An Analysis of the Causes of Mortality: Scottish Salmon Sector 2018-2020

Background

The Farmed Fish Health Framework (FFHF) is a 10-year collaboration between the Scottish aquaculture sector and Scottish Government, which aims to drive forward improvements in farmed fish health and welfare.

The FFHF includes a specific workstream relating to mortalities, which seeks a high-level analysis of the causes of mortality in marine grown salmon and trout. This analysis will help inform future activities within the FFHF.

This paper outlines the approach taken by the Scottish salmon farming sector in undertaking this high-level analysis, and thereafter presents the findings.

Approach

The following bullet points outline the approach that was taken for this analysis of the causes of mortality.

The analysis:

- considered all mortalities occurring in each full calendar year (Jan 1st to Dec. 31st).
- included data from all salmon farming companies.
- considered each calendar year from the formation of the Farmed Fish Health Framework (2018 to date).
- reports against the ten, previously agreed, overarching categories of mortality (Table 1. below).
- reports on the relative percentage mortality, i.e., it assesses mortalities as a percentage of the overall number of mortalities in each given year.

Table 1. Descriptions of the ten overarching categories of mortality

No.	Mortality cause	Descriptor / further detail
1.	Smolt and Transfer	Inc. fish dead on arrival or mortalities that are the result of incomplete or de- smoltification. Smolt and transfer mortalities should only be recorded as such up to 60 days post transfer.
2.	Predation	Predation mortalities are primarily due to seal or bird attacks, but this category should include any other predator related losses. Only direct mortalities will be categorised, as losses from induced stress from attacks will not be clearly identifiable.
3.	Jellyfish / plankton	Physical or toxic algal damage and jellyfish stings (inc. those impacting gills where jellyfish damage is the primary cause of mortality).
4.	Environment	Physico-chemical impacts (i.e., not biological), including dissolved oxygen levels, suspended solids, injury due to physical impact (e.g., storms).
5.	Viral disease	All viruses, inc. PD, HSMI, CMS, IPN.

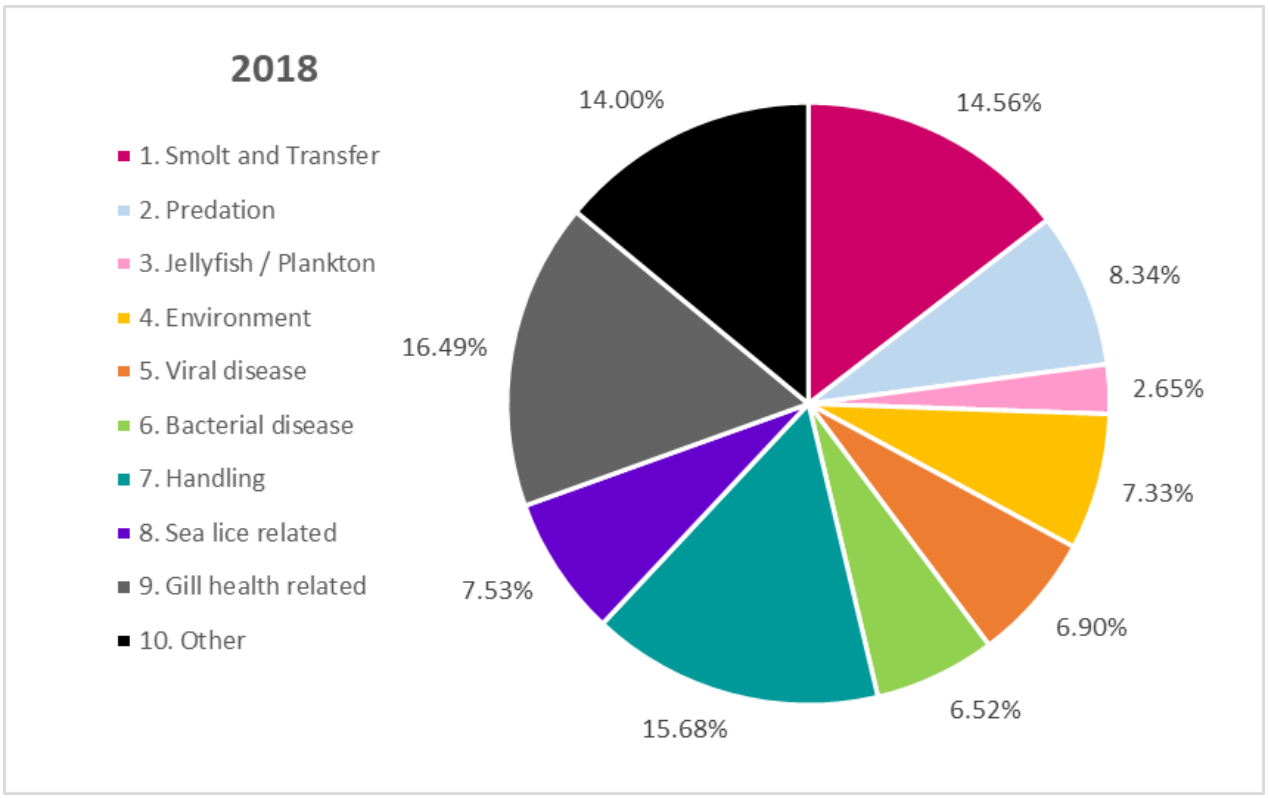
6.	Bacterial disease	All bacterial diseases, inc. Vibriosis, ERM, *Moritella*, *Pasteurella*, etc.
7.	Handling	Damage that might result from essential physical handling, inc. wellboat operations, grading. This category should not include any treatment mortalities, which will be categorised. *
8.	Sea lice related	Any mortality that is due to sea lice management activities, inc. physical or medicinal treatments.
9.	Gill health related	Any mortality linked to poor gill health or gill health management, inc. AGD, PGD, CGD, Anaemia and treatment.
10.	Other	Underperforming fish (w/ deformities / those that do not grow normally leading to mortality) & any other cause of mortality, for example maturation.

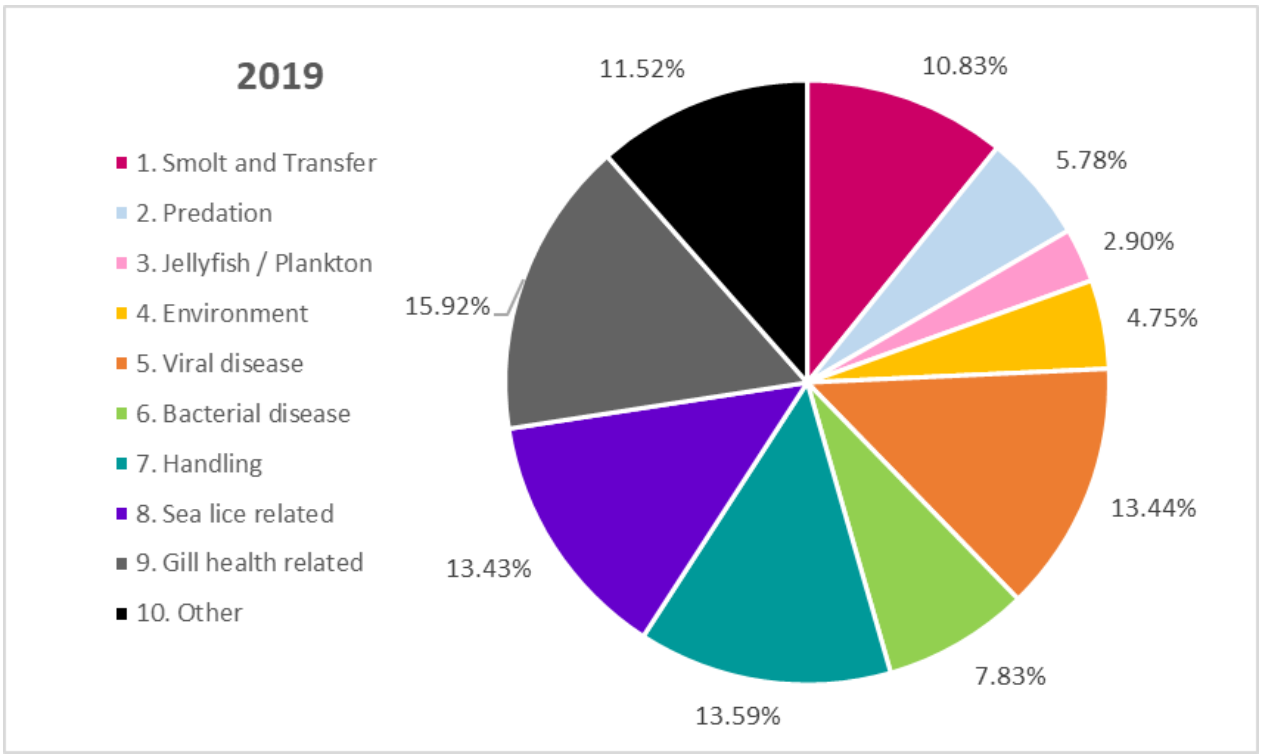
* It is likely that, for the analysis undertaken here (and reported below), which considers historically collated data held in existing data management systems, the "Handing" category may include some mortalities due to treatment. With the establishment of the 10 reporting categories through the FFHF, minor adjustments to company data management systems will be made to ensure that, in the future, treatment mortalities are assigned to their relevant treatment purpose (e.g. "gill health related").

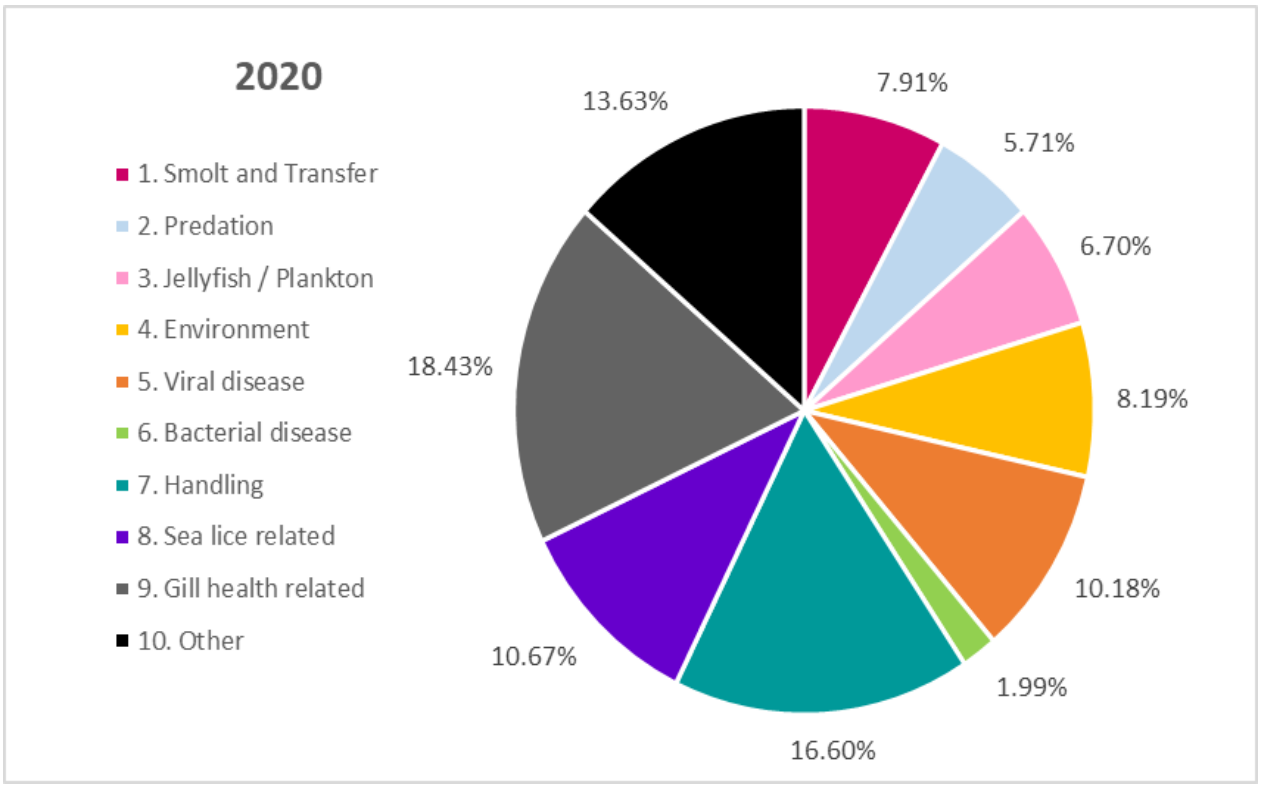
Results

The results of this analysis are provided in the pie charts, below.

In summary, in each year from 2018 to 2020, the leading cause of mortality was "gill health related". Subsequent to that, within each year, there was a subset of several other categories displaying similar levels of relative mortality (above 10%), with all other categories having a relative level of mortality below 10%.


2018
1. Smolt and Transfer
2. Predation
3. Jellyfish / Plankton
4. Environment
5. Viral disease
6. Bacterial disease
7. Handling
8. Sea lice related
9. Gill health related
10. Other
14.56%
8.34%
2.65%
7.33%
6.90%
6.52%
15.68%
7.53%
16.49%
14.00%


2019
1. Smolt and Transfer
2. Predation
3. Jellyfish / Plankton
4. Environment
5. Viral disease
6. Bacterial disease
7. Handling
8. Sea lice related
9. Gill health related
10. Other
10.83%
5.78%
2.90%
4.75%
13.44%
7.83%
13.59%
13.43%
15.92%
11.52%


2020
1. Smolt and Transfer
2. Predation
3. Jellyfish / Plankton
4. Environment
5. Viral disease
6. Bacterial disease
7. Handling
8. Sea lice related
9. Gill health related
10. Other
7.91%
5.71%
6.70%
8.19%
10.18%
1.99%
16.60%
10.67%
18.43%
13.63%

From: [Redacted]
To: Cowan C (Caroline); [Redacted]
Cc: [Redacted]
Subject: RE: Cabinet Secretary TNZJT - Briefing for Committee
Date: 19 June 2023 13:26:00

Hi all,

I think [redacted] has already given a good overview on marine heatwaves from MCCIP.

A few other points to note:

- There is also a warm record in the wider North Atlantic, so this signal in the coastal seas could have been transported in along the ocean current pathways, but it could also be due to local atmospheric processes (the recent warm weather). Most likely it's a combination of both.
- We still know very little about these short-lived, extreme events: both in terms of their extent through the water column (or whether only a near-surface phenomenon) and how they impact marine species, habitats and ecosystems.
- Examples of the impacts of ocean warming more generally include changes to fish body size in wild capture fish species and higher mortality rates in salmon aquaculture when winters are milder.
    - Baudron, A.R., Needle, C.L., Rijnsdorp, A.D. and Tara Marshall, C. (2014), Warming temperatures and smaller body sizes: synchronous changes in growth of North Sea fishes. Glob Change Biol, 20: 1023-1031. https://doi.org/10.1111/gcb.12514
    - Moriarty M, Murray AG, Berx B, Christie AJ, Munro LA, Wallace IS. Modelling temperature and fish biomass data to predict annual Scottish farmed salmon, Salmo salar L., losses: Development of an early warning tool. Prev Vet Med. 2020 May;178:104985. doi: 10.1016/j.prevetmed.2020.104985. Epub 2020 Apr 6. PMID: 32289615.
- 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.
- We anticipate warming temperature to continue to grab headlines this year: forecasts suggest a shift to El Nino conditions by late 2023 (with significant impacts in the Pacific and usually higher global average temperatures), and the warming in the Atlantic mentioned above means there is now a significant "hurricane generation region" (the seasonal forecast has already been adjusted from "near normal" in May, to a "above average but more unpredictable" this past week by one weather forecaster).

[Redacted]

[Redacted - out of scope]

Marine heatwaves

19 June: **VARIOUS MEDIA REPORTS** (BBC, Guardian) - UK Met office climate scientists and US National Oceanic and Atmospheric Administration (NOAA) warning of a marine heatwave concentrated around the UK and Ireland, impacting Scotland's coastal seas (to the west of Scotland and in the North Sea).

Above average temperatures have been recorded for the time of year, and may be four degrees above the long-term average. The region has been categorised as being hit by category 4 (extreme) marine heatwave (most severe on scale). The exact cause of the heatwave is being investigated but a combination of natural variation in weather patterns and climate change are factors. Further study marine observation data is needed to confirm the magnitude and extent of this current warming event.

The implications for Scotland's marine ecosystems remain unknown at this stage. 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.

We anticipate ocean temperatures and the role of the ocean in the global climate to continue making global news headlines in the coming months. Forecasts suggest a shift from neutral to El Niño conditions by late 2023 and ocean temperatures globally are above average.

TOP LINES

Scotland's seas are experiencing an unprecedented, extreme, marine heat wave due to a combination of factors including climate change, illustrating the importance of not only Scotland but all nations taking climate action and building an effective pathway to net zero.

- Marine Heatwaves are an increasing risk in Scottish waters but are currently poorly understood due to limited targeted monitoring, it is therefore important we maximise learning from this event to understand the risks and resilience of Scotland's marine environment.
- Scotland is making good progress towards net zero, and our next full Climate Change Plan will set out our pathway to meeting our emissions reduction targets to 2045 including in relation to Scotland's Blue Economy.
- **Professor Daniela Schmidt, University of Bristol.** "*As long as we are not dramatically cutting emissions, these heatwaves will continue to destroy our ecosystems.*"

The Scottish Government is monitoring this event though our marine monitoring programme on ocean climate and in collaboration with international partners and will assess the various risks to marine species and potential risks to human health.

- Scotland has an established ocean climate monitoring programme. This helps us to understand both these short-lived extremes and the long term changes in the ocean climate which occur because of natural variability and global warming.
- Scotland's marine environment monitoring is also helping us to understand wider impacts of climate change and ocean acidification.
- Marine heatwaves can influence the potential for Harmful Algal Blooms. Food Standards Scotland monitoring will identify any potential risk to human health.

We recognise that more needs to be done to improve the resilience of the marine environment to the changing climate including through sustainable management, protection, restoration and enhancement.

- We are developing an updated statutory adaptation programme, which will be published in draft for public consultation early next year which includes development of adaptation actions for marine climate risks.
- Sites in the MPA network must be managed to achieve the conservation objectives for their protected features, whilst still allowing other activities to take place.
- We have taken an evidence-based approach to developing fisheries management measures for our MPAs. Measures for the most vulnerable sites were implemented in 2016 and measures for the next phase of sites will be implemented by 2024.

The ocean around the world is connected, higher ocean temperatures are a global issue impacting countries around the world. We will continue to use our international influence to highlight the importance of the ocean in climate change conversations and share our science expertise.

Background Briefing

Scotland's coastal seas (to the west of Scotland and in the North Sea) are experiencing anomalously warm sea surface temperatures. A marine heatwave occurs when sea water temperatures are anomalously warm for five days or more compared to the long-term average. This is similar to the definition of heatwaves in the weather. The US National Oceanic and Atmospheric Administration (NOAA) is categorising the region as being hit by a category 4 (extreme) marine heatwave (most severe on scale). Although further study of high resolution, sustained ocean observations is needed in order to confirm the magnitude and extent of this current warm event and place it in context. Marine Directorate scientists continue to monitor research outputs and will also investigate further from our own monitoring data.

The Atlantic Ocean surface waters have been warming extremely fast in recent weeks. These warm waters could have been transported along the known ocean current pathways into Scottish waters, thus being the source of these extreme warm sea surface temperatures. Local sunny and calm weather may also have contributed. The reason for this warm event still needs to be investigated. The exact reason for the extreme warm sea surface temperatures in the Atlantic are also still being investigated, but weaker than average winds, reduced input of Saharan dust and atypical weather patterns over North America may all play a role. Colleagues will continue to monitor this event in our own sustained observations of ocean climate and in collaboration with partners.

The implications for Scotland's marine ecosystems remain unknown at this stage. Evidence of the impacts of marine heatwaves in the UK is limited. Marine heatwaves have been associated globally with blooms of gelatinous plankton (such as jellyfish), coral reef loss and mass mortality events across marine organisms (these are often linked to knock-on environmental influences and/or cascading effects across species). Previous analyses have, for example, linked milder winter temperatures to higher mortality in Scottish salmon aquaculture, and warmer sea temperatures have been linked to a tendency towards smaller adult fish in the North Sea on average.

We anticipate ocean temperatures and the role of the ocean in the global climate will continue making global news headlines in the coming months. Forecasts suggest a shift from neutral conditions to El Niño conditions by late 2023: this change in the prevailing weather patterns of the subtropical Pacific has repercussions for the local ocean climate and strong El Niño events have been known to impact marine ecosystems, as well as have severe weather impacts on land. Global mean temperatures in the year following an El Niño are often higher and the period 2023-2027 is predicted to be between 1.1 °C and 1.8 °C warmer than the 1850-1900 average (World Meteorological Organisation; global mean temperature in 2022 was 1.15 °C above 1850-1900 mean).

Reaction

- **Professor Kim Cobb, earth sciences at Brown University.** "*The combination of El Niño and global warming will bring a stepwise decline in marine ecosystem capacity….. not steady and gradual, it's a cliff that species and ecosystems fall off…..It does not bode well for ecosystems around the world…..This is an important year for monitoring and identifying ways to assist species through these next couple of decades*".
- **Dr Dan Smale from the Marine Biological Association** "*Current temperatures are way too high but not yet lethal for majority of species, although stressful for many … If it carries on through summer we could see mass mortality of kelp, seagrass, fish and oysters*".