From the Coastal Communities Network - Aquaculture subgroup

Terry A'Hearn
SEPA

24th September 2018

Dear Mr A'Hearn

Thank you for taking the time to go through our concerns yesterday.

Here is a brief summary of what we discussed:

The Coastal Communities Networks' Aquaculture sub-group represents communities concerned about the environmental impact of fish farms and their potential for harming our existing and future sustainable jobs. We agree with your vision for One Planet Prosperity.
No industry can claim that it or its growth plans are sustainable, if they harm the environment for the next generation.

SEPA promises environmental improvements through DZR and its sector review, but it will take at least 4 years to review every aquaculture CAR licence, to monitor problem farms and then to act to limit damage. By this time much of the sector's expansion will have been consented, including 3500+ tonne farms in coastal locations that threaten wild salmonids and the wider environment, including commercial shellfisheries. Meanwhile existing inshore, open-net fish farms will operate as before, under their existing licences.
Adaptive Management has failed to deal with the industry's problems at its present size. We have no confidence that it will protect the environment during rapid expansion

The main thing we ask is that SEPA should assess the large-scale cumulative impacts of this industry before its expansion is approved.
We urge SEPA to apply the precautionary principle and to pause the CAR consenting process while this is done, to allow the regulatory system to catch up with the increasing knowledge of the problems, and while DZR, as a potential solution, is discussed and finalized.

Unknown carrying capacity - no EIA done for the whole system
SEPA consents all fish farm biomass, but only assesses the environmental impact of this biomass on a farm-by-farm basis. Fish farms are not unrelated, point-sources of pollution, like land-fills. The sea is one continuous system, so the cumulative impact of the total consented biomass affects the whole system into which all the farms discharge their waste.

Does SEPA know the carrying capacity of the sea in Scotland's 'Aquaculture Zone' for marine fish farming?

When asked by the REC Committee whether SNH knew this, Cathy Tilbrook (i/c aquaculture) replied, 'we are quite far from that'.

Changing to DZR and controlling the impact of larger farms by allowing them to expand until they each have an AZE of 0.5 km sq (which is larger than the AZEs of present farms) does nothing to assess their cumulative impact at the largest scale.
Anne Anderson's August 2nd letter to Friends of the Sound of Jura says:
'There is no other single sector making discharges to the water environment which have the same total cumulative extent of impacts as fish farms…'
And that *'The approach used by SEPA accepts that the zone where impacts may occur from fish farm discharges is generally very much larger than from discharges made from other industrial sectors.'*

In July we asked Marine Scotland and (this month) also asked the Cab Sec for the Environment to explain why the Government has never done a Strategic Environmental Assessment of the environmental and socio-economic impact of Government policies that support expansion of this industry. This is a legal requirement. They have not answered.

Have the environmental impacts of SEPA's policies for controlling the cumulative impact of pollution ever been tested by a Strategic Environmental Assessment?

Unknown impacts on Priority Marine Features
SNH told the REC committee that it does not survey marine life around fish farms, as the results would not be typical. Anne Anderson's letter tells us that SEPA does not check for impacts on sensitive marine life away from farms, except with occasional studies, eg at Fetlar and Shune, to inform policy.
The National Marine Plan protects all PMF species from developments that would adversely affect their national status but the Government's ongoing review of the protection from bottom-contacting fishing practices given to Priority Marine Feature species shows that SNH does not know the location of all these PMFs.
Autodepomod and Newdepomod modelling shows that much of the waste from some fish farms leaves the modeled domain; 99.2% at East Tarbert Bay (**CAR/L/1161484**) for instance, as modeled by Autodepomod.
The PAMP2 emamectin benzoate study showed a correlation between a 60% average decline crustacean abundance on a 'sea loch' scale, and the use of emamectin on farms. As you know, this effect covered a much larger spatial area than suggested by Autodepomod modelling results.
SEPA's hydrodynamic modelling studies at Shuna and Fetlar, show that waste from multiple farms accumulates away from all of them. At Fetlar, Andrew Berkeley told us the modelling shows an additional 1% or so of seabed is impacted outside the consented AZEs of the farms. SEPA's policy, of achieving environmental protection by limiting harm to an AZE, is failing when this happens.

Given that fish farms pollute areas outside their AZEs, and that SNH and SEPA do not know where all the PMFs are, how can SEPA know whether fish farm waste and chemicals are affecting their national status?

Unknown impacts on commercial species

The same question applies to impacts on commercial species.
All licenced fish farm chemicals are very toxic to crustaceans (of course, since sea lice are crustaceans), even hydrogen peroxide, which SEPA presently more or less ignores. Norwegian research (the PestPuls study, which has collaborators at the University of Leicester) (https://www.forskningsradet.no/prosjektbanken/#/project/NFR/267746/Sprak=en) shows that hydrogen peroxide kills 100% of commercially fished shrimps at 1/100 the dose used in fish farms, and kills many of them at 1/1000 the dose, such as might be experienced 1-2km from the farm. This distance estimate is contained in a PestPulse presentation that we can send you.
Quoting from the English abstract of the study's interim report:
'The main conclusion is that a few hours exposure to AlphaMax (2 ng/L deltamethrin) or Paramove (1.5 mg/L hydrogen peroxide) cause significantly increased mortality of shrimp. This means that the shrimp were affected at 1000 times diluted treatment solution for salmon. Salmosan (100 microgram azamethiphos per litre) *was less toxic, but tissue damage was observed in the hepatopancreas after exposure to 1000 times lower concentration than used to treat the salmon (0.1 microgram/L).*
In September representatives from the authorities, the industry and several research institutes were invited to a workshop where the aim was to discuss if anti-parasitic chemicals used in salmon aquaculture can affect local populations of crustaceans. Results from PestPuls were presented and the conclusions from the group discussions will be summarized and sent to the authorities. IRIS is leading the project and NIVA, University of Leicester, DEBtox Research and Burridge Consulting Inc. are project partners. In addition, PestPuls has a national advisory board with representatives from the Norwegian authorities, the aquaculture industry and the Norwegian fishermen's association.'

There is a great deal of other research on these impacts on crustaceans.

The aquaculture industry is unique in being licensed to dump such large quantities of untreated biocidal chemicals into the sea.
PestPuls found the impact to be worse when multiple chemicals are used as cocktails, as is often the case in Scotland as well.

This study was triggered by Norwegian fishermen reporting lower crustacean catches around fish farms. Fishermen in Wester Ross and the Outer Hebrides have reported the same thing, yet Anne Anderson told us (02/08/2018) 'SEPA *does not collect or produce data on crustacean fisheries or on the stocks that are pursued by fishermen. SEPA has been aware either through direct reports or through information provided indirectly - for example in media stories of a possible change in crustacean abundance which may have been anecdotally linked to the use of sea louse medicines such as emamectin benzoate.'*
This of course includes the PAMP2 study on emamectin/Slice.

What is SEPA doing to understand these impacts and to protect commercially-important species?

What does SEPA know about the impacts of hydrogen peroxide on non-target species, and of 'cocktails' of chemicals?

Unknown impact of dissolved nutrients on Harmful Algal Blooms
Prof Tett told the ECCLR Committee that Harmful Algal Blooms (HABs) are natural events, triggered by dissolved nutrient changes far off shore. The SAMS report says the same thing. in 2016 HABs killed millions of farmed salmon in Chile. Even more wild fish, birds and even whales were found dead. These HABs decimated the economy and have been linked to nutrient loading of the sea caused by salmon farming.
Marine Harvest's Scottish 2016 annual report contained this table:

MAIN CAUSES OF REDUCED SURVIVAL

	INFECTIOUS		NON-INFECTIOUS	
	FISH NUMBERS	BIOMASS	FISH NUMBERS	BIOMASS
1	HSMI	Gill infections	Algal blooms	Treatments
2	Gill infections	CMS	Treatments	Algal blooms
3	CMS	HSMI	Poor performers	Poor performers
4	PD	PD	Handling	Handling

(HSMI, Heart and Skeletal Muscle Inflammation; CMS, Cardiomyopathy Syndrome; PD, Pancreas Disease)

Clearly algal blooms are having a big impact on the industry here too, if they are the number one non-infectious cause of death, by fish numbers, and the second most important cause of lost biomass.

The SAMS report says that 5-10% of the dissolved nitrogen in the Minch is already derived from salmon farming, and quotes Heath et al (2002) that nutrient inputs from aquaculture in parts of the west coast contribute more than 80% of land-derived inputs.
The studies referred to by SAMS seem only to look at phytoplankton blooms but fish excrete ammonia from their gills, which is known to promote the growth of bacteria in the sea. These are linked to Harmful Algal Blooms.
HABs often cause shellfish closures in Scotland, especially in warm weather. Loch Roag, Lewis, where so many salmon died this summer, was also closed for shellfish harvesting because of toxic microorganisms. This causes economic losses in rural coastal communities of course, yet there seems to have been no serious study of whether fish farms cause or contribute to these events, or of the impact of doubling the industry's size.
As SNH admitted, the carrying capacity of our seas for aquaculture is unknown.

Will you, in SEPA, look closely at what is going on?

Applying the Precautionary Principle
At the UN's 1992 Rio 'Earth Summit' the UK signed the Convention on Biological Diversity. The preamble to the Convention says: '*where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat.'*

One part of this convention, legally-binding on the UK, is incorporated in the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic: '*Preventive measures are to be taken when there are reasonable grounds for concern that human activities may bring about hazards to human health, harm living resources and marine ecosystems, damage amenities or interfere with other legitimate uses of the sea, even when there is no conclusive evidence of a causal relationship. A lack of full scientific evidence must not postpone action to protect the marine environment.'*

Roseanna Cunningham recently restated the Government's commitment to the Precautionary Principle (and to the 'polluter pays' principle, tackling pollution at source and to taking preventative action).

Yesterday, we discussed how SEPA applies the Precautionary Principle by setting conservative EQS levels for chemicals and that a lower interim EQS has been set for emamectin while the UK TAG reports on a new EQS. This lower interim level is supposed to apply to all new marine fish farms and to all those in qualifying protected areas. We believe that this has not been applied consistently and will send you more information, with specific examples.

How does SEPA apply the Precautionary Principle at a larger scale than farm by farm, to ensure the protection of the national status of PMFs, given that no agencies knows where they all are, and when pollution from fish farms is known to spread outside the monitored areas around fish farms?

How does SEPA apply the Precautionary Principle to protect commercially-important crustaceans, given that the fish farm chemicals dumped into the sea are known to affect them, but the location of the chemicals and organic pollution is not known or predicted once they leave the modelled domain of Autodepomod/Newdepomod?

How does SEPA apply the Precautionary Principle to prevent Harmful Algal Blooms occurring as a result of the dissolved nutrient loading from multiple farms, in particular dissolved ammonia/bacteria interactions?

Sea lice and SEPA's Biodiversity Duty
Every UK public body has a duty to protect biodiversity when making decisions, for instance, under the Nature Conservation (Scotland) Act 2004, '*to further the conservation of biodiversity so far as is consistent with the proper exercise of (its) functions.'*

As the Explanatory Notes to the 2004 Act states, the point of the biodiversity duty *'is to place the onus on public bodies* ***to take direct responsibility*** *for the impacts which their policies and operations may have on the natural environment.'*

At our meeting with Anne Anderson in April 2018, she said SEPA's job is only to regulate pollution. Sea lice are not pollution as they are alive but, in open cage farms, the numbers of sea lice released into the sea is a direct consequence of the biomass of fish in the cages. Larger farms will release more sea lice.
Marine Scotland and parts of the industry (eg Marine Harvest) accept that sea lice impact wild salmonids. Marine Scotland also points out that even if sea lice are kept below industry CoGP levels, *'adherence to the suggested criteria for treatment of sea lice on individual farm sites stipulated in the industry Code of Good Practice may not necessarily prevent release of substantial numbers of lice from aquaculture installations.'*

Salmon and sea trout are both PMF species, and both are in decline. Several factors are causing this decline, possibly including global warming, but the decline is steepest in the 'aquaculture zone'. In Loch Roag, Lewis, this summer, tens of thousands of farmed salmon were being eaten alive by sea lice, and wild salmon were found dying in the nearby Blackwater River, with up to 700 sea lice per fish. There are multiple farms in Loch Roag, consented one-by-one by SEPA on the basis that their impact on the seabed was acceptable, but ignoring the effect of the total biomass of all those farms on sea lice numbers.
SEPA used to accept this responsibility, as its 2005 Fish Farm Manual shows:
'…in order to better protect wild salmonid stocks however, SEPA has adopted a Limiting Factor approach to consenting marine caged fish farms. SEPA may, in determining biomass limits for sites where proximity to important wild stocks is considered as a significant issue, impose a biomass limit equivalent to that biomass which can be effectively treated for sea lice infestations using an authorised sea lice medicine.'

Subsequent Acts of Parliament have not changed SEPA's biodiversity duty, but it no longer recognises its obligation to limit biomass to protect wild fish. Its latest Biodiversity Duty Report says nothing about salmon and sea trout.

The Fish Health Inspectorate is unable to limit farm biomass to protect wild salmonids, as it is only legally concerned with farmed fish. Once a farm has planning permission, neither Marine Scotland nor the Local Authority can modify its biomass for wild fish reasons. Only SEPA can do this.

The ECCLR Committee concluded that it, *'is not convinced SEPA (or any other agency) is effectively monitoring the environmental impact of salmon fisheries...'*

Would you please look at whether SEPA is fulfilling its statutory Biodiversity Duty to protect wild salmonids from sea lice, by failing to consider the cumulative impact of consenting biomass of multiple farms? Anne Anderson told us at the April meeting that SEPA had no responsibility in this respect, saying that it asks Marine Scotland for

advice instead, but Marine Scotland has failed to deliver Locational Guidance on the sensitivity of different parts of the Scottish coast for wild salmonids, an obligation of the National Marine Plan. It is now four years overdue. This failure is hindering Local Authorities too, in their ability to judge the impact of fish farms on wild salmonids. Argyll ands Bute's planners say that Marine Scotland gives non-committal advice on the significance of this impact. MS tell us they do not know how significant the impact is - a clear case for the Precautionary Perinciple.

The DZR plan to site larger fish farms in 'remote exposed' sites, in order to halt the rising pollution pressure on inshore waters (which is necessary), takes no account of where wild salmonids live. These farms are not necessarily far offshore, where there may be fewer wild salmonids. Dounie, in the Sound of Jura is an 'exposed site' but the proposed farm there would have been just 50-100m from the shore and only a few kilometres from a salmon breeding river, in a place used all year by sea trout,. BDNC Loch Shuna, given planning permission to expand to 3500t this August, is close to the same river and also in an area used by sea trout all year.
You wrote to Mr Dey of the ECCLR Committee (28/03/18), to explain that new farms should be located in *'exposed, dispersive environments where current speeds significantly reduce accumulation of waste on the sea bed'* and added that '*…in practice, large farms would be limited to more exposed locations* ***where the risk of infection with sea lice and other diseases can be less'****.*

This is wrong.
Adams et al (*Temporal variability in sea lice population connectivity and implications for regional management protocols.* T.P. Adams *et al*. SAMS. Aquaculture Environment Interactions Vol. 8: 585–596, 2016) have modelled the spread of sea lice larvae from fish farms. They found that viable larvae can be carried on currents from the Scottish mainland to the Outer Hebrides, while others could move in the opposite direction. The sea is one system. The effects of consenting all fish farms are cumulative. Siting larger farms in exposed places with stronger currents will spread sea lice further afield.

Closed containment solves the sea lice issue and contains all pollution too.

Please review SEPA's biodiversity responsibility to protect wild salmonids from sea lice.

Why is an AZE acceptable at all?
Yesterday, we discussed that AZEs are not unique to aquaculture, but that their size is. The degree of depletion of life permitted in the AZE is extraordinarily high: it is acceptable, across hundreds of thousands of square metres around each farm, to kill all life on the seabed apart from two species of polychaete burrowing worms, in order to keep the sediment aerated. Even then many farms fail or are borderline on their AZE standards.
Anne Anderson explained that even such failures do not preclude expansion at those farms, under some circumstances. This was clearly seen to be the case at BDNC Loch

Shuna, where the Local Authority gave permission for expansion to 3500t, despite its 2017 seabed monitoring report being borderline, at 2500t.
How can a farm improve on such performance when the only change being made is to increase biomass by 40%?
This expansion has no CAR licence yet but Marine Harvest's application to the Local Authority must have assured them that the seabed impact would be acceptable to SEPA.
Marine Harvest has applied for a CAR licence to expand Poll na Gille, which is near BDNC Loch Shuna and discharges waste into the same waterbody. Pol na Gille was deliberately overstocked by Marine Harvest in 2017 to 2207t, when its licence was for 1500t. It has had 6 'borderline' seabed monitoring reports, 6 'unsatisfactory' and 2 'not acceptable' reports. MH has applied to expand it to 2500t (**CAR/L/1000800**).

SEPA's hydrodynamic study of the area around Shuna Island showed waste from up to seven farms (including these two) accumulating in some places outside all of their AZEs.

Why are companies applying to SEPA for 3500t farms?
The 2500t cap on biomass per farm was imposed by the modelling limitations of Autodepomod. Newdepomod is said to be able to model the impact of farms with larger biomass, but has not been approved for use. Doesn't approval for this need to go beyond SEPA, given that the latest modelling guidance is still in draft form and has only been issued to industry, so the public cannot see how Newdepomnod works or understand its limitations, in order to comment.
Despite this, Muck (**CAR/L/1109999**), N Kilbrannan Sound (**CAR/L/1168182**) and perhaps others on the list of 16 MFF CAR licence applications, are for 3500 tonne farms.
Marine Harvest has applied to A&BC for its N. and S. Carradale farms to expand to 3500t each.
The industry and the council apparently think it's going to be fine to have 3500t farms, before DZR has even been through its second consultation.
In addition, four farms in Loch Fyne have applied to Argyll and Bute Council for 'deletion of biomass limits'.

Does SEPA also allow biomass limits to be deleted? This is something that will not come in until DZR isn't it?

Newdepomod modelling at Muck shows that only a single emamectin treatment would be possible without breaching its EQS. Previously some farms have administered more than five such treatments in one production cycle.
At N. Kilbrannan Sound, the Newdepomod results show that only enough emamectin could be used to treat 2400t of the proposed 3500t farm. Treating only some of the fish would be pointless. How is realistic to apply for a CAR licence on this basis? Cleaner fish and new physical treatments are not proving that effective.

We are reassured to understand from you that none of the 3500t CAR applications will be considered until DZR is finalised. This is correct isn't it?

Meanwhile, why is Autodepomod still being used to assess sites such as East Tarbert Bay (**CAR/L/1161484**) which is described as 'highly dispersive' in its application? It says that 99.2% of waste would leave the Autodepomod modelled domain. This model makes no allowance for seabed slope, for high current flow, for storms re-suspending sediment, for any of the exported material re-entering the small modelled domain when the tide changes, and it bases a whole year's sediment transport and deposition on only 15 day's data, deliberately collected when the wind speed is low. It cannot assess multiple chemical treatments or the cumulative effects of other farms further away than 500m.
Anne Anderson and others have told us repeatedly that none of this matters because Autodepomod is only used for 'risk-screening', but this is clearly not the case.
Its predictions are displayed as maps showing deposition. These are sent by applicants to the Local Authority planners, who look at maps as showing something real. So do the public. Autodepomod's maps in the above cases are a misleading fiction.

The CAR application for a two cage 515t fish farm at Gravir West, Lewis (**CAR/L/1166445**) is actually adding two cages to a 2500t farm only 200m away. Yet Autodepomod's deposition maps show no overlap at all between the footprint of the two farms. This is utterly unrealistic. The total biomass would of course exceed the 2500t limit of Autodepomod's modelling ability.

Autodepomod should be discontinued now and no new CAR applications using it should be considered.

Will you stop accepting new applications while this regulatory and modelling muddle is resolved?

Also, as you now know that the cumulative impacts of multiple farms are so complex and potentially damaging, can you not make it a requirement that hydrodynamic modelling is used whenever a new farm or an expansion is requested?

Non-compliance
The SPICe report for the Parliamentary Inquiry into the environmental impact of salmon farming quoted Sepaview, saying that in 2015 there was 21% non-compliance with aquaculture licence terms. Anne Anderson confirmed that *'The current level of non-compliance in the finfish sector is not acceptable'* (02/08/2018).

Despite this she also confirmed that: *'No marine cage fish farm licences have been revoked by SEPA for persistent breach of licence terms and there have not been any successful prosecutions of marine cage fish farm operators for non-compliance with licence conditions in the recent past.'*

We can see the argument for SEPA having a better and more collaborative relationship with the industry, but it is hard not to draw the conclusion that this has been extended to letting companies off the hook when they transgress. The rules are

generous already, with uniquely large AZEs and licences to dump untreated biocial chemicals into the sea.
You can see why our communities have lost trust in the regulator. Having your Head of Compliance leave to work for the SSPO, having been party to every confidential discussion about DZR and the future shape of regulation makes this even worse.

We discussed the limitations of relying on the industry to self-report the harm it is doing to the environment, and that self-reported data is not admissible as evidence in court. Roseanna Cunningham and Anne Anderson have assured us that this does not matter as that data can flag up a problem, allowing SEPA to collect its own evidence. This may be true of accidental breaches but self-reported data will not reveal deliberate fraud.
We discussed the allegations of such fraud that we have been sent by an employee of one fish farming company, saying that this company deliberately overstocks its farms, keeping one official set of records to shows SEPA, FHI etc, and a second secret set showing the higher biomass, amounts of feed, pesticides etc. Anne Anderson ignored this when we wrote to her about it in April. Perhaps she did not read the letter thoroughly.
In her reply she did confirm that the biomass on farms is largely judged by believing what the farming companies say. Yesterday, we talked about several farms in Loch Fyne applying for retrospective planning permission for larger biomasses. Presumably they were in breach of CAR licences too?

We would be happy to join you in three-way discussions with aquaculture firms, but we would want to see evidence that the present culture of allowing non-compliance with the rules has come to an end. The regulator in Norway charges very substantial fines for licence term breaches.

It seemed from the DZR consultation that SEPA was proposing to collect more of its own data on environmental impacts. Later, to Mr Dey, you suggested that the industry is resisting this, because of biosecurity concerns about moving boats and monitoring equipment from farm to farm. The industry moves thermolicers, wellboats etc between farms all the time of course.
It seems entirely consistent with 'polluter pays' that SEPA could extract a levy from firms to pay for its own independent monitoring services.

It is essential to repair much needed public trust in the regulator and the industry, which have both been reluctant to disclose their plans, methods and their environmental consequences. We discussed the vital need to publish all documents relating to fish farm monitoring, in close to real time. Having to resort to FOI requests in order to see documents is a waste of everyone's time.

Best practice
The industry's pollution and sea lice problems would be solved, and your regulatory/compliance burden would be much reduced, if farms stopped using open nets. They are not best practice and, as you know, Norway is moving new farms to close containment. This is consistent with One Planet Prosperity.

In 2016 Akvafuture harvested 2000 tonnes of salmon from its closed containment farm, without any sea lice or the need to treat fish with pesticides. They capture organic waste and turn it into biogas. The farm is also powered by hydroelectricity. (https://www.akvafuture.com/)

Aquaculture is a highly profitable industry. This year Marine Harvest's operating revenue will exceed 1 billion Euros. It can afford to adopt best practice here, as it is doing in Norway.

What can SEPA do to make this happen? How can we help?

Claims to be one of the lowest carbon foods

This is a common claim of the industry, much repeated by Mr Ewing.
To redress that, and given that your sector review is look at the whole industry from 'egg to plate', we thought you might be interested in the following details, which we have also sent to Roseanna Cunningham.

The industry claims that farming salmon in open cages is sustainable and that this way of producing protein has one of the lowest carbon footprints. The sustainability claim falls apart in the light of the industry's plans to double its capacity.
Farmed salmon are fed other fish, such as anchovies caught off Peru in a fishery that is already at its conservation limit, or other species caught more locally - such as sandeels; vital to puffins and other seabirds that are now in serious decline for lack of food. Soya and palm oil has been substituted for fish to the maximum extent the Scottish industry will support, before its customers complain that its products are unnatural. Soya or palm oil cannot be 100% certified as causing no deforestation. The industry now wants to feed fish GM canola with omega-3 producing genes inserted, and is turning increasingly to using Antarctic krill, adding enormous CO^2 emissions by unsustainably fishing down the food chain, halfway around the world. Feeding insects to salmon would make more sense.

This is not a low carbon industry. The following table shows how many units of CO^2-releasing fossil fuel energy are used by different farming methods to produce each unit of energy in edible food. (From *Salmon & Sustainability: The Biophysical Cost of Producing Salmon Through the Commercial Salmon Fishery and the Intensive Salmon Culture Industry*. PH Tyedmers, PhD Thesis. University of British Columbia. 2000)

Food production system	Amount of energy and carbon used per unit of edible food energy
Third world farmers	0.01
First world vegetable production	1 - 3
Commercially caught coho salmon (B.C.)	13.5
Milk (USA)	14.1
Swine (USA)	17.9
Commercial cod fishery (USA)	20.0
Chicken (USA)	26.3

Eggs (USA)	26.3
Lamb (USA)	50.0
Intensively cultured Atlantic salmon	**50.0**
Beef (USA)	52.6

Tyedmers' calculations show that the sea cage salmon farming system requires about 50 times more fossil fuel energy than is contained in the salmon, as edible food energy. This is less carbon and energy efficient than many other food production systems, except for some other intensive aquaculture systems and intensive beef production. It is definitely not the most efficient food production system.
Food energy calculations, using the Scottish salmon farming industries' production figures and fish feed manufacturer's feed composition data (cross-checked with data from the USDA, FAO and the UK governments food consumption surveys), show that in 2015 salmon feed contained 6.67 times the food energy contained in the harvested salmon. In 2016 it contained 7.40 times the food energy.
It would be c.7x more efficient for humans to eat the ingredients of the salmon food.

In its latest sustainability report, the salmon feed production company BioMar, which has a factory at Grangemouth, says it bought 19,400 tonnes of Antarctic krill and 19,500 tonnes of sandeels. In total it bought 304,000 tonnes of fish, for fish meal and oil, of which 77,000 were fish trimmings from other fisheries, so it used almost a quarter of a million tonnes of wild fish and krill to make salmon food that year.
The European salmon farming industry requires a marine support area for feed estimated at 40,000 to 50,000 times the area of cultivation and is equivalent to about 90% of the primary production of the fishing area of the North Sea (*Naylor et al., 1998)*.

BioMar also says that 1.6 tonnes of CO^2 are emitted for every tonne of feed it produces.
The industry's carbon footprint argument seems to be based on one 2011 paper: '*Marine Finfish: Super-Chickens of the Sea?*' O. Torrissen (Nordland Faculty of Biosciences & Aquaculture, Norway) *et al*. Reviews in Fisheries Science, 19(3):257–278, 2011. This paper gives these CO^2 equivalents, *'in terms of calculations based in relation to edible product': **'Atlantic salmon (farming) shows an emission comparable to wild-caught Atlantic cod and chicken** while substantially less than beef and pork'*
It also says that Scotland's salmon farming emits almost twice as much CO^2 as Norway's: '1.78 kg CO^2 eq/kg (whole weight) for Norwegian-produced salmon, to 3.27 CO^2 eq/kg (whole weight) for fish produced in the United Kingdom (Pelletier et al., 2009), explaining this by 'the higher use of marine resources for fish produced in the United Kingdom.'

The CO^2 emissions from salmon feed production must be added to those from running the farming operations, and should include the c. 25% of Scottish salmon that are fed but die before harvest, the 146,000 or so that escape each year, and the many more that are discarded at processing - according to the '*super-chicken'* paper

this happens to 1.9 million fish pa in Norway, so perhaps to 400,000 in Scotland. Diseased fish grow more slowly too: 'substantial costs are also associated with poor growth rate'

Nor does the '*super-chicken'* paper account for the CO^2 emitted during distribution, which is enormous, because the fish are farmed so far from processing factories and their markets, increasingly in the Far East and USA. In 2017, 92,000 tonnes of salmon were exported, 53% of it outside the EU (*Scotland's 10 Year Farmed Fish Health Framework).* Research published in 2016 concluded that the *'carbon footprint of salmon produced in land-based closed containment water recirculating aquaculture systems, delivered to market in the US, is less than half of that for salmon produced in traditional open net pen systems in Norway that is delivered to the US by air freight.'*
(*Comparative economic performance and carbon footprint of two farming models for producing Atlantic salmon (Salmo salar): Land-based closed containment system in freshwater and open net pen in seawater*. Yajie Liu et al. Aquacultural Engineering Volume 71, March 2016, Pages 1-12)