Monterey Bay Aquarium
Seafood Watch®

Rainbow trout

Onchorynchus mykiss

Canada

Freshwater net pens
Raceways, Tanks

December 19, 2018
Seafood Watch Consulting Researcher

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Final Seafood Recommendation

Net pens

Criterion	Score	Rank	Critical?
C1 Data	7.50	GREEN	
C2 Effluent	7.00	GREEN	NO
C3 Habitat	7.33	GREEN	NO
C4 Chemicals	3.00	RED	NO
C5 Feed	6.95	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	5.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-3.00	GREEN	NO
C10X Introduced species escape	-0.50	GREEN	
Total	**37.29**		
Final score (0-10)	**5.33**		

OVERALL RANKING

Final score	5.33
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical criteria?	**NO**

FINAL RANK
YELLOW

Scoring note: scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates that the aquaculture operations have no significant impact. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of –10 reflects a very significant impact. Two or more Red criteria result in a Red final result.

Summary

The final numerical score for rainbow trout produced in net pens in Canada is 5.33 out of 10, which is in the Yellow range. There is one Red criterion (Chemicals). The final recommendation is a Good Alternative.

Final Seafood Recommendation

Raceways, Tanks

Criterion	Score	Rank	Critical?
C1 Data	7.50	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	8.13	GREEN	NO
C4 Chemicals	3.00	RED	NO
C5 Feed	6.95	GREEN	NO
C6 Escapes	6.00	YELLOW	NO
C7 Disease	6.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-1.00	GREEN	NO
C10X Introduced species escape	-0.50	GREEN	
Total	**44.09**		
Final score (0-10)	**6.30**		

OVERALL RANKING

Final score	6.30
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical criteria?	**NO**

FINAL RANK

YELLOW

Scoring note: scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of –10 reflects a very significant impact. Two or more Red criteria result in a Red final result.

Summary

The final numerical score for rainbow trout produced in raceway and tank systems in Canada is 6.30 out of 10, which is in the Yellow range. There is one Red criterion (Chemical). The final recommendation is a Good Alternative.

Executive Summary

This Seafood Watch assessment involves a number of criteria covering impacts associated with effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability.

Trout farming is a small but growing aquaculture industry in Canada. In 2015, 6,698 metric tons (MT) were produced, with the province of Ontario leading national production at 4,000 MT. The predominant production systems vary by province, with Ontario and Saskatchewan (another leading producer) primarily employing freshwater open net pens in lakes; these systems are also used in British Columbia. In Quebec, the production is via flow-through and semi-closed raceway and tank systems, which are also used to some degree in other provinces.

Canada rainbow trout farming is characterized by a range of quality and quantity of data, depending on the topic, but data availability is moderate–high. Information is ample and accessible on industry production and farm information, as well as on federal and provincial management and regulation. Scientific research on effluents and benthic impacts is rich, and monitoring occurs; but monitoring data and enforcement information are generally unavailable (though they were provided by one large producer). Regulations on chemical use and disease are comprehensive and readily available, both federally and provincially, though data on chemical use and compliance are not. Information regarding escapes and interactions with predators and wildlife have limitations. The quantity of information on feeds is rich, but the quality is variable. The movement of live animals is well documented, information is publicly available, and regulators, researchers, and some members of the industry were accessible for further information. This criterion would benefit from additional information on diseases and from the provision of additional data on effluent and habitat monitoring and enforcement, as well as on chemical use. The final numerical score for Criterion 1—Data is 7.50 out of 10 for net pen and for raceway and tank systems.

Effluent discharge is an important management focus for rainbow trout farming in Canada. Land-based and net pen systems all have potential to discharge nutrients and wastes that can cause harmful farm-level and cumulative effects to receiving waterbodies. Canada has implemented waste and nutrient release reduction strategies, including improved feeds, regulations on feeding, and improved water retention and filtration approaches (particularly for semi-closed systems). Additionally, siting guidelines and monitoring requirements in provinces using lake net pen systems aim to reduce and regulate effluents. There is some evidence that monitoring is occurring, although access to data is limited; access to enforcement data is also limited. There is some evidence that regulation and best practices have been effective in reducing concerns related to effluent in all provinces. Each province scores differently due to different provincial management regimes and the different production systems used.

Net pen production systems, which use improved feeds, are sited according to cumulative impacts concerns; available data suggest that management and regulation have been effective in reducing nutrient concerns related to effluent, although monitoring data and enforcement information are limited. The final score for Criterion 2—Effluent for net pen systems is 7 out of 10. Flow-through and semi-closed production systems have demonstrated significant reductions in nutrient effluent emissions through the use of improved feeds and filtration strategies. Regulations are robust, but information on enforcement is limited. The final score for Criterion 2—Effluent for raceway and tank systems is 8 out of 10.

Net pen structures typically have little direct impact on the habitats where they are sited, but operational impacts are considered more likely. Waste materials settling under structures have been demonstrated to alter sediment chemistry and impact community structure directly under the farm site. Recovery may be facilitated by fallowing, but this is not explicitly required, and recovery time may vary by site and monitoring metric. Regulation in Canada is generally effective, is guided by science, includes monitoring, and considers farm-level and cumulative impacts. Evidence of enforcement, industry compliance, and effective best management practices exists. Content of management measures is considered comprehensive and enforcement is deemed robust. For net pens, Factors 3.1 and 3.2 combine to give a final Criterion 3—Habitat score of 7.33 out of 10. Raceway and tank systems are generally situated adjacent to high-quality water sources from which water is withdrawn before being returned to a watercourse. Groundwater may also be withdrawn and discharged; some recirculation also occurs. These production systems are efficient with land use, so they require small areas of land for operation and may also be situated on existing terrestrial farmland; small farms (< 5 MT annual production) are also most common in Quebec. Concerns with these systems center more around effluent, as described in Criterion 2. The content of management measures and enforcement are considered robust. Factors 3.1 and 3.2 combine to give a final Criterion 3—Habitat score of 8.13 out of 10.

The availability of data on chemical use in Canadian rainbow trout production is moderate across relevant provinces; however, it is clear that the industry does use antibiotics, including those classified as Highly Important for Human Medicine. There are indications that use is low, but detailed data to confirm this are unavailable. Although a regulatory system with demonstrable enforcement is in place to restrict the types of chemicals used and to require a veterinary prescription for use, there are no practical limits on the frequency of antibiotic use or on the total quantity used, and recent examples show that their use can increase rapidly in response to disease challenges (e.g., from abnormally warm conditions). Understanding the industry's contributions to antibiotic resistance is challenging, but there are examples of clinical resistance to at least one of these antibiotics. Canada has developed a monitoring program to define a baseline of resistance, track changes, and make management decisions to manage risk of resistance development. Ultimately, overall use appears low and there is evidence of compliance with effective management measures; however, the systems employed for trout farming in Canada are open to the natural environment, thus allowing active chemicals or by-products to be discharged. The final score for Criterion 4—Chemical Use is 3 out of 10.

Canadian rainbow trout farming relies on fish meal and fish oil inputs (estimated collective inclusion rate of 26%), supported by a variety of wild-caught forage fish from fisheries considered to have a range of sustainability; but feeds are improving, and alternative ingredients are being explored. Canadian feed companies derive a significant portion of fish meals and fish oils from by-products. This assessment scores 7.91 out of 10 for Factor 5.1—Wild Fish Use. Feeds have continued to lessen reliance on fish meal as a protein source, and rainbow trout feeds feature a mix of inedible land-based animal by-products and edible crop ingredients. A relatively low eFCR (1.25), a moderately favorable edible yield value (60%), but high dietary protein needs (43%) result in a score of 5 out of 10 for Factor 5.2—Net protein gain/loss. The score for Factor 5.3—Feed Footprint is 7 out of 10 because of a moderate inclusion level of fish meal and inclusion of a mix of crop and animal ingredients. The scores from Factors 5.1, 5.2, and 5.3 combine to give a final numerical score of 6.95 out of 10 for Criterion 5—Feed.

Large escape events from net pen production systems have been documented in the past, although they are reported to be limited to infrequent occurrences by best management practices, as required by regulators. But there is a lack of data or information available to confirm this. Rainbow trout escape risk for these systems is considered moderate–high and scores 2 out of 10 for Factor 6.1. Rainbow trout is not native to Ontario or Saskatchewan, but is fully ecologically established as a result of historic and ongoing provincial stocking programs to support fisheries. Farmed fish are selectively bred and have genetic differentiation from their wild counterparts; use of single-sex and triploid fish reduces opportunity for introgression. The risk of competitive or genetic impact of escaped rainbow trout from net pen farms is considered to range from low to low–moderate, and scores 7 out of 10 for Factor 6.2. Overall, the final score for net pens is 4 out of 10 for Criterion 6—Escapes.

Large escape events are a low risk for land-based raceway and tank systems. Land-based systems provide opportunity to limit escapes by using physical barriers, which is common practice in Quebec as required by regulators. But there are no data to confirm the efficacy of these measures. Land-based raceway and tank systems score 6 out of 10 for Factor 6.1—Risk of Escape. Rainbow trout is not native to Quebec but is fully ecologically established in the production region as a result of historic and ongoing provincial stocking programs to support fisheries. (Invasion outside of production regions is a problem in eastern Quebec, although not necessarily attributed to aquaculture.) Farmed fish are selectively bred and have genetic differentiation from their wild counterparts, but wide use of single-sex and triploid fish reduces opportunity for introgression. The risk of competitive or genetic impact of escaped rainbow trout from land-based raceway and tank systems is considered to range from low to low–moderate, and scores 7 out of 10 for Factor 6.2. Overall, the final score for raceway and tank systems is 6 out of 10 for Criterion 6—Escapes.

Canada's disease risk management system is well developed, and disease issues are apparently not a major concern for the Canadian rainbow trout aquaculture industry because of regulatory controls and best management practices. But this Criterion would benefit from additional rainbow trout-specific and farm-level information on overall incidence of disease and interaction with wild fish, and from data enabling understanding of disease trends. For net pen production, biosecurity measures and fish health best practices are in place and offer some risk reduction; plus, there are some indications of low–moderate disease rates with Canadian commercial production, reported by regulators. But, because of the open nature of the production methods used, the susceptibility of cultured fish to various diseases, and limitations on industry-wide data availability, the score for net pen production systems is 5 out of 10 for Criterion 7—Disease. The flow-through and semi-closed systems (such as those used in Quebec) offer additional risk-management benefits that are not possible in open net pen systems, including physical separation of farmed fish from wild fish, and (in some cases) the sourcing of spring water. Quebec also benefits from robust federal and provincial biosecurity measures and fish health practices. Disease is also apparently not a significant issue for Quebec farms, but data to verify disease occurrences and trends are limited. Thus, the score for raceway and tank systems is 6 out of 10 for Criterion 7—Disease.

Rainbow trout is native to western North America but has long been cultivated and is now domesticated and farmed worldwide. The Canadian rainbow trout industry is supported by hatcheries, from which all cultivated rainbow trout are sourced, with no reliance on wild stocks. Criterion 8X—Source of Stock is a deduction of 0 out of –10.

Regulations at various levels are designed either to prohibit lethal take of some predators at aquaculture sites or to restrict lethal control. Best Management guidelines aimed at excluding predators from aquaculture structures are in place and appear to be common practice at Canadian rainbow trout farms. In most cases, provinces have also not issued any lethal take permits in several years, and species that would be potential candidates for such take have populations considered at low risk at international and national levels. Wildlife may occasionally become entangled or trapped in aquaculture gear, but this is apparently limited to exceptional cases, even though no data on actual mortalities or take are available. The final numerical score for Criterion 9X—Wildlife Mortalities is –3 out of –10 for net pens, and –1 out of –10 for Quebec's upland production, much of which is completely enclosed.

The Canadian rainbow trout industry relies on the movement of live animals in the form of eggs and larvae. International movement occurs in the form of significant import of eggs and/or larvae from hatcheries in the Unites States. Inter- and intra-provincial movement (including trans-waterbody) occur as well, because Canada also produces a large percentage of domestically used eggs/larvae. All import and movement of live animals require compliance with permitting and regulatory conditions, and both source and destination facilities are subject to biosecurity standards. Thus, the risk of introduction of secondary species (besides the cultivated species) is considered low. The final numerical score for Criterion 10X—Escape of Secondary Species is –0.5 out of –10.

The final numerical score for rainbow trout produced in net pens in Canada is 5.00 out of 10, which is in the Yellow range. There is one Red criterion (Chemicals). The final recommendation is Good Alternative. The final numerical score for rainbow trout produced in raceway and tank systems in Canada is 5.97 out of 10, which is in the Yellow range. There is one Red criterion (Chemicals). The final recommendation is Good Alternative.

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Introduction

Scope of the analysis and ensuing recommendation

Species
Oncorhynchus mykiss

Geographic Coverage
Canada

Production Method(s)
Freshwater net pens
Raceways, Tanks

Species Overview

Brief overview of the species

Rainbow trout (*Oncorhynchus mykiss*) is a species of fish in the family Salmonidae, which includes Pacific salmon and trout (genus *Oncorhynchus*), Atlantic salmon and brown trout (genus *Salmo*), char (genus *Salvelinus*, e.g., brook trout and Dolly Varden), and whitefishes and grayling (Behnke 2002). The native distribution of rainbow trout is entirely west of the Rocky Mountains, from northwest Mexico to the Kuskokwin River, Alaska; however, since 1984, the species has been extensively introduced around the world for aquaculture purposes (and much earlier for angling purposes) and can now be found in waterways on all continents except Antarctica (Cowx 2005).

Rainbow trout are hardy fish that have adapted to a variety of environments. They typically inhabit cold freshwater rivers, streams, and lakes. Spawning and growth are limited to a temperature range of 9–14°Celsius (C), but rainbow trout can tolerate temperatures from 0 to 27°C (Cowx 2005). Spawning occurs in early spring (April to June), with eggs hatching four to seven weeks later (Scott and Crossman 1973) (Wheeler 1985).

Different strains of *O. mykiss* display different life histories. Most rainbow trout permanently inhabit freshwater environments; some remain within localized areas throughout their life cycles, traveling short distances from natal streams to adjacent larger water bodies. But migratory rainbow trout in the Great Lakes may travel long distances; a rainbow trout tagged in Great Lakes rivers in Michigan was caught 8 months later in Lake Ontario, having traveled 375 kilometers (km) (Scott and Crossman 1973). One strain of *O. mykiss*, known as steelhead, has developed an anadromous life history in which juveniles migrate to the ocean and spend their adult life in marine waters, returning to freshwater streams to spawn (Scott and Crossman 1973) (Wooding 1994) (Cowx 2005).

The hardiness and adaptability of this species have suited it well to aquaculture.

Production system

This assessment focuses on freshwater-raised rainbow trout and excludes steelhead, which are raised in saltwater, though some freshwater producers are marketing their rainbow trout as "steelhead." Rainbow trout is farmed to some degree in nine Canadian provinces: Alberta, British Columbia, Manitoba, New Brunswick, Nova Scotia, Ontario, Prince Edward Island, Quebec, and Saskatchewan (CAIA 2017). The three largest producers (Ontario, Quebec, and Saskatchewan) are the primary focus of this assessment and, for the purposes of this assessment, are assumed to be representative of the industry as a whole.

Production systems for farming rainbow trout vary somewhat by province.

Ontario

Figure 1. A typical Ontario net pen system**.** Photo: Northern Ontario Fish Farmers Association 2016.

There has been a significant shift in the model of the Ontario trout farming industry in the past two decades. In 1988, land-based culture (typically in ponds) accounted for over 95% of production by volume. By 2010, net pen culture accounted for 88% of production by volume (OMAFRA 2010); presently, lake-based net pen culture represents 85% of total Canadian trout aquaculture production (Moccia and Bevan 2017), with the remaining share produced by land-based systems (but only about 75 metric tons [MT] of rainbow trout produced for food fish) (Boysen 2009). Farms that annually produce more than 5 MT of trout (typically rainbow trout) are largely concentrated in the Georgian Bay–Manitoulin Island regions of Lake Huron. There are eight net pen culture farms in this region (Wetton 2013) and fewer than ten farms dominate production (Blanchfield et al. 2009) in Ontario; 80% of all Canadian net pen production is from this region of Ontario (Martens et al. 2014). Rainbow trout is also farmed by First Nations in Ontario, with one farm producing about 360–450 MT annually (Aboriginal Aquaculture Association 2012). A small but growing segment of the industry in Ontario is using closed (i.e., recirculating) land-based systems, and some producers also use flow-through raceway systems (pers. comm., Steve Naylor, OMAFRA 2017) (pers. comm., J. Taylor 2017). Agriculture and Agri-Foods Canada (2009) reports that the industry loosely self-organized so that the farms in southwestern Ontario typically provide fingerlings for growout in net pens in the northern farms, as well as for stocking "U-fish" ponds (stocked ponds for recreational fishing) and enhancement of wild stocks. Ontario is mostly supported by domestic hatchery production, though some import from the United States may occur as needed.

All farms in Ontario are currently working toward Global Aquaculture Alliance Best Aquaculture Practices (BAP) (pers. comm., S. Naylor 2017), though none has been certified at the time of this assessment (Global Aquaculture Alliance 2018). Additionally, one producer is Canadian Organic certified (pers. comm., S. Naylor 2017) (Blue Goose Pure Foods 2017) (Organic Trade Association 2017).

Quebec

Quebec began farming rainbow trout in the 1980s and is currently Canada's second-largest producer of farmed rainbow trout; it is the province's major freshwater aquaculture species produced for food. Most farming operations are located in the Estrie, Laurentides, Outaouais, and Center-du-Québec regions of Quebec (MAPAQ 2017). Trout farming in Quebec occurs exclusively on land in a variety of systems, from outdoor flow-through ponds to recirculating aquaculture systems and aquaponic systems; net pen aquaculture in lakes is prohibited by Quebec provincial regulations. Many of the smaller producers in Quebec, which represent a minor fraction of total production, use traditional flow-through systems (about 20%; pers. comm., G. Vandenberg 2017), as do some producers in Ontario. The majority of total Quebec rainbow trout production for the food market is via outdoor flow-through systems (ponds, raceways, circular tanks), with about 30–40% using recirculating or partial re-use systems; such closed and semi-closed systems are a growing segment of production in Quebec (Government of New Brunswick 2010) (pers. comm., Grant Vandenberg, Universite Laval 2017) (Government of New Brunswick 2010a) and are in use by some of the province's largest producers (Bobines Fish Farm 2017). These systems may reuse 50–85% of total water flow and provide enhanced opportunities to mitigate effluent, to treat water, and to manage fish health (Government of New Brunswick 2010) (Bobines Fish Farm 2017).

Figure 2. A modern semi-closed system in Quebec. Google Earth image 2017**.**

Trout culture for food markets in Quebec accounts for about 21% of total provincial trout production and is primarily focused on rainbow trout. Sales to stocking and enhancement programs account for approximately 78% of total provincial farmed trout production, and the primary species for this purpose is brook trout (MAPAQ 2012); this production is outside the scope of this assessment. Quebec is mostly supported by domestic hatchery production, though some import from the United States may occur as needed.

Saskatchewan

Saskatchewan is a major producer of rainbow trout, which is the most important aquaculture species in the province. Production is concentrated in Lake Diefenbaker using net pen culture by a single producer, which began production in 1993 (pers. comm., Murray Drew, University of Saskatchewan 2017). The farm operation in Lake Diefenbaker includes arrays of 15 m x 15 m and 30 m x 30 m net pens suspended from the surface to a depth of 12 m and features about 28 net pens in total (Otu et al. 2017a). Saskatchewan's only major producer has its own hatchery but may import eggs from the United States (pers. comm., DFO 2017) (pers. comm., Murray Drew, Government of Saskatchewan 2017). The farm markets its fish as "steelhead," though they are produced exclusively in freshwater.

Other provinces

Rainbow trout is also farmed to varying degrees in British Columbia, Nova Scotia, New Brunswick, Prince Edward Island, Manitoba, and Alberta in land-based flow-through systems, net pens in freshwater lakes, and recirculating systems (Watersong Farms 2017).

Of these, British Columbia is the largest "minor" producer. There is one rainbow trout producer in the province using lake net pen systems. Other producers are using land-based flow-through systems (pers. comm., Monica Walker, DFO 2017). The provnce's lake net pen operator is vertically integrated with a broodstock-based hatchery, while the other hatches imported eggs in a nursery system (pers. comm., Shane Peterson, DFO 2017).

Some production is occurring in upland recirculating systems in British Columbia and Manitoba (Summerfelt and Christianson 2014) (West Creek Aquaculture 2017) (Miracle Springs Inc. 2018). These systems are included in an existing Seafood Watch assessment of global recirculating aquaculture systems (Seafood Watch 2014) and are excluded from this assessment.

Although some commercial-scale trout farming is occurring in these provinces, most production is relatively small-scale: mostly hatcheries or fingerling producers, and/or more directed to private production and/or U-catch operations. Commercial production values are not reported to Fisheries and Oceans Canada (DFO) by any of these provinces—partly because of confidentiality concerns (pers. comm., DFO 2017).

This assessment focuses on the two main production systems (net pens and flow through systems) and on Ontario, Saskatchewan, and Quebec—the nation's largest producers that are assumed to be representative of the industry as a whole.

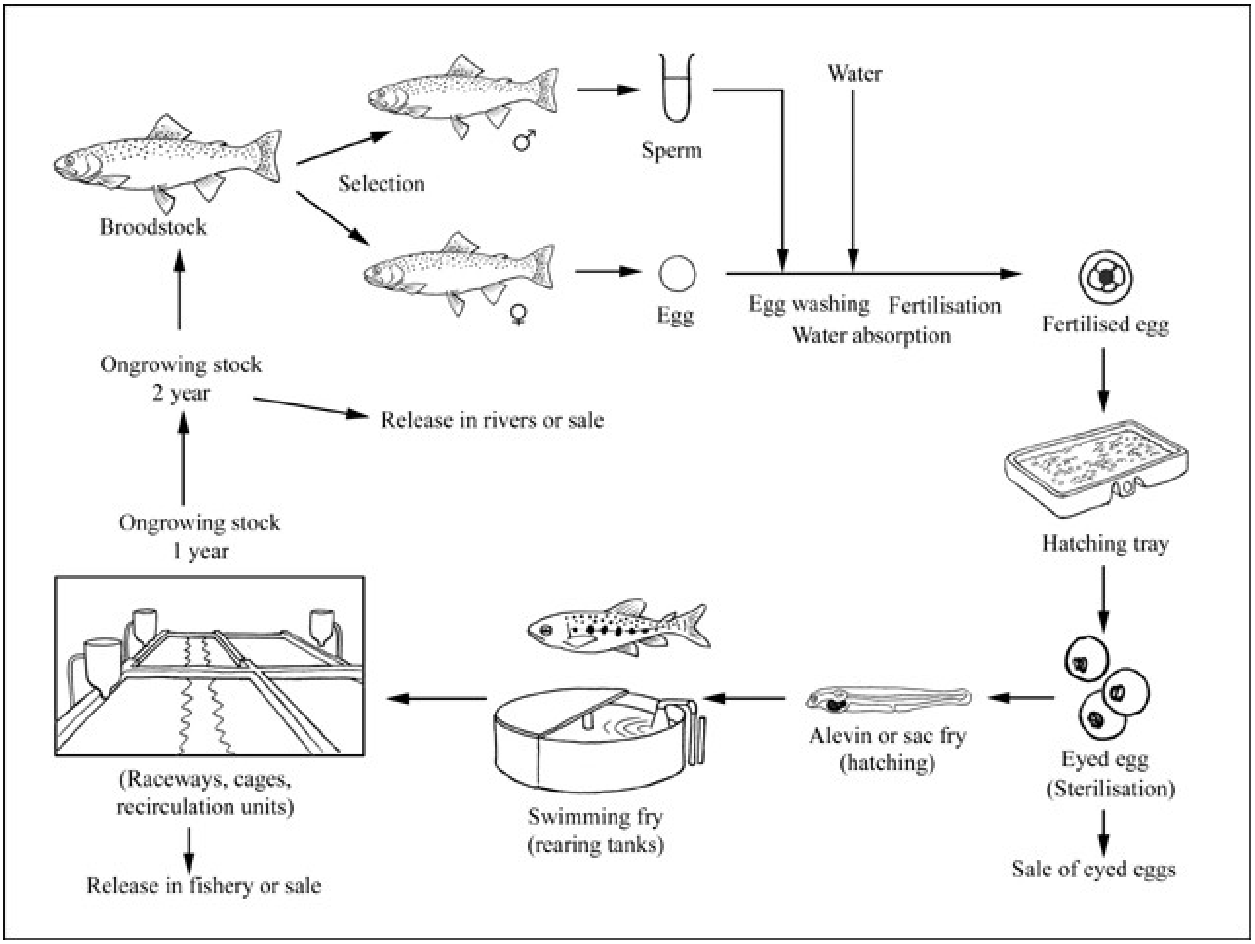

Figure 3. Example of rainbow trout production system. Ontario and Saskatchewan are primarily using net pens while Quebec uses land-based systems. From FAO 2017.

Production Statistics

Canada sits well behind global leaders in rainbow trout production—including Chile, Norway, Iran, and Italy, which annually produce from about 40,000 to 150,000 MT, respectively (Adeli and Baghaei 2013)—but the species is the most important freshwater species farmed in Canada (Manitoba Water Stewardship 2004), where 11 freshwater net pen farms dominate Canadian production (Wetton 2013).

Reporting on rainbow trout specifically is imprecise because Canada aggregates all trout in reported production statistics. Because of confidentiality concerns in protecting individual producers, Canada also does not report production statistics for some provinces (such as Saskatchewan). In other cases, reporting between the federal and provincial governments is inconsistent. For example, Quebec reports higher rainbow trout production numbers than the federal government reports for all trout combined in some years. But some patterns are discernible: Ontario is by far the largest producer of farmed trout in Canada, contributing over 60% of national production in 2015 at 4,510 MT, and 5,060 MT of production in 2016 (Government of Canada 2017) (Moccia and Bevan 2017). Most trout production in Ontario is rainbow trout, representing 90–100% of all trout reported to Statistics Canada (Manitoba Water Stewardship 2004) (DFO 2015a) (Moccia and Bevan 2015).

Saskatchewan is frequently reported as the third leading producer but appears to be second, with about 900–1,000 MT annually, though specific numbers are not reported to protect the confidential production data of the province's single producer (DFO 2016a); production may be as high as 1,500–2,000 MT (pers. comm., S. Naylor 2017). Production is concentrated in Lake Diefenbaker, a large reservoir, by a single producer that is reported as one of Canada's largest (Otu et al. 2017a).

Quebec is Canada's other important producer of rainbow trout, contributing about 13–19% of total Canadian trout from 2014 to 2016. The government of Quebec reports annual provincial production of rainbow trout at about 570 MT from 2011 to 2013 (MAPAQ 2014); about half of the province's production is contributed by 7% of license holders (Aquaculture Quebec 2018). Production in 2014 was 555 MT, worth CAD 3.3 million farmgate value; this amounts to slightly more than half of total trout production in the province by value (Gouvernement du Quebec 2016). The remaining quantity of trout is produced for private ponds and the U-catch market, much of it brown and brook trout (DFO 2016b) (pers. comm., S. Naylor 2017).

A number of other provinces contribute lesser amounts to total national production. Nova Scotia and British Columbia are the leading minor producers of trout at about 1–2.5% of national production each (Government of Canada 2017). British Columbia has two major producers (pers. comm., Monica Walker, DFO 2017).

Table 1: Canadian Aquaculture Production of Trout*# by Volume and Value (MAPAQ 2014) (Government of Canada 2017).

	2011	2012	2013	2014	2015
By Volume (MT)					
Ontario	3,385	3,700	3,580	4,000	4,510
Quebec	577	586	543	579	546
Saskatchewan	No data**	No data**	No data**	900#	900#
British Columbia	64	88	62	44	0
Nova Scotia	124	113	104	0	114
New Brunswick	80	142	0	0	5[1]
Canada (total)**	**5,600**	**6,077**	**6,695**	**6,698**	**7,062**
By Value (x 1,000; CAD)					
Ontario	17,200	18,300	18,000	20,500	23,200
Quebec*	2,266	1,951	10,735	9,329	7,957
Saskatchewan	No data**	No data**	No data**	No data**	No data**
British Columbia	408	478	501	344	0
Nova Scotia	1,796	1,412	1,042	0	No data**
New Brunswick	400	1,420	0	0	0
Canada (total)**	**29,927**	**31,516**	**38,555**	**37,612**	**40,264**

* Reporting aggregates rainbow, brown, golden, and other trouts.
\# Estimated (DFO 2016a) (Otu et al. 2017a).
** Canada withholds reporting of some data to protect confidentiality where only one producer is present.
[1] Mostly production for U-fish operations (pers. comm., Michel DesJardins, Government of New Brunswick 2017).

Import and Export Sources and Statistics

Most of the trout farmed in Canada is sold to domestic markets, with only about 20% of production (by volume) exported in 2014. Of exported product, about 70% is exported to the United States, with the top three destination states being Ohio, Illinois, and Wisconsin. Other countries where trout is exported include France, Switzerland, Germany, and China (CANSIM 2015).

Common and Market Names

Scientific Name	*Onchorynchus mykiss*
Common Name	Rainbow trout, *truit arc-en-ciel* (Fr.), steelhead trout, freshwater salmon, redband trout

Product forms

Sold whole or filleted as fresh or frozen. Value-added productions such as breaded, stuffed, or smoked are also common.

Analysis

Scoring guide

- With the exception of the exceptional criteria (8X, 9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rating. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the three exceptional criteria result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Standard that the following scores relate to are available on the Seafood Watch website. https://www.seafoodwatch.org/-/m/sfw/pdf/criteria/mba_seafood%20watch_aquaculture%20standard_version%20a3.2.pdf?la=en

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: having robust and up-to-date information on production practices and their impacts publicly available.

Criterion 1 Summary

All production systems

Data Category	Data Quality	Score (0-10)
Industry or production statistics	7.5	7.5
Management	10	10
Effluent	7.5	7.5
Habitat	7.5	7.5
Chemical use	7.5	7.5
Feed	7.5	7.5
Escapes	7.5	7.5
Disease	5	5
Source of stock	10	10
Predators and wildlife	5	5
Introduced species	7.5	7.5
Other—(e.g., GHG emissions)	Not Applicable	n/a
Total		**82.5**

C1 Data Final Score (0–10)	**7.5**	**GREEN**

Brief Summary

Canada rainbow trout farming is characterized by a range of quality and quantity of data, depending on the topic, but data availability is moderate–high. Information is ample and accessible on industry production and farm information, as well as on federal and provincial management and regulation. Scientific research on effluents and benthic impacts is rich and monitoring occurs; but monitoring data and enforcement information are generally unavailable (though they were provided by one large producer). Regulations on chemical use and disease are comprehensive and readily available, both federally and provincially, though data on chemical use and compliance are not. Information regarding escapes and interactions with predators and wildlife have limitations. The quantity of information on feeds is rich, but the quality is variable. The movement of live animals is well documented, information is publicly available, and regulators, researchers, and some members of the industry were accessible for further information. This criterion would benefit from additional information on diseases and from the provision of additional data on effluent and habitat monitoring and enforcement, as well as on chemical use.

The final numerical score for Criterion 1—Data is 7.50 out of 10 for net pen and for raceway and tank systems.

Justification of Rating

The trout farming industry in Canada is regulated both federally and provincially, and there is variability in the type or quality of regulatory data from province to province. Information for this report was derived from a variety of resources, including government websites and reports; personal communications with government, academic, and industry representatives; academic literature; and through drawing on reporting of similar production systems for this species in other countries (especially the United States), where relevant and as needed.

The scientific literature on rainbow trout aquaculture's impacts is ample. Specific to lake net pen culture in Canada, a collaborative research program focused on this topic in Ontario's Experimental Lake Experimental Lakes Area (ELA)—simulating rainbow trout aquaculture under contemporary industry operating standards and investigating whole ecosystem effects (Kullman et al. 2007). The program resulted in a host of publications on topics ranging from the fate of escaped fish to the fate of nutrient inputs associated with trout farming, and the program is cited throughout this assessment. The literature is bolstered by a body of Canadian and international research and study on similar production systems for this species. Both academic and government institutions have made significant contributions to the literature on farmed rainbow trout, and industry is involved in such research.

Production. The quality and availability of industry or production statistics is sufficient to understand and assess the industry. Fisheries and Oceans Canada reports annual production of rainbow trout (by volume and value) by province. These statistics are in some cases coarse or incomplete because data for provinces with lower production (i.e., fewer growers) are withheld for commercial confidentiality purposes. But production data for the bulk of the industry are publicly available by province. Further detail on production or industry statistics can be found at the provincial level in some provinces (e.g., Ontario and Quebec, but not Saskatchewan; British Columbia rainbow trout is aggregated with other species). For example, Ontario publishes an up-to-date annual snapshot of its aquaculture production that provides insight into total production, species produced, distribution of farms and licenses, and economic value. The Government of Quebec also publishes recent data specific to rainbow trout production. Data quality and availability for industry and production statistics scores 7.5 out of 10 because data are considered reliable and current, with minor gaps.

Management. Regulatory and management information quality and availability varies by province and subject. In general, both federal and provincial regulations at a coarse, overarching level are readily available and accessible via government websites. Each province has developed and published general aquaculture guidelines in a variety of forms, from Conditions of License to Environmental Impact Assessment requirements and comprehensive aquaculture management systems. For some topics, such as effluent and chemical use, provincial and federal regulations are quite specific. The federal government also provides fairly detailed guidelines; for example, on developing fish health management plans. All provinces require reporting of data on certain items—such as water quality monitoring, sediment monitoring, chemical use, mortality events, and incidental wildlife mortalities—but in almost all cases, these data are not readily available, although some producers were able to help fill gaps by providing information. Data and information on industry-specific enforcement interactions are also limited. Agency contacts in each province provided some helpful additional information for this assessment, but were often limited by confidentiality obligations. Data quality and availability management scores 10 out of 10 because data are considered reliable and up-to-date, though with some non-critical gaps.

Effluent. Regulation of effluents is clearly outlined in easily accessible government documents and websites, and this includes restrictions on the composition of feeds and site-specific limits. But none of the jurisdictions that oversee trout farming in Canada provides easily accessible public reports or data (farm-level or industry aggregated) on water quality or benthic impacts associated with freshwater aquaculture operations—despite clearly outlined monitoring and reporting requirements. (Similar data for marine and salmon production are more transparent.) Some limited monitoring data are indirectly available via peer-reviewed scientific publications studying this topic at aquaculture sites and via government publications. Comments that affirmed general regulatory compliance were provided by agency, industry, and academic contacts and multiple government resources, and data were provided by one major producer to offer some level of verification. Despite the inaccessibility of comprehensive monitoring data, the quality and availability of data for Effluent is moderate–high, allowing for a confident assessment of this Criterion and scores of 7.5 out of 10. This data category would benefit from the provision of additional monitoring data to verify industry-wide compliance with regulations.

Habitat. Provinces largely provide at least general information on the locations of farms (fairly specific in most cases), as well as accessible information on aquaculture licensees, environmental impact assessment reports, and public notice. Industry academic publications offer additional information about site locations. In provinces with few producers, locations are easy to identify and locate through published government resources. Regulations related to habitat—including benthic impacts, site water quality, and decommissioning requirements—are in most cases clearly included in agency literature, especially in conditions of license. Provinces also appear to consider cumulative impacts in concert with other human uses of water resources. Ontario in particular has produced a significant amount of literature to support its lake net pen management. Quebec is less clear and thorough in its regulations related to habitat, but it prohibits lake net pen aquaculture (to protect lake habitats) and offers substantial regulations aimed at effluent and water quality concerns. Quebec also has fairly comprehensive regulation aimed at managing water withdrawals—including ecosystem-wide and cumulative impact considerations. Saskatchewan considers siting criteria and cumulative impacts, and mandates monitoring. General enforcement information (such as annual reports outlining enforcement actions across a wide scope of permitted industries) is lacking in aquaculture specifics across provinces, though several resources are available that verify industry compliance, including provision of limited data from one major producer and comments from regulators. The data quality for the locations/habitat criterion scores 7.5 out of 10 because licensing and siting requirements are available from all jurisdictions that farm trout; however, habitat monitoring data are not easily available although they are being collected. The provision of additional sediment monitoring data and reports to validate industry-wide compliance would be beneficial for this assessment.

Chemical Use. Canadian agencies clearly outline regulations on chemical and therapeutant use and make transparency, availability, and clarity of regulations a priority. The CFIA and Health Canada are involved in monitoring veterinary drug residues in food products, which may offer some insight into whether illegal antibiotics are used (there was no evidence), while provinces monitor for compliance with antibiotic and chemical application regulations. Monitoring and compliance data are confidential, but some information is available via government fish health summaries and expert comment. Data on national individual therapeutant use patterns in aquaculture may not be available (Lalonde et al. 2012); however, Quebec publishes helpful annual reports on industry antibiotic use, even though rainbow trout are aggregated with brook and other trout species produced there. Three major producers in Ontario (representing > 95% of annual production) and one in Saskatchewan provided information on recent antibiotic usage, and both government regulators and academic researchers provided information and comment on Ontario, Quebec, and national production. Additionally, government data and reports related to monitoring of bacterial antibiotic resistance are published and available, although sometimes limited in resolution. Ultimately, the data about chemical use on Canadian rainbow trout farms or the potential ecological impacts are moderate and could be improved with more detail in reporting. Thus, the data score is 7.5 out of 10.

Feed. The quality and availability of data related to feeds is moderate–high. Although the typical proprietary nature of commercial feed ingredients applies for this industry, numerous sources can be mined for information. For example, a number of studies conducted in an experimental rainbow trout farm in Ontario’s Experimental Lakes provide some helpful details on the “typical” feed that was used there. Additional scientific literature and academic theses provide useful pieces of information, as do organizations such as the Food and Agriculture Organization of the United Nations (FAO). Government agencies have provided some useful documents—such as those regulating effluent via feed composition—and both industry and agencies were able to provide information helpful for constructing a complete assessment of the Feeds criterion. One major Canadian feed company provided important supporting information for this assessment; also, this assessment was able to use some information from the 2015 and 2017 Seafood Watch assessments of the U.S. rainbow trout industry and from feed company sustainability reports. The quality and availability of data for the Feeds criterion receive a score of 7.5 out of 10 for being high and sufficient to assess the industry, but with some minor limitations.

Escapes. Canada and rainbow trout-producing provinces clearly outline requirements to limit the risk of escape and to report (mostly large) escape events; in some cases, they provide ambiguous requirements on recapture. Reports of escape events are available for some provinces (such as British Columbia) and informally for others. Research on the potential ecological impacts of escapes is ample, including those specific to Canada. Industry contacts were able to provide additional information, including on escape prevention measures. The Escapes criterion scores 7.5 out of 10 for data quality: although there is incomplete public reporting of escape events, significant research has been conducted on the invasiveness of rainbow trout and sufficient commentary on recent trends was provided to confidently assess this criterion. This data category could further benefit from actual escapes and recapture data, as well as confirmation that escapes data are being reported as required by regulators.

Disease. Information on regulations related to disease risk management is ample, starting with well-developed websites for federal agencies involved in disease risk management—including the Canadian Food Inspection Agency and the Department of Fisheries and Oceans. Documents detailing disease risk management protocols are extensive and available, including permitting requirements for imports, introductions and transfers, disease reporting, and standards for developing Fish Health Management Plans. Data on reported disease occurrences (for federally "Reportable" diseases) are published on the CFIA website in real time, as well as on the World Organization for Animal Health's (OIE) website, although these data are geographically coarse because the site reports at the provincial level and focuses only on some diseases. The CFIA does not separate incidents into wild vs. farmed fish, though the OIE does. Provincially, regulatory documents are also generally available; for example, the government of Ontario publishes quarterly fish health summaries, though they are coarse. Quebec provides a detailed annual report of diagnostic testing that is readily available. Both federal and provincial government regulators (as well as academic and industry contacts) were accessible for obtaining additional information on disease risk management and representative fish health. Biosecurity plans were provided by an agency contact and two large producers, which suggests industry compliance. Relative to the Disease criterion, information availability is good, although gaps exist in the incidence of disease occurrences at the farm level. Though the therapeutant usage data provided by several producers allow some inference, this data category would benefit from additional data on disease occurrence, such as farm-level data and data related to non-reportable diseases. The quality and availability of information for the Disease criterion is a moderate score of 5 out of 10.

Source of Stock. Data quality and availability related to Source of Stock is high, because information is available through industry, agency, and in the scientific literature regarding hatchery licensees, practices, and locations. The movement of live animals—including eggs—is strictly regulated, and regulators were able to describe the source of stock for individual provinces. Regulators were also able to estimate the ratio of domestic versus imported eggs and fry. The source of stock criterion scores 10 out of 10 for data quality because it is known that all stock are sourced from hatcheries with fully domesticated broodstock, and supporting information is ample.

Predator and Wildlife Mortalities. Provincial and federal regulations on the take of wildlife associated with aquaculture licenses are readily available. Federal regulations are clear, while provincial regulations are more general. Follow-up with agency regulators provided clarifications on lethal take permitting and reporting, though the enforcement picture is unclear. Information on industry best practices was provided by agency contacts and one large producer. There is no public reporting of wildlife interaction or enforcement activities, although provinces do have requirements for reporting production-related mortalities. Relevant provincial regulations and personal communications with government and industry representatives provided some relevant (but non-verifiable) data. This data category would benefit from provision of actual mortality data or conclusive statements from provincial regulators. Data quality and availability for this criterion is moderate and scores 5 out of 10.

Unintentional Introductions. The Canadian rainbow trout industry relies on the movement of live animals in the form of eggs and larvae. Information on the industry's supply chain of rainbow trout eggs and fingerlings is available via scientific publications, industry and agency websites, and contacts at regulatory agencies and within the industry. Information on the regulation of import and movement of live animals is readily available through agency websites. Estimates on the trans-boundary movement of live animals was also accessible through regulatory contacts, although specific numbers were not provided. Data quality and availability for this criterion is moderate–high and scores 7.5 out of 10.

Conclusions and Final Score

Canada rainbow trout farming is characterized by a range of quality and quantity of data, depending on the topic, but data availability is moderate–high. Information is ample and accessible on industry production and farm information, as well as federal and provincial management and regulation. Scientific research on effluents and benthic impacts is rich, and monitoring occurs; but monitoring data and enforcement information are generally unavailable (though they were provided by one large producer). Regulations on chemical use and disease are comprehensive and readily available, both federally and provincially, though data on chemical use and compliance are not. Information regarding escapes and interactions with predators and wildlife have limitations. The quantity of information on feeds is rich, but the quality is variable. The movement of live animals is well documented, information is publicly available, and regulators, researchers, and some members of the industry were accessible for further information. This criterion would benefit from additional information on diseases and from the provision of additional data on effluent and habitat monitoring and enforcement, as well as on chemical use.

The final numerical score for Criterion 1—Data is 7.50 out of 10 for all production systems.

Criterion 2: Effluent

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: not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Criterion 2 Summary

Net pens

Effluent parameters		Value	Score
F2.1a Waste (nitrogen) production per ton of fish (kg N ton^{-1})		60.88	
F2.1b Waste discharged from farm (%)		80	
F2.1 Waste discharge score (0–10)			5
F2.2a Content of regulations (0–5)		5	
F2.2b Enforcement of regulations (0–5)		4	
F2.2 Regulatory or management effectiveness score (0–10)			8
C2 Effluent Final Score (0–10)			7.00
	Critical?	NO	**GREEN**

Raceways, Tanks

Effluent parameters		Value	Score
F2.1a Waste (nitrogen) production per ton of fish (kg N ton^{-1})		60.88	
F2.1b Waste discharged from farm (%)		48	
F2.1 Waste discharge score (0–10)			7
F2.2a Content of regulations (0–5)		5	
F2.2b Enforcement of regulations (0–5)		4	
F2.2 Regulatory or management effectiveness score (0–10)			8
C2 Effluent Final Score (0–10)			8.00
	Critical?	NO	**GREEN**

Brief Summary

Effluent discharge is an important management focus for rainbow trout farming in Canada. Land-based and net pen systems all have potential to discharge nutrients and wastes that can cause harmful farm-level and cumulative effects to receiving waterbodies. Canada has implemented waste and nutrient release reduction strategies, including improved feeds, regulations on feeding, and improved water retention and filtration approaches (particularly for semi-closed systems). Additionally, siting guidelines and monitoring requirements in provinces using lake net pen systems aim to reduce and regulate effluents. There is some evidence that monitoring is occurring, though access to data is limited; access to enforcement data is also limited. There is some evidence that regulation and best practices have been effective in reducing concerns related to effluent in all provinces. Each province scores differently due to different provincial management regimes and the different production systems used.

Net pen production systems, which use improved feeds, are sited according to cumulative impacts concerns; available data suggest that management and regulation have been effective in reducing nutrient concerns related to effluent, although monitoring data and enforcement information are limited. The final score for Criterion 2—Effluent for net pen systems is 7 out of 10.

Flow-through and semi-closed production systems have demonstrated significant reductions in nutrient effluent emissions through the use of improved feeds and filtration strategies. Regulations are robust, but information on enforcement is limited. The final score for Criterion 2—Effluent for raceway and tank systems is 8 out of 10.

Justification of Rating

This criterion aims to assess the impact of farm effluent on the regional environment; i.e., beyond the immediate farm boundary or allowable zone of effect (AZE). Impacts of the farming operation on the immediate vicinity of the farm are addressed in the following criterion, Habitat.

Effluent, especially that which can cause waste-related eutrophication, has generally been considered the most concerning environmental impact for Canadian rainbow trout farming (McPhee et al. 2015). Effluent concerns related to rainbow trout production in Canada vary by the type of production system. For example, all production in Quebec occurs in land-based systems rather than in lakes or other open waterbodies. Most production in Quebec utilizes partially closed systems, which provide enhanced opportunities for the reduction of effluent discharge to the surrounding environment through greater opportunity for water filtration (Rooney 2006) (pers. comm., G. Vandenberg 2017).

In Quebec, many of the smaller producers (which represent a minor fraction of total production) use traditional flow-through systems (about 20%) (pers. comm., G. Vandenberg 2017), as do some producers in Ontario (pers. comm., S. Naylor 2017) (pers. comm., J. Taylor, Cedar Crest Trout Farm 2017). In flow-through systems, particulate matter may drain to the surrounding environment, and dissolved waste is difficult to remove. The solubilization of the particulate matter releases dissolved carbon, nitrogen, and phosphorus into the water column (Paterson et al. 2006). For example, impacts around farm discharge points might include eutrophication and shifts in microbial community structure (Boyd et al. 2005) (Sindilariu 2007). In some instances, residues from therapeutants used in Canadian land-based aquaculture have been observed near effluent outfalls above levels known to be toxic to aquatic invertebrates (Lalonde et al. 2012).

In flow-through systems, waste gathers at the ends of the raceway where it can be removed by a suction device or draining (usually to a settling basin) before entering the surrounding environment (Boyd et al. 2005) (pers. comm., J. Taylor 2017). This is also true of the small percentage of Ontario production using flow-through systems: the use of settling basins (pers. comm., J. Taylor 2017) and vegetated buffers has helped most flow-through producers comply with phosphorus discharge regulations (pers. comm., S. Naylor 2017). In Nova Scotia, 90% of land-based fish farm operations use some form of such treatment before discharge, although these systems are not entirely effective at removing all dissolved waste, such as therapeutants (Lalonde et al. 2012).

In a review of "typical" flow-through trout culture, Boyd et al. (2005) points out that the composition of effluent in outflows did not contain much greater concentrations of several parameters investigated than inflow water—including total suspended solids (TSS), settleable solids, 5-day biological oxygen demand (BOD), dissolved organic carbon (DOC), and total unionized ammonia (NH_3)—but that total effluent outputs over the course of a production cycle may be significant. Strides have been made in Quebec in reducing waste generated by flow-through and partially closed systems, in which up to 85% of water may be recirculated via methods such as rotating drum filters and on-site wastewater treatment plants—offering additional control over effluent water quality (Bobines Fish Farm 2017). See Section 2.2 for information on regulatory management of effluent impacts.

Open net pen culture represents the greatest potential concern for effluents. Rainbow trout net pen aquaculture operations release effluent directly into the surrounding environment—as either particulate matter or dissolved wastes (Boyd et al. 2005) (Otu et al. 2017a). For example, one large farm using net pens released between 18.9 and 23.2 MT of total phosphorus and between 97.3 and 120.4 MT of total nitrogen during 5 years of observation (as summarized in Otu et al. 2017). Particulate matter, which comprises feces and uneaten feed, typically settles to the benthos beneath a net pen array, including in rainbow trout culture (Boyd et al. 2005) (Otu et al. 2017a).

Most of the phosphorous is typically deposited on the benthos as solids (and some as dissolved waste (DFO 2015)), while the dissolved nitrogen can lead to increased ammonium or ammonia concentrations in the water column (Paterson et al. 2006). The release of nutrients from aquaculture facility effluent could lead to enhanced primary production beyond the allowable zone of effect (AZE). Increased primary productivity can yield a net positive impact on the ecosystem by increasing nutrient availability at the base of the food web; however, there is also the possibility of over-nutrification that can lead to a decrease in oxygen availability in the water column (in severe cases, anoxia), and cascading ecosystem effects. Oxygen depletion associated with net pen aquaculture has been implicated in mass cultured and wild fish mortalities under certain conditions (Boyd et al. 2005).

Ecological impacts outside of the farm area can be assumed as a potential risk associated with net pen rainbow trout farming in Canada. In 2003, DFO researchers established an experimental rainbow trout farm in Experimental Lake 375 to support research in understanding how rainbow trout net pen aquaculture might affect lake environments (Paterson et al. 2011), resulting in several publications.

For example, changes to water quality parameters were observed, including greater oxygen depletion (Bristow et al. 2008) (Mills et al. 2008), increases in water column total phosphorus (Bristow et al. 2008) (McPhee et al. 2015), and increases in ammonium (Bristow et al. 2008)—as well as greater loading of nitrogen and carbon (as reviewed in Paterson 2011). Sediments have also accumulated excess nutrients (Cornel and Whoriskey 1993) (Bristow et al. 2008).

Observed ecosystem effects attributed (directly or indirectly) to the presence of rainbow trout net pen culture in this experimental system included substantial decrease in benthic invertebrate density and diversity up to 100 m from trout net pens (McPhee et al. 2015), increased phytoplankton densities and shifts in community structure (Findlay et al. 2009), increases in growth and abundance of lake trout (Mills et al. 2008), declines in abundance and distribution of mysid shrimp (also with increasing growth rates in mysid shrimp (Paterson et al. 2011)), and greater growth and reproduction for clams a short distance from the net pen footprint (Kullman et al. 2007). Wellman et al. (2017) note that recovery from impacts for food webs or for some species may take several years, and Findlay et al. (2009) point out that impacts from nutrient loading are accumulative with continued/successive stocking of farmed fish.

Although stocking densities of trout for this experimental project (which was also sited in a small lake) were higher than permitted in Canada, it is clear from these experiments that rainbow trout aquaculture has the potential to impact ecosystems beyond the perimeter of the aquaculture net pen if not properly managed.

Nutrient inputs associated with Canadian lake net pen rainbow trout farming may be assimilated widely throughout the lake ecosystem and used directly and indirectly by native species, which could affect life history characteristics (Wellman et al. 2017). Impacts to sediments are likely to be more localized: Wetton (2013) observed that carbon deposition rates are highest directly beneath net pens, with 88–95% attenuation at 30 m from net pens, and summarizes that similarly high rates of attenuation were also observed at 5 m from net pens in previous studies. Wetton (2013) also observed that impacts of farm waste on sediment chemistry were limited to within 20–30 m from the net pens; Rooney and Podemski (2010) observed effects limited to within 3 m of the net pen boundary.

As Wellman et al. (2017) point out, ecosystem effects of effluent from lake net pen rainbow trout aquaculture likely vary, depending on local lake conditions and farming practices. The extent of effluent impacts beyond the AZE largely depends on farm siting criteria to ensure that the density of farmed fish does not exceed the overall carrying capacity of the receiving waterbody. For example, much of Ontario's rainbow trout net pen aquaculture is located in areas characterized by high flushing rates and large volumes of water, serving to alleviate nutrient buildup (Findlay et al. 2009). Otu et al. (2017) point out that, despite several attempts at finding or tracking aquaculture-associated algal blooms, only one published report exists since 1997, and suggest that smart management regulatory practices can mitigate impacts of effluents.

The Experimental Lakes research has served to advise management of rainbow trout culture in Canada. The risk of eutrophication in Canadian lakes from inputs of phosphorus at current net pen aquaculture production levels and practices is currently considered "low" by DFO; the agency also calls this industry in Lake Huron, for example, "currently sustainable" (DFO 2015b). And, DeJager (2009) points out that long-term monitoring has yet to document detectable increases in nutrient concentrations—something also stated by Otu et al. (2017) as true in Saskatchewan.

Risk-Based Assessment
Effluent data quality and availability is moderate–high (i.e., Criterion 1 score of 7.5 out of 10 for the Effluent category) for the majority of the national industry's production. But effluent data quality and availability is lacking for flow-through systems, and much of the information available is based on experimental farm research rather than on actual farm monitoring data. Thus, the Seafood Watch Risk-Based Assessment was utilized. This method involves estimating the amount of waste produced by the fish and then the amount of that waste that is discharged from the farm. The effectiveness of the regulatory system in managing wastes from multiple farms is used to assess the potential cumulative impacts from the industry.

Factor 2.1 Waste discharged per ton of fish production

<u>Factor 2.1a—Biological waste production per ton of fish</u>
Factor 2.1a uses a formula that includes the protein content of rainbow trout feed, the Economic Feed Conversion Ratio (eFCR), the protein content of harvested whole fish, and a nitrogen content factor to derive nitrogen[1] fluxes in the form of fish produced and harvested.

A precise economic feed conversion ratio (eFCR) for trout farming is difficult to ascertain because it can vary substantially from farm to farm, based on feeding practices, quality of feed, environmental conditions, and production practices. One of the largest trout producers in Ontario provided eFCR data for each of its operational net pens from 2011 to 2014 and confirmed that eFCR values ranged from 1.29 to 1.39; data from a 2008–2013 survey of five producers suggested a mean of 1.39 and a range of 1.20–1.68 (Skipper-Horton 2013). A review by Out et al. (2017a) suggests a typical range of 1.15–1.35; this range aligns with reports from experts in Ontario's aquaculture sector (pers. comm., S. Naylor 2016) and as reported by

[1] It is acknowledged that phosphorus is the limiting nutrient in freshwater systems, and therefore more directly applicable to actual ecological impact than nitrogen; however, the use of waste/discharged nitrogen as a proxy for impact is nevertheless a relevant metric and is used in all Seafood Watch aquaculture assessments.

studies on rainbow trout aquaculture in Canada (Wetton 2013) (Wellman et al. 2017). Additionally, Canadian researchers have demonstrated an eFCR of 1.19 when using newer, high-performance feeds, which are currently part of provincial efforts at reducing phosphorus effluents (pers. comm., G. Vandenberg 2017), and an FCR of 1.1 might becoming more common (pers. comm., D. Marcotte 2017). For this assessment, 1.25 (the median from Otu et al. 2017) was used as a point of overlap between the reported ranges and from evidence that improved feeds have helped to achieve recent gains in reducing phosphorus effluent by this industry.

Crude protein levels in trout feeds vary from 40% to 46% (Cowx 2005) (Tucker and Hargreaves 2009) (Martin Mills 2017) (Taplow Ventures 2017) and an average value of 43% was applied to this assessment.

The protein content of whole harvested farmed trout is 15.7% (Dumas et al. 2007) (Liu 2016).

The values discussed above result in 60.88 kg of nitrogen produced per ton of farmed fish.

Factor 2.1b—Production system discharge

Net pens

Net pen culture systems sited in lakes—such as the typical production in Ontario and Saskatchewan—are considered open-exchange systems that receive a “Basic discharge score” of 0.8, which assumes that 80% of the waste produced by fish is discharged by the farm outside the immediate farm area (i.e., outside the AZE) per the Seafood Watch Aquaculture Standard. No adjustments were awarded for waste-collection modifications or deductions taken for any reason.

With a discharge factor for Factor 2.1b of 0.8 out of 1, there is an estimated 48.7 kg of nitrogen discharged outside the farm boundary per ton of production.

The combination of Factors 2.1a and 2.1b results in a final Factor 2.1 score of 5 out of 10 for net pen culture.

Raceways, Tanks

Raceway and tank systems, such as those used by some producers in Quebec and Ontario, feature at least some solids collection and appropriate disposal (pers. comm., G. Vandenberg 2017). Thus, a “Basic discharge score” of 0.8 is awarded, which assumes that 80% of the waste produced by fish is discharged by the farm per the Seafood Watch Aquaculture Standard. A growing segment of the industry in Quebec is adopting semi-closed systems, which include enhanced water quality improvement opportunities. For raceway and tank systems, an additional adjustment of –0.32 is awarded for the strong industry participation in a program (Quebec) that limits phosphorus discharge by 40% (i.e., 40% reduction of 0.8 = 0.48 (adjustment of –0.32)). This program makes use of improved feeds, increased water retention times, and filtration strategies to achieve reductions (pers. comm., D. Marcotte, MAPAQ 2017) (pers.

comm., G. Vandenberg 2017) (Bobines Fish Farm 2018), and is discussed in greater detail in Factor 2.2.

With a discharge factor for Factor 2.1b, there is an estimated 29.22 kg of nitrogen discharged outside the farm boundary per ton of production.

The combination of Factors 2.1a and 2.1b results in a final Factor 2.1 score of 7 out of 10 for raceway and tank systems.

Factor 2.2 Management of farm-level and cumulative impacts

Factor 2.2a: Content of effluent management measures

DFO's federal Aquaculture Activities Regulations mandate that finfish aquaculture facilities must take reasonable measures to minimize detriment from deposit of feces and feed, as well as mitigate risk of serious harm to fish outside the facility if the facilities are part of a commercial, recreational, or Aboriginal fishery. But provinces are more directly involved in the management of effluent in territorial waters.

Net Pens

Ontario

Phosphorus budgets for the Great Lakes have been assessed historically, with total phosphorus targets first set in 1983. The International Joint Commission, which regulates Great Lakes water quality cooperatively between Canada and the United States, revised total phosphorus targets in 2012 and again in 2015, with plans to set regional/site-specific targets (Otu et al. 2017b). Management of effluent from rainbow trout farms in Canada has focused on management of phosphorus released from these operations, and the work to understand total-lake phosphorus budgets is important to cumulative and farm-level management.

In Ontario, the Ministry of Natural Resources and Forestry (MNRF) is the lead agency responsible for aquaculture, because it issues licenses under the Fish and Wildlife Conservation Act (FWCA)[2] and manages the use of Crown lands under the Public Lands Act (PLA). The Ministry of Environment and Climate Change (OMECC) is responsible for issues relating to Ontario's waters (including sediments in waterbodies) as they enact the Ontario Water Resources Act (OWRA)[3] and the Environmental Protection Act (EPA).[4] Joint efforts between the two provincial ministries and other relevant stakeholders to establish water quality and sampling guidelines for aquaculture have been ongoing since 1999.

Under the Fish and Wildlife Conservation Act, the government of Ontario requires that operators of net pen aquaculture test, maintain, and report on water quality as a condition of

[2] https://www.ontario.ca/laws/statute/97f41
[3] https://www.ontario.ca/laws/statute/90o40
[4] https://www.ontario.ca/laws/statute/90e19

license (Government of Ontario 1997). In 2001, the Ministry of Environment (now OMECC) published *Recommendations for Operational Water Quality Monitoring at Cage Culture Aquaculture Operations*[5] following a multi-stakeholder workshop on the topic. The recommendations identified total phosphorous and dissolved oxygen as the most important water quality indicators and put forward six recommendations relevant to water quality and sediment sampling, as well as proposed limits for several water quality and sediment parameters (Ontario Ministry of Environment 2001). Although no formal policy or law was established from these recommendations, many were adopted as conditions of license at the time of publication, and aquaculture farms were then required to establish water quality and sediment monitoring stations and provide an annual report to the OME on sampling results (DFO 2015b) (Otu et al. 2017b) (pers. comm., Steve Summerfelt 2015). In addition, aquaculture licenses in Ontario allocate total annual feed volumes (the maximum at the largest facility in Ontario is 2,500 MT) and allowable phosphorus levels in feed to better monitor overall effluent impacts of the industry (Ontario Ministry of Environment and Climate Change 2016). Allowable feed quotas may be reduced if adverse impacts are detected in monitoring. The licensing process also limits sites to areas with sufficient flushing at depth to limit risk of anoxia (DFO 2015b) and considers cumulative inputs by restricting siting based on proximity to other cage sites, vacation cottage developments (i.e., housing), tributary outlets, and other factors (Otu et al. 2017b).

In 2009, the OMECC posted a *Water Quality Discussion Paper* and a *Sediment Discussion Paper* to support the new draft Coordinated Guidelines for Cage Aquaculture Application in Ontario proposed by the MNRF. Public comments on the draft guidelines suggested that further research and clarity were needed on some key aspects of the industry, particularly relating to overall environmental impacts on water and sediment quality. This led the MNRF to launch a 4-year research phase, including the 2010–2014 Collaborative Cage Aquaculture Sediment Policy Development Process (which involved First Nations, NGOs, net pen aquaculture operators, and provincial and federal agencies) and a collaborative research project with Fisheries and Oceans Canada on the environmental impacts conducted at the Experimental Lakes Area. The results of this research are the recently published *Provincial Policy Objectives for Managing Effects of Cage Aquaculture Operations on the Quality of Water and Sediment in Ontario's Waters*,[6] which were designed to support the new *Application Guidelines for Cage Aquaculture Facilities*. Both documents were released in March 2016 for public comment. The new *Application Guidelines for Cage Aquaculture*[7] outline, in detail, the process undertaken to determine the potential impacts of proposed operations on water and sediment quality. The Guidelines identify three types of potential farm sites,[8] and the review process for water and sediment quality varies depending on the type of application. Although the *Application Guidelines for Cage Aquaculture*

[5] https://archive.org/details/recommendationsf00boyd00002

[6] Retrieved from http://www.downloads.ene.gov.on.ca/envision/env_reg/er/documents/2016/012-7186.pdf

[7] https://www.ontario.ca/document/draft-guidelines-cage-aquaculture

[8] The three types of farm sites are: 1) enclosed basins/embayments with limited flushing; 2) partially exposed sites having good epilimnion/metalimnion flushing but limited or no hypolimnion exchange; 3) exposed locations where the hypolimnion is also well flushed.

are still under review, the embedded regulations (including standards and monitoring programs) have been fully implemented as of the 2015 aquaculture licenses (DFO 2015b) (pers. comm., S. Naylor 2017).

Although there is some uncertainty in the models used to set discharge limits (DFO 2015b), the effluent regulations now in place in Ontario are considered to be robust, because the new regulations are aquaculture-specific but part a system that considers cumulative impacts of all inputs at the waterbody scale; consider waterbody carrying capacity; are scientifically rigorous; and lead to site-specific effluent, biomass, and discharge limits that must be monitored multiple times per year.

Saskatchewan

Aquaculture impacts in Saskatchewan are managed by the Ministry of Environment and the Ministry's *Environmental Code*[9] and *Fisheries Regulations*.[10] Saskatchewan's *Environmental Code* widely encompasses human uses and impacts, and it outlines some general protections for water quality—including reporting of discharges, monitoring requirements, and licensing requirements (Saskatchewan Ministry of Environment 2015). Saskatchewan's conditions of license currently require an inspection of the waterbody prior to licensing—including gathering of baseline environmental conditions (Sweeney International Management Corp. 2010) (Government of Saskatchewan 2014a) and ongoing monitoring of total phosphorus, dissolved oxygen, and sediment quality—with adverse impacts triggering additional monitoring and possible reductions in allowable feed quotas (DFO 2015b). Annual reporting of results is required (Government of Saskatchewan 2014b) but protected for confidentiality reasons (pers. comm., Jennifer Merkowsky, Saskatchewan Ministry of Environment 2017). The province also mandates use of low-phosphorus feeds and appropriate siting (Otu et al. 2017a).

Saskatchewan's Environmental Assessment Act[11] (which is guided by and coordinated with the federal Environmental Assessment Act) additionally mandates that projects (such as aquaculture development projects) that pose significant environmental risk undergo a formal Environmental Impact Assessment (EIA) process. For example, a permit application for facility expansion by the lone rainbow trout operator in this province mandated the consideration of the aquaculture carrying capacity of Lake Diefenbaker (making it site-specific), with consideration of existing inputs, and outlined data requirements in setting a baseline and conducting monitoring (Saskatchewan Ministry of Environment 2008). Nitrogen and phosphorus loading from this facility have been estimated, as well as relative contributions of total phosphorus inputs to the lake from this facility (Otu et al. 2017a); study of lake-wide phosphorus cycling has also been done (Otu et al. 2017b). But Otu et al. (2017b) note that overall monitoring data for this reservoir are sparse, which may make it challenging to understand cumulative impacts from a management standpoint.

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[9] http://publications.gov.sk.ca/documents/66/89764-f50902aa-6efc-438f-b4c7-89a3b83c94c2.pdf

[10] http://www.publications.gov.sk.ca/details.cfm?p=1116

[11] http://www.qp.gov.sk.ca/documents/English/Statutes/Statutes/E10-1.pdf

Management objectives and regulatory limits are outlined in *Saskatchewan's Surface Water Quality Objectives*[12] and *Canadian Council of Ministers of the Environment (CCME) Environmental Quality Guidelines*[13] specific to water quality and aquatic sediments. These guidelines are used to develop permits related to effluent/wastewater discharge, seek protection of aquatic life and drinking water, and are science- and ecosystem-based, as well as site-specific. The *Surface Water Quality Objectives* set out to prevent nutrient loading that results in eutrophication or algal blooms, and establish levels in relation to the carrying capacity of the receiving waterbody for all potential sources of effluent/wastewater (Canadian Council of Ministers of the Environment 2003) (Saskatchewan Water Security Agency 2015).

Permit specifics are not publicly available, although insight into the monitoring program and some requirements is possible via a 2010 Environmental Impact Statement, pursuant to an expansion sought by the producer in Lake Diefenbaker. Evidence also exists of ongoing management practices by the producer and regulators aimed at limiting effluent impacts (Sweeney International Management Corp. 2010) (Otu et al. 2017a).

Saskatchewan appears to have a site-specific and cumulative management system in place for effluents from across inputs, including the aquaculture industry. Limits are based on the carrying capacity of the waterbody, and evidence exists that monitoring is occurring. Some monitoring data are available in recently published literature.

The content of effluent management measures of net pen production systems is deemed comprehensive, because they consider other effluent input sources along with the carrying capacity of the receiving water body. Therefore, the score for Factor 2.2a is 5 out of 5.

Raceways, Tanks

Quebec

The Ministry of Agriculture, Fisheries and Food (MAPAQ) is the lead regulatory authority in Quebec for licensing and monitoring freshwater aquaculture, and it oversees the Quebec Aquaculture Regulation. The Aquaculture Regulation lays out a number of conditions aimed at protecting the environment and wildlife: such as, that aquaculture operations must not leach toxic substances to the surrounding environment; that solids must be retained and removed between production cycles; and that effluents be limited to the absorptive capacity of the receiving waterbody.

The Ministry of Sustainable Development, Environment, and Fight Against Climate Change (MDDELCC) additionally enacts regulation applicable to effluent: *Loi sur la qualité de l'environnement* (Law on the Quality of the Environment).[14] The Law does not establish

[12] http://www.saskh2o.ca/pdf/epb356.pdf
[13] http://ceqg-rcqe.ccme.ca/en/index.html
[14] http://www.mddelcc.gouv.qc.ca/lqe/autorisations/index.htm

aquaculture-specific regulations, but does require aquaculture operators to get a certificate of authorization (CA) that permits them to discharge wastes and effluents into the environment. In 2014, the MDDELCC published an environmental risk matrix for phosphorous levels in effluents discharged from freshwater aquaculture (*Grille d'analyse environmentale pour les piscicultures en fonction des rejets de phosphore total*[15]) that sets out specific guidelines on how farms can receive their CA, based on the size and type of waterbody where the farm is located, and as part of an assessment on where projected effluent inputs fit within established total loads for a given watercourse. The regulations consider cumulative impacts to waterbodies, with regard to existing inputs and the assimilative capacity of the receiving environment (MAPAQ 2016).

In 2004, the Association of Aquaculturists in Quebec (AAQ), the MAPAQ, and the MDDELCC (then known as the Ministry of Environment and Parks) developed the Strategy to Develop Sustainable Freshwater Aquaculture in Quebec (STRADDAQ).[16] The general objective of the STRADDAQ was to have aquaculture farms reduce the phosphorous content of their effluent to 4.2 kg per ton of fish per year by 2017, which was equivalent to about a 40% reduction in phosphorous levels. The program makes use of improved feeds, increased water retention times, and filtration strategies to achieve reductions (pers. comm., D. Marcotte 2017) (pers. comm., G. Vandenberg 2017), and also contains guidelines on sludge treatment (Government of Quebec 2010). The program was voluntary and, to date, 32 companies (representing at least 80% of Quebec's production) have joined by monitoring their phosphorus discharges and completing environmental improvements. One company reached the target in 2015, and individual reporting for all participants is currently in progress, though it appears that widespread compliance has been achieved recently (pers. comm., G. Vandenberg 2017). For farms licensed after 2014, participation is mandatory (MAPAQ 2014) (pers. comm., M. Lambert 2017); presently, all the large and medium-sized producers are participants (pers. comm., G. Vandenberg 2017).

Notably, the industry in Quebec, where production is dominated by flow-through systems, is now moving toward the increased use of semi-closed systems—including by the province's largest producer, which reports recirculating 85% of its water (pers. comm., G. Vandenberg 2017) (Bobines Fish Farm 2018).

Factor 2.2a scores 5 out of 5 for raceway and tank systems, such as those found in Quebec, because the content of effluent management measures is deemed comprehensive and they consider other effluent input sources along with the carrying capacity of the receiving water body.

Factor 2.2b: Enforcement of effluent management measures

[15] http://www.mddelcc.gouv.qc.ca/milieu_agri/aquacole/grille-analyse-piscicultures.pdf
[16] http://www.mapaq.gouv.qc.ca/fr/Pages/Details-Publication.aspx?guid=%7B7dbdc609-93bf-41b5-adc6-0c6582f8fb01%7D

Net pens

Ontario

Aquaculture operators are required to sample a suite of water quality and sediment parameters (e.g., total phosphorous, Secchi disk readings for water clarity, dissolved oxygen, and temperature) to monitor both near-field and far-field effects. The results of this monitoring are self-reported annually (by a third party/qualified consultant) to the Ministry of Environment; a registered laboratory must analyze water and sediment quality testing, and audits of self-reported data occur. If water quality or sediment sampling exceed the trigger limits, then license holders are required to conduct an operation audit, submit an abatement plan, and increase frequency of sampling (pers. comm., S. Naylor 2017). The Ministry of Natural Resources is charged with inspection of facilities, which is scheduled with consideration for the level of risk associated with the operation (Ontario Ministry of Natural Resources 2009). Overall compliance and enforcement activities are coordinated between the Ministry of Natural Resources and Ministry of Environment.

Conversations with regulators in Ontario indicate that all the land-based operators meet phosphorus discharge requirements. Noncompliance, as indicated by mandatory monitoring and reporting, comes with an abatement plan requirement (pers. comm., S. Naylor 2017), though some apparent uncertainty exists in that some operators are not reporting relevant data (DFO 2015b). Some snapshots of data are available in the scientific and government literature (Otu et al. 2017a). Otu et al. (2017) state that, although there have been some detections of slightly elevated levels of total phosphorus near net pen farms, there have been no instances of exceedances of regulatory limits on total phosphorus at net pen farms in Ontario since 1998. The same review also states that there have been no reports of elevated Chl-a or phytoplankton community composition changes at fish farms in Lake Huron or Lake Diefenbaker, and that no permitting revocations have been required in 15 years. One major producer, representing > 95% of Ontario production, provided copies of their water and sediment quality monitoring data for some sites and provided reports from the previous 2 years, and this work indicates compliance for this operator. The same producer provided evidence that their feeds comply with low phosphorus requirements (pers. comm., R.J. Taylor 2018).

Further, there is evidence that most feeds are in compliance with maximum permitted phosphorus levels (McPhee et al. 2015) (Otu et al. 2017b) and that, industry-wide, reductions in phosphorus effluent through management measures have been effective (DFO 2015b); phosphorus inputs from cage aquaculture to freshwaters have been in decline since 2001 (Otu et al. 2017b). Although actual enforcement data are lacking in the public domain, agency publications state that no significant noncompliance issues have been detected with water quality standards for this industry since monitoring was implemented, and these publications demonstrate that regulatory action has been taken in the past (DFO 2015b). Regulators describe cage aquaculture in Lake Huron in terms of effluent management as “currently sustainable” (Otu et al. 2017b). The Ontario industry apparently plans to make all water quality monitoring data publicly available via their industry website in 2019.

Saskatchewan

Saskatchewan's Environmental Code widely encompasses human uses and impacts, and it outlines some general Enforcement and Compliance authority and guidelines, including the use of investigations and audits, the issuance of warnings and penalties, license suspension or cancellation, and prosecution (Saskatchewan Ministry of Environment 2015).

Saskatchewan's conditions of license for fish farming currently require ongoing monitoring of water and sediment quality—with adverse impacts triggering additional monitoring and possible reductions in allowable feed quotas (DFO 2015b), along with evidence that the Ministry of Environment conducts audits related to environmental permitting requirements. The Saskatchewan Ministry of Environment's website has a Compliance and Enforcement page that provides some general information on enforcement infrastructure and provides enforcement data (e.g., the number of inspections and audits conducted across all environmentally regulated entities) in annual reports, although this information is also general and lacks specific insight into the aquaculture industry.[17]

Though enforcement is identifiable and contactable, specific monitoring data are not publicly available due to confidentiality concerns associated with a single producer in the province. A 2010 Environmental Assessment for an expansion of Saskatchewan's lone farm provides some evidence that water quality and sediment monitoring is occurring and that baseline studies related to siting are being conducted (Sweeney International Management Corp. 2010). A 2017 study by Otu et al. provides some evidence that this farm may not be a significant source of nutrient loading to the lake (Otu et al. 2017c). The study credits best practices by the farm and provincial regulation. This study is only a snapshot, and provision of ongoing monitoring data could strengthen this argument. There is additional evidence that most feeds are in compliance with maximum permitted phosphorus levels (McPhee et al. 2015) and that monitoring of these production systems nationwide has not revealed any significant noncompliance issues (DFO 2015b).

Overall, enforcement of regulations pertaining to net pen systems is considered effective, but with some uncertainty due to the lack of provision of monitoring or enforcement data and the apparent lack of full reporting. Thus, Factor 2.2b scores a 4 of 5 for net pen systems.

Factors 2.2a and 2.2b combine to result in a final Factor 2.2 score of 8 out of 10 for net pen systems, such as those found in Ontario and Saskatchewan. This reflects the uncertainty over regulatory limits and enforcement effectiveness. This factor would benefit from additional information.

Raceways, Tanks

[17] http://www.environment.gov.sk.ca/compliance-enforcement;
http://www.publications.gov.sk.ca/details.cfm?p=87095

Quebec
The STRADDAQ outlines procedures for handling environmental impacts that can be attributed to aquaculture facilities. These procedures include finding the means to reduce effluent pollutants (phosphorus), such as through implementation of technology, reduction in production volumes, relocation of the farm, or closure. Monitoring to validate phosphorus effluent reduction program functionality is conducted by MDDELCC (pers. comm., D. Marcotte 2017). Monitoring and detailed compliance information is not publicly available, and attempts to acquire information from regulators at MDDELCC and MAPAQ were unsuccessful for this assessment. Additionally, this program only applies to farms producing over 5 tons and is voluntary, but the wide participation in terms of both total production and number of producers (32 companies representing at least 80% of Quebec's production) is evidence of its effectiveness. Additionally, all participants have maintained compliance with program standards (Aquaculture Quebec 2018).

Both MAPAQ and the MDDELCC have some degree of an enforcement branch. MDDELCC maintains a website with general information on reporting complaints, investigation, and issuance of penalties, but without data useful in assessing its effectiveness.

Enforcement agencies are clearly identifiable and contactable, with evidence of infrastructure regarding environmental compliance and penalties. The broad participation of the rainbow trout industry in the STRADDAQ program is some evidence of industry compliance with regulations aimed at managing effluent, as are statements by regulators that monitoring occurs. There is additional evidence that most feeds are in compliance with maximum permitted phosphorus levels (McPhee et al. 2015).

But specific information and data on enforcement (and monitoring) has not been made available. Thus, the score for Factor 2.2b for raceway and tank systems, such as in Quebec, is 4 out of 5.

Factors 2.2a and 2.2b combine to result in a final Factor 2.2 score of 7 out of 10 for raceway and tank systems, such as those found in Quebec. This reflects the comprehensive quality of the existing regulations but significant uncertainty around enforcement. This sub-criterion would benefit from additional information.

Factor 2.2 Summary

Net pens
The open nature of net pen trout farms makes the release of effluent a potentially significant concern in these production systems. Application of best management practices and regulatory requirements at the farm and cumulative levels, including feed management, appropriate farm siting guidelines, and use of low-phosphorus feeds, helps to alleviate some of the environmental concern of effluents. Monitoring is occurring, and agency documents provide statements on industry compliance; however, access to monitoring data is limited—some short-term monitoring data available for Saskatchewan are suggestive of effective effluent

management. The new regulations recently implemented in Ontario provide a stronger regulatory oversight of effluent from net pen aquaculture, but robust data on enforcement are limited.

Raceways, Tanks

Quebec scores highly for content of regulations and effectiveness of its land-based systems. Documented and measurable reductions in phosphorus discharge from improved feeds, increased water retention, and improved filtration systems allow for adjustments to the Effluent Basic Score for raceway and tank systems, but there is a lack of availability of monitoring data or further information on enforcement and compliance to further validate.

Conclusions and Final Score

Effluent release is a primary concern for rainbow trout farms in Canada. Land-based and net pen systems have the potential to discharge nutrients and wastes that can cause harmful farm-level and cumulative effects to receiving waterbodies. Canada has implemented comprehensive and science-based waste and nutrient release reduction strategies, including improved feeds, regulations on feeding, and improved water retention and filtration approaches (particularly for land-based systems). Additionally, siting guidelines and monitoring requirements in provinces using lake net pen systems aim to reduce and regulate effluents. There is some evidence that monitoring is occurring, though access to data is limited; access to enforcement data is also limited. There is some evidence that regulation and best practices have been effective in reducing concerns related to effluent in all provinces.

Net pen systems score 7 out of 10 for the use of improved feeds, appropriate siting, and monitoring, although the availability of monitoring data and enforcement information is limited.

Raceway and tank systems score 7 out of 10 for demonstrated significant reductions in nutrient effluent emissions through the use of improved feeds and filtration strategies. Regulations are robust, but information availability on monitoring and enforcement is limited.

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: being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats.

Criterion 3 Summary

Net pens

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		7
F3.2a Content of habitat regulations	5	
F3.2b Enforcement of habitat regulations	4	
F3.2 Regulatory or management effectiveness score		8
C3 Habitat Final Score (0–10)		**7.33**
Critical?	NO	**GREEN**

Raceways, Tanks

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		9
F3.2a Content of habitat regulations	4	
F3.2b Enforcement of habitat regulations	4	
F3.2 Regulatory or management effectiveness score		6
C3 Habitat Final Score (0–10)		**8.13**
Critical?	NO	**GREEN**

Brief Summary

Net pen systems typically have little direct impact on the habitats where they are sited, but operational impacts are considered more likely. Waste materials settling under structures have been demonstrated to alter sediment chemistry and impact community structure directly under the farm site. Recovery may be facilitated by fallowing, but this is not explicitly required, and recovery time may vary by site and monitoring metric. Regulation in Canada is generally effective, is guided by science, includes monitoring, and considers farm-level and cumulative impacts. Evidence exists of enforcement, industry compliance, and effective best management practices. The content of management measures is considered comprehensive and enforcement is deemed robust. For net pens, Factors 3.1 and 3.2 combine to give a final Criterion 3—Habitat score of 7.33 out of 10.

Raceway and tank systems are generally situated adjacent to high-quality water sources, from which water is withdrawn before being returned to it. Groundwater may also be withdrawn and discharged; some recirculation also occurs. These production systems are efficient with land use, so they require small areas of land for operation and may also be situated on existing terrestrial farmland; small farms (< 5 MT annual production) are also most common in Quebec. Concerns with these systems centers more around effluent as described in Criterion 2. Content of management measures and enforcement are considered robust. Factors 3.1 and 3.2 combine to give a final Criterion 3—Habitat score of 8.13 out of 10.

Justification of Rating

Factor 3.1. Habitat conversion and function
Criterion 3—Habitat aims to assess the impact of aquaculture farms on the immediate vicinity of farm sites; i.e., within the allowable zone of effect (AZE). For open freshwater aquaculture systems, direct ecosystem impacts occur from either the physical siting of a farm in an ecosystem or the release of wastes and particulate matter that settle on the benthos below a net pen array.

<u>Net pens</u>
Net pen systems are likely to have little direct habitat impacts as a result of siting the farm infrastructure and the structures themselves may offer some habitat services (DeJager 2007) (pers. comm., S. Naylor 2018), but they have been demonstrated to impact benthic habitat through sedimentation of waste materials.

Sediments beneath experimental rainbow trout net pens in Canada have seen an accumulation of excess nutrients (Cornel and Whoriskey 1993) (Bristow et al. 2008). The impact of particulate wastes such as phosphorus (DFO 2015b) released from aquaculture farms can be a significant concern on overall ecosystem health, especially in net pen systems where waste capture and filtration methods are not used (unlike in typical raceway and tank systems). Particulate wastes, such as uneaten feed and feces (DFO 2015b), typically settle to the benthos below a net pen. There, they increase nutrient availability, which can lead to zone of hypoxia and a reduction of benthic biodiversity (Brooks and Mahnken 2003) (Paterson et al. 2011).

The extent of benthic impacts from freshwater net pen aquaculture in Canada has been investigated in the Experimental Lakes Area, where an investigational commercial rainbow trout farm was introduced and the environmental impacts were monitored (Wellman et al. 2017). Researchers with this program documented a variety of habitat impacts attributed to the farm. For example, Rooney and Podemski (2010) observed significant changes to sediment chemistry under experimental trout net pens, including elevated pore-water ammonium, sediment nutrients, and heavy metals. Rooney and Podemski (2009) studied the changes to the zoobenthos and found that, within two months of the trout farm being active, there was a decrease in invertebrate abundance and taxa richness; however, the impacts were localized and only detectable within 15 m of the net pen edge. Kullman et al. (2007) observed total mortality of a native clam species directly under trout net pens that was associated with a change in the sediment density and high concentrations of zinc. The potential for significant habitat impacts beneath a floating rainbow trout pen is apparent.

Wellman et al. (2017) note that recovery from impacts for food webs or for some species may take several years, and Findlay et al. (2009) point out that impacts from nutrient loading are accumulative with continued stocking of farmed fish. On the other hand, the DFO considers fallowing as a mitigation tool (DFO 2015b).

As Wellman et al. (2017) also point out, ecosystem effects of effluent from net pen rainbow trout aquaculture likely vary by local lake conditions and farming practices. The extent of habitat impacts may be influenced by farm siting criteria to facilitate dispersal of wastes. For example, much of—though not all of (Otu et al. 2017b)—Ontario's rainbow trout net pen aquaculture is located in areas characterized by high flushing rates and large volumes of water, serving to alleviate nutrient buildup (Findlay et al. 2009). Otu et al. (2017a) suggest in their review that benthic habitat impacts from net pens (in terms of solid phosphorus waste) are typically limited to the footprint of the net pen farm.

Findings from the experiments at Lake 375 have been used to advise regulation of freshwater net pen aquaculture. Proper siting, adjusting stocking densities, and feed management strategies can mitigate benthic impacts—all of which are considered as part of aquaculture licensing processes in Canada. Ontario and Saskatchewan mandate sediment monitoring as part of conditions of license, but monitoring data are not publicly available. One major producer provided sediment monitoring data and summary reports from 2016 and 2017, thus indicating compliance with monitoring and reporting requirements, validating that monitoring design evaluates the onsite and offsite impacts of aquaculture waste, and suggesting the ability of large producers to comply with conditions of permit aimed at minimizing habitat impacts. So, it is assumed that habitat impacts resulting from sedimentation of aquaculture wastes are occurring within the boundary of the farm footprint (as research indicates is possible) but that research-based regulations are effective at minimizing impacts and to within the footprint of farm sites.

Raceways, Tanks

Land-based systems are most often constructed of concrete raceways, earthen ponds, or circular tanks, and they have a more apparent physical footprint than net pen aquaculture. They are often situated adjacent to a water source (Rooney 2006); can be sited in high-value habitat along rivers and streams in Canada (Lalonde et al. 2016) or in riparian lands that require water diversion from rivers, streams, or wells; and may, in some cases, be associated with erosion. Other designs withdraw groundwater, and these and partially closed systems (or partial reuse systems) may be sited in areas of more limited water resources (Government of New Brunswick 2010) and may be sited on existing terrestrial farm sites (Bobines Fish Farm 2017) (Ferme Cedar Creek 2018). Small farms (< 5 MT annual production) are also most common in Quebec. Impacts may come in the form of changes to stream flow patterns or groundwater resources (Boyd et al. 2005) (Rooney 2006) resulting from water diversion. Additional habitat impacts—and the focus of more attention with raceway and tank systems—relate to discharged effluent, which can lead to oxygen depletion and benthic impacts around outfalls in receiving waters, as described in Criterion 2—Effluent.

But overall, the types of raceway and tank systems used for rainbow trout production in Canada are an efficient production method in terms of land conversion: a small amount of land is required for commercial scale production. Boyd (2005) estimates that a large farm producing 1,000 MT of trout annually will require (generally, not specific to Canada) only about 3.33 ha of culture area, and contrasts this with the land-intensive production systems for catfish and tilapia. In Quebec, about 4.58 hectares of a potentially suitable 200 hectares are presently used for aquaculture—about a 2.3% occupation of suitable space (Canadian Aquaculture Alliance 2017). Further, only 20% of Quebec producers are using traditional flow-through systems (gravity-fed, often near streams) (pers. comm., G. Vandenberg 2017), and land used for upland fish farming may be converted from previous terrestrial farm sites (Bobines Fish Farm 2017) (Ferme Cedar Creek 2018).

Boyd (2005) also argues that water use in flow-through trout culture should not be considered “consumptive,” because water is returned to the system following its use. Impacts related to flow-through systems focus primarily on effluent, as covered in Criterion 2.

<u>Summary</u>

Raceway and tank systems are generally located near water sources, such as in the riparian area of streams or nearby. They may also be sited in land converted from temperate forest, and thus can be sited in “moderate” value habitat. On the other hand, some farms rely on groundwater and exist on sites converted from other human uses. But in general, the area of the land converted is small, and impacts are focused more on effluent, as assessed in Criterion 2. Habitat impacts from raceway and tank systems on the functionality of the ecosystems in which they are sited are considered minimal. For raceway and tank systems, the score for Factor 3.1 is 9 out of 10.

Net pen systems are sited in freshwater lakes, which are considered high-value habitats. Impacts to benthic habitat underlying rainbow trout farms have been demonstrated to influence abundance and community structure within the farm footprint but are likely reversed through fallowing (Tucker and Hargreaves 2009), and limited monitoring data suggest that at least some habitat functionality can be preserved through proper management. Thus, habitat impacts resulting from net pen systems are considered moderate. For net pens, the score for Factor 3.1 is 7 out of 10.

Factor 3.2. Farm siting regulation and management

Factor 3.2a: Content of habitat management measures

As previously noted, licensing and regulation of freshwater aquaculture in Canada occurs provincially, so the specifics of the management effectiveness vary from province to province. Therefore, an overview of management systems in the three main freshwater trout producing provinces is provided here.

Net pens

Ontario

New *Application Guidelines for Cage Aquaculture Facilities* were released by the Ontario Ministry of Natural Resources and Forestry (MNRF) in 2015. Although they are still being finalized formally, they have been fully implemented for all aquaculture applications and licenses as of 2015 (pers. comm., S. Naylor 2017). The guidelines document an extensive application process that can take from 6 months to 2 years to complete, depending on the scope of the proposed project. The guidelines require that all projects go through some level of environmental impact assessment and require a site-specific assessment for each project relative to the carrying capacity of the receiving waterbody. No specific limits on industry size or concentration are outlined therein but, as stated in the OMECC 2016:

The receiving water-based OMECC water and sediment quality objectives for cage aquaculture operations set out in this document are supported by research information available in literature and the OMECC's own data from extensive monitoring of water quality and sediment conditions at both operational and decommissioned cage aquaculture operations in Ontario.

Surface water quality objectives are further outlined in a number of related policy documents, such as *Water Management Policies, Guidelines, Provincial Water Quality Objectives; Procedure B-1-5 Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters* (a procedure for deriving wastewater effluent requirements); and *Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An Integrated Approach, which includes the Provincial Sediment Quality Guidelines (OMECC 2016).*

There are numerous laws in place at both the provincial and federal level that protect sensitive and high-value habitat that aquaculture development are subject to, such as:

- Fish and Wildlife Conservation Act, 1997[18] and Ontario Regulation 664/98 (provincial)
- Public Lands Act[19] (provincial)
- Ontario Water Resources Act[20] and the Environmental Protection Act[21] (provincial)
- Provincial Parks and Conservation Reserves Act, 2006 (provincial)
- Endangered Species Act,[22] 2007 (provincial)

[18] https://www.ontario.ca/laws/statute/97f41
[19] https://www.ontario.ca/laws/statute/90p43
[20] https://www.ontario.ca/laws/statute/90o40
[21] https://www.ontario.ca/laws/statute/90e19

- Fisheries Act[23] (federal)
- Species at Risk Act[24] (federal)

The siting of cage operations considers other habitat values (Figure 4), such as spawning grounds, tributary mouths, and species at risk habitats (Otu et al. 2017b).

Layer	Red Zone Ruling
Operational Cage Sites	No new cage site within 3000 m of an existing site
Water Protection Act Obstructions	No cage site within a minimum of 100 m of an existing NWPA obstruction
Navigable Waters Protection Act (NWPA) Obstructions	No cage site within a minimum of 100 m of an existing NWPA obstruction
Whitefish Spawning Area	No cage site within 100 m of spawning area
National/Provincial Parks and NGO Reserves	No cage site within 100 m of park/reserve boundary
Tributary Mouth	No cage site within 1000 m of tributary mouth
Species At Risk	No cage site within 5000 m of a location where SAR has been found

Figure 4. Rules for siting aquaculture cage operations (DFO unpublished data, from Otu et al. 2017a).

In Ontario, conditions of license for aquaculture farms require that water quality and sediment monitoring occur, with sampling data reported to the OME. This monitoring also requires a full year of baseline monitoring prior to installation of new facilities or, in some cases, for the reissuance of permits for existing facilities (Ontario Ministry of Natural Resources 2009) (DFO 2015b) (pers. comm., Steve Summerfelt 2016). In addition, aquaculture licenses in Ontario allocate total annual feed volumes per farm (the maximum for the largest site is 2,500 MT) and allowable phosphorus levels in feed as a means to better monitor overall effluent impacts of the industry (Ontario Ministry of Environment and Climate Change 2016). Allowable feed quotas may be reduced if adverse impacts are detected in monitoring. The licensing process also limits sites to areas with sufficient flushing at depth to limit the risk of phosphorus loading and anoxia (DFO 2015b). There are additional siting guidelines in place as well as requirements for the development of decommissioning plans, which include post-decommission monitoring to ensure environmental impacts are resolved (for 10 years or until benthic habitats have recovered) (Ontario Ministry of Natural Resources 2009). Additionally, fallowing has been

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[22] https://www.ontario.ca/laws/statute/07e06
[23] http://laws-lois.justice.gc.ca/eng/acts/f-14/
[24] http://laws-lois.justice.gc.ca/eng/acts/s-15.3/

recommended as a potential management tool if needed, although it is not explicitly required (DFO 2015b).

The application and farm siting process articulated in the new application guidelines are clear, transparent, and extensive, and function according to ecosystem-based management principles by assessing site applications relative to the carrying capacity of the receiving waterbody.

Additionally, as described in Criterion 2—Effluent, Ontario scores well for content of management measures because it considers cumulative impacts of effluents on benthic habitat and implements decommissioning and recovery requirements.

Saskatchewan

Project applicants in Saskatchewan are required to conduct an Environmental Impact Assessment, which directs the consideration of cumulative impacts to habitat related to effluent and sedimentation, including the mitigation of impacts (Saskatchewan Ministry of Environment 2011). An EIA also mandates that applicants develop site decommissioning and reclamation plans, lend consideration to proper siting, and provide evidence of the producer's desire to reduce the risk to habitat and water quality through best management practices (Saskatchewan Ministry of Environment, 2008).

Saskatchewan's conditions of license currently require ongoing monitoring of total phosphorus, total nitrogen, and ammonia (twice annually); dissolved oxygen and temperature (daily); and benthic invertebrate population data (annually). Data are presented in an annual report to provincial regulators, with adverse impacts triggering additional monitoring and possible reductions in allowable feed quotas (DFO 2015b) (pers. comm., D. Foss 2017). The Saskatchewan industry is currently a single producer in a single waterbody.

Additionally, as described in Criterion 2—Effluent, Saskatchewan scores well for content of management measures in regard to managing the impacts of effluents on benthic habitat.

<u>Summary</u>

Overall, the habitat and farm siting management for net pens in Canada is considered comprehensive. Aquaculture impacts are managed as part of a cumulative perspective considering other potential inputs to the lake environment, with baseline and monitoring requirements in place to guide potential expansion, and with requirements that decommissioning and reclamation plans be developed. The score for Factor 3.2 is 5 out of 5.

A score of 5 out of 5 is awarded for Factor 3.2a: Content of habitat management measures for net pens.

Raceways, Tanks

Quebec

The Ministry of Agriculture, Fisheries and Food (MAPAQ) is the lead regulatory authority for aquaculture in Quebec and acts as a single source for aquaculture licensing and operations.

MAPAQ issues aquaculture licenses under the provincial Act Respecting Commercial Aquaculture. But it will also coordinate with other provincial agencies that have relevant mandates, such as the Department of Forests, Wildlife and Park, which grants approval to ensure the conservation and development of wildlife and its habitat; and the Department of Sustainable Development, the Environment and the Fight Against Climate Change (MDDELCC), which is responsible for issuing aquaculture leases for waters on Crown lands.

Aquaculture in Quebec is subject to a number of laws aimed at resource protection:

- Environmental Quality Act[25]
- Act to Affirm the Collective Nature of Water Resources and Provide for Increased Water Resource Protection[26]
- Act Respecting Commercial Aquaculture[27]
- Act Respecting the Conservation and Development of Wildlife[28]

A full description of the application process for freshwater aquaculture is readily available.[29] Under articles 22 and 32 of the Law on Environmental Quality, enacted by the MDDELCC, aquaculture operations are required to obtain a permit for the construction and operation of an aquaculture facility that would require some degree of environmental impact assessment. Results of all permitting decisions for projects requiring environmental assessment since 2000, as well as copies of certificates and reports, are publicly available.[30] The MAPAQ does set out 28 specific aquaculture zones, and rainbow trout culture is only allowed in 9 of them (use of open net pen systems in freshwater environments is additionally prohibited to protect lake environments); the cumulative impact of the farms has been addressed in siting criteria as it relates to effluents, with consideration for the assimilative capacity of the receiving environment (MAPAQ 2016).

The Commercial Aquaculture Regulations contain standards of construction requirements aimed at land-based aquaculture facilities and at ensuring the health of the surrounding environment and its wildlife. For example, facilities are to be constructed in a way that prevents contamination from leaking, facilitates retention and removal of solid wastes and of emptying, prevents contamination from surface water runoff from ponds, and includes a setback from watercourses. The Act additionally states (without offering many specifics) that a site used for commercial aquaculture, as well as the surrounding unexploited area, must be maintained as free of debris and returned to conditions satisfactory to the Minister after operations have ceased. The Wildlife Conservation and Enhancement Act empowers the government to restrict siting of aquaculture to protect wildlife; for example, the government does this through its

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[25] http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/Q-2
[26] http://www.mddelcc.gouv.qc.ca/eau/protection/index_en.htm
[27] http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=5&file=2003C23A.PDF
[28] http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/C-61.1
[29] http://www.mddelcc.gouv.qc.ca/milieu_agri/aquacole/cadre-reglement.htm
[30] http://www.mddelcc.gouv.qc.ca/evaluations/index.htm#meri

Aquaculture License Categories Regulations, which use zoning to protect native species of fish (Government of Quebec 2016).

Quebec manages water resources through its comprehensive Water Levy and Protection Regulations[31] and its Regulation respecting the declaration of water withdrawals.[32] Permitting of withdrawals takes into account the needs of aquatic ecosystems and other users of the resource—a cumulative approach. The Government of Quebec also directs water withdrawal permitting decisions to take into account the precautionary principle and the uncertainty associated with climate change (Government of Quebec 2018a).

Additionally, as described in Criterion 2—Effluent, Quebec scores well for content of management measures in regard to managing the impacts of effluents on benthic habitat.

Overall, regulatory requirements aimed at cumulative impacts management appear to be in place, but specific siting details are not readily available. For Quebec, the score for Factor 3.2a is 4 out of 5.

Factor 3.2b: Enforcement of habitat management measures

Because the most significant habitat impacts related to Canadian rainbow trout farms result from wastes discharged in the form of effluent, many of the same management and enforcement measures discussed in Criterion 2—Effluent apply here.

Net pens

Ontario

Aquaculture operators are required to monitor sediment chemistry parameters according to regulatory limits for phosphorus; additional parameters have been proposed. The results of this monitoring are annually self-reported to the Ministry of Environment; however, a registered laboratory must analyze water and sediment quality testing. If water quality or sediment sampling exceeds the trigger limits, license holders are required to conduct an operation audit, submit an abatement plan, and increase the frequency of sampling (pers. comm., S. Naylor 2017). The Ministry of Natural Resources is charged with inspections of facilities, which are scheduled based on consideration of the level of risk associated with the operation (Ontario Ministry of Natural Resources 2009). Overall compliance and enforcement activities are coordinated between the Ministry of Natural Resources and Ministry of Environment. Some documentation was provided in the form of monitoring data and reports to regulators from a large Ontario producer, indicating compliance with requirements. Copies of communications with regulators were also provided, providing some indication that compliance enforcement is active.

[31] http://legisquebec.gouv.qc.ca/fr/ShowDoc/cr/Q-2,%20r.%2035.2
[32] http://legisquebec.gouv.qc.ca/fr/ShowDoc/cr/Q-2,%20r.%2014

Conversations with regulators in Ontario indicate that all land-based operators meet phosphorus discharge requirements (pers. comm., S. Naylor 2017). There is evidence that most feeds are in compliance with maximum permitted phosphorus levels (McPhee et al. 2015) and that, industry-wide, reductions in phosphorus effluent through management measures have been effective (DFO 2015b). Although actual enforcement data are lacking, an agency publication states that no significant noncompliance issues have been detected with water quality standards for this industry since monitoring was implemented and demonstrates that regulatory action has been taken in the past. The same document also points out that some uncertainty exists in that some operators are not reporting relevant data (DFO 2015b), but this is refuted by the industry. Producers interviewed for this assessment state that they provide a substantial amount of data and information to regulators (pers. comm., D. Foss 2017) (pers. comm., O. Skipper-Horton 2018) (pers. comm., Anonymous 2018). Seafood Watch was additionally provided with some documentation to verify that federal regulators are engaged in compliance with federal regulations (pers. comm., Anonymous 2018).

Saskatchewan

Saskatchewan's Environmental Code widely encompasses human uses and impacts, and outlines some general Enforcement and Compliance authority and guidelines; e.g., the use of investigations and audits, the issuance of warnings and penalties, license suspension or cancellation, and prosecution (Saskatchewan Ministry of Environment 2015).

Saskatchewan's conditions of license for fish farming currently require ongoing monitoring of water and sediment quality—with adverse impacts triggering additional monitoring and possible reductions in allowable feed quotas (DFO 2015b), along with evidence that the Ministry of Environment conducts audits related to environmental permitting requirements. The Saskatchewan Ministry of Environment's website has a Compliance and Enforcement page that provides some general information on enforcement infrastructure, and it provides enforcement data (such as the number of inspections and audits conducted across all environmentally regulated entities) in annual reports, although this information is also general.[33]

Though enforcement is identifiable and contactable, specific monitoring data are not publicly available due to confidentiality concerns associated with a single producer in the province. A 2010 Environmental Assessment for an expansion of Saskatchewan's lone farm provides some evidence that water quality and sediment monitoring is occurring and that baseline studies are being conducted related to siting (Sweeney International Management Corp. 2010). A 2017 study by Otu et al. does provide some evidence that this farm may not be a significant source of nutrient loading to the lake (Otu et al. 2017c). The study credits best practices by the farm and provincial regulation. This study is only a snapshot, and ongoing monitoring data could strengthen this argument. There is additional evidence that most feeds are in compliance with

[33] http://www.environment.gov.sk.ca/compliance-enforcement; http://www.publications.gov.sk.ca/details.cfm?p=87095

maximum permitted phosphorus levels (McPhee et al. 2015) and that monitoring of these production systems nationwide has not revealed any significant noncompliance issues (DFO 2015b).

Overall, enforcement is considered effective, but with some uncertainty due to the lack of monitoring or enforcement data, the lack of full reporting, or the absence of a statement on industry compliance. Without specific data, it is difficult to comprehensively assess the effectiveness of enforcement of effluent management as it relates to habitat impacts. For this reason, this sub-factor scores 4 out of 5 because of some uncertainty that could be supported with additional information.

Factors 3.2a and 3.2.b combine to result in a final Factor 3.2 score of 8 out of 10 for net pens.

Raceways, Tanks

Quebec

Permitting and licensing in Quebec is transparent, with resources available on government websites.[34] The STRADDAQ outlines procedures for handling environmental impacts that can be attributed to aquaculture facilities. These procedures include finding means to reduce effluent pollutants (phosphorus); e.g., through the implementation of technology, reduction in production volumes, relocation of the farm, or closure. Monitoring to validate the phosphorus effluent reduction program functionality is conducted by MDDELCC[35] (pers. comm., D. Marcotte 2017). Monitoring and detailed compliance information is not publicly available, and attempts to acquire information from regulators at MDDELCC and MAPAQ were unsuccessful for this assessment. Additionally, this program only applies to farms producing over 5 tons and is voluntary, but the wide participation (32 companies, representing at least 80% of Quebec's production) in terms of total production and number of producers is evidence of its effectiveness.

Both MAPAQ and the MDDELCC have some degree of an enforcement branch. MDDELCC maintains a website with general information on reporting complaints, investigation, and issuance of penalties, but provides no data useful in assessing its effectiveness.[36] Enforcement agencies are clearly identifiable and contactable, with evidence of infrastructure regarding environmental compliance and penalties. The broad participation of the rainbow trout industry in the STRADDAQ program is some evidence of industry compliance with regulations aimed at managing effluent, as are statements by regulators that monitoring occurs. There is additional evidence that most feeds are in compliance with maximum permitted phosphorus levels (McPhee et al. 2015).

[34] http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/A-20.2,%20r.%201; https://www.canlii.org/en/qc/laws/regu/cqlr-c-a-20.2-r-1/latest/cqlr-c-a-20.2-r-1.html
[35] http://www.mddelcc.gouv.qc.ca/milieu_agri/aquacole/grille-analyse-piscicultures.pdf
[36] http://www.mddelcc.gouv.qc.ca/milieu_agri/ecoconditionnalite/index.htm#systeme

But specific information and data on enforcement are limited, which leaves some uncertainty. Therefore, the score for Factor 3.2b is 4 out of 5.

Overall, a score of 6.4 out of 10 was achieved for the management of farm-level and cumulative impacts of aquaculture habitat for raceway and tank systems, as a result of the comprehensive quality of the existing regulations but with significant uncertainty as to enforcement. This sub-criterion would benefit from additional information.

Conclusions and Final Score
Land-based raceway and tank systems are generally situated adjacent to high-quality water sources, and surface water and/or groundwater are used to supply the farm. These production systems typically require small areas of land for operation, so they are considered to be of minimal impact. Concerns with these systems center more around effluent, as described in Criterion 2. The content of management measures and enforcement are considered robust. Factors 3.1 and 3.2 combine to give a final Criterion 3—Habitat score of 8.13 out of 10 for raceway and tank systems.

The open nature of net pen systems allows waste materials to settle under pen arrays, and these discharges have been demonstrated to alter sediment chemistry and to impact community structure directly under the farm site. Recovery may be facilitated by fallowing, though this is not explicitly required, and recovery time may vary by site and monitoring metric. Regulation in Canada is generally effective, is guided by science, includes monitoring, and considers farm-level and cumulative impacts. Evidence exists of enforcement, industry compliance, and effective best management practices. The content of management measures is considered comprehensive and enforcement is deemed robust. For net pens, Factors 3.1 and 3.2 combine to give a final Criterion 3—Habitat score of 7.33 out of 10.

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: limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms.

Criterion 4 Summary

All production systems

Chemical Use parameters	Score	
C4 Chemical Use Score (0–10)	3	
Critical?	No	RED

Brief Summary

The availability of data on chemical use in Canadian rainbow trout production is moderate across relevant provinces; however, it is clear that the industry does use antibiotics, including those classified as Highly Important for Human Medicine. There are indications that use is low, but detailed data to confirm this are unavailable. Although a regulatory system with demonstrable enforcement is in place to restrict the types of chemicals used and to require a veterinary prescription for use, there are no practical limits on the frequency of antibiotic use or on the total quantity used, and recent examples show their use can increase rapidly in response to disease challenges (e.g., from abnormally warm conditions). Understanding the industry's contributions to antibiotic resistance is challenging, but there are examples of clinical resistance to at least one of these antibiotics. Canada has developed a monitoring program to define a baseline of resistance, track changes, and make management decisions to manage risk of resistance development. Ultimately, overall use appears low and there is evidence of compliance with effective management measures; however, the systems employed for trout farming in Canada are open to the natural environment, thus allowing active chemicals or by-products to be discharged. The final score for Criterion 4—Chemical Use is 3 out of 10.

Justification of Rating

To treat water, fish, or pathogens on trout farms, various chemical agents may be used, including fungicides, disinfectants, anesthetics, pigments, hormones, and antibiotics; however, therapeutant use (antibiotics or pesticides) is the most common use of chemicals in trout farming. As in other animal husbandry industries, the use of therapeutants is of concern because it may lead to resistance in pathogenic bacteria or impact downstream organisms and ecosystems by accumulating in sediments and exposed organisms (Benbrook 2002) (DFO 2004).

Chemical Use Regulation and Management
Restrictions on the use of pesticides and other chemicals in Canadian waters are outlined in various federal and provincial regulations. Federally, the use of therapeutants in aquaculture is regulated by Health Canada under the Food and Drugs Act[37] (1985) and the Aquaculture Activities Regulations under the Fisheries Act[38] as of 2015. Medicated feeds are regulated under the federal Health of Animals Act[39] and Feeds Act[40] (Ontario Ministry of Environment and Climate Change 2016). Per the regulation, a drug or pesticide may only be applied (including via medicated feed) if prescribed by an approved veterinary practitioner, and measures to minimize deposition of the drug to the environment are taken.

Pesticides must be permitted under the Pest Control Products Act[41] (PCPA). The PCPA mandates a science-based risk assessment approach (including a precautionary principle) prior to use of pesticides, which includes cumulative and synergistic effects in a watershed. The Act dictates that pesticides be used only after alternatives have been considered. Use of chemicals must cease if unusual mortality of wild fish in the area of the farm site is observed, and samples must be collected of water, sediment, and tissue (Ontario Ministry of Environment and Climate Change 2016).

Use of other chemical substances is also regulated by the DFO's federal Aquaculture Regulation, which mandates that finfish aquaculture facilities must take reasonable measures to mitigate risk of serious harm to fish outside of the facility if they are part of a commercial, recreational, or Aboriginal fishery. As a condition of license, DFO also requires that a Fish Health Management Plan (FHMP) be submitted, which must abide by the core principle of "judicious application of chemicals and drugs" as part of its development (DFO 2014).

Provinces and Canada require veterinary prescription for purchasing and applying certain therapeutants, with record-keeping obligations for producers and advanced notice; at least some monitoring is occurring. All provinces dictate that antibiotics be used as a measure of last resort (Morin et al. 2004a), with application according to labeling instructions (Morin et al. 2004b). As of 2018, Canada will be enhancing its veterinary oversight by moving all antibiotics important for human health to tighter restrictions (Chiasson and LePage 2017). For example, by the end of 2018, all such antibiotics will be placed on the Prescription Drug List—eliminating the option of being purchased over the counter, and requiring instead a prescription for their obtainment and use (Chiasson et al. 2017) (Chiasson et al. 2018a). A major rainbow trout producer provided Seafood Watch with evidence that compliance is occurring (anonymous industry representative, 2018), as also stated by experts intimately familiar with Canada's management of antibiotic usage (pers. comm., Dr. Marcia Chiasson, University of Guelph 2018).

[37] http://laws-lois.justice.gc.ca/eng/acts/f-27/
[38] http://laws-lois.justice.gc.ca/eng/acts/f-14/
[39] http://laws-lois.justice.gc.ca/eng/acts/H-3.3/
[40] http://laws-lois.justice.gc.ca/eng/acts/F-9/
[41] http://laws-lois.justice.gc.ca/eng/acts/P-9.01/

Prophylactic use of therapeutants is not allowed (Chiasson et al. 2018b), and the use of antibiotics also currently comes with reporting requirements (pers. comm., D. Foss 2018). But importantly, there are currently no regulations—provincially or federally—that place limits on the frequency or total quantity/volume of chemicals used in trout aquaculture.

There are currently five chemical classes that are authorized by Health Canada for sale and use in salmonid aquaculture (Table 1), with at least four of these substances (the antibiotics oxytetracycline, ormetoprim, sulfadimethoxine, and florfenicol) used by the rainbow trout industry either currently or in the recent past (anonymous industry personal comment, 2016) (pers. comm., M. Lambert 2017). Of these, sulfadimethoxine is being phased out in 2018 (Chiasson et al. 2018a). Florfenicol is the most important antibiotic used in Quebec, followed by oxytetracycline (LaFaille 2018).

Table 1. List of veterinary drugs authorized for use in salmonid aquaculture by Health Canada (Health Canada 2010)

Use	Class Name	Substance Name
Antibiotic	Amphenicols	Florfenicol*
Antibiotic	Tetracyclines	Oxytetracycline*
Antibiotic	Sulfonamides	Ormetoprim
		Sulfadiazine*
		Sulfadimethoxine*
		Trimethoprim*
Pesticide	Avermectins	Emamectin Benzoate
Pesticide	Benzoylureas	Teflubenzuron
Disinfectant	Other	Bronopol
		Formalin

* listed as highly important for human medicine by World Health Organization (WHO)

Of the six antibiotics authorized by Health Canada, the World Health Organization (WHO) lists five as highly important for human medicine—including florfenicol and oxytetracycline; none is listed as critically important (WHO 2017). In addition to Health Canada's responsibility for authorizing the use of therapeutants in aquaculture, the Canadian Food Inspection Agency (CFIA) runs an inspection program that routinely monitors commercially sold aquaculture products to ensure that chemical residues in harvested product do not exceed limits set by Health Canada.

Additional chemicals used for fish health and sanitary application by the industry include formaldehyde, chloramine-T, chlorine, iodine, salt, lime, copper sulfate, and hydrogen peroxide—though frequency and dosage details are not publicly available (pers. comm., M. Lambert 2017).

<u>Quantity and Frequency of Chemical Use</u>

Although there is strong regulation and oversight of therapeutant use in Canadian aquaculture, there is little publicly available information on the frequency or volume of chemical use by the industry, or on potentially associated environmental impacts. A 2004 scientific review by DFO of the environmental fate and effect of chemicals associated with Canadian freshwater aquaculture concluded in part that there was a need for "an inventory of therapeutant usage patterns that includes reports of what is used, where and in what amount" (para. 8). But more than a decade later, reports of chemical use at either the farm level or in aggregate are still not publicly available nationally or provincially for any trout farming jurisdictions.

Currently, medicated feed represents the only drug or pesticide chemical used at any of Ontario's net pen aquaculture sites (Ontario Ministry of Environment and Climate Change 2016) (pers. comm., D. Foss 2017). Although diseases are still a concern in Canadian trout farming (particularly coldwater disease, furunculosis, and Weisselosis), good husbandry practices are said to have limited the need for chemical therapeutant use (pers. comm., T. Gordon 2016) (pers. comm., S. Naylor 2016) (pers. comm., B. Walker 2016). For example, in Ontario, the amount of medicated feed coming from the primary feed supplier was only 1.7% of total feed provided in 2013, where the industry had previously been at about 1–4% medicated feed for previous years (pers. comm., S. Naylor 2016) (pers. comm., D. Foss 2017). Today, it is significantly less than 1% (pers. comm., S. Naylor 2018). Four trout farms in Ontario (including the two largest producers, by volume) provided data for their antibiotic use in 2015, and one provided data for 2015–2017. Between the four companies with data available for 2015, one treatment of oxytetracycline (62.4 kg of the medication) was reported to treat a Columnaris infection. One company with data available for 2015–2017 used an average of 48 kg per year, and treatment was once or twice per year. Medicated feed currently makes up 0.0026% of the annual feed volume of 1,918 MT for the same company, which also reports an annual decrease in the total use of medicated feed during this period (pers. comm., Anonymous 2016) (pers. comm., Anonymous 2018). Another large company reports using one treatment annually in recent years to respond to Weisselosis and furunculosis (pers. comm., Anonymous industry 2018).

Moccia and Burke (2016) describe the use of antibiotics as possibly "heavy" when confronting bacterial coldwater disease, which has been an issue for land-based systems (DeJager 2009) and consistently diagnosed in Ontario aquaculture in recent years. Florfenicol is the therapeutant of choice when dealing with coldwater disease in these systems and has been described as a critical part of its management (Geiling 2007). Because of the confirmation of coldwater disease in recent years (Chiasson and LePage 2016) (Chiasson and LePage 2017), florfenicol's recent use can be inferred. But it is reported that only one net pen producer, representing about 10% of total production, uses medicated feed in Ontario due to disease-facilitating stress in early-life stage trout (fingerlings) associated with pollen problems (pers. comm., S. Naylor 2018), with 1–2 treatments per year (pers. comm., Anonymous industry 2018); environmental conditions, rather than infectiousness, often drive disease issues (Chiasson and LePage 2016) (Chiasson and LePage 2017). The remaining 90% of Ontario's production is reported to not use antibiotics (pers. comm., S. Naylor 2018), and another large producer has stated that it hasn't used antibiotics in growout for at least 6–8 years or longer, though use in the hatchery setting occurs (pers. comm., Anonymous industry 2018). Overall, industry reports that Ontario net pen production has experienced major reductions in use, attributed to lower stocking densities and other improved husbandry practices beginning over 10 years ago (pers. comm., S. Naylor 2018); however, there is a lack of detailed data to confirm this. The industry is currently trialing vaccines to address specific disease (pers. comm., D. Foss 2018).

Quebec rainbow trout production is also reported to have a "low" need for antibiotics (pers. comm., G. Vandenberg 2018). Data specific to rainbow trout farming are not available (it is aggregated with production of other trout or finfish generally), but the province's finfish aquaculture industry documented a slight trend of reductions in the total number of antibiotic prescriptions from 1998 to 2004. This trend has continued: the total number of prescriptions from 1998 to 2004 averaged 47 annually compared to about 30 in recent years (2011 to 2017). But there is a slightly positive trend in the number of prescriptions written annually between 2011 and 2017; the quantity of florfenicol used in 2017 more than doubled compared to 2015, and 2016 saw 40 prescriptions issued. Additionally, 2014 saw a significant spike in total and relative use (e.g., more than five-fold compared to 2013 and 2015) without a parallel increase in the number of prescriptions; the reasons for this are not currently known, but demonstrates the unpredictability of on-farm antibiotic use.

The number of farms requiring antibiotics in a given year may be low; for example, of the 35 prescriptions issued industry-wide in 2017 for trout (brook trout, rainbow trout, and other species), 26 went to just 3 farms (LaFaille 2018). Several types of antibiotics are in use for production of various trout species in Quebec. Some industry references suggest that the need for therapeutant usage in Quebec's upland production systems is low (Bobines Fish Farm 2017), and there are published indications that use may be low overall (LaFaille 2018) but moderate on a relative (per-production volume) basis. Annual antibiotic usage data are available from the University of Montreal and, although it aggregates all trout produced in Quebec, it offers some clues about the use of antibiotics in Quebec trout farming. Because of potential differences in production practices and species susceptibilities, these data may not be a perfect representation of rainbow trout aquaculture production.

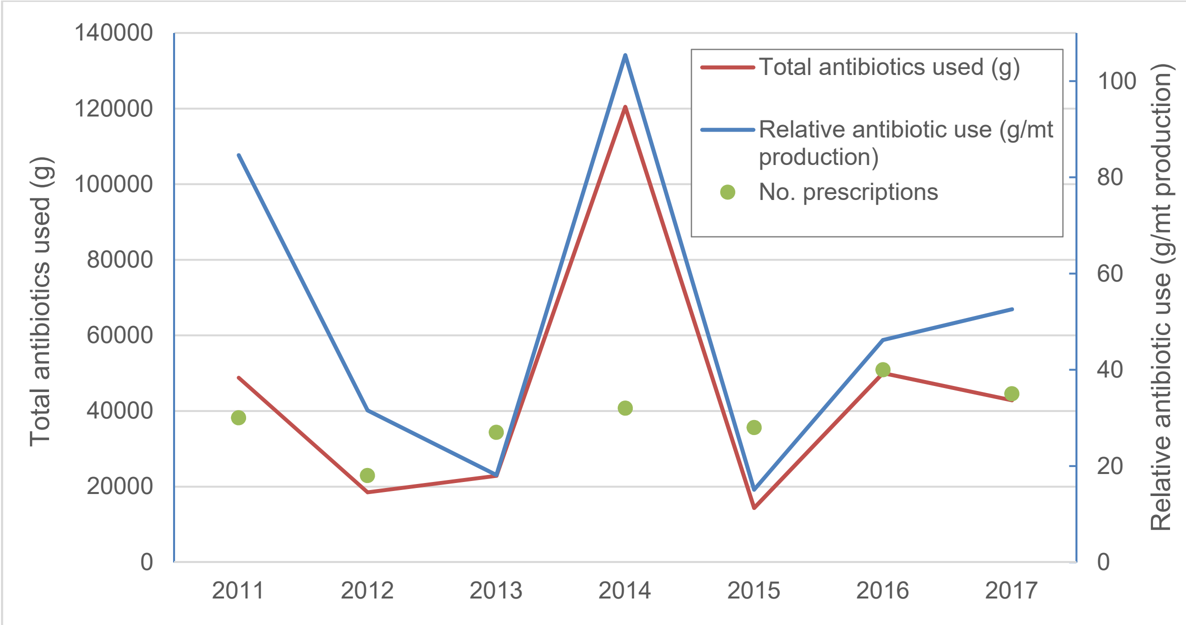


Figure 5. Antibiotic use in Quebec trout farming. Data represent all trout production, not necessarily rainbow trout—though rainbow trout is included. Note that production statistics reported by federal agencies often differ from those reported by provincial authorities. DFO reports Quebec production as all trout combined and Quebec reports rainbow trout only. In 2011–2012, the total of all trout produced as reported by DFO was lower than what Quebec reported for rainbow trout production. For these years, the higher of the two values was used for total trout production. Thus, the relative antibiotic use may be slightly inflated for 2011 and 2012. Because these data represent all trout production, it is possible that these values are not a perfect representation of usage of antibiotics in rainbow trout farming in Quebec. Source: (MAPAQ 2014) (Government of Canada 2017) (LaFaille 2018).

It should be noted that these data make no distinction between antibiotics used for rainbow trout versus other species of trout, and this may indeed not be reflective of rainbow trout specifically. Brook trout is the other major species produced in Quebec (about 60% of total production (pers. comm., G. Vandenberg 2018) (MAPAQ 2014), and it is said to be more susceptible to furunculosis (pers. comm., G. Vandenberg). It is thus possible that rainbow trout production is responsible for only a fraction of reported antibiotic use in Quebec; however, there are no detailed data available to determine this.

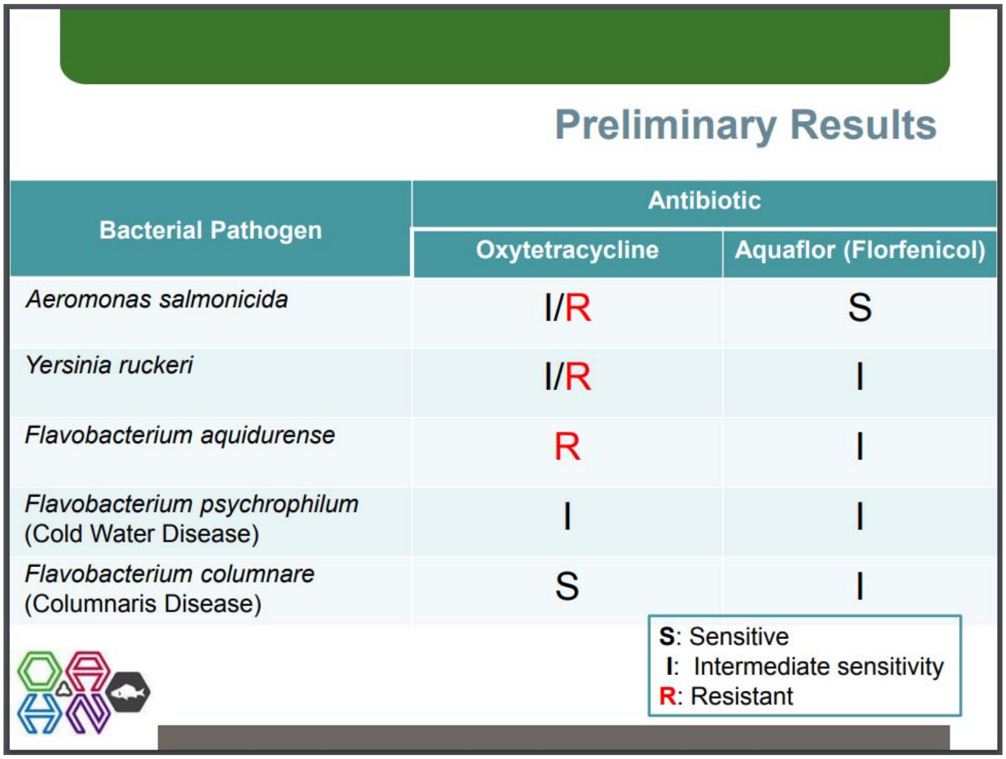
Saskatchewan's only producer states that less than 0.02% of their feed has been medicated in the 10 years prior to 2017 ("Wild West Steelhead" 2017), and Lake Diefenbaker apparently typically has few disease issues (pers. comm., S. Naylor 2017). But medicated feed use increased to about 3% of feed in 2017 because of disease challenges linked to abnormally warmer environmental conditions in the last 2 years (pers. comm., D. Foss 2018). Unfortunately, actual use data (e.g., for total volume, relative volume, and frequency of treatments) are unavailable.

Antibiotic resistance

Of some concern are recent references to declines in bacterial sensitivity to—or full resistance to—antibiotics, including florfenicol and oxytetracycline, by pathogens associated with farmed rainbow trout. Both florfenicol and oxytetracycline have been in recent use by this industry, and both are listed as highly important for human medicine by the World Health Organization (WHO) (WHO 2017) and as critically important for veterinary medicine by the World Organisation for Animal Health (OIE) (OIE 2018). In 2012, Lalonde et al. reported oxytetracycline observed in sediments near land-based system outfalls at levels favorable to the development of microbial antibiotic resistance. More recently, through the 2016–2018 project by the Ontario Animal Health Network (OAHN), *Antibiotic Resistance in Ontario Aquaculture*,[42] reduced sensitivity or resistance to these two antibiotics has been observed in several bacteria that are the causative agents of diseases relevant to farmed rainbow trout (including *Yersinia ruckeri*, *Aeromonas salmonicida, Flavobacterium psychrophilum,* and *Flavobacterium columnare*) in work by Chiasson et al. (2017). In their final report (Chiasson et al. 2018a), the authors concluded the following:

> One hundred percent of *A. salmonicida* (n = 13) and *A. hydrophila* (n = 10) isolates were susceptible to florfenicol. The results for oxytetracycline were different, where 54% of *A. salmonicida* isolates (n = 7) were sensitive and 46% (n = 5) were resistant to the antibiotic. Eighty percent of *A. hydrophila* isolates (n = 8) were sensitive to oxytetracycline, one isolate was intermediate and one was resistant.

[42] http://oahn.ca/resources/oahn-fish-research-project-antibiotic-resistance-in-ontario-aquaculture/


Preliminary Results

Bacterial Pathogen	Antibiotic	
	Oxytetracycline	Aquaflor (Florfenicol)
Aeromonas salmonicida	I/R	S
Yersinia ruckeri	I/R	I
Flavobacterium aquidurense	R	I
Flavobacterium psychrophilum (Cold Water Disease)	I	I
Flavobacterium columnare (Columnaris Disease)	S	I

S: Sensitive
I: Intermediate sensitivity
R: Resistant

Figure 6: Preliminary results from the Ontario Aquatic Health Network's research project *Antimicrobial Resistance in Ontario Aquaculture* demonstrating the reduced sensitivity and resistance of bacteria to antibiotics used in Canadian rainbow trout aquaculture. Image taken directly from Chiasson et al.'s presentation.[43]

And with the recognition that field results are of high importance, they further state: "In some cases, farm operators initiated treatments with oxytetracycline and found the treatments to be ineffective. Following test results indicating the bacteria were resistant to oxytetracycline, they were able to switch to florfenicol." Farm operators test bacterial sensitivity prior to application of medicated feed (pers. comm., D. Foss 2018). Lafaille et al. (2018) outline that antibiotic resistance by the causative agent of furunculosis (*Aeromonas salmondica* bacteria) has also been observed in Quebec (Figure **7**)—although not necessarily specifically in association with rainbow trout, because these data aggregate with other trout species produced in Quebec.

[43] http://cahln-rctlsa.com/wp-content/uploads/2014/11/1-MARCIA-CHIASSON.pdf

Tableau 6 : Antibiorésistance détectée lors de culture bactérienne à la FMV

Antibiotique	Résistance (2014)	Résistance (2015)	Résistance (2016)	Résistance (2017)	Limite (2017)
Florfénicol	1				
Tétracycline	2	1			1
Sulfadiméthoxine		1			
Florfénicol, Tétracycline			1		
Florfénicol, Sulfa, Tétracycline					
Florfénicol, Érythromycine				1	
Tétracycline, A-Nalidixique				2	
Érythromycine, A-Nalidixique					1
Érythromycine	1				6
Enrofloxacin*, Érythromycine					1
Enrofloxacin*					
A-Nalidixique*		2	1	3	

*L'acide-nalidixique et l'enrofloxacin n'ont jamais été prescrit par le vétérinaire en poste à la FMV.

Figure 7. Antibiotic resistance observed in Quebec aquaculture fish 2014–2017. Cultures not necessarily from rainbow trout. From LaFaille et al. 2018.
(Translation of French-language text above table: *Table 6: Antibiotic resistance detected during bacterial culture at FMV.*)
(Translation of French-language text below table: *Nalidixic acid and enrofloxacin have never been prescribed by the FMV veterinarian.*)

For Canada's rainbow trout production, there is some concern about bacterial resistance to antibiotics, though resistance is not necessarily attributable to rainbow trout aquaculture or to aquaculture in general. Aquatic pathogens are routinely exposed to antimicrobials in runoff from terrestrial agriculture and human waste streams (pers. comm., Dr. Alexandra Reid, OMAFRA 2018). Inferring a link between reductions in bacterial sensitivity to antibiotics used in rainbow trout aquaculture to that application is further complicated by naturally occurring resistant microbes. The intent of the work done by OAHN was in constructing a baseline of bacterial sensitivity to antibiotics for long-term monitoring of patterns in resistance (pers. comm., M. Chiasson 2018), which helps to advise management of the use of antibiotics. The work in Quebec by LaFaille et al. (2018) makes similar arguments and has thus far not shown any increasing trends in antibiotic resistance (Figure 8).

Conclusions and Final Score

The availability of data on chemical use in Canadian rainbow trout production is moderate across relevant provinces. But it is clear that the industry does use antibiotics, including those classified as Highly Important for Human Medicine. There are indications that use is low, but detailed data to confirm this are unavailable. Although a regulatory system with demonstrable enforcement is in place to restrict the types of chemicals used and to require a veterinary prescription for use, there are no practical limits on the frequency of antibiotic use or on the total quantity used, and recent examples show their use can increase rapidly in response to disease challenges (e.g., from abnormally warm conditions). Understanding the industry's contributions to antibiotic resistance is challenging, but there are examples of clinical resistance to at least one of these antibiotics. Canada has developed a monitoring program to define a baseline of resistance, track changes, and make management decisions to manage risk of resistance development. Ultimately, although overall use appears low and there is evidence of compliance with effective management measures, the systems employed for trout farming in Canada are open to the natural environment, allowing active chemicals or by-products to be discharged. The final score for Criterion 4—Chemical Use is 3 out of 10.

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: sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains.

Criterion 5 Summary

All production systems

Feed parameters	Value	Score
F5.1a Fish In: Fish Out ratio (FIFO)	0.68	8.31
F5.1b Source fishery sustainability score	–3.00	
F5.1: Wild fish use score		7.91
F5.2a Protein IN (kg/100 kg fish harvested)	32.22	
F5.2b Protein OUT (kg/100 kg fish harvested)	16.49	
F5.2: Net Protein Gain or Loss (%)	–48.82	5
F5.3: Feed Footprint (hectares)	8.95	7
C5 Feed Final Score (0–10)		**6.95**
Critical?	NO	**GREEN**

Brief Summary

Canadian rainbow trout farming relies on fish meal and fish oil inputs (estimated collective inclusion rate of 26%), supported by a variety of wild-caught forage fish from fisheries considered to be of a range in sustainability; but feeds are improving, and alternative ingredients are being explored. Canadian feed companies are deriving a significant portion of fish meals and fish oils from by-products. This assessment scores 7.91 out of 10 for Factor 5.1—Wild Fish Use. Feeds have continued to lessen reliance on fish meal as a protein source, and rainbow trout feeds feature a mix of inedible land-based animal by-products and edible crop ingredients. A relatively low eFCR (1.25), a moderately favorable edible yield value (60%), but high dietary protein needs (43%) result in a score of 5 out of 10 for Factor 5.2—Net protein gain/loss. The score for Factor 5.3—Feed Footprint is 7 out of 10 because of a moderate inclusion level of fish meal and inclusion of a mix of crop and animal ingredients. The scores from Factors 5.1, 5.2, and 5.3 are combined to give a final numerical score of 6.95 out of 10 for Criterion 5—Feed.

Justification of Rating

As with most aquaculture industries, it is difficult to identify specific details of trout feed formulations because of the highly proprietary nature of the commercial information. Skretting is Canada's major feed supplier, with Taplow supplying organic producers (which are a small fraction of total production; pers. comm., S. Naylor 2018). There are at least two feed companies providing trout feeds in Canada (Skretting and Taplow Feeds) and each has numerous product lines for trout growout feeds. Details of a feed formulation are available from both feed companies and the level of information disclosed was moderate–high. Those data are included herein, along with information found in academic literature, publicly available research reports, and expert interviews.

Factor 5.1. Wild Fish Use

The wild fish use score is derived by assessing the average Feed Fish Efficiency Ratio (FFER) for the aquaculture system along with the sustainability of the source fisheries for fish meal and fish oil.

Although research into protein alternatives is ongoing (McPhee et al. 2015) and improvements to feed have been made, rainbow trout farming still relies on feeds with wild fish ingredients.

<u>Factor 5.1a—Feed Fish Efficiency Ratio (FFER)</u>

A precise economic feed conversion ratio (eFCR) for trout farming is difficult to ascertain because it can vary substantially from farm to farm, based on feeding practices, quality of feed, environmental conditions, and production practices. One of the largest trout producers in Ontario provided eFCR data for each of its operational net pens from 2011 to 2014. Those data show that eFCR values ranged from 1.29 to 1.39; data from a 2008–2013 survey of five producers suggest a mean of 1.39 and a range of 1.20–1.68 (Skipper-Horton 2013). A review by Otu et al. (2017a) suggests a typical range of 1.15–1.35; this range aligns with reports from experts in Ontario's aquaculture sector (pers. comm., S. Naylor 2016) and as reported by studies on rainbow trout aquaculture in Canada (Wetton 2013) (Wellman et al. 2017). Additionally, Canadian researchers have demonstrated an eFCR of 1.19 when using newer, high-performance feeds (Government of Canada 2016), which are currently part of provincial efforts at reducing phosphorus effluents (pers. comm., G. Vandenberg 2017), and an FCR of 1.1 may becoming more common (pers. comm.,D. Marcotte 2017). For this assessment, 1.25, the median from Otu et al. 2017, was used as a point of overlap between the reported ranges and because of evidence that improved feeds have helped to achieve recent gains in reducing phosphorus effluent by this industry.

Trout feeds are typically a high-protein (approximately 40–45%) and a high-lipid (15–25%) composition (Tucker and Hargreaves 2008) (FAO 2016) (Wellman et al. 2017). There is a high reliance on fish meal and fish oil to supply the high levels of protein and lipid; however, there has been a trend toward finding alternate proteins (plants and rendered animals) and oil (namely plant oils) (FAO 2016). Inclusion rates of fish meal and fish oil can vary significantly: Tucker and Hargreaves (2008) report a generalized manufactured trout feed diet to include 40% fish meal and 12–21% fish oil; the Food and Agriculture Organization of the United Nations (2016) reports a generalized trout grower feed to include 30% fish meal and 9% fish oil; Tacon and Metian (2008) report fish meal inclusion of 30–50% and fish oil inclusion levels of 15–30% specifically for Canadian trout production. Studies of experimental rainbow trout aquaculture by the government of Canada report using a commercial feed with 20–28.1% fish meal (Wellman et al. 2017). Despite the variability in these reported numbers, there is some overlap between them. But the challenge is that most of the data used in these reports are fairly dated (the cited papers use data from 2002 to 2007) and improvements in feed formulation have certainly been made since that time.

The 2017 Seafood Watch assessment for trout farmed in raceways and ponds in the United States applied fish meal and fish oil inclusion levels of 20% and 6%, respectively, based on recent literature and interviews with industry experts (Seafood Watch 2017). This assessment was unable to acquire data more specific to Canada production, so it uses the same data. But one of Canada's main feed suppliers stated that their feeds use 40% by-products in their fish meal and 55% by-products in their fish oil (pers. comm., R.J. Taylor 2018) and these values are used here.

Table 2. Factor 5.1a Feed fish efficiency ratio (FFER) data

Parameter	Data
Fish meal inclusion level	20%
Percentage of fish meal from by-products	40%
Fish meal yield (from wild fish)	22.5%
Fish oil inclusion level	55%
Percentage of fish oil from by-products	10%
Fish oil yield	5%
Economic Feed Conversion Ratio (eFCR)	1.25
Calculated Values	
Feed Fish Efficiency Ratio (fish meal)	0.67
Feed Fish Efficiency Ratio (fish oil)	0.68
Seafood Watch FIFO Score (0–10)	**8.31**

Overall, from the eFCR and by-product inclusion rates discussed above, the calculated FFER score is 0.67 for fish meal and 0.68 for fish oil. The SFW methodology applies the higher of these two scores (in this case, fish oil) and it means that, from first principles, 0.68 MT of wild fish are required to produce 1 MT of cultured rainbow trout. This results in a score of 8.31 out of 10 for Factor 5.1a.

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

The sources of fish meal and fish oil are variable because feed producers purchase these products on the international market and sourcing is influenced by a variety of factors, including price, availability, quality, and source fishery adherence to food safety and sustainability certifications. Skretting, Canada's main supplier of rainbow trout feeds (pers. comm., S. Naylor 2018), discloses some (though not exhaustive) information on their "important" source fisheries for marine ingredients in their annual sustainability reports. The most recent reports (2016, 2017) do not provide specific information on source fisheries, though earlier reports (2012–2015) do; the 2016 report lists species (which is reflective of species listed in earlier reports) but not specific fishery information. Although the lists of source fisheries (see Table 3) are not specific to their trout feeds, they are helpful in identifying the potential source fisheries. Attempts to reach Skretting for more information specific to Canada trout feeds were unsuccessful. For this assessment, it was assumed that source fisheries in 2018 feeds were not dissimilar to those identified in 2015–2016 (Table 3).

Significant efforts have been made over the years to improve the sourcing of fish meal and fish oil to more environmentally sustainable sources. In particular, larger companies such as Skretting have made public commitments through their supplier codes of conduct[44, 45] to encourage certification (either through MSC or IFFO) of source fisheries—among other initiatives. There is some uncertainty whether the list in Table 3 (derived from Skretting sustainability reports) represents all capture fisheries supplying the company for its feed manufacturing, but it is the best information available to assess the sustainability of capture fisheries providing raw ingredients for fish meal and fish oil. Of the 23 fisheries listed, only 1 has any FishSource scores < 6, while 22 feature all FishSource scores of ≥ 6 and, of those, 14 score 8 or higher in "Stock Health." Table 3 outlines the corresponding Seafood Watch score assigned to each fishery and, for Factor 5.1b of this assessment, an average score of the 23 source fisheries is used. Thus, Factor 5.1b scores –3 out of –10.

[44] EWOS Supplier Code of Conduct: http://www.ewos.com/wps/wcm/connect/ewos-content-group/ewos-group/sustainability/code-of-conduct-suppliers
[45] Skretting Supplier Code of Conduct: http://www.skretting.com/en/our-story/sustainability/

Table 3. Important capture fisheries supplying Skretting feeds. As reported by Skretting for all feeds (not specific to Canada rainbow trout market); list is not exhaustive, but includes fisheries described as "important" sources by Skretting. *Skretting does not provide exhaustive list of source fisheries and this value may be imprecise, but is useful for understanding relative importance of source fisheries (Skretting 2015) (Skretting 2016).

Target	Stock	% of total reported*	FishSource score	SW score
Anchoveta	North-central Peru	0.40	All ≥ 6	–4
	Southern Peru	0.13	All ≥ 6	–4
	Chilean regions vx-i-ii	0.08	All ≥ 6, 8 stock health	–2
Araucanian herring (Chile sardine)	Chile	0.06	All ≥ 6, 8 stock health	–2
Jack mackerel	Chile	0.06	All ≥ 6, 8 stock health	–2
Blue whiting	NE Atlantic	0.05	All ≥ 6, 8 stock health	–2
Gulf menhaden	Gulf of Mexico	0.03	All ≥ 6, 8 stock health	–2
Sprat	Baltic	0.03	All ≥ 6, 8 stock health	–2
	North Sea	0.01	All ≥ 6, 8 stock health	–2
European pilchard	NW Africa central	0.03	All ≥ 6, 8 stock health	–2
	NW Africa southern	0.02	All ≥ 6	–4
	Iberian	0.01	1 score < 6	–6
Lesser sand eel	North Sea central eastern	0.03	All ≥ 6, 8 stock health	–2
	North Sea central and southern		1 score < 6	–6
Capelin	Barents Sea	0.02	All ≥ 6	–4
	Icelandic	0.01	All ≥ 6	–4
Atlantic horse mackerel	NE Atlantic western	0.01	All ≥ 6	–4
Atlantic herring	North Sea	0.01	All ≥ 6, 8 stock health	–2
	Baltic Sea Gulf of Bothnian	0.01	All ≥ 6, 8 stock health	–2
	NE Atlantic southern	0.00	Not listed	N/A
	Icelandic summer-spring	0.02	All ≥ 6, 8 stock health	–2
	Norwegian spring spawn	0.01	All ≥ 6, 8 stock health	–2
Norway pout	North Sea	0.00	All ≥ 6, 8 stock health	–2
			Average score	**–2.9**

Subfactors 5.1a and 5.1b combine for a score of 7.91 out of 10 for Factor 5.1.

Factor 5.2. Net Protein Gain or Loss

Crude protein levels in trout feeds vary from 40% to 46% (FAO 2016) (Martin Mills 2016) (Taplow Feeds 2016) (Tucker and Hargreaves 2008) and a median value of 43% was applied to this assessment. Protein sources in the feed typically include fish meal, poultry by-product meal, soybean meal, corn gluten meal, blood meal, feathermeal, and meat and bone meal (Hardy 2013). Based on the aforementioned inclusion of 20% fish meal, of which 40% is by-product derived (see Factor 5.1), fish meal was found to contribute 30.93% of the protein, with 18.56% of total protein derived from whole fish (edible) fish meal ingredients and 12.37% of protein derived from by-product fish meal ingredients. Edible crop ingredients make up 41.05% of feed protein, while inedible animal by-product ingredients contribute to the remainder (FAO 2016) (Taplow Feeds 2016) (Tucker and Hargreaves 2008); a value of 66.5% was used for this assessment (Seafood Watch 2015).

A report from the FAO (Hardy 2013) provides guidance on rainbow trout feed ingredients. The following statistics were used in calculations for Factor 5.2. Protein content values are from Seafood Watch (2015):

Table 4. Rainbow trout feed protein sources. From (Hardy, 2013) unless otherwise noted.

Ingredient	Protein content (%)	Inclusion rate (%)	% of total feed protein	Edible?
Whole fish fish meal*	66.5	12	18.56	Yes
By-product fish meal**	66.5	8	12.37	No
Corn gluten meal	60.7	4	5.65	Yes
Poultry by-product meal	58.7	6	8.19	No
Feather meal	84.9	6	11.85	No
Soybean meal	45.8	12	12.78	Yes
Blood meal	79.8	4	7.42	No
Ground wheat	15.2**	22	7.78	Yes
Soybean oil	41.6	5	4.84	Yes
Other crop ingredients[#]	Unknown	Unknown	10.59	Yes

* Data from Seafood Watch 2017; ** Data from pers. comm., R.J. Taylor 2018; [#] Data from Tacon et al (2009); *** See explanation in following section.

From these values, calculations using the Seafood Watch scoring tool estimate a total feed protein originating from edible crops at 31.05% and total feed protein from non-edible land animal ingredients at 27.46% (Table 4). Summing the protein contributions of fish meal (30.9%), edible crops (30.46%), and non-edible land ingredients (27.46%) accounts for 89.41% of total feed protein. The 2017 Seafood Watch U.S. Rainbow Trout Assessment (Seafood Watch 2017a) concluded that an increasing percentage of rainbow trout feed protein is sourced from crop sources, assuming as high as 50% of total feed protein. For this reason, the final 10.59% is

assumed to be from edible crops, providing a sum fraction of 41.05% of total protein from edible crops.
The protein content of whole harvested farmed trout is 15.7% (Dumas et al. 2007). Fillet yields are found to vary from 56% to 65% (Bugeon et al. 2010) and a median value of 60.5% is applied herein. Without specific information on the fate of harvesting by-products, the Seafood Watch assumption that 50% of non-edible by-products are commonly used for other food production purposes is applied here. Values used and results of calculations for Factor 5.2 are presented in Table 5.

Table 5. Net protein gain or loss equation data.

Parameter	Data
Protein content of feed	43%
Percentage of total protein from non-edible sources (by-products, etc.)	40.06%
Percentage of protein from edible sources	59.94%
Economic Feed Conversion Ratio	1.25
Edible Protein INPUT per 100 kg of farmed rainbow trout	32.22 kg
Protein content of whole harvested rainbow trout	15.7%
Edible yield of harvested rainbow trout	60.5%
Percentage of farmed rainbow trout by-products utilized	50%
Utilized Protein OUTPUT per 100 kg of farmed rainbow trout	16.49 kg
Net protein loss	–48.82%
Seafood Watch Score (0–10)	**5**

Proteins in feeds used for rainbow trout in Canada are sourced from 30.93% marine ingredients, 41.05% crop ingredients, and 27.46% land animal ingredients. About 59.94% is considered fit for human consumption. These values combine to determine that the production system yields a net protein loss of –48.82%, which leads to a final score of 5 out of 10 for Factor 5.2.

Factor 5.3. Feed Footprint

Based on average feed formulations found in academic literature and research reports, the average ocean and land areas to produce the feed necessary to produce farmed rainbow trout were calculated using the Seafood Watch scoring tool.

Table 6. Feed footprint equation data.

Parameter	Data
Marine ingredients inclusion	26%
Crop ingredients inclusion	59%
Land animal ingredients inclusion	16%
Ocean area (hectares) used per ton of farmed rainbow trout	8.45

Land area (hectares) used per ton of farmed rainbow trout	0.50
Total area (hectares)	8.95
Seafood Watch Score (0–10)	**7**

The area necessary for production of marine ingredients required for 1 ton of rainbow trout is 8.45 ha/ton of farmed fish. The area necessary for production of terrestrial (crop and land animal) ingredients required for 1 ton of rainbow trout is 0.50 ha/ton. The combination of these two values results in an overall feed footprint of 8.95 ha/ton of farmed fish. This results in a final Factor 5.3 score of 7 out of 10.

Conclusions and Final Score

Canadian rainbow trout farming relies on fish meal and fish oil inputs (estimated collective inclusion rate of 26%), supported by a variety of wild-caught forage fish from fisheries considered to have a range of sustainability, although feeds are improving and alternative ingredients are being explored. Canadian feed companies are deriving a significant portion of fish meals and fish oils from by-products. This assessment scores 7.91 out of 10 for Factor 5.1—Wild Fish Use. Feeds have continued to lessen reliance on fish meal as a protein source, and rainbow trout feeds feature a mix of inedible land-based animal by-products and edible crop ingredients. A relatively low eFCR (1.25), a moderately favorable edible yield value (60%), but high dietary protein needs (43%) result in a score of 5 out of 10 for Factor 5.2—Net protein gain/loss. The score for Factor 5.3—Feed Footprint is 7 out of 10 because of a moderate inclusion level of fish meal and inclusion of a mix of crop and animal ingredients. The scores from Factors 5.1, 5.2, and 5.3 are combined to give a final numerical score of 6.95 out of 10 for Criterion 5—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: preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes.

Criterion 6 Summary

Net pens

Escape parameters	Value	Score
F6.1 System escape risk	2	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		2
F6.2 Invasiveness		7
C6 Escape Final Score (0–10)		**4**
Critical?	NO	**YELLOW**

Raceways, Tanks

Escape parameters	Value	Score
F6.1 System escape risk	6	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		6
F6.2 Invasiveness		7
C6 Escape Final Score (0–10)		**6**
Critical?	NO	**YELLOW**

Brief Summary

Large escape events from net pen production systems have been documented in the past, although they are reported to be limited to infrequent occurrences by best management practices, as required by regulators. But there is a lack of data or information available to confirm this. Rainbow trout escape risk for these systems is considered moderate–high and scores 2 out of 10 for Factor 6.1. Rainbow trout is not native to Ontario or Saskatchewan, but is fully ecologically established as a result of historic and ongoing provincial stocking programs to support fisheries. Farmed fish are selectively bred and have genetic differentiation from their wild counterparts; use of single-sex and triploid fish reduces opportunity for introgression. The risk of competitive or genetic impact of escaped rainbow trout from net pen farms is considered low to low–moderate, and scores 7 out of 10 for Factor 6.2. Overall, the final score for net pens is 4 out of 10 for Criterion 6—Escapes.

Large escape events are typically low risk for land-based systems. Land-based systems provide opportunity to limit escapes by using physical barriers, which is common practice in Quebec as required by regulators. But there are no data to confirm the efficacy of these measures. Land-based flow-through and semi-closed systems score 6 out of 10 for Factor 6.1—Risk of Escape. Rainbow trout is not native to Quebec but is fully ecologically established in the production region as a result of historic and ongoing provincial stocking programs to support fisheries. (Invasion outside of production regions is a problem in eastern Quebec, although not necessarily attributed to aquaculture.) Farmed fish are selectively bred and have genetic differentiation from their wild counterparts, but wide use of single-sex and triploid fish reduces opportunity for introgression. The risk of competitive or genetic impact of escaped rainbow trout from land-based systems is considered low to low–moderate, and scores 7 out of 10 for Factor 6.2. Overall, the final score for raceway and tank systems is 6 out of 10 for Criterion 6—Escapes.

Justification of Rating

Factor 6.1. Escape risk

In Canada, rainbow trout is most commonly farmed in two types of systems: land-based raceway or tank systems, or net pens. Both systems are, to some degree, open to the natural environment, which means there is potential for farmed stock to escape. Lake-sited net pens, which are the primary production system employed in Ontario and Saskatchewan, are considered to have an inherently high risk of escapes, and large escape events have been documented for this industry in these provinces (Government of Saskatchewan 2000) (Blanchfield et al. 2009) (Saskatchewan Ministry of Environment 2011) (DFO 2017). Recapture is typically not required provincially, though measures aimed at reducing impacts of escaped rainbow trout have included more aggressive recreational fishing opportunities to reduce the number of escaped farm fish in the wild (pers. comm., S. Naylor 2017).

Blanchfield et al. (2009) state that escape of freshwater fish from net pens is “common”—typically in small numbers because of handling error or in large numbers from storm damage or vandalism. Annual escape may be about 3–5% of total net pen production (as reviewed in Blanchfield et al. 2009) or as low as 0.3% (as reviewed in Anderson 2015). Significant damage to net pens leading to large escape events is apparently uncommon, but escapes generally cannot be avoided in net pen aquaculture (Anderson et al. 2015). Escapes of aquaculture trout do occur from net pen systems in Canada: besides several documented large escape events, a detectable aquaculture strain of rainbow trout is known to be present in Lake Huron as the result of net pen escapes (Kerr and Lasenby 2000) (Martell et al., 2013).

Land-based systems, as employed in Quebec, are also connected to waterbodies and represent an escape risk. But escapes in these systems are easier to prevent by placing screens on inflow and outflow pipes, and all of Quebec's systems typically use physical barriers to prevent escapes (pers. comm., G. Vandenberg 2017).

There are a number of best management practices in place, either through government regulation, license conditions, or industry best practice to prevent or reduce escape events.

Net pens

Ontario

As a condition of license, the Ontario Ministry of Natural Resources (OMNR) requires that aquaculture operators maintain a Facility Security Plan that outlines strategies to ensure escape prevention, and a contingency plan for escape events. Details should include such things as a description of escape prevention technology and routine containment inspection procedures. If an applicant's facility has experienced escapes previously, the applicant must demonstrate that improvements have been made, as a condition of license renewal. All escapes data must be recorded and maintained by the operator and available to MNR upon request and in annual reporting. Escape events exceeding limits (numbers of escapes) on an issued license must also be reported to MNR within 48 hours; within 24 hours for larger escape events (> 1,000 fish). Recapture is permitted to be attempted when practical, but it is not required. Ontario also requires that all fish culture proposals undergo a detailed risk analysis to evaluate potential risk of escapes on the receiving ecosystem as one consideration in the analysis (OMNR 2009).

One major producer provided their Fish Containment Plan for this assessment, which contained each of the elements required in their conditions of license. The plan outlines how careful inventory is taken and managed throughout the production cycle, as well as additional risk management considerations such as replacing old nets and using an ROV to inspect for holes (pers. comm., Anonymous 2018). Net pen operators have also incorporated designs that prevent ice damage by sinking net pens to depths below the risk of ice damage, making use of regular inspection dives to verify net pen integrity, and covering the tops of net pens with nets (pers. comm., S. Naylor 2017).

Major escape events are suggested to be rare (pers. comm., S. Naylor 2017), with one major escape event in Ontario in the past 10 years (pers. comm., J.O. Skipper-Horton 2018), though no reporting data were available for this assessment despite attempts to reach out to regulators.

Saskatchewan

In Saskatchewan, the Ministry of the Environment has required that Environmental Impact Assessments address fish escapes—including likelihood, probable effects, prevention measures, and recapture plans (Saskatchewan Ministry of Environment 2011). A large escape event of about 400,000 rainbow trout from a farm in Saskatchewan occurred in 2000, attributed to ice damage to net pens ("Accident doubles fish in Lake Diefenbaker"—Canada—CBC News n.d.), but large escape events have not been a problem since (pers. comm., D. Foss 2017). The producer here uses regular inspection dives to monitor net pen conditions to reduce the risk of escape (Winter and Kamaitis 2008).

Raceways, Tanks

Quebec

Quebec makes use of zoning to restrict fish seeding and transport, with the aim of natural resource protection; rainbow trout production is limited in where it can occur, to protect certain waterbodies (MAPAQ 2016). Quebec's Aquaculture Regulation further requires that producers maintain systems in a manner that prevents escape. Aquaculture license holders must inform the MAPAQ immediately of an accidental escape of organisms and provide details of the incident. The license holder must also take all necessary measures to recover the organisms. Quebec additionally has comprehensive regulations strictly managing the movement and introduction of live fish, aimed at preventing ecological harm (Government of Quebec 2018b).

The nature of Quebec's upland (i.e., land-based) production systems provides increased ability to prevent escape by screening intake and outlet points (pers. comm., G. Vandenberg 2017) and by near total fish isolation from the surrounding environment (Bobines Fish Farm 2017). And, fish escapes are apparently a low risk for this industry in Quebec (pers. comm., M. Lambert 2017) or elsewhere for this species (Tucker and Hargreaves 2009), though no data on escapes were specifically available for Quebec.

<u>Factor 6.1. Summary and scoring</u>

<u>Net pens</u>

Net pen systems represent a greater risk of escape, and large escape events have been documented in multiple provinces (Ontario, Saskatchewan) from these systems. Regulations and best management practices aimed at preventing escapes may be effective in keeping large escape events infrequent, and large escape events have not been reported in recent years. But knowledge of past escapes and a lack of current data demonstrating the true efficacy of escape prevention measures result in net pens being considered vulnerable to escape, including chronic trickle losses. The score for Factor 6.1 is 2 out of 10 for net pen systems.

<u>Raceways, Tanks</u>

Raceway and tank systems sited on land present some risk of escape, although best management practices, including the use of physical barriers at intake and outflow pipes, limit occurrences. In Quebec, where only upland-based systems are used, significant escape events are a low risk, though no data were available for verification. Escape risk in these systems is considered low–moderate to moderate. The score for Factor 6.1 is 6 out of 10 for raceway and tank systems.

Factor 6.2. Competitive and Genetic Interactions

Escaped farm fish have the potential to impact surrounding ecosystems through competition, predation, introgression, or via spreading parasites or pathogens (see Criterion 7—Disease).

Potential impacts

The impact of rainbow trout introductions on other salmonids has been well studied in Canada. Rainbow trout has been documented to compete with wild native fish populations for food and habitat (Thibault and Dodson 2013) (Houde et al., 2014), to act as additional predation pressure on wild native populations, and to modify habitat to the detriment of other species (Thibault and Dodson 2013). These impacts have been most extensively documented to brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*), but have also been noted with bull charr (*Salvelinus confluentus*), cutthroat trout (*Salmo clarkii*), and Atlantic salmon (*Salmo salar*), among others (Kerr et al. 2000) (Thibault and Dodson 2013). There are multiple observations of rainbow trout hybridization with other salmonids including brown trout, golden trout (*Salmo aquabonita*), and cutthroat trout (Kerr et al. 2000), which demonstrates that they compete with wild native populations for breeding partners and/or are capable of disturbing the breeding behavior of other species. Additional negative interactions between hatchery-reared rainbow trout and wild fish have been documented—including disease introduction, as reviewed by (Kerr and Lasenby 2000).

Farmed rainbow trout are selectively bred to improve production traits, which means that genetic differences in trout historically introduced are likely to occur. Rainbow trout is one of the oldest artificially propagated fish species (Okumuş 2002), with a wide diversity of strains in existence (Kerr and Lasenby 2000). The Canadian government is making investments in breeding programs to develop pedigreed broodstock and optimize the performance of farmed fish—such as in improving growth and disease resistance, managing sexual maturity, reducing phenotypic anomalies, and producing less polluting strains (Martell et al. 2013) (McPhee et al. 2015). The escape of farmed rainbow trout is a potential concern for native and/or wild rainbow trout (and other species) populations because of the threat of introgression by selectively bred animals. A detectable aquaculture strain of rainbow trout is known to be present in Lake Huron as a result of net pen escapes, and research demonstrates the potential for such escapees to outcompete existing wild strains of the same species (Kerr and Lasenby 2000) (Martell et al. 2013).

Most producers of rainbow trout are currently using only female fish (approximately 45% of total production; pers. comm., J.O. Skipper-Horton 2018), and about 10% (pers. comm., J.O. Skipper-Horton 2018) or perhaps up to 50% of Ontario production is in triploid fish. About 95% of Saskatchewan production is using all-female triploid fish (pers. comm., D. Foss 2017) (Sweeney International Management Corp. 2010), which effectively renders them unable to reproduce. The use of sexually viable diploid fish (approximately 45% of Ontario production; pers. comm., J.O. Skipper-Horton 2018) often involves harvesting fish before they reach sexual maturity (pers. comm., D. Foss 2017). These practices serve to limit reproductive interaction of escapees with wild fish, and ecological interactions are more likely to come through competition and predation.

Rainbow trout is an extremely robust and adaptable species. Kerr and Grant (2000) describe rainbow trout as “one of the most successful colonizers of Great Lakes tributaries” (p. 378) because they established self-sustaining populations throughout the Great Lakes basin in slightly more than 100 years. Blanchfield et al. (2009) studied a simulated escape of farmed rainbow trout in Ontario's Experimental Lake 375. Once escaped, the study observed that farmed rainbow trout dispersed widely and rapidly throughout the lake, that many fish adapted quickly to wild food resources, and suggested that continued high growth rates are possible. World-record sized rainbow trout have been caught in Lake Diefenbaker following a large escape of farmed fish there, lending further (anecdotal) support to this hypothesis ("48-Pound Trout: World Record or Genetic Cheat?" WIRED n.d.).

Blanchfield et al.'s (2009) study found (and reviewed) that post-escape survival of farmed rainbow trout was low, that escaped trout are attracted to the aquaculture site (this behavior could serve to aid in recapture), and are frequently targeted by anglers, which would likely reduce survival further. Nonetheless, the authors warn that impacts are possible to food webs and fish communities from escaped farm fish.

Rainbow trout has been extensively introduced across Canada primarily for angling purposes, beginning as early as the 1920s. In Ontario, where the majority of trout farming in Canada occurs, rainbow trout is not native but has been fully established for decades because of intentional introductions by local authorities (Kerr and Lasenby 2000) (Ontario 2014). Ontario has an ongoing rainbow trout stocking program in lakes throughout the province (Ontario 2014), with stocking events in the Great Lakes beginning in 1882. Lake Huron received rainbow trout spread from Lake Superior by 1930 (Kerr and Lasenby 2000), and Ontario's stocking program released over 240,000 rainbow trout in Lake Huron in 2015–2016 (including over 116,000 yearlings). But fish stocked by the Ontario Ministry of Natural Resources are "wild stock" that is genetically different from stock used in Lake Huron net pen aquaculture (Martens et al. 2014).

Stocking programs also exist in southwestern Quebec in regions overlapping with rainbow trout aquaculture zoning. An invasion of rainbow trout in eastern waterbodies is ongoing and of concern; Quebec prohibits farming of rainbow trout outside of approved zones in the southwestern part of the province. Saskatchewan has maintained an active stocking program for rainbow trout, including Lake Diefenbaker, though not in recent years (Government of Saskatchewan 2017).

In most regions where rainbow trout is being farmed, the species has been established because of intentional introductions that predate aquaculture development, and it is considered naturalized, including in Ontario, Quebec, and Saskatchewan. Eggs used in both Canada's aquaculture and stocking programs are sourced from the same supplier and are likely similar genetically (pers. comm., D. Foss 2018) (pers. comm., J.O. Skipper-Horton 2018), though there is evidence of at least some genetic differentiation—as would be expected for animals selectively bred for aquaculture.

<u>Factor 6.2 summary and scoring</u>

For the provinces where rainbow trout is non-native (Ontario, Quebec, Saskatchewan), rainbow trout is fully ecologically established in the production regions as the result of historic (pre-dating aquaculture) and ongoing stocking for recreational angling purposes. Because there is genetic differentiation of escaped fish from stocked and naturalized stocks, but production practices (including some degree of monosex and polyploidy) reduce risk, rainbow trout escaped from farms is considered a low to low–moderate risk for competitive or genetic interactions and scores 7 out of 10.

Conclusions and Final Score

Large escape events from net pen production systems have been documented in the past, though they are reported to be limited to infrequent occurrences by best management practices, as required by regulators. But there is currently a lack of data or information to confirm this. Rainbow trout escape risk for these systems is considered moderate–high and scores 2 out of 10 for Factor 6.1. Rainbow trout is not native to Ontario or Saskatchewan, but is fully ecologically established as a result of historic and ongoing provincial stocking programs to support fisheries. Farmed fish are selectively bred and have genetic differentiation from their wild counterparts; use of single-sex and triploid fish reduces opportunity for introgression. The risk of competitive or genetic impact of escaped rainbow trout from net pen farms is considered low to low–moderate, and scores 7 out of 10 for Factor 6.2.

Overall, the final score for net pens is 4 out of 10 for Criterion 6—Escapes.

Large escape events are a low risk for land-based raceway and tank systems. Land-based systems provide opportunity to limit escapes by using physical barriers, which is common practice in Quebec as required by regulators. But there are no data to confirm the efficacy of these measures. Land-based raceway and tank systems score 6 out of 10 for Factor 6.1—Risk of Escape. Rainbow trout is not native to Quebec but is fully ecologically established in the production region as a result of historic and ongoing provincial stocking programs to support fisheries. (Invasion outside of production regions is a problem in eastern Quebec, although not necessarily attributed to aquaculture.) Farmed fish are selectively bred and have genetic differentiation from their wild counterparts, but wide use of single-sex and triploid fish reduces opportunity for introgression. The risk of competitive or genetic impact of escaped rainbow trout from land-based raceway and tank systems is considered low to low–moderate, and scores 7 out of 10 for Factor 6.2.

Overall, the final score for raceway and tank systems is 6 out of 10 for Criterion 6—Escapes.

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: preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites.

Criterion 7 Summary

Net pens

Pathogen and parasite parameters, risk-based assessment	Score	
C7 Disease Score (0–10)	5	
Critical?	NO	YELLOW

Raceways, Tanks

Pathogen and parasite parameters, risk-based assessment	Score	
C7 Disease Score (0–10)	6	
Critical?	NO	YELLOW

Brief Summary

Canada's disease risk management system is well developed, and disease issues are apparently not a major concern for the Canadian rainbow trout aquaculture industry because of regulatory controls and best management practices. But this Criterion would benefit from additional rainbow trout-specific and farm-level information on overall incidence of disease and interaction with wild fish, and from data enabling understanding of disease trends. For net pen production, biosecurity measures and fish health best practices are in place and offer some risk reduction; plus, there are some indications of low–moderate disease rates with Canadian commercial production, reported by regulators. But, because of the open nature of the production methods used, the susceptibility of cultured fish to various diseases, and limitations on industry-wide data availability, the score for net pen production systems is 5 out of 10 for Criterion 7—Disease. The flow-through and semi-closed systems (such as those used in Quebec) offer additional risk-management benefits that are not possible in open net pen systems, including physical separation of farmed fish from wild fish, and (in some cases) the sourcing of spring water. Quebec also benefits from robust federal and provincial biosecurity measures and fish health practices. Disease is also apparently not a significant issue for Quebec farms, but data to verify disease occurrences and trends are limited. Thus, the score for raceway and tank systems is 6 out of 10 for Criterion 7—Disease.

Justification of Rating

Because disease data quality and availability is moderate–low (i.e., Criterion 1 score of 5 or lower for the disease category), the Seafood Watch Risk-Based Assessment was utilized.

Rainbow trout are susceptible to a number of bacterial and viral diseases. As with all aquaculture, there is a risk of disease amplification at culture sites because of the high stocking densities of hosts (i.e., fish) in one area. The nature of production, either connected to waterbodies (i.e., land-based) or open within waterbodies (i.e., net pens), also represents a risk of disease spread.

Rainbow trout disease issues are generally well understood, and Canada has well developed federal and provincial systems for managing disease risk. Canada maintains a list of reportable diseases under the Health of Animals Act and its Reportable Disease Regulations, which require that those involved in husbandry of animals report the presence of an animal infected (or suspected to be) with a listed disease. The Canadian Food Inspection Agency (CFIA), which has a key role in overseeing disease risk management in agriculture, lists the diseases that are considered a concern for rainbow trout in Canada:

- Ceratomyxosis
- Infectious haemtopoietic necrosis (IHN)
- Infectious pancreatic necrosis (IPN)
- Infectious salmon anaemia (ISA)
- Viral haemorrhagic septicaemia IVa (VHS Iva)
- Viral haemorrhagic septicaemia IVb (VHS IVb)
- Whirling disease (*Myxobolus cerebralis*)

In addition to the federally reportable diseases, Fisheries and Oceans Canada lists bacterial kidney disease (BKD), enteric redmouth (ERM), and furunculosis as other diseases of concern with rainbow trout culture (DFO 2016b); some of these were diagnosed in Ontario in 2016 (Chiasson and LePage 2016). The FAO includes a longer list specific to rainbow trout (FAO 2017), though not all are applicable to Canada at the time of this assessment. Provinces may have additional concerns—for example, Ontario adds *Oncorhynchus masou* virus, epizootic epitheliotropic disease, and proliferative kidney disease (Government of Ontario 1997). Weisselosis has presented challenges in Saskatchewan recently (pers. comm., D. Foss 2018).

The availability of specific, detailed disease occurrence data from rainbow trout farming in Canada is not extensive and is protected by confidentiality restrictions, though some information is publicly available. The CFIA maintains a real-time list of confirmed disease cases for the current year as well as publicly accessible archives from the previous 5 years, with additional details available via the OIE (such as whether outbreaks were with wild or farmed fish in some cases). No incidents of OIE-reportable diseases in rainbow trout for any of the major producing provinces (Ontario, Quebec, Saskatchewan, and British Columbia) are listed from 2012 to 2017.

An Ontario Animal Health Network Expert Report (Chiasson and LePage 2016) indicates that several federally reportable disease diagnoses occurred in late 2016 (Figure 8; some were also confirmed throughout 2017) (Chiasson and LePage 2017) (Chiasson et al. 2017).

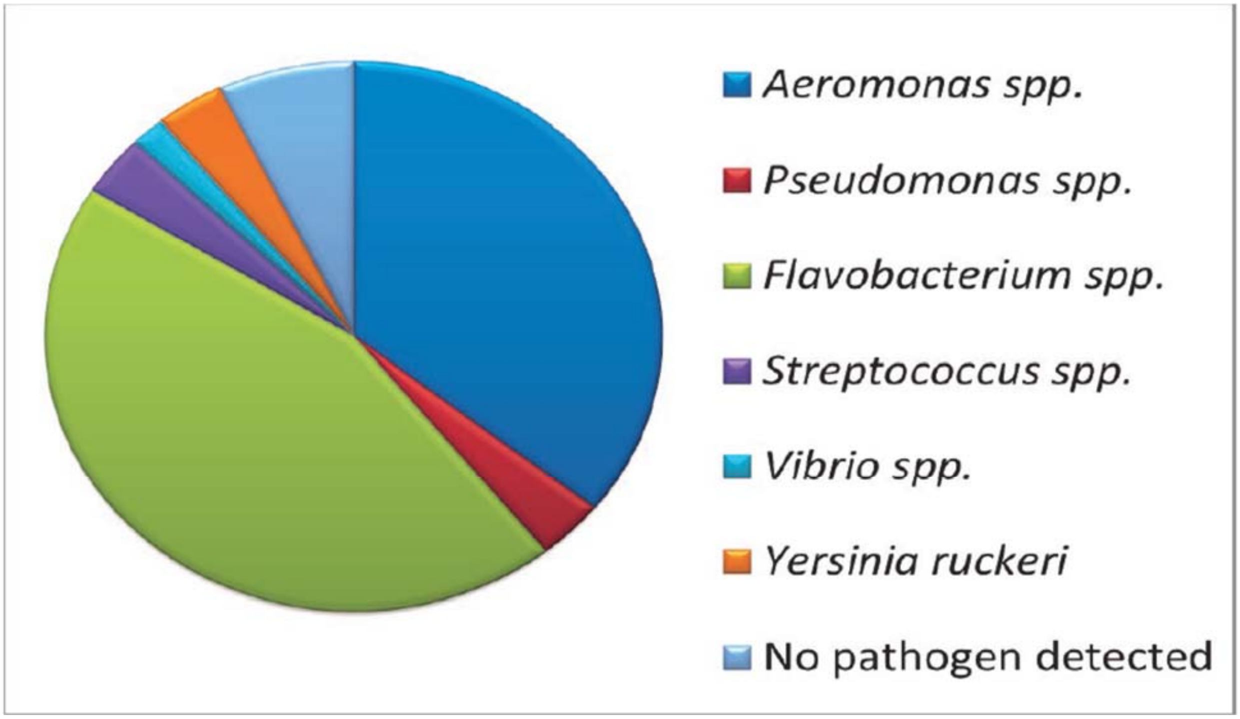


Figure 8. Results of bacterial analyses of fish samples submitted to University of Guelph as part of a baseline disease assessment of the province's aquaculture industry in 2016 (from Chiasson and LePage 2016).

In Ontario, bacterial coldwater disease, which is caused by the bacterium *Flavobacterium psychrophilum*, has been the most important production-limiting disease for trout farmers, and several producers have reported treating for columnaris in recent years (pers. comm., Anonymous 2018). Incidents of disease are reported to be quite infrequent in Ontario (pers. comm., S. Naylor 2016) and Quebec (pers. comm., M. Lambert 2017), and multiple farms have reported operating disease-free for multiple years (Parliament of Canada 2015)—though at least one major farm reports annual issues with columnaris in recent years. The University of Montreal maintains a fish diagnostics services lab, which reports on disease diagnoses in fish samples submitted by growers. Reports from recent years (2012–2017) appear to indicate low numbers of disease occurrences, though analyses are limited to samples voluntarily submitted to the lab and may not be representative of the industry as a whole. Furunculosis is the most common disease issue for Quebec finfish aquaculture (LaFaille 2018), though rainbow trout are apparently somewhat less susceptible than brook trout (pers. comm., G. Vandenberg 2018). Apparently, Saskatchewan traditionally has few rainbow trout disease issues (Sweeney International Management Corp. 2010), but recent years have presented challenges associated with warmer temperatures (pers. comm., D. Foss 2018). For at least some producers and at least recently, disease-related mortality exceeds 5% annually (one scoring benchmark used by Seafood Watch).

Canada has a thorough regulatory system aimed at disease risk management in aquaculture. Federal and provincial governments take management actions based on reported disease, such as making use of management zones and restricting movement of live animals according to disease risk. Additionally, Canada's Food Inspection Agency (CFIA) has developed a third-party submission process with the capacity for reviewing submitted aquaculture biosecurity standards. The CFIA requires that standards be developed with government consultation, be based on best-available science and established best practices, are adaptable to evolving risks, and incorporate the agency's Basic Principles of Biosecurity (such as managing animal movements, observations for disease, development of response plans, and basic facility management). The CFIA has also published some general biosecurity guidance specific to aquaculture operations. The CFIA states that they use surveillance as a tool to monitor compliance, have not identified lack of compliance by laboratories and veterinarians, and maintain strong relationships with the veterinary community, laboratories, and provincial regulators (pers. comm., Kim Klotins, CFIA 2017). One major producer has provided copies of their biosecurity protocols for this assessment, which suggests that compliance occurs and that investments are made in disease prevention as a primary management strategy (pers. comm., Anonymous 2018).

The DFO provides diagnostic and laboratory support to the CFIA and conducts research on fish health and disease for introductions and transfers (DFO 2013). Fish culture licenses also require the establishment of farm-specific Fish Health Management Plans in all cases (DFO 2014). FHMPs are intended to outline good health conditions for cultured finfish; to reflect the commitment of the producer to comply with best management principles, concepts, and requirements; and for use in staff training and guiding day-to-day interactions with fish. DFO outlines that FHMPs must abide by "four key principles" of management of health (DFO 2014):

1. Characterizing the health status of the animal population
2. Identifying and managing risks
3. Reducing exposure to disease-causing agents
4. Judicious application of chemicals and drugs

To reduce the risk of spreading and introducing disease, Canada has restrictions on the movement of live fish. The CFIA requires an import permit for movement of live fish (including as eggs, eyed eggs, and larvae) into Canada and maintains an automated system to help importers of live animals understand their regulatory requirements. Imports are subject to an extensive list of requirements for permits, which, for live rainbow trout from Idaho or Washington (the United States hubs for hatchery facilities supplying Canada), include:

- Visual inspection
- Veterinary inspection with accompanying Zoosanitary Export Certificate
- Aquatic Animal Health Import Permit

- Defined liability for dissemination of diseases
- Sanitary requirements for shipment containers
- Treatment and disposal requirements for water used in transport
- Animal stress minimization requirements
- Record-keeping requirements
- Investigation of unexplained mortalities
- Use of approved laboratories for diagnostics
- Premises of origin must have a biosecurity plan and exports to Canada are also subject to USDA APHIS requirements
- Isolation from other animals, quarantine requirements
- Additional requirements for import of germplasm

All movements of fish between provinces also require an Introductions and Transfers permit, issuable only to producers with a Fish Health Certificate that proves facility inspection (complete with sampling) and compliance with applicable fish health regulations (DFO 2011).

At the provincial level, each province with a significant trout farming industry maintains animal health guidelines and biosecurity protocols that are relevant to aquaculture. For example, Ontario and Quebec make use of spatial management zones to minimize the spread of disease (as does Canada at the federal level). Ontario's *Fish and Wildlife Conservation Act*[46] puts forth licensing requirements for aquaculture, including elements relevant to disease risk management—such as prohibiting the stocking of fish to locations other than those described in licensing, requiring the reporting of disease incidents, and directives on disposal of carcasses (Government of Ontario 1997). The province also administers the National Code of Introductions and Transfers of Aquatic Organisms (which, for provincial management, requires stricter standards than federal standards). Quebec's Aquaculture Regulation outlines a number of items pursuant to fish health, including transfer requirements, facility biosecurity measures, and reporting of veterinary consultations. MAPAQ also maintains a health certification program aimed at promoting industry-wide best practices for biosecurity. Saskatchewan incorporates fish health management requirements into its EIS process and as conditions of license (Saskatchewan Ministry of Environment 2008). Improvements in fish health have also been realized through reduced stocking densities (pers. comm., S. Naylor 2018). The industry is working with veterinarians to trial vaccines for Weisselosis and furunculosis, and regulators are actively monitoring for transfer of diseases from farm to wild fish (pers. comm., D. Foss 2018).

Provinces generally have record-keeping and reporting requirements, and there is evidence that producers are following regulatory guidelines via Environmental Impact Statements (Sweeney International Management Corp. 2010) and via records provided by both the largest farm operator in Ontario (> 95% Ontario production) and the largest hatchery operator in Ontario (80% of province's fingerlings), as well as information from the largest producer in

[46] https://www.ontario.ca/laws/statute/97f41

Saskatchewan (pers. comm., D. Foss 2018) (pers. comm., R.J. Taylor 2018) (pers. comm., J.O. Skipper-Horton 2018).

Canada's disease risk management system is well developed, but this Criterion would benefit from additional rainbow trout-specific and farm-level information on overall incidence of disease and interaction with wild fish, and from data enabling understanding of disease trends.

Conclusions and Final Score

Canada's disease risk management system is well developed, and disease issues are apparently not a major concern for the Canadian rainbow trout aquaculture industry because of regulatory controls and best management practices. But this Criterion would benefit from additional rainbow trout-specific and farm-level information on overall incidence of disease and interaction with wild fish, and from data enabling understanding of disease trends.

For net pen production, biosecurity measures and fish health best practices are in place and offer some risk reduction; plus, there are some indications of low–moderate disease rates with Canadian commercial production, reported by regulators. But, because of the open nature of the production methods used, the susceptibility of cultured fish to various diseases, and limitations on industry-wide data availability, the score for net pen production systems is 5 out of 10 for Criterion 7—Disease.

The flow-through and semi-closed systems (such as those used in Quebec) offer additional risk-management benefits that are not possible in open net pen systems, including physical separation of farmed fish from wild fish, and (in some cases) the sourcing of spring water. Quebec also benefits from robust federal and provincial biosecurity measures and fish health practices. Disease is also apparently not a significant issue for Quebec farms, but data to verify disease occurrences and trends are limited. Thus, the score for raceway and tank systems is 6 out of 10 for the Criterion 7—Disease.

Criterion 8X: 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: using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture.

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. A score of zero means there is no impact

Criterion 8X Summary

All production systems

Source of stock parameters	Score	
C8X Independence from unsustainable wild fisheries (0–10)	–0	
Critical?	NO	GREEN

Brief Summary

Rainbow trout is native to western North America but has long been cultivated and is now domesticated and farmed worldwide. The Canadian rainbow trout industry is supported by hatcheries, from which all cultivated rainbow trout is sourced, with no reliance on wild stocks. Criterion 8X—Source of Stock is a deduction of 0 out of –10.

Justification of Rating

Rainbow trout is native to western North America, has been introduced to every continent (except Antarctica), and is widely farmed. It is believed that many cultivated stocks hail from fish transferred from California's McCloud River in the 1870s (Okumuş 2002). Cultivation of the species in Canada began for stocking private ponds, and it has widely been stocked into waterways as a recreational resource (as reviewed in Adeli and Baghaei 2013). Farming of the species in Canada began in the 1970s but it has been cultivated elsewhere for more than 100 years, with the species now successfully domesticated—complete with advanced hatchery and breeding technology.

The culture of trout is completely independent of wild stocks because eggs are all sourced from 100% domesticated broodstock. A number of hatcheries across Canada breed trout and supply the industry with eggs; however, domestic production is not sufficient to meet domestic demand, and some eggs are imported from international hatcheries, such as Trout Lodge in the United States (Government of New Brunswick 2010) (pers. comm., D. Madeiros 2017) (pers.

comm., S. Peterson 2017). Efforts at developing a national broodstock program aimed at improved fish performance is currently underway (Government of New Brunswick 2010).

The final score for Criterion 8X—Source of Stock is 0 out of –10 because all production comes from fully domesticated broodstock, and the industry is fully independent of wild stocks.

Conclusions and Final Score

The Canadian rainbow trout industry is supported entirely by hatcheries, from which all cultivated rainbow trout is sourced.

Because no farmed stock is dependent on wild broodstock or wild fisheries, and no farmed stock is dependent on endangered species, the final numerical score for Criterion 8X—Source of Stock is a deduction of 0 out of –10.

Criterion 9X: Wildlife and predator mortalities

Impact, unit of sustainability and principle

- Impact: mortality of predators or other wildlife caused or contributed to by farming operations
- Sustainability unit: wildlife or predator populations
- Principle: aquaculture populations pose no substantial risk of deleterious effects to wildlife or predator populations that may interact with farm sites.

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. A score of zero means there is no impact.

Criterion 9X Summary
Net pens

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0–10)	–3	
Critical?	NO	GREEN

Raceways, Tanks

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0–10)	–1	
Critical?	NO	GREEN

Brief Summary

Regulations at various levels are designed either to prohibit lethal take of some predators at aquaculture sites or to restrict lethal control. Best Management guidelines aimed at excluding predators from aquaculture structures are in place and appear to be common practice at Canadian rainbow trout farms. In most cases, provinces have also not issued any lethal take permits in several years, and species that are potential candidates for such take have populations considered low-risk at international and national levels. Wildlife may also occasionally become entangled or trapped in aquaculture gear, but this is apparently limited to exceptional cases; however, no data on actual mortalities or take are available. The final numerical score for Criterion 9X—Wildlife Mortalities is –3 out of –10 for net pens, and –1 out of –10 for raceway and tank systems because much of Quebec's upland production is completely enclosed.

Justification of Rating

Aquaculture operations, which act as a potential food source for wild animals, will typically attract wildlife and predators. Interactions between wildlife and fish farms are of concern because they have the potential to be lethal to wildlife that may become entangled in nets (Anderson et al. 2015) and they can cause significant economic loss for the farm because of direct or indirect fish losses. Birds are a classic predatory nuisance for finfish aquaculture. For example, great blue herons (*Ardea herodias*) are a common predator of cultured trout in parts of Canada and can consume up to two live trout per hour, or 0.35 kg/day (AMAF 1999). At feeding time, gulls can be a nuisance (pers. comm., Anonymous 2018). In freshwater culture systems, birds are the primary predator of concern (Bevan et al. 2002). In some cases, lethal control may also be an aquaculture-related source of mortality for wildlife, although Canada appears to emphasize non-lethal controls.

In Canada, all species of birds and most mammals are protected by either federal or provincial laws (Bevan et al. 2002). At the federal level, birds are protected against unregulated take by the federal *Migratory Birds Convention Act*[47] (MBCA) of 1994. The statute protects most species of birds in Canada—including those that might typically be problematic for a finfish farm, such as loons, ducks, terns, gulls, and herons. The MBCA prioritizes use of non-lethal methods of deterrence for birds causing or likely to cause damage, and the Canadian Wildlife Service (under Environment and Climate Change Canada [ECCC]) may issue scare permits as necessary. Though the MBCA does authorize the issuance of relocation and lethal take permits by Regional Directors (Bevan et al. 2002) (CMOJ 2016), current policy by ECCC has forbidden lethal take since 2000 (CWS 2000) (pers. comm., Jon Dunlop, CWS 2017). Reports on bird scaring, relocation, and nest removal actions are maintained by the Canadian Wildlife Service (CWS). Permittee information is protected by privacy, but general data, such as number of permits issued, are available via an Access to Information and Privacy (ATIP) request (pers. comm., Caitlin Andersen, CWS 2017). The CWS states that they have not issued any lethal take permits since 2008 (pers. comm., J. Dunlop 2017).

The *Species at Risk Act*[48] prohibits the unpermitted take of protected species, in order to provide safeguards against extinction or extirpation, which include considerations of important habitat in siting aquaculture (CMJ 2015) (ECCC 2016).

At the provincial level, the *Ontario Endangered Species Act*[49] provides additional protection against harm to listed species and their habitat, and other species (such as kingfishers) may receive protections under the Fish and Wildlife Conservation Act of Ontario (Moccia and Bevan 2000). The Ontario Ministry of the Environment is authorized to issue permits for take of provincially protected species, subject to specific conditions of license (LEO 2007). For other

[47] http://laws-lois.justice.gc.ca/eng/acts/m-7.01/
[48] http://laws-lois.justice.gc.ca/eng/acts/s-15.3/
[49] https://www.ontario.ca/laws/statute/07e06

species, no authorization is required for lethal take (pers. comm., B. Burdick 2017). Some farms in Ontario have used lethal control against double-crested cormorants (*Phalacrocorax auritus*) (Cross 2013), though cormorants have not been a significant issue in recent years (pers. comm., S. Naylor 2017). Other provinces contain similar regulations:

- Quebec mandates a policy of exclusion and non-lethal deterrent first, and is similarly allowed to issue take permits with reporting requirements. But it has not issued any lethal take permits in recent years, and no rainbow trout producers currently have such a permit (MAPAQ 2013) (pers. comm., Benoit Audet, ECCC 2017).

- Saskatchewan has required that project proponents include details of probable wildlife interactions and prevention measures as part of an Environmental Impact Statement (Saskatchewan Ministry of Environment 2011). For example, a large producer in Saskatchewan has previously been permitted by the federal government to kill 8–16 gulls per month for 8 months per year. Saskatchewan Environment has also previously permitted this producer to take a limited number of white pelicans. The aim of limited permitting is to use lethal control on a restricted number of birds as a way to intimidate a larger flock into deterrence, and it is apparently effective (Sweeney International Management Corp. 2010). But according to the ECCC, no such permits have been issued since about 2008 (pers. comm., John Dunlop, ECCC 2017) and, according to the producer, wildlife interactions are infrequent (pers. comm., D. Foss 2017).

The ECCC (as well as individual provinces) offers general guidance and a number of online resources in support of developing best management practices to limit interactions with migratory birds (Environment and Climate Change Canada 2011). Guiding principles include (pers. comm., B. Audet 2017):

1. Know your legal obligations;
2. Avoid potentially destructive or disruptive activities during periods and sensitive locations to reduce the risk of impact on migratory birds, nests or eggs;
3. Develop and implement appropriate prevention and mitigation measures to minimize the risk of by-catch and to help maintain viable populations of migratory birds.

Conversations with agents at ECCC and provincial agencies indicate that violations are enforceable and that some enforcement takes place, though specifics were not available.

It is common practice for both net pens and outdoor raceway and tank systems to use various types of predator exclusion nets to reduce wildlife interactions (Sweeney International Management Corp. 2010), and conversations with producers suggest that non-lethal control is the primary strategy in wildlife interactions. One major net pen producer, representing > 95% of Ontario production, provided a Wildlife Interaction Plan for this assessment. The plan educates staff on avoidance of harm to protected species and prioritizes prevention of wildlife interactions—such as maintenance of top nets with a tight seal to exclude predators, and regular net inspections with an ROV to monitor for holes. Use of non-lethal methods is also emphasized, such as using live traps (pers. comm., R.J. Taylor 2018); biodegradable paintballs to deter gulls may occur if necessary (pers. comm., Anonymous 2018). In Quebec, a significant portion of production occurs in completely covered systems—such as raceways in covered barns and greenhouses (Bobines Fish Farm 2017) (Ferme Cedar Creek 2018) (ML Aquaponics 2018) that completely isolate fish ponds from predatory wildlife—including at Quebec's largest producer.

Although lethal control is not currently being permitted in Canada, some birds may become entangled or trapped in netting designed to contain fish or exclude predators—but this is suggested to be limited to occasional instances (pers. comm., B. Audet 2017) (pers. comm., S. Naylor 2017) (pers. comm., D. Foss 2017). These incidents come with reporting requirements to federal or provincial agencies (depending on species), and at least some operators are apparently reporting mortality data, but no data are publicly available or were otherwise provided to verify this.

Species likely to occur as nuisance species at rainbow trout farms (as listed by Kevan and Kevan 1993; Table 2) are considered species of Least Concern by the International Union for the Conservation of Nature (IUCN) (IUCN 2016), and previous studies of population-level impacts on aquaculture-associated bird depredation actions in North America have concluded negligible effects on species such as great blue heron, double-crested cormorant, and others (Belant et al. 2000) (Blackwell et al. 2000). But the lack of data on rainbow trout-aquaculture interactions does leave some uncertainty.

Table 7. Known predatory birds at Canadian fish farms (adapted from Kevan and Kevan 1993, Sweeney International Management Corp. 2010):

Common name	Scientific name	IUCN status*	Canada Status**
Belted kingfisher	*Megaceryle alcyon*	Least Concern; Stable	Secure
Black-crowned night heron	*Nycticorax*	Least Concern; Decreasing	Secure; Moderate concern
Double-crested cormorant	*Phalacrocorax auritus*	Least Concern; Increasing	Secure; Not currently at risk
Great blue heron	*Ardea herodias*	Least Concern; Increasing	Secure; Not currently at risk
Green heron	*Butorides striata*	Least Concern; Decreasing	Secure; Low Concern
Osprey	*Pandion haliaetus*	Least Concern; Increasing	Secure
American white pelican	*Pelecanus erythrorhynchos*	Least Concern; Increasing	Sensitive; Increasing

* (IUCN 2016); ** (Government of Canada 2018)

Overall, because best practices for wildlife exclusion are being applied, mortalities appear to be limited to exceptional to occasional cases, but actual data on mortalities are unavailable.

Conclusions and Final Score

Regulations at various levels are designed either to prohibit lethal take of some predators at aquaculture sites or to restrict lethal control. Best Management guidelines aimed at excluding predators from aquaculture structures are in place and appear to be common practice at Canadian rainbow trout farms. In most cases, provinces have also not issued any lethal take permits in several years, and species that are potential candidates for such take have populations considered low risk at international and national levels. Wildlife may also occasionally become entangled or trapped in aquaculture gear, but this is apparently limited to exceptional cases—though no data on actual mortalities or take are available. The final numerical score for Criterion 9X—Wildlife Mortalities is –3 out of –10 for net pens, and –1 out of –10 for raceway and tank systems because much of Quebec’s upland production is completely enclosed.

Criterion 10X: Escape of secondary species

Impact, unit of sustainability and principle

- Impact: movement of live animals resulting in introduction of unintended species
- Sustainability unit: wild native populations
- Impact: aquaculture operations by design, management or regulation avoid reliance on the movement of live animals, therefore reducing the risk of introduction of unintended species.

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.

Criterion 10X Summary

All production systems

Escape of secondary species parameters		Score	
F10Xa International or trans-waterbody live animal shipments (%)		5	
F10Xb Biosecurity of source/destination		9	
C10X Escape of secondary species Final Score		**–0.50**	**GREEN**

Brief Summary

The Canadian rainbow trout industry relies on the movement of live animals in the form of eggs and larvae. International movement occurs in the form of significant import of eggs and/or larvae from hatcheries in the Unites States. Inter- and intra- provincial movement (including trans-waterbody) occurs as well, because Canada also produces a large percentage of domestically used eggs/larvae. All import and movement of live animals requires compliance with permitting and regulatory conditions, and both source and destination facilities are subject to biosecurity standards. Thus, the risk of introduction of secondary species (besides the cultivated species itself) is considered low. The final numerical score for Criterion 10X—Escape of Secondary Species is –0.5 out of –10.

Justification of Rating

Factor 10Xa International or trans-waterbody live animal shipments

Demand for rainbow trout eggs and fry in Canada (including from the aquaculture, research, and recreational fishing industries) outpaces domestic production. Thus, the Canadian rainbow trout industry is supported by both domestic and international hatchery production for eggs, larvae, and fingerlings. Although most rainbow trout eggs and fry grown out at Canadian fish farms are produced within Canada, there is some reliance upon imports from hatcheries—particularly from the United States. The relative reliance on U.S. hatcheries varies by region: reliance is lower in eastern Canada (Ontario, Quebec) because of the prevalence of hatcheries in eastern provinces; British Columbia is about 75% supported by geographically closer hatcheries in the western United States; and Saskatchewan imports all its eggs from the United States (Sweeney International Management Corp. 2010) (pers. comm., D. Madeiros 2017) (pers. comm., S. Peterson 2017). The DFO reports general statistics regarding permitting applications for live animal transfers. Nationwide, the largest share of movements (41%) of live aquatic organisms in 2016 was related to aquaculture operations; of that, 48% were for freshwater finfish—the dominant category of aquatic organisms. For Ontario, 20% of all applications were for international imports of live aquatic organisms, 20% from outside the province, and 60% within the province. Although Canada is mostly supported by domestic hatcheries, the rainbow trout industry relies on imports for about 21% of its egg and fry (pers. comm., D. Madeiros 2017); as recently as 2010, this number was greater than 50%.

The movement of live animals into and within Canada is governed by a system of oversight. Aquaculture in Canada is guided by the *National Code on Introductions and Transfers of Aquatic Organisms*[50] to minimize ecological, disease, and genetic risks. The Code is jointly managed by federal and provincial/territorial governments and involves science-based, objective risk assessment to permitting transfers of live animals within province, province-to-province, and internationally. This framework is additionally based on internationally accepted principles.

The Canadian trout farming industry depends, to some extent, on the international and/or trans-waterbody shipment of live eggs. The Canadian Food Inspection Agency maintains strict regulations and biosecurity protocols for aquatic animal imports and domestic movements in an effort to minimize the risk of disease transfer. Regulations and protocols are aimed at the prevention of the introduction and spread of disease, and they set a strong biosecurity standard that indirectly addresses the concern of unintentionally introduced species during live shipments. For the purpose of this assessment, it was assumed that 21% of product is being sourced internationally and an additional 20% moves across provincial lines (or trans-waterbody), as indicated by multiple sources.

Because an estimated total of 40% of production relies on international/trans-waterbody animal movements, the score for Factor 10Xa is 5 out of 10.

Factor 10Xb Biosecurity of source/destination

<u>Source</u>
Canada relies on a mix of domestic and international hatcheries to supply its rainbow trout industry. The United States is a major hatchery supplier to Canada. Canada has a system of oversight of the movement of live animals in place. Imports are subject to extensive requirements for import permits aimed at disease risk management but serving to reduce likelihood of trans-border movement of secondary organisms in general. Import requirements include visual inspections for parasites, veterinary inspection, and accompanying certificates and transport sanitation requirements (including for shipping containers and transport water).

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[50] http://www.dfo-mpo.gc.ca/aquaculture/management-gestion/2013-IT-Code-Aug-26-eng.pdf

Imports also require certifiable biosecurity standards for the facilities of origin (see also Criterion 7—Disease).

For example, Trout Lodge is a major U.S.-based supplier to Canada. Trout Lodge maintains an independent health certification program that meets World Organization for Animal Health (OIE) disease-free standards (Sweeney International Management Corp. 2010) (Trout Lodge 2010), a program not only attractive to potential customers but also required to export to Canada by both the CFIA and USDA APHIS .

These facilities are additionally operated as tank-based recirculation systems and are of low biosecurity concern.

The movement of live animals also requires an application to an Introductions and Transfers committee, science-based risk management in permitting decisions, reporting requirements, and additional ad hoc mitigation measures as appropriate. The Committee may deny applications for reasons related to intolerable risk of introductions.

Biosecurity of the source for live animal movements (eggs and larvae) is considered low risk, and Factor 10Xb/Source scores 9 out of 10.

<u>Destination</u>
The destination facilities are open systems that are considered to be of moderate biosecurity concerns (flow-through raceways) or moderate–high biosecurity concerns (net pens with best management practices in design for escape prevention). Quebec features a significant portion of producers using partially closed systems. Quebec also has a voluntary farm-level provincial biosecurity and certification system in place, which includes measures to prevent interactions between cultured and wild fish, water treatment, and veterinary inspection (MAPAQ 2018).

Raceway and tank systems with active Best Management Practices aimed at biosecurity, such as those used in Quebec and by smaller producers in other provinces, score 6 out of 10 for Factor 10Xb/Destination.

Net pen systems with BMPs for escape mitigation and biosecurity implemented, such as those that dominate production in Ontario and Saskatchewan score 2 out of 10 for Factor 10Xb/Destination.

The Seafood Watch Aquaculture Standard uses the higher of the two Factor 10Xb scores. In this case, the Source score (9 out of 10) for live animals (eggs, larvae) is used for Factor 10b for all production systems in all provinces.

Conclusions and Final Score
The Canadian rainbow trout industry relies on the movement of live animals in the form of eggs and larvae. International movement occurs in the form of significant import of eggs and/or larvae from hatcheries in the Unites States. Inter- and intra-provincial movement (including

trans-waterbody) occur as well, because Canada also produces a large percentage of domestically used eggs/larvae. All import and movement of live animals requires compliance with permitting and regulatory conditions, and both source and destination facilities are subject to biosecurity standards. Thus, the risk of introduction of secondary species is considered low. The final numerical score for Criterion 10X—Escape of Secondary Species is –0.5 out of –10.

Overall Recommendation

The overall recommendation is as follows:

The overall final score is the average of the individual criterion scores (after the two exceptional scores have been deducted from the total). The overall rating is decided according to the final score, the number of red criteria, and the number of critical scores as follows:

- **Best Choice** = Final Score ≥6.661 **and** ≤10, and no Red Criteria, **and** no Critical scores
- **Good Alternative** = Final score ≥3.331 and ≤6.66, **and** no more than one Red Criterion, **and** no Critical scores.
- **Red** = Final Score ≥0 and ≤3.33, **or** two or more Red Criteria, **or** one or more Critical scores.

Net pens

Criterion	Score	Rank	Critical?
C1 Data	7.50	GREEN	
C2 Effluent	7.00	GREEN	NO
C3 Habitat	7.33	GREEN	NO
C4 Chemicals	3.00	RED	NO
C5 Feed	6.95	GREEN	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	5.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-3.00	GREEN	NO
C10X Introduced species escape	-0.50	GREEN	
Total	**36.29**		
Final score (0-10)	**5.18**		

OVERALL RANKING

Final Score	5.18
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

Raceways, Tanks

Criterion	Score	Rank	Critical?
C1 Data	7.50	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	8.13	GREEN	NO
C4 Chemicals	3.00	RED	NO
C5 Feed	6.95	GREEN	NO
C6 Escapes	6.00	YELLOW	NO
C7 Disease	6.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-1.00	GREEN	NO
C10X Introduced species escape	-0.50	GREEN	
Total	**44.09**		
Final score (0-10)	**6.30**		

OVERALL RANKING

Final Score	6.30
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

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About Seafood Watch®

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States 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. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org . The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides 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 conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out 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 regularly 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.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer
Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[51] 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

[51] "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 rating has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ratings 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.

Appendix 1 - Data points and all scoring calculations

Net pens

Data Category	**Data Quality (0-10)**
Industry or production statistics	7.5
Management	10
Effluent	7.5
Habitats	7.5
Chemical use	7.5
Feed	7.5
Escapes	7.5
Disease	5
Source of stock	10
Predators and wildlife	5
Unintentional introduction	7.5
Other—(e.g. GHG emissions)	n/a
Total	**82.5**

C1 Data Final Score (0-10)	**7.5**	**GREEN**

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**0**	**GREEN**
Critical?	NO	

Protein content of feed (%)	43
eFCR	1.25
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	15.7
N content factor (fixed)	0.16
N input per ton of fish produced (kg)	86
N in each ton of fish harvested (kg)	25.12
Waste N produced per ton of fish (kg)	**60.88**

Basic production system score	0.8
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score (0-1)	**0.8**

% of the waste produced by the fish is discharged from the farm

Waste discharged per ton of production (kg N ton-1)	48.70
Waste discharge score (0-10)	**5**

2.2a Content of effluent management measure	5
2.2b Enforcement of effluent management measures	4
2.2 Effluent management effectiveness	**8**

C2 Effluent Final Score (0-10)	**7.00**	**GREEN**
Critical?	NO	

F3.1 Score (0-10)	7

3.2a Content of habiat management measure	5
3.2b Enforcement of habitat management measures	4
3.2 Habitat management effectiveness	**8**

C3 Habitat Final Score (0-10)	**7**	**GREEN**
Critical?	NO	

Chemical Use parameters	**Score**	
C4 Chemical Use Score (0-10)	**3**	
C4 Chemical Use Final Score (0-10)	**3**	**RED**
Critical?	NO	

Feed parameters	Score
5.1a Fish In : Fish Out (FIFO)	
Fish meal inclusion level (%)	20
Fish meal from by-products (%)	40
% FM	12
Fish oil inclusion level (%)	6
Fish oil from by-products (%)	55
% FO	2.7
Fish meal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.25
FIFO fish meal	0.67
FIFO fish oil	0.68
FIFO Score (0-10)	**8.31**
Critical?	NO
5.1b Susutainability of Source fisheries	
Sustainability score	-3
Calculated sustainability ajustment	-0.41
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**7.91**
Critical?	NO

Protein INPUTS	
Protein content of feed (%)	43
eFCR	1.25
Feed protein from fish meal (%)	
Feed protein from EDIBLE sources (%)	59.94
Feed protein from NON-EDIBLE sources (%)	40.06
Protein OUTPUTS	
Protein content of whole harvested fish (%)	15.7
Edible yield of harvested fish (%)	60.5
Use of non-edible by-products from harvested fish (%)	50
Total protein input kg/100kg fish	53.75
Edible protein IN kg/100kg fish	32.22
Utilized protein OUT kg/100kg fish	16.49
Net protein gain or loss (%)	-48.82
Critical?	NO
F5.2 Net protein Score (0-10)	**5**

5.3a Ocean Area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	26
eFCR	1.25
Carbon required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	8.45
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	59
Inclusion level of land animal products (%)	16
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.25
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.50
Total area (Ocean + Land Area) (ha)	8.95
F5.3 Feed Footprint Score (0-10)	7

C5 Feed Final Score (0-10)	**6.95**	**GREEN**
Critical?	**NO**	

6.1a System escape Risk (0-10)	2	
6.1a Adjustment for recpatures (0-10)	0	
6.1a Escape Risk Score (0-10)	**2**	
6.2. Invasiveness score (0-10)	**7**	
C6 Escapes Final Score (0-10)	**4**	**YELLOW**
CriticaL?	**NO**	

Disease Evidence-based assessment (0-10)		
Disease Risk-based assessment (0-10)	5	
C7 Disease Final Score (0-10)	**5**	**YELLOW**
Critical?	NO	

C8X Source of stock score (0-10)	0	
C8 Source of stock Final Score (0-10)	**0**	**GREEN**
Critical?	NO	

C9X Wildlife and Predator Score (0-10)	-3	
C9X Wildlife and Predator Final Score (0-10)	**-3**	**GREEN**
Critical?	NO	

F10Xa live animal shipments score (0-10)		5.00
F10Xb Biosecurity of source/destination score (0-10)		9.00
C10X Escape of unintentionally introduced species Final Score (0-10)		**-0.50**
Critical?		n/a

Raceways, Tanks

Data Category	**Data Quality (0-10)**
Industry or production statistics	7.5
Management	10
Effluent	7.5
Habitats	7.5
Chemical use	7.5
Feed	7.5
Escapes	7.5
Disease	5
Source of stock	10
Predators and wildlife	5
Unintentional introduction	7.5
Other—(e.g. GHG emissions)	n/a
Total	**82.5**

C1 Data Final Score (0-10)	**7.5**	**GREEN**

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**0**	**GREEN**
Critical?	NO	

Protein content of feed (%)	43
eFCR	1.25
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	15.7
N content factor (fixed)	0.16
N input per ton of fish produced (kg)	86
N in each ton of fish harvested (kg)	25.12
Waste N produced per ton of fish (kg)	**60.88**

Basic production system score	0.8
Adjustment 1 (if applicable)	-0.32
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score (0-1)	**0.48**

% of the waste produced by the fish is discharged from the farm

Waste discharged per ton of production (kg N ton-1)	29.22
Waste discharge score (0-10)	**7**

2.2a Content of effluent management measure	5
2.2b Enforcement of effluent management measures	4
2.2 Effluent management effectiveness	**8**

C2 Effluent Final Score (0-10)	**8.00**	**GREEN**
Critical?	NO	

F3.1 Score (0-10)	9

3.2a Content of habiat management measure	4
3.2b Enforcement of habitat management measures	4
3.2 Habitat management effectiveness	**6.4**

C3 Habitat Final Score (0-10)	**8**	**GREEN**
Critical?	NO	

Chemical Use parameters	**Score**	
C4 Chemical Use Score (0-10)	**3**	
C4 Chemical Use Final Score (0-10)	**3**	**RED**
Critical?	NO	

Feed parameters	**Score**
5.1a Fish In : Fish Out (FIFO)	
Fish meal inclusion level (%)	20
Fish meal from by-products (%)	40
% FM	12
Fish oil inclusion level (%)	6
Fish oil from by-products (%)	55
% FO	2.7
Fish meal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.25
FIFO fish meal	0.67
FIFO fish oil	0.68
FIFO Score (0-10)	**8.31**
Critical?	NO
5.1b Susutainability of Source fisheries	
Sustainability score	-3
Calculated sustainability ajustment	-0.41
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**7.91**
Critical?	NO

Protein INPUTS	
Protein content of feed (%)	43
eFCR	1.25
Feed protein from fish meal (%)	
Feed protein from EDIBLE sources (%)	59.94

Feed protein from NON-EDIBLE sources (%)	40.06
Protein OUTPUTS	
Protein content of whole harvested fish (%)	15.7
Edible yield of harvested fish (%)	60.5
Use of non-edible by-products from harvested fish (%)	50
Total protein input kg/100kg fish	53.75
Edible protein IN kg/100kg fish	32.22
Utilized protein OUT kg/100kg fish	16.49
Net protein gain or loss (%)	-48.82
Critical?	NO
F5.2 Net protein Score (0-10)	**5**

5.3a Ocean Area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	26
eFCR	1.25
Carbon required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	8.45
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	59
Inclusion level of land animal products (%)	16
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.25
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.50
Total area (Ocean + Land Area) (ha)	8.95
F5.3 Feed Footprint Score (0-10)	7

C5 Feed Final Score (0-10)	**6.95**	**GREEN**
Critical?	**NO**	

6.1a System escape Risk (0-10)	6	
6.1a Adjustment for recpatures (0-10)	0	
6.1a Escape Risk Score (0-10)	**6**	
6.2. Invasiveness score (0-10)	**7**	
C6 Escapes Final Score (0-10)	**6**	**YELLOW**
CriticaL?	**NO**	

Disease Evidence-based assessment (0-10)		
Disease Risk-based assessment (0-10)	6	
C7 Disease Final Score (0-10)	**6**	**YELLOW**
Critical?	NO	

C8X Source of stock score (0-10)	0	
C8 Source of stock Final Score (0-10)	**0**	**GREEN**
Critical?	NO	

C9X Wildlife and Predator Score (0-10)	**-1**	
C9X Wildlife and Predator Final Score (0-10)	**-1**	**GREEN**
Critical?	NO	

F10Xa live animal shipments score (0-10)		5.00
F10Xb Biosecurity of source/destination score (0-10)		9.00
C10X Escape of unintentionally introduced species Final Score (0-10)		**-0.50**
Critical?		n/a