Environment, Climate Change and Land Reform Committee

Environmental impacts of salmon farming

Written submission from Dr James Merryweather (ecologist), Scottish Salmon Think-Tank

Salmon aquaculture, as currently conducted in nets, is responsible for numerous detrimental impacts, both environmental and socio-economic. I wish to discuss aspects of pollution, confident that other contributors will be submitting responses that cover other impacts.

In my own routine criticisms of net-cage salmon aquaculture, since 2012 mostly as objection comments sent to the Highland Council's planning department during public consultations on fish farm developments, I divide pollution into three categories: 1. Solid organic waste. 2. Dissolved inorganic chemicals, chiefly compounds of nitrogen (N) as ammonia and urea and phosphorus (P) as various phosphates. 3. Excess toxic pesticides and chemotherapeutants. Fortunately, that is essentially the way they are presented in SAMS report that informs this inquiry, summarised on pages viii and ix.

1. **"A combination of reduced oxygen levels coupled to the physical smothering effect of the particulates, the diversity of the community of seabed (benthic) animals is much reduced."**

   Direct observation has routinely shown that, beneath active fish farms, native benthic animals rapidly become not so much 'reduced' but eliminated, overwhelmed by deep, dense, anoxic *Beggiatoa* bacterial mat containing little more other life than massively increased populations of the detritivorous polychaete worm *Capitella capitata.* No wise ecologist would declare a seabed that has been modified in this manner to be fully recovered after a fallow period of between six months and two years, as is conventional practice and dogma. As an ecologist whose research featured soil micro-organisms, I am all too aware of how little we know about soil or seabed life other than the iconic macro species, so that changes in habitat quality are very difficult to define properly and recovery following major disturbances unpredictable. That being said, I acknowledge that, given time, organisms disperse and recolonise more readily in aquatic than terrestrial habitats.

   All marine water bodies are tidal, particularly in more exposed locations, so redistribution of a proportion of fish farm solid waste is inevitable. Too little research has investigated the distribution of sediments and, as far as I can tell, no long-term studies have been undertaken. Hall-Spencer *et al*., 2006 demonstrated smothering impacts on maerl beds up to 100 m from the fish farm perimeter, but did not investigate beyond that periphery (p.57).

   A lot is said and written about the regulation of organic waste outputs, relatively confident that quantities released at present are within reasonable ecologically sustainable limits. Specialist scientists may be confident that organic waste disposal can be controlled by dispersion and regulation, but as an ecologist myself lacking relevant expertise, it is as a member of the public that I will represent contradictory arguments based on industry and government statistics, and common sense.

   Solid organic waste released *per annum* by a single modern fish farm (12 x 120 m cages, up to 2,500 T of fish[1]) straight into the sea untreated = 1,000 tonnes.[2] At the last available count there were 250 fish farms active in Scotland.[3] Therefore, total fish farm solid waste (Scotland) released into the sea untreated is approximately 250,000 tonnes annually (1,000 x 250 = 250,000). It does not require scientific expertise to consider that that amounts to unacceptable pollution.

   If current Government policy is realised and aquaculture continues unreformed, this is set to double by 2030[4] so that solid fish farm waste disposed of in the sea untreated may be predicted to total approximately 500,000 tonnes *per annum*. Common sense and a general understanding of the current degraded condition of the world's oceans might suggest that such depositions should actually be deemed intolerable and mitigation measures instigated. N.B. these figures are annual measurements, therefore cumulative impacts, already several decades-worth thereof, should not be overlooked. *When will the Precautionary Principle, to which Britain is a signatory and which is routinely recommended by the statutory authorities (e.g. SNH), ever be implemented?*

2. **Increased (but not harmful) concentrations of ammonium** [*sic*] **and phosphate can be observed within a few tens of metres from farms.** (p. ix)

Once again, one reaches contradictory conclusions from data available to the public, derived from industry and government sources. I question the assertion "but not harmful". In 2000, concentrations of dissolved nitrogen (N) as ammonia and urea, and phosphorus (P) as phosphates liberated from Scotland's fish farms were estimated to be equivalent to the entire human sewage of Scotland (were it to be released into the sea untreated).[5] By 2015, farmed salmon production had increased significantly (75%).[6] Today, dissolved N & P compounds released from Scotland's more numerous and larger fish farms greatly exceed their equivalents as Scotland's hypothetical untreated sewage.

In Scotland, we must consider potential impacts of eutrophication on sea grass meadows (*Zostera marina*). The impacts of fish farm generated organic sediments on maerl beds, seagrass meadows and serpulid reefs have been considered in the SAMS report's Additional commentary (p. viii), but sea grass was omitted from the equivalent box under *Eutrophication* on p. ix. However, eutrophication – such as would be caused by dissolved N and P from salmon farms – has well-proven harmful and fatal consequences for sea grasses. Salmon farms have in the past been proposed for siting very close to important sea grass meadows on Skye.

Burkholder *et al.*, stated without equivocation: "… chronic exposure to nitrate enriched waters is directly lethal to *Zostera marina* even at low enrichment levels, and likely represents an important causative agent in the disappearance of eelgrass meadows from many quiet embayments and coastal lagoons throughout the world."[7] We have observed on Skye that in some years, even in the absence of nearby fish farms, sea grass leaf surfaces become densely colonised by algae, hydrozoans and encrusting sea squirts that, as the scientific literature has frequently described, reduce the plant's ability to photosynthesise efficiently.[1] Sea grass is highly light dependent. Plants growing in deeper water, where red light penetration is reduced, die and the colony must gradually contract, surviving only in shallower water or perhaps becoming locally extinct. Had the four south Skye salmon farms applied for (2012-2015) been permitted there can be little doubt that Loch Eishort's fine sea grass beds – surveyed and admired by Project Seagrass[8] – would have been compromised, or if Burkholder *et al.* predictions had been realised, rendered extinct.

A Cautionary Tale of Unforeseen Eutrophication

Research in Australia[9] discovered a chain of apparently unconnected events that linked sugar cane farming in Queensland, Australia to substantial coral mortalities on the Great Barrier Reef.

a) Queensland farmers, as is conventional, applied fertiliser to their sugar cane crops.
b) Rain, seepage and flood water washed a proportion of that fertiliser off the land into the streams and rivers that empty into the Coral Sea.
c) Phytoplankton thrived on elevated nutrients inadvertently provided by sugar cane farmers.
d) Consequently, there was a phytoplankton population explosion ('algal bloom').
e) Larvae of the Crown-of-Thorns starfish feed on phytoplankton, so they also became more plentiful and, therefore, better fed than previously, the baby starfish enjoyed a greatly enhanced survival rate.
f) Increased starfish larvae caused a population explosion among Crown-of-Thorns adults.
g) Crown-of-Thorns starfish adults feed on coral polyps, so corals got grazed to death.

Since the mid-1980s, Crown-of-Thorns starfish *Acanthaster planci* have been estimated to account for 42% of coral damage on the Great Barrier Reef. This is a complicated example of catastrophic environmental nutrient overload, eutrophication. Salmon farm eutrophication potential may be more significant than concluded by the SAMS report.

Postscript It might be noteworthy that a significant number of objections to salmon farm planning applications submitted by lay members of the public complain that if they may be prosecuted for accidentally allowing a septic tank to overflow into a water course, why is an entire high profit industry permitted to dispose of all its waste, untreated, into the sea, intentionally?

3. **Excess pesticides and chemotherapeutants** Contamination of the sea and seabed by chemical therapeutants used, in the main, to control sea lice has long been a cause of public concern, though confirmatory data have not been readily available for public scrutiny. However, SEPA has recently released figures revealing that 45 Scottish sea lochs had been found to be contaminated thus, principally with emamectin benzoate (SLICE®) and teflubenzuron, both of which are deadly to crustaceans in particular (crabs, lobsters, prawns as well as sea lice) plus a wide range of other organisms, notably humans. This raises issues for the livelihoods of inshore fishermen, the safety of the public and the health of the environment in general. SEPA describes emamectin thus, reflecting warnings printed on labelling of its agricultural formulations: "Emamectin benzoate is toxic to birds,

mammals, fish and other aquatic organisms (particularly those living on the sea bed)." The manufacturers warn that this pesticide is not suitable for application in or near water.

We might also note that SLICE® is applied in salmon feed, migrating from the gut to the skin where the sea lice feed, presumably suffusing the entire fish. Under most circumstances (not specifically in fish muscle) this chemical's half-life is approximately 175 days whereas application in feed is stopped at about 60 days before harvest. Can we be confident that there is no residue of this toxin remaining in the fish at point of sale and consumption? If it were not necessary – see mitigation – there would be no such risk.

MITIGATION OF SALMON FARM IMPACTS

Fish farms that maintain their salmon in nets cause many more impacts than pollution alone. Of them, only one – the wild fish constituent, as meal and oil, of salmon feed – cannot be mitigated by conversion to closed containment, otherwise known as Recirculating Aquaculture Systems (RAS), in which the fishes are maintained in tanks.

Therefore, *ALL* disadvantages associated with salmon farming in net-cages (see Table 1) are eliminated if tanks replace the nets that allow free passage between farm and sea of waste, excess pesticides, pests, diseases and alien genes (via escapes).

Aquaculture industry spokespersons routinely deny the efficacy and cost effectiveness of closed containment. That seems not to be the opinion of the companies that are currently operating closed containment fish farms, many of which raise salmon, even Atlantic salmon. Norway, home country of the polluting net-cage salmon farmers, is leading the way to conversion, at home and around the world. I request that the Scottish Government should do likewise, obliging salmon famers to convert, by stages as will be necessary, but progressively and urgently.

Mentioning just a few: Numerous RAS installations are being built in Norway. NIRI has recently completed a production cycle (26,000 salmon, not tonnes) in a single tank establishment at Machrihanish, Argyll & Bute.[10] Another Norwegian company has begun building a full scale RAS salmon farm at Belfast, Maine, another in China and somebody is erecting a gigantic land-based salmon farm near Miami FL, which is projected to produce 90,000 T of salmon per cycle. That sort of investment must be backed up by a significant degree of confidence in the method, which the salmon aquaculture companies working in Britain ought to find persuasive, particularly if strictly encouraged by the Scottish Government.

Table 1. and references overleaf

Table 1.

COMPARISON

✓ advantageous
× disadvantageous
= equally good or bad

Big Nets	*Big Tanks*
NET-CAGES (PENS)	**CLOSED CONTAINMENT**
Full of holes, open to the sea ×	No holes, fully contained ✓
Waste disposed of in the sea ×	Waste contained ✓
Marine environment polluter ×	Marine environment non-polluter ✓
Waste treatment non-existent, therefore completely free ×	Waste treatment costs ✓ money, but see next two:
Waste is thrown away ×	Waste can be reused ✓
Waste is not recycled ×	Waste can be recycled ✓
Pests & Diseases affect farmed fishes ×	Pests & Diseases almost eliminated ✓
Pests & Disease affect wild fishes ×	Pests & Diseases do not affect wild fishes ✓
Pesticides & Medicines required ×	Pesticides & Medicines much reduced ✓
Pesticides & Medicines pollute ×	Pesticides & Medicines do not pollute ✓
Fishes escape ×	Fishes do not escape ✓
Genetic exchange with wild fishes ×	No genetic exchange with wild fishes ✓
Invasion by carnivorous mammals and birds ×	Carnivorous mammals and birds excluded ✓
Carnivorous mammals and birds 'culled' ×	Carnivorous mammals and birds no culling ✓
Cages damaged or destroyed by rough seas ×	Cages not damaged by rough seas ✓
Creates a few new jobs =	Creates a few new jobs =
Contribution to local economy? =	Contribution to local economy? =
Fish feed contains wild caught fish as meal =	Fish feed contains wild caught fish as meal =

The Scottish Salmon Think-Tank (SST-T) is a member of the Salmon Aquaculture Reform Network, Scotland (SARNS). Other SARNS members have responded to the ECCLR Committee's call for comments, each dealing with a particular topic. As the SST-T agrees entirely with these other submissions by members of SARNS, please record that I fully support their submissions.

REFERENCES

[1] N.B. the SAMS report (p. viii) cites data based on 1,500 T.

[2] Data: e.g. ES DOC 6 APP 7.5.1a AUTODEP MODELLING REPORT (page 7)
http://wam.highland.gov.uk/wam/applicationDetails.do?activeTab=documents&keyVal=ORYFDYIH0FN00

[3] Munro, L.A., & Wallace, I.S. (2016). Scottish Fish Farm Production Survey 2015. Marine Scotland Science.
http://www.gov.scot/Resource/0050/00505162.pdf

[4] Anon. (2016). *New Strategy to Double Size of Scotland's £1.8 billion Aquaculture Sector*. Scotland Food & Drink.
http://www.foodanddrink.scot/news/article-info/7209/new-strategy-to-double-size-of-scotlands-%C2%A318-billion-aquaculture-sector.aspx

[5] MacGarvin M. (2000). *Scotland's Secret? Aquaculture, nutrient pollution, eutrophication and toxic blooms.* WWF Scotland.
http://www.wwf.org.uk/filelibrary/pdf/secret.pdf

[6] Total salmon production **(Scotland, 2000) = 128,830 tonnes**. Data: Stagg, R.M & Allan, C.E.T. (2001). Scottish Fish Farms Annual Production Survey 2001. Marine Scotland Science.
http://www.gov.scot/Uploads/Documents/survey2001.pdf.
Total salmon production **(Scotland, 2015) = 171,722 tonnes**. Data: Munro & Wallace, 2016 (note 3).

[7] Burkholder JoAnn M., Katherine M. Mason, Howard B. Glasgow, Jr. (1992). Water-column nitrate enrichment promotes decline of eelgrass *Zostera marina:* evidence from seasonal mesocosm experiments. *Marine Ecology Progress Series*, 81: 163-178.

[8] http://www.projectseagrass.org/

[9] Fabricius, K. E., Okaji, K. & De'ath, G. (2010). Coral Reefs. Three lines of evidence to link outbreaks of the crown-of-thorns seastar Acanthaster planci to the release of larval food limitation. 29(3), 593-605.

[10] Industry spokespersons gleefully point to the harvest having to be a little earlier than expected. The system failed only in that, due to an easily remedied mechanical failure, the salmon needed to be rescued from what I understand was an oil leak.