Marine Conservation Society

Aquaculture

Ratings Methodology Handbook

Version 3 2020

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4. INTRODUCTION

This document provides in depth discussion of how MCS assesses the environmental performance of various fish farming production methods. It is aimed at internal MCS assessors and staff, consultants, seafood businesses and other professionals requiring a thorough understanding of the MCS farmed seafood ratings methodology.

Please click:

- Here to see an **Introduction to MCS Seafood Ratings;** and
- Here to see the **MCS Wild Capture Seafood Ratings Methodology**.

If you have any questions or specific queries about MCS seafood ratings or you would like to comment on or contribute to information in the Good Fish Guide please contact MCS at:

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5. OVERVIEW OF RATINGS PROCESS

5.1 UNIT OF ASSESSMENT

The Unit of Assessment (UoA) for the MCS aquaculture methodology is the aquaculture production system within a region.

The region may be defined at country level (e.g. Vietnam) or at the regional level (e.g. Mekong Delta) and further determined by the scope and geographical application of regulations and management practices in the area. Each UoA is further defined by production method and species.

A rating is a tool that communicates the relative environmental performance of one production system against specific criteria, which in the opinion of MCS represent the key issues of environmental concern in aquaculture, compared to another. An overview of the ratings process for the unit of assessment - species farmed within a specific region and using a method of production we rate is presented in the figure below (Figure 1).

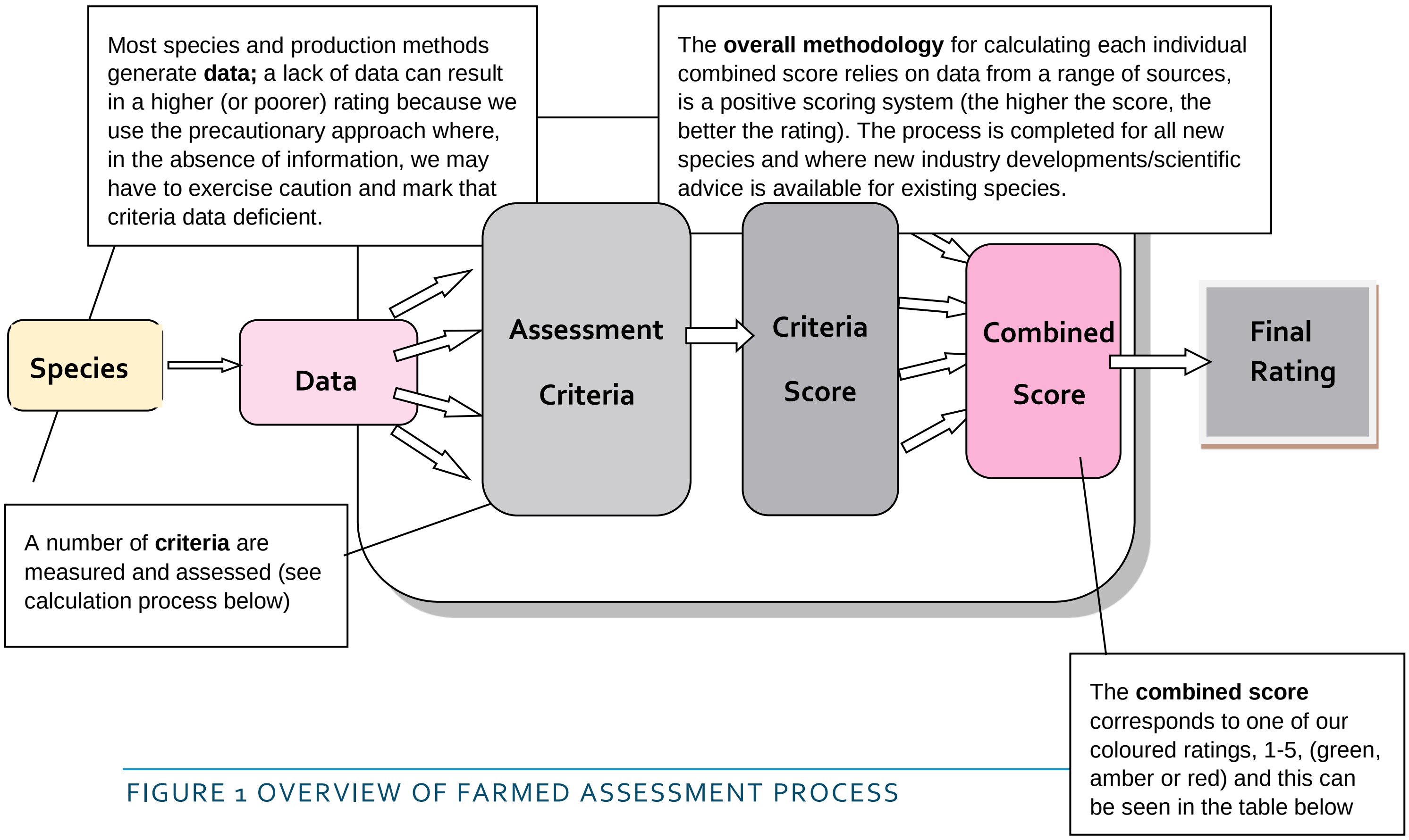

FIGURE 1 OVERVIEW OF FARMED ASSESSMENT PROCESS

The criteria against which we measure sustainability are:

- **Feed resources** – traceability, sourcing and inclusion of both marine and non-marine feed ingredients.
- **Environmental Impacts and Interactions** – the impacts of production on: freshwater; habitats; water quality and other species both indirectly and directly by reliance on other species such as juveniles and cleaner fish.
- **Fish welfare** – welfare standards, including slaughter.
- **Regulations and Management** – planning, strategic assessment, regulation and its enforcement and third party certification standards.

The relationship between the combined criteria score and the overall rating is presented in the table below (Table 1).

TABLE 1 RELATIONSHIP BETWEEN COMBINED SCORE AND OVERALL RATING

Combined criteria score	Overall Rating	
9 - 21	Dark Green (Best)	Best choice
Between 4 - 8	Light Green (Good)	
Between -2 and 3	Yellow (OK)	Think
Between -10 and -3	Orange (Requires improvement)	
-11 or less or Critical fail	Red (Avoid)	Fish to Avoid

No weighting of criteria or assessment questions is used in the aquaculture assessment methodology due to the diversity of production systems and species each having their unique impacts. However, the split of the criteria questions within the methodology reflects the priority of the issues in relation to MCS Conservation Strategy:

- Feed Resources and Use – 26.5%
- Environmental Impacts and Interactions – 47.5%
- Fish Welfare – 5%
- Management and Regulations – 21%

CRITICAL FAIL

For some species the impacts of one or more aspects of production are of such concern/so severe that regardless of the environmental performance in other areas a rating of Critical Fail/ Fish to Avoid is the only appropriate advice.

TABLE 2. ASSESSMENT SECTION SCORING

Section	Scoring Range
Feed Sourcing and Use	5 to - 9/CRITICAL FAIL
Ecological Impacts and Interactions	8 to -17/ CRITICAL FAIL
Fish Welfare	1 to -1
Regulation and Management	7 to -5

6. THE DECISION-MAKING PROCESS

Once all the scientific advice and any other information has been collated and reviewed against MCS aquaculture assessment criteria the species (Unit of Assessment) is rated, the assessment is then cross checked internally before going for external review. A database of ratings is maintained and any changes to the ratings are compiled and made available for public review and comment. Ratings are then reviewed against these comments and any other information received.

The review process also provides an opportunity for industry and other key interests to submit information on developments and innovations within aquaculture so that good practice and any conservation initiatives developed or being developed by industry and other stakeholders such as standards holders can be promoted and reflected within the ratings.

6.1 WHEN DO RATING UPDATES TAKE PLACE?

Ratings are on a 3- year scheduled full update with an annual "health check "for the key, most popular species. A rating review can also be triggered by changes in regional practices or certification standard updates/amendments or to reflect significant changes in production.

6.2 HOW CAN RATINGS CHANGE?

Ratings will change in response to the availability of new scientific data and other information for production practices such as updated independent certification standards or a change to management or the way the industry is regulated.

6.3 LIMIT TO AQUACULTURE RATINGS.

The scope of the ratings for aquaculture species is limited to a species, within a certain region using a specific production method. For example, we assess Atlantic salmon, farmed in Scotland, in Open Marine Pens. We do not assess or rate individual farms or producers; we also do not rate companies. Farm/producer level assessments can only take place by certifiers against an independent production standard and use external auditors to check compliance. Standards such as those held by Global Aquaculture Alliance Best Aquaculture Practice (GAA BAP); the Aquaculture Stewardship Council (ASC); Organic standards such as the Soil Association or other standard holders such as GlobalGap.

7. CRITERIA CATEGORY DESCRIPTORS AND VALUES

The complexity of the methodology lies in the allocation of values to assessment criteria. We allocate values for each question, the higher the score the better the Unit of Assessment performs.

CRITERION 1. FEED SOURCING AND USE

1.1 RATIONALE

Growth in aquaculture is dependent on natural resources, such as freshwater, space and proteins and oils to provide feeds. The production and subsequent consumption of feed incorporating marine proteins and oils from poorly managed feed fisheries is a crosscutting issue of global concern across many species as aquaculture production continues to expand.

The primary area of concern regarding feed fish management and feed production is with many of the Asian countries supplying the UK with popular farmed species such as warm water prawn and pangasius. Many South East Asian fisheries are unregulated, poorly managed and heavily overexploited[1]. The increasing demand on aquaculture to fill the "the fish gap"; combined with the static nature of wild capture fisheries which are at best already exploited to their maximum capacity to supply fish for marine proteins and oils for feed production, makes it imperative that fish for feed are managed responsibly and exploited sustainably. For aquaculture to continue to expand to meet increasing demand for seafood, marine proteins and oils will need to be augmented from an array of non-marine ingredients such as vegetable proteins and oils; processed animal proteins (PAP's), algae oils and/or other emerging innovative ingredients such as insect meal.

1.2 AIMS

To achieve responsible production of farmed fish and work towards greater sustainability the fish farming industry must be underpinned by a well-managed, traceable feed supply that is used responsibly. Within the feed resource and use section of this assessment methodology MCS are encouraging and rewarding the following actions:

- The use of sustainable marine proteins and oils in the manufacture of commercial aquaculture feeds.
- The use of sustainable sources of soy products and palm oil given the environmental impacts of their production.
- A partial substitution diet that both maintains farmed fish health whilst delivering the health benefits of marine proteins and oils to as many consumers as possible
- The farming of aquaculture species that have a low dependency on marine proteins and oils and therefore represent a net gain in fish protein.
- The maximization of the use of trimmings from human consumption fisheries as a source of marine proteins and oils

1 Leadbitter, D. 2013. A Risk Based Approach for Promoting Management Regimes for Trawl Fisheries in South East Asia. Asian Fisheries Science 26 (2013): 65-78

1a. Does the Unit of Assessment in this country/region rely on feed inputs?	
Answer Options	**Answer Descriptors**
Yes	Proceed to question 1B
No	Award 5 points and proceed to Section 2.

1b. Is the protein and oil component (marine, vegetable and terrestrial) of the feed* used in the country/region known and traceable to species level, or from a certified factory (in countries using a mixed species fishery regime e.g. Asia) for marine components? * Any feed components contributing over 1% of the feed, i.e. not including vitamins, minerals and additives etc.		
Score	**Answer Options**	**Examples and Answer Descriptors**
0	Yes.	(Continue to question 1c)
-3	No	(Skip questions 1c & 1d and award minus 3 points)
	No Information available	

1c. Are marine wild capture protein and oil components of the feed (as defined above) used in the country/ region sourced sustainably or responsibly?		
Score	**Answer Options**	**Examples and Answer Descriptors**
2	The marine wild-capture protein and oil components of the feed are independently certified as being sustainable*.	*** Sustainable -** ISEAL accredited with criteria for low trophic species and ecosystem impacts (currently only Marine Stewardship Council (MSC) certified)
	No marine ingredients are used.	
	Independent certification (production) standards ** require the responsible sourcing of marine proteins and oils, verifiable by audit.	**** Independent Certification Standards** refer to production standards set by a certification body and audited by a third

1	Feed suppliers and/or supply chain have a policy in place that ensure the responsible sourcing of the marine wild-capture protein and oil source and this can be independently verified***	party. e.g. Aquaculture Stewardship Council; Global Aquaculture Alliance Best Aquaculture Practices; GlobalGap *****Responsible** - Independent certification of responsible sourcing (Currently only IFFO RS Standard for Responsible Supply)
0	The independent Certification Standards encourage/recommend responsible marine protein and oil sourcing but do not verify via audit	Criteria in production standards that recommend or advise sourcing responsible/sustainable ingredients.
	Feed suppliers and/or supply chain have an internal policy in place that includes responsible sourcing of the marine protein and oils but implementation of this policy cannot be verified.	This would include a Fishsource[2] score over a certain threshold
-1	There is no independent certification or feed suppliers/supply chain policy to ensure the sustainable or responsible sourcing of the wild-capture protein component of the feed but the source is known	
-2	There is no information available about the source of the marine proteins and oils	
	The feed is known to include overexploited species or from damaging fisheries (Including MCS Red rated).	
Critical fail	There is evidence that the marine proteins and oils used in feed originates from IUU (Illegal, Unreported, Unregulated) fisheries which are demonstrably contributing to ecosystem	***Fishing down the food web** is the process whereby fisheries in a given ecosystem, "having depleted the large predatory fish on top of the food web, turn to increasingly smaller species,

[2] https://www.fishsource.org/

	changes caused by fishing down the food web*	finally ending up with previously spurned small fish and invertebrates".[3]

1d. Are soy (and soy derivatives) products and palm oils used and responsibly sourced?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Any soy and/or palm used is certified as sustainable*	* Proterra Soy and Roundtable for Sustainable Palm Oil (RSPO)
	Soy and palm not used	
0	Any soy and/or palm used is responsibly sourced**	** Roundtable for Responsible Soy (RTRS), Soybean Sustainability Assurance Protocol Criteria, Organically certified
-1	No data available	
	Any soy and/or palm used is untraceable	

3 Pauly, Daniel and Watson, Reg (2009) "Spatial Dynamics of Marine Fisheries" *In:* Simon A. Levin (ed.) *The Princeton Guide to Ecology*. Pages 501–509.

1e. What is the overall Fish-in Fish-out ratio calculated as Feed Fish Dependency Ratio (FFDR*) for the unit of assessment?		
Score	**Answer Options**	**Examples and Answer Descriptors**
2	The species has a FFDR of less than 0.5	***FFDR** = **Feed Fish Dependency Ratio** - the quantity of wild fish **used per quantity of cultured fish produced. This measure can be calculated for fishmeal or fish oil whichever component creates the largest burden of wild fish in feed. ** **Wild fish**: includes both meal and oil produced from wild fish, but not include by-products from processing (trimmings). FFDR meal = $\frac{(\%\ \text{fishmeal in feed})(\text{eFCR})}{22.2}$ FFDR oil = $\frac{(\%\ \text{fish oil in feed})(\text{eFCR})}{5}$ eFCR= $\frac{\text{Feed,kg or MT}}{\text{Net aquacultureal production,kg or MT (wet weight)}}$
1	The species has a FFDR of 1 or less	
-1	The species has a FFDR between 1.1 and 2	
-2	The species has a FFDR between 2.1 and 3	
-3	The species has a FFDR greater than 3.1	

CRITERION 2. ENVIRONMENTAL IMPACTS AND INTERACTIONS

2.1 RATIONALE

The construction and operation of aquaculture facilities can have an adverse impact on the surrounding environment; this can include sensitive habitat destruction[4] or disturbance and/or impacts on other species. In some production systems in certain areas it can also include degradation or depletion of freshwater supplies by extraction or salinisation.

2.2 CHEMICALS AND THERAPEUTANTS

The unregulated or misuse of chemicals and/or therapeutants in some areas[5], combined with water pollution from nutrients and treatments and benthic impacts from faeces and uneaten

4 Ilman, Muhammad & Tricahyo Wibisono, Iwan & Suryadiputra, Nyoman. (2011). State of the Art Information on Mangrove Ecosystems in Indonesia.. 10.13140/RG.2.1.3967.9120.
5 Rico, A. , Satapornvanit, K. , Haque, M. M., Min, J. , Nguyen, P. T., Telfer, T. C. and van den Brink, P. J. (2012), Use of chemicals and biological products in Asian aquaculture and their potential environmental risks: a critical review. Reviews in Aquaculture, 4: 75-93. doi:10.1111/j.1753-5131.2012.01062.x

feed[6] is a key concern within global aquaculture production for many species. It is essential that these impacts are understood, monitored, managed and reduced as far as possible.

2.3. JUVENILES AND COMPANION SPECIES

Some forms of aquaculture, sometimes known as ranching but is more accurately described as fattening, rely upon wild stock for the provision of juveniles for on-growing in cages/tanks until they reach harvest size. This is opposed to true aquaculture that relies on hatchery reared eggs and fry. By its nature ranching/fattening does not take the pressure off wild species as there remains an element of fisheries in the process.

Companion species refers to both the use and reliance on other fish to assist with production, primarily cleaner fish species such as wrasse and lumpfish, and species that are produced alongside the primary species in a multi-trophic aquaculture system. Whilst the salmon farming industry is transitioning to farmed cleaner fish as a biological form of control of sea lice, there is a still a reliance on wild caught species. This is a concern due to the lack of stock data and fisheries management measures to ensure the sustainable exploitation of these species[7].

The reliance on wild caught stocks for the provision of juveniles or companion species like cleaner fish is of concern if coming from stocks that are over-exploited or fisheries that damage other species and habitats. Where stocks are heavily overfished or depleted e.g. European eel (*Anguilla anguilla*)[8] and species of Bluefin tuna; *or* the fishing method causes significant damage to other species or habitats (e.g. Illegal, bottom towed gear in seagrass, reefs or MPAs, dynamite fishing), a critical fail is triggered and the farmed species which relies on these fisheries is assigned a default red rating.

2.4 DISEASE AND PARASITES

The risk of disease and parasite transfer can be a problem in a number of systems for a number of species. This risk can be minimized by effective management and mitigation measures however in some cases there is little or no information available to ascertain the level or extent of the risk. In some areas widespread disease outbreaks have occurred[9].

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6 Handy, R.D. & Poxton, M.G. 1993. Nitrogen pollution in mariculture: toxicity and excretion of nitrogenous compounds by marine fish. Rev Fish Biol Fisheries 3: 205. https://doi.org/10.1007/BF00043929
7 Marine Conservation Society. 2018. Use of cleaner fish in aquaculture. https://www.mcsuk.org/media/seafood/Cleaner_Fish_Position_Paper.pdf. Accessed 15/02/2018
8 Marine Conservation Society, 2018. Good Fish Guide: European eel. Available at https://www.mcsuk.org/goodfishguide/fish/150. Accessed 15/02/2018
9 WORLD BANK REPORT NUMBER 88257-GLB. 2014. REDUCING DISEASE RISK IN AQUACULTURE. AGRICULTURE AND E N V I RONMENTAL S E R V I C E S D I S C U S S I O N PAPER 09

2.5 ESCAPES

Escapes from production sites are not only a financial loss for the farmer but can also have an adverse effect on the surrounding ecosystem, particularly in the case where the cultured species may be non-native to the area or can interbreed with wild species[10]. Escapes can be prevented by either the type of production system in place or by management measures such as barrier use, however in some cases escapes can be significant in both number and impact.

2.6 PREDATOR CONTROL

MCS would like to see all aquaculture facilities relying solely on non- lethal predator control measures. There are a number of non-lethal management measures available to deter predators which MCS advocates the use of. Where lethal control is used it is a particular concern when used against species that are protected or listed as threatened or endangered.

AIMS

Aquaculture facilities and operations can have a number of damaging or unwanted ecological effects to the surrounding, environment, habitats and local species. It is essential that these impacts are well understood, monitored and mitigated to keep environmental impacts within acceptable levels and to demonstrate best management practices and responsible environmental stewardship. In particular, MCS would like to see aquaculture facilities that:

- In regions with limited freshwater supplies do not cause depletion or degradation through salinisation.
- Avoid locating in areas of high conservation status or ecological sensitivity.
- Avoid chemical usage or to use them in enclosed systems without waste discharge.
- Encourage the development and adoption of aquaculture systems that do not discharge directly into the surrounding open water environment, or for those that do to ensure that the discharge is known and managed so as not to cause negative impacts on habitats or species.
- Undertake the farming of species that do not have a parasite burden OR the use of systems that prevent parasite transfer outside if the farming system.
- Proactively maintain or improve the health status of cultured fish and minimise the risk of disease transmission to surrounding ecosystems.
- Use systems that prevent escapes and promote best management practices in those systems where escapes are a possibility.
- Do not lethally control or adversely disturb local wildlife

10 Svåsand T., Crosetti D., García-Vázquez E., Verspoor E. (eds), 2007.Genetic impact of aquaculture activities on native populations.
Genimpact final scientific report (EU contract n. RICA-CT-2005-022802). 176 p. http://genimpact.imr.no/

2a. Do the production systems for this species in this region deplete freshwater supplies and/or degrade freshwater bodies by salinisation*? * Degradation of freshwater in this question does not refer to any kind of organic pollution or chemical contamination, both of which are addressed in separate questions.		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	No Not applicable*	*Not applicable = Open or closed seawater systems, re-circulating freshwater system, plentiful freshwater supply and no salinisation occurring.
0	Depletion/degradation is possible but is mitigated by management/certification standards criteria	
-1	Depletion of supplies and/or degradation of freshwater bodies (surface and groundwater) by salinisation occurs OR is data deficient	

2b. Does the production system for this species in this country/region require habitat alteration that impacts ecosystem functionality?		
Score	**Answer Options**	**Examples and Answer Descriptors**
0	No Alteration is small-scale OR alteration occurs in areas of low ecological sensitivity	Ecological sensitivity*: **Low:** Land less susceptible to degradation, e.g. formerly used for agriculture or previously developed

-1	Alterations are in areas of moderate ecological sensitivity	**Moderate**: Coastal & near-shore waters; rocky intertidal or subtidal zones; river or stream shorelines **High:** Coastal wetlands; mangroves; coral reefs; rainforest; any areas containing threatened or endangered species ** Historical degradation = occurring 15 years and over *** Verifiable restoration = An auditable criteria (a "must" not a recommendation) in certification standards or occurring at a regional scale with documented evidence
	Alterations are in areas of historical degradation** with verifiable restoration*** occurring	
-2	Alterations are in areas of high ecological sensitivity with ongoing or recent habitat loss and there is no reforestation program in place	
	Data is deficient	
-3	Yes high value/sensitive habitats are impacted with high, irreversible consequence	

2c. Does the unit of assessment rely on chemical* usage, if so are there associated risks and impacts on the environment? * Chemicals include antibiotics, chemotherapeutants, pesticides, fungicides, antifoulants		
SCORE	**ANSWER OPTIONS**	**EXAMPLES AND ANSWER DESCRIPTORS**
1	No chemical usage	The production system is closed and does not discharge active chemicals or by-products (e.g. antibiotic resistant bacteria), or; The method of treatment does not allow active chemicals or byproducts to be discharged Data show that chemical treatments are used on average less than once per production cycle or once per year for longer production cycles, or;

	No environmental impact	The production system does not discharge water over multiple production cycles, or; Evidence of no impacts on non-target organisms
0	Yes but the environmental impact of chemical use is known and effectively** regulated and or mitigated by independent certification standard criteria	**Clear regulations that include all chemicals used in production, which set limits for their use and those limits are not exceeded by the of producers in the unit of assessment Specific data may be limited, but the species or production systems have a demonstrably low need for chemical use, or; Evidence of only minor impacts on non-target species within the allowable zone of effect (i.e. no population-level impacts), or; The production system has very infrequent or limited discharge of water (e.g., once per production cycle or < 1% per day). Occasional, temporary or minor evidence of impacts to non-target organisms beyond an allowable zone of effect, or; Some evidence or concern of resistance to chemical treatments, or; Regulations or management measures with demonstrated effective enforcement are in place that limit the frequency of use and/or total use of chemicals.
-1	Yes, but the use of chemicals is within an ineffective*** regulatory or management framework	***Despite regulations specifying limits and monitoring chemicals used, there is evidence of limits being exceeded or there is evidence of poor enforcement Chemicals are known to be used on multiple occasions each production cycle and the treatment method allows their release into the environment, or; Chemical use (type and/or volume) is unknown but the production viability is considered to be dependent on chemical intervention, and the treatment method allows their release into the environment, or; Regulatory limits on chemical type, frequency and/or dose exist with unknown enforcement effectiveness or; Confirmed cases of resistance to chemical treatments, or;

		Chemicals highly important to human health are being used in significant or unknown quantities.
-2	Yes, there are no clear regulations for the use of chemicals Chemical use is unknown due to data deficiency	Illegal chemicals (as defined by the country of production) are used beyond exceptional cases or; Chemicals critically important to human health are being used in significant or unknown quantities, or; Negative impacts of chemical use seen on non-target organisms beyond an allowable zone of effect. Evidence of developed clinical resistance to chemicals (e.g. loss of efficacy of treatments) that are highly important or critically important to human health, or; Illegal activities with demonstrable negative environmental impacts.

2d. Does the unit of assessment discharge* directly into the aquatic system, if so does this cause a negative impact?

* Discharge: Includes faeces, pseudofaeces, uneaten food, effluent, sludge.

Score	Answer Options	Examples and Answer Descriptors
1	No discharge Little or no negative impact	Zero input systems; Zero exchange systems; Recirculating systems; IMTA system
0	Measurable negative impact within regulation and/or certification standard boundaries	E.g. defined allowable zone of effect (AZE) or within regulatory limit for effluent nutrient levels Ponds with one discharge per production cycle; extensive systems; OR ponds with frequent water exchange; intensive systems; pen net pens; flow through tanks and raceways that are operating within regulations/independent certification criteria and demonstrating full compliance
		Ponds with frequent water exchange; intensive systems; pen net pens; flow through tanks and raceways that are

-1	Yes, but discharge occurs within an ineffective regulatory or management framework	operating within ineffective/absent regulations and/or independent certification criteria
-2	There are no clear regulations for the limiting and monitoring of discharge	All systems that operate within regions with no regulation pertaining to discharge and water quality AND /OR where negative effects caused by illegal and unnecessary discharge are known
	Data deficient	

2e. What is the main source of juveniles or companion species for the unit of assessment?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Hatchery based	
0	Naturally settling juveniles	
	Hatchery-based juvenile or companion species production using wild caught broodstock from healthy, not overexploited wild stocks	
-1	Juveniles or companion species are taken from healthy, not overexploited wild stocks	
-2	Juveniles or companion species are caught by methods destructive* to the environment	* Destructive: Illegal or use of bottom towed gear in sensitive habitat (e.g. sea grass, MPAs, maerl beds & other reefs), explosives or chemicals for fishing.
	Juveniles or companion dependent species are caught from a stock[s] which is considered at risk (e.g. Biomass below Bmsy or mortality above Fmsy or other proxies or reference points with similar intent)	
Critical Fail	Juveniles source are heavily over-fished and the species is of listed conservation concern**	**Refer to table below

TABLE 3 SUMMARY OF DEFAULT WILD FISHERY RATINGS

Criterion	When …	Default rating
Stock or species status	• ICES or equivalent scientific advice is for zero catch or no direct i.e. targeted fishery and this advice is **not** followed • Biomass (B) is at or below B_{lim} (see Glossary) and no precautionary Recovery Plan is in place for the stock • a species is listed as Endangered or Critically Endangered by IUCN or equivalent for the sea area e.g. FAO 27 North East Atlantic in which the fishery is taking place, and the assessment report is still considered relevant (i.e. current and best assessment of species status available) • with respect to Low Trophic Level (LTL) species if there is evidence that the status of it is significantly reducing the state of other species (through links in the food chain)	**5**
Management	• there is no appropriate or relevant management system or regulatory framework in place including • no measures to address critical issues e.g. intrinsic and widespread IUU fishing, for example	**5**
Capture method and ecological effects	• the fishing method is: • causing substantial or long-lasting damage e.g. dynamite fishing, high seas drift netting, unmanaged deep-sea trawling • damaging protected features of MPAs • illegal • bottom trawling below 600m (deep sea fishing) without robust regulation in place	**5**

2f. Is there a risk of parasitic* transfer to adjacent wild species? *multicellular organisms i.e. crustaceans (e.g. sea lice) and helminths (e.g. flatworms)		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	No risk of parasitic transfer**	**Either no parasites or no possibility of reaching wild fish
0	There is a potential problem, but the impact on wild species is limited by effective management and/or 100% farmed cleaner fish	
-1	Unknown status of parasitic transfer and unknown environmental impact***	***Poor data collection and transparency
-2	Yes, there is a known problem and/or risk and impact on a wild population (including cleaner fish) is evident	

2g. Is the species in this assessment subject to pathogenic* disease outbreaks that threaten the viability of the whole country/region? *unicellular organisms i.e. bacteria (e.g. Motile Aeromonad Septicemia (M. A. S.)), viruses (e.g. Infectious Salmon Anemia (I.S.A.), fungi, myxosporeans (emaciation disease in Sea Bream) or pathogens specific to the Unit of Assessment.		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	No, aquaculture activity occurs where pathogenic disease outbreaks are not observed/recorded in wild species. Not applicable due to completely closed system.	Data indicates that there is either no transmission of pathogens from farmed to wild species Data shows that wild species are not affected by pathogen transfer Disease transmission may occur but data shows that the disease level is not amplified above background levels Disease transmission may occur but do not cause physiological impacts to wild species
0	Disease outbreaks can/do occur but do not threaten regional level operations	Pathogens effect wild species but do not result in mortality Pathogens effect wild species resulting in mortality but not a population level

-1	Yes, pathogenic disease outbreaks occur that threaten the viability of the whole region	Disease transmission occurs resulting in negative impacts on species population size or its ability to recover
	Unknown due to data deficiency	Disease transmission occurs and effects population-level species listed on any conservation list as vulnerable, threated, endangered (IUCN red list, OSPAR etc.)

2h. is there a risk of escapes or introductions of exotic species from this type of production, and if so, would escape cause negative ecological effects?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	There is no risk of escape Not applicable to naturally settling spat	No connection to natural water bodies Tank based recirculation systems Static ponds with no water discharge and no flood risk Independent monitoring data shows that escapees are not present in the wild.
0	There is a potential escape risk but with limited environmental impact	There is evidence of escapes, but no alteration of wild species and their habitats Any system that uses Best Management Practices to prevent escapes which can be verified by audit AND independent data indicated escape numbers are low. Flow through systems Ponds with a moderate risk of vulnerability to flooding events Ponds with moderate exchange (e.g. 3–10% per day) or that drain externally at harvest Open systems with demonstrably effective Best Management Practices for design, construction, and management of escape prevention
-1	Unknown escape risk Unknown environmental impact*	Open systems with Best Management Practices for design, construction, and management of escape prevention are in place but their efficacy cannot be demonstrated. *poor data collection and transparency Production systems vulnerable to large escape events or frequent trickle losses Monitoring data indicates escapees are frequently detected in the wild Ponds with high exchange > 10% per day

-2	There is an escape risk with evidence of negative ecological effects	Open systems (e.g., net pens, cages, ropes) vulnerable to escape, without effective Best Management Practices for design, construction and management of escape prevention Large escapes or frequent trickle losses have occurred in the last 10 years, and no corrective action has been taken, or corrective actions taken have not been adequate Ponds in flood prone areas Monitoring data indicates frequent occurrence of large numbers of escapees in the wild Negative ecological effects include competition for resources; displacement of wild species eggs/larvae; interbreeding and genetic dilution.

2i. In general, does this type of production have direct negative impacts on local predatory species in the region?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	No	
0	Potential impacts, not including lethal control	Use of ADD's that may disturb species such as cetaceans.
-1	Yes, predatory species are lethally controlled	
	Unknown due to data deficiency	
-2	Yes, predatory species that are listed as threatened, endangered or protected on any domestic or protected on any domestic or international list are lethally controlled	

CRITERION 3. FISH WELFARE

3.1 RATIONALE

Fish welfare is both a key concern for many consumers and a key indicator of good management practices within the culture system.

Scientific evidence from behavioural, physiological and anatomical studies shows that it is highly likely that fish feel pain. Fish also have a similar stress response system to mammals. It is essential that staff managing farmed fish are aware of the importance of welfare as an integral part of production.[11]

The Farm Animal Welfare Council define the "Five Freedoms" to promote good welfare and prevent suffering[12]:

- Freedom from hunger and thirst by ready access to fresh water and a diet to maintain full health and vigour.
- Freedom from discomfort by providing an appropriate environment including shelter and a comfortable resting area.
- Freedom from pain, injury or disease by prevention or rapid diagnosis and treatment.
- Freedom to express normal behavior by providing sufficient space, proper facilities and company of the animal's own kind.
- Freedom from fear and distress by ensuring conditions and care which avoid mental suffering.

AIM

To encourage and support welfare and humane slaughter standards for aquaculture species that respect the Five Freedoms outlined above.

11 RSPCA Welfare Standards for farmed Atlantic salmon. February 2018. Available online at: file:///C:/Users/Dawn%20Purchase/Downloads/Salmon%20standards%202018PT.pdf. Accessed 06/04/2018.
12 Farm Animal Welfare Council. 2009. Farm Animal Welfare in Great Britain: Past, Present and Future. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/319292/Farm_Animal_Welfare_in_Great_Britain_-_Past__Present_and_Future.pdf. Accessed 06/04/2018.

3a. Are there practices in place to ensure animal welfare and humane slaughter for the unit of assessment?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Yes, there are practices to ensure animal welfare* and humane slaughter**	*Compromised animal welfare leads to physical damage, aggression and pre-harvest mortalities. Culture conditions that lead to physical deformities can compromise animal welfare and should be included in this question. This question only refers to the culture species. **Humane slaughter RSPCA definition: "An animal must be either killed instantly or rendered insensible to pain until death supervenes" (generally only applicable to electrical or mechanical stunning followed by bleeding *** Shellfish species
	Not applicable***	
0	Either provisions for animal welfare or humane slaughter are provided but not both	Provision included in regulations in the country or region assessment and/or in certification criteria
-1	No	
	Unknown due to data deficiency	

CRITERION 4. REGULATION AND MANAGEMENT

4.1 RATIONALE

Alongside the impacts of individual fish farms there is a need to understand both the cumulative impacts and the cumulative carrying capacity[13] (not applicable to land based systems) of aquaculture operations in a given area, be it loch, lake, or river basin. The impacts and carrying capacity can be determined by the use of strategic environmental assessments and spatial planning.

Robust regulations can ensure the establishment, structure and function of aquaculture facilities does not adversely affect sensitive habitats, species, water quality or other marine users. It is therefore imperative that a robust regulatory framework is in place in the region under assessment.

Robust regulations are meaningless unless there is effective implementation, with sufficient monitoring in place. If for instance there was a regulation to prevent the introduction of non-native species yet it was recorded that non-natives were prevalent in an area, this would indicate the regulation is not effective in achieving its aims.

Independent, 3rd party audited production standards ensure that many, if not all the issues of environmental concern, including criteria used in this assessment are addressed. Consumer facing eco-label schemes have the added advantage of directing consumers to the most responsibly produced farmed seafood, which also helps drive demand for these products. Schemes which also have robust chain of custody traceability requirements, also have the added bonus of providing confidence to consumers and businesses, that specific products have been produced to the standard of the ecolabel on pack.

AIMS

Robust and effective regulation, along with good farming practices is the foundation of responsible production and good environmental performance. MCS aims to support and encourage production systems in regions that operate to robust regulations and /or certification criteria that address key issues of environmental concern. These include:

- The adoption of a regional level planning system with effective enforcement that includes aquaculture operations and their cumulative effects.
- Regulations/criteria in place are enforced and effective in reducing/minimizing negative impacts.

13 Á Borja, JG Rodríguez, K Black, A Bodoy, C Emblow. 2009. Assessing the suitability of a range of benthic indices in the evaluation of environmental impact of fin and shellfish aquaculture located in sites across Europe. Aquaculture. Volume 293, Issues 3–4, 16 August 2009, Pages 231-240

- The adoption of 3rd party certification standards or progress towards certification. 3rd party certification ensures transparent, audited and traceable product.

4a. Is aquaculture production in this region integrated within strategic environmental planning?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Yes there is strategic environmental planning	e.g. spatial planning, river basin planning, strategic environmental assessment, cumulative capacity planning
0	Not applicable*	*Land based recirculation systems that are subject to terrestrial planning
	Strategic planning is in development/being implemented	
-1	No strategic environmental planning	Refer to the MCS Strategic Environmental Planning 2016 spreadsheet
	Unknown due to data deficiency	

4b. Is there a regulatory framework OR independent certification criteria for this species in the region that includes/addresses the following issues:
Farm Level Environmental Impact Assessment (EIA)
Identification and protection of valuable habitats & species
Use of land and water resources
Use of chemicals including licensing
Discharges including effluents and their impacts
Bio-security & disease management
Species introduction

Score	Answer Options	Examples and Answer Descriptors
2	There are regulations or standard criteria for all issues that apply	List regulations or standard criteria which relate to each of the issues above in the description box of assessment form.
1	There are regulations or standard criteria for >5 of the issues that apply	
0	There are regulations or standard criteria for 3-5 of the issues that apply	
-1	There are regulations or standard criteria for <3 of the issues that apply	
	There is no information available	
-2	There are no regulations or standard criteria	

4c. Is the regulatory framework or independent certification criteria for the species in this region effective in minimising negative impacts?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Regulations or standard criteria are fully* effective	*None of the assessment questions have been scored negatively due to poor regulation
0	There is evidence indicating regulations or standard criteria are only partially** effective	**One or more of the assessment questions have been negatively scored due to poor regulation
-1	There is insufficient information to assess effectiveness***	***There may be regulations but there is no data to ascertain effectiveness, there is no public data/auditing reports
	There is evidence indicating regulations or standard criteria are ineffective****	****There are records of regulations or standard criteria being broken

4d. Are producers of this species in the region producing to independently on-site audited, 3rd party certification standards?		
Score	**Answer Options**	**Examples and Answer Descriptors**
2	Producers in this unit of assessment farm to an independent audited standard *	*See Appendix 3 for more details
1	Producers in this unit of assessment are working towards improvement via a credible Aquaculture Improvement Project (AIP)* or Fisheries Improvement Project (FIP) (for the feed component) which is operational and demonstrating improvements including those schemes that lead to certification.	* See description below
0	No certification scheme or AIP/FIP is available for the unit of assessment	
-1	There are certification schemes or AIP's/FIP's available for the unit of assessment but no efforts are being made to apply	

8. DEFINITION OF AQUACULTURE AND FISHERIES IMPROVEMENT PROJECTS

AQUACULTURE IMPROVEMENT PROJECTS (AIP'S)

According to the Sustainable Fisheries Partnership: *"An Aquaculture Improvement Project (AIP) is an alliance of producers, processors, suppliers, and buyers working together to address sustainability issues in a fish- (or shrimp-) farming zone. The zone may be a common water input/discharge source (canal, river, aquifer, or reservoir); a government-designated administrative division such as a development plan area or "park"; and/or a geographic feature such as an island, valley, or coastal area.*
AIPs are designed to bring all stakeholders together to recognize their responsibilities and take actions to improve the environmental and social quality of the production zone. Key actions include understanding and implementing carrying capacity models, agreeing on specific control measures to deal with disease outbreaks, and developing market incentives for improvements."[14]

There are a range of ways to improve aquaculture facilities towards sustainability and MCS is very supportive of AIPs, particularly for high risk species, such as those that are red or amber rated by MCS.

For an AIP to be considered as 'credible' the following general criteria should apply:

- An independent observer/facilitator (e.g. NGO)
- Relevant stakeholder participation
- Identification and addressing of key environmental issues in production
- Adherence to SMART objectives
- Public accountability

In addition to the above, for an AIP to be considered by MCS in its ratings assessments, it should be at a stage where it is making progress according to the indicators and timelines in its work plan and achieving improvements so as to address the key issues of environmental concern.

FISHERIES IMPROVEMENT PROJECTS (FIP)

According to the US Conservation Alliance for Sustainable Seafood (CASS) a 'fishery improvement project is a multi-stakeholder effort to improve a fishery. These projects are unique because they utilise the power of the private sector to incentivise positive changes toward sustainability in the fishery. Participants may vary depending on the nature of the fishery and the improvement project, and may include stakeholders such as producers, non-governmental organisations, fishery managers, government and members of the fishery's supply chain'.[15] The Sustainable Fisheries

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14 Aquaculture Improvement Projects. Sustainable Fisheries Partnership. Available at: https://www.sustainablefish.org/Programs/Aquaculture/Aquaculture-Improvement-Projects. Accessed 30/04/2018

[15] CASS. FIP Guidelines, available at: http://cmsdevelopment.sustainablefish.org.s3.amazonaws.com/2013/08/01/Conservation%20Alliance%20FIP%20Guidelines-b7586ofc.pdf [Accessed 1/09/16]

Partnership (SFP) note that whilst each FIP is unique, the common thread is that the supply chain plays a critical role in helping a fishery in the journey towards sustainability.[16]
There are a range of ways to improve fisheries towards sustainability and MCS is very supportive of FIPs, particularly for high risk fisheries, such as those that are red or amber rated by MCS.
For a FIP to be considered as 'credible' the following general criteria should apply:

- An independent observer/facilitator (e.g. NGO)
- Relevant stakeholder participation
- Identification and addressing of key environmental issues in fishery
- Adherence to SMART objectives
- Public accountability

In addition to the above, for a FIP to be considered by MCS in its ratings assessments, it should be at a stage where it is making progress according to the indicators and timelines in its work plan and achieving improvements in the way the fishery is managed or operated so as to address the key issues of environmental concern. This would correspond to **Stage 4** or more of the Conservation Alliance for Seafood Solutions (CASS) Fisheries Improvement Guidelines10 or equivalent.
In cases where a FIP has been publicly launched and a programme of work agreed, but is not yet at the stage of achieving improvements in management or practices (ie. CASS **Stage 3**), MCS may recognise the initiative through an alternative sourcing recommendation provided the FIP remains within its agreed schedule.

RECOGNITION OF AIP'S AND FIP'S

In cases where an Improvement Project (IP) has been publicly launched and a programme of work agreed, but is not yet at the stage of achieving improvements in management or practices (ie. CASS **Stage 3** for FIP's), MCS may recognise the initiative through an alternative sourcing recommendation provided the IP remains within its agreed schedule.

This will be depicted (see Figure) by the addition of a left facing arrow over the normal 5 rating, indicating that although participation in the IP would not be sufficient to influence the rating assessment, it would serve to recognise that credible improvement work is underway. In such instances, MCS would not advise against sourcing species from the production area or fishery, thus providing, we hope, an incentive for businesses to support credible improvement projects.

FIGURE 2 EXAMPLE OF RATING GRAPHIC FOR RED RATED SPECIES IN A RECOGNISED IMPROVEMENT PROJECT

[16] SFP. Seafood industry guide to FIPs, available at: http://cmsdevelopment.sustainablefish.org.s3.amazonaws.com/2014/04/28/SFP%20FIPS%20Guide%202014-46b3eb10.pdf [Accessed 5/05/17].

9. SOURCES OF INFORMATION

MCS relies upon a number of sources of scientific information, organizational information including regulations and production standards to inform our aquaculture assessments. These resources include but are not limited to the following:

- Food and Agriculture Organisation of the United Nations (FAO)
- Europa – website of the European Union
- Standard holders and Certification bodies, such as Aquaculture Stewardship Council (ASC), Global Aquaculture Alliance Best Aquaculture Practices (GAA BAP 2*, 3*,4*) and GlobalGap
- Marine Scotland
- Environment Agency
- Centre for Environment Fisheries and Aquaculture Science (CEFAS)
- Scottish Environment Protection Agency (SEPA)
- Scientific journals
- Industry contacts

10. APPENDICES

APPENDIX 1 EXTERNAL REVIEW PROCESS

Following the release of the latest scientific advice and as part of MCS scheduled ratings updates in the Summer and Winter each year (see Appendix II), MCS consults externally on proposed changes to seafood ratings.

Interested parties with technical insight, relevant industry or scientific expertise or those with information that could contribute to the comprehensiveness and quality of the assessments, are particularly invited to input.

To receive notifications about ratings updates and consultations, please email us (ratings@mcsuk.org and request to be added to our interested parties email distribution list, and follow the Good Fish Guide on Twitter @GoodFishGuideUK.

Details of ratings consultations will also be made available online at:

https://www.mcsuk.org/responsible-seafood/about-our-ratings

APPENDIX II GOOD FISH GUIDE UPDATE SCHEDULE

Action	Timescale
ICES Summer Advice	June-Mid September Approx. 3.5 months
New ICES (and other) advice accessed	June/July
Advice processed (Post Acom Industry Briefing Meeting 1st week July)	July
Internal discussion of any ratings changes	Last Week July
Ratings agreed internally	Last week July
Proposed changes to Good Fish Guide ratings published online at https://www.mcsuk.org/responsible-seafood/about-our-ratings and comments invited **https://www.mcsuk.org/responsible-seafood/about-our- ratings**	Early August
External comments reviewed	Early September
Rating changes (if any) made and agreed internally	Mid-September
Confirmation of final ratings returned to those consultees providing comment including those with relevant interest inviting final comment before publication	Mid -September
Rating changes sent to Interested parties	Mid September
Database changes (GFG Master) sent to IT for data cleansing	Mid September
Database uploaded to website and App and ratings checked	Mid/late September
ICES Autumn Advice	October/November to end Feb Approx. 4 months
New ICES (or other) advice received	August to December
Advice processed	Ongoing from August
Internal discussion of any ratings changes	Ongoing as they arise
Ratings agreed internally	Ongoing as they arise
Proposed changes to Good Fish Guide ratings published online at **https://www.mcsuk.org/responsible-seafood/about-our- ratings** and comments invited	Mid-December
External comments reviewed	From third week in January
Rating changes (if any) agreed internally	End Jan
Fish Lists/layout compiled/finalised for Pocket Good Fish Guide and sent to printers	End Jan
Confirmation of final ratings returned to those consultees providing comment including those with relevant interest inviting final comment before publication	Early Feb
Rating changes sent to Interested parties	Mid/late Feb
Database changes (GFG Master) sent to IT for data cleansing	1st week in March
Database uploaded to website and App and ratings checked	Mid-March
Delivery of new PGFG (published annualy)	Mid-March

APPENDIX III AQUACULTURE CERTIFICATION PROGRAMMES RECOGNISED BY MCS AS BENCHMARKED BY GSSI[17]

Aquaculture Stewardship Council (ASC)
Global Aquaculture Alliance Best Aquaculture Practices (GAA BAP) 2* (Farm) 3* (Farm+ Hatchery or Feed Mill) 4* (Farm+ Hatchery+ Feed Mill). **Please note 1* refers only to the processing plant and as such is not recognised by MCS**
GlobalGap
ORGANIC AQUACULTURE CERTIFICATION PROGRAMMES RECOGNISED BY MCS - WITH A CONSUMER FACING LOGO, STANDARD REVIEW PROCESSS AND INDEPENDANT AUDITING
Soil Association Organic
Naturland Organic
Organic Food Federation
Irish organic
EU organic standard

[17] https://www.ourgssi.org/gssi-recognized-certifcation/

APPENDIX IV: AQUACULTURE PRODUCTION SYSTEMS

Salmon, trout, marine fish, flatfish in cages
Salmon, trout, marine fish, flatfish in tanks onshore without recirculation
Salmon, trout, marine fish, flatfish in tanks onshore with recirculation
Salmonids in ponds without recirculation
Salmonids in ponds with recirculation
Freshwater fish in ponds without recirculation
Freshwater fish in ponds with recirculation
Freshwater fish in cages
Freshwater fish in tanks without recirculation
Freshwater fish in tanks with recirculation
Shrimps in ponds without recirculation
Shrimps in ponds with recirculation
Shrimps in tanks without recirculation
Shrimps in tanks with recirculation
Shellfish in tanks without recirculation
Shellfish in tanks with recirculation
Shellfish on ropes
Shellfish in baskets
Shellfish on sticks
Shellfish ranched

MCS AQUACULTURE ASSESSMENT. VERSION 3 2018

Species:	**Atlantic salmon. *(Salo salar)***
Production Country:	Norway
Production Method:	Open net pen
Certification Status:	Uncertified
Assessment Date:	2018
Assessor:	Gill Banner-Stevens
Cross Checker:	Dawn Purchase

SCORING SUMMARY TABLE	
SECTION	**SCORE**
Feed Resources and Use	**3**
Environmental Impacts and Interactions	**-6**
Fish Welfare	**1**
Management and Regulations	**0**
Total assessment score	**-2**
Total rating score	**3**

Total score	**Total rating score**	**Colour**
9 or more	1	Dark Green
4 - 8	2	Light Green
(-2) - 3	3	Yellow
(-10) - (-3)	4	Orange
(-11) or less	5	Red

1a. Does the Unit of Assessment in this country/region rely on feed inputs?	
Answer Options	**Answer Descriptors**
Yes	Proceed to question 1B
No	Award 5 points and proceed to Section 2.

Yes, farmed Atlantic salmon rely upon commercially formulated feed inputs at all stages of development (FAO 2018). Of all aquatic feeds produced globally, around 11% is used in the production of salmonids; in turn, 83% of salmonid feeds are used to culture Atlantic salmon, the most commonly farmed salmonid species (Marine Harvest 2017)."

Three international feed producers – Skretting (Nutreco), Cargill EWOS, and BioMar – predominate in the Norwegian salmon sector: these three companies have a market share of 90% of salmon feed in Norway (Ytrestøyl et al. 2015). Globally, Cargill and Skretting both supply around one third of the salmon feed market each (Star Tribune 2015). Both of these feed companies are associate members of the Global Salmon Initiative (GSI 2018). Data from these three main suppliers show that inclusion levels of fishmeal and fish oil from forage fisheries continue to decline with increasing replacement with by-product sources, particularly terrestrial crop sources (MBA 2017).

1b. Is the protein and oil component (marine, vegetable and terrestrial) of the feed* used in the country/region known and traceable to species level, or from a certified factory (in countries using a mixed species fishery regime e.g. Asia) for marine components? * Any feed components contributing over 1% of the feed, i.e. not including vitamins, minerals and additives etc.		
Score	**Answer Options**	**Examples and Answer Descriptors**
0	Yes.	(Continue to questions 3-4)
-2	No	(Skip questions 1c & 1d and award minus 3 points)
	No Information available	

A review of the policies of the three main feed providers to the Norwegian salmon sector shows that the answer is yes.

BioMar's 2015 company sustainability report notes that: "*Roughly one out of four farmed fish in Europe and Chile are produced with BioMar fish feed*," and further affirms that 100% of both marine and plant raw materials are fully traceable throughout the supply chain (BioMar 2015).

Skretting, attests that: "*Most Skretting companies have an electronic system in place that precisely traces feed batches back to their raw materials. It provides accurate and accessible records of all ingredients, production processes and feed deliveries. This system delivers rapid upstream and downstream information, which is essential for an efficient recall programme*," (Skretting 2014).

Similarly, **Cargill**'s sustainability report (Cargill 2016) includes charts which detail the specific terrestrial and marine protein and oil components that are included in their feed formulations, plus a percentage breakdown detailing which species comprise the marine inputs (species which comprise less that 2% of marine inputs are aggregated into in a miscellaneous category, which accounts for 5% of the total).

Score is 0

1c. Are marine wild capture protein and oil components of the feed (as defined above) used in the country/ region sourced sustainably or responsibly?		
Score	**Answer Options**	**Examples and Answer Descriptors**
2	The marine wild-capture protein and oil components of the feed are independently certified as being sustainable*.	*** Sustainable -** ISEAL accredited with criteria for low trophic species and ecosystem impacts (currently only MSC)
	No marine ingredients are used.	
1	Independent certification (production) standards ** require the responsible sourcing of marine proteins and oils, verifiable by audit.	**** Independent Certification Standards** refer to production standards set by a certification body and audited by a third party. e.g. Aquaculture Stewardship Council; Global Aquaculture Alliance Best Aquaculture Practices; GlobalGap
	Feed suppliers and/or supply chain have a policy in place that ensure the responsible sourcing of the marine wild-capture protein and oil source and this can be independently verified***	*****Responsible** - Independent certification of responsible sourcing (Currently only IFFO RS Standard for Responsible Supply)
0	The independent Certification Standards encourage/recommend responsible marine protein and oil sourcing but do not verify via audit	Criteria in production standards that recommend or advise sourcing responsible/sustainable ingredients
	Feed suppliers and/or supply chain have an internal policy in place that includes responsible sourcing of the marine protein and oils but implementation of this policy cannot be verified.	This would include a Fishsource score over a certain threshold

-1	There is no independent certification or feed suppliers/supply chain policy to ensure the sustainable or responsible sourcing of the wild-capture protein component of the feed but the source is known	
-2	There is no information available about the source of the marine proteins and oils	
	The feed is known to include overexploited species or from damaging fisheries (Including MCS Red rated).	
Critical fail	There is evidence that the marine proteins and oils used in feed originates from IUU (Illegal, Unreported, Unregulated) fisheries which are demonstrably contributing to ecosystem changes caused by fishing down the food web*	***Fishing down the food web** is the process whereby fisheries in a given ecosystem, "having depleted the large predatory fish on top of the food web, turn to increasingly smaller species, finally ending up with previously spurned small fish and invertebrates".[18]

"In 1990, 90% of the ingredients in Norwegian salmon feed were of marine origin, whereas in 2013 only around 30%. The contents of fish meal and fish oil in the salmon feed were 18% and 11%, respectively, in 2013. Between 2010 and 2013, salmon production in Norway increased by 30%, but due to a lower inclusion of marine ingredients in the diet, the total amount of marine ingredients used for salmon feed production was reduced from 544,000 to 466,000 tonnes," (Ytrestøyl et al. 2015).

BioMar's latest sustainability report (BioMar 2015) gives a detailed breakdown of the source of marine wild-capture protein and oil components used in their feed formulations. As can be noted in Figure 6, **92% of fishmeal (FM) used by BioMar is certified to IFFO's Responsible Supply (RS) Standard and 86% of fish oil (FO) used is IFFO certified**. Additionally, 100% of the krill meal used is MSC (Marine Stewardship Council) certified as being sustainable. IFFO certification assures and independently verifies adherence to the following three key principles:

- *Responsible Sourcing: of fishery material (non IUU) from fisheries that comply with the key principles of the FAO Code of Conduct for Responsible Fisheries.*
- *Responsible Traceability: of marine ingredients back to fisheries that are compliant with this Standard.*
- *Responsible Production: of safe marine ingredients in a safe working place* (IFFO 2017).

[18] Pauly, Daniel and Watson, Reg (2009) "Spatial Dynamics of Marine Fisheries" *In:* Simon A. Levin (ed.) *The Princeton Guide to Ecology*. Pages 501–509.

Skretting also have a policy in place whereby suppliers must sign a code of conduct (Nutreco 2014). The company note that their: "*… Ingredient and Supplier Assessment & Management pillar ensures only healthy, safe and sustainable raw materials are used for the production of fish and shrimp feeds. It includes common standards for assessing and managing ingredients and suppliers*, (Skretting 2014).

The following is an overview of the section of the code of conduct that pertains to marine feed components: "*Skretting has established the minimum criteria that we expect from our suppliers with regards to the sustainable sourcing of marine ingredients and the responsible management of the fisheries where these ingredients originate. These criteria cover:*

- *Traceability systems to verify species and country and origin;*
- *Species are not classified as Endangered or Critically Endangered on the IUCN Red List. Species that are listed as Vulnerable are not eligible for use as a trimmings product, unless it's from a sub-population assessed to be responsibly managed;*
- *Marine ingredients must not be from illegal, unreported and unregulated (IUU) fishing activity;*
- *Promoting compliance with the fishery management principals of the FAO Code of Conduct for Responsible Fisheries; and*
- *Encouraging suppliers to obtain recognised third-party certification, such as International Fishmeal and Fish Oil code of Responsible Supply (IFFO RS) or Marine Stewardship Council (MSC).*

***Where possible Skretting purchases fish meal and fish oil that are certified by IFFO RS or MSC**," (Skretting 2018).

The company state that 100% of their FM and FO suppliers have signed their code of conduct, however, this does not provide the same degree of assurance of the responsible/sustainable sourcing of marine components as would be provided by third party certification. According to the company's 2016 sustainability report, they strive to align their goals with the United Nation's Sustainable Development Goals.

Cargill EWOS's sustainability report is highly detailed in the degree of transparency that it offers. As can be noted in Figure 7, **33% of marine ingredients were sourced from by-products and 67% from forage fisheries, the vast majority of which were IFFO certified (i.e. responsibly sourced) and one third of which were MSC certified (i.e. certifiably sustainable)**.

Of additional note is that four Norwegian salmon producers (Cermaq, Grieg Seafood, Marine Harvest, and Nova Sea AS) are members of GSI (GSI 2018). This industry organisation publishes an online 'Sustainability Report' in an effort to promote industry transparency in a variety of production parameters, including one indicator pertaining to "Use of Marine Ingredients in Feed". This is an interesting source of information, but since there are presently only four Norwegian producers, it does not give an accurate overview of the 'majority' of production, as is required by Q3.

In summary, the majority of feed manufacturers supplying the Norwegian Atlantic salmon sector do have a policy in place that ensures the responsible sourcing (i.e. IFFO certified) of the marine wild-capture components of their feeds. At present, both BioMar and Cargill have sourcing policies in place that further assure the responsible/sustainable sourcing of these marine components through third-party certification. Substantial amounts of the marine ingredients used by these three main feed suppliers are also certified as being sustainable (i.e. MSC certified) but since this does not reflect the majority of feeds, the **final score for Q1c is 1**.

Score 1

1d. Are soy (and soy derivatives) products and palm oils used and responsibly sourced?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Any soy and/or palm used is certified as sustainable*	* Proterra Soy and Roundtable for Sustainable Palm Oil (RSPO)
	Soy and palm not used	
0	Any soy and/or palm used is responsibly sourced**	** Roundtable for Responsible Soy (RTRS) and Soybean Sustainability Assurance Protocol Criteria
-1	No data available	
	Any soy and/or palm used is untraceable	

Skretting's sustainability report (Skretting 2016a) discusses the impact of terrestrial feed ingredients in great detail – but, notably, does not attest to using specific percentages or quantities of such ingredients that are certified by third-party schemes. It is evident that Skretting is very much engaged in the issue of responsible terrestrial crop sourcing, however, and the primarily tool it uses to address this concern is its own, in-house Supplier Code of Conduct.

The 2016 report states the following: "*Many of our feeds contain soy and palm based ingredients that come from production systems that potentially contribute to deforestation and the loss of other valuable ecosystems. To minimise the associated footprint of these purchases, Nutreco is an active member in both the Roundtable for Responsible Soy (RTRS) and the Roundtable for Sustainable Palm Oil (RSPO). Membership of these two groups keeps us in the conversation of how we can help shape progress. As part of our effort to address the impact palm oil has in forestry and other valuable landscapes, Nutreco purchases book and claim certificates annually to offset 100% of all palm oil ingredients purchased in 2016, excluding palm kernel oil which accounted for 19% of our total palm oil purchased in 2016. We excluded palm kernel oil from our program for the time being. This is due to the limited availability of this product and the associated costs which are in the order of approximately 10 times that paid for crude palm oil in 2016.*

For soybean and soy products the panorama is much more complex. There is a plethora of environmental standards commercially available and no real agreement. This is further complicated by the lack of widespread industry support for these schemes. The costs of certified commodity product (premiums) when there is limited coverage of specific deforestation issues or lack of commercial uptake in the market (limited demand) - has slowed our commitment to any one of the schemes available. As such, we have piloted a step-wise approach with the purchase of Proterra soy concentrates in Skretting Norway from 2015 onwards. In 2017 we will explore options for extending this approach in the future. We have also engaged in multi-stakeholder platforms such as the European Feed Manufacturers Federation (FEFAC) that are focused on driving the entire industry towards a more sustainable approach. Nutreco is an active member of the FEFAC Sustainability Committee which recently launched the minimum criteria for responsible soy guidelines. Nutreco is also an active member of the US Soy Export Council Sustainability Committee. We will continue our efforts to reach a shared understanding with all industry stakeholders on the best approach to move forward with a responsible soy (deforestation free) agenda."

Cargill's 2016 sustainability report notes that: "*Cargill Aqua Nutrition has developed a new data set for reporting use of soy and palm materials certified to specific standards*," (Cargill 2016).

As can be noted in Figure 8, 100% of the 87,924 MT of soy products - used specifically for Cargill's feed produced in Norway during 2016 - was ProTerra certified (ProTerra 2014). Zero palm oil was used in Cargill's Norwegian feed formulations during 2016. Regarding terrestrial ingredients, Cargill states in its report that:

- *"Cargill signed the New York Declaration on Forests and we will work towards a goal of zero deforestation in our supply chain by 2030, having halved it by 2020.*
- *We will source all palm oil products from responsible supply chains audited to standards such as RSPO or equivalent.*
- *For our EWOS brand, we will source all soy products from responsible supply chains audited to standards successfully benchmarked against the FEFAC Soy Sourcing Guidelines."*

In conclusion, the majority of terrestrial components used in the formulation of salmon diets in Norway is fully traceable and any soy and palm used is certified as sustainable or not used at all. This results in a score of 1

Score 1

1e. What is the overall Fish-in Fish-out ratio calculated as Feed Fish Dependency Ratio (FFDR*) for the unit of assessment?		
Score	**Answer Options**	**Examples and Answer Descriptors**
2	The species has a FFDR of less than 0.5	***FFDR** = **Feed Fish Dependency Ratio** - the quantity of wild fish **used per quantity of cultured fish produced. This measure can be calculated for fishmeal
1	The species has a FFDR of 1 or less	

-1	The species has a FFDR between 1.1 and 2	or fish oil whichever component creates the largest burden of wild fish in feed. ** **Wild fish**: includes both meal and oil produced from wild fish, but not include by-products from processing (trimmings). FFDR meal = $\frac{(\%\text{ fishmeal in feed})(\text{eFCR})}{22.2}$ FFDR oil $= \frac{(\%\text{ fish oil in feed})(\text{eFCR})}{5}$ eFCR$= \frac{\text{Feed,kg or MT}}{\text{Net aquacultureal production,kg or MT (wet weight)}}$
-2	The species has a FFDR between 2.1 and 3	
-3	The species has a FFDR greater than 3.1	

The Feed Fish Dependency Ratio (FFDR) is the quantity of wild fish used per quantity of cultured fish produced. In the case of farmed salmon, the sector's use of fish oil (FO) has a greater impact upon forage fisheries than does its use of fishmeal (FM), therefore Q1e has been scored basis the industry's average FFDR for FO. The industry average FO FFDR of 1.5 therefore **the score is 1.**

Score 1

2a. Do the production systems for this species in this region deplete freshwater supplies and/or degrade freshwater bodies by salinisation*? * Degradation of freshwater in this question does not refer to any kind of organic pollution or chemical contamination, both of which are addressed in separate questions.		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	No Not applicable*	*Not applicable = Open or closed seawater systems, re-circulating freshwater system, plentiful freshwater supply and no salinisation occurring.
0	Depletion/degradation is possible but is mitigated by management/certification standards criteria	
-1	Depletion of supplies and/or degradation of freshwater bodies (surface and groundwater) by salinisation occurs OR is data deficient	

The production cycle of farmed Atlantic salmon typically takes around three years (24-40 months). The first year (10-16 months) of production takes place in a freshwater environment. The hatchery phase is conducted primarily in tanks in indoor recirculation systems (RAS) on land and no evidence of hatcheries depleting freshwater supplies has been identified in literature. At the end of this freshwater stage the juvenile salmon, which are now called smolts, weigh around 100g and are ready to be put to sea for the saltwater phase of their lifecycle. Atlantic salmon are on-grown in marine net pens over a period of 14-24 months, until they attain a harvest weight of 4-5kg (Marine Harvest 2017). This process does not impact freshwater supplies or degrade freshwater bodies by salinization.

Score 1

2b. Does the production system for this species in this country/region require habitat alteration that impacts ecosystem functionality?

Score	Answer Options	Examples and Answer Descriptors
0	No	Ecological sensitivity*:
	Alteration is small-scale OR alteration occurs in areas of low ecological sensitivity	**Low:** Land less susceptible to degradation, e.g. formerly used for agriculture or previously developed
-1	Alterations are in areas of moderate ecological sensitivity	**Moderate**: Coastal & near-shore waters; rocky intertidal or subtidal zones; river or stream shorelines
	Alterations are in areas of historical degradation** with verifiable restoration*** occurring	**High:** Coastal wetlands; mangroves; coral reefs; rainforest; any areas containing threatened or endangered species
-2	Alterations are in areas of high ecological sensitivity with ongoing or recent habitat loss and there is no reforestation program in place	** Historical degradation = occurring 15 years and over *** Verifiable restoration = An auditable criteria (a "must" not a recommendation) in certification standards or occurring a regional scale with documented evidence
	Data is deficient	
-3	Yes high value/sensitive habitats are impacted with high, irreversible consequence	

A typical cage site for growing Atlantic salmon uses circular HDPE (High-density polyethylene) floating cages. These cages are moored in a square-shaped grid system and held onto the sea bed with mooring lines. Since the ocean is dynamic, the mooring system and the grid system need to be strong but also flexible enough to accommodate the forces of wave action.

"Norway's AKVA group is one of the biggest – if not the largest – aquaculture equipment suppliers in the world. It produces both plastic and steel cages; roughly 45,000 of the former, and 15,000 of the latter, since its inception, it estimates" (UCN 2018).

In conclusion, Atlantic salmon farms in Norway use mooring techniques which cause minimal alteration to the seabed.

Score 0

2c. Does the unit of assessment rely on chemical* usage, if so are there associated risks and impacts on the environment? * Chemicals include antibiotics, chemotherapeutants, pesticides, fungicides, antifoulants		
SCORE	**ANSWER OPTIONS**	**EXAMPLES AND ANSWER DESCRIPTORS**
1	No chemical usage No environmental impact	The production system is closed and does not discharge active chemicals or by-products (e.g. antibiotic resistant bacteria), or; The method of treatment does not allow active chemicals or byproducts to be discharged Data show that chemical treatments are used on average less than once per production cycle or once per year for longer production cycles, or; The production system does not discharge water over multiple production cycles, or; Evidence of no impacts on non-target organisms
0	Yes but the environmental impact of chemical use is known and effectively** regulated and or mitigated by independent certification standard criteria	**Clear regulations that include all chemicals used in production, which set limits for their use and those limits are not exceeded by the of producers in the unit of assessment Specific data may be limited, but the species or production systems have a demonstrably low need for chemical use, or; Evidence of only minor impacts on non-target species within the allowable zone of effect (i.e. no population-level impacts), or; The production system has very infrequent or limited discharge of water (e.g., once per production cycle or < 1% per day). Occasional, temporary or minor evidence of impacts to non-target organisms beyond an allowable zone of effect, or; Some evidence or concern of resistance to chemical treatments, or; Regulations or management measures with demonstrated effective enforcement are in place that limit the frequency of use and/or total use of chemicals.
-1	Yes, but the use of chemicals is within an ineffective*** regulatory or management framework	***Despite regulations specifying limits and monitoring chemicals used, there is evidence of limits being exceeded or there is evidence of poor enforcement Chemicals are known to be used on multiple occasions each production cycle and the treatment method allows their release into the environment, or; Chemical use (type and/or volume) is unknown but the production viability is considered to be dependent on chemical intervention, and the treatment method allows their release into the environment, or;

		Regulatory limits on chemical type, frequency and/or dose exist with unknown enforcement effectiveness or; Confirmed cases of resistance to chemical treatments, or; Chemicals highly important to human health are being used in significant or unknown quantities.
-2	Yes, there are no clear regulations for the use of chemicals Chemical use is unknown due to data deficiency	Illegal chemicals (as defined by the country of production) are used beyond exceptional cases or; Chemicals critically important to human health are being used in significant or unknown quantities, or; Negative impacts of chemical use seen on non-target organisms beyond an allowable zone of effect. Evidence of developed clinical resistance to chemicals (e.g. loss of efficacy of treatments) that are highly important or critically important to human health, or; Illegal activities with demonstrable negative environmental impacts.

Yes, as is the global norm for commercial finfish farming operations, the Norwegian salmon sector relies on chemicals for a variety of aspects of production. Chemicals, such as disinfectants and antifoulants, which are used to manage production systems, as well as veterinary chemicals, such as anaesthetics, vaccines, antibiotics and pesticides, are all used. Of these, antibiotics and pesticides are generally identified as having the most potentially damaging environmental impacts if they are not used with caution.

Fish farm-specific information on chemical treatments is available in English from the BarentsWatch website (https://www.barentswatch.no/en/), which collects, develops and shares information about Norwegian coastal and marine areas.

Antibiotics

According to the Aquaculture Stewardship Council (ASC) webpage (https://www.asc-aqua.org/five-things-saw-asc-certified-salmon-farm-norway/) "Currently, less than one percent of all farmed salmon is treated with antibiotics in Norway". The most recent (2016) annual fish health report published by the Norwegian Veterinary Institute reports that, "The total volume of antibacterial substances used in Norwegian fish farming in 2016 [predominantly Atlantic salmon] was equivalent to 212 kg active substance. This is the lowest reported volume since the mid-1970s, prior to the fish farming boom. According to statistics released by the Norwegian Food Safety Authority (Vetreg) the majority of prescriptions relate to treatment of cleaner fish, with only a small proportion prescribed for ongrowing salmonids" (Hjeltnes et al. 2017).

The development of antimicrobial resistance is an emerging problem worldwide. To help prevent the development and spread of antimicrobial resistance, the Norwegian human public health and veterinary sectors, including food production, are all subject to ongoing surveillance and a public report is produced annually. The most recent report states that, "The sales of antimicrobial veterinary medicinal products in Norwegian aquaculture declined by approximately 99% from 1987 to 1996 and have thereafter remained relatively constant. This reduction was mainly attributed to the introduction of effective vaccines and full-scale vaccination of salmonids - and to some extent also to improved health management," (NORM/NORM-VET 2016).

Although their use is minimal, it should be noted that the latest World Health Organization report on 'Critically important antimicrobials for human medicine' (WHO 2017) lists Quinolones – the family of drugs that included oxolinic acid – under the category of 'critically important microbials', whereas Amphenicols – which include the agent florfenicol – are listed as 'highly important microbials'.

Sea Lice Treatments and Pesticides

Sea lice are an aquatic ectoparasitic copepod of the family Caligidae, which feeds on the mucus, skin and blood of the host fish. While low level infestations of sea lice cause only minimal effects on the host, high numbers can result in progressively worsening skin damage and even death of the host. As early as 1940, there were reports of high numbers of sea lice causing severe damage and mortality in wild fish (Jones et al. 2012). However, a report commissioned by the Salmon and Trout Conservation Scotland states that, "Salmon lice generally occur in low numbers on wild salmonids in areas lacking fish farming. Salmon lice have historically been observed in low numbers on wild salmonids, and few adverse effects on the host have been reported. However, since the late 1980s, in parallel with the expansion of fish farming, there have been several reports of marked sea lice outbreaks on salmonids in Norway, Canada, Ireland and Scotland. Salmon lice epizootics are not a common phenomenon for wild salmonids in farm-free areas," (Thorstad & Finstad 2018).

Sea lice were first identified as a substantial problem by the salmon farming industry around 1994. To control them, emamectin benzoate (EMB) became the chemical of choice, but by 2009 it was evident that sea lice were becoming resistant to this pesticide (Independent 2017). The first reported incidences of EMB, pyrethroid compounds, and azamethiphos (AZA) failing in its efficacy to treat sea lice infestations (i.e. increased tolerance and resistance) all date back to approximately this same time period (Aaen & Helgesen et al. 2015).

"Apart from chemical intervention through bath treatments and medicated feed, several non-chemical methods are utilized to remove or reduce the number of parasites attaching to farmed fish. Fallowing, synchronized treatments within geographic zones, cleaner fish, delousing laser, and plankton shielding skirts are already in use, with others such as snorkel cages and enclosed cages on the verge of commercial introduction. Despite the use of alternatives to chemical treatment, extensive use of medicinal compounds combined with limited access to effective chemical compounds has led to widespread resistance towards the most applied medicinal products. The evolving reduced sensitivity in sea lice is a good example of microevolution, and shows how humans can influence nature considerably in a relatively short time frame," (Aaen & Helgesen et al. 2015).

In 2013, the Norwegian Food Safety Authority initiated a monitoring and surveillance program to assess the status and determine the extent of the sea lice/ antimicrobial resistance problem. The survey demonstrated that: "Reduced sensitivity towards AZA, deltamethrin (DELTA), and EMB was present in all counties except Finnmark, the northernmost county in Norway. The survey also revealed that the areas with the most severe problems were located in the Hordaland county in the south west, the Nord-Trøndelag county in mid-Norway, and the northern part of the adjacent county Nordland. In these areas, resistance towards all agents in the program (AZA, DELTA, and EMB) was widespread, whereas in many cases the same population displayed resistance traits towards all the above-mentioned compounds simultaneously, a scenario of multiple resistance. In the other areas, the situation was more subtle, with variations from susceptible parasites to resistance towards one or several agents. Resistance towards hydrogen peroxide (H2O2), a compound also used against amoebic gill disease, has also been reported from mid-Norway. For the chitin synthesis inhibitors diflubenzuron (DIFLU) and teflubenzuron (TEFLU), no evidence for resistance is reported, although some reduced treatment efficacy was seen in 2011 and 2012," (Aaen & Helgesen et al. 2015).

The most recent (2016) annual fish health report published by the Norwegian Veterinary Institute reports that, "Resistance has developed over several years, but peaked in 2016, with treatment failure and lice damage recorded on several farms. The registered number of chemical-based treatments fell by 41% in 2016 while use of mechanical de-licing methodologies increased more than six times compared to the previous year," as can be noted in Figure 14 (Hjeltnes et al. 2017).

Norway's interactive and GIS-based website BarentsWatch site (https://www.barentswatch.no/en/) provides detailed information on fish health from the salmon farming sector and this includes data on fish diseases, which is updated from the Veterinærinstituttet (the Norwegian Veterinary Institute) every four hours, whereas information on sea lice is updated every day.

The impacts that these sea lice treatments have upon the environment vary and is dependent upon the type of pesticide used and the method in which it is administered. Azamethiphos, pyrethroids (deltamethrin and cypermethrin) are used as bath treatments, and diflubenzuron, teflubenzuron, and emamectin benzoate are administered in feed. Importantly, these pesticides are non-specific in that their toxicity also has the capacity to impact non-target organisms, particularly crustaceans, which sometime share the same habitat as salmon net pens (MBA 2017).

A recent paper, which discusses the environmental risks of veterinary medicines used in aquaculture (Lillicrap et al. 2015), notes the following in connection with Norwegian management measures: "Encouragingly, the Ministry of Trade, Industry and Fisheries of Norway in collaboration with the Norwegian Seafood Federation and the Norwegian Seafood Association, recognise the challenges within aquaculture and the potential environmental consequences of the use of veterinary medicines. Subsequently, in an attempt to alleviate the environmental impact of aquaculture processes within Norway, the following three measures have been implemented: whole or partial withdrawal of the licensing approval in locations where the problems are most pronounced; review and monitoring of internal systems for salmon lice and veterinary medicines used by industry; and increased supervision of the use of veterinary medicines. How these measures will be implemented in practise or the affect they will have on the environmental impact of veterinary medicines is currently not clear. It is therefore also our responsibility as environmental scientists to help protect the environment from adverse effects of chemicals and the question is whether current environmental risk assessment data requirements are sufficient for all aquaculture medicines? In answer, standard acute and chronic ecotoxicity data may be appropriate for assessing the environmental hazards of a large number of substances. However, it is clearly not sufficient for substances that specifically affect certain organisms or where hazards may not be predicted based on standard environmental hazard assessments alone".

In conclusion, although antibiotic use in Norway has diminished greatly, and this progress is laudable, those antimicrobials that are utilized by the industry are defined as being of critical importance to human health by the World Health Organization, which is a cause for concern. Furthermore, evidence which demonstrates that sea lice have been developing resistance to multiple pesticides over the course of the last decade suggests that these chemicals have been over-used by the industry and that their use has, to date, been poorly managed. There is also high concern regarding the potential impact that these chemicals may have upon non-target organisms, particularly crustaceans, which frequent the same habitat as salmon net pens. In consideration of these concerns, **the score for Q2c is -1.**

Score -1

2d. Does the unit of assessment discharge* directly into the aquatic system, if so does this cause a negative impact?

*** Discharge: Includes faeces, pseudofaeces, uneaten food, effluent, sludge.**

Score	Answer Options	Examples and Answer Descriptors
1	No discharge Little or no negative impact	Zero input systems; Zero exchange systems; Recirculating systems; IMTA system
0	Measurable negative impact within regulation and/or certification standard boundaries	E.g. defined allowable zone of effect (AZE) or within regulatory limit for effluent nutrient levels Ponds with one discharge per production cycle; extensive systems; OR ponds with frequent water exchange; intensive systems; pen net pens; flow through tanks and raceways that are operating within regulations/independent certification criteria and demonstrating full compliance
-1	Yes, but discharge occurs within an ineffective regulatory or management framework	Ponds with frequent water exchange; intensive systems; pen net pens; flow through tanks and raceways that are operating within ineffective/absent regulations and/or independent certification criteria
-2	There are no clear regulations for the limiting and monitoring of discharge Data deficient	All systems that operate within regions with no regulation pertaining to discharge and water quality AND /OR where negative effects caused by illegal and unnecessary discharge are known

The organic wastes, nutrients and chemicals, which are generated as a by-product of farming fish in open net pens, inevitably flow unimpeded from the culture zone into the surrounding environment. These wastes include fish faeces and uneaten food, which are dispersed as solid particles, alongside dissolved nutrients (primarily nitrogen and phosphorus) which are released from the gills and also from the urine of fish. The regulatory framework in Norway requires mandatory environmental monitoring of benthic impacts from marine fish farms as described in Norwegian standard 9410:

2016. Fish farmers must hire independent professionals to conduct environmental surveys, and report to the Directorate of Fisheries (Fiskeridirektoratet 2018).

Price et al. (2015), in a research paper that discussed the impacts of fish farm wastes upon primary productivity, noted: “Many studies have been unable to detect a phytoplankton response tied to nutrient loading from fish farm effluent.”

A risk assessment of the environmental impacts of salmon farming in Norway found that: “From ~500 yearly investigations of local organic loading under fish farms, only 2% of them displayed unacceptable conditions in 2013. The risk of eutrophication and organic load beyond the production area of the farm is considered low,” (Taranger et al. 2015).

A recent study on the regional impacts of fish farming in Hardangerfjord, one of the largest salmon-farming areas in Norway, which studied ecological conditions in intertidal macroalgal and benthic deep basin communities, in addition to measurements of nutrients and chlorophyll, reported that: “Macroalgal communities in the intertidal zone and the deep water fauna communities showed a high ecological status in the intermediate part of the fjord and a good status in the inner part of the fjord. Faunal communities in the outermost basin indicate that the assimilative capacity for farm waste of this deep basin could be limited. Nutrients and chlorophyll-a values were within national thresholds defined as high water quality. The good ecological conditions of the parameters studied in the fjord show little evidence of a regional impact from the fish farming industry despite the intensive production level, (Husa et al. 2014).

Another study, titled ‘Interactions between salmon farming and the ecosystem: Lessons from the Hardangerfjord, western Norway’ noted that: “Dense establishments of filamentous algae were recorded at many sites, in particular in the central part of the fjord. This phenomenon may be caused by local nutrient enrichment from fish farms in the area, climatic variations or by the massive urchin grazing on ephemeral seaweeds (kelp) providing space for opportunistic species. Apart from the proximity of the fish farms, no clear biological effects of nutrient release from the salmon farming could be found. Nutrient levels and chlorophyll-a levels in the main fjord, measured during a three-year period, showed no indications of elevated concentrations due to anthropogenic emissions,” (Skaala et al. 2014).

Monterey Bay’s Seafood Watch report on the sector concludes that “The regulatory structure and enforcement appear to be good at the site level, with robust monitoring data available, but cumulative impact mitigation does not appear to be an explicit theme of the regulatory structure. There is still scope for improvement in understanding cumulative habitat impacts of the industry,” (MBA 2017).

Interestingly, recirculating aquaculture systems (RAS) technology is developing rapidly in Norway, “Larger salmon farming companies in Norway have also begun experimenting with growing their juvenile salmon to a larger size before moving them to ocean net-pens, thereby limiting the duration of the salmon life cycle in seawater. Therefore, Norway has made a significant investment in building these “post-smolt” facilities that are typically large-scale, land-based recirculating aquaculture systems,” also of note is that “In Norway, there are approximately 190 land-based fish farms operating, most are primarily salmon smolt farms with smaller facilities producing various other species. The largest land-based operation has a capacity to produce more than 3,000 metric tonnes of smolt per year," (MAACFA 2018). By design, closed containment RAS systems allow fish farmers to have greater control over waste removal from the production system.

In conclusion, although Atlantic salmon net pens discharge directly into the aquatic environment, the regulatory framework that is in place requires that this aspect of production is monitored closely and reported upon and **the score for Q2d is therefore 0**.

Score 0

2e. What is the main source of juveniles or companion species for the unit of assessment?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Hatchery based	
0	Naturally settling juveniles	
	Hatchery-based juvenile or companion species production using wild caught broodstock from healthy, not overexploited wild stocks	
-1	Juveniles or companion species are taken from healthy, not overexploited wild stocks	
-2	Juveniles or companion species are caught by methods destructive* to the environment	* Destructive: Illegal or use of bottom towed gear in sensitive habitat (e.g. sea grass, MPAs, maerl beds & other reefs), explosives or chemicals for fishing.
	Juveniles or companion dependent species are caught from a stock[s] which is considered at risk (e.g. Biomass below Bmsy or mortality above Fmsy or other proxies or reference points with similar intent)	
Critical Fail	Juveniles source are heavily over-fished and the species is of listed conservation concern**	**Refer to table below

As is the case in all Atlantic salmon farming nations, the Norwegian industry uses domesticated, hatchery-raised broodstock which means that the entire production cycle is independent of wild salmon stocks for broodstock, eggs, or juveniles (MBA 2017). The score for Q2e is therefore 1.

Score 1

2f. Is there a risk of parasitic* transfer to adjacent wild species?

***multicellular organisms i.e. crustaceans (e.g. sea lice) and helminths (e.g. flatworms)**

Score	Answer Options	Examples and Answer Descriptors
1	No risk of parasitic transfer**	**Either no parasites or no possibility of reaching wild fish
0	There is a potential problem, but the impact on wild species is limited by effective management and/or 100% farmed cleaner fish	
-1	Unknown status of parasitic transfer and unknown environmental impact***	***Poor data collection and transparency
-2	Yes, there is a known problem and/or risk and impact on a wild population (including cleaner fish) is evident	

Norway's interactive and GIS-based website BarentsWatch site (https://www.barentswatch.no/en/) provides detailed information on fish health from the salmon farming sector and this includes data on fish diseases, which is updated from the Veterinærinstituttet (the Norwegian Veterinary Institute) every four hours. Overall, this data demonstrates that viral diseases and sea lice parasites present the greatest threat in terms of potential ecological impact.

Sea Lice Parasites
"The effects of sea lice on the marine survival of wild salmonids are widely debated. In Norway this debate has reached a crescendo as the Norwegian government has recently ratified a management system where the growth in the salmonid aquaculture industry will be conditional on regional estimated impact of salmon lice on wild fish. Sea lice have thus become the most prominent obstacle to the stated political aim of quintupling aquaculture production in Norway by 2050. Scientific documentation that salmon lice impact the marine survival of salmon is robust. However, it is also evident that marine survival of salmon is strongly impacted by other factors, and that the effect of salmon lice is most likely an integral part of these other mortality factors," (Vollset et al. 2018).

"Salmon lice may reduce marine survival of wild Atlantic salmon in farmed areas along the Norwegian coast, especially in the southwestern and middle parts, but also in parts of northern Norway. Thus, the number of affected populations is high, and the geographical distribution was classified as regional to national," (Forseth et al. 2017).

"Escaped farmed Atlantic salmon and salmon lice were the two anthropogenic impact factors identified as expanding threats to Atlantic salmon populations in Norway, which affect wild salmon populations to the extent that they may be critically endangered or lost, and which have a large likelihood of causing even further reductions and losses in the future. The main reason for the heavy impact by these factors is the size (1.3 million tons farmed salmon produced in 2015) and expected growth in the production of farmed salmonids. In 2015, there were 382 million farmed Atlantic salmon at nearly 600 farm localities along the coast. In comparison, the number of wild adult Atlantic salmon returning to Norway the same year was estimated at 522 000 individuals. Hence, the abundance of farmed Atlantic salmon was 732 times the abundance of wild Atlantic salmon. Indeed, the number of farmed Atlantic salmon in a single location typically exceeds the total abundance of adult wild Atlantic salmon in Norway. Although the proportion of farmed salmon that escape is low, between 0.04 and 0.16% in 2015, and their survival to adulthood is low,

the sheer numbers of farmed fish result in high risk of genetic changes in many populations. Similarly, while the permitted level of salmon lice per fish in farms is strictly regulated, the large number of farmed fish results in a worst case daily release of more than 1 billion salmon lice larvae. Consequently, monitoring indicates moderate or high risk for lice-related mortality in wild Atlantic salmon smolts at several locations along the coast," (Forseth et al. 2017).
In an attempt to address the impact of sea lice, the Norwegian government has recently introduced new management measures which specify the amount of sea lice that it is permissible to have on a farm. Vollset et al. (2018) explain this new 'traffic light system': "Recently the Norwegian government ratified a new regulatory framework, where environmental sustainability within independent production zones will be the governing principle for management decisions ("produksjonsomra˚ deforskriften", www. regjeringen.no). This proposal has recently been ratified and the system will be tested spring and autumn 2017, and officially implemented from October 2017. In short, the new regulatory framework divides the Norwegian coastline into thirteen independent production zones. Within each zone, an evaluation of the environmental impact of fish farming will determine whether the production volume of farmed fish should be changed every second year. Several environmental indicators will eventually be included in the evaluation, but at present, only effects of sea lice on wild fish have been found to be sufficiently studied to be used as a sustainability indicator. Within the management system referred to as "the traffic light system", three different impact categories are suggested: Green if 0–10% of the wild population dies due to sea lice, yellow if 10–30% of the population dies due to sea lice, and red if >30% of the population dies due to sea lice. If the traffic light comes out as green within a given zone, production volume may increase, if yellow production will be maintained at the current volume, whereas red would cause reduced biomass within the zone. These threshold levels have been based on scientific advice given in peer-reviewed articles."

In addition to government regulations to tackle the sea lice problem, the industry has also been proactive in seeking solutions and many avenues are being explored. One such idea is "A technological development in Norway that is part of an integrated salmon aquaculture process is near-shore floating containment systems. These floating systems are semi-closed and draw seawater from depth to provide temperature and oxygen control. The water is pumped creating a current for salmon to swim against which keeps them on the move and feeding. It is early days for these systems, but the expectation is that they can grow fish from 100 g to 1 kg more efficiently than in land-based systems while reducing risk from sea lice and exposure to harmful algae," (MAACFA 2018).

<u>Bacterial and viral diseases</u>

As is evident from the findings detailed in Q2b, there is a very low use of antibiotics in Norwegian aquaculture and bacterial diseases arising on salmon farms do not present a significant environmental threat to wild populations at present. The most recent (2016) annual fish health report published by the Norwegian Veterinary Institute reports that, "Aside from the salmon louse it is the viral diseases which have the greatest effect on fish health in Norwegian aquaculture. Pancreas disease (PD) remains the most important viral disease both economically and biologically. The number of affected farms was similar in 2016 to the previous year. The number of farms affected by infectious salmon anaemia (ISA) was also similar to the year before with the disease diagnosed on 12 farms, with a further 3 suspected cases," (Hjeltnes et al. 2017). A recent risk assessment of the environmental impacts of salmon farming in Norway found that: "Viral disease outbreaks (pancreas disease, infectious pancreatic necrosis, heart and skeletal muscle inflammation, and cardiomyopathy syndrome) in Norwegian salmon farming suggest extensive release of viruses in many areas. However, screening of wild salmonids revealed low to very low prevalence of the causal viruses," (Taranger et al. 2015).

Historically, "Norway experienced a serious ISA epidemic in the late 1980s and early 1990s which was controlled by depopulation and general zoosanitary measures imposed by the government and implemented in the industry. Norway has imposed the mandatory fallowing of sites (minimum two months), together with synchronised management areas with a minimum of one month of synchronised fallowing, regardless of disease status. Recent ISA cases have been restricted to the index case or a small group of adjacent farms before being brought under control by depopulation measures, suggesting that the overall control programme is efficient," (Pettersen et al. 2015).

"First described in Norway in 1989 pancreas disease (PD) has spread following two distinct introductions and epidemics caused by two different strains, SAV2 and SAV3. Neither strain has been described in wild fish, suggesting that both epidemics were largely or fully confined to farmed salmon" … "In 2006, the regional industry established the Hustadvika barrier (a 15–20 km zone with no farming activities) in mid-Norway, on the frontier between the endemic and non-endemic areas, with the purpose of preventing disease dissemination into the densely farmed areas further north in mid-Norway. In 2007, the government followed this up with a regulation requiring the depopulation of infected sites in the disease-free areas (i.e. north of the barrier) and alterations to management practices (e.g. diagnostic measures, transport restrictions and management areas)," (Pettersen et al. 2015).

"Several diseases that were once associated with severe losses are currently quite effectively controlled in many salmon-producing countries. The diseases that are being managed successfully include vibrosis (*Listonella anguillarum)*, cold-water vibrosis (*Allivibrio salmonicida*), furunculosis (*Aeromonas salmonicid*a), bacterial kidney disease (*Renibacterium salmoninarum*), and to some degree infectious pancreas necrosis (*Birnaviridae)* and infectious haematopoietic necrosis (*Rhabdoviridae)*. Heart and skeletal muscle inflammation, caused by piscine orthoreovirus, was first described in Norway in 1999 and has been recorded in approximately 150 salmon farms annually. Salmonid rickettsial septicaemia or piscirickettsiosis, caused by *Piscirickettsia salmonis*, is sporadic in Norway," (Pettersen et al. 2015).
In conclusion, while bacterial and viral diseases would appear to present little risk to wild populations, scientific review flags up major concerns over the impact of sea lice and the Norwegian Scientific Advisory Committee for Atlantic Salmon, which is appointed by the Norwegian Environment Agency, identified sea lice as the second largest threat (after escapes) to Norwegian wild salmon (NSACS 2017). Although many studies have been done on sea lice per se, it is difficult to quantify the impacts that they have on wild salmonids with presently available data and a precautionary approach is warranted. The situation has been summarised by Vollset et al. (2018) as follows, "Studies that aim to quantify the impact of salmon lice in the wild will be costly, but not conducting them could become even more costly. Although scientific consensus is that salmon lice are a risk to wild populations, studies on wild populations that accurately quantify the impact of salmon lice are still urgently needed. This might seem odd to a bystander, given the abundance of publications on the topic; however, most past studies were never intended to answer the questions now

being asked. In other words: We know enough to say that we should do something, but we know too little to know exactly how we should do it. Lack of knowledge will tend to lead to an exaggerated precautionary approach, which can have large economic consequences for the industry." Although there is no robust evidence which clearly demonstrates the extent of impact that sea lice from Atlantic salmon farms have upon wild salmonids, there is a consensus between the Norwegian government and scientists that this issue presents a high environmental concern – especially given the scale and intensity of the industry.

Score -2

2g. is the species in this assessment subject to pathogenic* disease outbreaks that threaten the viability of the whole country/region?

***unicellular organisms i.e. bacteria (e.g. Motile Aeromonad Septicemia (M. A. S.)), viruses (e.g. Infectious Salmon Anemia (I.S.A.), fungi, myxosporeans (emaciation disease in Sea Bream) or pathogens specific to the Unit of Assessment.**

Score	Answer Options	Examples and Answer Descriptors
1	No, aquaculture activity occurs where pathogenic disease outbreaks are not observed/recorded in wild species. Not applicable due to completely closed system.	Data indicates that there is either no transmission of pathogens from farmed to wild species Data shows that wild species are not affected by pathogen transfer Disease transmission may occur but data shows that the disease level is not amplified above background levels Disease transmission may occur but do not cause physiological impacts to wild species
0	Disease outbreaks can/do occur but do not threaten regional level operations	Pathogens effect wild species but do not result in mortality Pathogens effect wild species resulting in mortality but not a population level
-1	Yes, pathogenic disease outbreaks occur that threaten the viability of the whole region Unknown due to data deficiency	Disease transmission occurs resulting in negative impacts on species population size or its ability to recover Disease transmission occurs and effects population-level species listed on any conservation list as vulnerable, threated, endangered (IUCN red list, OSPAR etc.)

Norway's interactive and GIS-based website BarentsWatch site (https://www.barentswatch.no/en/) provides detailed information on fish health from the salmon farming sector and this includes data on fish diseases, which is updated from the Veterinærinstituttet (the Norwegian Veterinary Institute) every four hours. Overall, this data demonstrates that viral diseases and sea lice parasites present the greatest threat in terms of potential ecological impact.

Sea Lice Parasites

“The effects of sea lice on the marine survival of wild salmonids are widely debated. In Norway this debate has reached a crescendo as the Norwegian government has recently ratified a management system where the growth in the salmonid aquaculture industry will be conditional on regional estimated impact of salmon lice on wild fish. Sea lice have thus become the most prominent obstacle to the stated political aim of quintupling aquaculture production in Norway by 2050. Scientific documentation that salmon lice impact the marine survival of salmon is robust. However, it is also evident that marine survival of salmon is strongly impacted by other factors, and that the effect of salmon lice is most likely an integral part of these other mortality factors,” (Vollset et al. 2018).

“Salmon lice may reduce marine survival of wild Atlantic salmon in farmed areas along the Norwegian coast, especially in the southwestern and middle parts, but also in parts of northern Norway. Thus, the number of affected populations is high, and the geographical distribution was classified as regional to national,” (Forseth et al. 2017).

“Escaped farmed Atlantic salmon and salmon lice were the two anthropogenic impact factors identified as expanding threats to Atlantic salmon populations in Norway, which affect wild salmon populations to the extent that they may be critically endangered or lost, and which have a large likelihood of causing even further reductions and losses in the future. The main reason for the heavy impact by these factors is the size (1.3 million tons farmed salmon produced in 2015) and expected growth in the production of farmed salmonids. In 2015, there were 382 million farmed Atlantic salmon at nearly 600 farm localities along the coast. In comparison, the number of wild adult Atlantic salmon returning to Norway the same year was estimated at 522 000 individuals. Hence, the abundance of farmed Atlantic salmon was 732 times the abundance of wild Atlantic salmon. Indeed, the number of farmed Atlantic salmon in a single location typically exceeds the total abundance of adult wild Atlantic salmon in Norway. Although the proportion of farmed salmon that escape is low, between 0.04 and 0.16% in 2015, and their survival to adulthood is low, the sheer numbers of farmed fish result in high risk of genetic changes in many populations. Similarly, while the permitted level of salmon lice per fish in farms is strictly regulated, the large number of farmed fish results in a worst case daily release of more than 1 billion salmon lice larvae. Consequently, monitoring indicates moderate or high risk for lice-related mortality in wild Atlantic salmon smolts at several locations along the coast,” (Forseth et al. 2017).

In an attempt to address the impact of sea lice, the Norwegian government has recently introduced new management measures which specify the amount of sea lice that it is permissible to have on a farm. Vollset et al. (2018) explain this new ‘traffic light system’: “Recently the Norwegian government ratified a new regulatory framework, where environmental sustainability within independent production zones will be the governing principle for management decisions (“produksjonsomra˚ deforskriften”, www. regjeringen.no). This proposal has recently been ratified and the system will be tested spring and autumn 2017, and officially implemented from October 2017. In short, the new regulatory framework divides the Norwegian coastline into thirteen independent production zones. Within each zone, an evaluation of the environmental impact of fish farming will determine whether the production volume of farmed fish should be changed every second year. Several environmental indicators will eventually be included in the evaluation, but at present, only effects of sea lice on wild fish have been found to be sufficiently studied to be used as a sustainability indicator. Within the management system referred to as “the traffic light system”, three different impact categories are suggested: Green if 0–10% of the wild population dies due to sea lice, yellow if 10–30% of the population dies due to sea lice, and red if >30% of the population dies due to sea lice. If the traffic light comes out as green within a given zone, production volume may increase, if yellow production will be maintained at the current volume, whereas red would cause reduced biomass within the zone. These threshold levels have been based on scientific advice given in peer-reviewed articles.”

In addition to government regulations to tackle the sea lice problem, the industry has also been proactive in seeking solutions and many avenues are being explored. One such idea is “A technological development in Norway that is part of an integrated salmon aquaculture process is near-shore floating containment systems. These floating systems are semi-closed and draw seawater from depth to provide temperature and oxygen control. The water is pumped creating a current for salmon to swim against which keeps them on the move and feeding. It is early days for these systems, but the expectation is that they can grow fish from 100 g to 1 kg more efficiently than in land-based systems while reducing risk from sea lice and exposure to harmful algae,” (MAACFA 2018).

Bacterial and viral diseases

As is evident from the findings detailed in 2D, there is a very low use of antibiotics in Norwegian aquaculture and bacterial diseases arising on salmon farms do not present a significant environmental threat to wild populations at present. The most recent (2016) annual fish health report published by the Norwegian Veterinary Institute reports that, “Aside from the salmon louse it is the viral diseases which have the greatest effect on fish health in Norwegian aquaculture. Pancreas disease (PD) remains the most important viral disease both economically and biologically. The number of affected farms was similar in 2016 to the previous year. The number of farms affected by infectious salmon anaemia (ISA) was also similar to the year before with the disease diagnosed on 12 farms, with a further 3 suspected cases,” (Hjeltnes et al. 2017). A recent risk assessment of the environmental impacts of salmon farming in Norway found that: “Viral disease outbreaks (pancreas disease, infectious pancreatic necrosis, heart and skeletal muscle inflammation, and cardiomyopathy syndrome) in Norwegian salmon farming suggest extensive release of viruses in many areas. However, screening of wild salmonids revealed low to very low prevalence of the causal viruses,” (Taranger et al. 2015).

Historically, “Norway experienced a serious ISA epidemic in the late 1980s and early 1990s which was controlled by depopulation and general zoosanitary measures imposed by the government and implemented in the industry. Norway has imposed the mandatory fallowing of sites (minimum two months), together with synchronised management areas with a minimum of one month of synchronised fallowing, regardless of disease status. Recent ISA cases have been restricted to the index case or a small group of adjacent farms before being brought under control by depopulation measures, suggesting that the overall control programme is efficient,” (Pettersen et al. 2015).

“First described in Norway in 1989 pancreas disease (PD) has spread following two distinct introductions and epidemics caused by two different strains, SAV2 and SAV3. Neither strain has been described in wild fish, suggesting that both epidemics were largely or fully confined to farmed salmon" … "In 2006, the regional industry established the Hustadvika barrier (a 15–20 km zone with no farming activities) in mid-Norway, on the frontier between the endemic and non-endemic areas, with the purpose of preventing disease dissemination into the densely farmed areas further north in mid-Norway. In 2007, the government followed this up with a regulation requiring the depopulation of infected sites in the disease-free areas (i.e. north of the barrier) and alterations to management practices (e.g. diagnostic measures, transport restrictions and management areas)," (Pettersen et al. 2015).

"Several diseases that were once associated with severe losses are currently quite effectively controlled in many salmon-producing countries. The diseases that are being managed successfully include vibrosis (*Listonella anguillarum)*, cold-water vibrosis (*Allivibrio salmonicida*), furunculosis (*Aeromonas salmonicid*a), bacterial kidney disease (*Renibacterium salmoninarum*), and to some degree infectious pancreas necrosis (*Birnaviridae)* and infectious haematopoietic necrosis (*Rhabdoviridae)*. Heart and skeletal muscle inflammation, caused by piscine orthoreovirus, was first described in Norway in 1999 and has been recorded in approximately 150 salmon farms annually. Salmonid rickettsial septicaemia or piscirickettsiosis, caused by *Piscirickettsia salmonis*, is sporadic in Norway," (Pettersen et al. 2015).

In conclusion, while bacterial and viral diseases would appear to present little risk to wild populations, scientific review flags up major concerns over the impact of sea lice and the Norwegian Scientific Advisory Committee for Atlantic Salmon, which is appointed by the Norwegian Environment Agency, identified sea lice as the second largest threat (after escapes) to Norwegian wild salmon (NSACS 2017). Although many studies have been done on sea lice per se, it is difficult to quantify the impacts that they have on wild salmonids with presently available data and a precautionary approach is warranted. The situation has been summarised by Vollset et al. (2018) as follows, "Studies that aim to quantify the impact of salmon lice in the wild will be costly, but not conducting them could become even more costly. Although scientific consensus is that salmon lice are a risk to wild populations, studies on wild populations that accurately quantify the impact of salmon lice are still urgently needed. This might seem odd to a bystander, given the abundance of publications on the topic; however, most past studies were never intended to answer the questions now being asked. In other words: We know enough to say that we should do something, but we know too little to know exactly how we should do it. Lack of knowledge will tend to lead to an exaggerated precautionary approach, which can have large economic consequences for the industry." Although there is no robust evidence which clearly demonstrates the extent of impact that sea lice from Atlantic salmon farms have upon wild salmonids, there is a consensus between the Norwegian government and scientists that this issue presents a high environmental concern – especially given the scale and intensity of the industry. This results in a score of -2 for Q2F.

Score -2

2h. iI there a risk of escapes or introductions of exotic species from this type of production, and if so, would escape cause negative ecological effects?

Score	Answer Options	Examples and Answer Descriptors
1	There is no risk of escape	No connection to natural water bodies Tank based recirculation systems Static ponds with no water discharge and no flood risk Independent monitoring data shows that escapees are not present in the wild.
0	There is a potential escape risk but with limited environmental impact	There is evidence of escapes, but no alteration of wild species and their habitats Any system that uses Best Management Practices to prevent escapes which can be verified by audit AND independent data indicated escape numbers are low. Flow through systems Ponds with a moderate risk of vulnerability to flooding events Ponds with moderate exchange (e.g. 3–10% per day) or that drain externally at harvest Open systems with effective Best Management Practices for design, construction, and management of escape prevention
-1	Unknown escape risk Unknown environmental impact*	Open systems with Best Management Practices for design, construction, and management of escape prevention are in place but their efficacy cannot be demonstrated. *poor data collection and transparency Production systems vulnerable to large escape events or frequent trickle losses Monitoring data indicates escapees are frequently detected in the wild Ponds with high exchange > 10% per day
-2	There is an escape risk with evidence of negative ecological effects	Open systems (e.g., net pens, cages, ropes) vulnerable to escape, without effective Best Management Practices for design, construction and management of escape prevention Large escapes or frequent trickle losses have occurred in the last 10 years, and no corrective action has been taken, or corrective actions taken have not been adequate Ponds in flood prone areas Monitoring data indicates frequent occurrence of large numbers of escapees in the wild Negative ecological effects include competition for resources; displacement of wild species eggs/larvae; interbreeding and genetic dilution.

Due to the open nature of net pens, salmon are highly likely to escape from fish farms from time to time, particularly in bad weather events. According to the Norwegian Directorate of Fisheries (Fiskeridirektoratet), 132,000 salmon escaped from Norwegian fish farms in 2016 (Fiskeridirektoratet 2018). The Directorate administer a public hotline number (55 23 83 37/911 03 277) so that any marine emergencies, such as beached cetaceans, harmful jellyfish/algae, abnormal fish kills, fisheries crimes and farm escapes, can be promptly reported and acted upon by relevant agencies. The website of the Directorate contains follow-up reports complied after specific escape events, e.g. 'Recapture of farmed salmon after an escape from the locality Apalvikneset the Hardanger Fjord in June 2017' and 'Monitoring of rivers and extraction of escaped farmed salmon - measures following escapes from Rauma brood AS in 2017'.

Although there is a strong regulatory framework in place to mitigate the impact of escaped farmed fish in Norway, the sheer scale of the industry means that the number of individual fish that escape is high which in turn means that the risk of genetic introgression is also high. A risk assessment of the environmental impacts of salmon farming in Norway found that: "21 of the 34 wild salmon populations investigated indicated moderate-to-high risk for genetic introgression from farmed escaped salmon," (Taranger et al. 2015). The Norwegian Scientific Advisory Committee for Atlantic Salmon, which is appointed by the Norwegian Environment Agency, identified escaped farmed salmon as the greatest threat to Norwegian wild salmon (and sea lice as the second largest threat) (NSACS 2017).

The following explains the genetic impact of escaped farmed salmon on their wild counterparts in more detail: "Farmed salmon represent a limited number of wild source populations that have been exposed to ≥12 generations of domestication. Consequently, farmed and wild salmon differ in many traits including molecular-genetic polymorphisms, growth, morphology, life history, behaviour, physiology and gene transcription. Field experiments have demonstrated that the offspring of farmed salmon display lower lifetime fitness in the wild than wild salmon and that following introgression, there is a reduced production of genetically wild salmon and, potentially, of total salmon production. It is a formidable task to estimate introgression of farmed salmon in wild populations where they are not exotic. New methods have revealed introgression in half of ~150 Norwegian populations, with point estimates as high as 47%, and an unweighted average of 6.4% across 109 populations," (Glover et al. 2017).

Score -2

2i. In general, does this type of production have direct negative impacts on local predatory species in the region?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	No	

0	Potential impacts, not including lethal control	Use of ADD's that may disturb species.
-1	Yes, predatory species are lethally controlled	
	Unknown due to data deficiency	
-2	Yes, predatory species that are listed as threatened, endangered or protected on any domestic or protected on any domestic or international list are lethally controlled	

Cage farms are no doubt an attractant to opportunistic predators. GSI's (2018) published data on wildlife interactions reflects minimal impacts but this data does not represent the entire industry nationwide, since it only includes information from the present GSI members. "The presence of farmed salmon in net pens at high densities is likely to attract a variety of marine mammals, seabirds, and fish. Norwegian regulations for the control of seals allow them to be killed if they damage fishing gear or farm infrastructure at sea when "reasonable efforts and other measures to avert damage" have failed. Although the regulation also requires immediate reporting, there are no data publicly available except for the four companies GSI. This indicates an average of 2.5 birds are killed per site per year, and 3 seals are killed per 100 sites per year (i.e., <30 across the industry),"… "Although the numbers may be higher on farms not associated with GSI, they are considered unlikely to affect the population status of the affected species," (MBA 2017).

The impacts that Atlantic salmon farms have upon their wild counterparts can also be considered as an impact upon wildlife; Skaala et al. (2014) comment that: "The rapid expansion of fish farming has most probably had detrimental impacts on the wild populations of salmonids. To counteract this development, conservation and management action plans have to be implemented. As an important first step, the dispersal of salmon lice from fish farms has to be curtailed."

Score -1

FISH WELFARE

3a. Are there practices in place to ensure animal welfare and humane slaughter for the unit of assessment?		
Score	**Answer Options**	**Examples and Answer Descriptors**

1	Yes there are practices to ensure animal welfare* and humane slaughter**	*Compromised animal welfare leads to physical damage, aggression and pre-harvest mortalities. Culture conditions that lead to physical deformities can compromise animal welfare and should be included in this question. This question only refers to the culture species. **Humane slaughter RSPCA definition: "An animal must be either killed instantly or rendered insensible to pain until death supervenes" (generally only applicable to electrical or mechanical stunning followed by bleeding *** Shellfish species
	Not applicable***	
0	Either provisions for animal welfare or humane slaughter are provided but not both	Provision included in regulations in the country or region assessment and/or in certification criteria
-1	No	
	Unknown due to data deficiency	

The most recent (2016) annual fish health report published by the Norwegian Veterinary Institute includes a chapter on fish welfare and states that, "Most researchers consider fish to be able to register sensory stimulation and can therefore experience feelings such as fear, pain and discomfort. Farmed fish are subject to the animal welfare act and have the same rights as other domestic animals to an environment which ensures good welfare throughout the whole life cycle." Additionally, the report describes the provisions in place to assure humane slaughter (Hjeltnes et al. 2017).

Score 1

REGULATION AND MANAGEMENT

4a. Is aquaculture production in this region integrated within strategic environmental planning		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Yes there is strategic environmental planning	e.g. spatial planning, river basin planning, strategic environmental assessment, cumulative capacity planning
0	Not applicable*	*Land based recirculation systems that are subject to terrestrial planning
-1	No strategic environmental planning	Refer to the MCS Strategic Environmental Planning 2016 spreadsheet
	Unknown due to data deficiency	

As noted, concerns over the industry's sea lice problems has prompted a very recent overhaul of regulations for the sector and a new 'traffic light' system was put in place in 2017 which regulates capacity using sea lice numbers as an indicator. This came about due to the Norwegian Ministry of Trade, Industries and Fisheries identifying, in 2015, that: "With the current production technology (with net-pen sea cages), all salmon farming sites in a given area influence each other. Even if each individual site, in isolation, operates within acceptable limits, the overall environmental impact of several farms in the area could exceeded the carrying capacity of the area," (NMTIF 2015). Undercurrent News report that the new system: "Could potentially allow the Norwegian salmon farming industry an annual volume growth of 3%, but that's based on every producer being able to keep average sea lice levels below a limit of 0.2 per fish," (UCN 2017).

A general overview of the regulatory framework for Norwegian aquaculture, including strategic environmental planning, is covered in the following excerpt from a study by the New Zealand government which compared the international regulatory objectives, statutory regulations and best management practices for marine finfish farming in different countries. "Finfish farming in Norway is regulated by the Aquaculture Act (2005) (Norway), which aims to *"to promote the profitability and competitiveness of the aquaculture industry within the framework of a sustainable development and contribute to the creation of value on the coast."* The Aquaculture Act (2005) (Norway) focuses on the growth and innovation of the aquaculture industry, simplification of the approval process, protection of the environment, and consideration of other users of the coastal zone. New aquaculture applications are made to the Directorate of the Regional Fisheries Office, which, upon approval, sends the application out to various other regional authorities for approval. An Environmental Impacts Assessment (EIA) is required prior to the approval of new large farms, and compliance with BMP tends to be regulatory. Several regulations govern the operation of finfish farms. Aquaculture regulation in Norway is very focused on equipment specifications and net-pen construction and mooring systems are standardised in the Regulation on Technical Standards for

Equipment used in Farming Operations (NYTEK) (2004) (Norway). Environmental monitoring requirements are set at a local and a regional scale. Local environmental monitoring requirements are based on the level of impact and exploitation of the site, whereas, regional environmental monitoring requirements are set at the discretion of the local authority. Environmental monitoring in Norway is primarily based on the accumulation of organic matter. The level of accumulation on each farm is modelled through a 'Modelling On-growing Fish Farm Monitoring' (MOM) system. Farms that have the lowest level of impact are not required to conduct any environmental monitoring, whereas farms with the highest level of impact must have a comprehensive environmental assessment that is conducted by specialists in benthic fauna. Previously, farms that did not meet environmental standards were allowed to move the farm to a different location, but this is rarely the case now, instead they must either lower production levels or allow the site to fallow," (MPI 2013).

Although strategic environmental planning has been practiced by the industry for some time, specific regulations to take cumulative impacts into consideration have only just been implemented. This is a good initiative toward regulatory control, but it is too early to determine if these measures will address the current outstanding environmental concerns that are associated with salmon farming in the region. Due to these factors the score for Q4a is 0.

Score 0

4b. Is there a regulatory framework OR independent certification criteria for this species in the region that includes/addresses the following issues:

- **Farm Level Environmental Impact Assessment (EIA)**
- **Identification and protection of valuable habitats & species**
- **Use of land and water resources**
- **Use of chemicals including licensing**
- **Discharges including effluents and their impacts**
- **Bio-security & disease management**
- **Species introduction**

SCORE	ANSWER OPTIONS	EXAMPLES AND ANSWER DESCRIPTORS
2	There are regulations or standard criteria for all	List regulations or standard criteria which relate to each of the issues above in the description box of assessment form.
1	There are regulations or standard criteria for >5	
0	There are regulations or standard criteria for 3-5	
-1	There are regulations or standard criteria for <3	
	There is no information available	

-2	There are no regulations or standard criteria	

As noted , concerns over the industry's sea lice problems has prompted a very recent overhaul of regulations for the sector and a new 'traffic light' system was put in place in 2017 which regulates capacity using sea lice numbers as an indicator. This came about due to the Norwegian Ministry of Trade, Industries and Fisheries identifying, in 2015, that: "With the current production technology (with net-pen sea cages), all salmon farming sites in a given area influence each other. Even if each individual site, in isolation, operates within acceptable limits, the overall environmental impact of several farms in the area could exceeded the carrying capacity of the area," (NMTIF 2015). Undercurrent News report that the new system: "Could potentially allow the Norwegian salmon farming industry an annual volume growth of 3%, but that's based on every producer being able to keep average sea lice levels below a limit of 0.2 per fish," (UCN 2017).

A general overview of the regulatory framework for Norwegian aquaculture, including strategic environmental planning, is covered in the following excerpt from a study by the New Zealand government which compared the international regulatory objectives, statutory regulations and best management practices for marine finfish farming in different countries. "Finfish farming in Norway is regulated by the Aquaculture Act (2005) (Norway), which aims to *"to promote the profitability and competitiveness of the aquaculture industry within the framework of a sustainable development and contribute to the creation of value on the coast."* The Aquaculture Act (2005) (Norway) focuses on the growth and innovation of the aquaculture industry, simplification of the approval process, protection of the environment, and consideration of other users of the coastal zone. New aquaculture applications are made to the Directorate of the Regional Fisheries Office, which, upon approval, sends the application out to various other regional authorities for approval. An Environmental Impacts Assessment (EIA) is required prior to the approval of new large farms, and compliance with BMP tends to be regulatory. Several regulations govern the operation of finfish farms. Aquaculture regulation in Norway is very focused on equipment specifications and net-pen construction and mooring systems are standardised in the Regulation on Technical Standards for Equipment used in Farming Operations (NYTEK) (2004) (Norway). Environmental monitoring requirements are set at a local and a regional scale. Local environmental monitoring requirements are based on the level of impact and exploitation of the site, whereas, regional environmental monitoring requirements are set at the discretion of the local authority. Environmental monitoring in Norway is primarily based on the accumulation of organic matter. The level of accumulation on each farm is modelled through a 'Modelling On-growing Fish Farm Monitoring' (MOM) system. Farms that have the lowest level of impact are not required to conduct any environmental monitoring, whereas farms with the highest level of impact must have a comprehensive environmental assessment that is conducted by specialists in benthic fauna. Previously, farms that did not meet environmental standards were allowed to move the farm to a different location, but this is rarely the case now, instead they must either lower production levels or allow the site to fallow," (MPI 2013).

Although strategic environmental planning has been practiced by the industry for some time, specific regulations to take cumulative impacts into consideration have only just been implemented. This is a good initiative toward regulatory control, but it is too early to determine if these measures will address the current outstanding environmental concerns that are associated with salmon farming in the region.

Score 0

4C. IS THE REGULATORY FRAMEWORK OR INDEPENDENT CERTIFICATION CRITERIA FOR THE SPECIES IN THIS REGION EFFECTIVE IN MINIMISING NEGATIVE IMPACTS?		
Score	**Answer Options**	**Examples and Answer Descriptors**
1	Regulations or standard criteria are fully* effective	*None of the assessment questions have been scored negatively due to poor regulation
0	There is evidence indicating regulations or standard criteria are only partially** effective	**One or more of the assessment questions have been negatively scored due to poor regulation
-1	There is insufficient information to assess effectiveness***	***There may be regulations but there is no data to ascertain effectiveness, there is no public data/auditing reports
	There is evidence indicating regulations or standard criteria are ineffective****	****There are records of regulations or standard criteria being broken

"Norway has a high level of transparency related to the aquaculture industry, including timely salmon farming information available online, and a science council that reports annually on the state of the wild salmon populations and effects of salmon farming on wild salmon. The national government's objective is to increase production significantly and is providing financial support and licensing incentives to develop more environmentally sustainable technologies such as closed systems in fjords, open pens further offshore and land-based systems," (MAACFA 2018). Although the regulatory framework in Norway is robust, it can only be assessed as being partially effective in mitigating negative impacts due to the high concerns for environmental impact posed by escapes and sea lice.

Score 0

4D. ARE PRODUCERS OF THIS SPECIES IN THE REGION PRODUCING TO INDEPENDENTLY ON-SITE AUDITED, 3RD PARTY CERTIFICATION STANDARDS?		
Score	**Answer Options**	**Examples and Answer Descriptors**
2	Producers in this unit of assessment farm to an independent audited standard*	*See Appendix 3 for more details
1	Producers in this unit of assessment are working towards improvement via a credible Aquaculture Improvement Project (AIP)* or Fisheries Improvement Project (FIP) (for the feed component) which is operational and demonstrating improvements	* See description below
0	No certification scheme or AIP/FIP is available for the unit of assessment	
-1	There are certification schemes or AIP's/FIP's available for the unit of assessment but no efforts are being made to apply	

The International Institute for Sustainable Development recently produced a report titled 'State of Sustainability Initiatives Review: Standards and the Blue Economy' report (Potts et al. 2016) which states that Norway leads the global supply of certified aquaculture. This statement was based on the data that is illustrated in Figure 17. It can be assumed that the majority of this aquaculture produce is Atlantic salmon, since in 2016, this species accounted for 93% of total aquaculture production in Norway with the balance primarily being comprised of rainbow trout (FAO 2018).

Although the report also covers Global Aquaculture Alliance (GAA) Best Aquaculture Practices (BAP) in its scope and documents that 56% of BAP certified produce is farmed salmon (396,662 MT), Norway is not listed as one of the countries included in this quantity – neither are there presently any Norwegian certified facilities listed on the GAA BAP website, although a 2013 news article by SeafoodSource (2013) commented that Vikenco, owned by Salmar, had just become Europe's first salmon-processing plant to achieve BAP certification. By contrast, ASC's website includes a great many certified Norwegian salmon farms in their online database; although the number of certified farms is extensive, it is not possible to discern what percentage of the sector this reflects.

Whilst the percentage of currently-certified facilities in Norway is difficult to quantify, there is no doubt that the majority of producers are working towards producing greater volumes of certified produce. In 2013, Marine Harvest committed to becoming 100% ASC certified by 2020 (Bonsaksen 2014), as has Cermaq (Cermaq 2016). Both of these producers, along with Grieg Seafood and Nova Sea AS, are presently GSI members; the GSI website states that: "Members commit to prioritizing collaboration over competition when it comes to improving the sustainable performance of the industry. By working together, all GSI members have committed to reaching the Aquaculture Stewardship Council (ASC) Salmon Standard by 2020; improving biosecurity management, including an immediate focus on sea lice; and working with industry stakeholders to secure sustainable sources of salmon feed to meet growing demand," (GSI 2018). Interestingly, the ASC website notes that the first salmon farm to achieve ASC certification (in 2014) was owned by Norwegian company, Lerøy Seafood Group, and states: "As a member of the Global Salmon Initiative (GSI), Lerøy is committed to meeting the ASC Salmon Standard by 2020. There are 15 member companies in GSI which represents approximately 70 per cent of the global salmon industry," (ASC 2014) – however, Lerøy is not presently listed as a GSI member – although they do have certified farms listed in ASC's database. Another of Norway's largest aquaculture companies is SalMar, which claims to be the world's largest producer of organic salmon (SalMar 2018) and also lists the company's ASC certified facilities. In addition to the six companies listed above, the ASC database also includes numerous Norway Royal Salmon accredited farms.

Taken together, and in comparison to the company-by company production volumes illustrated in Figure 2, it is clear that the majority of producers are working towards third party certification. It may also be true that the majority of producers *presently* farm to an audited standard, but it is not possible to verify this as a percentage of the industry with the data that is publicly available at the present time, therefore the score for Q4d is 0.

Score 0

- ASC. 2017. Aquaculture Stewardship Council Salmon Standard, version 1.1 – April 2017. https://www.asc-aqua.org/wp-content/uploads/2017/07/ASC-Salmon-Standardv1.1.pdf
- ASC. 2014. First salmon farm achieves ASC certification - 09 January 2014 https://www.asc-aqua.org/news/latest-news/first-salmon-farm-achieves-asc-certification/
- Aaen S & Helgesen K. et al. 2015. Drug resistance in sea lice: a threat to salmonid aquaculture. Trends in Parasitology, Volume 31 , Issue 2 , 72 – 81 https://www.researchgate.net/publication/271707505_Drug_resistance_in_sea_lice_A_threat_to_salmonid_aquaculture
- Bonsaksen E. 2014. Challenges and Potential of the Aquaculture Stewardship Council Standard in Salmon Fish Farming Case: Marine Harvest Group - Norwegian University of Science and Technology Department of Industrial Economics and Technology Management https://brage.bibsys.no/xmlui/bitstream/handle/11250/235657/746143_FULLTEXT01.pdf?sequence=2
- Cardia F, Lovatelli A. 2015. Aquaculture operations in floating HDPE cages: a field handbook,
  FAO Fisheries and Aquaculture Technical Paper No. 593. Rome, FAO. 152 pp. http://www.fao.org/3/a-i4508e.pdf
- Cargill. 2016. Cargill Aqua Nutrition Sustainability Report 2016 https://www.cargill.com/doc/1432092555283/aquaculture-sustainability-report-2016.pdf
- Cermaq. 2016. Every certification is a promise – 25.02.16 https://www.cermaq.com/wps/wcm/connect/cermaq/cermaq/our-sustainable-choice/certifications/
- EC. 2016. European Commission Staff Working Document: On the application of the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) in relation to aquaculture - Brussels, 18.5.2016 SWD (2016) 178 final http://ec.europa.eu/environment/marine/pdf/SWD_2016_178.pdf
- FAO. 2018. Atlantic Salmon Feed Production http://www.fao.org/fishery/affris/species-profiles/atlantic-salmon/feed-production/en/
- FAO. 2018. Fishery and Aquaculture Statistics. Global aquaculture production 1950-2016 (FishstatJ). In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 2018. www.fao.org/fishery/statistics/software/fishstatj/en
- FAO. 2007-2018. National Aquaculture Legislation Overview. Norway. National Aquaculture Legislation Overview (NALO) Fact Sheets. Text by Skonhoft, A. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. Updated 14 December 2010. [Cited 28 April 2018]. http://www.fao.org/fishery/legalframework/nalo_norway/en

- FAO 2004-2018. Cultured Aquatic Species Information Programme. Salmo salar. Cultured Aquatic Species Information Programme. Text by Jones, M. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. Updated 1 January 2004. [Cited 29 January 2018]. http://www.fao.org/fishery/culturedspecies/Salmosalar/en
- FAO Globefish. 2018 – Global salmon prices come down as farmed harvests flood the market 21/03/2018 http://www.fao.org/in-action/globefish/market-reports/resource-detail/en/c/1110416/
- Top of Form .FeedNavigator. 2017. 'In-built premium in soy standards doing farmers a disservice' – Nutreco. 19 July 2017 - By Jane Byrne. https://www.feednavigator.com/Article/2017/07/20/Nutreco-sustainability-director-talks-responsible-sourcing
- FishSource. 2018. https://www.fishsource.org/aqua_page/11
- FishUpdate. 2018. Norway salmon exports hit record £6bn - Posted on January 8, 2018 by Jenny Hjul https://www.fishupdate.com/norway-salmon-exports-hit-record-6bn/
- Fiskeridirektoratet. 2018. Norwegian Directorate of Fisheries – Aquaculture https://www.fiskeridir.no/Akvakultur
- Forseth et al. 2017. The major threats to Atlantic salmon in Norway - ICES Journal of Marine Science (2017), 74(6), 1496–1513. doi:10.1093/icesjms/fsx020 https://academic.oup.com/icesjms/article-pdf/74/6/1496/19178628/fsx020.pdf
- GAA BAP. 2017. Global Aquaculture Alliance Best Aquaculture Practices BAP - Finfish and Crustacean Farm Standard (FCFS) Issue 2.4 – 23-May-2017, Aquaculture Facility Certification – Certification Standards, Guidelines https://bapcertification.org/Downloadables/pdf/standards/PI%20-%20Standard%20-%20Finfish%20and%20Crustacean%20Farms%20–%20Issue%202.4%20–%2023-May-2017.pdf
- GSI. 2018. Global Salmon Initiative - https://globalsalmoninitiative.org/en/
- GlobalGAP. 2017. Aquaculture Standard Version 5. Integrated Farm Assurance – All Farm Base: Control Points and Compliance Criteria. English Version 5.1. Valid from 1 July 2017, Obligatory from 1 October 2017. https://www.globalgap.org/uken/media-events/news/articles/New-GLOBALG.A.P.-Aquaculture-Standard-Version-5/
- GlobalGAP. 2016. Compound Feed Manufacturing Standard Version 2.2. Control Points and Compliance Criteria. English Version 2.2. Valid from 1 August 2016 https://www.globalgap.org/uken/for-producers/globalg.a.p./cfm/
- Glover KA, Solberg MF, McGinnity P, et al. 2017. Half a century of genetic interaction between farmed and wild Atlantic salmon: Status of knowledge and unanswered questions. Fish Fish. 2017; 00:1–38. https://onlinelibrary.wiley.com/doi/epdf/10.1111/faf.12214
- GreenPalm. 2018. http://www.greenpalm.org
- Hjeltnes B, Bornø G, Jansen MD, Haukaas A, Walde C (Eds.). 2017. The Health Situation in Norwegian Aquaculture 2016 - Norwegian Veterinary Institute 2017 https://www.google.com/search?client=safari&rls=en&q=www.vetinst.no:fiskehelserapporten/Fiskehelser+apporten&ie=UTF-8&oe=UTF-8

- Husa V, Kutti T, Ervik A, Sjøtun K, Hansen PK, Aure J. 2014. Regional impact from fin-fish farming in an intensive production area (Hardangerfjord, Norway), Marine Biology Research, 10:3, 241-252, DOI: 10.1080/17451000.2013.810754 https://www.tandfonline.com/doi/pdf/10.1080/17451000.2013.810754?needAccess=true
- Independent. 2017. Plagues of Parasitic Sea Lice Depleting World's Salmon Stocks - 19 September 2017 https://www.independent.co.uk/life-style/food-and-drink/news/salmon-sea-lice-plague-outbreak-fish-farms-global-stocks-depleted-acquaculture-industry-a7955326.html
- IFFO. 2017. Global Standard for Responsible Supply of Marine Ingredients: Requirements for certification. Version 2.0, July 2017https://www.iffors.com/sites/iffors/files/2017-07/FINAL%20V2.0%20Standard%20for%20publication0.pdf
- Jones PG, Hammell KL, Dohoo IR, Revie CW. 2012. Effectiveness of emamectin benzoate for treatment of Lepeophtheirus salmonis on farmed Atlantic salmon *Salmo salar* in the Bay of Fundy, Canada – Dis Aquat Org 102: 53–64, 2012 https://www.researchgate.net/publication/233840195_Effectiveness_of_emamectin_benzoate_for_treatment_of_Lepeophtheirus_salmonis_on_farmed_Atlantic_salmon_Salmo_salar_in_the_Bay_of_Fundy_Canada
- Lillicrap A, Macken A, Thomas K. 2015. Recommendations for the inclusion of targeted testing to improve the regulatory environmental risk assessment of veterinary medicines used in aquaculture, Environment International, Volume 85, December 2015, Pages 1-4, ISSN 0160-4120 https://www.researchgate.net/profile/Adam_Lillicrap/publication/281170952_Recommendations_for_the_inclusion_of_targeted_testing_to_improve_the_regulatory_environmental_risk_assessment_of_veterinary_medicines_used_in_aquaculture/links/5a72f5f2a6fdcc53fe136acb/Recommendations-for-the-inclusion-of-targeted-testing-to-improve-the-regulatory-environmental-risk-assessment-of-veterinary-medicines-used-in-aquaculture.pdf
- MAACFA. 2018. Minister of Agriculture's Advisory Council on Finfish Aquaculture (MAACFA) – British Columbia, Canada, January 31, 2018 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/fisheries-and-aquaculture/minister-or-agriculture-s-advisory-council-on-finfish-aquaculture/maacfa-2017-docs/minister_of_agricultures_advisory_council_on_finfish_aquaculture_final_report_and_appendices.pdf

- MBA. 2017. Monterey Bay Aquarium Seafood Watch Assessment of Atlantic salmon cultured in Marine Net Pens in Norway https://www.seafoodwatch.org/-/m/sfw/pdf/reports/s/mba_seafoodwatch_farmednorwaysalmon_report.pdf
- MPI. 2013. Comparison of the international regulations and best management practices for marine finfish farming - MPI Technical Paper No: 2013/47 -This publication is available on the Ministry for Primary Industries website at http://www.mpi.govt.nz/news-resources/publications.aspx

- Marine Harvest. 2017. Salmon Industry Handbook http://marineharvest.com/globalassets/investors/handbook/salmon-industry-handbook-2017.pdf
- NMTIF. 2017. Norwegian Ministry of Trade, Industries and Fisheries – Presentation: Aquaculture and Innovation in Norway – Yngve Torgersen, Director, Dept. of Fisheries and Aquaculture, Victoria BC Canada, 11.10.2017 https://bcsfa.sharepoint.com/:p:/r/_layouts/15/WopiFrame.aspx?docid=1831f51598fd94e5b87e9463c96b46ece&authkey=ATfX6yWT5N4TVvKyXr7QqOs&action=view
- NMTIF. 2015. Norwegian Ministry of Trade, Industries and Fisheries - Norwegian salmon farming: predictable and environmentally sustainable growth - Publication number: W-0010 E https://www.regjeringen.no/contentassets/e16872de15804dbb9a94261042f29245/havbruk_handout.pdf
- NORM/NORM-VET 2016. Usage of Antimicrobial Agents and Occurrence of Antimicrobial Resistance in Norway. Tromsø / Oslo 2017. ISSN:1502-2307 (print) / 1890-9965 (electronic) https://unn.no/Documents/Kompetansetjenester,%20-sentre%20og%20fagråd/NORM%20-%20Norsk%20overvåkingssystem%20for%20antibiotikaresistens%20hos%20mikrober/Rapprter/NORM%20NORM-VET%202016.pdf
- NSACS. 2017. Norwegian Scientific Advisory Committee for Atlantic Salmon annual report; Status of wild Atlantic salmon in Norway http://www.vitenskapsradet.no/Portals/vitenskapsradet/Pdf/Status%20of%20wild%20Atlantic%20salmon%20in%20Norway%202017.pdf
- Nutreco. 2014. Nutreco Supplier Code of Conduct – Version June 2014 https://www.skretting.com/globalassets/nutreco-corporate1/our-way/en-nutreco-supplier-code-of-conduct.pdf
- Péron G, Mittaine JF, Le Gallic B. 2010. Where do fishmeal and fish oil products come from? An analysis of the conversion ratios in the global fishmeal industry. Marine Policy 34 (2010) 815–820. https://www.academia.edu/20508533/WheredofishmealandfishoilproductscomefromAnanalysisoftheconversionratiosintheglobalfishmealindustry?auto=download
- Pettersen JM, Osmundsen T, Aunsmo A, Mardones FA, Rich KM. 2015. Controlling emerging infectious diseases in salmon aquaculture - December 2015 in issue 34 (3) of the *Scientific and Technical Review* https://pdfs.semanticscholar.org/f45c/c5ce95de8872f1f889a5b8df1bb494f4b148.pdf
- PhysOrg. 2018. Salmon farms are in crisis – here's how scientists are trying to save them - April 12, 2018 by Lyndsay Christie, The Conversation https://phys.org/news/2018-04-salmon-farms-crisis-scientists.html
- Potts J, Wilkings A, Lynch M, McFatridge S. 2016. - © 2016 (IISD) http://www.iisd.org/sites/default/files/publications/ssi-blue-economy-2016.pdf#page=56

- Price C, et al. 2015. Marine cage culture and the environment: effects on water quality and primary production. Aquaculture Environment Interactions, Vol. 6: 151–174, 2015 https://pdfs.semanticscholar.org/d846/cf37b439df88b6f26c2262861b6af0bd78ac.pdf
- ProTerra. 2014. ProTerra Standard: Social Responsibility and Environmental Sustainability. Version 3.0, December 28, 2014. https://www.cert-id.eu/downloads/ProTerraStandardV3-0EN-2016
- RSPO. 2013. The Roundtable on Sustainable Palm Oil (RSPO) scheme is the main industry standard for sustainable palm oil. Palm oil growers and millers can qualify as producers of Certified Sustainable Palm Oil (CSPO) through this Standard. https://rspo.org/key-documents/certification/rspo-principles-and-criteria
- RTRS. 2017. RTRS Standard Responsible Soy production V3.1 (The Round Table on Responsible Soy is a civil organization that promotes responsible production, processing and trading of soy on a global level) http://www.responsiblesoy.org/wpdm-package/rtrs-standard-responsible-soy-production-v3-1/?lang=en
- SalMar. 2018. Norwegian organic salmon- farmed, processed and sold by SalMar https://www.salmar.no/en/norwegian-organic-salmon-farmed-processed-and-sold-by-salmar/
- SalmonBusiness. 2017. These are the world's 20 largest salmon producers - News by Aslak Berge - 30 July 2017 http://salmonbusiness.com/these-are-the-worlds-20-largest-salmon-producers/
- SalmonFacts. 2018. Escaped Fish https://salmonfacts.com/salmon-and-environment/escaped-fish/
- SeafoodSource. 2013. Norway plant earns first BAP certification in Europe - January 18, 2013 https://www.seafoodsource.com/news/aquaculture/norway-plant-earns-first-bap-certification-in-europe
- Seafood Watch. 2014. Farmed Atlantic Salmon Fact Sheet April 2014 - http://storage.montereybayaquarium.org/cr/crseafoodwatch/content/media/farmedsalmonfactsheet.pdf
- Skaala Ø, Sjøtun K, Dahl E, Husa V, Bjørge A, Uiblein F. 2014. Interactions between salmon farming and the ecosystem: Lessons from the Hardangerfjord, western Norway, Marine Biology Research, 10:3, 199-202, DOI: 10.1080/17451000.2013.840730 https://www.tandfonline.com/doi/pdf/10.1080/17451000.2013.840730?needAccess=true
- Skretting. 2018. Is fish feed sustainable? Skretting's feed ingredients sourcing policyhttps://www.skretting.com/en-AU/faqs/is-fish-feed-sustainable/
- Skretting. 2016. Company sustainability report for 2016 https://www.skretting.com/es-CL/sustentabilidad/reportes/#
- Skretting. 2014. Feed to Food Quality and Safety – Nutrace global feed-to-food quality and safety system. http://www.skrettingguidelines.com/readimage.aspx?pubid=6bc30594-fa7d-44e8-95de-96a2dbbc08bc
- Star Tribune. 2015. Cargill acquisition means a large and growing presence in salmon feed Acquisition gives it an immediate, large presence in that market. **By** Mike

Hughlett, Star Tribune, November 7, 2015. http://www.startribune.com/cargill-acquisition-means-a-large-and-growing-presence-in-salmon-feed/342087141/

- Tacon AGJ, Metian M. 2008. Global overview on the use of fishmeal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquaculture 285 (2008) 146–158. http://www.sciencedirect.com/science/article/pii/S004484860800567X
- Taranger GL, Karlsen Ø, Bannister RJ, Glover KA, Husa V, Karlsbakk E, Kvamme BO, Boxaspen KK, Bjørn PA, Finstad B, Madhun AS, Morton HC, Svåsand T. 2015. Risk assessment of the environmental impact of Norwegian Atlantic salmon farming, *ICES Journal of Marine Science*, Volume 72, Issue 3, 1 March 2015, Pages 997-1021 https://doi.org/10.1093/icesjms/fsu132
- Thorstad EB, & Finstad B. 2018. Impacts of salmon lice emanating from salmon farms on wild Atlantic salmon and sea trout. NINA Report 1449: 1-22 https://www.salmon-trout.org/wp-content/uploads/2018/01/Thorstad-Finstad-2018-Impacts-of-salmon-lice-NINA-Report-1449-2.pdf
- UCN. 2018. What does the salmon net pen of the future look like? By Neil Ramsden April 12, 2018 https://www.undercurrentnews.com/2018/04/12/what-does-the-salmon-net-pen-of-the-future-look-like/
- UCN. 2017. Norwegian salmon regulation on schedule for October – Undercurrent News March 9, 2017 https://www.undercurrentnews.com/2017/03/09/norwegian-salmon-regulation-on-schedule-for-october/
- Vollset KW et al. 2018. Disentangling the role of sea lice on the marine survival of Atlantic salmon - ICES Journal of Marine Science (2018), 75(1), 50–60. doi:10.1093/icesjms/fsx104 https://academic.oup.com/icesjms/article/75/1/50/3867702
- WHO. 2017. Critically important antimicrobials for human medicine – 5th rev. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO. http://apps.who.int/iris/bitstream/handle/10665/255027/9789241512220-eng.pdf;jsessionid=84BA62E6AE531947F331FFC9F27D4940?sequence=1
- Ytrestøyl T, Synnøve T, Torbjørn Åsgård T. 2015. Utilisation of feed resources in production of Atlantic salmon (Salmo salar) in Norway - T. Ytrestøyl et al. / Aquaculture 448 (2015) 365–374 https://www.sciencedirect.com/science/article/pii/S0044848615300624