Monterey Bay Aquarium
Seafood Watch®

Atlantic Salmon

Salmo salar

Image © Monterey Bay Aquarium

Worldwide

(Representative farms from Canada, Denmark, and United States of America)

Land-based Closed Containment Recirculating Aquaculture Systems

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About Seafood Watch®

The Monterey Bay Aquarium Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the North American marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. The program's mission is to engage and empower consumers and businesses to purchase environmentally responsible seafood fished or farmed in ways that minimize their impact on the environment or are in a credible improvement project with the same goal.

Each sustainability recommendation is supported by a seafood report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's sustainability criteria to arrive at a recommendation of "Best Choice," "Good Alternative," or "Avoid." In producing the seafood reports, Seafood Watch utilizes research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch research analysts also communicate with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying seafood reports will be updated to reflect these changes. Both the detailed evaluation methodology and the scientific reports, are available on seafoodwatch.org.

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Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[1] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

The following **guiding principles** illustrate the qualities that aquaculture must possess to be considered sustainable by the Seafood Watch program:

Seafood Watch will:

- Support data transparency and therefore aquaculture producers or industries that make information and data on production practices and their impacts available to relevant stakeholders.
- Promote aquaculture production that minimizes or avoids the discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.
- Promote aquaculture production at locations, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats without unreasonably penalizing historic habitat damage.
- Promote aquaculture production that by design, management or regulation avoids the use and discharge of chemicals toxic to aquatic life, and/or effectively controls the frequency, risk of environmental impact and risk to human health of their use.
- Within the typically limited data availability, use understandable quantitative and relative indicators to recognize the global impacts of feed production and the efficiency of conversion of feed ingredients to farmed seafood.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild fish or shellfish populations through competition, habitat damage, genetic introgression, hybridization, spawning disruption, changes in trophic structure or other impacts associated with the escape of farmed fish or other unintentionally introduced species.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.
- Promote the use of eggs, larvae, or juvenile fish produced in hatcheries using domesticated broodstocks thereby avoiding the need for wild capture.

1 "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates.

- Recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving practices for some criteria may lead to more energy intensive production systems (e.g., promoting more energy intensive closed recirculation systems).

Once a score and rank has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choices/Green: Are well managed and caught or farmed in environmentally friendly ways.

Good Alternatives/Yellow: Buy, but be aware there are concerns with how they're caught or farmed.

Avoid/Red: Take a pass on these. These items are overfished or caught or farmed in ways that harm other marine life or the environment.

Final Seafood Recommendation

Atlantic salmon (*Salmo salar*)
Land-Based, Recirculating Aquaculture Systems
Worldwide (based on production in Canada, Denmark, United States of America)

Criterion	Score (0-10)			Rank			Critical?
	Canada	Denmark	USA	Canada	Denmark	USA	
C1 Data	8.06			GREEN	GREEN	GREEN	n/a
C2 Effluent	9.00			GREEN	GREEN	GREEN	NO
C3 Habitat	6.63	9.22	7.50	YELLOW	GREEN	GREEN	NO
C4 Chemicals	6.00			YELLOW	YELLOW	YELLOW	NO
C5 Feed	4.55			YELLOW	YELLOW	YELLOW	NO
C6 Escapes	10.00	5.00	6.00	GREEN	YELLOW	YELLOW	NO
C7 Disease	10.00	8.00	8.00	GREEN	GREEN	GREEN	NO
C8 Source	10.00			GREEN	GREEN	GREEN	n/a
9X Wildlife mortalities	0.00			GREEN	GREEN	GREEN	NO
10x Introduced species escape	0.00	-2.00	-2.00	GREEN	GREEN	GREEN	n/a
Total	67.29	58.82	57.10				
Final Score	8.02	7.35	7.14				

OVERALL RANKING	
Final Score	7.14-8.02
Initial rank	GREEN
Red Criteria	0
Intermediate Rank	GREEN
Critical Criteria?	NO

FINAL RANK
BEST CHOICE

Scoring note – scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact.

Summary
Atlantic salmon raised in land-based, closed containment recirculating aquaculture systems rank green in all criteria with the exception of farms based in Canada and the United States, which all rank yellow for Feed (C5), Escapes (C6), and Habitat (C3). The final scores range from 7.14 to 8.02 due to variability in the Escapes and Habitat scores and the final recommendation for all regions is a green 'Best Choice.'

Executive Summary

Aquaculture currently accounts for more than 99% of global Atlantic salmon production and net pen culture is the most prevalent production system. However, in an effort to address ongoing environmental concerns of Atlantic salmon net pen culture, closed containment aquaculture—a broad term used to define a range of culture systems that attempt to separate the farming environment and the natural environment—has been presented as a possible alternative. Although overall production volume is still low (i.e., less than 0.1% of global farmed salmon production), the first land-based, closed containment, recirculating aquaculture farms to raise Atlantic salmon are set to bring approximately 1500 metric tons of product to North American markets in 2014. This report serves as an assessment of the new production practices based on three operational farms: Atlantic Sapphire (Denmark), The Conservation Fund Freshwater Institute (United States), and the 'Namgis closed containment farm (Canada). All three farms are relatively young, but by the time this assessment was completed all three farms had accomplished at least one full production cycle. Due to the early stage of development of Atlantic salmon farming in closed containment systems, these three farms are considered to be representative of current practices and, therefore, applicable to new farms as they develop unless there is a demonstrable difference in production practices.

The quality of the data used in this report (C1) is relatively high – scoring 8.06 out of 10 – due to two main factors: 1) the concept and engineering of land-based closed containment systems inherently reduces or eliminates the risk of many of the assessment categories and 2) all farm managers were highly cooperative and able to share key information that was often third party verified and/or publicly available, allowing for a relatively thorough assessment of each criterion. The lowest data quality score received by any one category was 5 out of 10 and is most commonly attributed to the lack of long-term data available to assess the potential risk of that given category.

The recirculating aquaculture systems (RAS) employed by all three farms included in this assessment recycle approximately 95%–99% of the culture water by filtering the water through various water treatment components and recirculating it back to the land-based culture tanks. This allows for all waste materials (i.e., sludge and wastewater) to be collected and treated on-site prior to discharge and greatly reduces—if not eliminates— the amount of effluent released to the surrounding environment. Furthermore, all three farms require a permit to discharge aquaculture wastes, which are regulated and frequently monitored, leading to a final score of 9 out of 10 for the effluent criterion (C2).

The land-based RAS also allow for greater control of the farming environment whereby all materials that enter the facility can be treated for any potential sources of pathogens or parasites. This reduces the risk of pathogens on-site and, hence, reduces the risk of transmission to wild populations, resulting in a score of 8 out of 10 for the disease criterion (C7) for farms that maintain some connection to natural waterbodies (i.e., Atlantic Sapphire and The Freshwater Institute) and a score of 10 out of 10 for farms that are fully biosecure. The

chemical use criterion (C4) scored 6 out of 10 because the lowered risk of on-site diseases also reduces the need to apply chemicals or antibiotics, however, the use of chemicals is not fully eliminated. There is evidence that chemicals rated as 'highly important' to human health may be used infrequently and so a lower score is applied herein, but treatment of all wastes prior to discharge does helps minimize the risk of active chemicals being released into the surrounding environment.

Land-based RAS use solid wall tanks that are enclosed in fully secure buildings, eliminating the risk of predator and wildlife interactions and resulting in a score of 0 out of -10 in the "exceptional" factor 9X. This characteristic of the aquaculture system also greatly reduces the risk of escapes in the grow-out phase of fish culture. The 'Namgis facility has no connection to natural waterbodies (all liquid waste is released after disinfection through a dry infiltration basin where it filters through sand and gravel prior to seeping into the ground water), which suggests that there is no risk of escapes at this site and a score of 10 out of 10 was achieved. On the other hand, TCFFI and Atlantic Sapphire maintain some degree of connection with the external environment, meaning that they are not fully biosecure. The invasiveness risk of escapees at these sites was deemed moderate due to their potential negative ecological impact on wild Atlantic salmon populations. This latter consideration resulted in a score of 6 and 5 (out of 10) for TCFFI and Atlantic Sapphire, respectively, for the escape criterion (C6). Further to these considerations, a score of -2 out of -10 for the "exceptional" criterion 10X, escape of unintentionally introduced species, for TCFFI and Atlantic Sapphire, while 'Namgis received a score of 0 out of -10 for this factor.

The habitat criterion (C3) scores ranged from 6.17 to 7.88. Two of the three farms (TCFFI and Atlantic Sapphire) are sited on land previously used for agriculture or aquaculture, suggesting zero loss in habitat functionality. The 'Namgis site, on the other hand, required clearing approximately 7 500 m^2 of second growth coniferous forest, suggesting a low-moderate functional loss of habitat due to the siting the farm. The management effectiveness for habitat and farm siting, however, was quite different between regions. The regulatory and management effectiveness of farm siting in British Columbia, West Virginia and Denmark scored, 3.9, 2.50, and 7.65 (out of 10), respectively. The differences are namely due to variability in the regulatory regimes consideration of (or lack of) cumulative impacts, use of zoning, and application of pertinent ecological principles in farm siting.

The feed criterion (C5) scores ranged from 4.55 to 7.33 out of 10 because all three farms use different feed formulations. The scores are driven largely by differences in fishmeal and fish oil inclusion levels, which are reflected in moderate fish in: fish out (FIFO) values (1.24 -2.55. This means that between 1.24 to 2.55 tons of wild fish would need to be caught to provide the fish oil needed to produce 1 ton of farmed salmon and relatively low area use value per ton of fish production (5.04-9.91 hectares per ton of fish). In order to ensure that this report can be broadly applied with confidence to future and similar closed containment recirculating aquaculture systems farming Atlantic salmon, the lowest scoring feed formulation was applied in the overall quantitative evaluation of this assessment. However, each feed formulation is detailed and scored individually within the report so as to outline their degree of variation.

The source of stock criterion (C8) scored 10 out of 10 because domesticated broodstock is used throughout the global Atlantic salmon farming industry, which suggests that closed containment aquaculture facilities farming Atlantic salmon are independent of wild salmon populations for their source of juvenile fish.

Overall, the final scores vary from 7.14 to 8.02 due to variability in the habitat and escapes scores, but the final rank for all regions is green. Therefore, Atlantic salmon raised in land-based closed containment farms in Canada, Denmark and the United States is a 'Best Choice.' These three farms are considered to be representative of current practices and therefore the assessment and recommendation is applicable globally to additional farms as they develop unless there is a demonstrable difference in production practices

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Introduction

Scope of the analysis and ensuing recommendation

Species
Atlantic salmon (*Salmo salar*)

Geographic coverage
This assessment is based on three existing facilities, listed below, but is considered to be applicable globally to Atlantic salmon produced in other closed containment recirculating systems unless significantly different production characteristics are apparent.

- 'Namgis Closed Containment Farm, British Columbia, Canada
- The Conservation Fund Freshwater Institute (TCFFI), West Virginia, United States
- Atlantic Sapphire, Denmark

Production Methods
Land-based, closed containment recirculating aquaculture systems (RAS). The 'Namgis Closed Containment Farm and the Atlantic Sapphire farm grow Atlantic salmon in slightly saline conditions, while TCFFI facility is a freshwater system.

Species Overview
The native distribution of Atlantic salmon extends along both sides of the North Atlantic Ocean: from Russia to Portugal along the eastern side and from Labrador to Cape Cod on the western side. Native populations also exist throughout the North Atlantic islands including the United Kingdom, Iceland and Greenland. Atlantic salmon is an anadromous species whereby it spends up to four years feeding out at sea before returning to their rivers of origin to spawn in freshwater. Eggs hatch in freshwater and juveniles will remain for 2-5 years until they undergo smoltification and migrate downriver to sea.

Culture of Atlantic salmon began in the 19th century for the purpose of stock enhancement for anglers. It was not until the 1960s, however, when the first commercial net pen culture was developed in Norway to raise Atlantic salmon to marketable size. The success of early net pen culture operations spawned a rapid development of Atlantic salmon farming through the 1980s during which time Scotland, Ireland, the Faroe Islands, Canada, the USA, Chile and Australia all adopted net pen culture production practices (FAO 2014a). Today, aquaculture accounts for more than 99% of Atlantic salmon production globally (FAO 2012) and net pen culture is by far the predominant production system.

One driving factor for the emergence of recirculating aquaculture systems in the salmon farming industry has been concerns about the environmental impacts of net pen culture of salmon. Commonly cited impacts have included, the release of chemotheraputants (Ernst et al. 2001, Peacock et al. 2013), benthic impacts from the release and deposition of farm effluent (Weber 1997, Merceron et al. 2002, Bureau & Hua 2010), potential increase in disease

prevalence and the amplified risk of disease transfer to wild populations (Krkosek et al. 2005, Bjorn et al. 2001), negative ecological impacts of escaped farmed fish (McGinnity et al. 2003, Naylor et al. 2005), and the relatively high use of fish meal and fish oil in salmonid feeds (Naylor et al. 2005, Tacon & Metian 2008, Naylor et al. 2009). Significant efforts and research continue to be employed in an effort to adequately assess the environmental risks of net pen aquaculture and explore innovative alternatives. Closed containment aquaculture has been presented as one such plausible alternative.

Production Statistics

In 2012, global aquaculture production of Atlantic salmon exceeded 2 million metric tons (mt). The five top producing countries accounted for slightly more than 93% of global production and included Norway (1.23 million mt), Chile (386 607 mt), the United Kingdom (162 600 mt, the Faroe Islands (76 564 mt), and Canada (71 998 mt)(FAO 2013).

Using closed containment aquaculture production systems for Atlantic salmon farming is still a very new practice and is considered to be in the trial phase, but by the time this assessment was finished all three farms had completed at least one full production cycle and successfully brought product to market. As such, their production volumes—which cumulatively will be less than 1500 mt in 2014— are still small relative to the globalized net pen production systems.

Common and market names

In the general marketplace, this new product will likely be referred to as 'land-based farmed salmon,' 'closed containment farmed Atlantic salmon' or some combination of these words. The brand name planned for product from the 'Namgis Closed Containment project will be *Kuterra*™.

Product forms

Atlantic salmon raised in land-based closed containment systems from the three farms included in this assessment will come to market primarily as fresh filets or fresh whole fish.

Analysis

Scoring guide

- With the exception of the exceptional factors (9X and 10x), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here.
- The full data values and scoring calculations are available in Annex 1.

Considering the young age of the farms being assessed, it is the author's recommendation that this assessment be reviewed either when there is a significant change in production practices or after each farm has complete five production cycles.

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

- *Impact: poor data quality and availability limits the ability to assess and understand the impacts of aquaculture production. It also does not enable informed choices for seafood purchasers, nor enable businesses to be held accountable for their impacts.*
- *Sustainability unit: the ability to make a robust sustainability assessment*
- *Principle: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Criterion 1 Summary

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	10	10
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	10	10
Chemical use	Yes	5	5
Feed	Yes	7.5	7.5
Escapes, animal movements	Yes	10	10
Disease	Yes	5	5
Source of stock	Yes	10	10
Other – (e.g. GHG emissions)	No	Not relevant	n/a

Total		**72.5**

C1 Data Final Score	**8.06**	**GREEN**

Brief Summary

The quality of the data used in this report was relatively high due to two main factors: 1) the concept and engineering of land-based closed containment systems reduces or eliminates the risk of many of the assessment categories and 2) all farm managers were highly cooperative and able to share key information that was often third party verified and/or publicly available allowing for a relatively thorough assessment of each criterion. As such, a score of 8.06 out of 10 was achieved for Criterion 1.

Justification of Ranking

Due to the relatively short history of this production method, there is limited peer reviewed, independent data specific on land-based closed containment aquaculture systems used for raising Atlantic salmon. The practice of farming Atlantic salmon in recirculating aquaculture systems (RAS) is still in the trial/implementation phase. As a result, much of the specific quantitative data that were required to complete this report were provided directly from farm managers. The data provided in most cases were third-party verified and/or publicly available by the nature of the business partnership agreements for these farms. For example, The Conservation Fund Freshwater Institute (TCFFI) acts primarily as a research facility and hence they publish much of their data and findings either on their website or in peer-reviewed journals. This makes TCFFI's inclusion in this assessment somewhat novel given that their motivation is not first and foremost the commercial production and sale of seafood. They have previously sold a small portion of their harvest to the North American market, but more germane is that the RAS system employed at TCFFI has been modeled by many, including the 'Namgis Closed Containment project.

The quality of data may be questioned due to the lack of long-term data sets available specific to this production system. By the time this assessment was complete, all three farms had completed at least one full production cycle. Despite the short production practice history for all three farms, the author assessed the data quality to be relatively high because the inherent design of closed containment aquaculture has the potential to address many of the key criteria included in this assessment.

The production statistics category scored 10 out of 10 on the data quality because farm managers provided this information. The source of stock criterion received a score of 10 out of 10 for data quality, as it is the industrywide practice in Atlantic salmon farming to use domesticated broodstock. Finally, the predator and wildlife category scored 10 out of 10 because all production systems are based on land in fully biosecure buildings, which virtually eliminates any risk of interaction with wildlife.

The Effluent Criterion scored 7.5 out of 10 because monitoring and reporting for effluent impacts are thorough and complete and the design of the production system reduces the impact of this assessment category, but there remain minor data gaps in monitoring that have resulted due to the short history of production. The 'locations/habitats' category scored a 7.5 to reflect the lack of legislation that relates directly to closed containment aquaculture. The 'Feed' category also received a score of 7.5 out of 10 because it was necessary to aggregate and average some of the data provided directly from feed companies so that it was in the appropriate format to be applied to this assessment.

The chemical use and disease categories scored 5 out of 10 because the data provided were up-to-date and gave a reliable representation of current operations, but the short history of these data collections and operations do not provide the level of confidence required to reach the higher scores.

Overall, the data quality criterion scored 8.06 out of 10 and ranks green.

Criterion 2: Effluents

Impact, unit of sustainability and principle

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: aquaculture operations minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.*

Criterion 2 Summary

Effluent Evidence-based Assessment

C2 Effluent Final Score	**9.00**	**GREEN**

Brief Summary

The evidence-based assessment was used to evaluate the effluent criterion because all three farms employ RAS that recycle 95%–99% of the culture water, and this allows for all waste materials (i.e., sludge and wastewater) to be collected and treated on-site prior to discharge. Furthermore, all three farms require a permit to discharge aquaculture wastes, which are regulated and frequently monitored. Some post-treatment effluent is discharged to nearby waterbodies, but the risk of a negative impact is very low, leading to a final score of 9 out of 10 for the effluent criterion (C2).

Justification of Ranking

This factor aims to assess the direct ecological impact that aquaculture farm effluents have on the environment downstream of the farms (i.e., outside the immediate proximity of the farm or an allowable zone of effect—environmental impacts in the immediate farm area are considered in Criterion 3 – Habitat).

Each farm assessed was able to provide highly detailed descriptions of their land-based culture systems, effluent discharge practices, monitoring schedules and effluent discharge permits. Land-based closed containment aquaculture systems are designed to minimize the connection between the farm and surrounding environment by physically isolating the culture environment (i.e., water and fish) from the external environment. Recirculating aquaculture system (RAS) technology, which is employed by all three farms included in this assessment, allows approximately 95%–99% of the culture water to be treated and recirculated through the land-based culture tanks, which greatly minimizes the volume of effluent produced by farms (Summerfelt et al. 2013).

Despite this high level of water recirculation through the RAS systems, there remains some effluent waste that must be disposed of. The discharged effluent is separated and handled in two waste streams: sludge waste (i.e., solid wastes, including uneaten food and feces) and liquid waste (including backwash flow and wastewater). Sludge wastes are captured using drum filters and settling tanks, held and dewatered on-site and then, typically sold to composting companies or contract haulers for land application ('Namgis Closed Containment 2013, Summerfelt et al. 2013). Liquid wastes will go through mechanical filtration, biological filtration, oxygenation, UV disinfection and/or chlorination and dechlorination prior to being discharged into a nearby waterbody or a dry ground infiltration system (Summerfelt et al. 2013; Bram Rohaan, operations manager at Atlantic Sapphire, pers. comm.; 'Namgis Closed Containment 2013). Furthermore, all regions included in this assessment require a permit for the discharge of liquid waste and specific environmental monitoring is conducted on a regular basis[2,3,4] (weekly, biweekly, or monthly depending on the parameter). The ability for effluent to be captured, treated and monitored upon discharge in RAS closed containment systems suggests that effluent is of low environmental concern and a score of 10 out of 10 is feasible for the production system. However, because all farms maintain some degree of connection to natural waterbodies and can only provide short-term environmental monitoring results, a score of 9 out of 10 was applied to ensure a precautionary approach is taken.

[2] http://www.dep.wv.gov/wwe/permit/individual/pages/default.aspx#CAFO
[3] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/27_68_94
[4] http://www.mst.dk/NR/rdonlyres/A4C55451-A29B-4F97-A734-CD6026DEE3E2/0/DanishOrderonenvironmentalpermittingandconcurrentcasemanagementwithregardtofreshwaterfi.pdf

Criterion 3: Habitat

Impact, unit of sustainability and principle

- *Impact: Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats and to the critical "ecosystem services" they provide.*
- *Sustainability unit: The ability to maintain the critical ecosystem services relevant to the habitat type.*
- *Principle: aquaculture operations are located at sites, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats.*

Criterion 3 Summary

Habitat parameters	British Columbia, Canada	USA	Denmark
F3.1 Habitat conversion and function	8.00	10.00	10.00
F3.2a Content of habitat regulations	3.00	2.50	4.50
F3.2b Enforcement of habitat regulations	3.25	2.50	4.25
F3.2 Regulatory or management effectiveness score	3.9	2.50	7.65
C3 Habitat Final Score	**6.63**	**7.50**	**9.22**
Critical?	No	No	No

Brief Summary

Two of the three RAS farms included in this assessment are sited on land previously used for agriculture or aquaculture and hence their development resulted in no further loss of habitat function. The 'Namgis farm in B.C. did require clearing approximately 7 500m^2 of second growth coniferous forest during the siting of their facility, which was deemed to result in low-moderate functional loss of habitat. The regulatory and management effectiveness of farm sitings in British Columbia, West Virginia and Denmark scored, 3.9, 2.50, and 7.65 (out of 10), respectively. The differences are namely due to variability in the regulatory regimes' consideration of (or lack of) cumulative impacts, use of zoning, and application of pertinent ecological principles in farm siting. The final score for the habitat criterion for British Columbia, West Virginia, and Denmark are 6.63, 7.50 and 9.22, respectively.

Justification of Ranking

Factor 3.1. Habitat conversion and function

This factor aims to assess the direct ecological impact that aquaculture farms have on the area upon which they are sited. Land-based closed containment aquaculture systems can be sited in a number of different habitats, however it is common for them to be sited on lands that were previously used for farming or ranching. Such is the case for the sites used by Atlantic Sapphire and The Conservation Fund Freshwater Institute and hence it is not expected that the siting of a closed containment aquaculture facility would result in any loss of habitat functionality and a

score of 10 out of 10 was achieved for factor 3.1. Siting of the 'Namgis farm, on the other hand, required clearing up to 7 500m^2 of second growth coniferous forest, which is likely to result in minor-moderate impacts on habitat functionality. As such, this farm received a lower score (8 out of 10) in factor 3.1.

Factor 3.2. Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Scoring the effectiveness of management regimes responsible for land-based closed containment aquaculture is challenging for most regions because of the overlap in jurisdictional and departmental authority, which can make it unclear at times as to who is the responsible authority. An overview of the jurisdictional authorities and applicable regulations is provided here for the regions in which each of the three farms included in this assessment are sited: British Columbia, West Virginia, and Denmark.

British Columbia

Marine aquaculture in B.C. was classified as a fishery and therefore placed under the exclusive jurisdiction of the federal in February 2009. As such, in December 2010, regulatory authority of the finfish and shellfish aquaculture industries in B.C. was transferred from the Province of British Columbia to the federal department of Fisheries and Oceans Canada (DFO).

The primary federal legislations for the regulation of aquaculture siting are the Fisheries Act Regulations (1995, as amended 2012) and the Pacific Aquaculture Regulations (2010), while the applicable provincial regulations include the Fisheries Act (1996), the Aquaculture Regulation (2002), the Environmental Management Act (SCBC 2003 C.53), and the Land-Based Finfish Waste Control Regulation (1994, as amended 2004). As a result of significant changes in 2012 to the federal Canadian Environmental Assessment Act (now known as the Canadian Environmental Assessment Act 2012), aquaculture-type projects are no longer required to conduct environmental impact assessments under national legislation. The province of British Columbia, however, remains responsible for authorizing tenure of provincial crown land —a process that often triggers, at a minimum, an environmental screening of the site under the British Columbia Crown Land Use Operational Policy for Aquaculture[5]. Such screenings do not necessarily include full environmental impact assessments (EIA) nor do they address the cumulative impacts of farm siting beyond the scope of effluent management. Although there is no specific limit set on the future expansion of this industry in B.C., all new application will be subject to the above regulations.

In British Columbia, fisheries officers from the Conservation and Protection (C&P) unit within the British Columbia Aquaculture Regulatory Program are responsible for enforcing relevant regulations, monitoring aquaculture operations, and performing investigations in response to complaints (Fisheries and Oceans Canada 2013*a*). The C&P unit has staff stationed in regional offices throughout the Province and all contact information is available online[6].

[5] Retrieved from http://www.for.gov.bc.ca/land_tenures/documents/policies/aquaculture.pdf
[6] http://www.pac.dfo-mpo.gc.ca/locations-bureaux-eng.html

Overall, the regulatory and management effectiveness of farm siting in British Columbia scores 3.9 out of 10 due to the limited consideration of cumulative impacts and lack of regulation that speaks directly to closed containment aquaculture.

West Virginia

In West Virginia, closed containment aquaculture requires a state license for fish pond culture issued under the West Virginia Department of Natural Resources. The issuance of this license is most related to the commercial sale of wildlife and transfer of live animals and does not cover farm siting. Specifically, an EIA is not required nor does this license consider the cumulative impacts of multiple farms.

In addition to the state regulations, however, there are a number of applicable federal legislations that apply to aquaculture. The primary applicable national program is the NPDES, which is a national effort, under the Clean Water Act, to "establish requirements for stormwater discharges [...] so that the public health, existing water uses and aquatic biota are protected" (Environmental Protection Agency (EPA) 2009). Commercial aquaculture operations must be in compliance with Rule 5 and Rule 6 of this act, which speak specifically to construction sites and to industrial activity, respectively. These regulations, although thorough, consider only discharge and stormwater. They do not address potential habitat loss, energy usage, air quality or other factors that a complete EIA would include, but applications that fall under these regulations must provide detailed descriptions of the site, operations, monitoring plans, mitigation plans and response plans with respect to all activities that may impact stormwater.

Under the NPDES, aquaculture operations that produce more than 100,000 pounds of seafood must adhere to the Concentrated Aquatic Animal Production (CAAP) regulations (EPA 2006). The CAAP, along with Rule 5 and Rule 6 of the NPDES, have specific sections that set out required annual monitoring at discharge sites and states that all sites operating under these regulations are subject to inspection and enforcement (EPA 2006). Inspection typically occurs upon notice of potential violation, suggesting that a lack of inspection is actually a positive thing. There are local branches of the EPA throughout West Virginia and their staff work in collaboration with staff from West Virginia Department of Agriculture— Regulatory and Environmental Affairs Division to enforce applicable regulations. Although each of these offices are contactable[7], no details on aquaculture siting guidelines, current licenses or monitoring schedules could be found from either department suggesting a lack of transparency in regulatory enforcement.

Overall, the national regulations for discharges as applicable to the aquaculture industry suggest that there is a certain level of effective management to minimize direct habitat impacts from aquaculture facilities. The lack of regulations and legislation that speak directly to farm siting and habitat protection, however, results in a lower score for this factor of 2.5 out of 10.

[7] http://aquaculture.ext.wvu.edu/farming_fish/permits_inspections

Denmark

Land-based, recirculating aquaculture operations are regulated according to the new Statuary Order for Fish Farms nr. 130 of 8th of February 2012. Under this Statuary Order all large aquaculture facilities require an environmental inspection (as per the Environmental Protection Act (2001), Chapter 5) (Danish EPA, 2012a). As this Environmental Protection Act is written in Danish, the author of this report could not discern what is meant by 'large aquaculture facilities,' however, Atlantic Sapphire confirmed that their aquaculture licence required a full EIA. Further to the Environmental Protection Act, the Act Relative to Planning (2002) requires all counties in Denmark to produce a regional plan that sets guidelines for the use of water ways and lakes and waters, and also establishes aquaculture zones for a 12 year time period (FAO 2014b). Including aquaculture into broader land and coastal zone use planning implies that the cumulative impact of multiple farms is accounted for in siting regulations. Also applicable to land-based aquaculture habitat regulations are the Waste Water Permit Regulation (1999), which regulates the discharge or disposal of waste water into waterways, lakes or the ocean, and the Water Supply Act, which regulates water intake for land-based systems (Danish EPA 2012a).

The municipalities and the decentralised units of the EPA carry out inspection and enforcement of the habitat regulations, as per chapter 9 of the Environmental Protection Act. The EPA has established guidelines on environmental inspections that can be used by environmental authorities including minimum inspection frequencies for certain categories of industrial enterprises and livestock farms (Danish EPA 2012b). The environmental inspections are to be submitted by the municipalities to the EPA every year, at which point they are compiled and published on a public database (in Danish only)[8].

Overall, the strong regulations and zoning requirements for aquaculture siting and habitat protection result in a relatively high score for this factor of 7.65 out of 10.

Summary

The habitat impacts of siting closed containment farms are largely dependent on the site selected. For example, the siting of the 'Namgis farm resulted in the clearance of second growth coniferous forest, while the other two farms included in this assessment were sited on previously cultivated land. In addition, the management effectiveness for habitat and farm siting varies significantly between regions. The regulatory and management effectiveness of farm siting in British Columbia, West Virginia and Denmark scored, 3.9, 2.50, and 7.65 (out of 10), respectively. The differences are due namely to variability in the regulatory regimes consideration of (or lack of) cumulative impacts, use of zoning, and application of pertinent ecological principles in farm siting. The final score for the habitat criterion for British Columbia, West Virginia, and Denmark are 6.63, 7.50 and 9.22, respectively.

[8] Public database of environmental inspection: http://www2.mst.dk/databaser/MTilsynRapport/

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- *Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments.*
- *Principle: aquaculture operations by design, management or regulation avoids the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use.*

Criterion 4 Summary

Chemical Use parameters	Score	
C4 Chemical Use Score	**6.00**	
C4 Chemical Use Final Score	**6.00**	**YELLOW**
Critical?	NO	

Brief Summary

The chemical use criterion (C4) scored 6 out of 10 because the lowered risk of on-site diseases greatly reduces the need to apply chemicals or antibiotics, and the treatment of all wastes prior to discharge ensures that no active chemicals are released into the surrounding environment.

Justification of Ranking

By the nature of the closed containment systems employed, the facilities assessed here have a greater ability to control all materials that enter the facility and either exclude or treat any potential incoming sources of pathogens or parasites. This higher degree of biosecurity can reduce the amount and frequency of chemical applications on-site; however, it does not completely eliminate the need for chemical use. Yanong (2012) appropriately highlights that for some pathogens, biosecurity protocols alone "may not be an absolute elimination of risk of entry, but primarily an overall reduction of the number that do enter the facility" (p.2). Furthermore, Yanong explains that pathogens can become concentrated in RAS and that water quality fluctuations within RAS systems (such as temporary increases in ammonia or nitrate) may suppress the immune system of cultured fish making them susceptible to disease and could result in the need to apply chemicals. This point is an important consideration for the broader applicability of this report and is taken into account in the final scoring of this criterion, however, this is balanced with the reported production practices from the three active farms included in this assessment.

All farms covered by this assessment reported very low chemical use on-site. Common chemicals that are used on-site include cleaning and disinfecting compounds such as sodium hydroxide and Virkon® Aquatic (Syndel). The Conservation Fund Freshwater Institute was required to apply sodium chloride at one time during the 12-month grow-out trial due to an

external fungal infection (Summerfelt et al. 2013), while Atlantic Sapphire has applied Tribrissen, a feed-based antibiotic, on one occasion to control an on-site infection of *Furunculosis (a bacterial infection caused by Aeromonas salmonicida)*. Tribrissen contains a combination of antibacterial compounds called sulphadiazine and trimethroprim, both of which are listed as 'highly important' on the World Health Organization's list of critically important antimicrobials for human health. Use of chemicals that are rated highly important to human health typically trigger a lower score in the scoring methodology, however, all sites have strict discharge policies and treat all outgoing liquid wastes using UV filtration or Ozonation, while solid wastes are either composted (in high temperatures) or sent to local waste treatment facilities.

There is not yet sufficient data to show that chemical treatments are not going to be used over multiple production cycles due to the short history of production, but, to date, chemical treatments have been used, on average, less than once per production cycle. The production system has a demonstrably low need for chemical use and furthermore ensures that all discharges are treated and monitored upon release. As a result, a score of 6 out of 10 was achieved for the chemical criterion for these land-based, recirculating aquaculture systems.

Criterion 5: Feed

Impact, unit of sustainability and principle

- *Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.*
- *Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.*
- *Principle: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Criterion 5 Summary

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	2.55	3.63	
F5.1b Source fishery sustainability score		-6.00	
F5.1: Wild Fish Use		2.10	
F5.2a Protein IN	24.23		
F5.2b Protein OUT	20.00		
F5.2: Net Protein Gain or Loss (%)	6.61	8	
F5.3: Feed Footprint (hectares)	9.91	6	
C5 Feed Final Score		**4.55**	**YELLOW**
Critical?	NO		

Brief Summary

The feed criterion (C5) scores ranged from 4.55 to 7.33 because all three farms use different feed formulations and the relative environmental impacts of those feeds varied. The scores are driven largely by differences in fishmeal and fish oil inclusion levels, which are reflected in the moderate FIFO values of (1.24 to 2.55) and the relatively low area use value per ton of fish production (5.04-9.91 hectares per ton of fish). In order to ensure that this report can be applied broadly to future similar closed containment recirculating aquaculture systems farming Atlantic salmon with confidence, the lowest scoring feed formulation was applied in the overall quantitative evaluation of this assessment. However, each feed formulation is detailed and scored individually within the report so as to outline their degree of variation.

Justification of Ranking

All farms included in this assessment source their feeds from different feed supply companies, each of which has a different feed formulation. Each feed formulation is detailed and scored individually within the text below so as to outline their degree of variation, however, the lowest scoring feed formulation (i.e., Feed C) was applied to the final quantitative evaluation of this assessment (see Criterion 5 summary table) for two reasons: 1) to ensure the broader

applicability of this report despite inherent variability in feed formulation even within specific companies and 2) to ensure feed formulations and data are not attributable to specific feed companies in respect to requests to keep said data anonymous.

Factor 5.1. Wild Fish Use

Parameter	Feed Company "A"	Feed Company "B"	Feed Company "C"
Fishmeal inclusion level	8%	17%	25%
Percentage of Fishmeal from byproducts	0	17%	0%
Fishmeal yield (from wild fish)	22.5%[9]	22.5%[9]	22.5%[9]
Fish oil inclusion level	8%	12%	13%
Percentage of fish oil from byproducts	0	10%	0%
Fish oil yield (from wild fish)	5%[9]	9.5%[10]	5%[9]
Economic Feed Conversion ratio (FCR)	1.05	1.09	0.98
Calculated Values			
Fish In: Fish Out ratio for fishmeal	0.37	0.68	1.09
Fish In: Fish Out ratio for fish oil	1.68	1.24	2.55
Seafood Watch FIFO Score (0-10)	5.80	6.90	3.63

The notable differences in fishmeal and fish oil inclusion levels lead to great variability between the three assessed regions in this factor. A point of commonality is seen whereby the fish oil inclusion level is the primary driver behind the FIFO scores of all three feeds. Variability in the inclusion level of fish oil, byproduct inclusion rates and the higher fish oil yield value in Feed B, all contribute to the observed range in FI:FO values (1.24 – 2.55). The FI:FO value for feed company C (and applied to this assessment) is 2.55, which scores 3.63 out of 10.

A FI:FO of 2.55 means that 2.55 tons of wild fish would need to be caught and processed to supply sufficient fish oil to grow 1 ton of farmed salmon in land-based closed containment recirculating aquaculture systems.

Source fishery sustainability

Two of the three feed companies disclosed the source fisheries for their fishmeal and fish oil and these include sardine, anchovy, hake, menhaden and pollock. The sardines are sourced from a Mexican MSC certified fishery, while the other source fisheries are certified by the International Fishmeal and Fish Oil Organization. Although the MSC certified fishery would typically receive a sustainability adjustment score of -4 out of -10, this fishery only comprises a small proportion of the overall fishmeal and fish oil sources. The other source fisheries for fishmeal and fish oil listed by feed producers were not listed with sufficient information (particularly geographic location of fishery) to cross-reference their sustainability with FishSource and so a score of -6 out of -10 was applied.

[9] Default value provided in scoring tool; used when no alternative data is provided

[10] 9.5% is the average value, although the majority of the fish oil used is menhaden; avg yield is 12- 14%

After applying the sustainability score to the FIFO score, the final wild fish use score is 2.1 out of 10 indicating a potentially high use of wild fish in the production of Atlantic salmon in RAS (based on the worst case scenario of the assessed feeds).

Factor 5.2. Net Protein Gain or Loss

Parameter	Feed Company "A"	Feed Company "B"	Feed Company "C"
Protein content of feed	39%	39%	40%
Percentage of feed protein from non-edible sources	80 %	66.8%	29.7%
Percentage of protein from edible crop sources	4 %	22%	29.7%
Protein content of harvested farmed fish[11]	20%	20%	20%
Edible Yield of harvested farmed fish[10]	55%	55%	55%
Percentage of non-edible byproduct from harvested fish used for other food production	100%	100%	100%
Economic Feed Conversion Ration (eFCR)	1.05	1.09	0.98
Calculated Values			
Protein INPUT per ton of farmed fish	7.72 kg	11.44 kg	24.23 kg
Protein OUTPUT per ton of farmed fish	20 kg	20 kg	20 kg
Net protein gain	159%	74.8%	-17.5 %
Seafood Watch Score (0-10)	10	10	8

The percentage of feed protein from non-edible sources varies between the three feed formulations largely due to differing inclusion rates of land-animal byproduct such as poultry and feather meal. Despite the variability in calculated protein input per ton of farmed fish, Atlantic salmon has a relatively high protein content— approximately 20% based on trial grow outs at the TCFFI (Summerfelt et al. 2013)—and all facilities included in this assessment use 100% of their farmed fish byproducts in some type of subsequent food production stream (typically through compost). The relatively high use of non-edible ingredients in the farming of Atlantic salmon in closed containment RAS systems means that the production results in a minimum net edible protein gain of 74.8% and 159% for feeds B and A, respectively, resulting in a score of 10 out of 10 for this factor. Feed C was found to use a significantly lower amount of non-edible sources for protein and this system actually leads to a net protein loss of 17.5%, resulting in a score of 8 out of 10 for this factor. The lowest score (8 out 10) was applied to the final calculation of this criterion.

[11] Value derived from the TCFFI trial of Atlantic salmon grow out in RAS (Summerfelt et al., 2013)

Factor 5.3. Feed Footprint

Parameter	Feed Company "A"	Feed Company "B"	Feed Company "C"
Inclusion level of aquatic ingredients	16%	29 %	38%
Inclusion level of crop ingredients	29%	32 %	59%
Inclusion level of animal products	48%	34 %	0%
Economic Feed Conversion Ratio (eFCR)	1.05	1.09	0.98
Calculated Values			
Ocean area used per ton of farmed fish	4.37 hectares	8.22 hectares	9.69 hectares
Land area used per ton of farmed fish	0.67 hectares	0.54 hectares	0.22 hectares
Total area used per ton of farmed fish	5.03 hectares	8.76 hectares	9.91 hectares
Footprint score (0-10)	8	7	6

The calculated total area used to produce the feed ingredients required for one ton of farmed salmon ranges from 5.03 – 9.91 hectares across the three feeds, where the lower values correlate with a lower inclusion level of aquatic feed ingredients. These values suggest that the feeds used to raise Atlantic salmon in land-based, closed containment systems have a moderate to low feed footprint with scores ranging from 6-8 out of 10. The lowest score (6 out of 10) was applied in the final calculation.

Feed Criterion Summary

Parameter	Feed Company "A"	Feed Company "B"	Feed Company "C"
F5.1 Wild Fish Use	4.79	6.16	2.10
F5.2 Net Protein Gain or Loss	10.00	10.00	8.00
F5.3 Land Area Use	8.00	7.00	6.00
Final C5 Score	6.90	7.33	4.55

The final feed criterion scores range from 4.55 to 7.33 and bridge the green/yellow category delineation. This variation is largely driven by differences in fishmeal and fish oil inclusion levels, which are directly reflected in the FIFO scores and land area use scores. In order to ensure that this report can be broadly applied to future similar closed containment recirculating aquaculture systems farming Atlantic salmon with confidence, the lowest scoring feed formulation (i.e., Feed C) was applied in the overall quantitative evaluation of this assessment.

Summary

Applying the feed formulation from Feed C to this criterion a final score of 4.55 out of 10 (yellow rank) was awarded. This moderate feed score is the result of high degree of wild fish use which leads to a high Fish In: Fish Out ratio, and efficient protein conversion rate that results in a net protein gain, and a moderate land area being used in the production of the feed.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations*
- *Sustainability unit: affected ecosystems and/or associated wild populations*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Criterion 6 Summary

Escape parameters	'Namgis	TCFFI	Atlantic Sapphire
F6.1 Escape Risk Score	10.00	9.00	9.00
F6.1a Recapture and Mortality (%)	0.00	0.00	0.00
F6.1b Invasiveness	4.00	4.00	3.50
C3 Habitat Final Score	**10.00**	**6.00**	**5.00**
Critical?	No	No	No

Brief Summary

The 'Namgis facility has no connection to natural waterbodies as all liquid waste is released after disinfection through a dry infiltration basin where it filters through sand and gravel prior to seeping into the ground water, which suggests that there is no risk of escapes at this site. On the other hand, TCFFI and Atlantic Sapphire maintain some degree of connection with the external environment meaning that they are not fully biosecure. The invasiveness risk of escapees at these sites was deemed to be moderate due to their potential negative ecological impact on wild Atlantic salmon populations. Overall, scores of 10, 6 and 5 (out of 10) were achieved by 'Namgis, TCFFI and Atlantic Sapphire, respectively, for the escapes criterion (C6).

Justification of Ranking

Factor 6.1a. Escape risk

The risk of fish escaping from land-based closed containment aquaculture systems during the grow-out phase is of very low concern because the solid wall tanks create a physical barrier between the cultured fish and surrounding environment. The solid wall culture tanks used in land-based closed containment systems do require inflow ports, drains and overflows that allow for water exchange and recirculation (Summerfelt et al. 2013), meaning that they may be vulnerable to escape risk depending on how liquid discharge from drains and overflows is handled.

Both Atlantic Sapphire and TCFFI farms maintain some connection to natural water bodies (either streams or fjords) to allow for the discharge of liquid wastes, meaning that they do not meet the definition of fully biosecure. There are, however, a series of secondary capture measures such as filters and exclusion pits with appropriately sized screens in place (Summerfelt et al., 2013, Bram Rohaan, pers. comm.), which together greatly reduce any potential for escapes. As a result, a score of 8 out of 10 is awarded for this factor for farms that maintain a connection to natural waterbodies.

The 'Namgis Closed Containment farm, on the other hand, is considered to be fully biosecure as there is no connection to natural waterbodies. All liquid waste is released after disinfection through a dry infiltration basin where it filters through sand and gravel prior to seeping into the ground water. This system makes it physically impossible for any fish to escape from the system and hence a score of 10 out of 10 was achieved for this factor.

It was not possible to assess the efficacy of recapture or direct mortality of escapes from any of the sites because no escape events have occurred at any of the facilities included in this assessment. As such, no recapture or mortality adjustment score was applied.

Factor 6.1b. Invasiveness

In the Seafood Watch Criteria, the invasiveness score assesses the likelihood of ecological disturbance from escapes based on 1) their native/non-native status and/or their domestication and 2) their ecological characteristics. Scoring of this factor is obviously dependent on the geographic location of the farm as some are located within the native distribution of Atlantic salmon (e.g., Atlantic Sapphire) while others are not (e.g., 'Namgis Closed Containment project, TCFFI). For this reason, and in an effort to ensure broader applicability of this assessment, the scoring of this factor was separated to reflect both possible scenarios.

<u>Farmed species is native to the region (Denmark)</u>

As a result of ongoing domestication of the species (i.e., more than four generations) and concerns of the state of wild Atlantic salmon populations (World Wildlife Foundation 2001), the invasiveness of escapes is of greater concern throughout the native distribution of Atlantic salmon. The ecological impact of escapes on wild species would be significant as the escapes may act as additional competition for food and habitat (particularly if juveniles), act as additional predation pressure, and compete with native populations for breeding partners (Thorstad et al. 2008, Fisheries and Oceans Canada 2013b). The invasiveness of potential escapes received an intermediate score of 3.5.

<u>Farmed species is non-native to the region (British Columbia and West Virginia)</u>

Both 'Namgis Closed Containment, located in British Columbia, and TCFFI, located in West Virginia, are situated in areas where Atlantic salmon are not native to the region, but the history of Atlantic salmon farming in these two regions is starkly different. In B.C., open net-pen Atlantic salmon farming has been ongoing for over 30 years. Ongoing escapes from open-net pen Atlantic salmon farms have meant that the farmed stock is present in B.C. wild stock,

however, the limited number of observations of escapes successfully spawning in the wild[12] suggest that it is not likely that the species would establish viable populations. Meanwhile, in West Virginia no such salmon farming industry exists and Atlantic salmon are not present in the region. The ecosystem impact of ongoing escapes of non-native species could lead, to some extent, to increased competition of food and additional predation pressure on wild native populations (Piccolo & Orlikowska 2012). Overall, this results in an intermediate invasiveness score of 5.5 in circumstances where farms are raising non-native species.

By combining the two factors of this criterion in the risk matrix outlined in the Seafood Watch Criteria we find that the fully biosecure facility at 'Namgis negates the risk of potential invasiveness and a score of 10 out of 10 is awarded for the escapes criterion. For TCFFI and Atlantic Sapphire, the very low risk of escapes reduces the risk of potential invasiveness and an overall score of 6 and 5 were awarded for this criterion, respectively.

[12] Volpe et al. 2000 reported successful natural spawning of Atlantic salmon in the Tsitika River on Vancouver Island, B.C. in 1997 and 1998. Furthermore, three river systems in B.C. were reported to be supporting wild-spawned juvenile Atlantic salmon (Volpe et al. 2001). Further evidence and/or observations of this nature have not been made.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

- *Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body.*
- *Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Criterion 7 Summary

Pathogen and parasite Parameters	'Namgis	TCFFI	Atlantic Sapphire
C7 Biosecurity	**10.00**	**8.00**	**10.00**
C7 Disease; pathogen and parasite Final Score	**10.00**	**8.00**	**10.00**
	NO	**NO**	**NO**

Brief Summary

The land-based RAS allows for greater control of the farming environment whereby all materials that enter the facility can either be treated for any potential sources of pathogens or parasites. This reduces the risk of pathogen on-site and, furthermore, appropriate protocols are in place to treat any discharges, which minimizes the risk of disease transmission to wild populations. Overall, the potential for RAS systems to amplify disease and increase the risk transmission to wild populations was considered to be low, resulting in a score of 8 out of 10 for the disease criterion (C7).

Justification of Ranking

Closed containment, recirculating aquaculture systems inherently reduce the risk of pathogen and parasite disease transfer to wild stocks as they: 1) employ high biosecurity protocols by controlling all materials that enter the facility and either exclude or treat any potential sources of pathogens or parasites; 2) minimize the amount of liquid waste discharged by the facility to the surrounding environment; and 3) treat all discharged liquid wastes. However, as mentioned in the summary of Criterion 4, these measures do not completely eliminate the risk of pathogens in closed containment systems and RAS may actually amplify pathogens on-site due to the recirculatory nature of the facilities (Yanong 2012).

Of the farms included in this assessment, two individual farms reported one single disease event each: an infection of *Furunculosis* in 2012 at Atlantic Sapphire (Bram Rohaan, pers. comm.) and an external fungal infection at the Freshwater Institute in 2012 (Summerfelt et al. 2013). For both occurrences, the disease rate is classified as low because the disease was present in less than 5% of the stock for less than 5% of time. This low rate of onsite disease in combination with the minimal discharge released by closed containment recirculating aquaculture systems raising Atlantic salmon suggests that the farms are highly unlikely to amplify pathogen rates in natural populations above background levels. As previously noted,

Atlantic Sapphire and TCFFI do maintain some connection to natural populations and, hence, are not fully biosecure; however, all wastes are treated prior to discharge. As such, this criterion scored 8 out of 10 for these two farms due to the low concern of pathogen amplification.

The ‘Namgis closed containment farm does not actually discharge directly into a waterbody and is considered fully biosecure as all treated discharge is released into the ground water via a dry ground infiltration basin and there is no connection to wild fish populations. Expert advisors to the ‘Namgis project believe that pathogen transfer via ground water is near impossible, but monitoring and testing by a third party environmental assessor is in place nonetheless (‘Namgis Closed Containment 2013). The biosecurity level at the ‘Namgis closed containment farm is robust enough to warrant a score of 10 out of 10 for this criterion.

Criterion 8: Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for on-growing to harvest size in farms*
- *Sustainability unit: wild fish populations*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture*

Criterion 8 Summary

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	100	
C8 Source of stock Final Score	**10.00**	**GREEN**

Brief Summary

The source of stock criterion (C8) scored 10 out of 10 because domesticated broodstock is used throughout the global Atlantic salmon farming industry; this demonstrates that closed containment aquaculture facilities farming Atlantic salmon are independent of wild salmon populations for their source of juvenile fish.

Justification of Ranking

Global Atlantic salmon culture began in the 19th century for stocking purposes and commercial net pen culture has been carried out for over fifty years. The long-standing history of culturing Atlantic salmon has led to widespread domestication of hatchery-reared broodstock that is used industrywide, suggesting that closed containment aquaculture facilities farming Atlantic salmon are independent of wild salmon populations for their source of juvenile fish. This criterion merits a score of 10 out 10 for this reason.

Criterion 9X: Wildlife and predator mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife.

This is an "exceptional" factor that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Factor 9x Summary

Wildlife and predator mortality parameters	Score	
F9X Wildlife and predator mortality Final Score	**0.00**	**GREEN**
Critical?	NO	

Justification of Ranking

The land-based, closed containment systems included in this assessment operate in fully enclosed and secure buildings, which completely eliminate the potential for interactions with predators and wildlife. As such, this exceptional factor is not applicable to this production and achieved a score of 0 out of -10 as there is no impact.

Criterion 10x: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species other than the principle farmed species unintentionally transported during live animal shipments.

This is an "exceptional criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score.

Factor 10x Summary

Atlantic Sapphire and TCFFI

Escape of unintentionally introduced species parameters	Score	
F10xa International or trans-waterbody live animal shipments (%)	0.00	
F10xb Biosecurity of source/destination	8.00	
C6 Escape of unintentionally introduced species Final Score	**-2.00**	**GREEN**

'Namgis Closed Containment

Escape of unintentionally introduced species parameters	Score	
F10xa International or trans-waterbody live animal shipments (%)	0.00	
F10xb Biosecurity of source/destination	10.00	
C6 Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Brief Summary

The land-based, closed containment Atlantic salmon farming industry remains reliant, to some extent, on the international shipment of live salmon eggs. In this transfer, however, both the source farm and destination farm are typically land-based, closed containment facilities and are either fully biosecure (such as the 'Namgis facility) or have low biosecurity risks due to extensive biosecurity protocols, which significantly reduces the risk of escaped (unintentionally introduced) species. As such, a score of 0.00 (out of -10.00) was awarded to the 'Namgis farm (for having a fully biosecure destination facility) and a score of -2.00 (out of -10.00) was awarded for both TCFFI and Atlantic Sapphire farms.

Justification of Ranking

Factor 10xa International or trans-waterbody live animal shipments

At the time of writing, both TCFFI and Atlantic Sapphire were dependent on international shipments of live salmon eggs for their production. The 'Namgis closed containment project has been sourcing from two British Columbia-based hatcheries, but the inconsistent supply of eggs from these hatcheries means that they are equally as likely to source salmon eggs from further afield (*e.g.* Eastern Canada or the United States) for future production. The ongoing dependency of land-based, closed containment Atlantic salmon farms on the international or trans-waterbody shipments of live animals results in a score of 0 out of 10 for this factor.

Factor 10xb Biosecurity of source/destination

Typical hatcheries and the Atlantic Sapphire and TCFFI farms maintaining some connection to natural waterbodies suggests that they are not fully biosecure, however the land-based closed containment nature of both the hatchery and grow-out facilities allows for appropriate protocols and mechanisms to be in place to treat both incoming and outflowing water. As a result, the biosecurity risk for the source farm and the destination of animal movements scored 8 out of 10.

The 'Namgis closed containment farm does not actually discharge directly into a waterbody, but treated discharge is released into the ground water via a dry ground infiltration basin. This means that the farm is fully biosecure. As such, a score of 10 out of 10 was awarded for the biosecurity of the destination farm in this case.

Overall, there exists a risk of escaped (unintentionally introduced) species in land-based closed containment Atlantic salmon farms due to the ongoing dependence on internal and trans-waterbody animal shipments for eggs, however, the nature of the production system greatly reduces this risk and a score of -2 and 0 was applied to farms that maintain some connection to natural waterbodies and to farms that do not, respectively.

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Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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Data points and all scoring calculations

This is a condensed version of the criteria and scoring sheet to provide access to all data points and calculations. See the Seafood Watch Aquaculture Criteria document for a full explanation of the criteria, calculations and scores. Yellow cells represent data entry points.

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	10	10
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	10	10
Chemical use	Yes	5	5
Feed	Yes	7.5	7.5
Escapes, animal movements	Yes	10	10
Disease	Yes	5	5
Source of stock	Yes	10	10
Other – (e.g., GHG emissions)	no	Not Relevant	n/a
Total			**72.5**

C1 Data Final Score	8.06	GREEN

Criterion 2: Effluents

Rapid Assessment Tool

C2 Effluent Final Score	**9.00**	**GREEN**
	Critical?	NO

Criterion 3: Habitat

British Columbia, Canada

3.1 Habitat conversion and function –

F3.1 Score	**8.00**

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Factor 3.2a – Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Moderately	0.5
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25
3 – Is the industry's ongoing and future expansion limited to appropriate locations, and thereby preventing the future loss of ecosystem services?	Partly	0.25
4 - Are high-value habitats being avoided for aquaculture siting? (i.e., avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Yes	1
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Yes	1
		3.00

Factor 3.2b – Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Yes	1
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Partly	0.25
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	Mostly	0.75
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Mostly	0.75
		3.25

F3.2 Score (3.2a*3.2b/2.5)	**3.9**

C3 Habitat Final Score	**6.63**	**YELLOW**
	Critical?	NO

Denmark

3.1 Habitat conversion and function

F3.1 Score	**10.00**

Factor 3.2a – Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Yes	1.0
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Yes	1.0
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Yes	1.0
4 - Are high-value habitats being avoided for aquaculture siting? (i.e., avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Mostly	0.75
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Mostly	0.75
		4.5

Factor 3.2b – Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Mostly	0.75
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Yes	1.0
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Yes	1.0
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	Mostly	0.75
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Mostly	0.75
		4.25

F3.2 Score (3.2a*3.2b/2.5)	**7.65**

C3 Habitat Final Score	**9.22**	**GREEN**
	Critical?	NO

West Virginia, USA

3.1 Habitat conversion and function

F3.1 Score	**10.00**

Factor 3.2a – Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Partly	0.25
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25

3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Partly	0.25
4 - Are high-value habitats being avoided for aquaculture siting? (i.e., avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Yes	1.0
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Mostly	0.75
		2.50

Factor 3.2b – Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Yes	1
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.50
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Partly	0.25
4 - Is the enforcement process transparent— e.g., public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	Partly	0.25
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Moderately	0.50
		2.50

F3.2 Score (3.2a*3.2b/2.5)	**2.5**

C3 Habitat Final Score	**7.50**	**GREEN**
	Critical?	NO

Criterion 4: Evidence of Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	**6.00**	
C4 Chemical Use Final Score	**6.00**	**GREEN**
Critical?	NO	

Criterion 5: Feed

5.1 Wild Fish Use

Factor 5.1a – Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	25
Fishmeal from byproducts (%)	0

% FM	25
Fish oil inclusion level (%)	13
Fish oil from byproducts (%)	0
% FO	13
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	0.98
FIFO fishmeal	1.09
FIFO fish oil	2.55
Greater of the 2 FIFO scores	2.55
FIFO Score	**3.63**

Factor 5.1b – Sustainability of the Source of Wild Fish (SSWF)

SSWF	-6
SSWF Factor	-1.53

F5.1 Wild Fish Use Score	**2.10**

5.2 Net Protein Gain or Loss

Protein INPUTS		
Protein content of feed		40
eFCR		0.98
Feed protein from NON-EDIBLE sources (%)		29.7
Feed protein from EDIBLE CROP sources (%)		29.7
Protein OUTPUTS		
Protein content of whole harvested fish (%)		20
Edible yield of harvested fish (%)		55
Non-edible by-products from harvested fish used for other food production		100
Protein IN		24.23
Protein OUT		20
Net protein gain or loss (%)		-17.5
	Critical?	NO
F5.2 Net protein Score	**8.00**	

5.3 Feed Footprint

Factor 5.3a – Ocean area of primary productivity appropriated by feed ingredients per ton of farmed seafood

Inclusion level of aquatic feed ingredients (%)	38
eFCR	0.98
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*

Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	9.69

Factor 5.3b – Land area appropriated by feed ingredients per ton of production

Inclusion level of crop feed ingredients (%)	59
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.4
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.22

Value (Ocean + Land Area)	**9.90**

F5.3 Feed Footprint Score	**6.00**

C5 Feed Final Score	**4.55**	**YELLOW**
	Critical?	**NO**

Criterion 6: Escapes

Factor 6.1a – Escape Risk – Atlantic Sapphire and FWI

Escape Risk	**9**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**9**

Factor 6.1a – Escape Risk – 'Namgis (fully biosecure)

Escape Risk	**10**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**10**

Factor 6.1b – Invasiveness

Native species
Part A - Native Species

Score	1

Part C –

Question	Score	
Do escapees compete with wild native populations for food or habitat?	To some extent	0.5
Do escapees act as additional predation pressure on wild native populations?	Yes	0
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	Yes	0
Do escapees modify habitats to the detriment of other species (e.g., by feeding, foraging, settlement or other)?	No	1
Do escapees have some other impact on other native species or habitats?	No	1
	2.5	2.5

F 6.1b Score	3.5

Final C6 Score	5.00	YELLOW
	Critical?	NO

Non- Native species

Part B – Non-Native Species

Score	1.5

Part C –

Question	Score	
Do escapees compete with wild native populations for food or habitat?	To some extent	0.5
Do escapees act as additional predation pressure on wild native populations?	To some extent	0.5
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	No	1
Do escapees modify habitats to the detriment of other species (e.g., by feeding, foraging, settlement or other)?	No	1
Do escapees have some other impact on other native species or habitats?	No	1
		4.0

F 6.1b Score	5.5

Final C6 Score	6.00	YELLOW
	Critical?	NO

Criterion 7: Diseases

Atlantic Sapphire and Freshwater Institute

Pathogen and parasite parameters	Score	
C7 Biosecurity	8.00	
C7 Disease; pathogen and parasite Final Score	**8.00**	
Critical?	NO	**GREEN**

'Namgis

Pathogen and parasite parameters	Score	
C7 Biosecurity	10.00	
C7 Disease; pathogen and parasite Final Score	**10.00**	
Critical?	NO	**GREEN**

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	10	
C8 Source of stock Final Score	**10**	
		GREEN

9X: Escape of unintentionally introduced species

Freshwater Institute
and Atlantic Sapphire

Escape of unintentionally introduced species parameters	Score	
F6.2Xa International or trans-waterbody live animal shipments (%)	0.00	
F6.2Xb Biosecurity of source/destination	8.00	
F6.2X Escape of unintentionally introduced species Final Score	**-2.00**	

'Namgis

Escape of unintentionally introduced species parameters	Score	
F6.2Xa International or trans-waterbody live animal shipments (%)	0.00	
F6.2Xb Biosecurity of source/destination	10.00	
C6 Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Exceptional Factor 10x: Escape of unintentionally introduced species

Atlantic Sapphire and Freshwater Institute

Escape of unintentionally introduced species parameters	Score
F10xa International or trans-waterbody live animal shipments (%)	8.00
F10xb Biosecurity of source/destination	8.00
F10x Escape of unintentionally introduced species Final Score	**-2.00**

'Namgis **GREEN**

Escape of unintentionally introduced species parameters	Score
F10xa International or trans-waterbody live animal shipments (%)	8.00
F10xb Biosecurity of source/destination	10.00
F10x Escape of unintentionally introduced species Final Score	**0.00**

GREEN