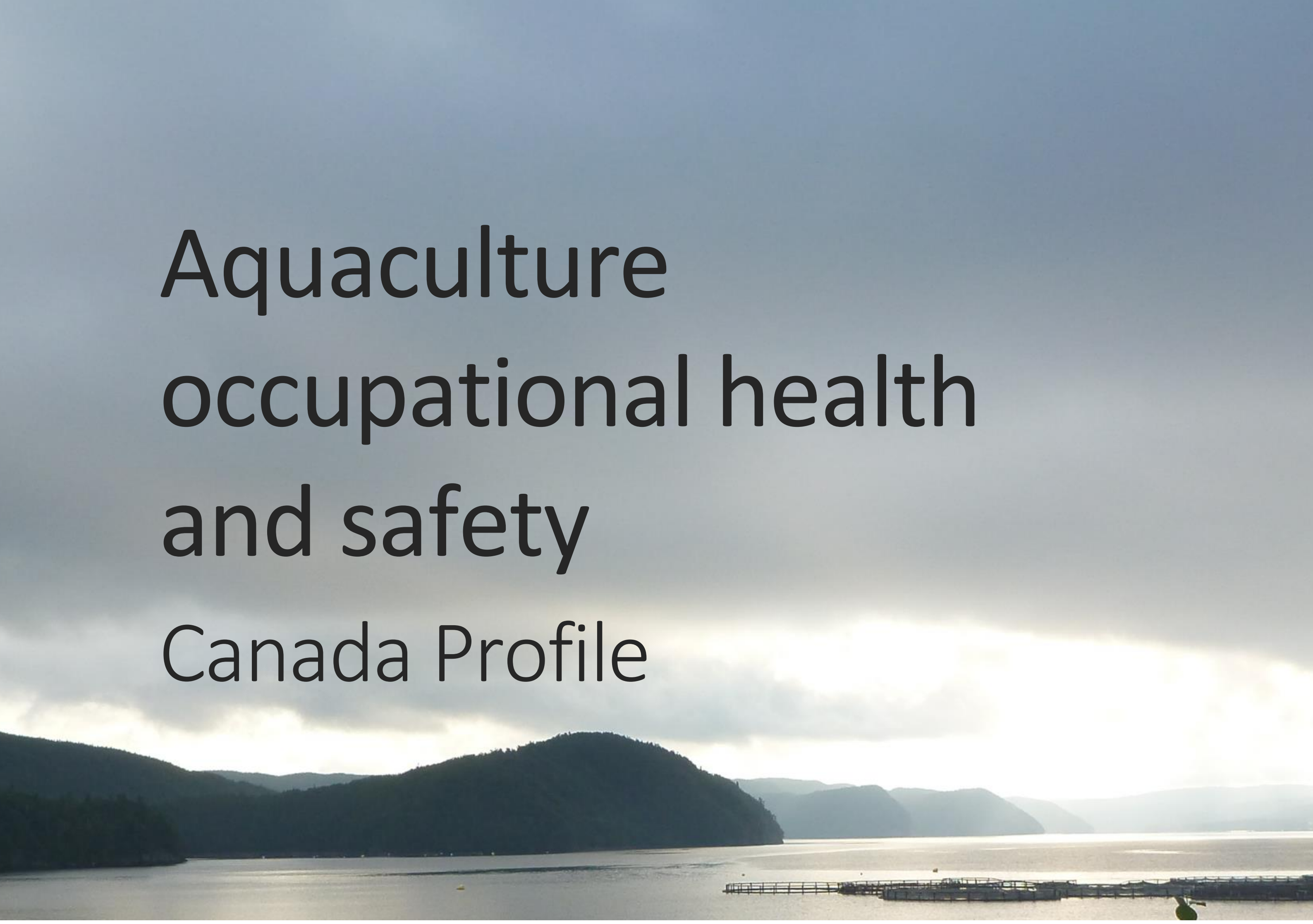

Aquaculture occupational health and safety

Canada Profile

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July, 2019

Acknowledgement: Production of this *Canada Profile* was supported with funding from the Food and Agriculture Organization of the United Nations as part of its larger global scoping review of aquaculture occupational health and safety. It was also supported by research funding from the Ocean Frontier Institute, through an award from the Canada First Research Excellence Fund. With thanks to Cory Ochs for support with analysis of the AWCBC data.

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1. Overview of Canadian aquaculture and aquaculture occupational health and safety issues

1.1 Introduction

While some types of aquaculture have a long history in Canada, it is only in the past few decades that the industry has seen rapid growth with a heavy focus initially on hatchery trout for recreational fisheries and stock enhancement and, more recently, on development of shellfish (oyster, blue mussel) and Atlantic salmon marine aquaculture. The industry is spread across the country but concentrated (in terms of production volumes and value) on the east and west coasts. Responsibility for regulation of the industry, including for occupational health and safety (OHS), is shared between federal and provincial governments. Aquaculture operations may not always fall under provincial OHS legislation (if they are classified as part of agriculture), but this needs to be verified. For marine operations, the federal government has some regulatory responsibility for safety under Marine Law and the precise relationship between federal and provincial responsibility for occupational health and safety (OHS) within maritime activities is currently somewhat ambiguous (Chircop 2006, 2016). Canada has a well-developed internal and external responsibility system for OHS with the weight on internal responsibility. Employers have a general duty, from a regulatory perspective, to protect the health of their workers. Canadian workers covered by OHS acts have three basic rights: the right to know about hazards, to participate in health and safety and to refuse unsafe work (Foster and Barnetson 2016). Government responsibilities appear to be largely limited to education and regulation. Workplace inspection rates are generally low in Canada across sectors and may have been, at least until recently, particularly low in this widely dispersed and often small sector of many provincial economies.

Estimates of aquaculture direct and indirect employment in Canada vary quite a lot and it is difficult to get precise figures including for employment in processing, transportation, aquaculture science, diving and other sectors where aquaculture-driven work often overlaps with employment driven by other sectors including wild harvest. There is very little research on aquaculture occupational health and safety OHS in Canada. The research that exists here and elsewhere suggests there is a wide range of potential hazards that differ across the sector and along the production chain, and that hazards are likely changing in conjunction with rapid changes in key parts of the industry. A relatively small proportion of the sector appears to be unionized. A small amount of inspection data from the Atlantic province of Newfoundland and Labrador provides a sense of the number and types of deficiencies identified by inspectors in recent years on aquaculture operations in that province. Some data on lost time injury (LTI) compensation claims are available through the Associated Workers Compensation Boards of Canada (AWCBC 2017). These claims data suggest that, as in Norway (Holen *et al.* 2017a, 2017b), there have been substantial numbers of accidents and fatalities in the industry but lost time injury rates that would permit a rough comparison with other sectors are currently only available for one province. The latter suggest the marine part of the industry (salmon/shellfish) has a relatively high accident rate as has been documented recently for Norway. Judging by differences in the industry across provinces, types of accidents and body part injured differ somewhat across land-based and marine aquaculture. This finding is consistent with hazard assessments done in Canada and the United States for marine and land-based forms of aquaculture (Moreau and Neis 2009; Myers 2010). Data on occupational illnesses in the sector are limited but the AWCBC data, as well as research done elsewhere, indicate work-related musculoskeletal disorders (WRMDs) or soft tissue injuries, diving-related illnesses, respiratory problems, infections caused by exposure to bacterial and parasitic diseases and through needle-stick injuries associated with vaccinations (Cole *et al.* 2009; Moreau and Neis 2009), as well as possible exposure to antimicrobial resistant bacteria (Burridge *et al.* 2010; Chuah *et al.* 2016), although current use of antibiotics appears to be quite limited in Canada relative to other countries such as particularly Chile. Noise-induced hearing loss may be present in parts of the sector.

Aquaculture operations in Canada are generally located in relatively remote rural areas. Large multinational companies dominate salmon aquaculture in Canada and globally. Other aquaculture sectors tend to be dominated by small operations, particularly shellfish aquaculture and trout farming. Small and medium-sized enterprises are known to have challenges in the area of OHS. The rate of unionization in the sector is well below the Canadian average. These operations involve a mix of relatively high and low skilled jobs, employ male and female workers, as well as relatively high numbers of indigenous (First Nations and possibly some Metis workers). Some aquaculture workers may be recent immigrants, and some have been brought in under Canada's Temporary Foreign Worker Programs (TFWPs) (Knott 2017). Young and older workers are also employed in the sector. Members of these groups can be at higher risk of injury and fatality and, as in the case of recent immigrants and temporary foreign workers, may confront issues related to filing compensation claims, as well as accessing health care and compensation (Otero and Preibisch 2010).

There appears to have been no research on aquaculture OHS in Canada since 2009. There are some industry-related OHS initiatives, including the development of an *Aquaculture Safety Code of Practice for Prince Edward Island* in 2008. Very little information is available concerning ergonomics initiatives in marine aquaculture including processing. A few of the aquaculture companies operating in Canada have acquired third party certifications some of which include certifications related to worker health.

Federal and provincial governments generally see the potential for expansion and diversification of the aquaculture sector as substantial given anticipated global seafood shortages, high market demand and Canada's very long coasts and large volume of relatively pristine lakes. The Canadian aquaculture industry, particularly mariculture of salmon and shellfish, has received extensive support from federal and provincial governments in recent years, including for research and development. The development and implementation of offshore aquaculture will increase the area available to the industry and might help to reduce some of the social license and environmental issues confronting parts of the industry but, as Norwegian research has shown, can introduce new hazards including around efforts to prevent fish escapes (Thorvaldsen *et al.* 2015). Very little of this research and development funding is apparently designed to identify and address aquaculture OHS issues including those associated with new projects, such as current efforts to rapidly develop the commercial aquaculture of lumpfish for use as groomer fish to address the sea lice problem in salmon aquaculture (Powell *et al.* 2017).

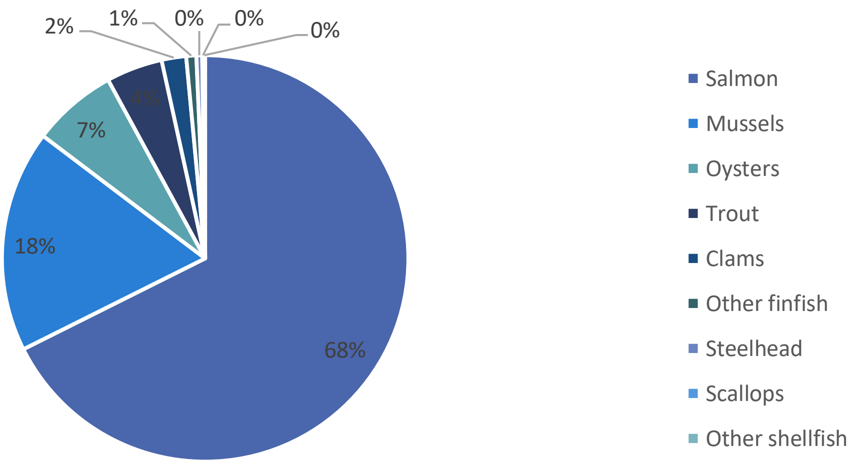
There is a move in Canada to develop a national aquaculture industry regulatory framework to streamline and speed up aquaculture development. Identifying, eliminating and, where this is not possible, reducing OHS hazards in the industry, as well as improved surveillance and prevention, should be key ingredients in preparing for an expanded, sustainable industry in the future with access to a skilled, healthy and stable labour force. We have found a few examples of OHS initiatives in Canada that show some promise and there are useful insights on hazards and prevention in some of the published literature particularly from the United States and Norway.

1.2 History of aquaculture in Canada

Aquaculture in Canada dates back to the mid 1800's with the start of oyster production in Prince Edward Island (PEI) on Canada's east coast in 1865, and the introduction of rainbow trout across multiple continents for recreational fishing. The cultivation of Pacific oysters in British Columbia (BC) on Canada's west coast started in the 1920s. Starting in the 1950s a network of hatcheries producing trout and salmon for stock enhancement and recreational fisheries began operation across the country. Shellfish aquaculture expanded in the 1960s, followed by the development of salmon and trout aquaculture in the 1970s and rapid growth of the former starting in the 1980s on Canada's east and west coasts (see DFO 2015a). In 2013, aquaculture production could be found in every province and the Yukon Territory in Canada (DFO 2013; Canadian Aquaculture Industry Alliance 2013). There were a total of 43 aquaculture species in 2014 including 26 types of finfish, 16 types of shellfish (Molluscs) and a variety of marine algae (kelp, moss and seaweed) (see OMAFRA 2019).

Figure 1.1 shows species farmed in order of production volume in Canada in 2015 highlighting the dominance of marine aquaculture salmon, mussels and oysters. (CAIA 2013; DFO 2017a).

Figure 1.1: Canadian aquaculture species by production volume 2015



Canada is the fourth largest aquaculture salmon producer globally but ranks only 21st globally in aquaculture production of finfish and shellfish (Senate Standing Committee 2016). Related to this, as indicated in Table 1.1, the Canadian aquaculture sector is dominated (in terms of value and volume) by marine production particularly the production of Atlantic salmon, which accounted for 65% of volume and 71% of value in the sector in 2015.

Table 1.1 Canadian aquaculture* production volume (tonnes) and value ($000), 2015**

Species	Volume (tonnes)	Value ($000)
Salmon	121,926	688,655
Mussels	22,725	43,342
Oysters	11,153	36,547
Trout	7,062	40,264
Clams	2,402	9,160
Other finfish	1,177	14,406
Steelhead	718	2,495
Scallops	31	314
Other shellfish	32	223
Total Aquaculture	187,374	967,441

* Provinces with data not available are not included.
** The production and value of aquaculture includes the amount and value produced on sites and excludes hatcheries and processing. Shellfish also includes some wild production. Source: Data is adapted from Aquaculture Quantities and Values (see DFO 2017a)

Tables 1.2 and 1.3 below detail the different types of finfish and shellfish farmed in Canada and their farming method. For finfish species, all brood stock and juveniles are reared on land. The grow-out of salmon happens almost exclusively in saltwater pens, while trout may be grown out in either saltwater (steelhead) or freshwater net pens, as well as in land-based systems. Arctic char is grown out only in land-based systems. Some salmon, sable fish and halibut production takes place in land-based ponds, or tanks (Farmed Species Profiles, DFO 2014a). For shellfish species, clams are seeded and grown out on ocean floor beds, mussel seed is collected from the wild and then grown out on ropes or rafts. Oysters are seeded and grown out on ocean floor beds or in bags, trays, or rope lines.

Table 1.2 Canadian aquaculture finfish species and their farming method (DFO 2014a)

	Broodstock	Juveniles	Grow-Out
Arctic Char	Land-based flow through and recirculation	Land-based hatchery facilities; flow through and recirculation	Land-based flow through and recirculation or marine saltwater net pens
Salmon	Land based flow through and recirculation	Land based hatchery Facilities, flow through and recirculation	Saltwater net pens and some land-based systems
Trout	Land based flow through and recirculation	Land based hatchery facilities; flow through and recirculation	Freshwater net pens; saltwater net pens (steelhead); land-based raceways, and ponds

Table 1.3	**Canadian aquaculture shellfish species and their farming method** (DFO 2014a)	
	seed	**Growout**
Clams	Ocean floor beds	Ocean floor beds
Mussels	Collection from wild (East Coast mostly)	Mussel socks suspended from long-line systems (ropes or rafts)
Oysters	Ocean floor beds or off-floor suspension (holding bags, cages, trays or rope lines).	Ocean floor beds or off-floor suspension (holding bags, cages, trays or rope lines).

According to Statistics Canada, in 2016 the value of Canada's Aquaculture Industry was $1, 339,075,000 with over 50% of this value coming from production in British Columbia (see Statistics Canada 2019). Table 1.4 shows aquaculture production volume and value by select Canadian province for 2015 indicating that of the total amount produced (185,644 tonnes) in 2015, British Columbia produced 55%, Prince Edward Island (PEI) 12%, Newfoundland and Labrador (NL) 12%, New Brunswick (NB) 13%, Nova Scotia (NS) 3%, Ontario 3% and Quebec 0.7% of aquaculture products (DFO 2017b).

Shellfish production (mussels, oysters, clams and scallops) occurs on both coasts of Canada. It remained constant between 2002 and 2012 in British Columbia but increased by 30% on the East coast (FAO 2017, 6). Fifty% of the trout produced in Canada came from Ontario (FAO 2017).

Table 1.4	**Total production (volume and value) by province, 2015** (DFO 2017b)		
Province	**Product**	**Total Production Volume (tonnes)**	**Total Production Value ($000)**
British Columbia	Finfish	93,850	474,455
	Shellfish	8,535	X
	Total	102,385	X
Ontario	Finfish	4,890	25,400
	Shellfish	0	0
	Total	4,890	25,400
Quebec	Finfish	964	8,170
	Shellfish	453	1,689
	Total	1,417	9,859
New Brunswick	Finfish	23,391	X
	Shellfish	940	X
	Total	24,331	162,580
Nova Scotia	Finfish	6,058	53,580
	Shellfish	1,109	2,395
	Total	7,167	55,975
Newfoundland	Finfish	19,684	148,536
	Shellfish	3,130	12,847
	Total	22,814	161,383
Prince Edward Island	Finfish	464	X
	Shellfish	22,176	40,690
	Total	22,640	X
			X indicates data not available

The United States is the largest importer of Canadian farmed shellfish and salmon; there have been small movements in the finfish industry towards land-based grow-out operations (recirculating aquatic systems (RAS); and organic product certification holds important potential for improving environmental degradation and social licence (FAO 2017).

1.3 Employment in aquaculture in Canada

It is difficult to access accurate statistics on the full range of aquaculture-related employment in Canada. Direct employment in aquaculture includes employment on farms and in hatcheries, processing plants and administration. Indirect employment includes employment in the production of feed supplies, equipment manufacturing, packaging, transportation and could also include research and development (DFO 2013). Frequent overlap in the processing of wild and aquaculture products in seafood processing plants contributes to the challenge, as does subcontracting of work such as net-making, building and site construction, net cleaning, marketing, diving and veterinary services where companies provide services for aquaculture and other sectors add to the challenge.

The FAO North American Regional Report (2017) indicates Canada's farmed finfish (mostly salmon) industry alone provides more than 10,000 jobs in coastal communities, some of which are in aboriginal communities. The origins of this statistic are unclear. Some sources have been shown to overestimate aquaculture employment (see MMK Consulting, Provincial Legislature's Special Committee on Sustainable Aquaculture 2007; and Knott 2017). A recent labour market forecast to 2025 done by the Canadian Agricultural Human Resource Council (CAHRC 2016) placed direct aquaculture employment on farms in Canada at roughly 4,000, excluding processing workers, and indicated that Statistics Canada estimated there were 8,000 workers in the sector.

Statistics Canada (2019) has a category for aquaculture occupations including management and a category for seafood product preparation and packaging. The former occupational category does not appear to include processing; the latter category includes all seafood processing, most of which is associated with capture or wild fisheries. Table 1.5 breaks out employment by province for each of these two categories between 2013 and 2015. If we exclude seafood processing, direct employment from all aquaculture in Canada in 2015 was only 3,316 using these data. This is clearly an underestimate but including seafood product preparation and packaging would result in a substantial over-estimate of the size of the aquaculture labour force in Canada. In Newfoundland and Labrador, the government estimated aquaculture employment in 2015 at 439 in 2015 – somewhat more than the 380 in the aquaculture category for Statistics Canada but much lower than the figure of 7,744 that includes seafood produce preparation and processing.

WorkSafeBC, the workers' compensation commission and OHS regulator for British Columbia, provided estimates of the number of aquaculture employers and person years of employment in aquaculture in British Columbia between 2010 and 2016 (Tables 1.5 and 1.6). Table 1.5 shows finfish farming in B.C. is quite concentrated and involves a relatively small number of employers and that the number of hatchery employers declined significantly between 2010 and 2016. Person years of employment in shellfish farming relative to the number of employers indicate most shellfish operations in B.C. are small employers providing an average of 3-4 person-years of employment. Average employment for fish hatcheries is also low. Table 1.6 indicates that simply using the aquaculture employment figures generated by Statistics Canada (Table 1.7) would result in a serious under-estimate at approximately 1400-1500 employees between 2013 and 2015 versus 4500-4900 during the same years from the AWCBC data. These statistics are for WorkSafeBC industry classification units (CUs) 702001, 702004, 711010. Table 1.7 shows that finfish farming in in other parts of Canada is similar to British Columbia in that it is highly concentrated with few employers, and that shellfish farming and fish processing have a large number of employers.

Table 1.5 Number of aquaculture employers in selected classification units in British Columbia (2010-2016)*

Classification Unit (CU)	CU Description	Number of Employers						
		2010	2011	2012	2013	2014	2015	2016
702001	Finfish farming	20	24	24	27	26	27	26
702002	Fish hatchery	31	26	25	21	21	21	20
702004	Shellfish farming/hand picking	92	92	90	89	94	96	101
711010	Fish processing, reduction, canning	116	110	115	111	115	114	118
	Totals	259	252	254	248	256	258	265

* Source: WorkSafeBC CUs 702001, 702004, 711010 statistics, 2010-2016, December 4, 2017, WorkSafeBC Statistical Services, Business Information and Analysis Department.

Table 1.6 Estimated person years in aquaculture in British Columbia for selected classification units (2010-2016)*

Classification Unit (CU)	CU Description	Number of Employers						
		2011	2011	2011	2011	2011	2011	2011
702001	Finfish farming	1375	1400	1275	1225	1325	1400	1500
702002	Fish hatchery	80	70	65	65	55	50	50
702004	Shellfish farming/hand picking	360	350	370	400	440	450	500
711010	Fish processing, reduction, canning	3250	3150	2900	2900	3050	3000	3150
	Totals	5065	4970	4610	4590	4870	4900	5200

* Source: WorkSafeBC CUs 702001, 702004, 711010 statistics, 2010-2016, December 4, 2017, WorkSafeBC Statistical Services, Business Information and Analysis Department.

Table 1.7 Employment in seafood processing and aquaculture by industry and province, 2013-2015*

	Seafood Product Preparation and Packaging (processing)**				Aquaculture***				Total Employment (processing and aquaculture)		
	2013^{E}	2014^{E}	2015	% of TE 2015	2013	2014	2015	% of TE 2015	2013	2014	2015
Newfoundland	..	..	7364	95%	370	320	380	5%	..	..	7744
PEI	..	..	1494	78%	415	405	410	22%	..	..	1904
Nova Scotia	6892	6759	5299	96%	225	235	230	4%	7117	6994	5529

New Brunswick	10331	9620	6,360	92%	525	540	550	8%	10856	10160	6910
Quebec	1506	1532	2206	95%	105	110	110	5%	1611	1642	2316
Ontario	472	452	664	81%	125	145	155	19%	597	597	819
Manitoba	X	..	x	x	...	...	...	x	..	..	..
Saskatchewan	X	..	x	x	...	...	...	x	..	..	..
Alberta	X	..	x	x	...	...	...	x	..	..	..
BC	2549	2519	2324[E]	61%	1410	1450	1480	39%	3959	3969	3804
Canada	33147	31899	26396	89%	3175	3205	3316	11%	36322	35104	29712

* Adapted from DFO 2019.
** Statistics Canada. CANSIM Table 301-0008. Employment data for all provinces are estimated by DFO, for the years 2013-2014, and for British Columbia in 2015. Seafood product and packaging (processing) includes both capture and aquaculture processing workers.
*** Statistics Canada, Survey of Aquaculture Industry, unpublished.

WorkplaceNL, the compensation commission in Newfoundland and Labrador, provided estimates of the number of aquaculture employees in that province for the period 2010 to 2016. They estimated the number of employees as varying between a low of 393 in 2010 and a peak of 509 in 2013. These figures are somewhat higher than those for aquaculture from Statistics Canada but much lower than broad statistics that would encompass all seafood preparation and packaging employment in the province. Only five of the 92 licensed seafood processing plants in Newfoundland and Labrador process aquaculture products.

There are similar uncertainties around the composition of the aquaculture labour force in Canada. Aquaculture labour forces include men and women and local as well as regionally, interprovincially and some internationally migrant workers. The FAO regional report for North America (2017) indicates seventy-five per cent of Canadian aquaculture workers are reported to be under 40, with a 60/40 split between men and women. However, the percent-age of women in the aquaculture and marine harvest workforce has been reported as low as 19% (Canada Job Market Report) and 25% (Statistics Canada; see also DFO 2016a).

Some aquaculture workers are members of First Nations and Inuit groups. We do not have statistics on the number of indigenous workers in the sector. However, according to the Canadian Aquaculture Industry Alliance, First Nations are involved in aquaculture in all provinces except one and 40% of First Nations communities have some direct or indirect involvement in aquaculture in Canada (see CAIA Report 2017).

According to the FAO regional report, there are some shortages of skilled aquaculture workers in Canada resulting in the aquaculture industry recruiting some workers from outside of the country (FAO 2017). The CAHRC's (2016) *Aquaculture Labour Market Forecast to 2025* study of the farm portion of the sector found industry reported 450 jobs left unfilled in 2014 (about 10% of the labour market) and projected a larger shortfall (up to 23%) by 2025. Unlike agricultural operators in Canada, aquaculture operators (excluding those in processing) have limited access to foreign workers because the industry is not on the list that gives employers access to the Seasonal Agricultural Worker Program (SAWP) or the Agricultural Stream of the Temporary Foreign Worker Program (TFWP). Because of this, the report argues, only a few foreign workers are employed in primary production in aquaculture relative to other commodity types. The situation may be somewhat different in processing where the number of TFWs recruited to the sector has grown a lot in recent years with workers recruited through other programs. For instance, the number of migrant workers brought in to work in seafood processing in New Brunswick jumped from only 165 (9% of total TFWs in NB) in 2008 to 1120 migrant workers in 2012 (48% of total TFWs recruited to New Brunswick that year) (ESDC 2014; Knott 2017). Some of these workers were employed in aquaculture for both the seafood processing and net mending occupations (Knott 2017). The CAHRC report indicates future labour challenges are likely to be greatest in British Columbia and the industry attributes the challenges to location in rural areas undergoing depopulation and worker mobility. The report notes, "the limited ability of workers to get transportation to worksites and the need for workers to move from their original location to one that is closer to work" (CAHRC 2016, p.9) as the main factors affecting recruitment and retention of workers on farms. It suggests that productivity gains have helped reduce labour shortages in the sector in recent years but productivity gains are expected to level off in the future.

2. Aquaculture locations in Canada

2.1 Introduction

Aquaculture in Canada occurs in all provinces and the Yukon Territory. Mariculture is concentrated on the east and west coasts, while most production of trout and other species takes place in in-land provinces.

2.2 British Columbia

Aquaculture in British Columbia is located in rural coastal communities on the northeast coast of Vancouver Island, as well as in several large sounds on the west coast of the Island. In 2016 there were 119 licensed fish farms and approximately 23 hatcheries in British Columbia. In 2017 there were over 450 licenses for shellfish farming (see Government of Canada 2019) and roughly 24 shellfish aquaculture operations. Farmed salmon is the largest agriculture export for British Columbia (FAO 2017). Table 2.1 has a list of aquaculture species farmed in British Columbia.

Finfish aquaculture is located in Clayoquot Sound, Broughton Archipelago and the Discovery Island and close to the communities of Port Hardy, Port McNeil, Tofino, Campbell River, as well as the two aboriginal communities of Klemtu (Marine Harvest) and Alhousaht (see BCSFA 2019a). The shellfish aquaculture operations are concentrated on the east coast of Vancouver Island and mainly located in Bayes Sound, around Cortes Island, and in Okeover Inlet (see BCSGA 2019). Research facilities that focus on aquaculture are located in Campbell River (BC Salmon Farmers Association Marine Environmental Research Program (MERP), Nanaimo (Centre for Aquatic Animal Health Research and Diagnostics), Vancouver (Genome-BC) and Calvert and Quadra Islands (Hakai Institute) (see DFO 2017c)

Table 2.1 British Columbia aquaculture breakdown by species

Finfish	Shellfish	Plant
Atlantic Salmon Chinook Salmon Coho Salmon Sturgeon Rainbow Trout Tilapia Sablefish Sockeye Salmon Rockcod	Pacific Oysters Manila Clams Varnish/Savory Clams Geoduck Blue Mussels Mediterranean Mussels Japanese Scallops	Seaweed

Source: Canadian Aquaculture Industry Alliance Website – Products-regions

2.3 New Brunswick

Aquaculture in NB, on Canada's Atlantic coast, also occurs in rural coastal communities. Table. 2.2 provides a list of species farmed in NB. Farmed Salmon is the largest crop in the New Brunswick agriculture sector (FAO 2017). Finfish aquaculture is located on the south east coast of New Brunswick in the Charlotte County region on the Bay of Fundy (see DFO 2014b). Shellfish aquaculture is much more widespread with, in 2016, more than 500 leases for sites spread along much of the east coast of New Brunswick (see Government NB Report 2017).

Several shellfish aquaculture companies in New Brunswick are run by Mi'gmaq communities either on their own, or in partnership with other companies. In these instances, First Nation Communities hold the licences, (see Government NB Report 2017)

Table 2.2 New Brunswick aquaculture breakdown by species

Finfish	Shellfish	Plant
Atlantic Salmon Rainbow Trout Steelhead Trout Cod Arctic Char Halibut Atlantic Sturgeon short nose sturgeon, Eels	Eastern Oysters Blue Mussels Northern Bay Scallops	Red Algae: Irish Moss/Dulse Green Algae: Sea Lettuce Brown Algae: Kelp

Source: Canadian Aquaculture Industry Alliance Website – Products-regions

New Brunswick also has a fairly diversified marine plant aquaculture sector producing 4 types of plant/algae products. Research on Aquaculture is carried out in Moncton (Centre for Aquatic Animal Health Research and Diagnostics) and St. Andrews (Huntsman Marine Science Centre 2019, see also DFO 2017c and HMSC 2019).

2.4 Newfoundland and Labrador

With only seven species farmed, aquaculture in Newfoundland and Labrador is less diversified than in British Columbia and New Brunswick (Table 2.3). Operations are concentrated in two rural coastal regions, with shellfish farms located mainly in Notre Dame Bay on the north-east coast of the Island of Newfoundland, and finfish aquaculture operations located mainly in the Coast of Bays Region (south coast) which includes Fortune Bay, Bay d'Espoir and the Connaigre Peninsula (see DFO 2016b). In 2016 there were 88 salmon licences and 53 shellfish site licences in Newfoundland and Labrador and, of the 92 licensed seafood processing companies, five were licensed for aquaculture (see NL Fisheries and Land Resources 2016). In 2013 there were three farmed salmon hatcheries in the province (see NL Fisheries and Aquaculture 2014).

Table 2.3 Newfoundland and Labrador aquaculture breakdown by species	
Finfish	**Shellfish**
Atlantic Salmon Steelhead Trout Rainbow Trout Cod	Mussels, Clams, Eastern Oysters
Source: Canadian Aquaculture Industry Alliance Website – Products-regions	

2.5 Nova Scotia

Aquaculture in Nova Scotia occurs (or has occurred – as some sites are abandoned) in coastal regions in every county in the province and it is comprised of many small-scale operations. According to a provincial government report, there were 44 companies and over 270 sites in 2014, but the industry was undergoing consolidation and was looking to build the shellfish and finfish production in the province in the future (see NS Fisheries and Aquaculture Report 2012). As indicated in Table 2.4, the industry was producing seven species of finfish, five of shellfish and five plants. Aboriginal communities are involved in both the finfish and the shellfish aquaculture industry in Nova Scotia, with DFO highlighting the Millbrook First Nation success with Arctic Char production (see DFO 2015b), and the Waycobah First Nation's successful joint venture with *Ocean Trout* (a subsidiary of Cold Water Fisheries) in its overview of the industry (see DFO 2015c). Aquaculture research is undertaken in Halifax at Genome- Atlantic.

Table 2.4 Nova Scotia aquaculture breakdown by species		
Finfish	**Shellfish**	**Plant**
Atlantic Salmon Arctic Char Halibut Steelhead Trout Rainbow Trout Atlantic Halibut Striped Bass	Eastern Oysters Blue Mussels Clams Quahogs Sea Scallops	Seaweed Red Algae: Irish Moss/Dulse, Green Algae Brown Algae: Kelp
Source: Canadian Aquaculture Industry Alliance Website – Products-regions		

2.6 Prince Edward Island

Aquaculture on Prince Edward Island takes place in most coastal regions and five species of finfish and two of shellfish are the main products (see Table 2.5). Shellfish aquaculture is mainly comprised of mussel and oyster culture and mainly occurs on the north and eastern coasts of the island. Mussels are farmed in 19 communities and oyster production takes place in the communities of Foxy River, Conway Narrows, Egmont, Orwell and Colville Bay. There are three freshwater hatcheries for salmon, 1 grow-out operation for halibut and 4 research facilities in the province (see Government of PEI 2016). Finfish aquaculture activities are concentrated in the eastern and central regions of the province in the communities of Cardigan, Fortune Bay, Souris, Dover, Brookvale and Victoria (see PEI Aquaculture Alliance 2019a) and take place in land-based facilities (see PEI Aquaculture Alliance 2019b). The Abegweit first nation runs the Abegweit Biodiversity and Enhancement Hatchery in PEI, which focuses on restocking rivers with wild trout.

Table 2.5	**Prince Edward Island aquaculture breakdown by species**
Finfish	**Shellfish**
Salmon Processing Rainbow Trout Arctic Char Atlantic Salmon, Atlantic Halibut hatchery	Blue Mussels, Eastern Oysters
Source: Canadian Aquaculture Industry Alliance Website – Products-regions	

2.7 Ontario

Ontario produced 55% of the average 7,000 tonnes of trout produced in Canada between 2011 and 2015. Other finfish produced in Ontario include rainbow trout, Arctic char, tilapia, perch, smallmouth bass and largemouth bass (Table 2.6). Trout are produced in south-western Ontario – primarily fingerlings for stocking and enhancement -- and in northern Ontario. Most grow-out operations are located in Georgian Bay and around Manitoulin Island on Lake Huron (see DFO 2017d). Rainbow trout operations employ approximately 100 people in Northern Ontario. Located in the communities of Little Current, Espanola, Manitowanig, Kagawong, Gore Bay, Mindemoya, Evansville, Val Caron, Parry Sound, Sudbury and North Bay (see DFO 2015d), trout farms can be found both in lakes, as well on land, with 43 land-based operations, 15 hatcheries and 15 stocking operations located in Northern Ontario. The provincial government is actively supporting growth of this industry in this region (see OMAFRA 2019). Indigenous communities in Ontario are being encouraged to enter this industry (see Northern Ontario Business 2015).

Table 2.6 Ontario aquaculture breakdown by species
Finfish
Rainbow Trout Arctic Char Tilapia Perch Smallmouth Bass Largemouth Bass
Source: Canadian Aquaculture Industry Alliance Website – Products-regions

2.8 Quebec

Quebec has a small aquaculture industry with only 159 employees in 2007 – the most recent date for which we have this information. Aquaculture operations are concentrated on the lower North shore, alongside the St. Lawrence River estuary and on the Gaspé Peninsula and around the Magdalen Islands (Nguyen and Williams 2013). Table 2.7 lists the finfish, shellfish and plant species produced in Quebec. It produces rainbow and brook trout throughout the province with some concentrations of production in the Estrie, Laurentians, Outaouais and Centre-Quebec regions (see DFO 2017d). Research on Aquaculture is carried out by Genome-Quebec and Fonds de researche du Quebec – Nature et Technologies (see DFO 2017c).

Table 2.7 Quebec aquaculture breakdown by species

Finfish	Shellfish	Plant
Arctic Char Rainbow Trout Brown Trout Speckled Trout Walleye/Pickerel Atlantic Salmon (Landlocked) Smallmouth Bass	Eastern Oysters Blue Mussels Sea Scallops	Green Algae: Sea Lettuce

Source: Canadian Aquaculture Industry Alliance Website – Products-regions

2.9 Alberta, Manitoba and Saskatchewan

The aquaculture industry in Canada's prairie provinces of Manitoba, Saskatchewan and Alberta is small and consists largely of freshwater production of finfish species in ponds/dugouts and tanks in rural areas (see Table 2.8). In Alberta, the industry had an estimated value of $10 million in 2013 with 60% from table fish sales and 40% from fingerling sales for u-fishing operations, government contracts, as well as stocking of private ponds, and the production of grass carp for vegetation control (see Government of Alberta Report 2014). Manitoba's aquaculture industry is predominantly 'hobby farming' for the purposes of stocking lakes and ponds for the recreational fishery. Intensive aquaculture was limited to 4 operations in 2004, located in the communities of Dugald, Blumenort and Warren, and this still seemed to be the case in 2015 (see Manitoba Co-operator 2015). Saskatchewan produces the highest volume of farmed fish of the three Prairie Provinces including rainbow and steelhead trout (see CAIA 2013). The commercial production of farmed trout is, for the most part, isolated to the Lake Diefenbaker area (see DFO 2017d).

Table 2.8 Alberta Saskatchewan and Manitoba breakdown by species

Province	Finfish
Alberta	Rainbow Trout Tilapia, Arctic Char Grass Carp Bigmouth Buffalo Fish

Saskatchewan	Rainbow Trout Steelhead Trout
Manitoba	Rainbow Trout Arctic Char
Source: Canadian Aquaculture Industry Alliance Website – Products-regions	

2.10 Yukon

The only farmed species in the Yukon in Northern Canada in 2013 was Arctic Char. In 2010 there were reported to be 16 fish farm licenses for 23 pothole lakes, as well as two char hatcheries and tank grow-out operations located in or near Whitehorse.

3. Aquaculture OHS in Canada

3.1 Introduction

This chapter provides a synthesis of what we have been able to learn from a review of secondary literature and other available sources regarding regulation of aquaculture OHS in Canada and safety hazards in the industry.

3.2 Regulation

Canada has a total of 14 jurisdictions (federal, 10 provincial and 3 territorial) with responsibility for health and safety laws and regulations (see Appendix A for a list of relevant links). Only about 10% of Canadians fall under the federal *Canada Labour Code* which includes federal employees and workers in interprovincial industries like transportation. OHS systems in Canada are based on the internal responsibility system, which assumes shared responsibility for OHS among employers and workers. Workers have three basic safety rights, the Right to Know, the Right to Participate (in OHS activities such as joint health and safety committees or as safety representatives and the Right to Refuse unsafe work. The role of government in this system is largely limited to education and enforcement (Foster and Barnetson 2016). All provinces and territories have a no-fault workers' compensation system to compensate for wage-loss, health care costs and, as needed, labour-market re-entry costs for injured and ill workers and some financial support for family members of those who die due to work-related causes. More research is needed to thoroughly document OHS regulatory and workers' compensation coverage of the aquaculture sector in Canada. Most aquaculture workers appear to be covered by provisions in the various provincial OHS acts but this may not always be the case. Some marine aquaculture activities in Canada fall under Maritime law, which is a federal responsibility, as is compensation for some groups.

According to Chircop (2016, p. 1051), regulation of the aquaculture industry in Canada involves federal, provincial and local authorities. The federal government has the power to make laws in relation to fisheries, shipping and navigation, trade and commerce and interprovincial and international matters. Furthermore,

> [a]ll provinces have legislation regulating aquaculture activities, and some provinces have a specific aquaculture act. In some cases, municipal governments also play a role through zoning bylaws. The legislation in each of the provinces is considered to be minimalistic, mandating few standards against which aquaculture sites are evaluated.

There is a set of memoranda of understanding between individual provinces and the federal government but in the case of British Columbia, the outcome of a recent court case led to the federal Department of Fisheries and Oceans assuming control of management (issuance and requirements for licenses) of that province's industry with the exception of marine plant cultivation, and for issues arising from operation of aquaculture sites. The Federal government also has a duty to consult with First Nations in its aquaculture management decisions.

Maritime aquaculture occupies a somewhat ambiguous position within Canadian federal/provincial jurisdiction as it applies to maritime law which, in Canada, falls under federal jurisdiction. Chircop (2006) examines the relationship between mariculture and Canadian maritime law. He notes that in the literature on aquaculture law and policy, "the relationship of mariculture to maritime law remains largely unaddressed" (p. 207). This has to do with those aspects of mariculture that include shipping and navigation and, in the case of safety, to the fact that "if harm is caused to persons or property, off or on board a ship, as a result of faulty navigation, or if a ship causes environmental or resource loss, maritime law governs the claims that may be advanced and the liability and compensation that will apply."(Chircop 2006, p. 207). He notes that even when ships/vessels *per se* are not involved in an incident, maritime law may still be triggered by the presence of navigation as this relates to both the location of a farm and support activities including, for example, the use of supply vessels. Furthermore, Chircop's review of legal cases indicates that the legal definition of a ship can include non-propelled craft (such as barges) so long as they have a navigation capability. He notes the leading case on determining whether a crane barge met the definition of a ship arrived at the following criteria:

1. construction for use on the water;
2. capability of being moved from place to place, even if only occasionally (e.g. with towage assistance);
3. cargo-carrying capability, even if only occasionally;
4. people-carrying capability (Chircop 2006, p. 212).

In some cases, activities that take place in locations that are on land may be considered to be maritime where there is a spatial relationship between those activities (as in the case of warehousing) and maritime carriage.

Chircop (2006) discusses the relationship between federal maritime law (federal) and provincial law in situations where there are parallel laws such as those relating to workers' compensation for aquaculture workers, indicating that both sets of law can apply but the boundary between the two bodies of law will depend on the particular case. Unlike offshore oil and gas installations, there is no requirement for registration or licensing in Canada of mariculture structures other than ships. However, Coast Guard approval is required "for any work built or emplaced in, on, over, under, through or across navigable waters that interferes, or may interfere, with navigation (p. 218). Shipowners "are subject to a duty of seaworthiness in relation to the vessels they put to sea" but "it is not clear that there is a similar duty for mariculturists, other than for mariculture vessels" (p. 218). Chircop discusses concerns about mariculture installations and structures that may obstruct navigation, collision avoidance regulations and safety of human life at sea. He notes that Norwegian regulatory safety requirements related to safe navigation are more specific around requirements for mariculture installations than those in Canada (p. 219). He concludes that there is an "incomplete patchwork of safety measures" outside of Collision Regulations that might be applied but "these regulations are restricted to boating and designated waters only, which tend to be mostly inland waters and bays" (pp. 220-221). This "patchwork of safety measures" is a potential issue for offshore movement related to aquaculture operations including, potentially, the development of future offshore installations.

There are dedicated regulations for offshore oil and gas in Canada, but not for aquaculture. Safety of life at sea is regulated by international standards including SOLAS safety standards. However, according to Chircop, it is

> not clear what the full safety of life at sea regulatory requirements applicable to mariculture are in situations other than when a ship is utilized. It is not even fully apparent whether the federal Marine Occupational Safety and Health Regulations apply to mariculture, although they are applicable to Canadian ships (2006, p. 221).

In terms of death and personal injury at sea within aquaculture, similar ambiguities can be found. Chircop (2006, p. 232) identifies the following broad issues related to death and personal injury in mariculture:

> First, in the absence of statutory provision, what is the legal status of mariculture workers? Second, depending on their legal status, what law applies to work safety matters (federal *or* provincial, or federal *and* provincial)? Third, what law governs claims from death and personal injury at the workplace, provincial workers' compensation or federal maritime law?

Mariculture workers are diverse including the aquaculturist (entrepreneur or license-holder), researchers and technicians and skilled and unskilled labourers, some of whom would be mariners. There is, Chircop notes, "no one definition of 'aquaculturist' in use for all regulatory purposes" (2006, p.223) – federal statutes are inconsistent and definitions vary across provinces – a situation that is quite different for ship-owners and crew. Some provincial occupational health legislation includes employees in aquaculture as eligible for compensation (for instance, NL) but are these workers or are some of them also subject to maritime law given the working conditions of seamen are regulated by the federal government? (2006, pp. 223-224). A related question is whether mariculture workers or some mariculture workers are entitled to workers' compensation. Seamen's compensation falls under federal legislation – the *Merchant Seamen Compensation Act*.

Health and Safety Acts vary from province to province along with workers' compensation eligibility. Workers' compensation falls under provincial jurisdiction with criteria for coverage, employer premium costs, levels of wage replacement and eligible services varying from compensation board to compensation board. Chircop (2006) indicates that while New Brunswick's Workers Compensation Act was general enough to apply to any industry in the province, in Nova Scotia the act only applied to designated occupations and, when his overview was published, aquaculture was not specifically designated in the Nova Scotia Act. If some aquaculture-related enterprises are fishing enterprises, they may be excluded from compensation legislation in some provinces. Furthermore, there is also some question about the application of compensation and OHS legislation to land-based aquaculture operations such as trout and char production in some Canadian provinces and territories. Agricultural operations are not always covered by either compensation or health and safety legislation and if aquaculture falls under agriculture, it is possible it is excluded. This requires further research Chircop (2006) concludes by arguing that there is a likely need for Canada to legislate a national framework for aquaculture to complement provincial aquaculture laws but even if this happens, maritime law will remain relevant to the sector. Chircop (2016) provides an update of his analysis of OHS and workers' compensation jurisprudence in Canada as these relate to aquaculture.

We know of no research that has systematically looked at access to compensation among aquaculture workers across multiple Canadian jurisdictions. Information on workers' compensation coverage by province can be found on the website of the AWCBC (http://awcbc.org/). The AWCBC data on lost time claims (summarized in the next chapter) suggests that some aquaculture workers are covered by workers compensation in most provinces and territories. Commercial fishers sometimes engage in aquaculture work. They are included under the Workers' Compensation Act in NL and British Columbia, but not in all provinces—for instance fishermen are excluded from compensation in Saskatchewan, New Brunswick and Nova Scotia. In Prince Edward Island, farming and fishing are excluded from the Workers Compensation Act. Indian bands and band endeavours on reserves are also excluded from the compensation act in Saskatchewan. In NL, an independent operator may be entitled to compensation, along with his or her dependents as though he or she is a worker.

3.3 Hazards

Despite its relatively long history, there is almost no research on aquaculture hazards or OHS more generally in Canada. The research we have found includes an unpublished consultant's report from the 1990s and Moreau and Neis' (2009) overview of OHS hazards in Atlantic Canadian aquaculture. The results of these two studies are summarized in the literature review below along with relevant hazard-related insights from research done in other countries.

Literature review

In 1992, ENTECH completed an aquaculture worker safety survey for the Aquaculture and Commercial Fisheries Branch in the Ministry of Agriculture, Fisheries and Food in British Columbia (ENTECH 1992). This 'relatively limited look' at the activities associated with farm fish in net pens and shellfish longline and bottom culture. At the time, the British Columbia aquaculture industry was exempt from Workers' Compensation Board regulations because it was deemed to be agricultural. The Consultants surveyed eight salmon farms and four oyster growers regarding safety policies and procedures and developed recommendations for policies and guidelines for the industry (ENTECH 1992). They also reviewed aquaculture industry regulations in other Canadian provinces and in Australia, Britain, Ireland, Scotland and Norway as appropriate. The hazards identified in the report included those related to diving, heavy equipment, firearms (for management of predators), construction and maintenance, hazardous materials, fire safety electrical equipment, manual materials handling and noise. In their site evaluations they looked at first aid safety policies, first aid kits, staff first aid training, communications equipment (in the event of an injury), transport for injured workers, knowledge about hypothermia, diving related training, skill levels and other diving related knowledge and equipment, as well as diving hazards such as bounce diving tidal currents, 'hour glassing' nets and other hazards. Small boat safety and handling hazards were identified as well as gaps in training and experience. They noted that beach culture of oysters "required boats to travel frequently in the dark to make use of the low tides occurring at night during the winter months" and that this work was done alone by some small operators (ENTECH 1992, p. 27). Vessel and engine maintenance practices were examined along with practices around setting limits on cargos for boats. They described the use of heavy equipment such as winches to lift bags and small cranes, access to and use of PPE, firearms and fire arm security and training.

In their 1992 report, ENTECH noted that none of the farms was using large numbers of chemicals with the most commonly used chemicals confined to iodine-based disinfectants and chlorine bleach, as well as some acids for making silage out of dead fish. Antibiotics were in use on salmon farms at that time: 2 out of 8 operators were still mixing antibiotic powder with wet or dry feed before feeding the fish. The others were purchasing pre-mixed feed. The report noted that "[e]xposure to antibiotic dust can cause allergies, the development of resistant strains of bacteria affecting humans, and changes to digestion resulting from intestinal bacteria being affected. In addition, pregnant women risk harming their developing fetuses (ENTECH 1992, p. 30).

ENTECH also reviewed communications on site and instances of working alone with a focus on safety communication for injured workers, as well as policies around liquor and drug use. Pen structure, particularly older pen systems were highlighted as a source of hazards due to "weakening of the structure and measures taken to strengthen it, such as additional guy wires slung across the walkways (a trip hazard). Walkways made of wood tended to be slippery and could also rot. They also noted that the use of more than one pen type on the same site could "mean that ramps are needed to compensate for the varying heights of the floating structures. On some sites, these ramps were unstable in conditions of normal use, and would be especially so during storm conditions" (ENTECH 1992, p. 31). They noted limited use of life buoys, heaving lines and navigation lights and noted some shortcomings around the availability and maintenance of fire-fighting equipment including smoke alarms in on-site living quarters. A final hazard discussed in the report was lifting requirements with "[a] great deal of lifting in many aspects of farm operations … on all salmon farms". Lifting included feed bag handling, handling clean and fouled nets and net anchors. Five of 8 salmon farms had mechanized feeding systems that had to be loaded manually with hoppers usually at shoulder height or above and feed bags weighting 25 kg. The presence of 'stoop labour' in oyster culture operations during harvesting and strain associated with pulling heavy 'french tubes' from the water and stripping them of oysters were also noted.

Common injuries reported to ENTECH included back strains and limb pains and cuts in oyster culture, and sore wrists and hands among oyster shuckers. They reported the loss of experienced shuckers from the industry due to wrist problems, along with risks of injury due to slipping and falling while working on rocky beaches, often after dark. They described a serious accident caused by winch failure and noted "[t]he failure of these winches is not an uncommon occurrence, as winches are often used beyond their design capabilities… ."

In 2009, Moreau and Neis published a paper on OHS hazards in Atlantic Canadian aquaculture including Atlantic salmon (*Salmo salar*), blue mussels (*Mytilus edulis*) and eastern oysters (*Crassostrea Virginica*). This paper highlighted the rapid growth of aquaculture in Canada, including globally and noted the fragmentary and limited OHS aquaculture research extant at the time (the authors found no peer-reviewed Canadian literature and only a small amount of grey literature and incident reports, and very little globally). The authors drew on existing peer-reviewed and grey literature, online resources and personal observations made by the authors, fine-tuned with inputs from a multi-stakeholder advisory committee, to develop a detailed outline of the structure of the industry from feed production through seafood processing and to identify *potential* OHS hazards associated with the hatchery, nursery and grow-out phases. Table 1 in their paper outlined existing and alternative aquaculture species under development at the time, outlined the associated culture techniques and explored potential work design, physical, chemical, biological and psychosocial hazards associated with hatchery facilities, grow-out facilities, processing plants and feed mills.

Moreau and Neis (2009) identified potential hazards associated with manual materials handling, fast pace, awkward postures, extended time standing and repetitive motion but noted the lack of research that quantified musculoskeletal symptoms among workers in the sector. Potential physical hazards included slips and falls, falls from height, workplace transportation including trucking, small and larger vessels, forklifts, ATVS and snowmobiles, as well as dangerous machinery, electricity, fire safety, extreme temperature, diving, excessive noise exposure and confined spaces hazards. Table 2 (reproduced as Table 3.1 below) in this publication listed chemicals approved for use in Atlantic Canadian aquaculture at the time, product/brand names for the chemicals and used Material Safety Data Sheet information to identify hazards associated with these chemicals. Chemical hazards included those associated with disinfectants, parasiticides, fungicides and antifoulants, anaesthetics and antibiotics. A comparison of the ENTECH survey report results with data in Moreau and Neis indicates that the number and types of chemicals in use in salmon and shellfish aquaculture had increased between 1992 and 2008.

Moreau and Neis (2009) note that "[a]s in the traditional fishing industry, biological hazards are potentially widespread in the aquaculture industry" (p. 407) including those associated with handling animals with sharp teeth and/or spines, exposure to sharp bones and shell fragments pointing to the potential for bites, cuts, puncture wounds, related infections and the risk of allergic reaction and disease. Fish and shellfish can be carriers of numerous human pathogens such as *Vibrio, Salmonella, Streptococcus* and toxic dinoflagellate species (p. 408) and exposure to dangerous microorganisms can occur through aerosol inhalation, broken skin and ingestion. The risk of needle puncture wounds in hatchery and grow-out operations linked to the administration of vaccines and blood sampling was also noted.

In terms of psychosocial hazards, Moreau and Neis also discuss the potential for work-related stress in the industry due to pressured work environments, potential situations of high demand and low control, employment uncertainty and shift work. They note the cyclical patterns of farming and the risk of losing an entire cohort to disease or poor growth as potential sources of stress for workers and employers.

Burridge *et al*. (2010) provide an overview of chemical use in salmon aquaculture with a focus on environmental effects with detailed information on the various antibiotics in use and their effects, as well as other chemicals. While focused on environmental effects, the paper has one reference to potential health effects on workers. The authors note:

> Furthermore, application of large quantities of antibiotics can also affect the health of workers employed in feed mills and on cage sites as a result of dust aerosols containing antibiotics that have been created in the process of medicating and distributing the feed to fish…Inhalation, ingestion and contact of the skin of workers with these aerosols will alter their normal flora, select for antibiotic-resistant bacteria and potentially generate problems of allergy and toxicity. (Burridge *et al*. 2010, p. 9).

Table 3.1 Notable chemicals approved for use in the Atlantic Canadian aquaculture industry (from Moreau and Neis 2009)

Disinfectants, Parasiticides, Fungicides and Antifoulants		
Chemical	**Product/Band Name**	**Hazard**
Benzalkonium Chloride	Benzalkonium Chloride	General irritant; ingestion danger; toxic compounds produced upon combustion[103]
Chloramine T	Chloramine T, Halamid	General irritant; produces chlorine gas upon combustion [104]
Cupric oxide	Aquashield®; Flexguard®; other copper-based paints	Mild skin, eye and lung irritant [105]
Emamectin benzoate	SLICE®	General irritant; ingestion may cause various CNS effects [106]
Formaldehyde	Parasite-S®; Paracide-F®; Formalin-F™; Formacide-B	General irritant; combustible; inhalation danger; CNS depression [107]
Hydrogen Peroxide	Hyperox; Perox-aid®	General irritant; corrosive; toxic; oxidizer [108]
Iodine	Various	Toxic [109]
Ivermectin	Stromectol®	General irritant; potential male reproductive effects [110]
Methanol	Parasite-S®	Flammable; toxic [111]
Sodium hydroxide	Biosolve	General irritant; corrosive [112]
Sodium hypochlorite	Bleach	Corrosive, poisonous, oxidizer [113]
Sulphamic acid	Antec Biofoam	General irritant; corrosive [114]
Teflubenzuron	Calicide®	Potential gastrointestinal or liver toxicant [115]
Potassium Peroxomonosulphate and Sodium alkyl benzene sulphonate	Virkon®	General irritant [116]
Anesthetics		

Chemical	Product/Band Name	Hazard
2-Phenoxyethanol	2-Phenoxyethanol	General irritant; potential effects to hematopoietic system [117]
Tricaine methanesulfonate	Finquel®; Tricaine-S	General irritant; corrosive [118]
Antibiotics		
Chemical	**Product/Band Name**	**Hazard**
Azamethiphos	Salmosan® 50wp	General irritant [119]
Erythromycin	Gallimycin® line	General irritant; toxic [120]
Florfenicol	Aquaflor® line	General irritant; Linked to digestive, reproductive and developmental complications [121]
Oxytetracycline hypochloride/dihydrate	Oxymarine™;Oxytetracycline HCl Soluble Powder-343; TETROXY Aquatic; Terramycin-343; Terramycin-200; Oxysol-220; Oxyvet® 200 LA	General irritant [122]
Sulphadimethoxine and Ormetoprim	Romet® 30; Romet® TC	General irritant; potential birth defects; potential effects to hematopoietic system [123]
Trimethroprim and Sulphadiazine	Tribrissen® 40%	General irritant; ingestion may cause vomiting, headache and nausea [124]

Burridge *et al.* describe regulation and reporting of antibiotic use by country for Norway, Chile, Scotland and Canada and list the following antibiotics as registered for use in Canada: Oxytetracycline, trimethoprim 80% / sulphadiazine 20%, sulfadimethoxine 80% / ormetoprim 20% and florfenicol.

Burridge *et al*. (2010) contains information on the quantities of antibiotic use in Canada, in British Columbia and New Brunswick, from 2006 to 2007 and for British Columbia in 2008 and compares these to quantities used in Chile. It is not clear that these data are for aquaculture only but they indicate much lower rates of antibiotic use in Canada than in Chile. The authors observe, “Since so few compounds are available in Canada and even fewer are actually applied (M. Beattie, Province of New Brunswick, personal communication) there may be reason for concern regarding resistance development. Without data about what compounds are applied, and where, it is difficult to assess risk.” They note that New Brunswick brought in new regulations around monthly reporting of incidence of disease and product applied in 2010 thus data on therapeutant use may have improved after 2010 (Burridge *et al*. 2010, p. 11).

In 2012, Weir *et al*. published a special report on zoonotic bacteria and antimicrobial resistance in aquaculture focused on opportunities for surveillance in Canada. They reviewed “the more important zoonotic bacteria in seafood, antimicrobial use and bacterial resistance in the sector and the main seafood safety regulations and surveillance programs in Canada” (Weir *et al*. 2012, p. 619). Their focus is on public health risks, not occupational health, and there is no reference to worker health risks or literature on this in the article. They note that globally only a few antimicrobials are approved for use in aquaculture, use varies a lot between countries, and that while the public health risk from antimicrobial use and related development of bacterial resistance in aquaculture is estimated to be relatively low, the risk should be quantified. They also note that international agri-food and health organizations had recently issued “a joint call for developing national and international surveillance programs for antimicrobial use and anti-microbial resistance in farm-raised aquatic animals to prevent and reduce the development and spread of bacterial resistance in aquaculture” (Weir *et al*. 2012, p. 621). The regulatory framework for the aquaculture and seafood industry in Canada is mainly focused on the processing sector and on protecting consumers from zoonotic organisms. The risks are discussed but again the focus is on public versus worker health.

In their brief discussion of antimicrobial resistance and aquaculture, Singer *et al.* (2016) conclude that “[t]he use and misuses of antibiotics in aquaculture has led to an increase in antibiotic resistance in fish pathogens, in the transfer of these resistance determinants to and from the sediment microbial community…Aquaculture has been shown to select for AMR in the fish microbiome and the surrounding environment” (p. 12); but the consequences of these changes, including for OHS are unknown.

Shellfish aquaculture is common on Canada’s east and west coasts. Guertler *et al.* (2016) used an Ergonomic Work Analysis based on a combination of observations, questionnaires and interviews to identify and suggest improvements to the main risks associated with activities on a Brazilian oyster culture farm. They identified the following hazards: noise generated by oyster wash machines and higher pressure water washers, non-ionizing radiation from sunlight, heat exposure and associated risk of dehydration, exhaustion and heat stroke, cold conditions linked to exposure to wind, rain and low temperatures, humidity, cuts caused by equipment and handling of oysters, slips, trips and falls in boats, on wet and slippery floors and from stepping on discarded oysters on the floor, drowning from falling overboard, fire caused by wiring and diesel oil problems, electric shock from washers, biological hazards including aquatic animals, inadequate postures and risks associated with manual materials handling (see Table 1, Guertler *et al.* 2016, p. 67).

We have found no peer-reviewed literature dealing with on-land aquaculture operations for species such as trout and Arctic char in Canada. Myers (2010) combined a review of ‘grey’ (American) and peer-reviewed (global) literature with an online search of investigation reports by OSHA and NIOSH in the United States, as well as court cases, to identify a range of hazards in aquaculture. Freedom of Information Act requests were used to get additional information on OSHA investigations. The review asked, “What is known about potential hazardous occupational exposures to fish farmers?” (Myers 2010, p. 414). Their findings are relevant for the Canadian context and included fresh-water aquaculture.

The review breaks documented hazards down by type of aquaculture including catfish pond aquaculture, hatchery (trout, salmon, halibut), tilapia, shellfish and shrimp culture as well as ornamental fish, tuna and mariculture. Myers found a high level of evidence for 6 hazard types including “electrical contact, drowning, crushing injury, falls from elevations, sprains and strains and chemical exposure, including decomposition products and confined spaces. Low-level hazards included fires, chemicals, and slips, trips and falls.” (Myers 2010, p. 414). Table 1 in Myers and Duborow (2012) summarizes common occupational hazards and consequences (potential fatal and non-fatal incidents) in aquaculture associated with rearing different fish and plant species. This is based on Myers 2010.

3.4 Other indications of aquaculture hazards in Canada

Crane failures documented in ENTECH (1992) continue to be a hazard in Canadian aquaculture and aquaculture elsewhere. In 2009, a young Tasmanian aquaculture worker was crushed to death by a deck-mounted crane on a fishing boat (ABC News, 2011). In 2016, a Transportation Safety Board Investigation report was issued concerning a fatal accident aboard a small aquaculture vessel in Prince Edward Island on Canada's east coast. The vessel was doing spring maintenance on oyster growing cages and the operator was working under the boom of the crane when it failed, striking and fatally injuring him (see Transportation Safety Board of Canada 2018). The Tasmanian worker had no safety training. The Canadian TSB report highlighted not only structural problems but also organizational failures including a failure on the part of owners to detect a design flaw in the crane and the failure of the crew to conduct a visual inspection of the crane before each voyage. It noted "there are no standards for the design and construction of lifting appliances on small fishing vessels". In addition, there were no PFDs on board.

The regulator for the Newfoundland and Labrador government provided a summary report on aquaculture orders issued in Newfoundland and Labrador in July 2017 for the years 2011-2017 (Table 3.2 below). This list is below and speaks to the presence of similar hazards to those identified by Myers as well as others. The most common deficiencies prompting these orders were related to machinery safety; training, usage and storage of hazardous substances; electrical hazards; respiratory protection; noise exposures; mobile equipment; emergency washing facilities; PPE and related education/instruction; missing, poorly maintained or inappropriately installed guardrails; diving-related hazards; material storage; machinery guarding; issues related to compressed gas/welding/burning; access and egress, fire protection, fall protection; and scaffolding and portable ladders (Giles, OHS Branch, personal communication, July 6, 2017). These hazards are also not dissimilar from those identified in the ENTECH Survey in 1992 and in other sources except they do not include work design issues linked to repetitive motions and include noise exposures.

The 1992 ENTECH survey also identified potential risks associated with aging salmon aquaculture pen systems. This does not appear to have been explored in subsequent research but emerges as an issue in media coverage around the recent (August 2017) Cooke Aquaculture Puget Sound salmon escape at Cypress Island. In that case, the pen collapsed and journalists investigating the escape, and events leading up to it, described a previous series of events in July where pens full of adult fish were slipping their moorings, and the employees worked through the night to stabilize the drifting farm. They also described a period of several days associated with efforts to stabilize the operation including periods when it was too unsafe to work on the walkways and surface structures. This suggests that aging farm sites and site replacement efforts may be associated with heightened OHS risks. This is not discussed in the larger research. ENTECH discussed the shift from manual to automated feeding in salmon aquaculture indicating that even with automated feeding, bags had to be lifted and fed into the feeder. On Cooke Aquaculture's Saddle Island Farm, feeding is done remotely from the office using computer controlled barges with feeding lines (Cooke Seafood, 2017). At that time, this was apparently the only system of its kind in Atlantic Canada, but this kind of automation would reduce lifting hazards associated with feeding in salmon and possibly trout aquaculture.

Moreau and Neis did not examine hazards on inland aquaculture farms. These are discussed in some depth in Myers (2010) and Myers and Duborow (2012), along with some strategies for hazard assessment and preventions. Ogunsanya *et al.* (2011) report on a study of work-related safety hazards, injuries and near-injury events on trout farms in North Carolina and Kentucky.

Table 3.2 Number and type of aquaculture orders issued for deficiencies in Newfoundland and Labrador, 2011 to July 2017*

Aquaculture Orders **Legislative Section/Deficiencies Observed**	**# Issued**	**Examples of deficiencies resulting in orders**
Safe Machinery	34	Damaged components, missing safety mechanisms, manufacturer's instructions not followed, uncompleted inspections
Hazardous Substances	31	Storage, worker education, worker training. decanted products, improper usage, information required
Electrical	24	Improper installation, improper procedures, exposed components, qualified workers
Respiratory Protection	23	Respiratory Protection Program, Fit Testing, Appropriate protection, Storage, Worker Education
Noise	22	Hearing Conservation, Noise Assessments, Worker Education, Appropriate Hearing Protection
Mobile Equipment	21	Inspection and maintenance, worker training, damaged or missing components.
Emergency Washing	20	Inappropriate emergency washing facilities, Maintenance
Personal Protective Equipment	20	Inappropriate PPE, Worker Education/Instruction
Guardrails	15	Inappropriate installation, repairs, missing railing
Diving	12	Training, appropriate crew size, appropriate equipment, documentation
Material Storage	11	Stacking and storage
Guarding	10	Missing and or damaged guarding on equipment
Compressed Gas /Welding/Burning	10	Improper storage, respiratory protection, damaged equipment, training
Access and Egress	9	Inappropriate stairs, ladders, gangways. Blocked or obstructed routes.
Fire Protection	8	Inappropriate equipment, maintenance, inspections
Fall Protection	8	Inappropriate training, equipment, procedures
Portable Ladder / Scaffolding	7	Inappropriate product, damaged product, inappropriate use, inappropriately constructed
Ventilation	6	Insufficient or missing ventilation, Assessment required
Forklift	6	Inspection and maintenance, worker training, damaged or missing components, inappropriate operation
Crane / Hoist	5	Inspection and maintenance, worker training, damaged or missing components, inappropriate operation

OHS Program / Committee / Representative	5	Develop, implement or additions required to programs. Worker education. Program review and maintenance
Working Alone	4	Develop safe work procedures, worker education
Worker Assessment	2	Monitor worker health and procedures when using hazardous substances
Sanitary Workplace	4	Clean or organize the work space
Traveling on Ice and Water	3	Written procedures and worker education
Floor Opening	2	Cover or guard openings
Navigation	2	Written procedures, necessary equipment
Written Procedures	2	Develop and train workers to the procedures
Thermal Environment	2	Procedures, worker clothing, worker training
Smoking in the work place	1	Smoke Free Environment Act
*Source: Giles, OHS Branch, Personal communication, July 6, 2017		

The types of hazards farmers reported included "falling live tank lids, slippery surfaces on hauling trucks, lifting strains, falls from raceway walls and walkways, needle sticks while vaccinating fish, allergies, hypothermia/drowning, falls from cranes, chemical exposure, fire/explosions related to oxygen exposure, and electrical contact with overhead power lines." (Ogunsanya *et al.*, p. 33).

4. Injury and fatality statistics

This chapter contains an overview of statistics on injury and fatalities in aquaculture In Canada. As noted in Chapter 3, with the exception of certain types of work that fall under federal jurisdiction, OHS is a provincial responsibility. Each province and most territories have their own compensation system. The Associated Workers Compensation Boards of Canada (AWCBC) National Work Injury/Disease Statistic Program (NWISP) has access to data on compensation claims for provinces and territories and can generate custom analyses of data on successful compensation claims for fatalities and lost-time injury (LTI) claims for a fee. We use AWCBC data in this chapter. There are, however, overlaps in employment in areas like seafood processing between capture and aquaculture industries, making it impossible to separate aquaculture from capture incidents in these data, particularly in the absence of information on aquaculture employers. AWCBC data also do not include information on numbers of workers making it impossible to generate information on LTI and fatality rates from these data. Finally, as noted in previous chapters, not all aquaculture operations in Canada are necessarily covered by compensation including particularly small operators and aquaculture operations on reserve. This would contribute, along with other factors such as widespread use of experience-based rating in Canadian provinces, to under-reporting in these data (Tompa *et al.* 2007). It is also worth noting that there is evidence of under-reporting of injuries and fatalities in compensation board statistics in Canada (Koehoorn *et al.* 2015; see also Smith *et al.* 2009), particularly among women, among those working in natural resources and other unspecified work, seasonal employment (Howse *et al.* 2012) and among those with certain types of diagnoses. This has also been documented elsewhere (see discussion of under-reporting in Norway in Holen *et al*. 2017a, 2017b). Individual workers' compensation boards can provide more detailed data and can produce comparable injury rates. In this chapter we supplement the AWCBC data with data derived from one of the compensation boards, WorkplaceNL, in Newfoundland and Labrador.

As part of a larger study on aquaculture OHS in Atlantic Canada recently funded through Module M of the Ocean Frontier Institute we requested from the AWCBC's National Work Injury/Disease Statistic Program (NWISP), custom data on lost time claims and fatalities for occupations NOC 8257 (Aquaculture Operators and Managers) and NOC 8613 (Aquaculture and Marine Harvest Labourers) broken down by nature of injury, age, gender, event, part of body, source of injury for all Canadian provinces and territories for the years 1996-2015.

Injuries and fatalities associated with a small number of questionable industries are captured by the aforementioned NOC aquaculture occupation codes and their link to aquaculture requires further clarification by the AWCBC and respective provincial compensation boards. The related 28 lost time injuries span across the provinces listed in Tables 4.1 – 4.4 and represent under 2% of accidents for each of British Columbia, NB, Newfoundland and Labrador and Nova Scotia. Questionable industries are associated with roughly 7.5% of the aquaculture related lost time injuries reported in Quebec.

The AWCBC custom data do not include all aquaculture work-related injuries because they do not include aquaculture processing workers (the code for these workers includes other seafood processing workers). These data also likely do not include injuries and fatalities in commercial fish harvesting that resulted from encounters with aquaculture operations.

In these AWCBC data, a fatality is defined as "[a] death resulting from a work-related incident (including disease) that has been accepted for compensation by a Board/Commission….Fatalities that result from an accepted lost time claim and are accepted outside of the time loss reference period from 1993-2008 may be underreported as not all jurisdictions captured these fatalities." Lost time claims include "[a]n injury where a workers is compensated by a Board/Commission for a loss of wages following a work-related injury (or exposure to a noxious substance), or receives compensation for a permanent disability with or without any time lost in his or her employment…Saskatchewan, Ontario, Nova Scotia and Newfoundland and Labrador do not include claims that receive compensation for a permanent disability without any time lost." These and other definitions/information about these data can be found at http://awcbc.org/?page_id=3966.

According to the AWCBC statistics, there were 12 fatalities among operators, managers and labourers in Canada between 1996 and 2015, of which 5 were due to transportation injuries. Eleven of those who died were men.

The Canadian Aquaculture Industry Alliance states aquaculture occurs in all provinces and the Yukon Territory with no mention of activity in the Northwest Territories (NWT) or Nunavut (NU). However, the AWCBC data on lost-time injuries and fatalities includes aquaculture-related lost time claims for these latter two territories, which are jointly represented by the Workers' Safety and Compensation Commission (WSCC). Four of the 12 fatalities reported by the AWCBC for the period 1996-2015 as part of the aquaculture occupation codes noted above, occurred within the NWT/NU and were classified as falling within the outfitter industry. The connection, if any, between these fatalities and aquaculture, is currently under discussion with the WSCC in the NWT/NU.

Table 4.1 Lost time claims for aquaculture operators, managers and labourers by nature and cause of injury, Canada and top 5 provinces (1996-2015)*

	Region											
Record Type	**Canada**	**%**	**BC**	**%**	**NB**	**%**	**NL**	**%**	**NS**	**%**	**QC**	**%**
Total Cases	**2596**	**-**	**1369**	**53**	**448**	**17**	**310**	**12**	**120**	**5**	**134**	**5**
Nature of Injury												
traumatic injuries/disorders	2310	89	1227	90	386	86	294	95	103	86	109	81
systemic diseases/disorders	254	10	139	10	49	11	14	5	13	11	22	16
injury causing events												
object/equipment contact	629	24	294	21	113	25	102	33	32	27	29	22
falls	451	17	243	18	108	24	23	7	22	18	30	22
bodily reaction/exertion	1179	45	680	50	195	44	117	38	54	45	56	42
harmful exposures	73	3	25	2	19	4	-	-	-	-	8	6
transportation accidents	232	9	118	9	12	3	65	21	0	0	6	4
fires/explosions	6	< 1	-	-	-	-	0	0	0	0	0	0
harassment/violent acts	5	< 1	-	-	0	0	0	0	-	-	0	0
other events/exposures	19	1	4	<1	0	0	0	0	8	7	5	4

*Source: Association of Workers' Compensation Boards of Canada (AWCBC), National Work Injury/Disease Statistic Program (NWISP), Received December 1, 2017

Table 4.2	Lost time claims for aquaculture operators, managers and labourers by source of injury, Canada and select provinces (1996-2015)*										
	Region											
Record Type	**Canada**	**%**	**BC**	**%**	**NB**	**%**	**NL**	**%**	**NS**	**%**	**QC**	**%**
Total Cases	2596	-	1369	53	448	17	310	12	120	5	134	5
Source of Injuries												
chemicals/chemical products	17	1	5	< 1	-	-	-	-	-	-	0	0
containers	413	16	200	15	92	21	54	17	21	18	20	15
furniture/fixtures	17	1	7	1	-	-	-	-	-	-	4	3
machinery	155	6	69	5	29	6	38	12	5	4	-	-
parts/materials	372	14	242	18	36	8	50	16	15	13	19	14
persons, plants, animals, minerals	570	22	309	23	87	19	46	15	35	29	41	31
structures/surfaces	328	13	187	14	63	14	28	9	9	8	15	11
tools, instruments, equipment	194	7	119	9	38	8	10	3	4	3	4	3
vehicles	364	14	171	12	57	13	72	23	8	7	19	14
other sources	162	6	60	4	41	9	9	3	21	18	10	7
*Source: Association of Workers' Compensation Boards of Canada (AWCBC), National Work Injury/Disease Statistic Program (NWISP), Received December 1, 2017.												

As indicated in Table 4.1, there were 2,596 successful lost time injury claims between 1996 and 2015. Of these injuries, 53% were in British Columbia, 17% in New Brunswick, 12% in Newfoundland and Labrador, 5% in Nova Scotia and 5% in Quebec with smaller proportions in other provinces and territories. Of these, 89% were traumatic injuries/disorders and 10% were systemic diseases/disorders. The main injury causing events were object/equipment contact, falls, bodily reaction/exertion and transportation accidents. The most common sources of injuries (Table 4.2) included persons, plants, animals, minerals, containers, parts/materials and vehicles, structures/surfaces, tools, instruments and equipment and machinery.

Table 4.3	Lost time claims for aquaculture operators, managers and labourers by location of injury on body, Canada and select provinces (1996-2015)*											
	Region											
Record Type	**Canada**	**(%)**	**BC**	**(%)**	**NB**	**(%)**	**NL**	**(%)**	**NS**	**(%)**	**QC**	**(%)**
Total Cases	2596	-	1369	53	448	17	310	12	120	5	134	5
Locations on Body												
head	79	3	40	3	9	2	10	3	-	-	7	5
neck, including throat	35	1	18	1	8	2	7	2	0	0	0	0
trunk	1144	44	623	46	199	44	126	41	50	42	69	51
upper extremities	697	27	363	27	124	28	81	26	38	32	27	20
lower extremities	473	18	258	19	78	17	53	17	19	16	22	16
body systems	20	1	10	1	4	1	0	0	-	-	-	-
multiple body parts	145	6	57	4	25	6	33	11	8	7	7	5
*Source: Association of Workers' Compensation Boards of Canada (AWCBC), National Work Injury/Disease Statistic Program (NWISP), Received December 1, 2017.												

Table 4.3 shows lost time claims by location of injury on the bodies of workers for Canada and select provinces. Forty-four% of injuries were to the trunk, 27% to upper extremities and 18% to lower extremities.

Table 4.4 Lost time injury claims by year, Canada and select provinces*

	Region			
Claim Year	**Canada**	**BC**	**NB**	**NL**
1996	119	65	36	6
1997	199	126	52	7
1998	117	76	20	10
1999	144	68	22	30
2000	200	113	20	35
2001	215	110	22	32
2002	250	132	29	33
2003	178	75	26	41
2004	118	68	25	-
2005	137	85	28	-
2006	122	72	23	5
2007	92	50	23	-
2008	86	52	18	6
2009	91	50	18	5
2010	88	43	11	9
2011	75	30	16	12
2012	114	45	16	28
2013	77	35	12	14
2014	92	39	19	10
2015	82	35	12	23

*Source: Association of Workers' Compensation Boards of Canada (AWCBC), National Work Injury/Disease Statistic Program (NWISP), Received December 1, 2017

Table 4.4 presents lost time injury claims by year for Canada and select provinces. Based on these data, the average number of successful lost time injury claims in these occupations in Canada declined by 43% from 155 in the five year period between 1996 and 2000 to 88 between 2011 and 2015. Over the past several years, most provincial compensation boards have introduced varying forms of experience rating programs. Experience rating programs include provisions for premium rebates/discounts and/or surcharges based on the experience of individual companies. The introduction of these programs has coincided with declining claims for compensation across jurisdictions. Evidence in the published literature on the general impact of experience-rating on prevention is limited. There is some evidence it can sometimes lead to improved prevention. However, it can also lead employers to focus on claims management and, related to this, to discourage reporting of injuries and illnesses as a way of reducing compensation premiums (Tompa *et al.* 2007).

AWCBC data do not include numbers of workers or person years making it impossible to track injury and fatality *rates* for these occupations over time within the data, or to compare them to other occupations. Unlike some other countries such as Australia, the United Kingdom and the United

States, Canada has no national source of information for on-the-job death rates. However, recent *Globe and Mail* newspaper and Statistics Canada initiative used AWCBC accepted fatality claims data as the basis for their estimate of deaths by occupation and Statistics Canada's labour force survey data to arrive at fatality rates for different occupations. They documented average traumatic injury fatality rates by occupation for 2011-2015. The fatality rate for fishing vessel deckhands (77/100,000) ranked second; fishing vessel skippers and fishermen/women (57.5/100,000) ranked fifth; and aquaculture and marine harvest labourers ranked sixth at 43.5/100,000 for this period. Overall, the investigation determined fishing (including deckhands, skippers and aquaculture and marine harvest labourers) had the highest fatality rate in the country indicating that compensation data under-estimate fatalities because only approximately 80% of Canadian fishermen are covered by compensation and for other reasons. While AWCBC data show 27 deaths in the fishing sector in Canada for 2011-2015, the Transportation Safety Board's (TSB) database of marine incidents documents 52 fishing fatalities in this period (Grant 2017a,b,c). The TSB database may include aquaculture-related fatalities and should be examined in future work.

While fatality rates in aquaculture are lower than in fishing, LTI's may be higher in some provinces. In NL, aquaculture is normally included in fishing industry compensation statistics. WorkplaceNL (the Newfoundland and Labrador compensation board) provided an industry analysis of lost time injuries for the Newfoundland and Labrador aquaculture industry produced for the OFI study for the years 2010-2016 based on an analysis of claims from aquaculture employers that included fish processing labourers and plant workers, aquaculture operators and managers, aquaculture and marine harvest labourers, fishing vessel deckhands, and others. These data were used to generate the lost-time incidence rate per 100 employees per year giving some indication of the relative risk in the industry and the extent to which our AWCBC data may underestimate LTIs. In these data, there was a total of 159 LTI claims for 2010-2016 compared to only 96 in the AWCBC data (40% more LTIs) pointing to the likelihood that the two aquaculture occupation codes used for the AWCBC data analysis do not capture all of the LTIs in the industry.

In the WorkplaceNL report, the number of employees varied between a low of 393 in 2010 to a peak of 509 in 2013 (average 448 employees between 2010 and 2016). The LTI rate in these data varied from a peak of 7.5/100 in 2015 to a low of 3.3 in 2016 with an average of 5.5 LTI's/100 workers between 2010 and 2016. This rate was 3.4 times the average LTI rate for Newfoundland and Labrador during those years. A scan of WorkplaceNL industry fact sheets shows it was higher than the LTI rate for fish processing and fish harvesting (which include aquaculture LTIs) and higher than rates for all other sectors between 2012 and 2016 (WorkplaceNL 2017).

5. Aquaculture occupational ill-health statistics

There is little available information on ill-health among aquaculture workers in Canada. According to the AWCBC statistics presented in Chapter 4, roughly 10% (256) of the successful lost time injury claims from aquaculture labourers and managers and operators between 1996 and 2015 were for systemic diseases and disorders. Processing workers and workers employed in diving, trucking and related service industries are not, to our knowledge, included in these data. Norwegian research has documented an increased risk of respiratory impairment (including an excess of work-related respiratory symptoms and reduced lung function) in Norwegian salmon industry workers as well as indication of sensitization to salmon (Shiryaeva *et al.* 2010). Respiratory symptoms do not seem to have been investigated in Canadian workers in salmon or other forms of aquaculture finfish or shellfish processing.

The report on LTI claims for the aquaculture industry in Newfoundland and Labrador (WorkplaceNL 2017) includes processing and other workers. It found that 61.5% of LTI claims were for soft tissue injuries (134/218) and the type of accident for 59% of those was bodily reaction and exertion. Repetitive work and awkward postures and prolonged standing are features of multiple parts of the industry and a major cause of work-related musculoskeletal disorders, "a set of diseases that affect muscles, tendons, nerves and vessels of upper and lower limbs" (Tortato Novaes *et al.* 2017, p. 112). Ergonomic analysis of postures associated with mussel aquaculture manual harvesting in Brazil has documented multiple harmful postures associated with this work (Ibid). Aquaculture work including work in processing plants often involves feeling cold at work and this has been shown to contribute to the risk of symptoms from muscles, skin and airways among Norwegian workers (Bang *et al.* 2005). Elevated occupational noise levels in aquaculture is an area in need of further research globally. We are not aware of any Canadian research examining this. Voorhees and Barnes (2017) documented elevated noise levels in two fish rearing buildings at an American aquaculture fishery. The levels were within regulatory limits but the authors recommended steps to reduce noise levels. In NL, 1.4% of accepted LTI claims between 2010 and 2016 were for deafness, hearing loss or impairment. This is a signal that noise levels may be too high in some aquaculture operations or, alternatively, may have been too high in the past.

As noted in Chapter 3, antibiotic use is widespread but uneven throughout the global aquaculture industry with potential occupational disease consequences. It appears to be relatively low in Canada compared to Chile at present but this may not have been the case in the past. Antimicrobial resistance has been identified as a major public health issue but there is limited knowledge of the contribution of agricultural antimicrobial use to resistance (Silbergeld *et al.* 2008; Singer *et al*. 2016) and even less is known about the contribution from aquaculture. The main focus in research on aquaculture and the use of antibiotics and antimicrobial resistance has been on impacts on benthic organisms, the presence of antimicrobial resistant bacteria in resulting products and on potential public health risks as opposed to occupational health risks. The use of biocides and metals can contribute to the development of antimicrobial resistance and, as noted above, all are in use on fish farms (Singer *et al.* 2016), including in Canada.

6. Welfare conditions and work-related factors that contribute to ill-health and injury

Canadian citizens have access to a universal health care system that includes medical treatment and hospital care but does not include costs of drugs (except when in hospital), hearing aids, or wage replacement. There is no general disability insurance program in Canada like in the Netherlands. Health insurance falls under provincial jurisdiction and so entitlements can vary from one jurisdiction to another. Allied health professional services sometimes fall outside of the regular health care system and thus must be paid for on a fee-for-service basis or through access to company health insurance plans which generally are not part of the fishing and aquaculture sectors when workers do not have access to compensation. Thus, services for physiotherapy, massage, chiropractic support may not be covered by provincial health care insurance.

As indicated by the AWCBC statistics provided above, some aquaculture employers are clearly covered by workers' compensation in Canadian provinces but some are likely excluded from these data and from coverage in some jurisdictions (the extent of this is unclear). Small operators might be eligible for compensation but may not register with the commission (this is the case with agriculture in Newfoundland and Labrador for example) (Neis *et al.* 2017). Workers' compensation is funded through employer premiums and for accepted claims can include not only partial wage replacement but also access to coverage for drugs and a broad range of medical services including allied health professional services. Legal research in Canada on the relationship between self-reported injuries and illnesses and compensation claims data in Canada indicates that the latter under-represent certain kinds of work-related illnesses and injuries, particularly among certain groups of workers. Reasons for this include limited coverage of some sectors of the labour market and some kinds of injury, low acceptance rates for certain kinds of claims and a failure to claim by some categories of workers. Legal research also indicates that compensation claims may be going down in part due to the transfer of costs by employers from the compensation system to private insurance and to such public social programs as medicare and social assistance (Cox and Lippel 2008).

The aquaculture sector employs some women, immigrant workers, young workers and temporary foreign workers, as well as aboriginal workers. It encompasses some small enterprises and some work is seasonal which means some aquaculture work is precarious. These groups tend to experience high accident rates and, as precariously employed workers, may not always be fully aware of their rights to safe workplaces and to compensation, and may fear loss of employment should they file claims (see for example Otero and Preibisch 2010). As a result, they may not submit compensation claims and those claims they submit may be less likely to be approved (Cox and Lippel 2008).

Moreau and Neis (2009) had no data on the number or source of migrant workers in the sector, on the age and education profile of industry workers, on safety training or other social and organizational factors. They noted the pervasive gender division of labour in seafood production in

Atlantic Canada in the capture fishing and seafood processing industries and the likelihood this was reproduced in aquaculture and thus, that hazardous exposures and injury and illness prevalence would differ by gender. They did not, however, have access to a gender breakdown of aquaculture workers in the region or to information on divisions of labour. They did not discuss the potential role of seasonality, race/ethnicity (including First Nations employment), immigration status or unionization in the distribution of OHS hazards exposures, injuries and fatalities, compensation claims and overall prevention in different parts of the sector and across regions and provinces. These issues remain under-researched in the sector in Canada and elsewhere. We noted above evidence of the use of temporary foreign workers in the New Brunswick aquaculture industry but this needs to be examined for other provinces. Aboriginal groups appear to have a high level of involvement with the industry in different parts of the sector on Canada's coasts and in places like Northern Ontario. There is very little research on workers compensation injuries among aboriginal people in Canada. A recent study done in British Columbia of worker compensation injuries among the aboriginal population in the province based on data from 1987-2010 found that as employment rates increase for aboriginal populations, the risk of workplace injury has also gone up (Jin *et al.* 2014). The authors recommend culturally sensitive prevention programs that target industries and regions where Aboriginal workers are concentrated.

Compensation claims rates for occupational diseases are generally lower than the actual rate of such diseases including, for example, occupational asthma and this may be the case in aquaculture as well as some other sectors. Occupational diseases like occupational asthma can be difficult to diagnose and rural and remote workers may face challenges and costs accessing appropriate specialist support. It is also significant that seasonally employed workers face a disincentive to filing compensation claims because time off on compensation is not eligible for Employment Insurance and seasonal workers often struggle to get enough hours of work to ensure they are eligible (Howse *et al.* 2012).

7. Labour relations consultation on OHS

Unionization plays an important role in OHS management and prevention. It is particularly important in systems like the Canadian system that are based on internal responsibility. Reasons for this include the extent to which those systems rely on mechanisms like joint health and safety committees in larger workplaces and OHS representatives in smaller workplaces, as well as on guaranteed basic worker rights, in order to reduce injury and illness risk, improve reporting and promote joint management workplaces inspections, surveillance and intervention when hazards are identified. In the absence of unions, particularly among precariously employed groups of workers such as casual and seasonal workers in low-skilled jobs, among aboriginal and temporary foreign workers, and in the context of limited access to OHS-related knowledge and training, medical expertise and where inspections are limited, the internal responsibility system is likely to be less effective.

The unionization rate for Canadian occupations as a whole is 31%. Unionization among those who fall within the occupational code for aquaculture and marine harvesters is only 15%. This suggests unionization in the sector is relatively low, but likely varies across both provinces and occupations. One reason for low unionization rates could be the extent to which the industry (particularly outside of salmon aquaculture) is dominated by owner-operators and small- and medium-sized companies. We know of only one union representing workers in the aquaculture sector, the Fish Food and Allied Workers Union (FFAW/UNIFOR) in Newfoundland and Labrador. Inspectors and other types of regulatory workers involved with aquaculture may be unionized provincial and federal employees (NUPGE 2010).

8. Analysis of what works, does not work and recommendations for improvements

No research on Canadian aquaculture OHS appears to have been published since 2009. There have been some industry-related OHS initiatives including the publication of *Fish Safe*: *A Handbook for Commercial Fishing and Aquaculture* by the Nova Scotia Fisheries Sector Council (MacGregor 2004) that includes a discussion of three main workplace risks including drowning, hypothermia and heat-related risks. Some aquaculture hazards and precautions are discussed in *FishSafe*. Drowning was indicated as the biggest risk; in smaller shellfish operations, workers often work alone, thus highlighting the need for a communications plan as well as access to means of communication to assist those at risk of injury/drowning. Further discussed are methods to reduce risk of hypothermia, sunstroke and dehydration and risks associated with barge and small vessel safety hazards, winches, fire, listing or capsizing and drifting. Cage structure, diving and harvesting safety and the possibility of lightning strikes were also identified as risks. The Newfoundland Aquaculture Industry Association provides a resource sheet on aquaculture safety hazards including hazards and possible injuries by site (open water, hatchery, processing plant and wharf) and a corresponding list of relevant safety measures for each (available at www.naia.ca).

The province of Prince Edward Island's *Aquaculture Safety Code of Practice*, current as of June 2008, was developed by a consulting firm under the direction of the Prince Edward Island Aquaculture Alliance and published by the provincial WCB. The Code highlights the need for:

- aquaculture safety planning
- boat, deck and navigational safety
- chemical, fuel and lubricant safety
- diving safety
- electrical, equipment and machinery safety
- ergonomics
- finfish safety
- fire prevention
- first aid, emergency and rescue protocols
- hand and power tool safety
- hoisting and conveyor system safety
- hydraulic safety
- training of new and young workers
- proper use of PPE
- hazards related to knives and needle sticks
- slip, trip and fall prevention
- transportation safety
- identification of weather hazards
- welding, cutting or soldering safety
- safe winter harvesting protocols
- appropriate workplace housekeeping
- chainsaw safety (used to cut through ice in winter)

The Code also includes sample OHS policies, voyage plans, safety checklists worksheets and purity requirements for Normal SCUBA tank air.

Very little information is available concerning initiatives focused on ergonomics in Canadian marine aquaculture and OHS in aquaculture processing. Merinov is engaged in an engineering study to design a mussel spat collection system and to modify a mussel stripping system to improve worker ergonomics and reduce physical effort through mechanization (AAC 2017, p. 113). One short article by the BC Salmon Farmers' Association (BCSFA 2019b) reported an ergonomics intervention funded by Cermaq Canada, one of the largest producers of farm-raised salmon in the province. Reported injuries across plants increased sharply from six injuries annually to 45 employee absences in 2012 due to sore shoulders, backs, and wrists. This increase in reported injuries motivated the Cermaq OHS Officer to contract a rehabilitation company to audit their Tofino plant and establish recommendations for changes (which included stretching exercises and related stretching breaks every two hours and modifications to the work station of an administrative worker). All Cermaq farms are reported to be three-star Global Aquaculture Alliance BAP certified. They also have Food and Manufacturing Industry Occupational Safety Alliance Certification and Operational Safety Standard of Excellence certification. The EWOS® feed company also reports application of safety programs and practices to satisfy industry standards.

Among the challenges with ergonomics interventions in seafood processing and other aquaculture contexts are the relatively frequent changes in products and production lines (particularly in capture plants) and related changes in work demands, as well as limited access to trained ergonomics expertise in rural and remote areas (Cermaq 2015). The SafetyNet Centre for Occupational Health and Safety, Memorial University developed and tested a participatory ergonomics toolkit in seafood processing as well as poultry and snackfood processing in order to address these and other challenges. The toolkit can be accessed at free of charge at http://www.participatoryergonomics.mun.ca/ (Antle *et al.* 2012).

At the end of their review of the literature and hazard assessment exercise for Atlantic Canadian mariculture, Moreau and Neis (2009) argue,

> [t]he results of very limited aquaculture OHS research to date and a detailed description of the various phases of the industry suggest there are multiple, potentially serious occupational hazards associated with the industry. … Systematic hazard identification, education, training and prevention are essential requirements for a safe industry, as is systematic research to document hazards, evaluate risks, identify appropriate prevention initiatives and evaluate the effectiveness of those initiatives." (p. 408).

These concerns have been supported by subsequent research conducted in the United States (Myers and Durborow 2012; Myers *et al.* 2012; Myers *et al.* 2013). Norwegian research has documented aquaculture-related injuries and fatalities and conducted statistical analyses using a combination of compensation and inspection reports data (Holen *et al.* 2017a, b). The possibility of applying these quantitative methods to assess aquaculture OHS in Canada or parts of Canada is currently being evaluated through the Ocean Frontier Institute. Norwegian researchers are also conducting important research on organisational aspects of Norwegian fish farming and their relationship to risks. Their research focus includes changes in the industry (such as pressure to reduce fish escapes and to move cages further offshore), organisational aspects that might enhance risk associated with these changes and the corresponding risk reduction strategies (Thorvaldsen *et al*. 2015; Støkersen

2012). These kinds of initiatives are particularly important in the context of dynamic industries subject to rapid change, including parts of the Canadian industry.

The Canadian aquaculture industry is expected to grow substantially over the next few decades and is changing rapidly. Many millions of dollars have been invested in aquaculture research and development in recent years. These investments continue to contribute to changes in the industry and have the potential to increase or decrease OHS hazards exposure and prevention. However, there appears to have been no systematic attempt to monitor these potential impacts. Current research and development initiatives and their potential OHS impacts are discussed in the remainder of this chapter.

A review of research and development related to Canadian aquaculture published by the Aquaculture Association of Canada (AAC 2017) included information on more than 210 different research projects underway between 2015 and 2017 (AAC 2017); none of these initiatives focused on OHS related issues. While the focus is on impacts of chemicals on benthic environments and on other species, a scan of these reviews provides useful background information on chemicals used, or contemplated for use, in the industry for such purposes as reducing the effects of sea lice. Examples include research on the benthic environmental effects and species impact of the organophosphate aquaculture pesticide *Salmosan® (*Azamethiphos, one of two pesticides approved for use as a bath treatment to control sea lice in farmed salmon in Atlantic Canada)*, SLICE,® Paramove 50,®* and in-feed pharmaceutical products, *Emamectin Benzoate or Ivermectin*. Other focal chemicals referenced in the Research and Development review include deltamethrin, cypermethrin (*not approved for use in Canada;* CFIA 2016*)* and hydrogen peroxide.

Reference to a study on tunicate infestations on mussel farms in the AAC (2017) review indicates high pressure water treatment for *C. intestinalis* is being tested for use in St. Mary's Bay. The studies also include experiments with deep water sites for blue mussel (*Mytilus edulis*) aquaculture in Newfoundland and Labrador (p. 92), and the mitigation of sea duck predation on mussels by the installation of nets, exclusion cages (p. 95) and transferring mussel socks to different locations, all of which could have consequences for OHS (p. 93). Experiments with the use of hydraulic dredges in the harvesting of soft shell clams in Atlantic Canada and marine spatial planning and carrying capacity research also have potential OHS implications, including those related to interactions between commercial fishing and aquaculture. These studies also include experiments involving the production of macroalgae independently versus integratively with mussel aquaculture and sea cucumbers, and research on non-biocidal antifouling paints in Atlantic Canada (p. 113). New aquacultured species have the potential to introduce new OHS hazards or, if their purpose is to eliminate chemical and other hazards, to reduce others.

A good example of what is happening in Canadian aquaculture research and development is the changes in oyster aquaculture production in Atlantic Canada where research is focusing on the industry shift away from reliance on natural wild spat collection towards hatchery-based production of spat, larvae and broodstock. Grow-out techniques are also changing from sea bed cultivation to floating systems. Floating systems are more vulnerable to biofouling than in the past so new grow-out systems are being developed to reduce this problem including the OysterGro ® system, the Zapco Aquaculture bag system and other initiatives. Stocking density and mechanization are increasing, as noted by Gionet (2017, p. 30):

> [W]ith the growth of the industry and farms, mechanization has started to appear. Automated machinery, such as graders for small seed and larger oysters, and counters and baggers are starting to take their place in most of the larger businesses. Mechanization reduces the amount of work required and lowers the physical demand, which can become strenuous on the employees.

All of these changes have the potential to substantially change OHS hazards in oyster production.

Hatcheries are associated with different hazards than wild spat collection. The OysterGro® system for controlling biofouling, for instance, requires operators to flip cages 7-10 times during a season and this “requires two to three people and can be very labour intensive.” Jaillet Aquaculture developed an automatic flipper; this will reduce the physical effort but might add new hazards (Gionet 2017, p. 31).

Some experimentation involving multi-trophic aquaculture in Atlantic Canada is occurring (Chopin 2017), including combined cage salmon aquaculture with mussel and kelp raft production. If and how these systems affect OHS hazards has not been studied in Canada. Seaweed production will bring with it new developments in aquaculture product processing as well.

It is especially important to note that careful attention to reducing OHS hazards and preventing injury, illness and fatalities needs to be built into change processes.

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Appendix A OHS Acts and Regulations
As of June, 2018

Federal OHS Acts and Regulations

Canadian Occupational Health and Safety Regulations (SOR/86-304)
http://laws.justice.gc.ca/eng/regulations/SOR-86-304/index.html

Canada's Labour Code
http://laws.justice.gc.ca/eng/acts/L-2/
Canada Labour Code, Part II - Overview (Human Resources and Social Development Canada)

Canada Shipping Act, 2001 (S.C. 2001, c.26)
http://laws-lois.justice.gc.ca/eng/acts/C-10.15/

Transport Canada's Relevant Regulations

- Marine Occupational Safety and Health Regulations (SOR/87-183) (Repealed by SOR/2010-120)
- Maritime Occupational Health and Safety Regulations (SOR/2010-120)
- Policy Committees, Work Place Committees and Health and Safety Representatives Regulations (SOR/2015-164)
- Memorandum of understanding between Human Resources Development Canada and Transport Canada respecting the application and enforcement of the Canada Labour Code, Part II

Provinces and Territories OHS Acts and Regulations

Alberta *(as of June 2018)

OHS Act
http://www.qp.alberta.ca/1266.cfm?page=O02.cfm&leg_type=Acts&isbncln=9780779775699&display=html

OHS Regulations
http://www.qp.alberta.ca/1266.cfm?page=2003_062.cfm&leg_type=Regs&isbncln=9780779776221&display=html

The OHS Code can be found at:

http://work.alberta.ca/documents/WHS-LEG_ohsc_2009.pdf

British Columbia

OHS Regulation
https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation

OHS Policies
https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-policies/policies-part-24

Other OHS regulation
https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/other-ohs-legislation

OHS Guidelines
https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-guidelines

Manitoba *under review 2017

Workplace Safety and Health Act and Regulation
https://www.gov.mb.ca/labour/safety/pdf/1_2016_wsh_ar_oc.pdf

New Brunswick

Workers Compensation Act
http://laws.gnb.ca/en/showfulldoc/cs/W-13//20171211

OHS Act
http://laws.gnb.ca/en/ShowPdf/cs/O-0.2.pdf

Newfoundland and Labrador

OHS Act
http://www.assembly.nl.ca/legislation/sr/statutes/o03.htm

OHS Regulation
http://www.assembly.nl.ca/Legislation/sr/Regulations/rc120005.htm

Nova Scotia

OHS Act
http://nslegislature.ca/legc/statutes/occupational%20health%20and%20safety.pdf

Workplace Health and Safety Regulations
https://novascotia.ca/just/regulations/rxam-z.htm#ohs

Ontario

OHS Act and regulations
https://www.ontario.ca/laws/statute/90o01?_ga=2.117342982.1240785944.1513012261-229439995.1510165641

Workplace safety and Insurance Act
https://www.ontario.ca/laws/statute/97w16?_ga=2.142978869.1240785944.1513012261-229439995.1510165641

Prince Edward Island

OHS Act
https://www.princeedwardisland.ca/sites/default/files/legislation/O-1-01-Occupational%20Health%20And%20Safety%20Act.pdf

OHS Act General Regulations
https://www.princeedwardisland.ca/sites/default/files/legislation/O%261-01G-Occupational%20Health%20and%20Safety%20Act%20General%20Regulations.pdf

PEI aquaculture alliance note on WCB benefits
http://www.wcb.pe.ca/DocumentManagement/Document/pub_peiaquaculturealliance.pdf

Quebec

OHS Act, Industrial Accident and Disease Act,
http://www.csst.qc.ca/en/Pages/en_legislation.aspx

Saskatchewan

Saskatchewan Employment Act
http://www.qp.gov.sk.ca/documents/English/Statutes/Statutes/S15-1.pdf

Not Covered
http://www.saskatchewan.ca/business/employment-standards/employment-standards-in-professions-and-industries/who-is-not-covered-under-sea

Yukon

OHS Act
http://yukonregs.ca/RegsPublic/Home/Details/8137

OHS Regulation
http://yukonregs.ca/RegsPublic/Home/Details/5689

Appendix B Industry trade bodies/companies in Canada As of June, 2018

Industry associations - national

Aquaculture Association of Canada [http://aquacultureassociation.ca/related-organizations/]

Industry associations - provincial

Alberta Aquaculture Association [http://www.affa.ab.ca]

Aquaculture Association of Nova Scotia [http://seafarmers.ca]

Association des Aquiculteurs du Québec [http://www.epaq.qc.ca]

Atlantic Canada Fish Farmers Association [http://www.atlanticfishfarmers.com]

British Columbia Salmon Farmers Association [http://bcsalmonfarmers.ca]

British Columbia Shellfish Growers Association [http://bcsga.ca/%5D

Canadian Aquaculture Industry Alliance [http://www.aquaculture.ca]

Newfoundland Aquaculture Industry Association [http://naia.ca]

PEI Aquaculture Alliance [http://www.aquaculturepei.com]

Canadian producers, suppliers and consultants

Aquaculture Communications Group [http://www.aquacomgroup.com/]

BC Seafood [http://www.bcseafoodonline.com]

Cooke Aquaculture Ltd. [http://www.cookeaqua.com]

Fish Farm Supply Co. [http://www.fishfarmsupply.ca]

HSC Fabrication [http://www.hscfabrication.com]JLH Consulting [http://www.jlhconsulting.tv/]

Select Canadian finfish aquaculture companies

Company	Locations	Type of Finfish
Cermaq	British Columbia	Atlantic Salmon, Chinook, Salmon, Coho Salmon, Sablefish, Rainbow Trout
Cold Ocean Salmon	Newfoundland and Labrador	Atlantic Salmon
Cook Point Fisheries Ltd	Nova Scotia	Atlantic Cod
Cooke Aquaculture	NewBrunswick, Nova Scotia Prince Edward Island, Newfoundland	Atlantic Salmon
Creative Salmon Co. Ltd.	British Columbia	Chinook Salmon
Dartek Transport	Nova Scotia	Atlantic salmon, Rainbow Brook Trout
FinfishAquabounty	Prince Edward Island	Atlantic Salmon
Halibut PEI	Prince Edward Island	Halibut Hatchery
Hollie Wood Oysters	British Columbia	Oysters
Innovative Fishery Products Incorporated	Nova Scotia	Atlantic Salmon, Rainbow Trout, Arctic Char
Golden Eagle Sablefish Inc	British Columbia	Sablefish, Chinook Salmon Pacific Halibut
Grieg Seafood BC Ltd	British Columbia,	Atlantic Salmon, Chinook Salmon, Coho Salmon, Rainbow Trout, Sablefish
Grieg NL SeaFarms	Newfoundland	Atlantic Salmon Hatchery
Kyuquot Seafoods	British Columbia	Sablefish
MacDonald2 Aquaculture & Consultation	Nova Scotia	Striped Bass
Marine Harvest Canada Ltd	British Columbia	Atlantic Salmon, Sablefish, Chinook Salmon, Rainbow Trout, Pacific Halibut, Pilchard, Coho Salmon
Northern Harvest Sea Farms	New Brunswick, Newfoundland, Prince Edward Island (brood stock)	Atlantic Salmon, Steelhead Trout
Northern River Fish Farms	Nova Scotia	Atlantic Salmon, Rainbow Trout, Brook Trout, Arctic Char
Nova Fish Farms (Coldwater Fisheries/Ocean Trout Farms)	Ontario, Newfoundland, Nova Scotia, Prince Edward Island	Steelhead trout, Rainbow trout
Omega Pacific Seafarms Ltd	British Columbia	Atlantic Salmon, Sablefish, Chinook Salmon, Pacific, Halibut, Rainbow Trout, Sockeye Salmon
Totem Sea Farms	British Columbia	Atlantic Salmon, Sablefish

		Chinook Salmon, Coho Salmon, Copper Rockfish, Rainbow Trout, Wolf Eel
Seaward Farms Inc	Newfoundland	Cod ranching
Yellow Island Aquaculture	British Columbia	Chinook Salmon
0917228 B.C. Ltd	British Columbia	Atlantic Salmon
622335 British Columbia Ltd	British Columbia	Atlantic Salmon, Sablefish, Chinook Salmon, Rainbow Trout

Shellfish aquaculture companies

Company	Locations	Type of Shellfish
Atlantic Aqua Farms Partnership	Prince Edward Island	Blue Mussels, Oysters, Clams, Quahogs
Badger Bay Mussel Farms Ltd	Newfoundland and Labrador	Blue Mussels
Eel Lake Oyster Farm	Nova Scotia	Oysters
Evening Cove Oysters Ltd.	British Columbia	Manila Clams, Oysters
Fanny Bay Oysters	British Columbia	Manila Clams, Pacific Oysters, Varnish/Savoury Clams
International Enterprises	Newfoundland and Labrador	Mussels
LBA Enterprises	Newfoundland and Labrador	Mussels
Little Shemogue Oyster Company/Atlantic Oyster Company	New Brunswick	Oysters
Little Wing Oysters Ltd.	British Columbia	Oysters
Mac's Oysters Ltd	British Columbia	Manila Clams, Pacific Oysters, Varnish/Savoury Clams
Maison Beausoleil	New Brunswick	Eastern Oysters
Malpeque	Prince Edward Island	Oysters
Norlantic Processors	Newfoundland and Labrador	Mussels
Oyster Kings	New Brunswick	Oysters
Paradise	British Columbia	Oysters
Pink Moon	Prince Edward Island	Oysters
Raspberry Point Oyster Co.	Prince Edward Island	Oysters
Salish Seafoods	British Columbia	Clams, Oysters
Salutation Cove	Prince Edward Island	Oysters
Savage Harbour	Prince Edward Island	Oysters
Sawmill Bay Shellfish	British Columbia	Mussels, Clams, Oysters
Stellar Bay Shellfish	British Columbia	Oysters
Summerside	Prince Edward Island	Oysters
Sunberry Point	Prince Edward Island	Oysters

Sunrise Fish Farms Inc (Connaigre and Atlantic Pacific Trading and Green Seafoods Ltd)	Newfoundland and Labrador	Mussels