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Oceans of opportunity: a review of Canadian aquaculture

Oceans of
opportunity

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Abstract

Purpose – The world's population is expected to increase by 30 percent to 10bn people by 2050 and with 70 percent of the earth's surface covered by water aquaculture will play an important role in producing food for the future. The paper aims to discuss this issue.

Design/methodology/approach – While Canada has the longest coastline in the world by far (202,080 km) with 80,000 km of marine coastline capable of supporting aquaculture and fisheries, it ranks only 25th in terms of world aquaculture production. The reasons are many and varied, and this review examines statistical reports and publications to trace the beginnings of the aquaculture sector in Canada, and highlights some areas of strength and potential, and the challenges for future growth and expansion.

Findings – Currently, less than 1 percent of the 3.8m hectares of freshwater and marine areas that are considered suitable for seafood (i.e. finfish, shellfish and aquatic plants) production are being farmed so Canada has an ocean of opportunity to be a leader in world aquaculture production in the future.

Originality/value – The review highlights the need for a national strategic plan to increase aquaculture production in Canada and the need to simplify the current complex regulatory framework that has resulted in significant uncertainties and delays that have limited growth in this sector. The review highlights the potential and interest to triple current production while fostering greater involvement of First Nation communities.

Keywords Aquaculture, Salmon farming, Shellfish farming

Paper type Literature review

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Introduction

The world's population in 2017 was approximately 7.5bn people, and by 2050, it is expected to increase by at least 30 percent to nearly 10bn people. Sustaining this growing population will require a commensurate increase in food production through agriculture, capture fisheries and/or aquaculture. While advances in technology, including the use of genetically modified plants and organisms, have and will continue to enhance food production, food quality, and food security in developed and developing countries (Herrera-Estrella and Alvarez-Morales, 2001; Bouis, 2007; Azadi and Ho, 2010), physical limits on available arable land are likely to temper any significant increases in traditional terrestrial plant and animal production. Climate change will also further challenge our ability to produce substantially more food from agriculture both as a result of rising temperatures as well as increased demand on our limited water resources due to population growth and other competing uses. With more than 70 percent of the earth's surface covered in water, it is clear that the best opportunity to increase food production is likely through increases in fish, shellfish and aquatic plant production and primarily through aquaculture, given the pressures facing wild fish stocks. Indeed, the demand for seafood production is expected to more than double by 2050, an increase that is disproportionately higher than the rate of population growth.

Fish and shellfish provide many valuable nutrients with numerous health benefits and demand for more fish, and shellfish in our diet has grown substantially over the past several decades. Per capita consumption of seafood globally has risen from approximately



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8 kg per capita in 1950 to ~22 kg per capita in 2015, and is expected to increase in a similar fashion in the future (Noakes, 2014b). Currently, approximately 170m tonnes of marine and freshwater fish, shellfish, and aquatic plants are commercially harvested or grown annually with the commercial catch of fish and shellfish holding relatively constant at 90m tonnes since the mid-1980s. The assessment of global fish stocks suggests that nearly 35 percent of all fish stocks are currently being overfished, 55 percent of the stocks are fished “sustainably” with the remaining 10 percent rated as underutilized (Noakes, 2014b). As such, there is little or no opportunity to increase catch from commercial fisheries, so any new growth in this sector must come from increased aquaculture production.

Total aquaculture production is currently about 80m tonnes, and while this is less than the commercial catch, it represents more than 50 percent of all seafood consumed by humans due to waste and alternative uses of some commercial catch. Globally, aquaculture is the fastest growing food production sector with world aquaculture output increasing by approximately 6.3 percent per year or about three times the rate of increase for meat production (beef, poultry, pork) between 2001 and 2010 (Food and Agriculture Organization (FAO), 2012). Annual growth rates have moderated slightly in recent years but were still 4.4 percent in Asia and 3.6 percent in Africa with little or no growth in the Americas in 2014 (FAO, 2016). Given the current and projected demand for seafood, production will need to increase by at least 30m tonnes by 2025 and increase substantially more by 2050, all of which must come from aquaculture since world fish stocks are unable to support increased catch (FAO, 2016).

In addition to food production, the seafood and, in particular, the aquaculture sector also have substantial social and economic benefits particularly for individuals living in rural communities (Noakes, 2014b). Globally, approximately one in ten people relied on the fisheries and aquaculture sector for their livelihood in 2014, so it influences the lives of a large segment of the world’s population in a direct way. In 2014, about 56.6m people including 10.8m women were engaged in primary capture fisheries and aquaculture operations with 18.8m involved in the aquaculture sector (FAO, 2016). While the vast majority were from Asian and African countries in coastal and rural areas, this is an important sector for many countries around the world. Globally, the value of seafood exports was approximately US\$150bn in 2014 with China and Norway accounting for 20 percent of this total and Canada ranking tenth at US\$4.5bn. The largest importers of seafood in 2014 were USA and Japan (~25 percent) with many of the other top ten importers being European countries. It is difficult to overstate the economic and social benefits of this sector to rural and coastal communities including those in Canada, given the level of employment and financial benefits and contribution to food security.

Canada has a long history in both fisheries and aquaculture and, in particular, providing global leadership in fisheries science and conservation, technological innovation and environmental sustainability. Canada has the longest coastline in the world by far (202,080 km), and even when areas in the Arctic are excluded, Canada still has nearly 80,000 km of marine coastline capable of supporting aquaculture and/or fisheries or roughly the same coastline as Norway, Australia and Japan combined. It also has one of the largest renewable internal freshwater resources per capita (80,200 cubic meters in 2014, compared to 153,100 in 1962), a measure of our internal renewable resources related to river flows and groundwater from rainfall, although this has decreased by 47.6 percent since 1962 (<https://data.worldbank.org/indicator/ER.H2O.INTR.PC>). The reduction has been much larger (55.8 percent) on a global basis reflecting the looming freshwater crisis the world faces over the next few decades. Despite substantial freshwater and marine natural resources and a long history in fisheries and aquaculture, Canada ranks only 20th in terms of its capture fisheries and 25th in terms of world aquaculture production. While further expansion in commercial fisheries is limited and likely to decrease, there are certainly

opportunities for future growth in both finfish and shellfish aquaculture. The following is a brief history of aquaculture in Canada and views on significant opportunities and challenges in this area.

Historical overview

Aquaculture has been practiced in various forms around the world for more than 2,500 years, but its commercial beginnings in Canada date back to the mid-1800s. Historically, many of the early initiatives and developments in this sector were small-scale and to a large extent undocumented but they nevertheless established the foundation for many of the key species cultured today. The aquaculture sector in Canada was in fact relatively small (a few thousand tonnes) until the last 30 or 40 years when advances in fish and shellfish husbandry combined with more favorable market and regulatory conditions resulted in substantial growth in the number of species being farmed and production. From that perspective, the aquaculture sector is not unlike other industry sectors where a few key breakthroughs laid the foundation and then technological innovation and market forces resulted in the creation of a viable and sustainable industry. The following are examples of some of the initiatives and breakthroughs that helped move the development of the Canadian aquaculture sector forward, but the list is by no means intended to be comprehensive.

From a species perspective, hatchery operations began for Atlantic salmon (*Salmo salar*) and Brook trout (*Salvelinus fontinalis*) in Quebec in 1857 and Atlantic oyster (*Crassostrea virginica*) production began in Prince Edward Island two years before Confederation in 1865 (Dunfield, 1985; Library of Parliament, 2010). In both Canada and the USA, Rainbow trout (*Oncorhynchus mykiss*) hatcheries became wide spread in the early 1870s, and this species was propagated and introduced into waterways on every continent except Antarctica to support recreational fishing and aquaculture (Knight, 2007). Pacific oysters (*Crassostrea gigas*) were imported from Japan to British Columbia in 1913 and oyster seed imports from Japan continued until the 1930s (Bourne, 1979). Pacific oyster farming began in the 1920s and now supports a large commercial industry. Commercial Mussel (*Mytilus edulis*) culture using seed collected from the wild did not start in Prince Edward Island until the mid-1980s but industry growth has been significant from about 40 tonnes in 1980 to more than 18,000 tonnes in 2015. Finally, in 1889, a Norwegian scientist, Adolph Nielsen, established a Cod (*Gadus morhua*) hatchery in Newfoundland and during its seven years of operation over a billion cod fry were released into the Newfoundland and Labrador coastal waters (Baker *et al.*, 1992). While species such as Atlantic salmon, trout, oysters and mussels remain some of the key species grown in Canada today, lessons learned in early attempts to farm these fish and shellfish helped to improve efficiencies in many areas and diversify the number of species grown (Table I).

From a science perspective, aquaculture like agriculture depends on favorable environmental conditions for its success but both rely heavily on good science and technology as well. The establishment of the Pacific Biological Station in Nanaimo, British Columbia and St Andrews Biological Station in St Andrews, New Brunswick both in 1908 lead to significant advances in fisheries science that resulted in the development and expansion of the aquaculture industries on both the Atlantic and Pacific coasts. Both were established to study the biology of commercially harvested stocks some of which were experiencing overfishing but the focus expanded to include the study of life histories and disease as well as oceanography. Eventually, the Fisheries Research Board of Canada was established in 1937 to oversee the programs at these institutes as well as at other research centers across Canada. The work of these research stations now continues as part of Fisheries and Oceans Canada. In addition to increasing our understanding of the basic biology of fish and shellfish, research on husbandry practices, nutrition and diseases of fish and shellfish (and the management of the diseases) substantially advanced industry's

Table I.
Primary freshwater
and marine
aquaculture species
grown in each
province and territory
in 2016

Province/territory	Species
Newfoundland and Labrador	Atlantic Salmon (<i>Salmo salar</i>), Steelhead/Rainbow Trout (<i>Oncorhynchus mykiss</i>), Cod (<i>Gadus morhua</i>), Blue Mussels (<i>Mytilus edulis</i>), Clams (<i>Macromeris polynyma</i> and/or <i>Arctica islandica</i>), Eastern Oysters (<i>Crassostrea virginica</i>)
Prince Edward Island	Atlantic Salmon, Steelhead/Rainbow Trout, Arctic Char (<i>Salvelinus alpinus</i>), Blue Mussels, Eastern Oysters
Nova Scotia	Atlantic Salmon, Arctic Char, Halibut, Steelhead/Rainbow Trout, Eastern Oysters, Blue Mussels, Clams, Sea Scallops (<i>Placopecten magellanicus</i>)
New Brunswick	Atlantic Salmon, Steelhead/Rainbow Trout, Cod, Atlantic Halibut (<i>Hippoglossus hippoglossus</i>), Eastern Oysters, Blue Mussels, Northern Bay Scallops (<i>Argopecten irradians irradians</i>), Eels (<i>Anguilla rostrata</i>), Seaweed/Kelp (<i>Saccharina latissima</i>)
Quebec	Arctic Char, Steelhead/Rainbow Trout, Brook or Speckled Trout (<i>Salvelinus fontinalis</i>), Eastern Oysters, Blue Mussels, Sea Scallops
Ontario	Steelhead/Rainbow Trout, Arctic Char, Tilapia (<i>Oreochromis Spp.</i>), Sturgeon (<i>Acipenser fulvescens</i>), Shrimp (<i>Litopenaeus vannamei</i>)
Alberta, Saskatchewan and Manitoba	Steelhead/Rainbow Trout, Tilapia, Arctic Char
British Columbia	Atlantic Salmon, Coho Salmon (<i>Oncorhynchus kisutch</i>), Chinook Salmon (<i>O. tshawytscha</i>), Steelhead/Rainbow Trout, White Sturgeon (<i>Acipenser transmontanus</i>), Tilapia, Sablefish (<i>Anoplopoma fimbria</i>), Pacific Oysters (<i>Crassostrea gigas</i>), Manila Clams (<i>Venerupis philippinarum</i>), Varnish/Savory Clams (<i>Nuttallia obscurata</i>), Blue Mussels, Mediterranean Mussels (<i>Mytilus galloprovincialis</i>), Japanese Scallops (<i>Patinopecten yessoensis</i>)
Yukon	Arctic Char

Note: In total, 56 species of finfish (27), shellfish (20) and aquatic plants (9) are grown commercially in Canada
Source: Statistics Canada

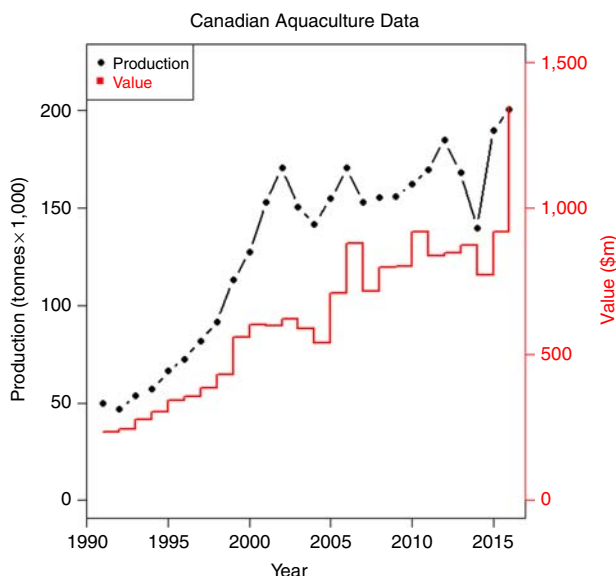
ability to commercialize a wide number of species both within Canada and around the world. While research at university and government continues, there is also significant research capacity and ability within industry today, particularly where production scale experiments and trials are required.

The final component required for the industry to grow was a regulatory framework to facilitate industry development and trade. While the management, harvest and trade aspects of “fishing” were well established, some unique aspects of aquaculture, including the tenure of crown land, stock ownership, overlap with fisheries involving the same species, and some operational details posed some new and challenging problems for producers, regulators and others. An appropriate workable framework was needed to provide the certainty required for investors and farmers to build the infrastructure and systems to grow, process and sell their shellfish and fish in Canada and internationally. To that end, in 1984, the Prime Minister named the Department of Fisheries and Oceans as the lead agency for aquaculture albeit without clarity around a number of key issues. In 1986 at the First Minister’s meeting, the Prime Minister and Provincial Premiers agreed on a statement of broad national goals and principles for aquaculture development, and between 1986 and 1989, negotiations resulted in the development of a federal–provincial memorandum of understanding to clarify the delineation of responsibilities between the two levels of government. Over the next six years, subsequent consultations between government, industry and a broad spectrum of stakeholders lead to the development of Canada’s first Federal Aquaculture Development Strategy in 1985 (Fisheries and Oceans Canada, 1995). This concept and related documents have evolved over time with the Canadian Council of Fisheries and Aquaculture Ministers producing the “Aquaculture Development Strategy 2016-2019” in 2016 (Fisheries and Oceans Canada, 2016). The expected long-term outcomes from this new strategy are an improved

federal–provincial–territorial regulatory framework for aquaculture, improved coordination of aquaculture fish health management, and improved federal and regional support for regional economic growth through aquaculture. While these broad goals or objectives have not fundamentally changed since 1995, there have been substantial changes and improvements in the industry with respect to production and environmental sustainability with First Nations also playing a greater role in various aspects of the industry. It is fair to say the different stakeholders involved have distinct views about what has and has not been accomplished over the last quarter century, but most would agree that improvements have been made slowly.

Canadian aquaculture and production trends

Until the early 1980s, the Canadian aquaculture industry could be described as developmental with total production being less than 10,000 tonnes. Production began to increase sharply in 1984 and by 1991 Canadian aquaculture production was 49,500 tonnes with a farm gate value of about CAN\$233.6m. Finfish, primarily Atlantic salmon, represented approximately 80 percent of the production by weight and that ratio and the importance of Atlantic salmon aquaculture to this sector has not changed significantly over time. By 2016, 56 species (Table I: 27 finfish, 20 shellfish and 9 aquatic plant species) were being farmed commercially in Canada with a total production of approximately 200,565 tonnes and an approximate value of CAN\$1.347bn (Figure 1). In 2016, there were 917 aquaculture sites in Canada, and, not surprisingly, most were located on either the east or west coasts (Table II). The four Atlantic Provinces had 508 associated with shellfish production. The vast majority of the inland aquaculture sites are land-based facilities rearing Rainbow or Brook trout. While the 243 sites in British Columbia are modest when



Note: Total production in 2016 was 200,565 tonnes valued at CAN\$1,347,311

Source: Statistics Canada

Figure 1.
Canadian aquaculture
production and value
from 1991 to 2016

compared to the East coast, many are associated with the salmon farming sector which contributes substantially to the overall economic benefit for Canada (Table II).

Commercial aquaculture operations can be found in every province and the Yukon Territory (Table I) with the majority of the production in 2016 from British Columbia (51 percent – 102,325 tonnes), Newfoundland and Labrador (14.1 percent – 28,622 tonnes), and New Brunswick (13.8 percent – 28,082 tonnes) (Table III). For all three of these provinces, the predominant species farmed is Atlantic salmon. At 24,115 tonnes, Prince Edward Island is the largest producer of shellfish in Canada with Mussels being the main species cultured. British Columbia is the second largest producer of shellfish with approximately 10,000 tonnes of mostly Pacific oysters being grown annually. Ontario is the largest producer of trout (5,440 tonnes in 2016) primarily grown in land-based systems. While many species are grown in each region, there are as expected areas of concentration by species reflecting local growing conditions (Table IV).

In 2016, direct employment in aquaculture production and subsequent processing was 25,000 full-time equivalents with a payroll in excess of CAN\$1.16bn. The contribution to GDP was in excess of CAN\$2.0bn with a net economic activity of CAN\$5.16bn (Canadian Aquaculture Industry Alliance (CAIA), 2017 and Statistics Canada). The full value-chain economic activity of the Canadian aquaculture sector in 2016 was estimated at CAN \$7.3bn, contributing CAN\$3.75bn to Canada’s GDP and providing employment for 54,000 people. The majority (75–80 percent) of our aquaculture production is exported with the USA being our primary market (BC Ministry of Agriculture, 2017a; BC Salmon Farmers Association (BCSFA), 2017a; CAIA, 2017). Approximately 90,000 tonnes of farmed Atlantic salmon (majority produced in British Columbia) valued at over CAN \$900m is currently exported each year, making it Canada’s third most important seafood export behind Atlantic lobster and snow crab (Table V). At CAN\$524.2m, farmed Atlantic salmon was British Columbia’s largest agricultural export in 2016 (and for the past several years) as well as being larger than all other seafood exports from British Columbia combined (BC Ministry of Agriculture, 2017a).

The nature of the industry has also changed substantially over time with much more involvement with local communities. For instance, more than 40 indigenous (First Nation) communities are involved in aquaculture ventures across Canada providing employment and associated financial and social benefits. In British Columbia, approximately 80 percent of farmed salmon are produced in partnership or under a collaborative agreement with local First Nations a level not matched by any other industry sector in Canada. There have also been significant improvements with respect to the environmental performance of the aquaculture sector in particular improvements in waste and fish health management and a reduction in its overall environmental footprint. Significantly, the Monterey Bay Aquarium Seafood Watch program recently rated BC Farmed Atlantic Salmon as a “Good Alternative” having conducted an extensive review of all of the available science and the policies and practices governing the industry. Their peer-reviewed process is comprehensive and their recommendations are widely respected and accepted. The BC salmon farming industry is also moving toward full

Table II.
Number of
aquaculture sites in
Canada by region
with corresponding
production and farm
gate value

	Pacific	Inland	Atlantic	Canada
Number of aquaculture facilities	243	166	508	917
Total production (metric tonnes)	102,325	5,440	90,540	200,565
Total value of production (\$'000)	1,090,436	32,500	224,375	1,347,311

Note: The Atlantic region includes New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland and Labrador

Source: Statistics Canada

Province	2010	2011	2012	2013	2014	2015	2016
<i>Newfoundland and Labrador</i>							
Total	15,360	17,264	21,228	26,550	9,240	22,814	28,622
Total finfish	12,899	14,264	16,831	22,196	5,980	19,684	25,411
Total shellfish	2,461	3,000	4,397	4,354	3,260	3,130	3,211
<i>Prince Edward Island</i>							
Total	22,872	24,048	27,358	24,887	24,329	22,640	24,492
Total finfish	283	472	620	593	358	464	377
Total shellfish	22,589	23,576	26,738	24,294	23,971	22,176	24,115
<i>Nova Scotia</i>							
Total	8,112	7,817	8,229	8,752	8,743	7,157	7,887
Total finfish	5,305	5,833	6,280	6,975	7,102	5,989	6,554
Total shellfish	2,807	1,983	1,949	1,777	1,641	1,168	1,333
<i>New Brunswick</i>							
Total	26,751	22,274	31,481	19,586	18,077	24,331	28,082
Total finfish	25,775	21,640	30,359	18,837	17,184	23,391	26,999
Total shellfish	976	634	1,122	749	893	940	1,083
<i>Quebec</i>							
Total	1,828	1,639	1,560	1,642	1,529	1,417	1,457
Total finfish	408	421	421	1,247	1,134	964	1,105
Total shellfish	546	394	333	395	395	453	352
<i>Ontario</i>							
Total	4,060	3,408	3,721	3,790	4,210	4,890	5,440
Total finfish	4,060	3,408	3,721	3,790	4,210	4,890	5,440
<i>British Columbia</i>							
Total	82,435	92,264	90,382	81,025	72,007	105,131	102,325
Total finfish	72,315	84,291	80,713	72,661	63,694	93,896	91,908
Total shellfish	10,120	7,973	9,669	8,364	8,313	11,235	10,417

Note: Aquaculture production from Manitoba, Saskatchewan, Alberta and the Yukon is relatively minor and not reported

Source: Statistics Canada

Table III.
Aquaculture
production of finfish
and shellfish species
(Table I) by province
2010–2016

Species	Production (metric tonnes)	Value (\$'000)	Main producing province
Salmon	123,522	1,022,127	British Columbia
Trout	9,507	56,275	Ontario
Other finfish	1,237	14,705	Nova Scotia
Clams	1,962	7,076	British Columbia
Oysters	13,824	39,693	British Columbia
Mussels	25,584	37,736	Prince Edward Island
Scallops	38	392	Quebec
Other shellfish	103	2,702	Nova Scotia
Total aquaculture	200,565	1,347,311	

Note: Aquaculture production statistics are sourced from Statistics Canada, CANSIM Table 003-0001

Source: Statistics Canada

Table IV.
Canadian production
of the major
aquaculture species in
2016 and the province
in which the majority
of the production
occurs for each
species

certification by the Aquaculture Stewardship Council an independent international third-party audit, certification and labeling program. While certification under this program is voluntary, it represents an ongoing industry commitment to improve environmental sustainability that will undoubtedly influence consumers and government regulators.

Challenges and opportunities

Like any industry, there are challenges and opportunities associated with the aquaculture sector in Canada some of which are the same or similar to those in other countries. The challenges fall into three broad categories: environmental and/or technical, an uncertain and complex regulatory framework, and changing socio-economics. While significant scientific and technical advances have increased efficiencies in production and improved environmental sustainability, problems such as disease outbreaks and large escapes of farmed fish that occurred in the 1970s and early 1980s have tainted attitudes toward the industry and negatively influenced public confidence to this day. The past 30 years have seen significant improvements in many areas including work on developing new vaccines to reduce or eliminate the incidence of some diseases and significantly reduced the amount of antibiotics used, new diet formulations that reduce the amount of fishmeal used and improved husbandry practices including using camera to monitor and control feeding reducing the production of waste (BCSFA, 2017b; McPhee *et al.*, 2017; Noakes, 2014a). While there is general acknowledgment even by opponents of the aquaculture industry of significant improvements in performance and a more positive view of this industry, the highly polarized debate has left a small segment of the population firmly opposed to the industry regardless of any scientific evidence to the contrary. As noted previously, the salmon farming industry in BC is moving toward full certification by the Aquaculture Stewardship Council in an effort to gain public confidence and improvements in performance have been noted by international organizations such as the Monterey Bay Aquarium Seafood Watch (2017) Program. Similar issues with salmon farming exist on the East Coast of Canada albeit with its own set of specific problems, given a different mix of species and unique oceanographic conditions. There are certainly far fewer environmental problems associated with shellfish aquaculture but there are many technical and scientific problems to overcome in order to increase production and to develop advanced hatchery technologies for new species.

Problems associated with governance and regulatory issues largely apply equally to both finfish and shellfish aquaculture and are, in many respects, one of the significant impediments to industry development and growth in Canada (Government of Canada, Standing Senate Committee on Fisheries and Oceans, 2016a). Currently, as many as 17 federal departments and agencies are involved in the oversight and governance of aquaculture in Canada in addition to a number of Provincial ministries and agencies, making it one of the most highly regulated industry sectors. This is not a situation that has developed over time but rather has remained largely unchanged since the mid-1990s when the problem was first highlighted in the 1995 Federal Aquaculture Development Strategy (Fisheries and Oceans Canada, 1995). In addition, aquaculture is currently managed as a fishery under the Fisheries Act despite some very obvious differences between aquaculture

Table V.
International trade in
fish and seafood
products,
2016 and 2017

Product exports (species)	Volume (metric tonnes)		Value (\$'000)	
	2016	2017	2016	2017
Lobster	83,757	84,390	2,148,504	2,125,996
Snow/Queen Crab	47,732	48,924	809,670	1,011,432
Atlantic Salmon	95,215	84,586	966,850	908,847
Shrimp	66,325	39,829	466,170	472,035
Crab	17,536	22,905	285,301	461,711
Total exports, all species	640,043	597,492	6,553,488	6,864,988

Note: Atlantic salmon are farmed while all other species are from capture fisheries

Source: www.dfo-mpo.gc.ca/stats/stats-eng.htm

and traditional commercial fisheries and its much closer resemblance to agriculture. Both nationally and provincially, the industry has, for many years, proposed creating an Aquaculture Act, but this has not materialized despite some interest from the Canadian Council of Fisheries Ministers. The complexities and uncertainties associated with having so many diverse groups involved in the oversight and management of the aquaculture sector has significantly affected decision-making processes and makes both short-term and long-term investment by industry and other much more and needlessly difficult.

Adding to tensions are significant declines in wild stocks and associated fisheries at the same time that aquaculture production is increasing. This is particularly evident on Canada's west coast where climate change, habitat loss and overfishing have resulted in significant declines in Pacific salmon stocks and the closure of many fisheries including First Nations food fisheries (Noakes and Beamish, 2011). The expected changes in temperature and freshwater distribution and abundance over the next 30–50 years are so significant (BC Ministry of the Environment, 2016) that many Pacific salmon stocks are likely to see further declines with some stocks in the interior of British Columbia disappearing completely (Noakes and Beamish, 2011). Despite the lack of any credible scientific evidence to link declines in Pacific salmon stocks at a population level to salmon farming (Noakes *et al.*, 2000; Noakes, 2011), those opposed to salmon farming and those wishing for a simplistic solution to restore Pacific salmon stocks to historic high levels suggest that removing salmon farms will accomplish that goal which it will not. This action will only serve to eliminate or significantly curtail the CAN\$400m salmon farming industry in British Columbia which will have significant negative economic and social consequences for coastal communities and in particular First Nation communities involved in aquaculture.

There are also significant changes in how industry and others now are expected to interact with First Nation (Indigenous people) in Canada in particular with respect to the development or use of natural resources. Recent court decisions in Canada with respect to First Nations rights and titles, the United Nations Declaration on the Rights of Indigenous Peoples (United Nation, 2008) and recommendations from the Truth and Reconciliation Commission of Canada (2015) increase the need for improved consultation and cooperation. It will take some time to bring clarity and agreement among stakeholders as to what those expectations are but the direction is clear. To that end, salmon farming companies in British Columbia have been building relationships and agreements with First Nations over the past two decades to the point where today nearly 80 percent of the farmed salmon produced in the province is done so with agreements or partnerships with local First Nations. The shellfish aquaculture sector has not made as much progress but there is significant interest for First Nations to become more involved in this sector. While progress in developing relationships can be time consuming and challenging, the short-term and long-term benefits of these agreements provide important opportunities, given farms are often located in remote areas in or adjacent to the traditional territories of local First Nations.

There are of course many significant opportunities for aquaculture development in Canada. An estimated 3.8m hectares of freshwater and marine areas are considered suitable for seafood (finfish, shellfish and aquatic plants) production in Canada. However, currently less than 1 percent of this available area is used for aquaculture production despite interest from many stakeholders to see growth in this sector. The usage varies by province and shellfish aquaculture such as oyster and mussel culture typically takes more area per tonne of production. For instance, Prince Edward Island which predominantly grows mussels uses approximately 3.2 percent of its available area while British Columbia uses only 0.8 percent of its available coastal area to produce approximately 80 percent of the farmed salmon and 75 percent of all oysters grown in Canada (CAIA, 2017). Compared with other nations, Canada lags far behind in terms of aquaculture production per km of coastline (Canada 2.1, USA 9.6, Norway 52.5 and Chile 157.8) (FAO, 2016). Recognizing the potential and importance of

expanding the Canadian aquaculture industry, the Finance Minister's Economic Advisory Council (2017) has suggest tripling aquaculture production with some provinces, such as Newfoundland and Labrador, supporting doubling of their aquaculture production to 60,000 tonnes (CAIA, 2017). The challenge, of course, will be realizing this planned growth, given the complex regulatory framework in place that significantly lengthens the time for decision making and introduces considerable uncertainty for potential investors.

Discussion

On September 25, 2015, the UN adopted the 2030 Agenda for Sustainable Development Goals (SDGs) with 17 objectives with 169 targets to guide government and international agencies over the next 15 years (www.undp.org/content/undp/en/home/sustainable-development-goals.html). Two of the seventeen goals that are directly related to aquaculture are: SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture; and SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Both are part of the FAO's Blue Growth Initiatives that are intended to support the sustainable management of living aquatic resources, balancing their use and conservation in an economically, socially and environmentally responsible fashion (www.fao.org/policy-support/policy-themes/blue-growth/en/). The importance of these goals and initiatives cannot be overstated, given the world's population is set to grown by 30 percent or more over the next 30–40 years. Aquaculture has and will continue to play an ever-increasing role in contributing to world food production in a changing climate that will provide its own set of challenges for decades.

At just over 200,000 tonnes, Canada ranks 25th in the world in terms of aquaculture production by volume and 20th in terms of value (FAO, 2016). While this contribution to seafood production is important and welcome, it does not reflect the potential for expanding the aquaculture sector nor the interest and wishes of participants (CAIA, 2017; Finance Minister's Economic Advisory Council, 2017; Fisheries and Oceans Canada, 2016). Significant progress in forming partnerships and working relationships with First Nations has been realized over the past two decades, and the social and economic benefits of the aquaculture industry have been clearly demonstrated to these communities, governments and others. The environmental performance of the industry has also improved substantially over the past three decades to the point where Canada's farming practices are now recognized as world class (MBASW, 2017). While there is still work to be done in these areas, there is general agreement by decision makers and others that Canada could easily double its production within a decade with the potential for still further growth. What is still missing and needed is a modern regulatory framework (national and provincial) that is specifically designed to govern a responsible and sustainable aquaculture industry and a commitment to implement the required legislation and aquaculture development strategy. Canada has provided leadership in the development of sustainable fisheries and aquaculture and can do so in the future.

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