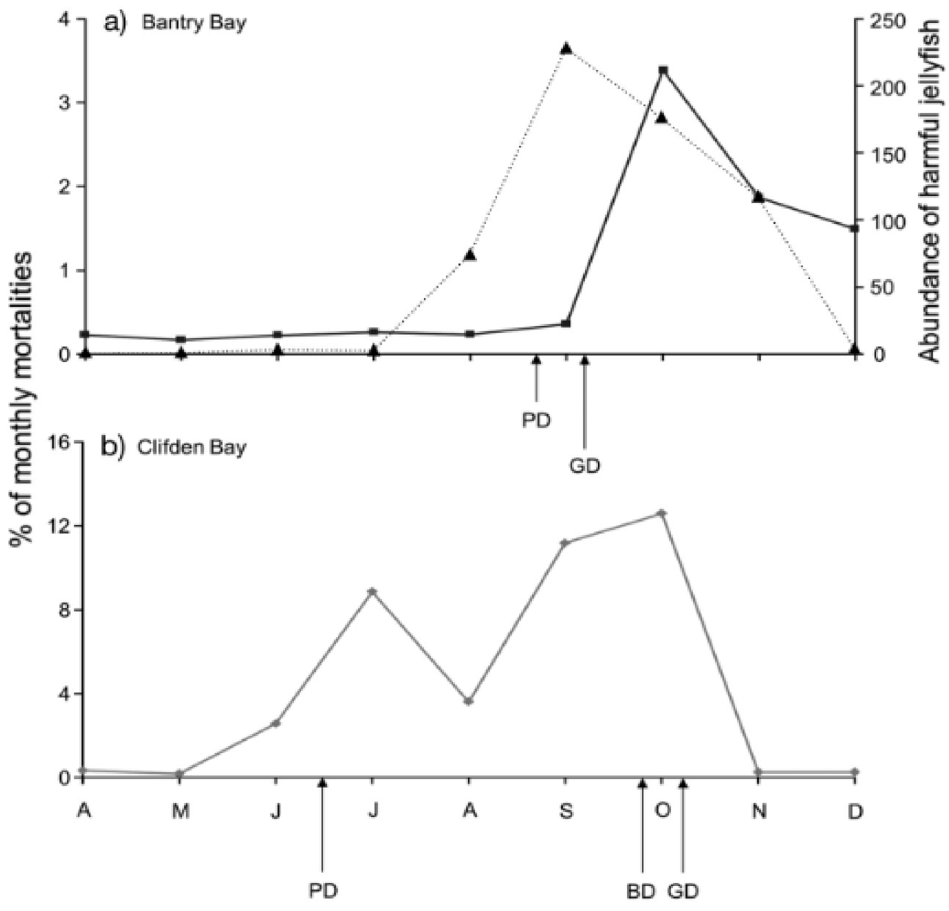


Fig. 6. *Salmo salar*. Percentage of monthly mortalities (of the current stock) observed at (a) Bantry Bay (—■—) and (b) Clifden Bay (—◆—), Ireland, salmon farms from April until December 2009. The mean abundance of harmful jellyfish (*Muggiaea atlantica*, *Phialella quadrata* and *Solmaris corona*) (····▲····) is also presented for Bantry Bay. Onset of each of the diseases/disorders experienced at each farm is indicated with an arrow. PD: pancreas disease; GD: gill damage; BD: bacterial disease


Fig. 1. Representatives of the gelatinous zooplankton identified during the present study from 4 phyla. a: trachymedusan hydromedusa – *Aglantha digitale*; b: calycophoran siphonophore – *Muggiaea atlantica*; c: calycophoran eudoxid – *M. atlantica*; d: larvacean – *Oikopleura* sp.; e: cydippid ctenophore – *Pleurobrachia pileus*; f: chaetognath – *Sagitta elegans*; g: leptomedusan hydromedusa – *Phialella quadrata*; h: leptomedusan hydromedusa – *Obelia* spp.; i: agalmid 'Athorybia' larvae – *Agalma elegans*; j: narcomedusan hydromedusa – *Solmaris corona*; h: doliolid – *Doliolum* sp. Scale bar = 1 mm for each organism

A scientific paper published in 2010 included:

Journal of Veterinary Diagnostic Investigation

AAVLD

Impact Factor: **1.5** / 5-Year Impact Factor: **1.6**

Free access | Research article | First published online May 1, 2010

## Jellyfish as Vectors of Bacterial Disease for Farmed Salmon (*Salmo Salar*)

Hugh W. Ferguson, M. J. Delannoy Christian, [...], and Margaret Crumlish +3 View all authors and affiliations

Volume 22, Issue 3 | https://doi.org/10.1177/104063871002200305

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### Abstract

Swarms or blooms of jellyfish are increasingly problematic and can result in high mortality rates of farmed fish. Small species of jellyfish, such as *Phialella quadrata* (13 mm in diameter), are capable of passing through the mesh of sea cages and being sucked into the mouth of fish during respiration. Results of the current study show that the initial damage to gills of farmed Atlantic salmon, likely produced by nematocyst-derived toxins from the jellyfish, was compounded by secondary bacterial infection with *Tenacibaculum maritimum*. Results also demonstrate that these filamentous bacteria were present on the mouth of the jellyfish and that their DNA sequences were almost identical to those of bacteria present on the salmon gills. This suggests that the bacterial lesions were not the result of an opportunistic infection of damaged tissue, as previously thought. Instead, *P. quadrata* is probably acting as a vector for this particular bacterial pathogen, and it is the first time that evidence to support such a link has been presented. No prior literature describing the presence of bacteria associated with jellyfish, except studies about their decay, could be found. It is not known if all jellyfish of this and other species carry similar bacteria or the relationship to each other. Their source, the role they play under other circumstances, and indeed whether the jellyfish were themselves diseased are also not known. The high proteolytic capabilities of *T. maritimum* mean that partially digested gill tissues were readily available to the jellyfish, which rely heavily on intracellular digestion for their nutrition.


### Discussion

The findings show that the jellyfish were carrying filamentous bacteria and that at least some of these were *T. maritimum*. It is not known where the bacteria on the gill arch originated, whether from the water or from the jellyfish, but the close association between the jellyfish and the lesions on the gill arch suggests that the bacterial lesions were not merely the result of secondary infection of an exposed and vulnerable tissue. The findings also suggest that the jellyfish were responsible for carrying bacteria to the gill arch and infecting with *T. maritimum* the tissue into which they were injecting toxins. In a species that has been shown to exhibit genetic variability,[3] the virtually identical gene sequences of the *T. maritimum* from gill and jellyfish (a single bp difference) support this suggestion. In future outbreaks, sampling of fresh gills and jellyfish would allow recovery of bacteria and direct comparison of isolates.

There is little doubt that the observed mortality in the salmon can be attributed to the gill lesions, but it is less certain whether these were due to the direct action of the jellyfish, the subsequent bacterial infection, or some combination of both. The severe inflammatory response that accompanied the major lesions of ballooning degeneration and denaturation (necrobiosis) of basement membrane and superficial dermal collagen suggests the possibility of complement activation due to injected jellyfish toxins, but these lesions by themselves would not necessarily have led to respiratory compromise, unless inflammatory cytokines and/or jellyfish toxins were carried by the circulation into the filaments and lamellae, with resulting changes in blood flow. By contrast, the observed lamellar epithelial changes would probably lead to turbulence, increased diffusion distance, and hypoxemia. *Tenacibaculum maritimum* is known to possess aggressive proteolytic enzymes,[26] so colonization of the gills by these bacteria would rapidly lead to further severe gill damage.

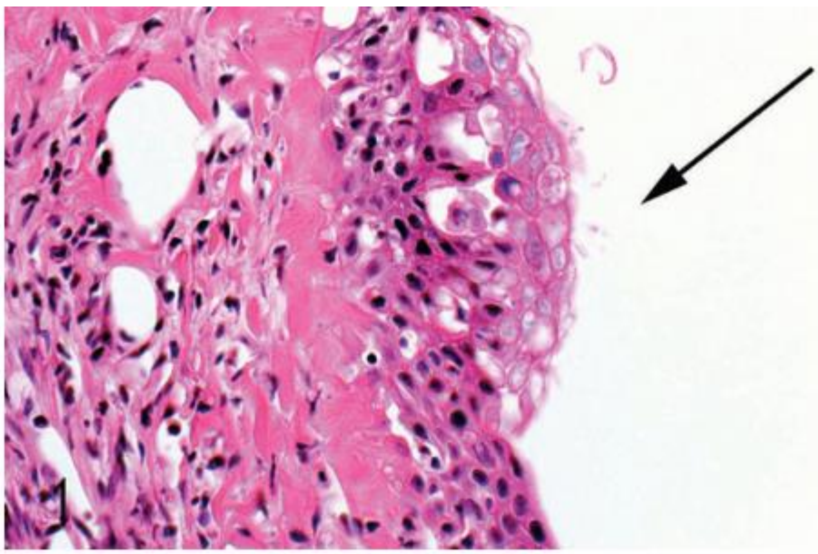


**Figure 1.** Micrograph of section of gill arch from moribund salmon showing 2 foci of acute hydropic and ballooning degeneration of arch epithelium (arrows). Hematoxylin and eosin.

The results raise several interesting questions. First, what is the relationship between the bacteria and the jellyfish? Are they a pathogen of the jellyfish, or are they present in a symbiotic or commensal capacity? Jellyfish do not have a "typical" digestive tract but instead variably complex gastric cavities and canals. These are usually ciliated and provided with secretory cells that release exoenzymes. Predigestion in the gastric cavities is followed by endocytosis of food particles and intracellular digestion in the gastrodermal cells. In the case of a small and simple medusa, such as *P. quadrata*, there is only a simple elastic stomach cavity linked to the radial and circular canals.[4] The presence of a population of proteolytic enzyme-producing bacteria on their mouths could therefore aid in predigestion of prey; in this case, the salmon gills were possibly the target. It is not known whether all *P. quadrata* harbor these bacteria or whether this is peculiar to this particular case. Nor do the authors of the present study know their source; maybe the salmon themselves supplied the bacteria for the jellyfish!

A report – [‘Developing the capacity to monitor the spatial and temporal distributions of jellyfish in western Scottish waters’] - published by the Crown Estate in 2010 included:

### 1.4 Jellyfish interactions with aquaculture - historical perspective

In August 1984, the Leptomedusa, *Phialella quadrata* (Figure 1.1) was reported as the cause of 1500 Atlantic salmon smolt mortalities at an unnamed location in Shetland (Bruno & Ellis, 1985; Seaton, 1989). This would appear to be the first such documented case of salmonid mortality related to medusae in Scottish waters in the scientific literature.

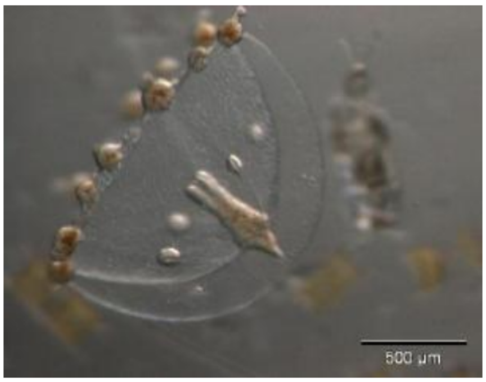



Figure 1.1 *Phialella quadrata* with scale. Photo courtesy of Susanna Knotz.

The late 1980’s must have seen a large number of jellyfish incidents in Norway, as a patent was granted (Vadseth & Vadesth, 1989) for a bag pen enclosure for cultivating a range of marine organisms, in part to avoid “… large schools of jellyfish carried by natural currents, becoming entangled in the nets and causing the farmed fish to suffocate due to a lack of circulated fresh water.” By the following decade, the presence of jellyfish was being included in a suite of indicators used to rate potential farm sites (Levings et al., 1995). A new species was also beginning to cause problems for Norwegian salmon farmers, the string jellyfish *Apolemia uvaria* (Figure 1.2). This species was first implicated in fish farm mortalities in November 1997 (Båmstedt et al., 1998).

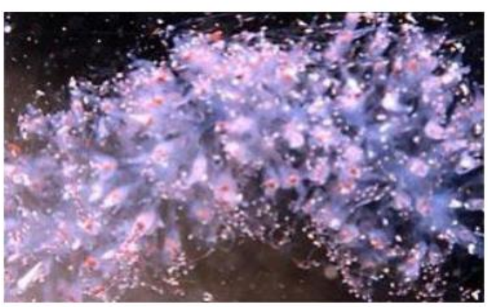


Figure 1.2. The string jellyfish *Apolemia uvaria* (Leseuer, 1815), a hydrozoan.

Around this time, the first mortalities associated with the narcomedusa *Solmaris corona* (Figure 1.3) were reported from Shetland (Båmstedt et al., 1998) whilst the mauve stinger *Pelagia noctiluca* was reported as causing fish mortalities in Brittany in 1995 (Merceron et al., 1995).

Figure 1.3 *Solmaris corona* (Keferstein and Ehlers, 1861). Photo courtesy of Dave Wrobel.

In their review of jellyfish blooms, Purcell et al. (2007) also listed *Phialidium* sp., *Leuckartiara octona* and *Catablema vesicarium* as having caused numerous fish mortalities and large financial loss in 2001-2002 on the Isle of Lewis, although it has not proved possible to verify this report. Occasionally, the scale of mortalities due to jellyfish have led to farm closures e.g. in Loch Torridon in 2001 (McKibben & Hay, 2002), although the jellyfish species responsible was not reported.

The Crown Estate report detailed the results of a survey of salmon farms:

### 2.2 WP1 Results

The most recent data available from 2008 show 257 active Atlantic salmon farm sites in Scotland (Figure 2.1) (Marine Scotland Science, 2008). The SSPO's membership (16 companies)[2] accounts for roughly 95% of the total salmon production in Scotland (J. Smith, SSPO, pers. comm). The questionnaires were disseminated *via* the SSPO but only nine farms made returns. Of these, 66% reported serious jellyfish incidents (defined as causing loss of feeding as a minimum). A total of six jellyfish species were identified as being involved in these incidents (*Cyanea capillata*, *Aurelia aurita*, *Phialella quadrata*, *Solmaris corona*, *Apolemia uvaria* and *Pelagia noctiluca*) and the gelatinous ctenophore (*Pleurobrachia pileus*); of these, three species (*Apolemia uvaria*, *Pelagia noctiluca* and *Solmaris corona*) were responsible for mortalities. Three farm sites had experienced mortalities and one estimated losses of 65%.

When all incidents of jellyfish (serious and non-serious) were plotted against time of year (Figure 2.2), it was found that June and August were the most common months for interactions. Mortalities were confined to August (one farm), September (one farm) and November (two farms). Farms which responded to the questionnaire and reported incidents are shown in Figure 2.3.

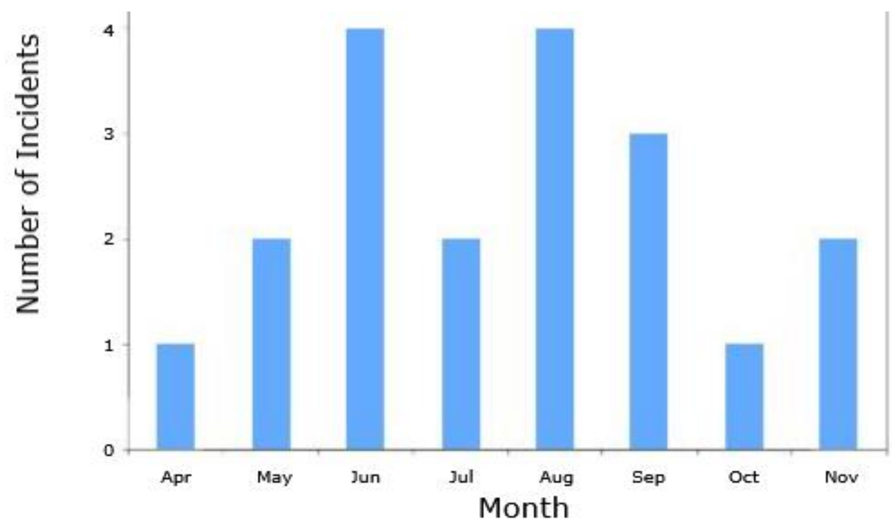



Figure 2.2. Graph showing jellyfish incidents by month.

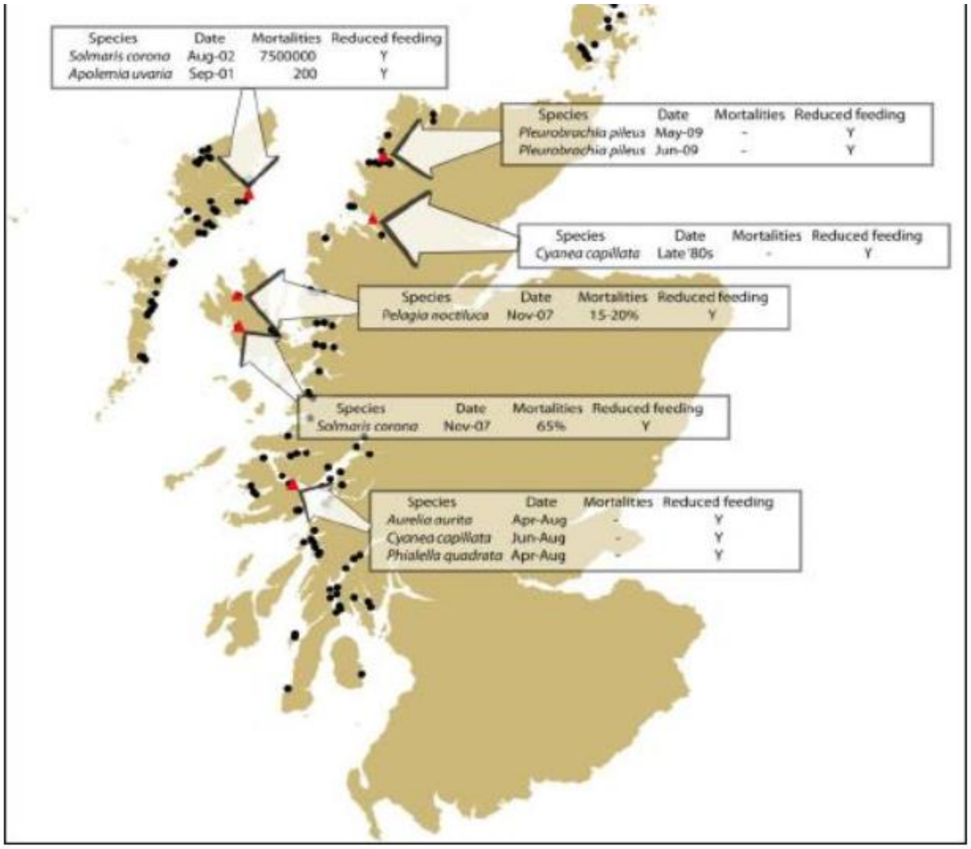



Figure 2.3. Map showing active Scottish fish farming sites (●) and incidents of jellyfish (▲) from responding farms. Data from Marine Scotland Science (2008).

In addition to the questionnaire responses received, the biological manager for a major Shetland producer (with around 45 sites) responded by email to say that they do monitor medusae in plankton samples and had recorded around 30 species, but were unwilling to release the data because of concerns about insurance risk. According to this source the smaller species present in the inshore waters throughout the summer months of the year are of greatest concern, with larger species of scyphomedusae and oceanic species of less concern, at least in Shetland waters.

### 2.3 WP1 Conclusions

The low rate of responses is most noticeable. It may be that concerns about exposing data to insurance companies may have discouraged some returns (presumably the concern is that this could lead to premium increases). Although at present the data are based on a small sample return, 66% of respondents who did respond indicated that jellyfish have caused problems to their operation. The fact that some producers also monitor jellyfish on a regular basis also suggests that this is a serious problem to the industry which requires further investigation within a framework that allows better integration of science and commercial aquaculture interests.

Another report – ‘Jellyfish sampling and identification manual’ - published by the Crown Estate included:

Since the 1990s several science papers have raised the prospect that the frequency and intensity of jellyfish blooms could increase as a consequence of climate change, over-fishing, coastal eutrophication and other factors (Purcell et al. 2007, Richardson et al. 2009, Brotz et al. 2012). However whether jellyfish abundances are really increasing, or not, is highly debateable (Condon et al. 2012). This is principally because we lack historical time-series with which to compare present observations. What is definitely accepted is that jellyfish blooms can cause severe problems for the finfish aquaculture industry.

The incident in which an influx of the oceanic species *Pelagia noctiluca* wiped out a salmon farm in Northern Ireland is often cited (Doyle et al. 2008, Nickell et al. 2010). However such extreme, but relatively rare events, can draw attention away from potentially more wide-spread but lower-level chronic problems. Working at two salmon farms in Ireland, Baxter et al. (2011a) recorded 27 taxa of jellyfish[1] plus other gelatinous zooplankton and potentially harmful algal cells in the water. Correlating the abundance of the various planktonic organisms against fish mortality in cages at the Bantry Bay site revealed a positive link with the abundance of harmful jellyfish[2], with a lag of 1 to 7 days but was not significantly linked with the abundance of harmful phytoplankton.

These results immediately highlight some issues with this sort of study – the potentially large number of jellyfish species which might cause problems (many of these species are hard for the non-specialist to identify), the fact that most of these species have small, transparent medusa and are not easily observed, the correlative nature of this type of study (bearing in mind that association does not always indicate cause and effect) and the potential multi-factor causes of the gill-disease related mortalities (as discussed in those papers). However, (Baxter et al. 2011b) went on to conduct challenge experiments where salmon were exposed to macerated *Aurelia aurita* under controlled experimental conditions – exposure for even short periods of time resulted in similar gill pathologies to those observed in the farm-based study. It seems likely therefore that many jellyfish species could cause problems and we cannot therefore assume that only those species previously identified as causing problems (principally *P. noctiluca*, *Muggea atlantica, Phialella quadrata* and *Solmaris corona*) will always be the culprits (Nickell et al. 2010).

[1]Here we use the term jellyfish to include members of the phylum Cnidaria. In addition other gelatinous organisms found in the plankton include sea-gooseberries (phylum Ctenophora), tunicates (sub-phylum Tunicata) and the arrow-worms (phylum Chaetognatha)

[2]In this study taxa grouped as harmful jellyfish included *Muggiaea atlantica, Phialella quadrata* and *Solmaris corona*, on the basis of previous reports implicating these species as causing problems for caged finfish.

**Figure 1**

***Pelagia noctiluca*** **(maeve stinger) – an example of a species where the benthic polyp stage has been lost**

**(reproduced with permission from Encyclodepia of Life, Owen Wangensteen)**

**Figure 2**

***Aurelia aurita*** **blooms of this species are common especially in the sea-lochs**

**(reproduced with permission from Encyclopedia of Life, image by Stanislav Krečjik)**

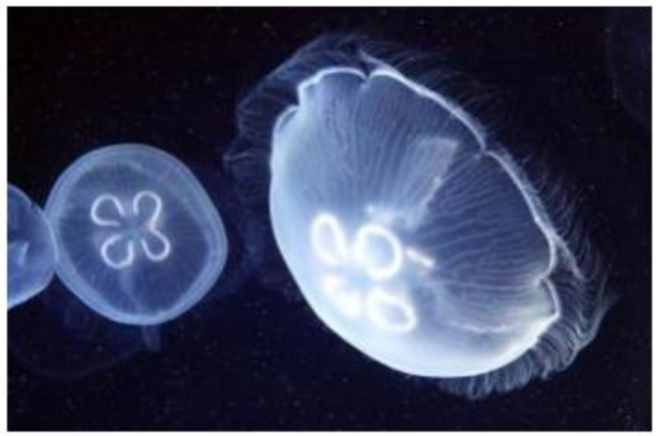


**Figure 3**

***Pleurobrachia pileus*****, a common ctenophore in UK waters showing the sticky fishing tentacles extended**

**Figure 4**

**An appendicularian (phylum Tunicata),** ***Oikopleura doica*****. Usually only the organism itself is seen in plankton samples (as illustrated here), the delicate 'house' it uses for fishing being destroyed during sampling.**

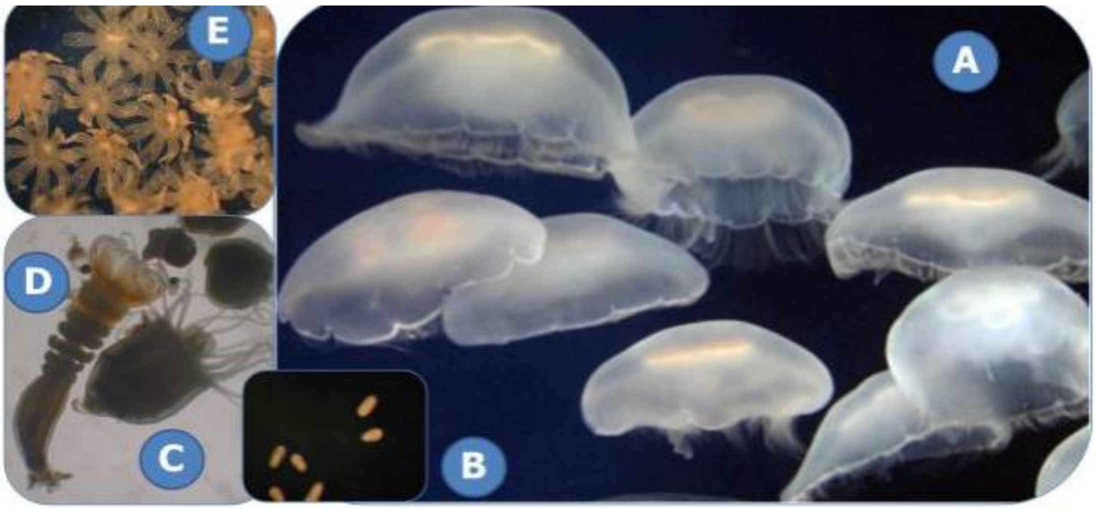



**Figure 5**
**Generalised jellyfish lifecycle (A) Medusae (B) Planktonic planula larvae (C) Benthic polyps (scyphisotma) (D) Planktonic juvenile stage (ephyrae) (Photos Chad Widmer)**

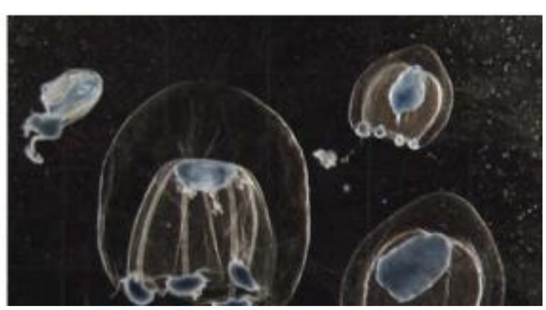
**As a group, the jellyfish show a remarkable range of life-cycles but these can be classified as variations on a basic pattern of alternating planktonic and benthic stages (**

**Figure 5 and Figure 6).**


**Figure 6**
**Example of another species with an alternating benthic and planktonic life-cycle, in this case the species is *Cyanea capillata* (A) Mature medusa (B) Planktonic planula larvae (2) Benthic polyp (scyphisotma) (3) Strobilating benthic polyp (4) Planktonic juvenile stage (ephyrae) (Photos Chad Widmer)**

**Figure 20**

**Many of the features of transparent medusa are more easily seen using dark-field illumination (for microscopes not fitted with this option, a similar result can be obtained using dark card under the sample tray and illuminating from above.**



**[7]** In August 2023, $camon $cotland filed a Freedom of Information request with the Scottish Government; namely:

Your request

You asked for information on jellyfish inside and around salmon farms including:

1) any monitoring data on jellyfish inside and around salmon farms; data on mortalities on salmon farms attributed to jellyfish; welfare problems and disease problems caused by jellyfish on salmon farms; and any other information pertaining to jellyfish (including 'microjellies') and salmon farming.

2) any photos, videos, emails, letters, 'expert advice' provided by Marine Scotland Science and other information relating to jellyfish inside and around salmon farms.

3) information on any scientific research looking into salmon farming as a cause of jellyfish blooms or scientific research on salmon farms exacerbating jellyfish blooms.

4) information on warming sea temperatures and outbreaks of jellyfish at salmon farms.

A FOI reply by the Scottish Government dated 14 September 2023 included:

Response to your request

A copy of some of the information you have requested is enclosed. In particular, this includes some summary information relating to mortalities attributed to jellyfish / plankton, along with some ministerial advice concerning mortality and welfare, and marine heatwaves. This information is provided in Annex 1 of this response.

Some of the information you have requested is available from the Scottish Government website. In particular:

1) Reports of aquatic animal health surveillance conducted by the Fish Health Inspectorate (FHI) where such reports relate to salmon farms and observational details relating to the presence of jellyfish on or near salmon farm sites have been recorded. Such reports may also detail welfare and disease problems caused by jellyfish in cases where this has been observed. Photographs where taken as part of an individual case are also published along with the case information:

https://www.gov.scot/collections/publication-of-fish-health-inspectorate-information/

2) Mortalities reported to the FHI in accordance with reporting requirements detailed within the industry code of good practice - Chapter 4, section 3.5:

https://www.gov.scot/collections/publication-of-fish-health-inspectorate-information/

3) Weekly plankton samples are collected and analysed by Scottish Government's Marine Directorate (SGMD) for the presence of gelatinous zooplankton at both Stonehaven and Loch Ewe – two sites in the Scottish Coastal Observatory (SCObs). SCObs data which have been quality flagged is available to download online:

https://data.marine.gov.scot/search/type/dataset?query=Scottish+coastal+observatory+&sort_by=changed&sort_order=DESC

Data which has yet to be quality flagged can be made available on request. Information on how to use the quality flag system when interpreting SCObs data can be found through:

https://data.marine.gov.scot/dataset/scottish-coastal-observatory-1997-2013-parts-1-3/resource/e67e50ae-e526-4d1b-b4d9

https://data.marine.gov.scot/dataset/scottish-coastal-observatory-dataset-1997-%E2%80%93-

2020/resource/dd3540f2-2e74-4682-a8d3

4) Information relating to scientific research concerning jellyfish and salmon farms can be obtained through simple internet searches.

Under the terms of the exception at regulation 10(4)(a) of the EIRs (information not held), the Scottish Government is not required to provide information which it does not have. The Scottish Government does not have some the information you have requested because:

1) Excluding the information referred to in relation to SCObs the Scottish Government does not undertake monitoring or collect monitoring data relating to the presence of jellyfish in and around the cages of salmon farms

2) Excluding your own video footage, provided to us as part of this request, we hold no video footage relating to jellyfish inside and around salmon farm cages

3) SGMD are not currently involved in any research relating to salmon farms exacerbating jellyfish blooms

**Annex 1 – Information released**

The following information has been extracted from our records as being in scope of your query and so is being released to you:

On mortality associated with jellyfish:

1) Analysis of the cause of mortality within the Scottish salmon Sector from 2018 to 2020 revealed that in, 2018 - 2.65%; 2019 - 2.90%; 2020 – 6.70% of the total mortality experienced for each year was attributed to Jellyfish / plankton as a cause. This information was shared through the Farmed Fish Health Framework in April 2021. The mortality values do not differentiate between jellyfish or plankton but rather are linked together under the term: *Physical or toxic algal damage and jellyfish stings (inc. those impacting gills where jellyfish damage is the primary cause of mortality.*

2) Scottish Government recognises the rise in recent mortality figures – it can be attributed to an unusual bloom of micro jellyfish (*Muggiaea atlantica*) occurring out with its normally recognised range. It is premature to say if this will cause similar problems in future years. *Advice concerning mortality and welfare on fish farms to the First Minister from Marine Scotland 14 March 2023.*

On water temperature, climate change and jellyfish:

1) Evidence of the impacts of marine heatwaves in the UK is limited as this is a rare event but international evidence suggests a variety of impacts are possible including algal blooms, deoxygenation of water column, jellyfish blooms, impacts on fish size and increased mortality risk for marine species including at aquaculture sites.
*Advice concerning marine heatwaves to the Cabinet Secretary for Rural Affairs Land Reform and Islands from Marine Scotland from communications dated 21 June 2023.*

2) Australia is at the forefront of research on the impact of marine heat waves globally.Scientists there have reported reductions of kelp forest, jellyfish bloom occurrences and coral reef loss due to marine heatwaves.
*Advice concerning marine heatwaves to the Cabinet Secretary for Transport, Net Zero and Just Transition from email communications dated 19 June 2023.*

You may also find the attached publicly available information relevant to your request:

https://www.mccip.org.uk/sites/default/files/2022-11/Aquaculture%20Formatted_updated%20and%20returned%20by%20authors.pdf

[$camon $cotland has filed a FOI review request to access further information]

The scientific paper – "Climate change impacts on marine aquaculture relevant to the UK and Ireland" – cited in the FOI disclosure above was published in November 2022 via the Marine Climate Change Impacts Partnership. The paper included:

## KEY FACTS

### What is happening

- In the UK, there have been no major changes to the types or locations of species farmed due to climate change.
- At salmon farms, a strong link between milder winter temperatures, disease and increased fish mortality has been identified.

### What could happen

- Temperatures are expected to remain suitable for salmon growth until the end of the century, when aquaculture in Northern Ireland and the southwest of Scotland may experience seasonal declines due to warming.
- Warming conditions will lead to a rise in outbreaks including sea lice, fish diseases and shellfish pathogens, with subsequent increased mortality.
- The risk of mortality due to more frequent and intense heatwave events will increase in the future, highlighting the need for adaptive management.
- Offshore facilities may be more exposed to structural damage due to potential changes in storm events, with an increased risk of farmed species escaping.

Jellyfish blooms can be a significant cause of mortality for penned finfish (Luisetti *et al*., 2018), mainly through exposure of gill tissue to the stingers resulting in direct traumatic damage, impaired function and triggering secondary diseases (Clinton *et al*., 2021). Globally, most reports of jellyfish impact on aquaculture are on salmon in the North Atlantic (Bosche-Belmar *et al*., 2021) with losses of up to $1.3 million in Scotland and Ireland.

A strong statistical link between increased mortality in salmon farms with milder winter temperatures has been identified (Moriarty *et al*., 2020).

Although complex environmental factors affect jellyfish blooms (Edwards *et al*., 2020), increasing temperatures appear to be a key factor for many species (Kennerley *et al*., 2021). Increasing temperatures may result in greater frequencies of blooming events within the natural long-term cycles

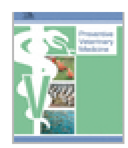
of jellyfish populations, with greater numbers of days occurring where ocean temperatures fall within the optimum physiological tolerances of several native and non-native species (e.g., Collingridge *et al*., 2014). However, there are significant knowledge gaps in species-specific physiological information in response to each of the environmental factors thought to influence jellyfish populations (Kennerley *et al*., 2021).

A scientific paper published in Preventative Veterinary Medicine in May 2020 included:

ELSEVIER

Preventive Veterinary Medicine

Volume 178, May 2020, 104985



# Modelling temperature and fish biomass data to predict annual Scottish farmed salmon, *Salmo salar* L., losses: Development of an early warning tool

M. Moriarty, A.G. Murray, B. Berx, A.J. Christie, L.A. Munro, I.S. Wallace

## Abstract

Losses due to mortality are a serious economic drain on Scottish salmon aquaculture and are a limitation to its sustainable growth. Understanding the changes in losses, and associated drivers, are required to identify risks to sustainable aquaculture. Data on losses were obtained from two open source data sets: monthly losses of biomass 2003-2018 and losses of salmon over production cycles (numbers input minus output harvest) 2002-2016. Monthly loss rates increased, accelerating after 2010, while losses per production cycle displayed no trend. Two modelling frameworks were investigated to produce an early warning tool for managers about potential increases in losses. Both linear regression and beta regression showed that monthly losses related to biomass and minimum winter air temperatures with high precision and low bias. These relationships apply at both the national and regional levels where the beta regression best fit model explain 82 % and 69 % of variation in mortality, some regional differences apply, particularly for the Northern Isles. The lack of trend in losses per production cycle may have been due to shorter production cycles as more salmon were harvested earlier, and possibly increasing losses of larger salmon (which affects biomass but not numbers lost). In the long-term, the models predict that milder winters and increased biomass will be associated with increased mortality, which will need to be managed. In the short-term, given relatively little year-to-year variation in biomass, minimum winter temperature is a powerful early warning of the likely extent of losses in the Scottish salmon farming industry.

A limiting factor in maximum production potential is mortality (Aunsmo et al., 2010). There are a number of contributors to losses such as management, environmental factors, predation and disease (Soares et al., 2011). Monitoring trends in mortality may be used as an operational welfare indicator, as high mortality may be an indication of poor welfare (Ellis et al., 2012). About one third of production losses are attributed to diseases (Soares et al., 2011), the significance of different diseases has changed over time with viral diseases and sea lice increasingly becoming the focuses of research (Murray et al., 2016). Loss levels of Scottish salmon production have been relatively consistent at 10–20 % per production cycle for many years (Salama et al., 2016; Murray and Munro, 2018), however, loss rates above 20 % have occurred in recent years (Munro, 2019) and the emergence of gill diseases is an increasingly serious problem (Oldham et al., 2016; Hall et al., 2017). Changes in climate, particularly water temperatures has been linked to emerging marine diseases (Harvell et al., 1999), and may be an associated factor in increasing mortality on salmon farms (Thyholdt, 2014). Coastal sea surface temperatures around Scotland were, on average, between 0.2 °C and 0.4 °C warmer in the 2006–2016 period when compared to the longer-term average from 1981 to 2010 (Hughes et al., 2018). These temperature rises have been associated with changes in ecology and wild fisheries including salmon growth (Beaugrand and Reid, 2003; Todd et al., 2008). Temperature changes are likely to be associated with changes in aquaculture; as warming temperatures have positive effects that includes increases in growth rate (Calloway et al., 2012; Collins et al., 2020). However, warming temperatures also have negative effects that include increased prevalence and severity in diseases and parasitic infestations such as bacterial diseases (Thompson et al., 2006), sea lice (Rittenhouse et al., 2016) and particularly gill diseases (Oldham et al., 2016; Benedicenti et al., 2019).

The transmission of pathogens in aquatic environments is also likely to be associated with increased biomass. Many pathogens ability to transmit is enhanced as population densities increase (Anderson and May, 1979; Murray, 2009). Pathogens are often exchanged between aquaculture sites, the risk of transmission between sites is attributed to water movements and the distances between sites, and is related to number of sites and biomasses on sites (Salama and Murray, 2011).

A ‘Journal Pre-Proof’ copy of the scientific paper – obtained from lead author Dr Moriarty of the Scottish Government’s Marine Directorate in September 2023 – included additional information not included in the online version:

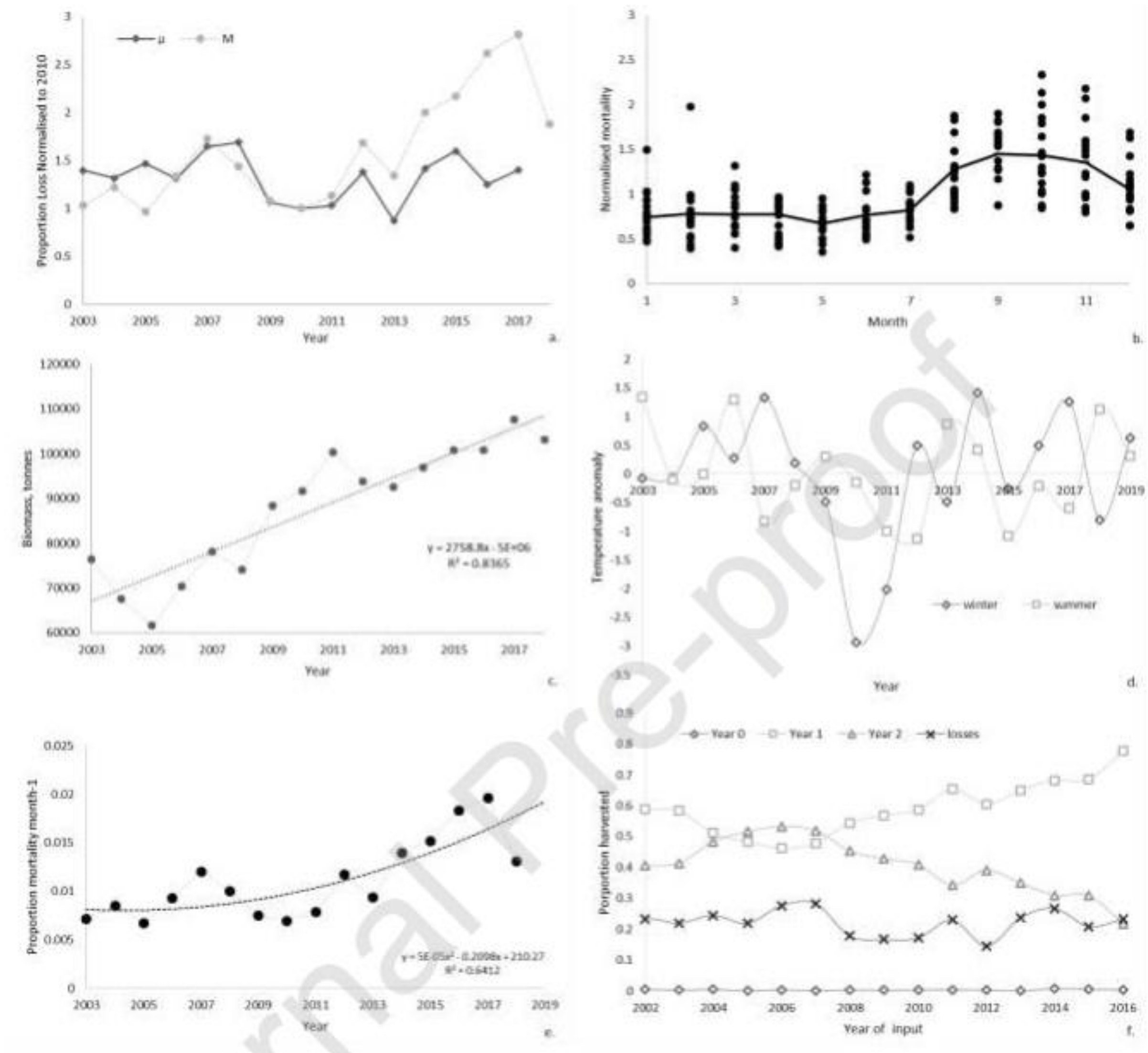



*Figure 2 Provides details about the preliminary data exploration undertaken. (a.) Losses as proportion of biomass per month (M) for 2003-2018 and per production cycle (μ) input in preceding year 2002-2017, normalised to 2010 values. (b.). Monthly losses as proportion of biomass lost per month at national level 2003 -2018, normalised to the average monthly mortality for the year, and mean loss (line). (c.) Average Scottish farmed salmon biomass by year (B) in tonnes for 2003-2018 and regression of 2759 tonnes per year increase. (d.) Temperature anomalies from mean air temperature 2003-2019 at the national level (e.) Proportion monthly biomass lost (M) by year 2003-2018, with a 2$^{nd}$ order polynomial fit (dash line). (f.) Proportion of salmon that are harvested in the year of input (year 0), a year later (year 1) or 2 years (year 2) after input, and proportion of salmon that are lost in the full production cycle (full production cycle: 2002-2016).*

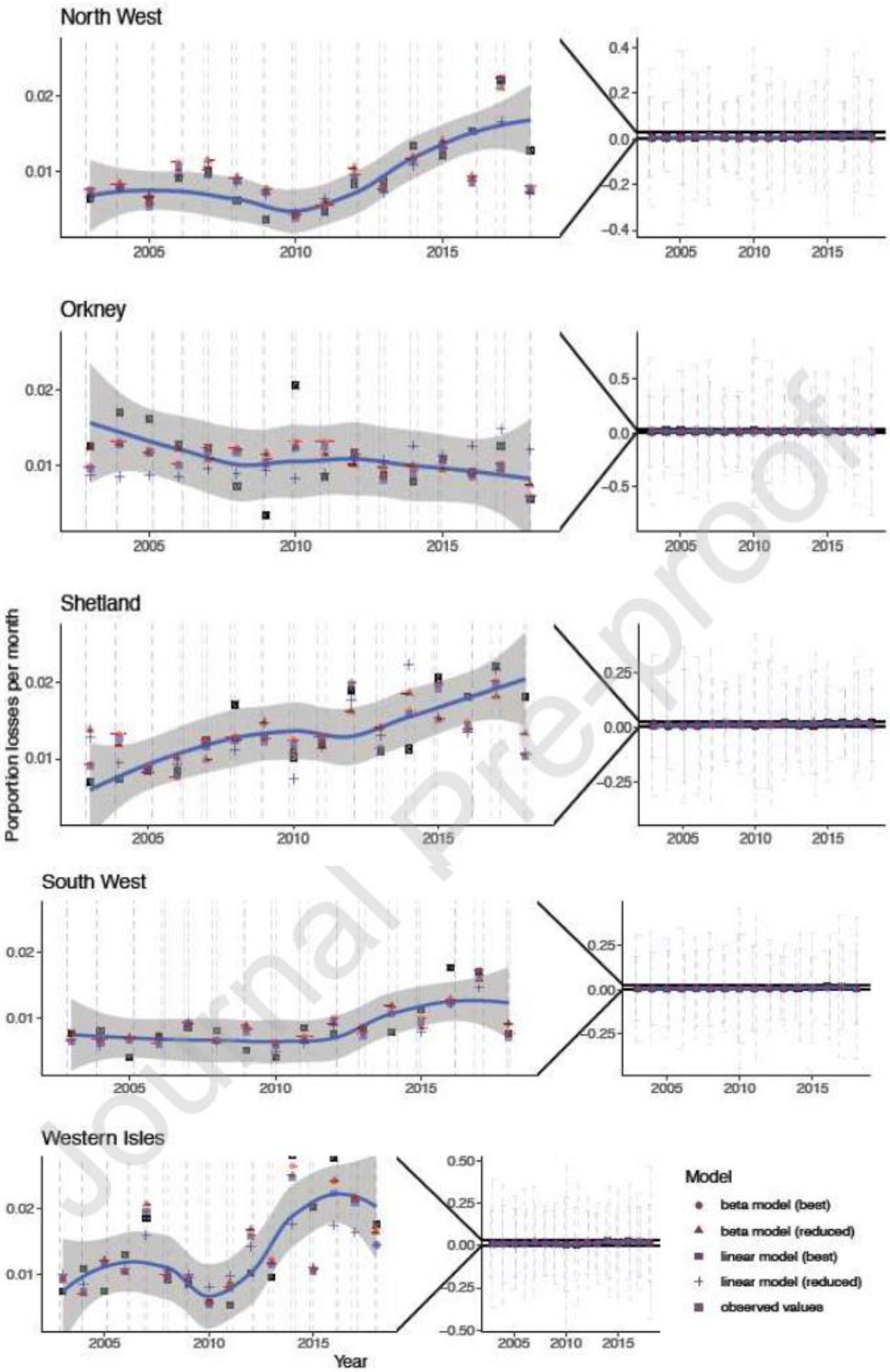



*Figure 3. Plots of regional LOWESS curves for losses with time 2003-2018 indicate an increase in average monthly proportion loss rate after 2010 for most regions. The predicted values from each model summarised in Table 2 are shown. LOWESS curve is based on observed data, error bars show the 95% confidence intervals associated with each model.*

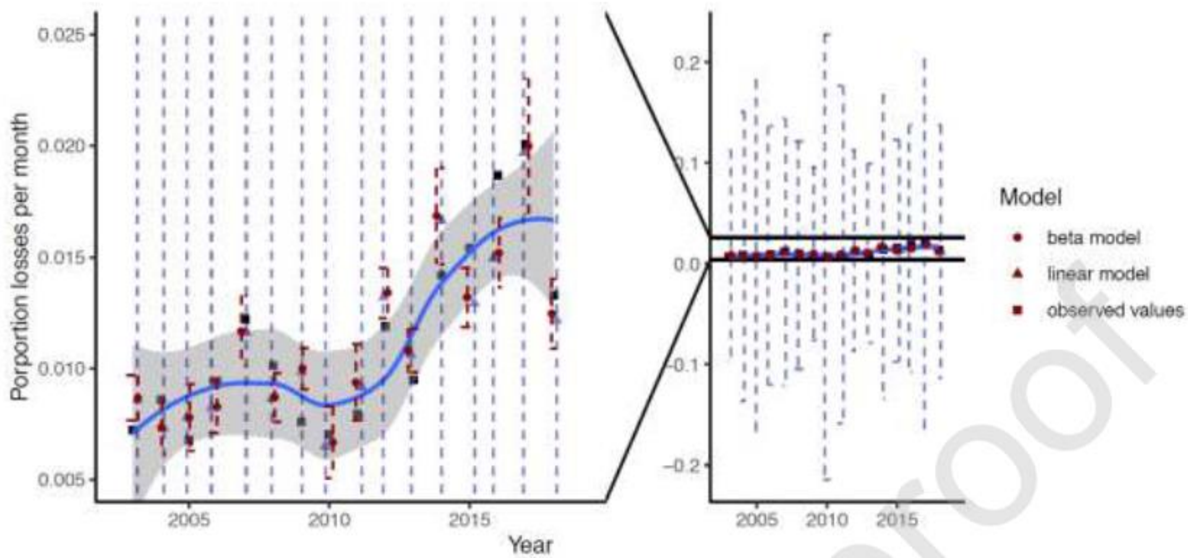



*Figure 4. Plot of national losses over time 2003-2018 indicate an increase in average monthly proportion loss rate after 2010. The predicted values from each model summarised in Table 2 are shown; LOWESS curve is based on observed data, error bars show the 95% confidence intervals associated with each model.*

**Appendix 1**: Monthly losses and biomass (SEPA)

A. Monthly loss as proportion of biomass.

| YEAR | SCOTLAND | NORTH MAINLAND | ORKNEY | SHETLAND | SOUTH MAINLAND | WESTERN ISLES (EILEAN SIAR) |
|---|---|---|---|---|---|---|
| **2003** | 0.007197 | 0.006466 | 0.012337 | 0.006811 | 0.007734 | 0.007277 |
| **2004** | 0.008527 | 0.007841 | 0.016649 | 0.007271 | 0.008135 | 0.010749 |
| **2005** | 0.006742 | 0.00613 | 0.015855 | 0.00829 | 0.004084 | 0.007329 |
| **2006** | 0.009339 | 0.009071 | 0.012545 | 0.008238 | 0.007282 | 0.012809 |
| **2007** | 0.012069 | 0.009865 | 0.012129 | 0.012209 | 0.008499 | 0.018105 |
| **2008** | 0.01003 | 0.006153 | 0.007246 | 0.016883 | 0.008068 | 0.009106 |
| **2009** | 0.007555 | 0.00374 | 0.003375 | 0.012721 | 0.00515 | 0.008313 |
| **2010** | 0.006987 | 0.004294 | 0.020127 | 0.010135 | 0.00405 | 0.005711 |
| **2011** | 0.007898 | 0.004684 | 0.008372 | 0.011955 | 0.008499 | 0.005334 |
| **2012** | 0.011753 | 0.008416 | 0.011493 | 0.018626 | 0.007656 | 0.010012 |
| **2013** | 0.009397 | 0.00866 | 0.008663 | 0.010921 | 0.008451 | 0.009421 |
| **2014** | 0.014001 | 0.013285 | 0.007849 | 0.011162 | 0.007802 | 0.02731 |
| **2015** | 0.015181 | 0.012015 | 0.01079 | 0.02022 | 0.011263 | 0.019701 |
| **2016** | 0.018343 | 0.015175 | 0.008953 | 0.017847 | 0.017363 | 0.026808 |
| **2017** | 0.019667 | 0.021658 | 0.012457 | 0.021681 | 0.016691 | 0.020905 |
| ***2018*** | 0.013120 | 0.012745 | 0.005562 | 0.017808 | 0.007594 | 0.017359 |

B. Monthly mean biomass tonnes by year.

| YEAR | SCOTLAND | NORTH MAINLAND | ORKNEY | SHETLAND | SOUTH MAINLAND | WESTERN ISLES (EILEAN SIAR) |
|---|---|---|---|---|---|---|
| **2003** | 76471 | 20401 | 2843 | 23867 | 15667 | 13691 |
| **2004** | 67529 | 23554 | 2397 | 18097 | 12523 | 10956 |
| **2005** | 61664 | 17759 | 1909 | 13832 | 13710 | 14452 |
| **2006** | 70427 | 24192 | 2009 | 15875 | 14628 | 13720 |
| **2007** | 78112 | 23062 | 3096 | 17848 | 16413 | 17691 |
| **2008** | 74022 | 23985 | 2948 | 20305 | 12678 | 14104 |
| **2009** | 88334 | 22118 | 4237 | 27224 | 20527 | 14226 |
| **2010** | 91687 | 24884 | 4730 | 25592 | 17584 | 18897 |
| **2011** | 100370 | 27023 | 5020 | 29749 | 19812 | 18765 |
| **2012** | 93843 | 24834 | 6380 | 27136 | 17053 | 18439 |
| **2013** | 92490 | 23375 | 6809 | 25920 | 18697 | 17686 |
| **2014** | 96968 | 23630 | 7464 | 27435 | 19007 | 19430 |
| **2015** | 100795 | 32624 | 7421 | 27079 | 18106 | 15564 |
| **2016** | 100791 | 23926 | 8971 | 23513 | 21594 | 22784 |
| **2017** | 107675 | 30004 | 9838 | 27128 | 22279 | 18425 |
| ***2018*** | 103194 | 24141 | 10127 | 23199 | 22220 | 23505 |

From: **Don Staniford** salmonfarmingkills@gmail.com
Date: Thu, Sep 21, 2023 at 9:36 AM
Subject: Re: PDF copy of your paper, pretty please?
To: Meadhbh.Moriarty@gov.scot

Dr Moriarty,

One quick question - when you write:

"Coastal sea surface temperatures around Scotland were, on average, between 0.2°C and 0.4°C warmer in the 2006 to 2016 period when compared to the longer-term average from 1981 to 2010".

Do you have updated data since 2016?

Don

From: Meadhbh.Moriarty@gov.scot
Date: Thu, Sep 21, 2023 at 12:03 PM
Subject: RE: PDF copy of your paper, pretty please?
To: salmonfarmingkills@gmail.com

Hi Don,

As written in the paper we downloaded these temperature data from the MET office website. Here is a link that will bring you directly to the Scotland mean temperature > metoffice.gov.uk/pub/data/weather/uk/climate/datasets/Tmean/date/Scotland.txt

It's best practise to go to the source for these data, as they are updated monthly by the MET office. For wider interest on other temperature data sets they collect have a look here > UK and regional series - Met Office.

Kind Regards,


**Dr. Meadhbh Moriarty**
**Senior Aquatic Epidemiological Modeller**
Marine Directorate| Scottish Government

e: meadhbh.moriarty@gov.scot
w: https://www.researchgate.net/profile/Meadhbh-Moriarty


Here's the latest data from the MET Office website for Scotland: https://www.metoffice.gov.uk/pub/data/weather/uk/climate/datasets/Tmean/date/Scotland.txt

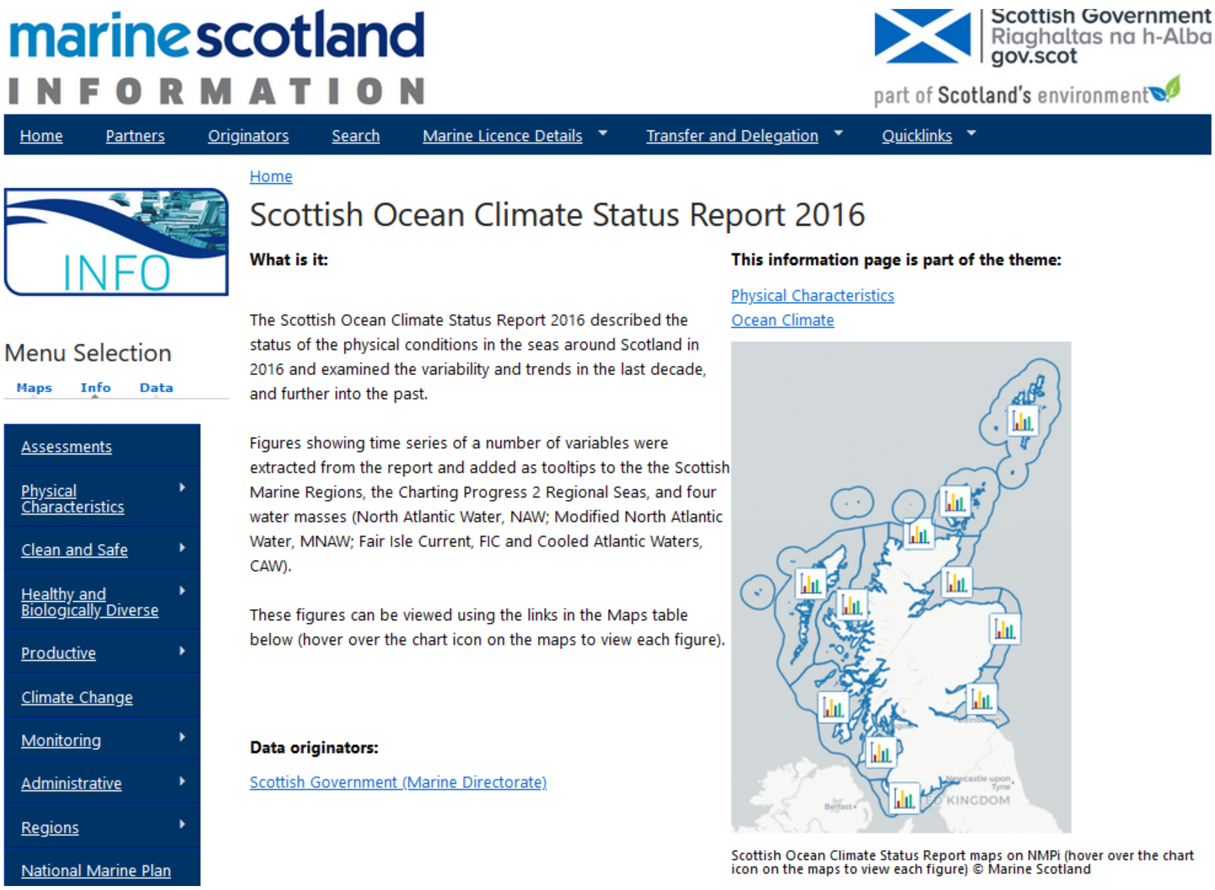
Areal values from HadUK-Grid 1km gridded climate data from land surface network
Source: Met Office National Climate Information Centre
Monthly, seasonal and annual mean air temperature for Scotland
Areal series, starting in 1884
Last updated 01-Sep-2023 10:47

| year | jan | feb | mar | apr | may | jun | jul | aug | sep | oct | nov | dec | win | spr | sum | aut | ann |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1978 | 1.1 | -0.1 | 4.1 | 4.5 | 9.5 | 11.1 | 11.7 | 12.3 | 11.0 | 9.4 | 5.9 | 2.4 | 1.69 | 6.00 | 11.70 | 8.75 | 6.94 |
| 1979 | -1.1 | -0.1 | 1.8 | 5.0 | 6.7 | 11.5 | 12.3 | 11.6 | 10.3 | 8.8 | 4.1 | 2.8 | 0.40 | 4.50 | 11.79 | 7.77 | 6.18 |
| 1980 | 1.1 | 3.1 | 2.4 | 6.7 | 9.1 | 11.2 | 12.0 | 12.7 | 11.6 | 6.4 | 4.4 | 3.8 | 2.30 | 6.05 | 11.99 | 7.45 | 7.04 |
| 1981 | 2.7 | 2.1 | 4.3 | 5.7 | 9.3 | 10.6 | 12.3 | 13.1 | 11.4 | 4.9 | 5.1 | -1.1 | 2.87 | 6.46 | 12.00 | 7.14 | 6.73 |
| 1982 | 1.1 | 3.5 | 3.9 | 6.6 | 8.5 | 11.6 | 13.6 | 12.7 | 10.4 | 8.1 | 4.8 | 2.2 | 1.08 | 6.30 | 12.67 | 7.77 | 7.27 |
| 1983 | 4.1 | 0.7 | 4.6 | 4.1 | 7.5 | 10.7 | 14.6 | 14.2 | 10.1 | 7.7 | 5.6 | 4.3 | 2.37 | 5.39 | 13.21 | 7.82 | 7.40 |
| 1984 | 0.3 | 2.8 | 3.0 | 6.4 | 8.2 | 11.6 | 13.8 | 14.0 | 10.0 | 8.0 | 5.5 | 4.0 | 2.43 | 5.84 | 13.12 | 7.85 | 7.30 |
| 1985 | -0.1 | 1.8 | 2.7 | 5.7 | 8.3 | 10.0 | 12.6 | 11.6 | 10.4 | 8.6 | 1.9 | 3.4 | 1.91 | 5.57 | 11.42 | 7.00 | 6.44 |
| 1986 | 1.3 | -1.1 | 3.5 | 3.7 | 8.4 | 11.7 | 12.3 | 10.6 | 9.2 | 8.2 | 5.5 | 3.1 | 1.27 | 5.20 | 11.55 | 7.64 | 6.42 |
| 1987 | 0.4 | 1.9 | 2.2 | 7.1 | 7.8 | 9.5 | 12.9 | 12.3 | 10.3 | 6.5 | 4.8 | 3.6 | 1.84 | 5.70 | 11.60 | 7.21 | 6.65 |
| 1988 | 2.5 | 2.9 | 3.5 | 5.9 | 9.1 | 12.3 | 12.2 | 12.4 | 10.8 | 7.8 | 4.5 | 5.8 | 3.00 | 6.15 | 12.29 | 7.69 | 7.49 |
| 1989 | 5.7 | 3.6 | 4.1 | 4.5 | 9.2 | 11.0 | 14.4 | 12.5 | 10.5 | 8.7 | 4.6 | 1.6 | 5.08 | 5.96 | 12.66 | 7.96 | 7.58 |
| 1990 | 4.1 | 4.0 | 5.8 | 5.8 | 9.6 | 11.0 | 13.3 | 13.5 | 9.9 | 8.7 | 4.4 | 3.0 | 3.21 | 7.09 | 12.62 | 7.70 | 7.79 |
| 1991 | 1.6 | 1.0 | 5.1 | 5.9 | 9.0 | 9.6 | 14.6 | 13.9 | 10.9 | 7.7 | 4.7 | 3.8 | 1.90 | 6.70 | 12.73 | 7.77 | 7.37 |
| 1992 | 3.2 | 4.0 | 4.6 | 5.9 | 10.3 | 12.8 | 12.6 | 11.8 | 10.1 | 5.3 | 4.4 | 2.2 | 3.65 | 6.98 | 12.38 | 6.61 | 7.28 |
| 1993 | 3.2 | 4.7 | 4.4 | 6.6 | 8.3 | 11.5 | 11.7 | 11.4 | 9.8 | 5.9 | 3.2 | 1.7 | 3.33 | 6.44 | 11.52 | 6.29 | 6.87 |
| 1994 | 2.4 | 1.3 | 3.8 | 5.3 | 7.8 | 10.8 | 13.8 | 12.3 | 9.9 | 7.5 | 7.5 | 3.8 | 1.80 | 5.64 | 12.33 | 8.29 | 7.22 |
| 1995 | 2.0 | 2.9 | 2.5 | 6.0 | 8.5 | 11.6 | 14.3 | 15.2 | 10.9 | 9.9 | 5.8 | 0.3 | 2.92 | 5.64 | 13.72 | 8.86 | 7.51 |
| 1996 | 3.7 | 1.4 | 3.0 | 6.4 | 6.7 | 11.3 | 12.7 | 13.7 | 11.5 | 9.0 | 3.1 | 1.7 | 1.82 | 5.36 | 12.56 | 7.88 | 7.03 |
| 1997 | 2.0 | 3.7 | 5.9 | 6.8 | 8.5 | 11.0 | 13.9 | 15.2 | 10.9 | 7.9 | 6.8 | 4.2 | 2.46 | 7.07 | 13.40 | 8.50 | 8.09 |
| 1998 | 3.2 | 6.4 | 4.9 | 5.0 | 9.6 | 10.6 | 12.3 | 12.6 | 11.9 | 7.0 | 4.3 | 4.1 | 4.53 | 6.55 | 11.84 | 7.72 | 7.67 |
| 1999 | 3.0 | 2.8 | 4.7 | 7.0 | 9.6 | 10.8 | 13.8 | 12.9 | 12.5 | 8.6 | 5.7 | 1.9 | 3.32 | 7.08 | 12.49 | 8.94 | 7.80 |
| 2000 | 3.8 | 3.6 | 5.4 | 5.4 | 9.3 | 10.8 | 12.6 | 13.3 | 11.8 | 8.1 | 4.5 | 3.2 | 3.09 | 6.73 | 12.27 | 8.10 | 7.67 |
| 2001 | 1.3 | 1.9 | 2.4 | 5.4 | 10.1 | 10.7 | 13.0 | 13.0 | 10.7 | 10.6 | 5.9 | 2.4 | 2.14 | 5.97 | 12.25 | 9.09 | 7.32 |
| 2002 | 4.1 | 3.5 | 5.0 | 7.0 | 9.5 | 11.9 | 12.6 | 14.0 | 11.7 | 6.7 | 6.1 | 3.4 | 3.34 | 7.14 | 12.82 | 8.17 | 7.98 |
| 2003 | 2.7 | 2.6 | 5.6 | 8.0 | 9.2 | 12.9 | 14.8 | 14.4 | 11.4 | 6.7 | 6.3 | 3.2 | 2.92 | 7.59 | 14.05 | 8.14 | 8.18 |
| 2004 | 3.3 | 3.0 | 4.7 | 7.4 | 9.8 | 12.0 | 12.7 | 14.4 | 11.6 | 7.6 | 6.0 | 4.4 | 3.17 | 7.28 | 13.07 | 8.41 | 8.09 |
| 2005 | 4.3 | 2.9 | 5.5 | 6.6 | 8.2 | 12.3 | 13.4 | 13.1 | 12.0 | 9.7 | 4.6 | 3.7 | 3.91 | 6.76 | 12.96 | 8.76 | 8.06 |
| 2006 | 3.3 | 2.9 | 2.4 | 5.7 | 8.8 | 12.6 | 15.6 | 13.3 | 13.2 | 9.8 | 6.0 | 4.3 | 3.31 | 5.63 | 13.85 | 9.70 | 8.20 |
| 2007 | 4.6 | 4.0 | 5.1 | 8.9 | 8.7 | 11.9 | 12.7 | 12.5 | 10.6 | 9.3 | 5.9 | 3.3 | 4.31 | 7.56 | 12.40 | 8.64 | 8.16 |
| 2008 | 3.4 | 4.1 | 3.6 | 5.7 | 10.6 | 11.2 | 14.0 | 13.5 | 11.2 | 7.1 | 4.7 | 2.3 | 3.58 | 6.66 | 12.94 | 7.67 | 7.64 |
| 2009 | 2.5 | 2.9 | 4.9 | 7.8 | 9.2 | 12.1 | 13.8 | 13.5 | 11.8 | 8.9 | 5.4 | 0.5 | 2.55 | 7.31 | 13.14 | 8.70 | 7.80 |
| 2010 | 0.2 | 0.4 | 3.8 | 6.6 | 8.3 | 12.6 | 13.2 | 12.4 | 11.2 | 8.0 | 2.7 | -1.7 | 0.36 | 6.23 | 12.75 | 7.33 | 6.51 |
| 2011 | 2.1 | 3.6 | 4.5 | 9.1 | 9.2 | 10.7 | 12.7 | 12.1 | 11.9 | 9.4 | 7.6 | 3.1 | 1.28 | 7.59 | 11.86 | 9.62 | 8.02 |
| 2012 | 3.2 | 4.3 | 7.1 | 4.9 | 8.6 | 10.4 | 12.2 | 13.5 | 10.3 | 6.1 | 4.5 | 2.3 | 3.50 | 6.89 | 12.04 | 6.94 | 7.29 |
| 2013 | 2.8 | 2.2 | 1.3 | 4.8 | 8.3 | 11.5 | 15.3 | 13.6 | 11.1 | 9.3 | 4.1 | 5.0 | 2.45 | 4.80 | 13.50 | 8.21 | 7.49 |
| 2014 | 3.5 | 3.8 | 5.4 | 7.9 | 9.7 | 12.8 | 14.5 | 12.2 | 12.4 | 9.1 | 6.4 | 3.1 | 4.11 | 7.69 | 13.18 | 9.29 | 8.43 |
| 2015 | 2.5 | 2.9 | 4.3 | 6.4 | 7.5 | 10.6 | 12.2 | 12.9 | 10.8 | 8.7 | 6.2 | 5.4 | 2.84 | 6.07 | 11.93 | 8.55 | 7.56 |
| 2016 | 3.1 | 2.2 | 4.6 | 5.1 | 9.7 | 12.2 | 13.1 | 13.3 | 12.7 | 8.4 | 3.4 | 5.6 | 3.57 | 6.49 | 12.89 | 8.14 | 7.80 |
| 2017 | 3.5 | 4.0 | 5.4 | 6.7 | 10.6 | 12.1 | 12.9 | 12.8 | 11.2 | 9.6 | 4.1 | 2.9 | 4.37 | 7.58 | 12.63 | 8.29 | 8.01 |
| 2018 | 2.1 | 1.6 | 2.3 | 6.6 | 10.7 | 13.0 | 14.9 | 12.9 | 10.4 | 8.0 | 6.2 | 4.1 | 2.21 | 6.53 | 13.62 | 8.19 | 7.77 |
| 2019 | 2.4 | 5.1 | 5.2 | 7.5 | 8.3 | 11.6 | 14.7 | 13.9 | 11.4 | 7.2 | 3.6 | 4.1 | 3.85 | 7.01 | 13.41 | 7.37 | 7.93 |
| 2020 | 4.8 | 3.1 | 4.2 | 7.1 | 9.7 | 12.6 | 12.3 | 13.5 | 11.0 | 7.9 | 6.6 | 3.4 | 4.03 | 6.97 | 12.81 | 8.47 | 8.02 |
| 2021 | 0.6 | 2.5 | 5.3 | 4.6 | 7.7 | 12.5 | 15.1 | 13.7 | 12.9 | 9.2 | 6.2 | 3.4 | 2.13 | 5.87 | 13.78 | 9.46 | 7.84 |
| 2022 | 4.7 | 3.9 | 5.2 | 6.7 | 10.2 | 12.5 | 14.2 | 13.9 | 11.9 | 9.7 | 6.9 | 1.6 | 4.00 | 7.40 | 13.57 | 9.53 | 8.49 |
| 2023 | 3.2 | 5.1 | 3.6 | 6.6 | 10.3 | 14.3 | 13.2 | 13.8 | | | | | 3.60 | 6.84 | 13.76 | | |

The full reference for the Hughes et al 2018 report cited in the 2020 Moriarty paper is:

Hughes, S.L., Hindson, J., Berx, B., Gallego, A. and Turrell, W.R. (2018) Scottish Ocean Climate Status Report 2016. Scottish Marine and Freshwater Science Vol 9 No 4, 167pp. DOI: 10.7489/12086-1

The above report is available online here




The 'Scottish Ocean Climate Status Report 2016' included:

Both air and sea temperatures around Scotland have warmed at a similar rate to the global pattern of century-scale warming as reported by the IPCC in 2014. At a multi-decadal scale, during the 1970-1980 to 2010 warming episode, air and sea temperatures across Scotland warmed at a rate faster than the global average.

- The period of 2006 to 2016 was, on average, warmer than normal in Scottish coastal waters, with sea surface temperatures between 0.2 and 0.4 °C warmer than the long-term average (1981–2010).

'Scotland's Marine Assessment 2020' – published online by the Scottish Government includes:

## *What is already happening?*

The global ocean has warmed continuously since 1970, and has taken up more than 90% of the excess heat in the climate system (Pörtner *et al.*, 2019). In line with the global warming trend (IPCC, 2014), Scottish waters (coastal and oceanic) have warmed by between 0.05 and 0.07 °C per decade (Figure 1), calculated across the period 1870 – 2016 (Hughes, Hindson, Berx, Gallego & Turrell, 2018).

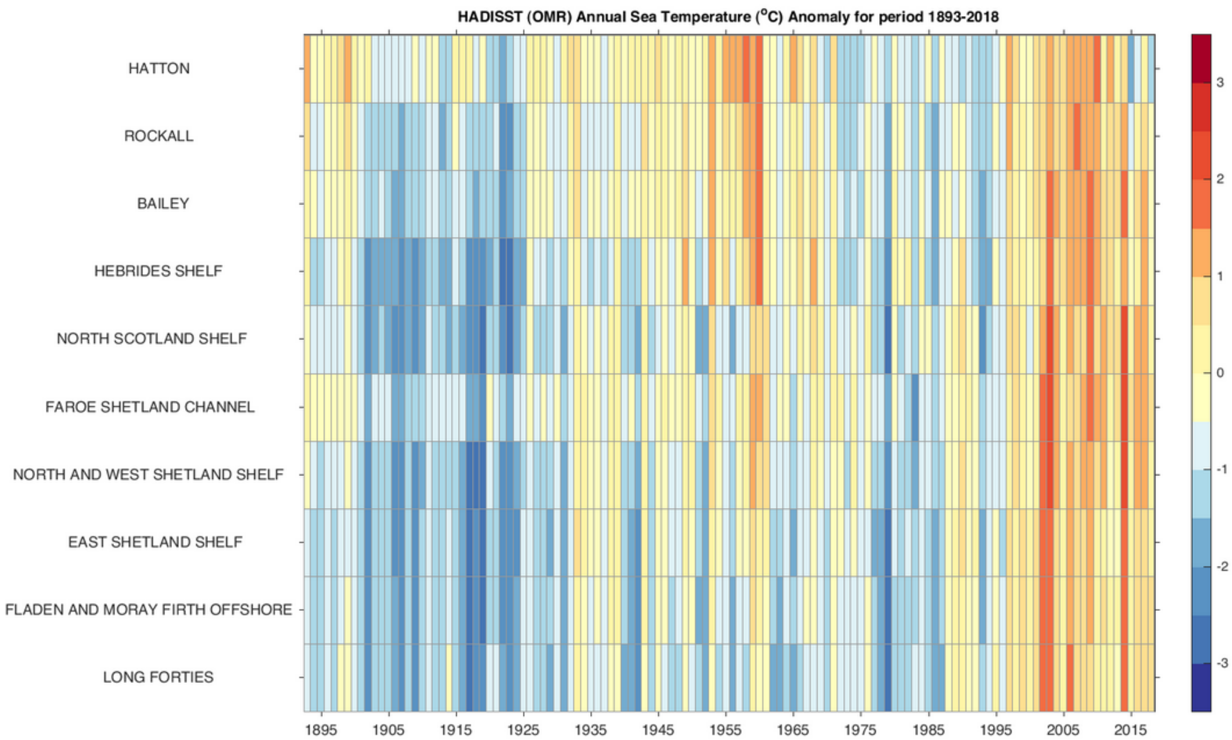



Figure 1: Annual Sea Surface Temperature anomalies relative to the 1981 - 2010 period by Offshore Marine Region (OMR) from an interpolated, combined in situ and satellite gridded product (HadISST 1.1; Rayner *et al.*, 2003). The use of these standardised values allows for easy comparison between regions which may have different variability. These anomalies have been normalised by removing the 1981 - 2010 mean and scaling by the 1981 - 2010 standard deviation for the region.

## *What is likely to happen in future?*

Most climate projections for the end of the 21st century indicate, with medium confidence, warming of between 1 and 4 °C of the north west European Shelf seas. Exact confidence of these trends on regional scales is lower still (Tinker & Howes, 2020), as often future climate projections for these regions have not been subject to dedicated studies.

## Links and resources

Literature and Data sources

Hughes, S.L. et al., 2018. ***Scottish Ocean Climate Status Report 2016***, Marine Scotland Science. Available at: https://data.marine.gov.scot/dataset/scottish-ocean-climate-status-report-2016.

IPCC, 2014. ***Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*** R. K. Pachauri et al., eds., Geneva, Switzerland: IPCC. Available at: https://epic.awi.de/id/eprint/37530/.

Josey, S.A. et al., 2018. **The recent Atlantic cold anomaly: causes, consequences, and related phenomena.** *Annual Review of Marine Science*, 10(1), pp.475-501. Available at: https://www.annualreviews.org/doi/10.1146/annurev-marine-121916-063102.

Pörtner, H.-O. et al., 2019. ***IPCC (2019): Special Report on the Ocean and Cryosphere in a Changing Climate.***, Available at: https://www.ipcc.ch/srocc/.

Rayner, N.A. et al., 2003. **Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century**. *Journal of Geophysical Research: Atmospheres*, 108. Available at: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2002JD002670.

From: **Don Staniford** <salmonfarmingkills@gmail.com>
Date: Fri, Sep 22, 2023 at 8:59 PM
Subject: Scotland's Marine Assessment 2021 or 2022?
To: <Barbara.Berx@gov.scot>

Dr Berx,

I was reading 'Scotland's Marine Assessment 2020': https://marine.gov.scot/sma/assessment/sea-temperature. Do you know if there is a 2022 version or an update?

From: <Barbara.Berx@gov.scot>
Date: Mon, Sep 25, 2023 at 3:01 PM
Subject: RE: Scotland's Marine Assessment 2021 or 2022?
To: <salmonfarmingkills@gmail.com>

Dear Don,

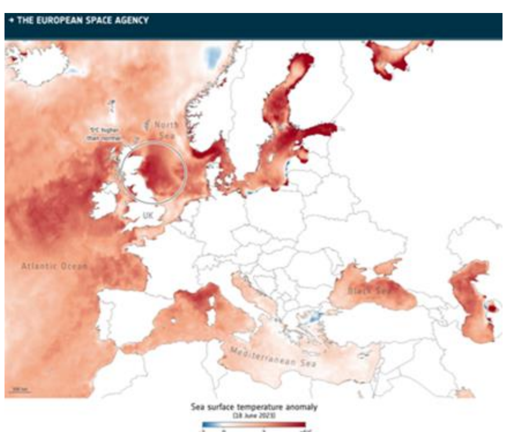
No, there has been no update to Scotland's Marine Assessment 2020.

Kind regards, Bee

From: **Don Staniford** <salmonfarmingkills@gmail.com>
Date: Mon, Sep 25, 2023 at 5:29 PM
Subject: Re: Scotland's Marine Assessment 2021 or 2022?
To: <Barbara.Berx@gov.scot>

Thanks - if an update is published a copy would be much appreciated. Do you have data on sea temperatures in Scotland?

The ESA reported in June:
https://www.esa.int/ESA_Multimedia/Images/2023/06/UK_suffers_marine_heatwave




Do you have data for the West coast of Scotland and salmon farming areas in the Western Isles, Orkney and Shetland?

From: Barbara.Berx@gov.scot
Date: Tue, Sep 26, 2023 at 8:00 AM
Subject: RE: Scotland's Marine Assessment 2021 or 2022?
To: salmonfarmingkills@gmail.com

Dear Don,

While we have looked at data from the recent heatwave through the products made available by NOAA in the USA, there is nothing further on this to share.

If we publish any updates to our time series, or assessments, I will be sure to let you know. At this stage, I can't help you any further with your questions.

Kind regards, Bee


**Dr Bee Berx**

Environment Monitoring and Assessment Programme
Oceanography Group
Physical Oceanographer / MSS Climate Change Lead

E-mail: Barbara.Berx@gov.scot

Marine Scotland Science, Marine Laboratory, 375 Victoria Road, Aberdeen, AB11 9DB, UK


**[8]** The University of Stirling reported in September 2021:

> A University of Stirling scientist has been awarded £1.5 million for an innovative four-year data project that will enable marine aquaculture to respond to impacts from climate change.
>
> Dr Lynne Falconer, of the University of Stirling's Institute of Aquaculture, has been awarded a UK Research and Innovation (UKRI) Future Leaders Fellowship award for her proposal to use data from salmon farms located on the coasts of Scotland and Norway to develop tools for better industry decision-making.

Dr Falconer co-authored a scientific paper published in 2020:

Collins C, Bresnan E, Brown L, Falconer L, Guilder J, Jones L, Kennerley A, Malham S, Murray A & Stanley M (2020) Impacts of climate change on aquaculture. In: *MCCIP Science Review 2020*. Lowestoft: Marine Climate Change Impacts, p. 482–520. http://archive.mccip.org.uk/media/2031/21_aquaculture_2020.pdf; https://doi.org/10.14465/2020.arc21.aqu

**Abstract**

Aquaculture is a significant industry in UK coastal waters, with annual turnover valued at more than £1.8bn. It particularly important in western and northern Scotland. • Aquaculture is sensitive to the marine environment and changes therein. • The dominant contribution of a single species (Atlantic salmon) to production tonnage and value potentially increases vulnerability to climate change. • Temperature increase is expected to increase growth rates for most species farmed. • Increased problems associated with some diseases and parasites, notably sea lice and gill disease (which has emerged as a serious problem), are likely to increase in the short term and to get worse in the longer term. Impacts may be synergistic. • Harmful Algal Blooms (HABs) and jellyfish swarms/invasions may also get worse, however complex ecosystem interactions make responses uncertain. • The situation for shellfish is similar to finfish, although they are additionally at risk of accumulation of toxins from HABs, and recruitment failure, and, in the longer term, to sea-level rises and ocean acidification. • Technical and management changes in the rapidly evolving aquaculture industry make long-term impacts of climate change difficult to forecast.

Read in full online here – including:

*2.2.6.1.2* Jellyfish blooms: Jellyfish blooms are reviewed in an accompanying MCCIP report (Edwards *et al.,* 2020). In terms of aquaculture, blooms impact the suitability of intermediate and supporting ecosystem services such as suitable seascapes for the rearing of penned finfish (Luisetti *et al.,* 2018). Blooms also impact the suitability of built human capital designed for the purposes of fish farming (Bosch-Belmar *et al.,* 2017). Specifically, jellyfish blooms cause extensive mortalities in finfish due to net obstruction, $O_2$ reduction and nematocyst liberation that causes gill disorders, which leads to intoxication (Lynam *et al.,* 2011; Lucas *et al.,* 2014). Some evidence also suggests that medusae are a significant carrier of pathogens (Delannoy *et al.,* 2001) and that blooms are a health hazard to aquaculturists (Bosch-Belmar *et al.,* 2017). Extensive blooms of *Pelagia noctiluca* in 2007 across the Celtic Sea were associated with the death of over 100,000 farmed salmon though intoxication, resulting in revenue losses of £1 million (Doyle *et al.,* 2008). In the early 2000s blooms of *Cyanea lamarkii* in waters surrounding the Isle of Lewis in Scotland were associated with mortality of around 2.5 million penned salmon, with estimations of total economic loss of £5 million (Johnson 2002).

2.2.6.2.2 Jellyfish blooms: Jellyfish blooms could occur more regularly under warming scenarios as perceptions exist that link the phenomenon to climate change (Attrill *et al.,* 2007). Evidence of increasing populations includes counts of gelatinous material in data collected by Continuous Plankton Recorder (CPR) tows, that suggest jellyfish biomass has been on the rise since the turn of the century (Licandro *et al.,* 2010). An array of studies in the literature and reports in the media also generally reference patterns of increasing bloom frequencies worldwide (Richardson *et al.,* 2009). However, caution is required when considering this perception, as these relatively short-term increases could simply have occurred within natural cyclical population patterns (generally over a 20–30 year time period) that jellyfish are known to undergo (Licandro *et al.,* 2010, Condon *et al.,* 2013). Also, biases towards the perception of increasing blooms have recently been identified (Condon, 2012, Sanz-Martin *et al.,* 2016), contributing to a high level of uncertainty in relation to future blooming patterns in response to climate change and the associated impact on aquaculture operations. There is also a lack of long-term population trends data to back up the perception as sampling of jellyfish has been relatively sporadic, but efforts have been underway to expand this since 2012 (e.g. the citizen science reporting tool: jellywatch.org).

Although complex environmental factors affect jellyfish blooms (Edwards *et al.,* 2020), increasing temperatures appear to be a key factor for many species (Philippart *et al.,* 2011, Mar-Lopez *et al.,* 2014), increasing temperatures may result in greater frequencies of blooming events within the natural long-term cycles of jellyfish populations. However, there are significant knowledge gaps in species specific physiological information in response to each of the environmental factors of relevance.

Read more via:

Edwards, M., Atkinson A., Bresnan E., Hélaouët P., Ostle C., Pitois S. and Widdicombe C. (2020) Plankton and Jellyfish. *MCCIP Science Review 2020,* 322–353

Including:

For example, long-term monthly changes in the frequency of jellyfish nematocysts (stinging cells) in CPR samples show an increase in frequency of gelatinous zooplankton in the North Sea and North-east Atlantic (Attrill *et al*., 2007). In many other marine regions worldwide, a proliferation of jellyfish are seen as an indicator of ecosystem degradation. Since some jellyfish feed on fish eggs, fish larvae, and zooplankton, they can exert both top-down and bottom-up control of fish recruitment.

Dr Lynne Falconer of the University of Stirling co-authored a scientific paper published in PLOS Climate in March 2022:

# PLOS CLIMATE

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

## Insight into real-world complexities is required to enable effective response from the aquaculture sector to climate change

Lynne Falconer, Trevor C. Telfer, Angus Garrett, Øystein Hermansen, Eirik Mikkelsen, Solfrid Sætre Hjøllo, Bruce J. McAdam, Elisabeth Ytteborg

Published: March 1, 2022 • https://doi.org/10.1371/journal.pclm.0000017

Article | Authors | Metrics | Comments | Media Coverage

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- 1. Introduction
- 2. Methodology
- 3. Analysis
- 4. Discussion
- 5. Conclusions
- Supporting information
- Acknowledgments
- References

Reader Comments
Figures

### Abstract

This study demonstrates how a comprehensive knowledge base can be used by the aquaculture industry, researchers, and policymakers as a foundation for more targeted and detailed climate change impact analysis, risk assessments and adaptation planning. Atlantic salmon (*Salmo salar*) production in Norway was used as a case study and to illustrate the need to consider impacts from multiple stressors across different production stages and the wider supply chain. Based on literature searches and industry news, a total of 45 impacts and 101 adaptation responses were identified. Almost all impacts were linked to multiple climate stressors, and many adaptation responses can be used for a range of impacts. Based on the research, a move towards more targeted and detailed assessments is recommended. This can be facilitated through a strong knowledge base, further research to address complexities, and better communication between all stakeholders. The results also demonstrate the need for more climate change research that reflects the challenges that the aquaculture sector faces, where multiple stressors and the range of impacts across production stages and the wider supply chain are included. Highlighting the wide range of stressors, impacts and adaptation responses provides a more holistic understanding of the real-world complexities that aquaculture producers face. This again could facilitate adoption of more effective responses to climate change needed to maintain or increase production sustainably.

From: **Don Staniford** <salmonfarmingkills@gmail.com>
Date: Tue, Sep 19, 2023 at 6:35 AM
Subject: Climate change & salmon farms
To: <lynne.falconer1@stir.ac.uk>

Dr Falconer,

I was reading the MCCIP paper you co-authored:
https://www.mccip.org.uk/sites/default/files/2022-11/Aquaculture%20Formatted_updated%20and%20returned%20by%20authors.pdf

Do you have sea temperature data for the salmon farming areas in Scotland?

Aquaculture North America [reported in December 2022](#):

Aquaculture North America

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"From research trials, we know that salmon can withstand temperatures up to 23 C," she said. "But, if you take into account the complexities of the environment as well as real-life activities at the farm, high temperature alone is not what the fish actually experience.

"In Canada, the fish had been handled for sea lice treatments three weeks before, then the temperature increased and the oxygen also dropped at the same time. So, the fish started actually to die at only 17 C. These are the real-world complexities of multiple stressors."

In the published research, the comprehensive analysis of these stressors yielded not only an in-depth discussion but also a matrix that readers can download and open in Excel.

"We are hoping that this spreadsheet will be used in discussions between researchers and industry as they prioritize which projects to pursue," said Ytteborg.

The Norwegian and Scottish researchers also identified a total of 101 adaptation responses, in four categories: biological (e.g., reduce handling; adjust feeding to encourage salmon to swim deeper), environmental (e.g., use spatial models to select most suitable sites; improve jellyfish and harmful algae bloom detection), policy (e.g., develop action plans to respond to fish health hazards; review and revise regulation on potential feed ingredients), and technical (improve feed storage facilities; use oxygen pumps). The paper also puts these adaptation responses in the context of the different production stages.

But adapting in the real world will bring challenges. "Not all adaptation responses are suitable at all locations, and there may be interactions between them that influence how effective they are," added Lynne Falconer, who is a research fellow at the Institute of Aquaculture at the University of Stirling.

"Industry will need to make decisions on what to prioritize. Some responses will be farm-specific, while others will be industry level," she said.

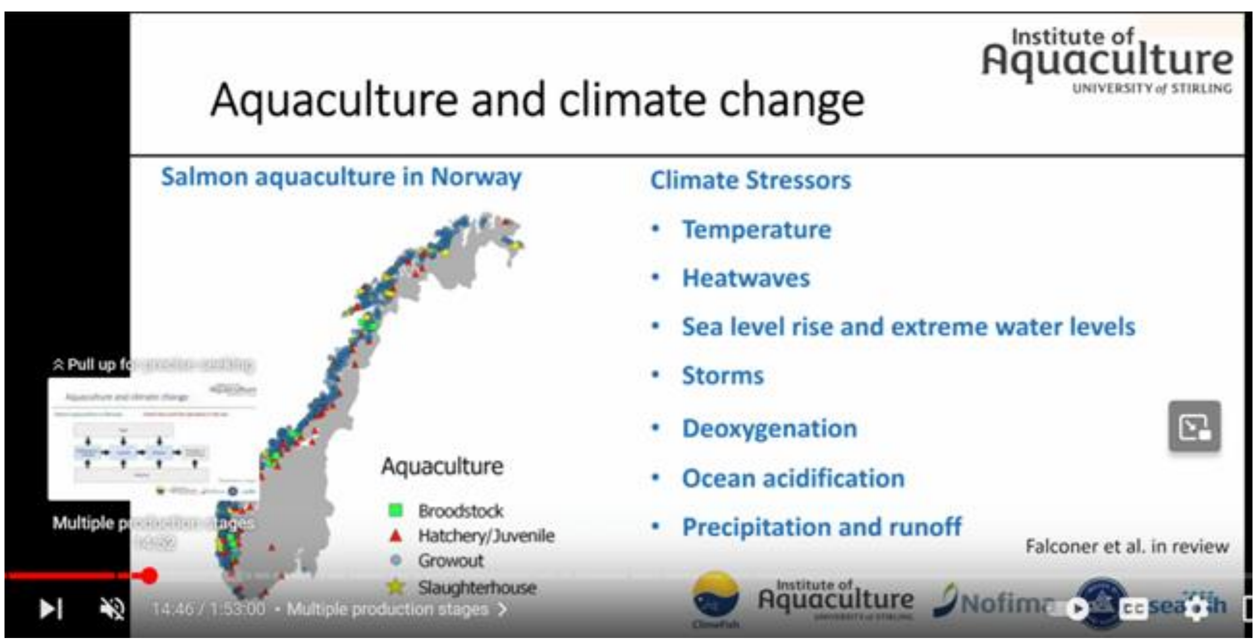
Examples of adaptation responses include technology that is already available, such as oxygen pumps, as well as longer-term strategies.

"In addition to what we identify in the paper, there are also transformative changes such as species diversification," she noted.

In September 2023, Dr Falconer was to be found [working with the Global Salmon Initiative:](#)

> *"Collaboration is essential for sustainable climate action. By working with GSI I get to see the realities about salmon farms rather than just my computer trying to work it out for myself, and we can learn from each other to adapt much quicker."*
>
> *— Dr. Lynne Falconer, UKRI Future Leaders Fellow at the University of Stirling*

In September 2021, Dr Falconer participated in a [climate change webinar hosted by Fish Farmer magazine]() and featuring Anne Anderson of Scottish Sea Farms:

Minutes of a ‘Fish Health Framework Group’ meeting in November 2022 – published in August 2023 – included reference to hydrozoans (hydrozoa is the largest group of jellyfishes, with some 3,800 species):

Scottish Government
Riaghaltas na h-Alba

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Publication - Minutes

# Farmed fish health: Scotland's Farmed Fish Health Framework group minutes - November 2022

Published: **8 August 2023**
Directorate: Marine Directorate,
+1 more ...
Part of: Environment and climate change, Farming and rural, Marine and fisheries
Date of meeting: **24 November 2022**

Minutes from the meeting of the group on 24 November 2022.

The group reviewed the work that has been completed by SAIC on harmfull algal blooms (HABs) including potential projects that could follow on that will help in the creation of early warning systems, including training for those in the sector. A discussion followed on the problems experienced by the sector this autumn with zooplankton and hydrozoans, and the need to include these species in further work. There is a need to understand both what is happening now, and what may develop in the longer term.

**[9]** The Herald [reported in August 2023](#):

The Herald

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# Why tiny jellyfish are such a big threat to salmon farming

26th August

SALMON FARMING | ENVIRONMENT

By Vicky Allan
Senior features writer

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Hydrozoan animal Hydra sp. under the microscope *(Image: D. Kucharski K. Kucharska/Shutterstock)*

**After record-breaking mortalities in 2022, the salmon farming industry in Scotland is facing another turbulent year of shockingly high fish deaths and reduced harvest revenues, which is already being part-blamed on blooms of micro jellyfish.**

But what exactly are these jellyfish, and are they really to blame? Certainly many are claiming so.

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The Herald article included:

> I started to look into this issue after, I went, with anti-salmon-farm campaigners, to observe a Bakkafrost farm off Mull which, local intelligence had informed, was in the midst of a significant mortality event.
>
> When I interviewed Bakkafrost CEO Regin Jacobsen, he acknowledged the problem at Geasgill farm and two others and blamed the tiny hydrozoans.
>
> "What we see right now," he said, "is mainly jellyfish which are coming in huge swarms or blooms. They are coming with the tide. It seems to be that specific sites are more vulnerable than others, and there is also a common factor that if the salmon is standing a very long time, meaning two years in the sea, they get more vulnerable after the second summer. We have three sites - Geasgill is one of them - and these three sites have in common that the fish have been standing there for a second summer now."
>
> **What are these jellyfish like?**
>
> The type of jellyfish Mr Jacobsen described really are "micro", at less than 1cm diameter, and one of the ways, he said, that they have an impact on the health of salmon is that when the fish breathe, the organisms run through the gills of the fish, stinging and burning them, and effectively reducing their capacity to breathe.
>
> "Just as lower lung capacity can affect human general health," Jacobsen said, "impacting on heart health and blood pressure, so the same happens in the fish. Then if there is somehow a stress event, then there are increased mortalities."
>
> Research is being done into the impact of various different species of the microjellyfish. Among them is Muggiaea atlantic, a type of hydrozoan known as a siphonophore. The Fish Health Forum quoted fish veterinarian Chris Matthews, who at an industry event explained how gill disease outbreaks were often linked with the presence of this organism whose range has expanded in recent years and is linked to warmer water.
>
> Also linked to gill disorders is the micro jellyfish Solmaris corona. But jellyfish don't just affect the gills, they also can cause skin lesions, and are known to carry pathogens, among them the bacteria causing the ulcerative disease tenacibaculosis.

This year's mortality records show the jellyfish Obelia blamed for problems by a number of farms.

**Are the micro jellyfish affected by warmer seas?**

One of the big questions is whether the rise in micro jellyfish impacts on salmon farms relates to climate change and a warming sea – and whether, therefore, this is only likely to get worse. This last year has seen what has been described as a marine heatwave, chiefly on surface water and, in the North Atlantic, which was particularly anomalous in the North Sea and Irish Sea in June.

Regin Jacobsen noted that, over the past ten years, microjellyfish incidents have become more severe and that has coincided this year with the heatwave. “We see that sea temperature is higher now. This year the temperature looked like it was running one month earlier than last year. We saw already in June this year that we had almost the same temperature in June that we had last year in July. This year in July we had the same

temperature as August, and the difference was 2C which is quite significant.”

Jacobsen, however, is not so sure that the warm seas are entirely to blame for the blooms. “If you look at the last twenty years,” he says, “we have also seen in the last twenty years similar temperatures – so we are still within the normal deviation. Therefore I don’t think the picture is so clear that we can only blame the temperature of the water.”

**READ MORE: One farm, 2 billion lice. Report shows extent of Scottish salmon industry infestation**

**READ MORE: A Scottish salmon farm visit. Haunted by mortalities and jellyfish**

**Are there any other reasons why jellyfish may be impacting salmon farms?**

Possibly the farms themselves are fostering the blooms. The 2013 book Advances in A Aquaculture Hatchery Technology declares: “Ironically, aquaculture may be inadvertently exacerbating the problems with jellyfish blooms.”.

Increased nutrients around farms, due to excess fish food and waste food, it said, “could create eutrophic conditions that may favour jellyfish over fish”.

**Is it really just the jellyfish that are to blame?**

Jellyfish are also not the only factor impacting on fish gill health. As anti-salmon-farm activist Don Staniford says: "The dead fish we've seen at Geasgill could have been killed by gill diseases, pathogens, viruses, pancreas disease – there are a whole raft of diseases and we only find out when the data is released later in the year."

"Salmon farming in Scotland is dead in the water," he says. "A deadly cocktail of warming seas, swarms of jellyfish and microjellies, plagues of lice and infectious diseases is killing off millions of Scottish salmon."

He is right to point out that it is a cocktail of factors. Most salmon farm deaths are, in fact, not officially credited to jellyfish. Rather the reasons noted include viral disease, bacterial disease, heart and skeletal muscle inflammation, pancreatic disease, cardiomyopathy syndrome (severe heart disease), furunculosis (boils), and various other conditions, not to mention those infamous lice.

The struggle against infestation with lice continues, and earlier this year WildFish issued a report which found that last year the Scottish industry breached its own guidelines on lice levels, or failed to supply a lice count, for 40% of its count.

By far the most common cause of death given, however, is "gill health-related", and in the Fish Health Inspectorate's mortality records kept since 2018, this appears 1265 times, eight times more often than jellyfish, though the two often appear in conjunction, and sometimes also with algae. Lice is mentioned 499 times.

Inside the phrase "gill health" is a multitude of causes and a whole bigger question about salmon health, welfare and sustainability.

Jellyfish are just one piece of a jigsaw that this year could see, in 2023, mortalities even worse than the 16.7 million of last year.

Fish Farming Expert reported in September 2023:

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The RASxFloater is designed to be towed for stocking or delivery, but would spend most of the farming cycle in a sheltered location such as a harbour. Image: Next Tuna / AFRY

# Floating RAS 'can be aquaculture's answer to climate change'

## Climate threat

"We all know that climate change is a threat to aquaculture, especially when we look into open net pen aquaculture. We see that events of extreme heatwaves are going to be more frequent, we're going to have more storms, more flooding, a more unsafe environment for open production in aquaculture," said Sindilariu. "These events lead to adverse production environments like algae blooms, water pollution that we cannot keep away from our fish, jellyfish invasions.

"On top of that we have the impact of farming to the surrounding environment, and the feedback loop to the farming environment [from fish faeces]. This then adds to image loss for aquaculture, and we see restrictions in licensing, and even public penalties like the tax in Norway or the reduction of the number of licences in Canada. These are all effects that are working against open net pen aquaculture, so we must have different approaches for an efficient, climate-resilient form of aquaculture production."

Alaska Public Media [reported in September 2023](#):

ALASKA PUBLIC MEDIA PBS npr

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# ‘Too hot’ for salmon: How climate change is contributing to the Yukon salmon collapse

By **Kavitha George, Alaska Public Media - Anchorage** - September 26, 2023

are low in a vitamin called thiamine, which may cause weakened immune systems.

ALASKA PUBLIC MEDIA TV RADIO NEWS EDUCATION SUPPORT ABOUT DONOR PO

ison said warming river water might also play a role.

In fact, the Yukon is warming twice as fast as rivers further south as a result of climate change.

“It’s crazy to be at the northern-range extent of salmon and talking about it being too hot for them,” said Vanessa von Biela, a U.S. Geological Survey ecologist.

Salmon are cold-blooded, meaning they can’t regulate their internal temperature. When the river gets above 65 degrees Fahrenheit, that’s a problem.

When it’s too hot, Von Biela said, the proteins that keep salmon cells functioning normally start to lose their shape. Warm water also makes it harder for their hearts to pump oxygen to their bodies.

“Their whole physiology, their whole body is designed to be in cold water,” she said. “So when that water is warm, they just really hit these limits.”

In a 2020 study, von Biela found that in an average year half of all Yukon kings swimming upriver have heat stress.

And it’s not just the river that’s warming. The ocean is heating up too. Climate change is bringing on more marine heat waves, or periods of severe ocean warming.

Plant Based News reported in September 2023:

## Farmed Salmon 'Plagued' With Sea Lice And Jellyfish During Summer Heatwave

Campaigners described the problems they saw as "monstrous"

BY CLAIRE HAMLETT 28TH SEPTEMBER 2023 4 MINUTES READ

***Warning: this article contains images that some might find distressing***

Salmon at farms supplying major UK supermarkets were "plagued" with sea lice and jellyfish blooms during an unprecedented marine heatwave this summer, according to a new investigation.

Vegan charity Viva! Captured footage from five farms operated by Bakkafrost, Scottish Sea Farms, and Mowi, all located in lochs off the west coast of Scotland. The farms supply Asda, Co-op, Sainsbury's, M&S, and Tesco. All were battling high levels of sea lice, gill inflammation, and bacterial disease.

Blooms of jellyfish also surrounded several of the farms, potentially contributing to more fish deaths. Increasing numbers of jellyfish in such areas may be down to warming oceans. This summer has seen exceedingly high water temperatures around the west coast of the UK – another source of stress for the caged salmon.

## Jellyfish and marine heatwaves

The number of jellyfish surrounding some of the farms was also alarming to Viva!. The salmon farming industry blamed micro-jellyfish for a rise in salmon deaths in 2022. The tiny jellyfish can kill salmon by blocking and stinging their gills, But some campaigners say that overcrowding on farms and a rise in infectious diseases is the real problem.

Whether jellyfish are killing fish or not, increasing jellyfish blooms may be caused by another environmental stressor to the fish: the climate crisis.

This summer, the waters off the west coast of the UK reached temperatures 4 to 5°C above normal. That made it one of the worst marine heatwaves in the world. The National Oceanic and Atmospheric Administration's (NOAA) Marine Heatwave Watch has categorised the event as a Category 4 (extreme) marine heatwave.

The Herald reported in September 2023 on mass mortalities at Bakkafrost's Geasgill salmon farm off the Isle of Mull:

The Herald

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## 210,000 salmon dead at one salmon farm in one month

11th September

SALMON FARMING ENVIRONMENT

By Vicky Allan
Senior features writer

**New data has revealed that a shocking 210,000 fish died at a single farm on Mull in the month of July alone.**

These are the dead fish I saw at Geasgill farm in early August. It confirms what we observed when I visited the site, run by Faroes-based company Bakkafrost, with activist Don Staniford in early August, following a local tip-off.

Nets full of dead fish were being pulled from the farm's pens. Skips were piled full with morts.

What was clear from observation was that a mass mortality event was in progress at Geasgill and these figures back that up. What we observed at the site was the seventh worst mortality event in Scottish salmon farm history - though further mortalities from August could make it even bigger.

The worst mortality event in Scottish salmon farm history was at Bakkafrost's Druimyeon site in 2021, which had a mortality of 82.1%, amounting to a mass of around twice that which has so far been seen at Geasgill.

But Geasgill, whose mortality rate for July was 23.7%, is not the only Bakkafrost farm struggling with mortalities this year. Bakkafrost's CEO told me that two other farms had been impacted by microjellyfish. One of these was Gravir Outer on Lewis which suffered mortalities of 22.6% in July.

Its CEO Regin Jacobsen told me: "We saw that the activity in the company was heavily under-invested and we have committed ourselves to do everything possible to bring the level of activity up to the same level as we have in the Faroe islands. But it takes a lot of investment to do so. We have had a range of issues to do in Scotland. Unfortunately, it takes time to change it.

"What we see right now is mainly jellyfish which are coming in huge swarms or blooms."

Fish Farming Expert reported in September 2023:

Fishfarmingexpert About us Contact Jobs FFE Newsletter


One of the new, larger pens being installed in Loch Nevis. Photo: SSF

# £1.5m upgrade for sites hit by micro-jellyfish last year

Bigger pens will enhance growing conditions for Scottish Sea Farms

*Editorial team*

PUBLISHED Monday 04. September 2023 - 08:30

Salmon producer Scottish Sea Farms is spending £1.5 million to upgrade farms in Loch Nevis where fish were severely impacted by micro-jellyfish blooms last autumn.

Two of its three farms in the loch – Nevis A and Nevis B – are being modernised, while Nevis C is being temporarily rested, SSF said in the latest edition of its newsletter, The Source.

Whereas previously there were 12 x 80-metre-circumference pens at each farm, there will now be five 120m pens, reducing the overall number of units from 36 to just 10 while maintaining the same overall biomass.

This will allow more space between pens and increase water exchange and oxygen flow in and around farms, which in turn will enhance growing conditions.

With fewer pens for the farm teams and support vessels to get around, the new configuration will also help maximise operational efficiencies and response times.

## Climate challenges

Innes Weir, SSF's regional production manager for the Scottish mainland, told The Source: "We've seen at other farms that have been through the process already that consolidating into fewer pens but of a larger size gives us the ability to better manage our resources, equipment, fish health and welfare, and water quality.

"It also provides greater scope to minimise the impact of environmental challenges that can pass through farms, such as the acute micro-jellyfish event that affected Loch Nevis last autumn.

"That was a natural point for us to pause, reflect on what worked well about the site but also what more we might be able to do going forward to pre-empt the challenges of an ever-changing climate."

## Reduced volumes

In September last year blooms of *Muggiaea atlantica*, a hydrozoan that can sting or block the gills of fish, causing death or exacerbating other problems, contributed to Scotland's three biggest salmon farmers slashing annual harvest estimates.

Mowi Scotland and Bakkafrost Scotland each reduced guidance by 10,000 tonnes, and SSF by 8,000 tonnes. Smaller operators also suffered losses.

The Loch Nevis farms were hard hit, with monthly mortality increasing from 0.8%, 1.6%, and 0.6% at Nevis A, B, and C respectively, to 12.8%, 21.6% and 27% in September, and 45%, 74%, and 12.2% in October, when Nevis C was fallowed. Nevis A and B were fallowed the following month.

Cumulative mortality for the full production cycle at Nevis A, B, and C was 46.8%, 64.3%, and 22.9% respectively.

The Observer reported in September 2023:

**The Observer**
Fish

# 'Monstrous' sea lice and jellyfish invasions blighting Scottish salmon farms

Vegan charity and its drones reveal that parasites are infesting fish reared for UK supermarkets

**Jon Ungoed-Thomas** *and* **James Tapper**

Sat 16 Sep 2023 15.46 BST

Filming at the Bakkafrost salmon farm at West Strome, Loch Carron, also showed fish lice infestations. The farm's own official reported counts in 2023 of weekly average female adult sea lice per fish have been between zero and 2.14. Filming at three farms operated by Scottish Sea Farms at Loch Kishorn showed sea lice and swarms of jellyfish.

Scottish Sea Farms at Kishorn South, one of the company's three farms where underwater drones revealed salmon infested by sea lice and jellyfish. Photograph: Viva!

Video footage [published by Viva in September 2023](#) shows jellyfish swarming in June 2023 around Kishorn South salmon farm operated by Scottish Sea Farms in Loch Kishorn:


Viva!
@vivacampaigns

We reveal the damaging impacts of cruel fish farming in our latest investigation into Scottish salmon producers 🐟

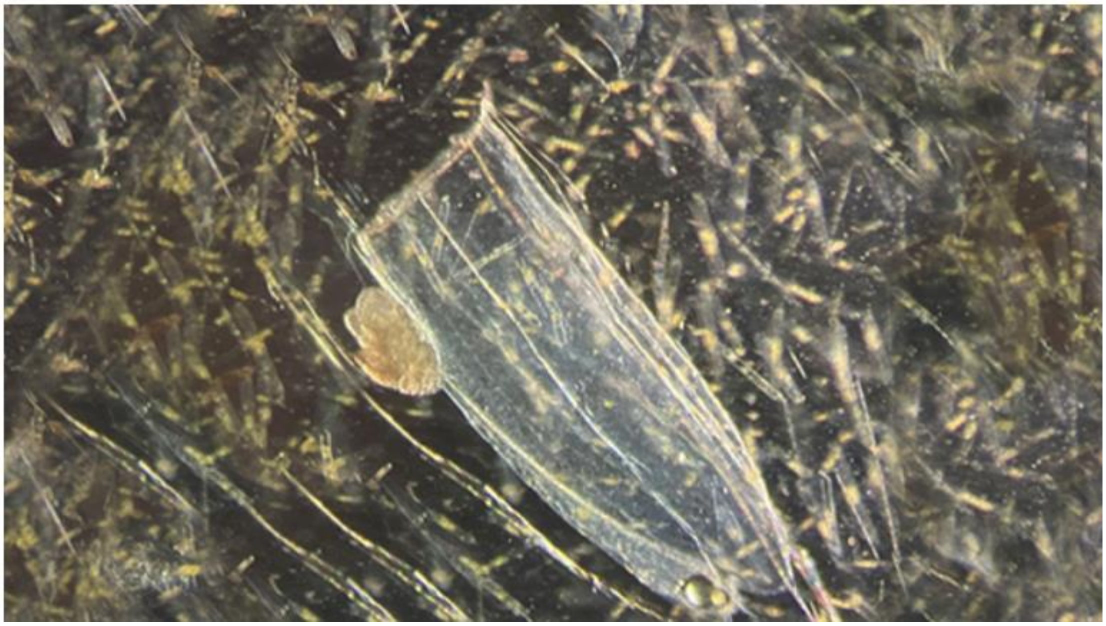
👀 Watch the video: buff.ly/44Uciyy


10:10 AM · Sep 17, 2023 · **219** Views

Fish Health Forum reported in April 2023:

## Tackling jellyfish blooms affecting farmed fish in the British Isles

By Carly Feeks | April 17, 2023 | 0



Tiny jellyfish have contributed to cases of gill disease in farmed Atlantic salmon in Scotland and Ireland in the past year, but early recognition and maintaining good general gill health are key to reducing the threat.

Speaking at an industry event in Inverness, Chris Matthews, business unit director for PHARMAQ Analytiq and fish veterinarian, explained that gill disease outbreaks in 2022 have often been linked to the presence of *Muggiaea atlantica,* a type of micro jellyfish known as a siphonophore.

*M. atlantica* is a relatively recent visitor to British waters, but recent years have seen an expansion of its range, brought on currents and linked to warmer water allowing it to more successfully reproduce around Britain's coast.

### Monitoring effort increasing

This type of jellyfish is capable of combining with one other to create functional colonies or chains yet remain difficult to see with the naked eye. High mortalities have previously been associated with the species in Norway and Scotland, Matthews said, with blooms reported of up to 2,000 colonies per cubic meter. However, even much lower levels — just one microscopic colony in every 5 liters of water — are known to cause behavioral issues and gill irritation in fish, meaning that vigilance is crucial.

"There was probably more zooplankton monitoring undertaken across Scotland in 2022 than we've ever done in the past. Many sites are now trained to collect samples at least once a day at different depths, and then examine the water to identify and count any micro jellyfish present," he said.

"Credit to those on-site who have to be trained up to do this, because counting them is a really difficult task."

## Timing provokes greater gill issues

Gill issues tend to peak in late summer and autumn, alongside seasonal peaks in jellyfish abundance, he continued. Challenge from amoebic gill disease (AGD) is more severe in relatively warm years such as the past year, so the arrival of jellyfish blooms causes pathology on top of pre-existing changes in the gill and, ultimately, higher mortalities than usual.

Attention to maintaining the best possible gill health ahead of seasonal peaks in plankton, including micro jellyfish, is key to achieving the best possible outcome when faced with elevated levels of harmful species.

"Attention to good net hygiene, AGD management in the early cycle and achieving a healthy, robust fish through optimal nutrition and husbandry all improve case outcomes in the face of elevated micro jellyfish levels," Matthews said.

"Particular focus on very early-stage identification and treatment of AGD in late spring, when amoebae levels are naturally low, is likely to be a good strategy ahead of the arrival of waterborne irritants such as jellyfish as the water warms."

## Range of jellyfish known to industry

*M. atlantica* is not the only type of jellyfish capable of causing issues on the Atlantic coasts of the UK and Ireland, he noted. Among several examples of harmful species, another species of micro jellyfish, *Solmaris corona*, has been associated with gill disease on Scottish salmon farms in the past, with blooms of around 200 individuals per cubic meter thought to be capable of killing fish.
*Pelagia noctiluca*, known as the mauve stinger, has caused mortalities around the Western Isles of Scotland when huge blooms arise between August and late autumn. The well-known moon jellyfish (*Aurelia aurita*) in lower numbers tend to be a benign presence, he said, but can occasionally bloom in "extraordinarily high" numbers and pose a fish health risk through deoxygenation of water.

## Understanding risks

The threat of jellyfish is generally connected to the numbers of individuals in blooms, and upon reaching a critical mass, there are a number of ways they can negatively affect fish.

Jellyfish venoms are extremely diverse, Matthews explained, and contact between the venom-producing organs of the animals and fish skin or gills can cause both trauma and the release of toxins into fish tissues. As found with *M. atlantica,* skin damage can result in infection by opportunistic pathogens, but jellyfish can play an even more direct role in this respect.

"We now know that jellyfish can carry species of bacteria potentially pathogenic to fish, and we do see cases of tenacibaculosis following exposure to jellyfish," he noted.

As well as tackling AGD early, carrying out regular zooplankton monitoring is also a good investment.

"Even though work is still underway to better identify what levels of different species should trigger management decisions such as changing feeding strategy or providing aeration, it does allow farmers to understand and recognize the threat and make decisions along with their health teams on how to manage these cases," he added.

"I expect both our knowledge and ability to use technology to characterize, quantify and manage harmful zooplankton blooms to increase significantly in the future."

The Herald reported in March 2023:

## A Scottish salmon farm visit. Haunted by mortalities and jellyfish

11th March

> Another farmer shook his head as he recalled the micro-jellyfish blooms that blighted some farms over the past autumn.
>
> The farm hand said: "We've never seen them like they were the end of last year, which was catastrophic."
>
> The issue of micro-jellyfish is a repeated refrain, though this farm, Fishnish, was not impacted by them last year.
>
> Anne Anderson, the director of sustainability for Scottish Sea Farms, said: "This farm was okay, but what might come in next year? What will the seas bring us? That's the thing. I'm constantly thinking what will the seas bring, where will it occur? And that's why that ocean monitoring, to give us an early warning, is so important."

Part of this story is believed to be down to jellyfish. In November last year, Scottish Sea Farms reduced estimates for its 2022 harvest by 8000 tonnes, blaming the mortalities on micro-jellyfish and gill health issues.

They were not alone. Mowi, Bakkafrost and Cooke Aquaculture, said something similar. Mowi, for instance, slashed its harvest guidance by 17 percent, saying, "Our Scottish farming operations has experienced a troublesome year with regards to biology."

Ms Anderson added: "Micro-jellyfish are the latest thing on top of a series of things. Small incremental differences in temperature, as we have with **climate change**, make a huge difference in the way that the tides and currents flow. They affect whether there are algal blooms and where they move to. We found micro-jellyfish at a level that has not been typically found in Scottish waters before."

Less than 2mm in size, these hydrozoans are so small, said Anderson, that the filtration and monitoring required to catch them and see them "was the next level down from what we were using". The damage they cause is believed to be through irritation to the salmon gills - and gill health is one of the biggest issues in salmon farming.

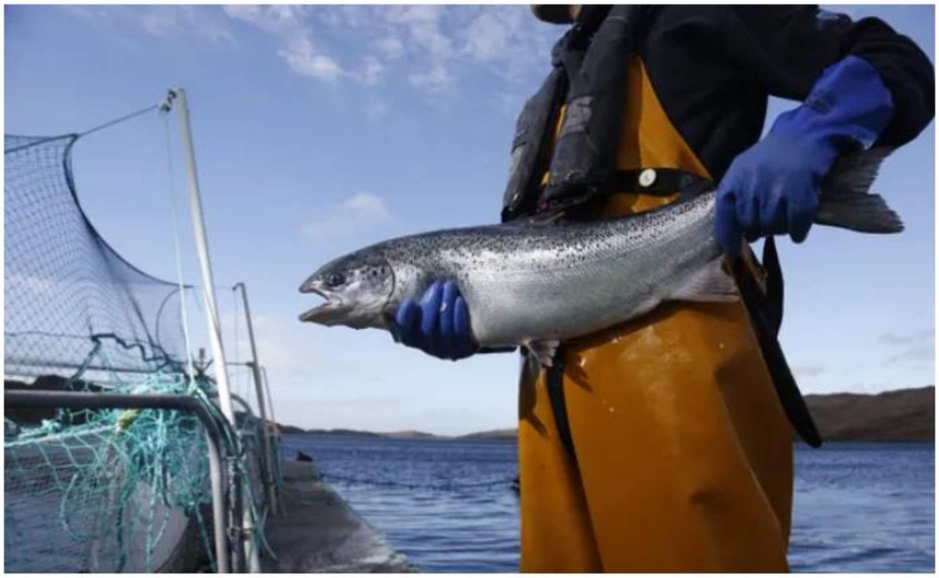
The Observer reported in January 2023:

# Salmon deaths on Scotland's fish farms double – but are jellyfish to blame?

**Marine farmers point finger at jellyfish swarms but campaigners call for boycott to curb 'ever-worsening problem' of overcrowding**

**James Tapper**

Sun 15 Jan 2023 10.00 GMT



A salmon farmed by the Loch Duart company in Sutherland, which uses lower than average density pens for its fish. Photograph: Murdo MacLeod/The Observer

Salmon deaths on fish farms in Scotland nearly doubled last year, official figures show, owing to growing levels of disease, parasites and jellyfish blooms. Campaigners have blamed overcrowding and called for a boycott.

The Fish Health Inspectorate, part of Marine Scotland, is responsible for monitoring the 213 seawater sites in Scotland farming salmon. The farms have a voluntary agreement to report salmon deaths over certain thresholds, a Scottish government spokesman said.

"The mortality reports list multiple factors – for example gill issues, bacterial or viral infection, handling, or predation – so it is not always possible to allocate mortalities to a specific cause," the spokesman said.

"However, gill health remains a key issue. There has been an increase in attributing environmental issues, including jellyfish and plankton blooms, and bacterial infections as a cause of mortalities in 2022."

Salmon Scotland said that jellyfish blooms can force a site to be closed down, or fallowed, with farmers harvesting all the fish.

Intrafish reported in January 2023:

IntraFish Latest News Salmon Whitefish Shrimp Aquaculture Fisheries Markets IntraFish.

# Jellyfish, diseases, parasites: Scotland's farmed salmon mortalities hit 15 million in 2022

Losses have increased 158% in two years.

19 January 2023 5:01 GMT *UPDATED 19 January 2023 5:01 GMT*

By **Matthew Wilcox**

The number of salmon deaths on fish farms in the UK nearly doubled in 2022 according to official figures released by Scotland's Fish Health Inspectorate (FHI).

Salmon producers have blamed the losses on poor genetics, increasing levels of disease, parasites and jellyfish blooms.

FHI data reveals that nearly 15 million salmon mortalities were reported from January to November 2022, a 75 percent increase on the 8.58 million reported in all of 2021 and 158 percent increase on the 5.81 million reported two years ago.

**Scotland marks sore point for farmed salmon producers as geography plays key role in Q3 profits**

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The Scottish government's 2021 fish farm production survey reveals that 205,393 metric tons of salmon was harvested in 2021, an increase of 7 percent on the previous year.

The biggest challenges facing farmed salmon normally come in the fall when seawater temperatures peak.

Tavish Scott, chief executive of Salmon Scotland said, said in a statement that survival rates were relatively high during 2022, but that losses spiked in September with the jellyfish blooms.

"We are working with industry and academia to develop an early-warning system that helps to safeguard fish from jellyfish blooms in the future," he said. (Copyright)

## Read more

- Scottish salmon in danger of losing market share as high prices and short supply wreak havoc
- Mowi slashes salmon harvest estimates in Scotland after jellyfish outbreaks cause steep losses
- Jellyfish fail to scupper Mowi's Q3 as salmon farmer scores 83% earnings hike

Fish Farming Expert [reported in November 2022](#):



A salmon undergoing a gill health check. Micro jellyfish that can sting and block gills have caused widespread problems in Scotland. Photo: Sustainable Aquaculture Innovation Centre

# Micro jellyfish blooms take heavy toll on Scottish salmon

Hydrozoans were a principal cause of record monthly mortality in September

*Editorial team*

PUBLISHED Wednesday 09. November 2022 - 09:30

Blooms of micro jellyfish have been blamed for the deaths of a significant number of farmed salmon in Scotland. Figures published today show that 2.8 million salmon died in September, making it the worst month for fish mortalities since farmers began publishing mortality statistics in January 2018.

The mortalities amounted to 4.6% of the salmon being farmed in Scotland in September.

Academic researchers and salmon and trout farmers have standardised procedures on how to collect and process water samples and share water quality data to tackle the problem, which may be linked to increasing sea temperatures caused by climate change.

## No clear trend

Regin Jacobsen, chief executive of Faroese company Bakkafrost, yesterday highlighted micro jellyfish, or hydrozoans, as a cause of large losses for the company's Scottish operations in the third quarter of this year.

Answering a question about the issue at the presentation of Bakkafrost's third-quarter results, he said: "There are some areas that have not been impacted, but they were impacted two years ago, so it's not a clear trend where you can say there are some areas that are clearly out of this.

"It seems like these algae, these blooms, are coming in different areas, and when you look at the whole industry, it is more or less all over."

Mortality figures published by trade body Salmon Scotland today show heavy losses at some sites as a direct result of jellyfish / plankton. Although the jellyfish can be as small as 2 mm, they can sting or block the gills of fish, causing death or exacerbating other problems.

Stings and cuts caused by micro jellyfish and sharp plankton (flagellates) also contribute to amoebic gill disease (AGD), another cause of die-offs.

## Orkney to the Hebrides

Salmon Scotland's figures show that the micro jellyfish blooms are not restricted to a specific area. In September, Cooke Aquaculture had 4.3% mortality at its Lyrawa Bay farm, Orkney, due to jellyfish / plankton and gill health related issues, and Loch Duart lost 55.9% of the stock at its Loch Carnan farm off the north coast of South Uist in the Western Isles.

Mowi Scotland lost 23.9% of the fish at its site off Muck and 25.2% at Rum, both in the Inner Hebrides, due to jellyfish / plankton. A further 21.7% of fish at Marulaig Bay off South Uist, 13.9% at Hellisay, Barra, and 9.7% at Loch Harport, Skye, died from the same cause.

Wester Ross Fisheries, now owned by Mowi, lost 7.6%, 8.6%, and 4.7% of stock at its Ardessie A, Ardessie B, and Ardmair farms respectively due to jellyfish / plankton, and 10.7% of the fish at Organic Sea Harvest's Invertote farm off the northeast coast of Skye perished for the same reason.

Scottish Sea Farms did not have any deaths directly caused by jellyfish / plankton in September but suffered losses of 12.8%, 21.6% and 27% at its Nevis A, B, and C sites on Loch Nevis due in part to gill health challenges.

## Emerging threats

Tavish Scott, chief executive of trade body Salmon Scotland, said: "Whether on land or sea, raising animals outdoors inevitably comes with risks as the climate continues to change and evolve, but that makes environment-induced events such as micro jellyfish no less devastating to the farmers caring for those animals day in, day out.

"It's why we're so committed to increasing our understanding of new and emerging threats in order to better safeguard the health and welfare of our salmon."

Intrafish reported in November 2022:

IntraFish Latest News Salmon Whitefish Shrimp Aquaculture Fisheries Markets IntraFish.no

# Mowi slashes salmon harvest estimates in Scotland after jellyfish outbreaks cause steep losses

Fourth quarter harvest volume for Scotland is predicted to be low as mortalities linked to jellyfish and poor genetics continue to drag on results.

15 November 2022 8:00 GMT UPDATED 15 November 2022 18:02 GMT

By Matthew Wilcox

Mowi, the world's largest salmon farmer, saw earnings at its Scottish operations drop by almost 70 percent as low growth and high mortalities took their toll.

CEO Ivan Vindheim blamed the losses in part on jellyfish outbreaks around Skye and the Western Isles.

As a result of the losses, Mowi was forced to slash its harvest guidance by 17 percent to 50,000 metric tons for this year, and reduced its projections for next year to 65,000 metric tons.

Micro jellyfish bloom events are increasingly common as oceans warm. Capable of impacting millions of fish at once, the jellyfish cause extensive damage to gill tissue in salmon, leading to infection and death.

**Jellyfish that caused mass farmed salmon deaths making a troubling return to Norway**

Read more

Vindheim also blamed restrictions on the importation of salmon eggs from Norway for limiting the health of the stocks raised in the country.

As a result of these challenges, fourth quarter volumes for Scotland will be low and costs will remain high, said Vindheim.

The company produced operational earnings before interest and taxes (EBIT) of €4.2 million ($4.2 million) compared to €13.4 million ($13.4 million) last year -- despite substantially higher prices. EBIT per kilo fell from from €0.90 ($0.90) to €0.29 ($0.29).

"Nothing is as sure as things fluctuating in salmon farming," said Vindheim. "Biology is the law and everything else is just a recommendation."

Intrafish reported in November 2022:

IntraFish Latest News Salmon Whitefish Shrimp Aquaculture Fisheries Markets IntraFish.no

# Jellyfish that caused mass farmed salmon deaths making a troubling return to Norway

This particular jellyfish species led to mass deaths in 1997 and 2001.

14 November 2022 5:01 GMT UPDATED 14 November 2022 14:08 GMT

By Torhild M. Martinussen and Hanna Gezelius

So far this year, scientists along the Norwegian costs have received 110 observations of a jellyfish that can be deadly for farmed fish, according to the Norwegian Institute of Marine Research.

"During the last 20 years, we have only seen this many sightings this year and in 2021," Norwegian Institute of Marine Research jellyfish scientist Tone Falkenhaug said.

This type of jellyfish led to mass deaths of farmed fish in 1997 and 2001. In 1997, the jellyfish killed 12,000 metric tons of salmon, and 600 metric tons of salmon were killed in 2001.

This year, the increase of sightings has mainly taken place in September and October.

Similar to other jellyfish, this species can appear suddenly only to disappear again for several years.

The species is colonial jellyfish, where the individual jellyfish have different tasks. Those that catch food or defend the colony have so-called nettle cells, and it is these cells that can burn and cause damage to farmed fish if they enter a broken netpen. (Copyright)

Intrafish reported in October 2022:

IntraFish Latest News Salmon Whitefish Shrimp Aquaculture Fisheries Markets IntraFish.n

# Jellyfish fail to scupper Mowi's Q3 as salmon farmer scores 83% earnings hike

Scotland, Ireland and Canada fell behind in the earnings stakes, but Mowi's other farming regions still managed to deliver substantial numbers.

RELATED NEWS

**Norway salmon farming companies shell out $400 million in auction for new licenses, well below expectations**
Salmon
14 October 2022 5:00 GMT

17 October 2022 6:44 GMT UPDATED 17 October 2022 6:44 GMT

By Rachel Mutter

The world's largest salmon farmer, Mowi, has reported a substantial rise in earnings for the third quarter of 2022, with larger than predicted harvests and strong price returns, despite environmental factors impacting its Scottish and Irish operations.

Harvest volume was 15 percent up on last year at 134,000 metric tons, 2 percent up on predicted numbers, with operational earnings before interest and tax (EBIT) hitting €240 million ($234 million), 83 percent up on last year.

EBIT per kilo rose 82 percent for Mowi's Norwegian farming operations, but Scotland and Ireland suffered from micro-jellyfish and incident-based mortalities.

Fish Farming Expert reported in October 2021:

Fishfarmingexpert About us Contact Jobs FFE Newsletter

# The tiny jellyfish suspected of causing a big problem

The damage that microscopic jellyfish might be doing to farmed salmon will be discussed at the International Gill Health Conference taking place online tomorrow and Wednesday.

*Editors*

PUBLISHED Monday 25. October 2021 - 13:49

The jellyfish, known as hydrozoans, are being closely monitored by salmon farmer Mowi Scotland to better understand how they affect gill health.

Lucy Fry, regional health manager at Mowi, said that daily monitoring of plankton and hydrozoans pointed towards a range of jellyfish species as a possible cause for some previously unexplained gill health challenges.

## 10% of sites affected

Due to their size, hydrozoans cannot be detected by the naked eye, but microscopic analysis is helping Mowi to map out their presence on its sites. Around 10% were found to have experienced significant blooms of different hydrozoan species since monitoring began 12 months ago.

Hydrozoans can be more problematic than larger jellyfish species, with stinging cells potentially causing damage to gill tissue. They can lead to significant gill damage and potentially complicate other concomitant gill infections such as amoebic gill disease (AGD). Because of their size there is also a risk of them causing significant internal damage to fish by getting into their digestive systems.

## Tracking patterns

Fry said: “We are constantly looking for new ways to enhance fish health and, with our improved system for monitoring micro jellyfish, we are now able to begin to track patterns and trends that will indicate the need for further preventative measures to protect fish stocks against hydrozoans.

“By continuing this research and sharing knowledge, we hope to develop a better cross-sector understanding of how fish are affected by micro jellyfish species and identify whether they do contribute to AGD and other unexplained gill health issues, as we currently suspect.”

Lucy Fry: Constantly looking for new ways to enhance fish health.

## An international concern

Hydrozoans are known to be an international concern, with producers in Canada, Norway, Chile and Ireland having previously reported their presence, but increased monitoring could be the key to managing their impact.

General mitigation measures for problems caused by other plankton, algae and zooplankton such as jellyfish include cessation of feeding to keep the fish deeper, aeration, bubble curtains and early harvesting.

The Fish Site reported in October 2021:

ATLANTIC SALMON | HEALTH | JELLYFISH +4 more 25 October 2021, at 9:58am

# Jellyfish blamed for gill health issues

**Hydrozoans, more commonly known as micro jellyfish, are being closely monitored by Mowi Scotland to better understand how they affect the gill health of salmon, attendees at this week's International Gill Heath Conference will hear.**

10 percent of Mowi Scotland's salmon farms were found to have been impacted by jellyfish in the last 12 months

Speaking ahead of the virtual event, Lucy Fry, regional health manager at Mowi, said that daily monitoring of plankton and hydrozoans pointed towards a range of jellyfish species as a possible cause for some previously unexplained gill health challenges.

Due to their size, hydrozoans cannot be detected by the naked eye, but microscopic analysis is helping Mowi to map out their presence on its sites. Around 10 percent were found to have experienced significant blooms of different hydrozoan species since monitoring began 12 months ago.

Hydrozoans can be more problematic than larger jellyfish species, with stinging cells potentially causing damage to gill tissue. They can lead to significant gill damage and potentially complicate other concomitant gill infections such as amoebic gill disease (AGD). Because of their size there is also a risk of them causing significant internal damage to fish by getting into their digestive systems.

ABC News reported in March 2019:

# Jellyfish stinging salmon industry profits, but could fish farms be creating the problem?

ABC Radio Hobart / By Georgie Burgess

Posted Sat 2 Mar 2019 at 1:01am, updated Sat 2 Mar 2019 at 5:08am

Dr Lisa-Ann Gershwin is warning aquaculture could provide a breeding ground for jellyfish. *(ABC News: Georgie Burgess)*

A world-leading jellyfish expert says aquaculture could be making rapid jellyfish population increases worse, causing fish deaths and hitting farmers' profits.

A moon jellyfish population explosion - known as a bloom - in Tasmania's Huon River and D'Entrecasteaux Channel in November cost Huon Aquaculture up to $10 million.

Dr Lisa-Ann Gershwin said it was not a one-off problem, but more research needed to be undertaken in Australia.

"Jellyfish are a problem, and they are a problem that's getting worse globally," she said.

"I believe there's every probability that aquaculture is making the jellyfish problem worse."

"We do have good data from places overseas that shows aquaculture stimulates the growth of the very organisms that cause problems for the aquaculture industry," she said.

> "It's a vicious cycle, where the aquaculture is making the problem worse, that is then impacting them.

"In my mind, the bigger problem is that it's not a one-off."

She said it was an area of science that needed attention.

## Tiny killers

Huon has tried mitigation strategies, including towing pens slowly through the water to allow the jellyfish to be pushed through the net.

While some have been successful, it's not without costs.

The jellyfish can kill the salmon and affect their growth, as well as fish later suffering from gill necrosis, a secondary impact.

> "They [jellyfish] are not lethal to most species, but what they do is sting, and it causes a little tiny injury and that can get infected," she said.

She said a little clump of hydroids, which are only about 4mm wide, could produce 100 to 200 jellyfish each season.

"When a polyp dies, it's replaced by more," she said.

## Industry could stimulate jellyfish growth

Dr Gershwin said the organisms grew naturally on any structure that was in the water, whether it be rocks, boats or jetties.

She said activity around the infrastructure they grow on could stimulate them to grow more.

The fragments turn into seeds and sprout new colonies.

"When they are scraped away, it creates fragments, which creates more colonies," she said.

She said aquaculture could be creating a breeding ground for jellyfish.

"More research needs to be done," she said, adding there was evidence of it occurring overseas.

"A reasonable hypothesis is that it could be happening here," she said.

Read more via:

CNN **Opinion** Political Op-Eds Social Commentary

# Jellyfish love the oceans we pollute

Lisa-ann Gershwin

Updated 2:27 PM EST, Fri November 15, 2013

Different types of jellyfish have caused mass fish kills at salmon farms all over the world. Ireland, Scotland, Chile, Australia, New Zealand... you name it. If salmon are being farmed, you can bet there are terrible jellyfish problems.

Hakai Magazine reported in 2018:

# Jellyfish Threaten Norway's Salmon Farming Industry

A Norwegian fish farm has been hit hard by tiny jellyfish.

by Gloria Dickie

February 9, 2018 | 500 words, about 2 minutes

Tiny *Dipleurosoma typicum* jellyfish wounded the salmon at Cermaq's fish farm in Ryggefjord, Norway, opening them up to infection and driving a string of mass die-offs. Photo by Cermaq Norway

Lurking in the water, Halsband discovered that a jellyfish, *Dipleurosoma typicum*, was blooming along the coast. The jellyfish is often found in the North Atlantic, and is thought to have a boreal-circumpolar range, but this was the first observation in Norwegian waters. Cermaq veterinarians had originally floated the idea that jellyfish were behind the deaths given the water's cloudy appearance when the deaths occurred, but until now they hadn't been able to show that the jellyfish were actually harming the fish.

Closer inspection of these jellyfish showed that they—unlike the jellyfish species observed in the region in the summer—were indeed hurting the salmon. The *Dipleurosoma typicum* jellyfish were likely wounding the salmon with their stingers, causing lesions that Halsband believes increased the spread of tenacibaculosis, a common bacterial disease in fish farms. Despite the lack of earlier evidence, these jellyfish were likely also the culprits behind the die-offs in 2012 and 2014.

In the past decade, destructive and costly blooms of other jellyfish species have hit salmon farms in Ireland, Scotland, and northern Norway. In many cases, these blooms clogged fish nets or pens, or suffocated fish. To put it succinctly, "jellies and salmon are not a good mix," says Halsband.

Fish Farming Expert reported in 2018:

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# Biological hazards on the rise

*Rodrigo Orrego*

PUBLISHED Saturday 24. February 2018 - 12:18

Siri Elise Dybdal

At the end of last year, thousands of tiny mauve stinger jellyfish squeezed through protective nets at Loch Duart's fish farm in Loch Maddy in the Western Isles. The jellyfish invasion wiped out 300,000 salmon, worth approximately £1m. It followed an incident in 2013 where 20,000 salmon were killed by a similar invasion at Marine Harvest's Clare Island site in Ireland. It was the same species of jellyfish that decimated Northern Ireland's only salmon farm in 2007, when more than 100,000 fish, worth around £1m, were destroyed at a site near Glenarm Bay. However, the biggest loss in recent years occurred in 2002, when thousands of solmaris jellyfish killed a million salmon in farms in the Western Isles. Fish valued at around £3m were destroyed in sea lochs at Leurbost, Gravir and Loch Erisort off Lewis. There have been several well-publicised incidents where blooms of jellyfish in northern Europe have caused damage to aquaculture operations. In addition to mass mortalities, chronic exposure has been linked to the development of gill pathologies, increased stress and reduced feeding in salmon. Warmer water temperatures are one of the main factors that have increased the presence of jellyfish. These have also spurred on harmful algal blooms (HAB), which can have a significant impact on salmon, as they irritate gills and compromise or kill the fish. Gill disease has been responsible for large-scale mass mortalities as well as poor growth and performance in farmed salmon.

Warmer water temperatures are one of the main factors that have increased the presence of jellyfish.

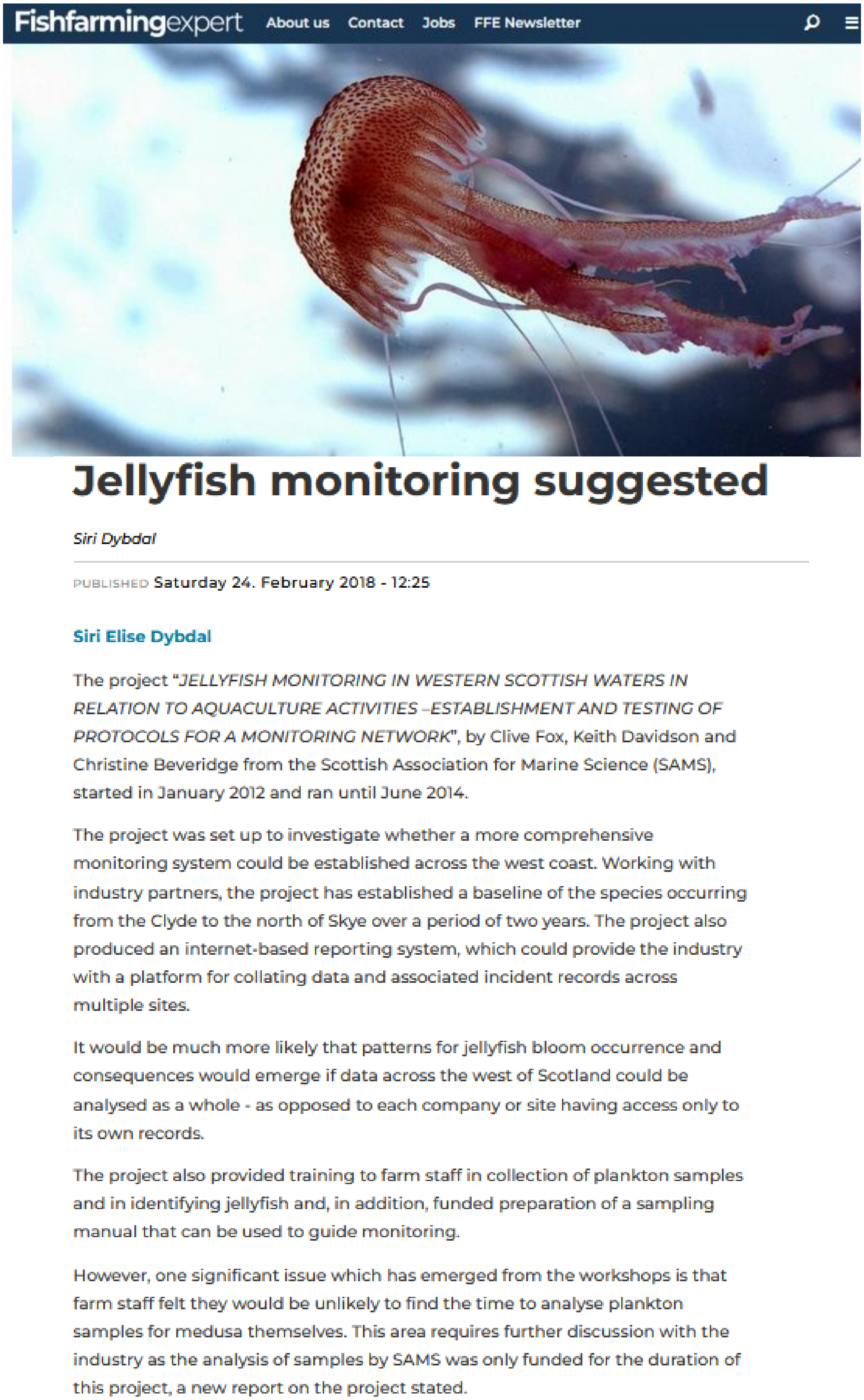
A risk "There are papers that claim that the frequency in bloom is due to climate change, but there are few historical records to back this up," says Dr Clive Fox, principal investigator in fisheries and plankton ecology at the Scottish Association for Marine Science (SAMS). He says this is due to lack of sampling. "We can't say for definite. What I can say is that the feeling is that it is a risk, but data from 10 years is not long enough." According to Dr Fox there are various ongoing projects attempting to spot jellyfish blooms from satellites. However, the weather in Scotland is often cloudy, which is an obstacle when using this method. "There is another project looking at using remotely operated aircraft," he says, and explains that this is basically a smaller scale drone. "It is still only at the research stage, but has the potential to spot blooms under the clouds," he points out. Currently, he says, the aquaculture industry's response to blooms is to put a tarpaulin or a ring of bubbles around the farm. "The bubble curtains just break the jellyfish up, but the stinging cells would still be active," says Dr Fox, who admits there is currently "nothing very obvious" that can be done. The situation is further complicated by the fact that there is relatively poor understanding of the different species and the ecology of jellyfish in relation to conditions triggering blooms and outbreaks. He says more research is needed and believes being able to monitor the incursion might help mitigate the challenges.

Dr Clive Fox, principal investigator in fisheries and plankton ecology at the Scottish Association for Marine Science (SAMS).

Working with industry partners The Crown Estate-funded project "Jellyfish monitoring in western Scottish waters in relation to aquaculture activities – establishment and testing of protocols for a monitoring network" by Clive Fox, Keith Davidson and Christine Beveridge from SAMS, was set up to evaluate the feasibility of establishing a monitoring program. It started in January 2012 and ran until June 2014. A previous project had already considered methods for monitoring the larger "true" jellyfish (scyphomedusae), but identified that many problems at farms would probably be caused by smaller hydromedusae in the water column. These species cannot be detected remotely and collection of plankton samples remains the only available method for monitoring their presence and abundance. The present project was set up to investigate whether a more comprehensive monitoring system could be established across the west coast. Working with industry partners, the project has established a baseline of the species occurring from the Clyde to the north of Skye over a period of two years. The project also produced an internet-based reporting system, which could provide the industry with a platform for collating data across multiple sites. It would be much more likely that patterns for jellyfish bloom occurrence would emerge if data across the whole west of Scotland could be analysed as a whole – as opposed to each company having access only to its own records. The project also trained farm staff in the collection of plankton samples and in identifying jellyfish, as well as preparing a sampling manual to guide monitoring. However, one significant issue which has emerged from the training workshops, is that farm staff felt they would be unlikely to find the time to analyse plankton samples for medusa themselves.

On farm practice "The challenge depends on the size and type of jellyfish – the larger ones can be pushed up against the nets, restricting the flow of water, which means the fish do not receive enough oxygen. The smaller jellyfish, which can pass through the mesh of the nets, can clog the gills and again restrict the flow of oxygen to the salmon or they can have a toxic effect on the gills. Thankfully this is a rare event," says Smith. "In the worst cases you can see the marks where fish have been stung along their flanks," says Steve Bracken, business development manager for Marine Harvest Scotland. According to Bracken, daily water quality monitoring takes place on Marine Harvest's farms to check for the presence of algae and the smaller jellyfish. Remote sensing is also used, but needs to be developed further as a method for early warning. Compressed air systems are used to flush the jellyfish away from the nets by creating an upwelling water movement, he says. Communication and cooperation "The dynamic marine environment alongside the effects of global climate change provides challenges for Scotland's salmon farmers," the SSPO says. "In 2014, there were anecdotal reports that water temperatures around the coast of Scotland were higher than expected, which had knock-on effects on the water quality. These changes to water temperature and quality can result in algal blooms, plankton and jellyfish swarms, which all present challenges for fish health."

Fish Farming Expert reported in 2018:



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# Jellyfish monitoring suggested

*Siri Dybdal*

PUBLISHED Saturday 24. February 2018 - 12:25

**Siri Elise Dybdal**

The project "*JELLYFISH MONITORING IN WESTERN SCOTTISH WATERS IN RELATION TO AQUACULTURE ACTIVITIES –ESTABLISHMENT AND TESTING OF PROTOCOLS FOR A MONITORING NETWORK*", by Clive Fox, Keith Davidson and Christine Beveridge from the Scottish Association for Marine Science (SAMS), started in January 2012 and ran until June 2014.

The project was set up to investigate whether a more comprehensive monitoring system could be established across the west coast. Working with industry partners, the project has established a baseline of the species occurring from the Clyde to the north of Skye over a period of two years. The project also produced an internet-based reporting system, which could provide the industry with a platform for collating data and associated incident records across multiple sites.

It would be much more likely that patterns for jellyfish bloom occurrence and consequences would emerge if data across the west of Scotland could be analysed as a whole - as opposed to each company or site having access only to its own records.

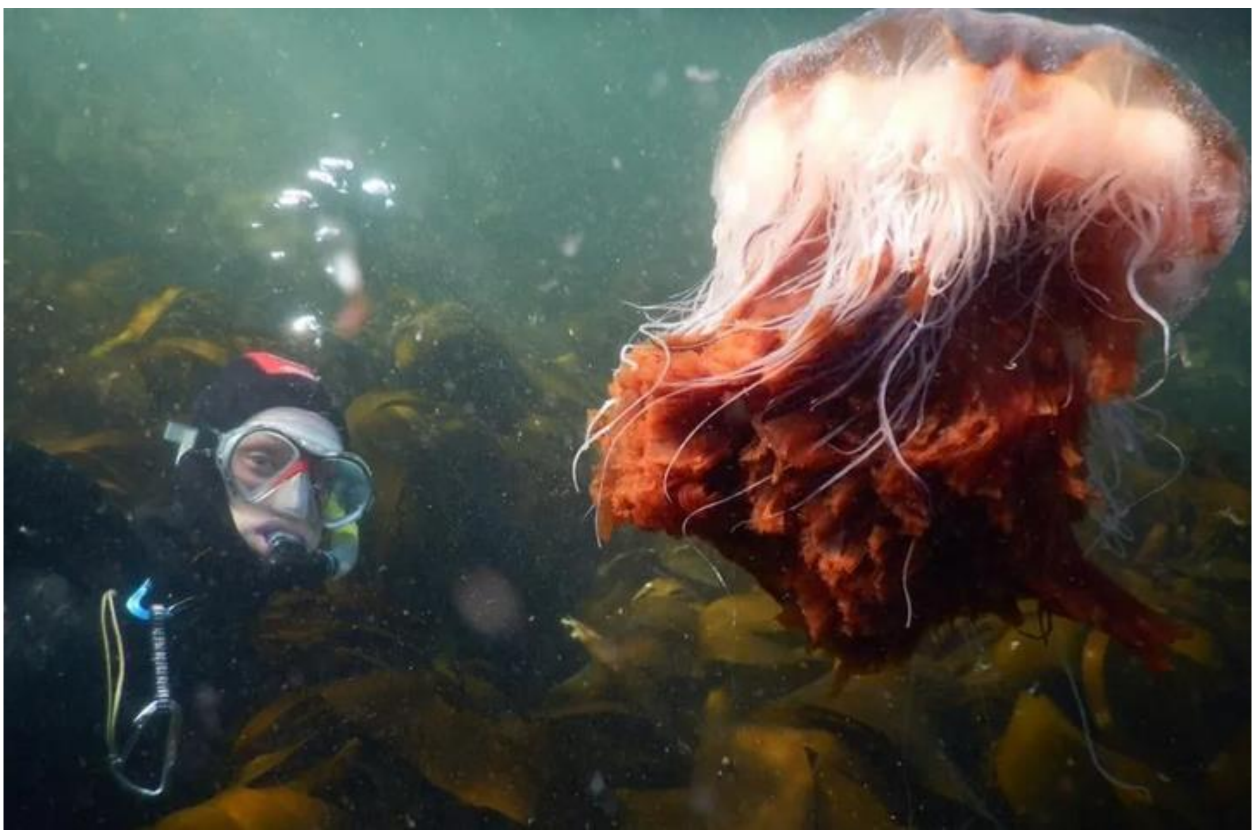
The project also provided training to farm staff in collection of plankton samples and in identifying jellyfish and, in addition, funded preparation of a sampling manual that can be used to guide monitoring.

However, one significant issue which has emerged from the workshops is that farm staff felt they would be unlikely to find the time to analyse plankton samples for medusa themselves. This area requires further discussion with the industry as the analysis of samples by SAMS was only funded for the duration of this project, a new report on the project stated.

The Fish Site reported in 2018 on jellyfish expert Dr Anna Kintner:

## What outstanding challenge would you most like to solve?

I'm obviously biased, but I'd suggest that harmful gelatinous zooplankton should be getting more attention. Complex gill disease has emerged as a real issue in salmon aquaculture, and I think a better understanding of stinging jellyfish population dynamics and interactions in that situation is a critical part of the solution going forward. In my opinion, this is something that gets neglected in favour of better known health issues. I'd like to see all sites adopt biological water quality sampling as part of their daily routine, with a centralised data input that would help us quantify and track the dynamics of harmful plankton.



Read more via Dr Kintner's PhD thesis: "HYDROZOAN JELLYFISH AND THEIR INTERACTIONS WITH SCOTTISH SALMON AQUACULTURE"

The Times reported in 2017:

THE TIMES | Today's sections | Past six days | Explore | Times Radio | Log in

# Thousands of west coast salmon killed by jellyfish stings

Dara Bradley

Saturday October 07 2017, 12.01am, The Times

The total death toll is not known, but environmentalists fear it may rise as salmon are removed from cages
GETTY IMAGES

Killer jellyfish have wiped out tens of thousands of salmon after invading fish farms along the west coast of Ireland.

Some 80 per cent of the salmon stock at Killary Harbour in Co Mayo died after being stung last month.

The Times reported in 2014:

THE TIMES | Today's sections | Past six days | Explore | Times Radio | Times+

# Double sting as jellyfish kill salmon

Lucy Holden

Tuesday December 16 2014, 12.01am, The Times

The same species of jellyfish wiped out Northern Ireland’s only salmon farm in 2007
GETTY IMAGES

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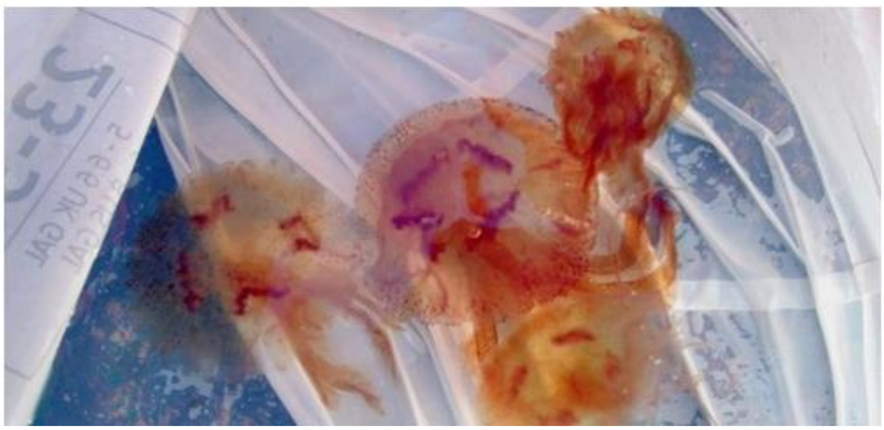
An invasion of jellyfish has killed more than 300,000 salmon in a Western Isles fish farm. Thousands of the mauve stinger jellyfish forced their way through safety nets at the Loch Duart fish farm in Lochmaddy, wiping out £1 million worth of stock.

BBC News [reported in 2014](https://www.bbc.co.uk/news/uk-scotland-highlands-islands-30493999):



# Jellyfish swarm kills 300,000 salmon at Uist fish farm

16 December 2014



Mauve stinger jellyfish have previously swarmed around Scotland's coast

**Swarms of jellyfish have killed up to 300,000 salmon at a fish farm in the Western Isles.**

The mauve stinger jellyfish, also known as *pelagia noctiluca*, are small enough to get inside salmon cages.

The jellyfish swarmed at salmon company Loch Duart's farm on North Uist last month.

Bad weather that followed the incident prevented the fish from recovering from their injuries. Loch Duart said half its stock at the farm had died.

In 2007, the stinging jellyfish swamped salmon cages off Northern Ireland before later appearing in swarms around the coast of Highlands Scotland.

Billions of the creatures covered an area of up to 10 square miles off the County Antrim coast.

The Times reported in 2007:

THE TIMES | Today's sections | Past six days | Explore | Times Radio | Times+

# Salmon wiped out in attack by shoal of killer jellyfish

David Sharrock, Ireland Correspondent

Thursday November 22 2007, 12.00am, The Times

Share Save

After the summer floods and freak weather comes a new jolt to our ecosystem: more than 100,000 salmon wiped out by jellyfish off the coast of Northern Ireland in a single attack.

The mauve stinger, which has caused Mediterranean beaches to be closed over the summer because of the fear of its potent sting, has arrived off British shores in unprecedented numbers.

Billions of the tiny jellyfish, covering an area of up to ten square miles (27 sq km) and up to 35ft (13.6m) deep, swamped fish-farm cages belonging to Northern Salmon Co and killed more than 100,000 salmon – valued at more than £1 million.

The attack took place last week at Glenarm Bay and Red Bay, Cushendun, off the scenic coastline of Co Antrim and has put the future of the Northern Salmon Co in jeopardy. "We are still assessing the full extent, but it's a disaster," said John Russell, the company's managing director.

The salmon died from their wounds and from the stress of the jellyfish stings. At one stage staff tried to reach the cages in three boats, but such was the density of the jellyfish they struggled to get through and arrived too late to make a difference.

Fish farms around Britain and the West Coast of Ireland have been attacked before by jellyfish, but the type blown towards the Antrim coast by winds from the North have never been recorded in the area before. It is extremely rare for mauve stingers to visit the colder waters around the British Isles.

Mr Russell, from Fort William, Scotland, who took over as the company's managing director three days before the attack, said: "I have never experienced such concentrations of jellyfish spread over such a wide area. The vastness was unbelievable.

"It's a disaster for this company. You cannot legislate for something like this."

The Times reported in 2003:



# Bubble curtain to save salmon stocks

By Shirley English

Wednesday January 15 2003, 12.00am, The Times

Share Save

A CURTAIN of air bubbles is to be used as a protective underwater shield for coastal salmon farms to stop attacks by millions of tiny jellyfish and algae blooms.

An experimental £70,000 project will start this spring in the Western Isles to combat what is viewed as the gravest threat to the fish farming industry.

In the past two years salmon farms around Scotland have lost four million fish worth an estimated £32 million because of jellyfish attacks and drifting algae blooms, according to Scottish Executive figures.

Thick swarms of the Pacific-based *Solmaris* jellyfish, which is just 5mm long, have been the main culprit, engulfing sea cages in which the salmon are farmed and suffocating or poisoning the fish.

The *Solmaris* are so small that the salmon breathe them in and clog up their gills.

The bubble curtain defence scheme is the brainchild of the Western Isles Seafood Company (WISCo) and is being developed with the technical help of Taytech Ltd, of Ayrshire.

WISCo owns four salmon farms on the isles of Lewis and Harris and one in the Moray Firth and contracts out two others on Skye, all of which have been affected by the increase in jellyfish, thought to be due to global warming.

The first trials will take place at Grabir salmon farm, on the east coast of Lewis, which suffered 100 per cent losses last year because of a jellyfish attack.

The system will be independently monitored for a year by the Institute of Aquaculture at Stirling University.

However WISCo, a subsidiary of Fjord Seafood ASA of Norway, hopes that all its Scottish salmon farms will be protected by the bubble curtain by late summer when the jellyfish and algae threat is at its height.

BBC News reported in 2002:

BBC NEWS

You are in: **Scotland**

Wednesday, 7 August, 2002, 15:14 GMT 16:14 UK

# £2m toll of salmon sting

Jellyfish have attacked salmon in the past

Dense shoals of tiny jellyfish have killed almost one million salmon at fish farms in the Western Isles.

It is thought that the jellyfish - known as Solmaris - may have found their way to Scottish waters from the Pacific Ocean.

They killed the salmon by stinging them and clogging up their gills.

Fish with an estimated value of more than £2m were destroyed at two farms off the Isle of Lewis.

> **We have never suffered this before - this has set us back four months**
>
> **Alan Anderson Western Isles Sea Foods**

Vast blankets of jellyfish moved up the sea lochs where the salmon cages are moored.

The larger fish were suffocated while smaller ones were stung to death.

Western Isles Sea Foods said almost all the fish at the two farms had been destroyed.

Managing director Alan Anderson said 750,000 fish were lost at one site and 150,000 at the other, meaning a loss to the firm of more than £2m.

**Fully grown**

"It's a disaster to lose that number of fish - it's almost a million fish but they're insured and business continues as normal.

Two decades later the salmon farming industry is still grappling with the jellyfish and zooplankton problem. Fish Farming Expert [reported in July 2023](#):

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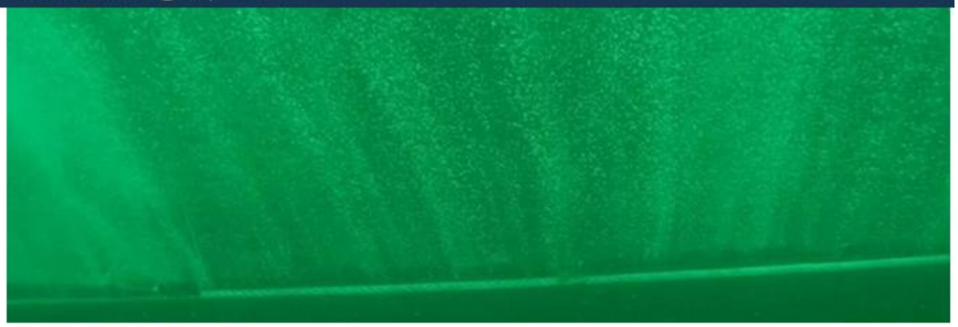

The bubble curtain in operation in Ireland. Image from LOW 02/PSP Solutions video

# Irish salmon farmer uses bubbles to block plankton problems

*Editorial team*

PUBLISHED Monday 24. July 2023 - 12:42

An Irish salmon farmer has joined a growing list of companies using bubble curtain technology supplied by Chilean consortium LOW O2 and PSP Solutions.

Bradan Beo Teoranta, which is part-owned by the Irish government, produces around 2,500 tonnes of organic salmon annually in Cill Chiarain Bay, Connemara, west Galway.

LOW O2/PSP Solutions said the project consisted of a submerged system of laminar flow microbubble barriers, specially designed for a site with 10 x 90-metre circumference circular pens.

The system was installed at a depth of 13.7 metres, due to site depth restrictions, and was designed to impede the passage of zooplankton and phytoplankton, such as jellyfish, micro jellyfish, and algal blooms, among others.

It is the second bubble curtain that the companies have delivered in Ireland.

The consortium has now carried out more than 200 developments in Chile, Canada, Ireland, Scotland and the Middle East, in the salmon and desalination industries.

"Currently, we are working hard to continue offering our systems in different countries and various industries that carry out their operations at sea. In addition, we have signed agreements with different universities and institutes to continue innovating and improving the efficiency of our systems," said Sepúlveda.

Also read:

**Salmon farmer buys 1km-long bubble curtain to block algal blooms**

Also read:

**Irish farms to test Chilean algal bloom bubble barrier**

Fish Farming Expert [reported in 2021](#):

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A salmon farm in Chile protected by a bubble barrier. A system adapted for Irish Sea conditions is to be tested at two farms in Ireland under a contract with Ireland's seafood development agency, Bord Iascaigh Mhara. Photo: Low O2 / PSP Soluciones.

# Irish farms to test Chilean algal bloom bubble barrier

Chilean technology that uses a microbubble barrier system to protect farmed fish from jellyfish and algal blooms is to be trialled at two salmon farms in Ireland.

*Gareth Moore*

PUBLISHED Friday 18. June 2021 - 18:09

A consortium formed by Chilean firms Low O2 and PSP Soluciones successfully tendered for a contract from Ireland's seafood development agency, Bord Iascaigh Mhara (BIM), which wants to test the efficacy of such systems in Ireland's more challenging sea conditions.

The project, which will start at end of July, involves the consortium supplying, installing and providing operational support for underwater microbubble barrier systems in two salmon farms at Donegal Bay and Clare Island, County Mayo. They will be installed at a depth between 20 to 22 metres and are intended to mitigate the passage of jellyfish and algal blooms and particulate from 4 microns upwards.

## 'World leader'

Low O2 general manager Luis Sepulveda said: "We are very happy because this is the first project of this type implemented by a Chilean company in Ireland. Our company's technology has been fully developed in Chile and this contract confirms Low O2 as the world leader in microbubble barrier systems and deep-water aeration."

The project awarded by the BIM was specially developed for the conditions of the Irish Sea that are very different from those at farm sites in southern Chile. "Because of that our engineers had to work considering different types of cages, anchors, currents, depths and temperatures, among other conditions," explained Sepulveda.

An underwater image of a microbubble curtain at a farm in Chile. Click on image to enlarge. Photo: Low O2 / PSP Soluciones.

The journal Aquaculture [reported in 2021](https://doi.org/10.1016/j.aquaculture.2020.735915):

Aquaculture
Volume 531, 30 January 2021, 735915

# Field and flume tank experiments investigating the efficacy of a bubble curtain to keep harmful jellyfish out of finfish pens

Damien Haberlin [a b], Rob McAllen [b], Thomas K. Doyle [a b]

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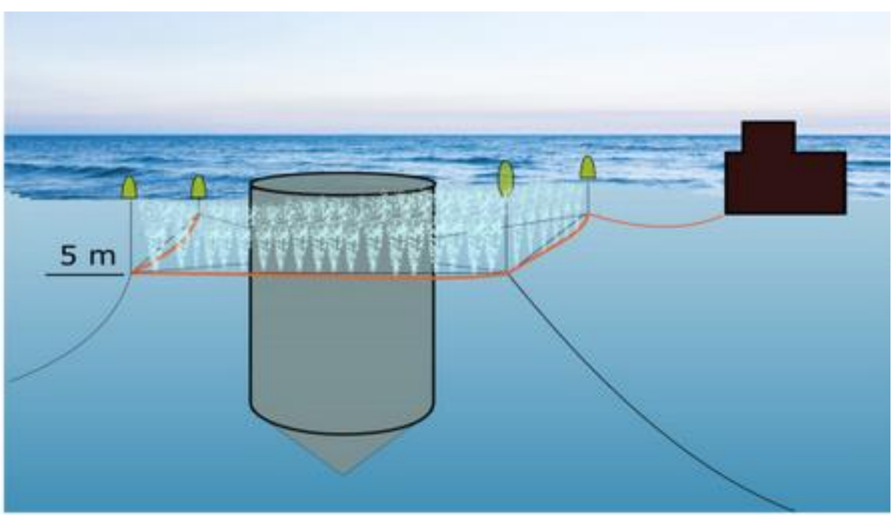
https://doi.org/10.1016/j.aquaculture.2020.735915  Get rights and content



## Highlights

- A bubble curtain is an effective barrier to positively buoyant model jellyfish in a flume.
- Current and wave conditions determine the efficacy of the bubble curtain as a barrier.
- A bubble curtain set at an angle to the current can deflect buoyant model jellyfish.



## Abstract

In recent years, salmon aquaculture has struggled to mitigate the impact of harmful jellyfish species in northern Europe and beyond. Typically, large aggregations of jellyfish are carried by currents through salmon pens, leading to unsustainable mortality levels in some years. One potential solution that has been regularly proposed is the creation of a 'bubble curtain' around fish pens. A bubble curtain is created by releasing compressed air from a perforated tube at depth, forming a plume of bubbles that entrain the water to create a vertical current. This study investigated the efficacy of a bubble curtain as a jellyfish barrier at several aquaculture locations in Ireland and in a controlled flume tank. Field tests on bubble curtains provided mixed results: a high air flow 8 m linear bubble curtain set at 5 m depth effectively deflected large compass jellyfish (*Chrysaora hysoscella*), whereas, a low air flow ca. 800 m circular bubble curtain set at 5 m depth, around a salmon farm, did not significantly impact the abundance of small hydromedusae on either side of the bubble curtain. Flume tank experiments demonstrated that increased wave height and increased air flow increased jellyfish transport through the curtain and the lateral movement was consistent with Stokes drift, i.e. an elliptical motion that includes forward movement with each wave. These results suggest that sites with relatively high wave energy may be unsuitable for bubble curtain use and that the variable size and shape of jellyfish may be an important factor in jellyfish and bubble curtain interactions.

## 4. Discussion

In terms of the efficacy of the bubble curtain as a barrier to jellyfish, the results here are mixed with both positive and negative implications for a real-world setting. The flume experiments suggest that where currents and wave energy are relatively low, the bubble curtain has the potential to prevent jellyfish moving through a farm. Many farms are located in very sheltered or even fjord like locations, e.g. in Norway and Chile, and thus might meet this low energy requirement. In fact, despite appearing quite exposed, many Irish sites experience wave heights of less than 1 m 90% of the time, from April to September. Conversely, at high energy sites and especially where high currents are present, the bubble curtain may be less useful. Interestingly, the introduction of an angle into the bubble curtain in order to 'guide' jellyfish in a certain direction, rather than simply present a barrier, did appear to be effective.

Most salmon farms are located where there is a balance between current velocity and wave exposure so that fish may receive a ready supply of fresh oxygenated water and their excrement may be dispersed rapidly. For structural reasons, greater exposure and excessive currents are avoided. Nonetheless, sites with currents below 0.5 $m^{-s}$ are classified as moderate in Norwegian site classification framework and 0.2–0.25 $m^{-s}$ are regarded as optimal (Cardia and Lovatelli, 2015). In the context of these values, it is tempting to conclude that the bubble curtain cannot be effective, as at the higher current of 0.24 $m^{-s}$ most jellyfish passed through. However, the flume tank is an artificial environment and the results should be interpreted with caution. Firstly, the flume tank is only 1 m deep and therefore the bubble plume has limited vertical distance within which to create a vertical current. Secondly, there was an obvious tank effect as the water column could not flow around the bubble curtain and had to pass over or through it. In a natural setting, a bubble curtain at 10–20 m depth (or possibly deeper) would have the vertical distance to create a stronger vertical current and in the wide-open space around an actual farm water can be diverted around a potential barrier. Initial pilot experiments demonstrated that a relatively powerful current was created from a 5 m depth, albeit the compressor in that instance was more powerful. Furthermore, the control of the flume current was limited and finer incremental increases in current were not available during the experiments. Though this may not have altered the broader conclusions here, there is certainly scope to improve the understanding of bubble curtain dynamics and the breakdown thresholds in the context of a jellyfish barrier system.

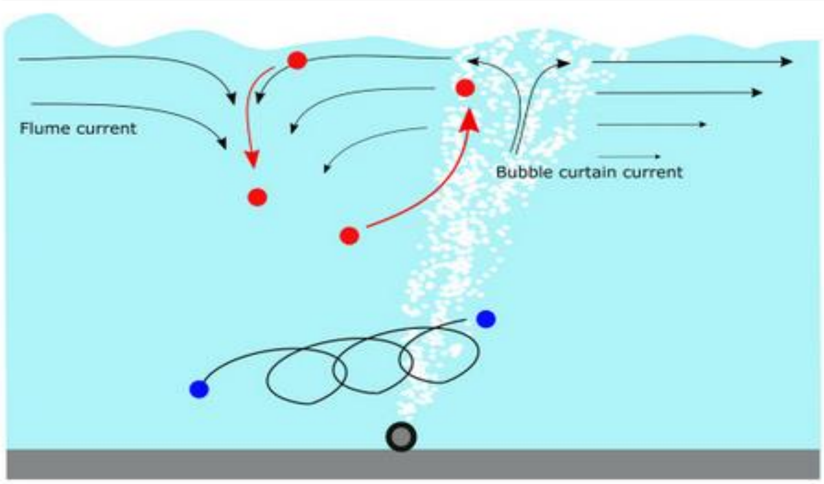



Fig. 5. Schematic of jellyfish movement at two different entry points into the bubble curtain during wave flume tests. The blue jellyfish (moving according to Stokes drift) enters a narrow plume where the vertical current is not established and passes through. In contrast, the red jellyfish encounters a wider plume with an increased vertical current and is entrained into the vertical current. At the surface it is pushed away from the plume, and when the horizontal current dissipates, it gets pulled into the horizontal vortex created by both the bubble curtain and the current. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

## 5. Conclusions

The most encouraging results in this study were the flume tanks experiments on the buoyant model jellyfish at the surface and suggest that the bubble curtain is highly effective under certain conditions, against some species. Taking advantage of this result will depend on a good knowledge of the environmental conditions at a site and a knowledge of the problematic jellyfish species at the site. The addition of a current dramatically increased the numbers of jellyfish passing through the bubble curtain and the flume tests suggest that over a certain threshold, current flow will be the overwhelmingly dominant factor. Nonetheless, experiments on oil slicks would suggest that bubble curtains can be adapted to increase efficacy. In addition, an efficient adaptable system is likely to be easier to integrate into existing farm systems. Before further field experiments are carried out, we would suggest that marine biologists need to collaborate more closely with marine engineers to develop a bubble curtain system fit for the harsh environments in which they need to operate.

An adaptable bubble curtain system capable of creating a barrier at specific sections around the farm, depending on tides and currents, could reduce the energy demand further and close the gap between that theoretical maximum power needed and the power available.

**[10]** Salmon Scotland stated in November 2022 via a press release:

> Around Scotland's west coast and islands, microscopic jellyfish – tiny translucent jellyfish measuring as small as 2mm and therefore almost invisible to the naked eye – are considered to have been a key contributor to the reduced survival of farmed salmon this summer.
>
> Data published by Salmon Scotland for September shows survival fell to 95.3 per cent; 2.4 per cent down on the past four-year average of 97.7 per cent and equating to a loss of 2.8 million fish across the sector.
>
> Tavish Scott, chief executive of Salmon Scotland, said: "Whether on land or sea, raising animals outdoors inevitably comes with risks as the climate continues to change and evolve, but that makes environment-induced events such as micro jellyfish no less devastating to the farmers caring for those animals day in, day out.
>
> "It's why we're so committed to increasing our understanding of new and emerging threats in order to better safeguard the health and welfare of our salmon."

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Business

# Salmon producers back early warning system to avoid 'devastating' micro organisms

by Simon Warburton

November 9 2022, 12.01am

The article included a statement from Salmon Scotland chief executive Tavish Scott:

## Behind the scenes: Salmon Scotland chief executive Tavish Scott

Despite the best efforts of our farmers, there are sometimes issues which they cannot compensate for. During September, we saw an increase in minuscule, but potentially harmful, plankton and jellyfish in Scotland's waters.

## Stinging cells can be fatal to salmon and trout

These jellyfish blooms are naturally-occurring and have been reported in Canada, Norway, Chile and Ireland. The organisms are as small as 2mm and translucent, making them almost impossible to spot, but their stinging cells can injure or be fatal to fish such as salmon and trout as they brush past.

Unfortunately, the latest figures for September recorded a higher-than-normal number of fallen stock, the majority of which we believe succumbed to jellyfish blooms.

The article concluded:

If the threat is wider-reaching, farmers may choose to remove their stock from the area through harvesting or relocation.

A PhD thesis - HYDROZOAN JELLYFISH AND THEIR INTERACTIONS WITH SCOTTISH SALMON AQUACULTURE – authored by Anna Kintner from St Andrews University published in 2016 included information on Marine Harvest (Mowi):

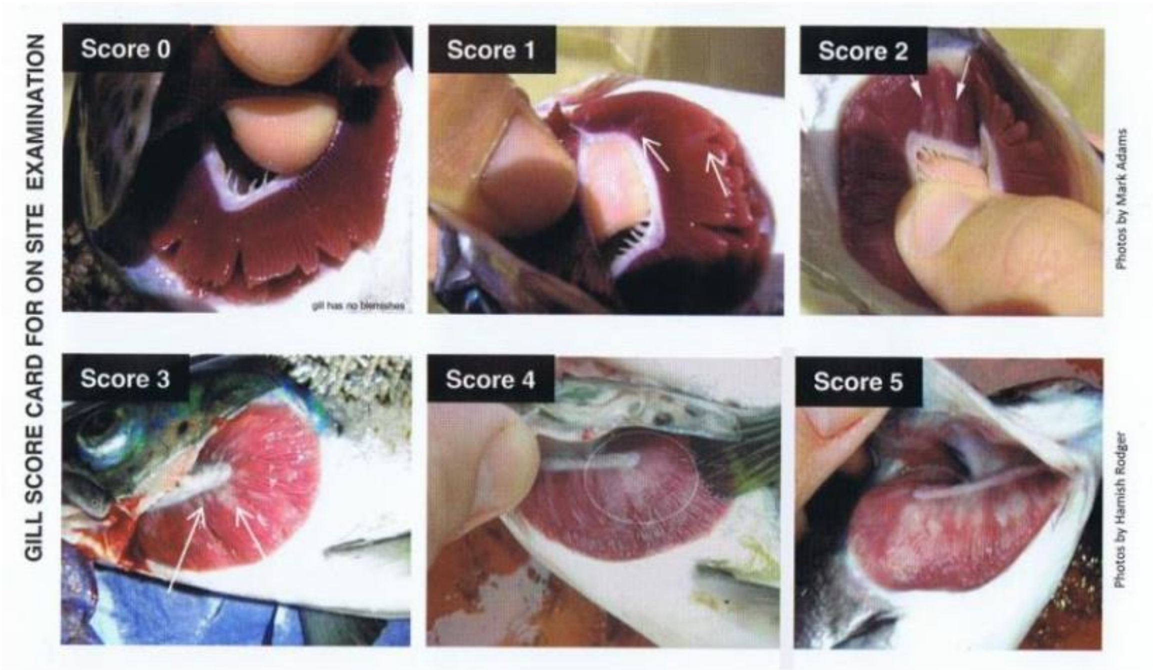



**Figure 2.3. Marine Harvest gross examination of gill scoring.** Adapted by Marine Harvest from Mitchell et al. 2011.

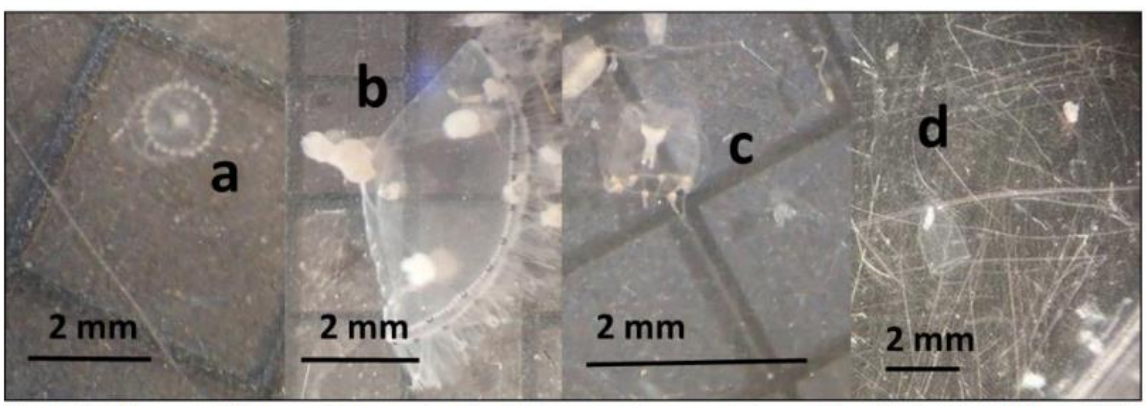



**Figure 2.5 The most frequently occurring hydrozoan species appearing at the study sites.** (a) small *Obelia* sp. medusa. (b) large *Obelia* sp. medusa. (c) *Lizzia blondina* medusa. (d) *Muggiaea atlantica* eudoxid.

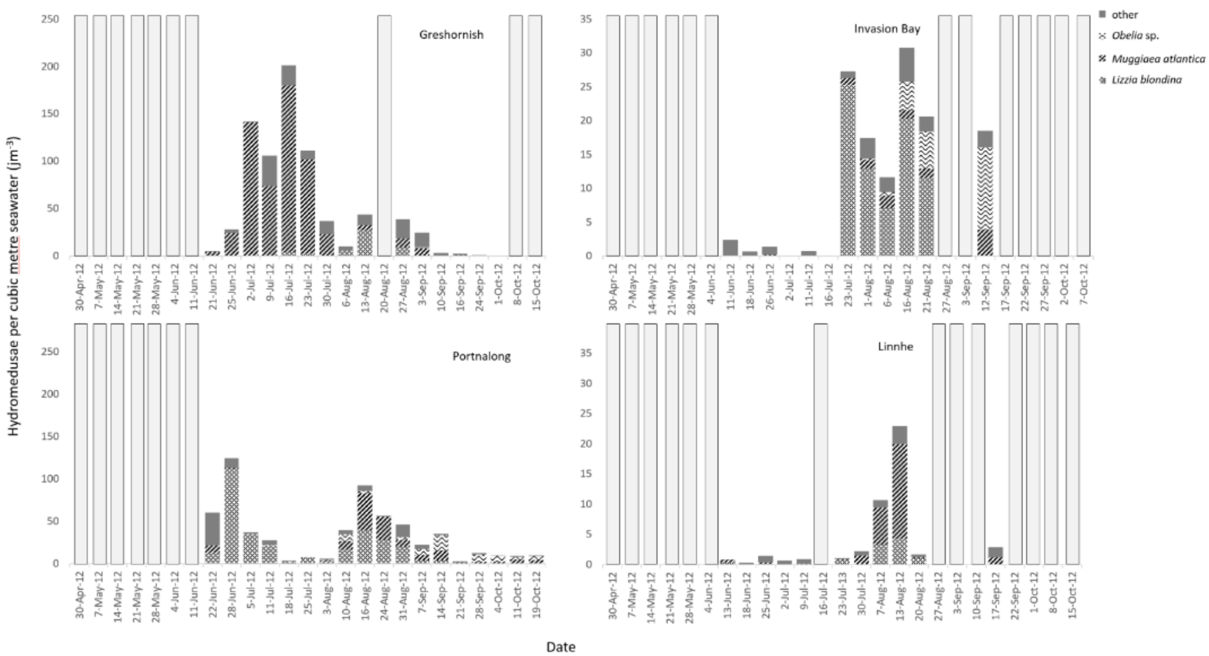



**Figure 2.7 Time-series 2012 hydromedusa populations ($jm^{-3}$ per date).** Top left: Greshornish. Bottom left: Portnalong. Top right: Invasion Bay. Top left: Linnhe. Grey bars denote no sampling taking place on this date. Note that Y axes are not standard.

**Table 2.3 Incidence of moderate and high-magnitude population density.** Long-duration single events occurring across multiple sampling dates are grouped by shading.

| Date | Site | Species involved | Population density | Density scale | Grouping |
|---|---|---|---|---|---|
| 2-Jul-12 | Greshornish | *Obelia* sp. | 142.08 | moderate | A |
| 9-Jul-12 | Greshornish | *Obelia* sp. | 105.82 | moderate | |
| 16-Jul-12 | Greshornish | *Obelia* sp. | 201.36 | high-magnitude | |
| 23-Jul-12 | Greshornish | *Obelia* sp. | 111.17 | moderate | |
| 28-Jun-12 | Portnalong | *Lizzia blondina* | 124.16 | moderate | B |
| 16-Aug-12 | Portnalong | *Obelia* sp., *L. blondina* | 92.23 | moderate | C |
| 19-Aug-13 | Greshornish | *Obelia* sp., *L. blondina* | 97.84 | moderate | D |
| 20-Jun-13 | Portnalong | *Obelia* sp., *L. blondina* | 79.32 | moderate | E |
| 28-Jun-13 | Portnalong | *L. blondina* | 145.73 | moderate | |
| 16-Aug-13 | Portnalong | *Obelia* sp. | 668.37 | high-magnitude | F |
| 22-Aug-13 | Portnalong | *Obelia* sp., *L. blondina* | 124.13 | moderate | |
| 3-Oct-13 | Portnalong | *Muggiaea atlantica* (nectophores) | 101.74 | moderate | G |
| 18-Oct-13 | Portnalong | *Muggiaea atlantica* (nectophores) | 145.31 | moderate | H |
| 14-May-13 | Linnhe | *Hybocodon prolifer* | 117.96 | moderate | I |
| 19-Jul-13 | Invasion_Bay | *Obelia* sp. | 84.08 | moderate | J |
| 18-Jul-14 | Greshornish | *Obelia* sp. | 308.11 | high-magnitude | K |
| 25-Jul-14 | Greshornish | *Obelia* sp., *L. blondina* | 359.98 | high-magnitude | |

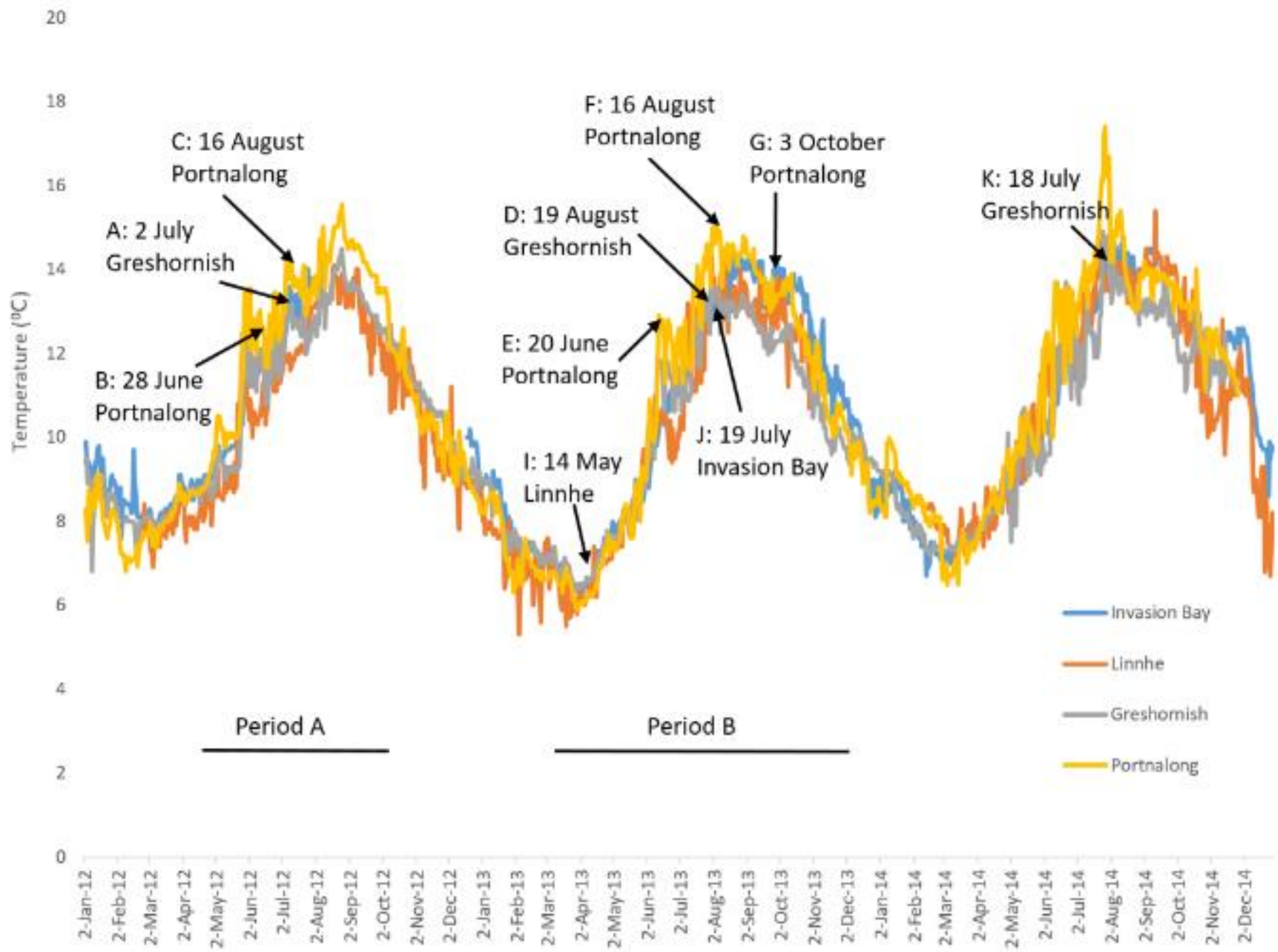



**Figure 2.12 Temperature records (including hindcast values) for all sites.** High magnitude bloom incidents, labeled as per Table 2.3, are indicated. Period A indicates values hindcast at Portnalong; Period B indicates hindcast at Greshornish. Blooms are labeled in accordance with Table 2.3.

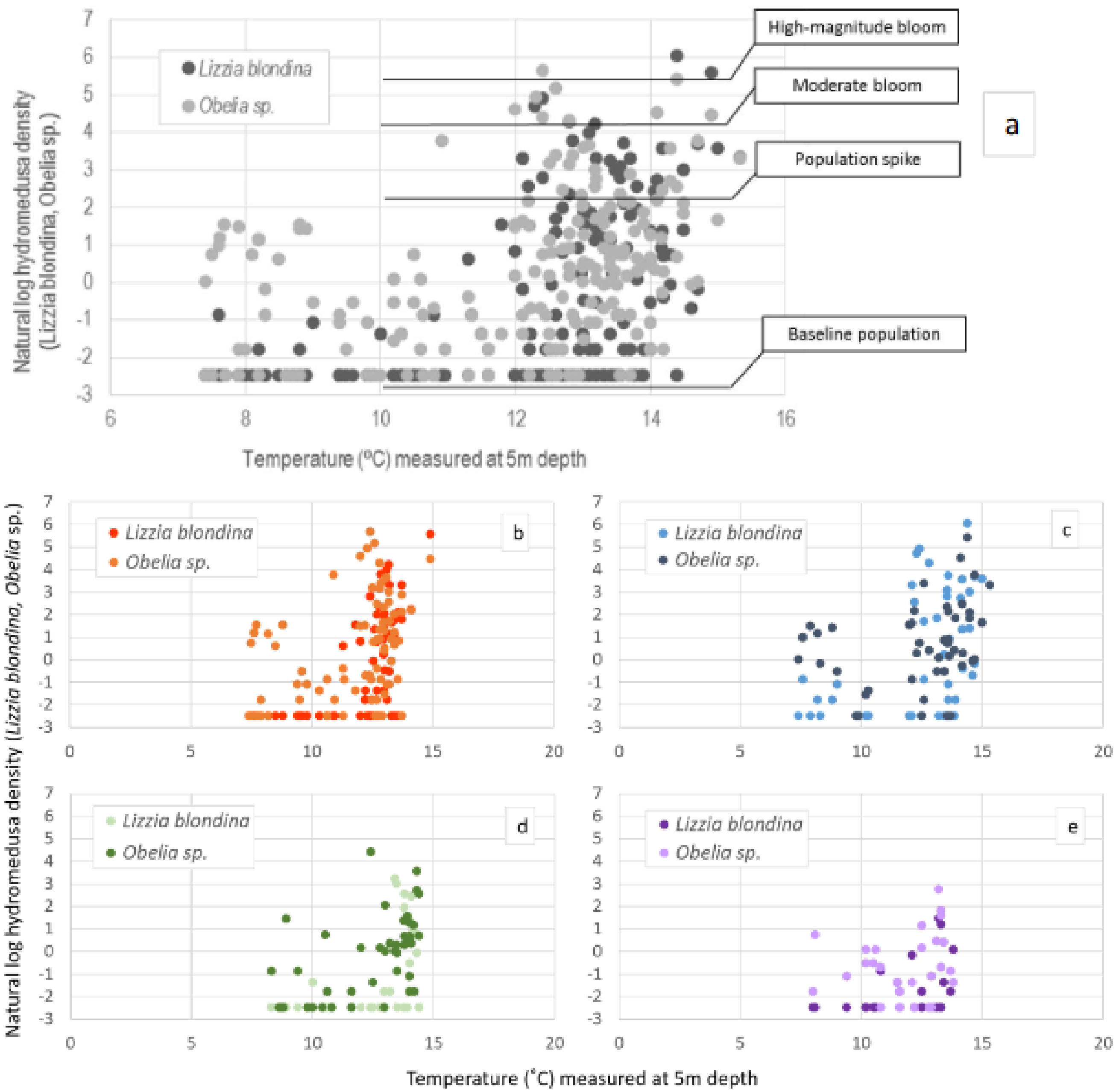



**Figure 2.13** ***Lizzia blondina*** **and** ***Obelia*** **sp. medusae are most likely to occur in both spike and bloom-level population density measures in water greater than 12˚C.** (a) all samples pooled; (b) Greshornish; (c) Portnalong; (d) Invasion Bay; (e) Linnhe.

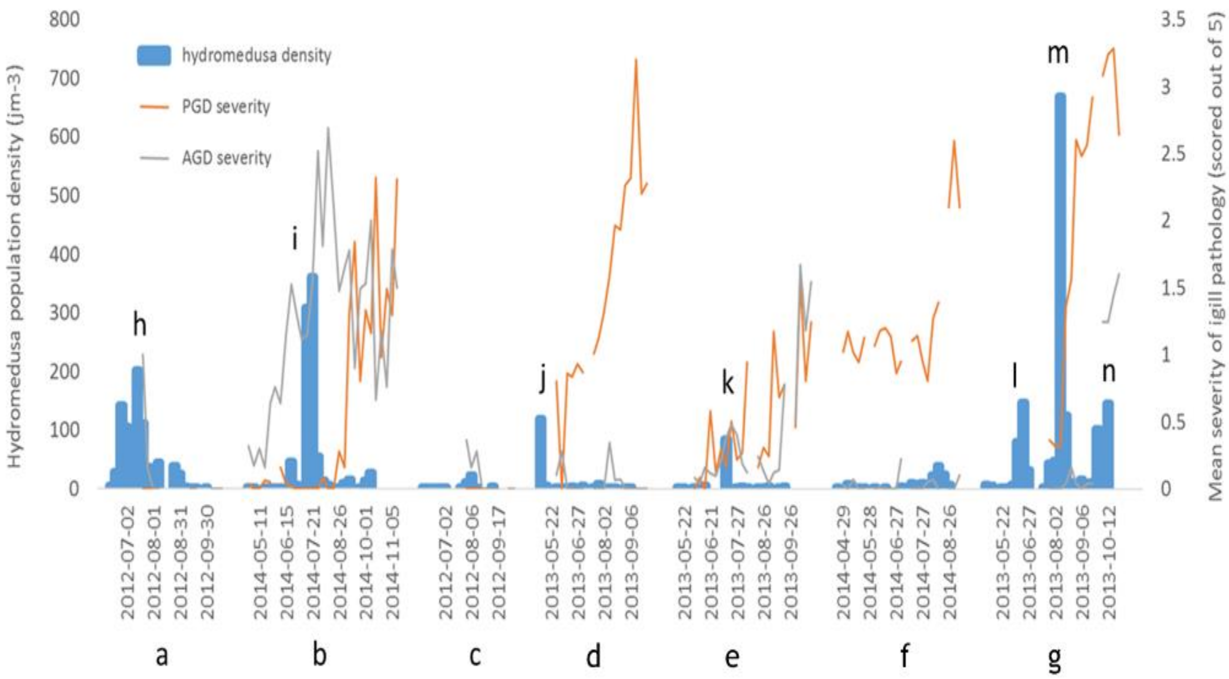



**Figure 2.22 Hydromedusa population density and incidence of gill pathology, summer 2012-2014.** Periods shown: (a) Greshornish 2012; (b) Greshornish 2014; (c) Linnhe 2012; (d) Linnhe 2013; (e) Invasion Bay 2013; (f) Invasion Bay 2014; and (g) Portnalong 2013. Specific blooms (see Table 2.3): (h) Bloom A, moderate to high magnitude and 4-week duration, involving *Obelia* sp.; (i) Bloom J, high magnitude and two-week duration, involving both *Obelia* sp. and *Lizzia blondina*; (j) Bloom H, moderate and 1-week duration involving *Hybocodon prolifer*; (k) Bloom I, moderate and 1-week duration involving *Obelia* sp.; (l) Bloom E, moderate and 2-week duration, involving both *Obelia* sp. and *Lizzia blondina*; (m) Bloom F, moderate to high magnitude and 2-week duration; involving both *Obelia* sp. and *Lizzia blondina*; and (n) Bloom G, representing not a true bloom but an incursion by the *Muggiaea atlantica* siphonophore.

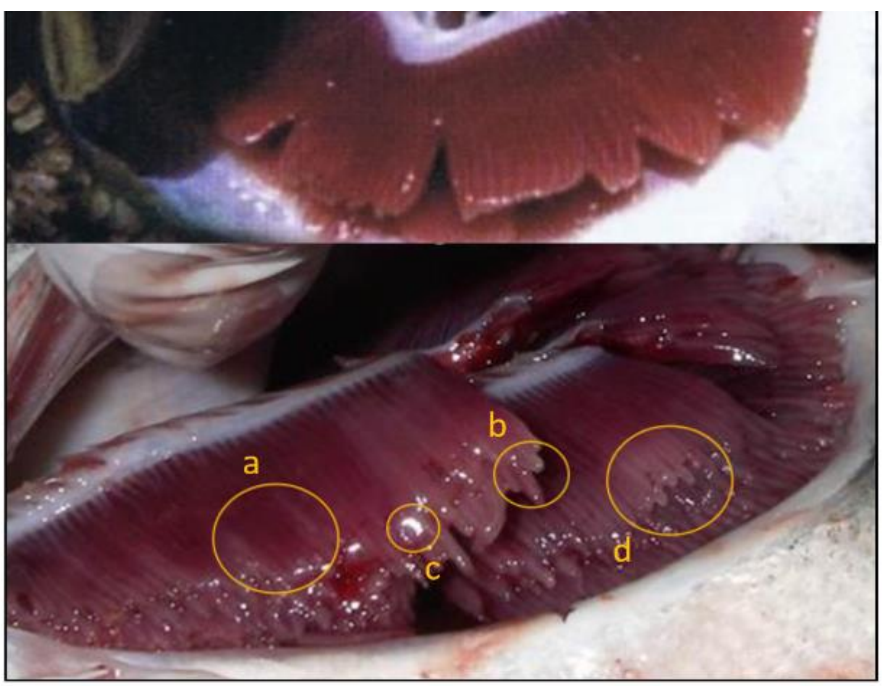



**Figure 2.23 Degradation and inflammation of gill lamellae following exposure to a hydrozoan bloom.** Top: normal healthy gill (photo by Mark Adams). Bottom: Gill exposed to *Obelia* sp. and *Lizzia blondina* medusae at a cumulative population density of nearly 670 jm$^{-3}$. Gills showed areas of both hyperhaemia (a) and anemia (b), overproduction of mucus (c), and thickening of the lamellar filaments (d).

Further histopathology examination on Oct 30 found significant chronic PGD with 50-80% of lamellar area involvement, and a further increased incidence of secondary AGD (Cox 2013d). A final examination on 12 November found amoebic infestation had increased further on compromised gill tissues, with no sign of resolving in PGD-affected areas (Cox 2013e). At this point the decision was taken to cull the remaining fish, at £2.5 million cost in lost product revenue, plus lost cost in treatment attempts.

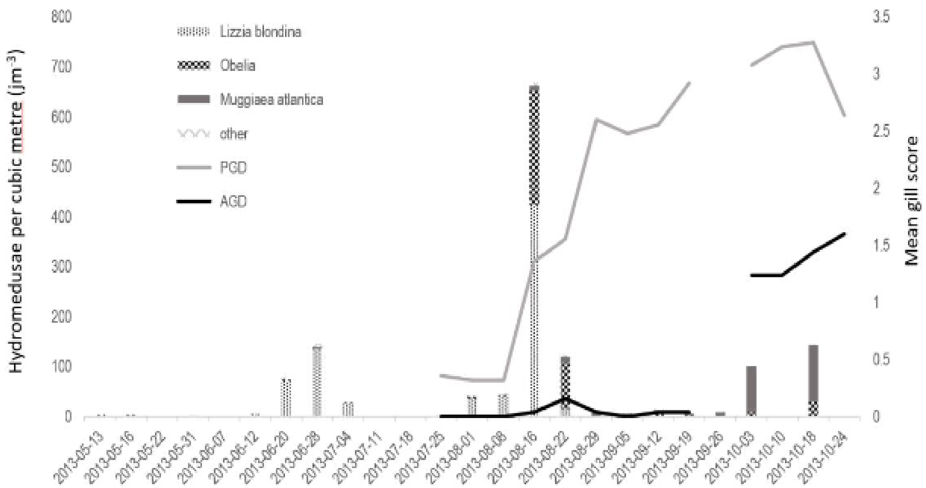



**Figure 2.24 Increase in PGD and AGD following bloom exposure.** A major increase in PGD followed a high-magnitude spike in populations of *Obelia* sp. and *Lizzia blondina*; AGD also increased with some lag.

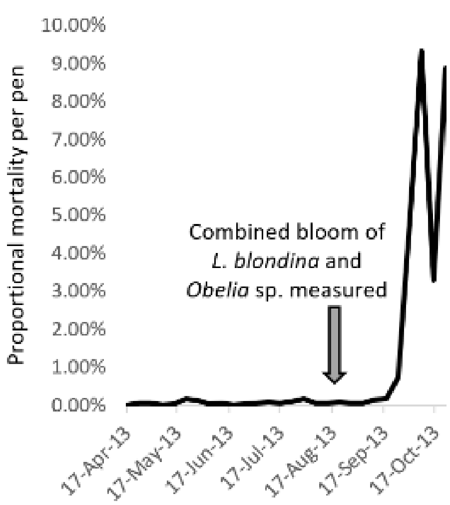


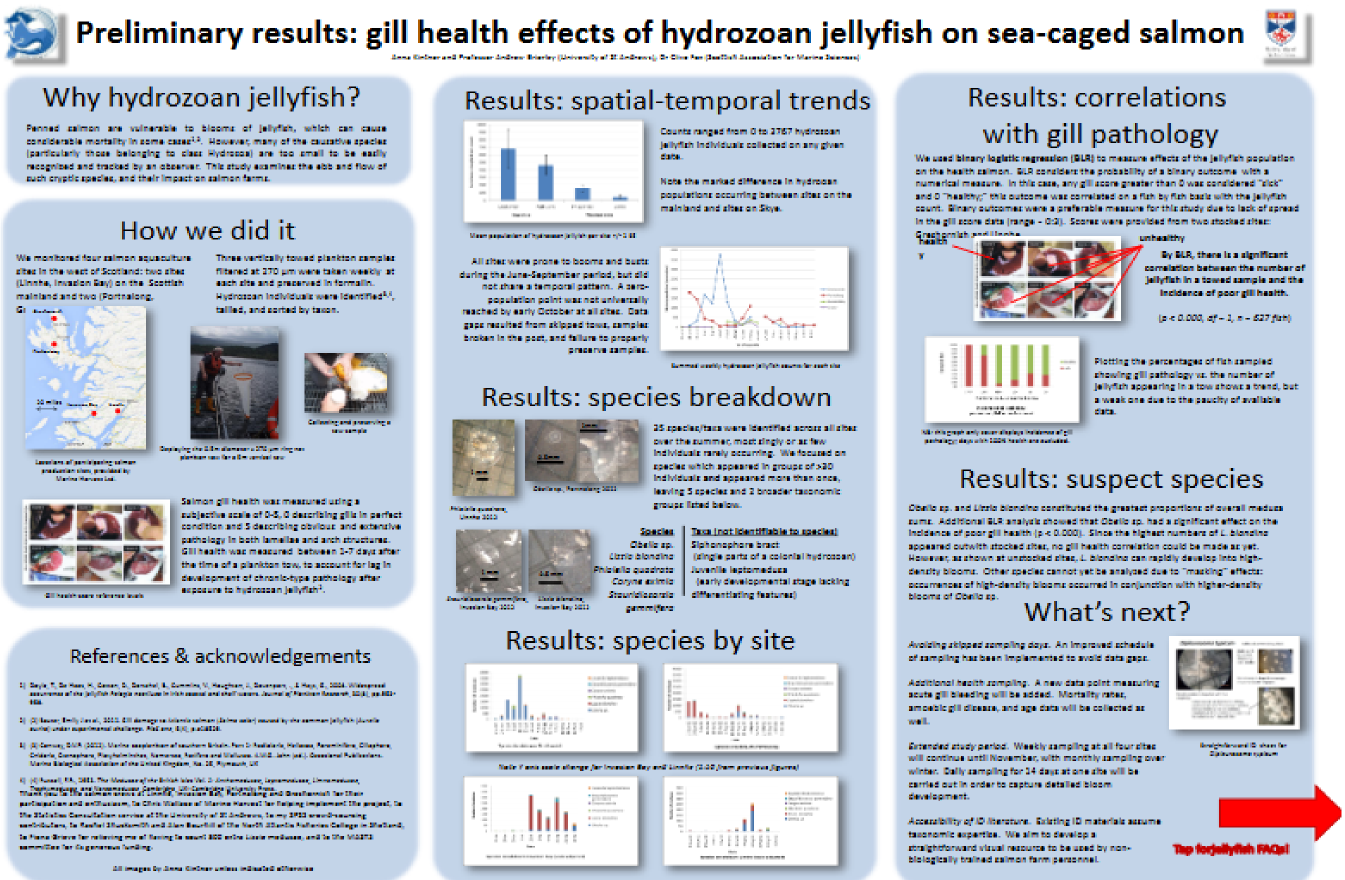

**Figure 2.25 Mortality increased dramatically at Portnalong in 2013 following exposure to multiple hydromedusan species and a rise in gill pathology.**

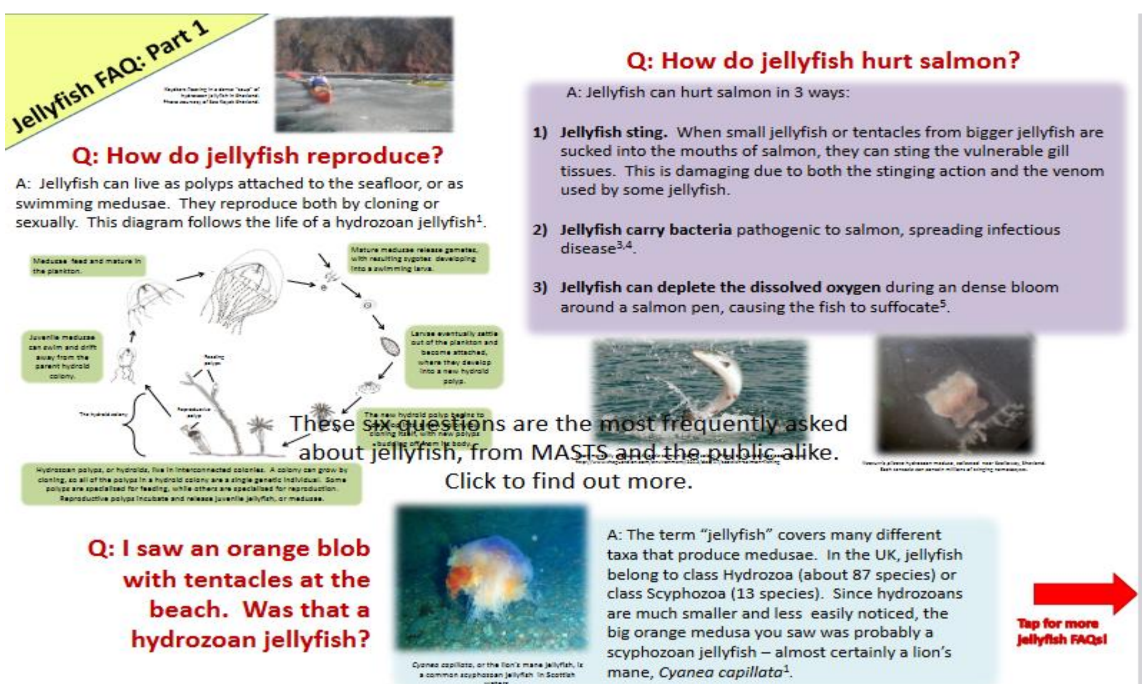
### 2.5.4 Impact on aquaculture

This study was unable to link statistically mortality and gill pathology of sea-caged salmon with their exposure to hydrozoan blooms, owing to a small overall sample size and the inconsistent compliance of sites involved. It may be that the only conclusive approach to forging this link will be the use of challenge trials, e.g. the intentional exposure of salmon to dose-calibrated population density levels of hydromedusae in a controlled setting. However, Baxter et al. (2011) demonstrated the serious and enduring effects of jellyfish nematocysts on salmon gills. The magnitude of both *L. blondina* and *Obelia* sp. population density immediately prior to a period of sustained and ultimately lethal gill pathology seems unlikely to be coincidental.

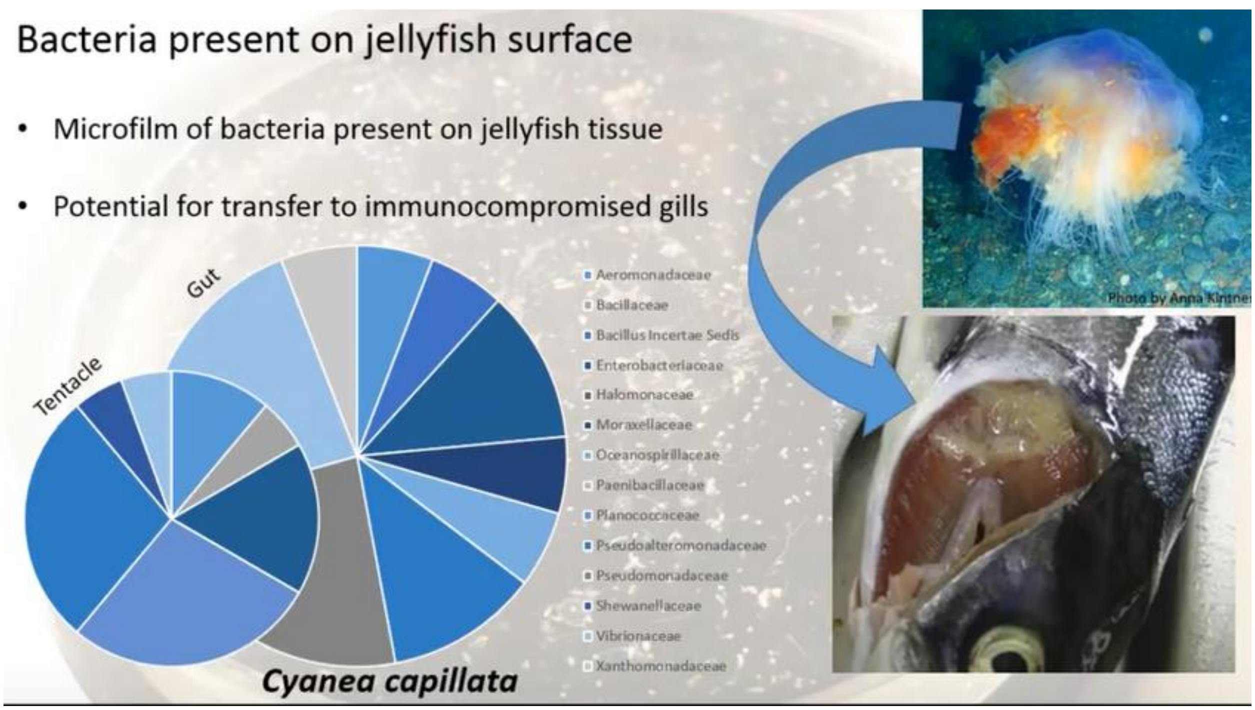
Some degree of gill damage is likely to self-resolve, when given opportunity to heal without further insult. However, sea-caged fish do not live in the proverbial vacuum, and are subject to a highly non-sterile environment. *Neoparamoeba perurans*, the species implicated in amoebic gill disease, are frequently present in very low numbers in farmed fish populations (Mitchell and Rodger 2011). An insult producing sustained PGD and inflammation, as seen in this investigation, is likely catalysing the overgrowth of amoebae and establishment of clinically relevant AGD. Complicating this further is the consideration of sea lice. Of the treatments for low-grade sea lice infestation, hydrogen peroxide baths have the least environmental impact, and are becoming comparatively less costly than pyrethroid pesticide treatments due to the development of parasitic resistance (Chris Wallace pers. comm., Aaen et al. 2015). These peroxide treatments have no appreciable side effects on healthy salmon, but produce considerable mortality when used on highly compromised gills (Chris Wallace pers. comm.). These knock-on health effects of exposure to hydromedusan blooms should put aquaculturists on their guard.

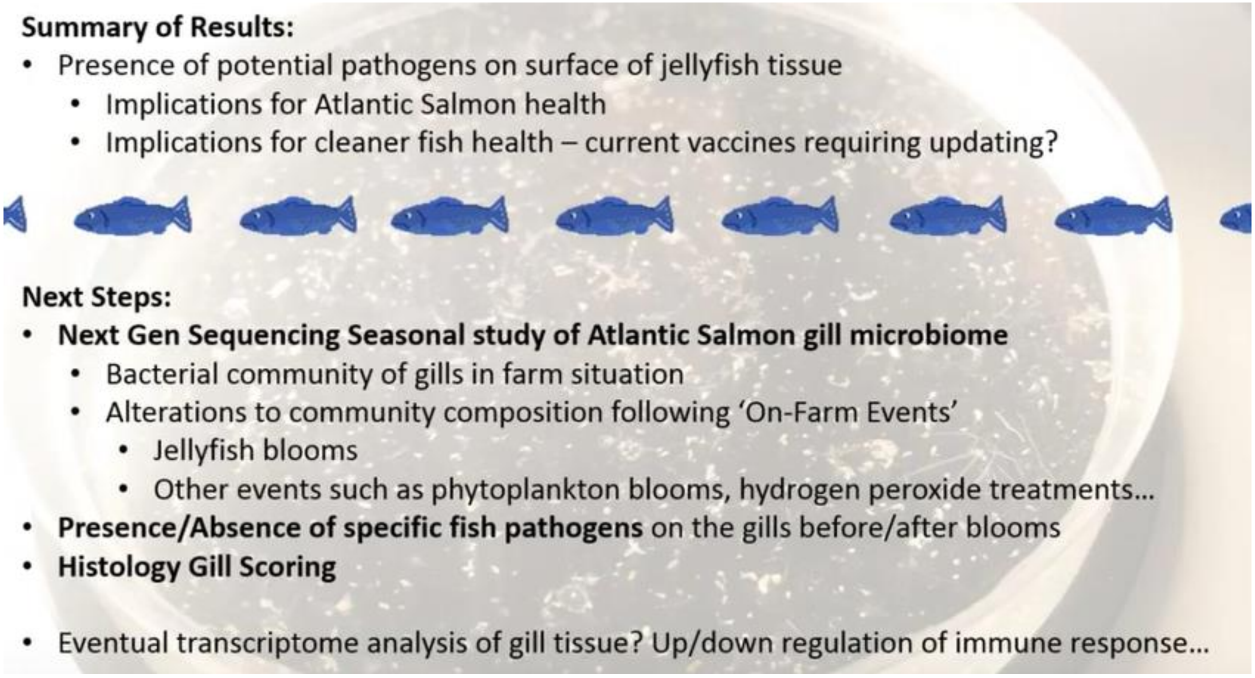
Read more [online here]



A presentation – ‘Jellyfish and their impacts on farmed fish – is available [online here]()




**[11] Overview: Medusas, Microjellies and Mass Mortalities by Don Staniford**

Salmon farmers love scapegoats – with seals, activists, nosey neighbours and government regulations all blamed for the industry's failings. Jellyfish* – specifically tiny microscopic medusa dubbed 'microjellies' - are the latest scapegoats in the $almafia's search for someone else to blame but themselves. The medusa monster, however, is a Frankenfish creation of the industry's own making: the spawn of the devil that is sea cage salmon farming. Rather than blame jellyfish, salmon farmers should look in the mirror at their self-inflicted wounds. And it's not a pretty sight: it stings the eyes just to sneak a peak.

Dr Lisa-ann Gershwin – author of Shapeshifters: The Wondrous World of Jellyfish and Stung! – On Jellyfish Blooms and the Future of the Ocean - has warned for over a decade that salmon farms exacerbate jellyfish blooms. "I believe there's every probability that aquaculture is making the jellyfish problem worse," said Dr Gershwin in an interview with ABC News in 2019. "We do have good data from places overseas that shows aquaculture stimulates the growth of the very organisms that cause problems for the aquaculture industry. It's a vicious cycle, where the aquaculture is making the problem worse."

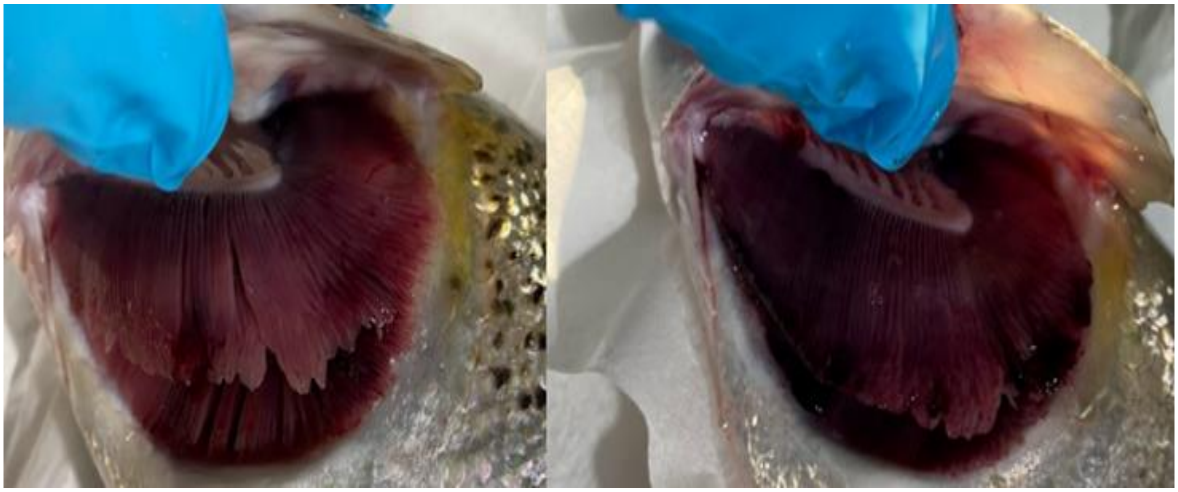
Plumes of untreated sewage effluents from salmon cages – containing uneaten feed, nitrogen, phosphorus, carbon, bacteria, faeces and other nutrients - create conditions for jellyfish, micro-jellies and plankton to thrive in. Moreover, the salmon cages, feed barges, work boats and farm equipment floating on pontoons in sea lochs provide ideal habitats, breeding grounds and nursery areas for more and more medusas. "When a polyp dies, it's replaced by more," explained Dr Gershwin who likens the multiplying effect of jellyfish reproduction with Disney's 'Fantasia' (the iconic broomstick scene still gives kids nightmares like War of the Worlds or Day of the Triffids). "When they are scraped away, it creates fragments, which creates more colonies."

Net cleaning, pressure washing and other attempts by salmon farmers to sweep the problem under the cages serve only to magnify and multiply medusas. Add in rising water temperatures – the Met Office warned in June of an 'unheard of' marine heatwave – with increasing gill diseases in farmed salmon and the salmon farming industry in Scotland is facing a perfect storm. Tavish Scott – who has the uneviable task of steering Salmon Scotland through a toxic soup – must know deep down that salmon farming in sea lochs is dead in the warming water.

If jellyfish had a heaven it would be in the shape of a salmon farm. Bigger jellyfish like the Lion's Mane congregate around salmon cages with their tentacles stinging, scaring and suffocating the tens of thousands of fish trapped inside the nets. Smaller microjellies like *Muggiaea atlantica* - a neritic species that forms part of the zooplankton – gorge on the copepod soup and planktonic smorgasbord from their safe haven deep inside the salmon cages. Salmon farm workers may not even see the microjellies but ravaged gills and lesions on the flanks of farmed salmon leave their mark.

In the vicious circle of life and death inside salmon feedlots – plastic circular cages which can be over 100 metres in diameter – the microjellies feast on free food like a swim-through McDonalds open 24 hours. It may be a free lunch for the jellyfish but farmed salmon pay the ultimate price:

peer-reviewed science has shown that their gills become clogged by the medusa menace triggering infectious diseases, parasites, viruses, bacteria and painful deaths.



Jellyfish blooms are described by fish health inspectors as ‘precursors’ to complex gill diseases. In other words, medusas are harbingers of death coming back to haunt salmon farms. No wonder Mowi – the world’s biggest salmon farmer – is on high alert in Scotland with ID posters of jellyfish circulated to workers as warnings like a fishy version of Interpol’s ‘Most Wanted’ list.

Jellyfish are not just the sting in the tail of Scottish salmon – they are covert killers and invisible assassins. The silent sting of the sea will be the death knell of salmon farming.

***** Jellyfish and sea jellies are the informal common names given to the medusa-phase of certain gelatinous members of the subphylum Medusozoa, a major part of the phylum Cnidaria.