Sustainable Aquaculture Development in Manitoba: Recommendations to Support the Expansion of the Industry

Final Report

Prepared for

Manitoba Agriculture and Fisheries and Oceans Canada

by

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Disclaimer

The analyses, opinions and recommendations contained in this document are those of the author and do not necessarily represent those of Manitoba Agriculture or Fisheries and Oceans Canada.

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Photo of tank layout in a Recirculating Aquaculture System farm courtesy of Ridgeland Aqua-Farms, Anola, MB.

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Finally, the author would like to thank Manitoba Agriculture and Fisheries and Oceans Canada for funding the development of this report.

Executive Summary

This report has been prepared for Manitoba Agriculture and Fisheries and Oceans Canada. It examines issues constraining Manitoba's emerging commercial aquaculture industry and makes recommendations which, if adopted, would promote its responsible growth and development. In doing so, the province would expand and diversify its rural and agricultural economies, enhance food security, and create new opportunities for Indigenous and non-Indigenous communities alike.

According to the FAO, the world's population reached 8.0 billion in 2023, is expected to reach 9.8 billion by 2050 and 11.2 billion by 2100. The demand for animal-based protein is predicted to increase by as much as 70% during this period. Meeting that demand will prove challenging, but aquaculture has the potential to play a central role. Modern fish farming practices are recognized as among the most environmentally efficient forms of large-scale animal protein production on the planet, and they continue to improve.

At the present time, 'seafood' production in Manitoba's aquaculture sector falls far below its inherent potential. However, the province has many competitive advantages, and the sector is well-positioned for significant growth.

The recommendations contained in this report draw from a detailed review of work undertaken in Manitoba and elsewhere in Canada over the past 20 years aimed at facilitating industry growth, from a review of other documents, and from interviews with more than 20 individuals.

The report identifies 16 Recommendations under six Strategic Objectives (summarized below). Each Strategic Objective is important, and timely progress on each recommendation is important to achieving the overall goal of supporting the development of Manitoba's commercial aquaculture sector.

Although it is difficult to prioritize the recommendations, three are particularly important.

- The first is Recommendation 1.1, which would involve the designation of a Government Champion, who would provide the leadership and profile necessary to drive the timely development of a Strategy and Action Plan, both of which are fundamental to achieving tangible progress.
- The second is Recommendation 2.1, which would involve the development of a Provincial Aquaculture Policy that, in turn, would clearly communicate Manitoba's intent to support the development of the sector and to provide a framework under which all related policies, regulations, licenses, permits and procedures would fit.
- The third is Recommendation 3.1, which would involve the establishment of a new Model Aqua-Farm initiative, would give investors much of the knowledge and confidence required to achieve success, and lenders the knowledge and confidence required to provide access to capital.

Strategic Objective 1 – Designate a Government Champion and Develop a Strategy and Action Plan

Recommendation 1.1 – *Manitoba should designate an executive level champion within government, preferably at the ADM level, with a mandate to work across ministries and with other levels of government to oversee the development a strategy and action plan to facilitate the responsible and sustainable growth of the commercial aquaculture sector. The plan should have ambitious timelines,*

clear targets, deliverables and reporting requirements, and a commitment to review progress within three years.

Strategic Objective 2 - Create an Enabling Policy and Regulatory Framework

Recommendation 2.1 – *Manitoba should develop a stand-alone Provincial Aquaculture Policy that articulates the province's support for the sector, its intent to manage growth in a way that ensures the protection of wild fish stocks and associated fisheries, and the effective management of effluents. It should identify the types of culture systems allowed and where, licensing and permitting requirements and the need to conform with other policies, legislation, and regulations.*

Recommendation 2.2 – *Manitoba should review and update its regulatory framework, associated guidelines, and administrative procedures to ensure alignment with the Provincial Aquaculture Policy recommended above, to streamline where feasible, and to provide greater clarity regarding the management of effluents.*

Recommendation 2.3 – *Manitoba should consolidate all relevant information pertinent to the establishment of a new aquaculture enterprise, or the expansion of existing ones, within a transparent, accessible, online document.*

Recommendation 2.4 – *Manitoba should consider a one window approach to the administration of the licensing and permitting process, with clearly identified points of contact. The staff responsible for administering the process should be knowledgeable about the process, should operate under clear service standards and should be committed to helping applicants navigate the process. They should also be able to refer clients to other staff with more technical expertise when required*.

Strategic Objective 3 – *Enable Production Success through Access to Knowledge, Proven Designs, and related Support Services*

Recommendation 3.1 – *Manitoba should invest in a new model aqua-farm initiative similar to that launched in 2008, and that it be established in partnership with an academic institution. The initiative should be aimed at helping farmers diversify their operations and at creating new opportunities for Indigenous communities. A successful model aqua-farm initiative would lead to the establishment of a standardized design for a modular system that would be easily shared, generate positive cash flow, stimulate operator and investor confidence, and by allowing people considering investing in or working at a fish farm to visit one first-hand.*

Recommendation 3.2 – *Manitoba should support persons interested in starting or expanding aquaculture businesses by enabling access to model aqua-farm design details and related investment and operational requirements, to operating and production plans and system performance data, and by facilitating access to professional support services for the development and/or review of business plans and facility designs, and by facilitating access to government marketing expertise and resources.*

Recommendation 3.3 – *Manitoba, in collaboration with the federal government, academic institutions and industry associations, should develop a plan to enhance support for Education, Training, Extension and Research. The new model aqua-farm should be an integral component of any such plan. Among other things, the plan should include information about existing training programs and provide links to important technical documents on its Aquaculture in Manitoba website.*

Recommendation 3.4 – *To the extent feasible, Manitoba should encourage the development of new aquaculture ventures in specific geographic clusters in order to facilitate more efficient access to support services and economies of scale.*

Strategic Objective 4 – Enhance Access to Capital and Risk Management Funding.

Recommendation 4.1 – *Manitoba should take an active role in addressing lender and investor concerns about the risks of land-based aquaculture by addressing misinformation and providing access to objective information to enhance investor and lender confidence.*

Recommendation 4.2 – *To further enhance investor and lender confidence, Manitoba should conduct a market analysis for farmed fish and, once complete, should work with industry to develop a marketing strategy.*

Recommendation 4.3 – *Manitoba should encourage the federal government to recognize land-based aquaculture as agriculture and to ensure its eligibility for federal agriculture funding programs, including loan programs, grants, seed funding, funding to support the adoption of green technology, and crop insurance/risk management programs.*

Recommendation 4.4 - *Manitoba should consider enhancing provincial financial support to the aquaculture sector by ensuring access to existing provincial programs and by considering the development of a new, dedicated funding program, similar to one recently announced for the province's commercial fisheries sector.*

Recommendation 4.5 – *Manitoba should develop an online document that provides easy access to up-to-date information on all potential funding sources***.**

Strategic Objective 5 – Facilitate Timely Access to Power

Recommendation 5.1 – *The province should work with Manitoba Hydro to explore options to ensure that critical electrical upgrades to new or expanding aquaculture operations are implemented in a timely manner.*

Strategic Objective 6 – Enhance Confidence and Social License Through Effective Communications

Recommendation 6.1 – *Manitoba should support the development of a communications strategy and action plan that identifies goals and objectives, audiences, products, and timelines for development. Consider hosting products on a single, comprehensive, and easy-to-navigate, Aquaculture in Manitoba website. Products should be aimed addressing misinformation, improving investor and lender confidence, improving consumer awareness of the sustainability and nutritional benefits of farmed fish, facilitating one-stop access to relevant policy, regulatory, and licensing requirements, and to technical information of interest to aquaculture practitioners or investors.*

Introduction

This report has been prepared for Manitoba Agriculture and Fisheries and Oceans Canada. It examines issues constraining Manitoba's emerging commercial aquaculture industry and makes recommendations which, if implemented, will promote its responsible growth and development. In doing so, the province would expand and diversify its rural and agricultural economies including support sectors, enhance food security, and create new opportunities for Indigenous and non-Indigenous communities alike.

The Case for Aquaculture

The world's population reached 8.0 billion in 2023, is expected to reach 9.8 billion by 2050, and 11.2 billion by 2100 (United Nations 2017, 2023). World food production, particularly protein production, will have to grow dramatically to meet this growth. Aquaculture can play a significant role, a role that was recognized in 1999 by Nobel laureate and economist, Peter Drucker, who said, "*Aquaculture, not the Internet, represents the most promising investment opportunity of the 21st Century*." (Seafood Source, 2012).

Aquaculture is the culture of fish and other aquatic and marine species, including both plants and animals. It is the fastest-growing form of food production in the world (FAO 2022) and has enormous potential to help feed the world.

Globally, per capita consumption of seafood has more than doubled over the past 60 years (FAO 2022). Seafood consumption presently accounts for around 17% of the world's protein intake, and up to 50% in parts of Asia and Africa (FAO 2022). It is expected to grow by 14% from 158 million MT in 2020 to 180 million MT by 2030 (FAO 2022) and to double (relative to 2015 levels) by 2050 (Naylor et al. 2021).

> *Since 1961, the annual global growth in fish consumption has been twice as high as population growth, demonstrating that the fisheries and aquaculture sector is crucial to meeting FAO's goal of a world without hunger and malnutrition.*
>
> *Jose Graziano da Silva, FAO Director-General*

The ability of capture fisheries to meet this demand is, at best, limited. Other than recent modest increases in harvest from some inland fisheries, global capture harvest has remained steady at about 90 million MT since the early 1990s (Figure 1), and an estimated 90% of world fisheries are already being fished at or over their sustainable capacity (Figure 2) (FAO 2020).

During that same period, aquaculture production has increased from approximately 10 million MT in 1990 to more than 90 million MT in 2021 (FAO 2022) (Figure 1). In 2013, for the first time, aquaculture production overtook capture fisheries as the primary source of aquatic production (FAO 2022).

Looking ahead, even if governments around the world improve the management of presently over-fished capture fisheries – which the FAO has estimated could increase total marine capture production by 16.5 million MT (FAO 2022) – meeting the bulk of the growing global demand can only be achieved with aquaculture. Cousteau had it right.

> *We must plant the sea and herd its animals using the sea as farmers instead of hunters. That is what civilization is all about – farming replacing hunting.*
>
> *Jaques-Yves Cousteau, Oceanographer, 1971*

Figure 1. World capture fisheries and aquaculture production, 1950-2020. (FAO, 2022).

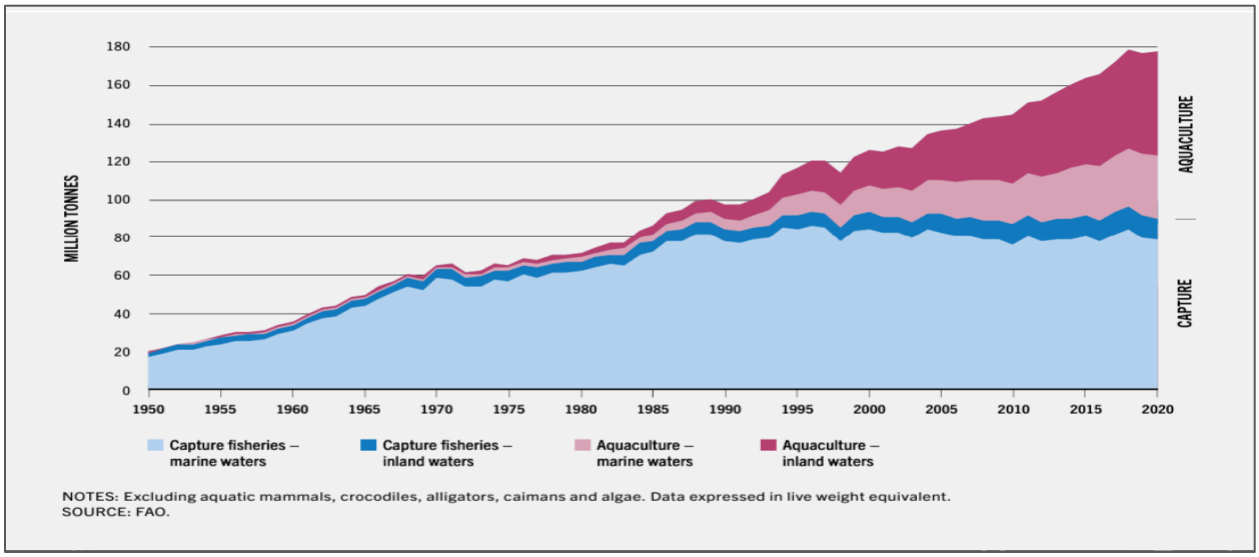
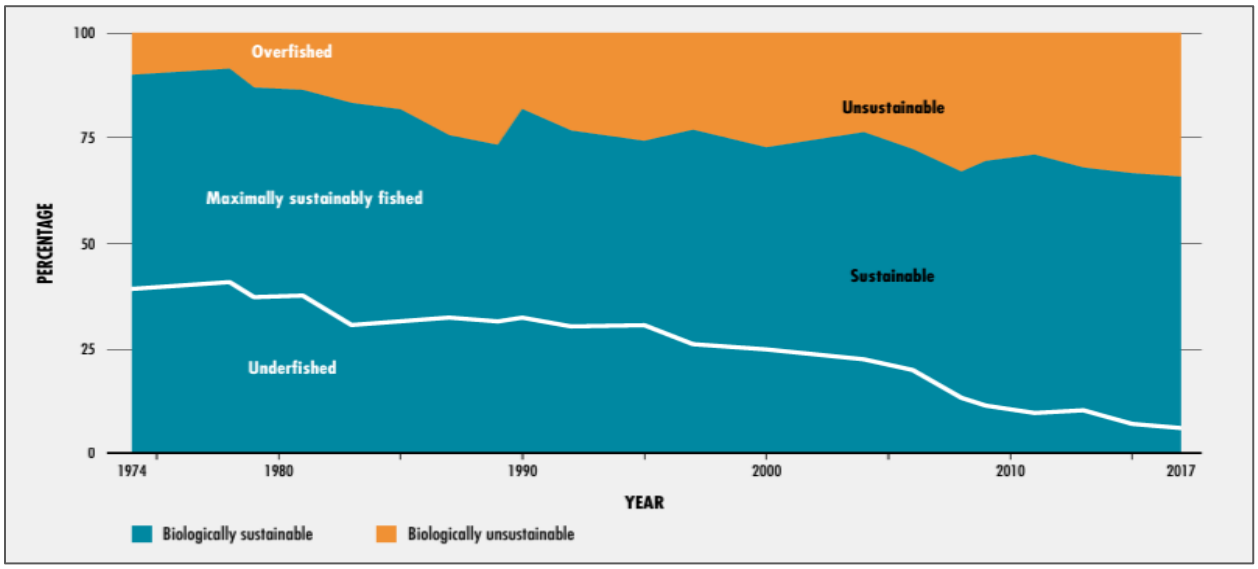


Figure 2. Global trends in the state of world's marine fish stocks, 1974-2017. (FAO, 2020).



Objective and Background

Government agencies, private sector investors, existing aquaculture business owners, aquaculture associations, Indigenous communities and academic institutions believe that there is an opportunity to expand commercial aquaculture in Manitoba.

This report examines the issues affecting aquaculture development in the province and proposes recommendations to support its sustainable expansion. It draws upon work undertaken in Manitoba over the past 15 years to develop and adapt aquaculture technologies and resources to support the

development of the industry. It also draws upon work undertaken in other jurisdictions across Canada and upon the experiences and opinions of interested collaborators and stakeholders.

Aquaculture production in Manitoba remains far below the province's inherent potential. Despite that, the sector is well-positioned to benefit from several competitive advantages, the most significant being:

- A resource base that includes excellent groundwater reserves, an extensive network of natural and man-made water bodies, and terrain that is readily amenable to construction.
- A desire to advance sustainable development.
- Considerable export potential to western Canada and to the U.S. market, which is one of the fastest growing seafood markets in the world.
- Increasing global demand for fish and seafood due to population growth, increased affluence, and the recognized health benefits of aquaculture products.
- A well-developed agricultural community with significant diversification potential, including latent infrastructure (such as vacant farm buildings) to support development.

Other competitive advantages include:

- Relatively low-cost, low carbon electricity.
- Existing fish processing capability with expansion potential.
- A government committed to advancing protein (including fish) production and a high-level strategy to support it.
- Academic institutions with strong agricultural programs, an emerging interest in aquaculture, and the potential to support related research, development, training, and extension.
- A population that is used to farming and a labour force that is experienced in animal husbandry.
- Relatively low-cost land.
- Access to major transportation hubs.
- An abundance of farmland, some of which can be responsibly used for the disposal of aquaculture waste.
- A well-established agricultural economy that produces a variety of crops, some of which are or can be used in fish feeds.
- A favourable currency exchange rate with the U.S., its primary export market.

Methodology

The preparation of this report began with a Project Team meeting where the scope of the project was confirmed, and where contacts and additional sources of information were identified.

Subsequent steps involved the collection and review of key documents (many of which described work undertaken in Manitoba over the past 15 years to support the industry), a review of government websites, interviews or discussions with key contacts, and the formulation of recommendations.

In total, more than 40 documents were reviewed, and 28 individuals were contacted. Ten of the documents reviewed were of sufficient relevance that their key findings have been summarized in this report. Other documents have been cited where appropriate.

The Benefits of Aquaculture

According to the National Oceanic and Atmospheric Administration (2020), responsible aquaculture fits the 17 Sustainable Development Goals established by the United Nations (2015). Aquaculture can sustainably and responsibly improve food security and nutrition by increasing food production, boosting economic growth in coastal and rural areas, and supporting cultural development. Some forms of culture can even help keep some waterways clean (The Nature Conservancy and Encourage Capital, 2019).

Historically, growth in aquaculture production in some parts of the world occurred at the expense of the environment (FAO, 2022), and this led some to portray the industry as unsustainable and its products as unsafe. Today's practices are more efficient and sustainable than those of the past, and governments and industry worldwide are committed to further improvements (FAO, 2022; Global Salmon Initiative, undated; Canadian Aquaculture Industry Association and the Fisheries Council of Canada, undated). Globally, the sector is making ever-increasing contributions to social and economic development and to food security.

Social and Economic Development

As a non-extractive, renewable sector, aquaculture has the potential to provide considerable benefits to jurisdictions that support its growth. Aquaculture is widely recognized as a critical development tool in many parts of the world, most notably in developing countries (FAO, 2022). By capitalizing on the opportunity that it provides, countries can create jobs, help meet the global demand for food, and achieve their own food security aspirations (World Bank, 2013). Aquaculture also offers significant potential in developed countries such as Canada. According to a report on the potential of aquaculture as agricultural diversification strategy in Canada, Stechey and Gilbert (2004) found that:

> *The sector offers significant potential for strategic job creation, particularly in rural and coastal communities, and it can provide processors with a dependable, year-round supply of products…*
>
> *Aquaculture also offers economic development opportunities to First Nations' peoples…*

Canada's Standing Committee on Fisheries and Oceans, in its review of closed containment aquaculture, also recognized the potential for closed containment aquaculture to support economic development in rural, coastal and Indigenous communities Canada-wide (Weston, 2013).

Nutritional Benefits and Safety

Salmon and trout, both farmed and wild, are widely recognized as providing many health benefits, and both the U.S. Department of Agriculture (2015) and Health Canada (2019) recommend seafood as an important part of a healthy diet. According to the Global Salmon Initiative (undated):

> *Salmon is an excellent source of protein including all 9 essential amino acids, healthy fats including omega-3 fatty acids, and several essential vitamins and minerals, making it an important component of healthy and sustainable diets.*
>
> *The average 3.5 oz. (100 g) portion of farmed salmon contains 41% of the recommended daily intake of protein and at least 20% of the recommended daily intake of vitamins B3, B5, B6, B12, vitamin D, vitamin E and selenium. It is also a good source of potassium.*

That same-sized portion contains ~2g of two essential omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). EPA and DHA are unique to seafood and the best dietary sources are found in oily fish. These two omega-3s are important for human health and are associated with multiple improved health outcomes, especially when consumed from fish.

Although there are small differences in the nutrient composition between farmed and wild salmon of the same species (Table 1), the differences between farmed and wild Atlantic salmon are smaller than those between different salmon and trout species (Aquaculture North America, Salmon Farming Inside and Out, March 8, 2024).

Table 1. Nutritional comparison of 3.5-ounce (100 gm) servings of wild vs farmed Atlantic salmon. The nutrient profiles of other salmon and trout species are similar. Source: U.S. Dept. of Agriculture (undated).

	Wild salmon	Farmed salmon
Calories	182	206
Protein	25 grams	22 grams
Fat	8 grams	12 grams
Vitamin B12	127% of the Daily Value (DV)	117% of the DV
Vitamin B6	56% of the DV	38% of the DV
Selenium	85% of the DV	75% of the DV
Niacin	63% of the DV	50% of the DV
Pantothenic acid	38% of the DV	30% of the DV
Thiamine	23% of the DV	28% of the DV
Phosphorus	21% of the DV	20% of the DV

Note: The USDA found higher levels of omega 3 fatty acids in farmed Coho Salmon than in wild Coho Salmon. It is likely a similar pattern would be found with other species of salmon and trout. Source: Global Salmon Initiative.

Despite its widely recognized nutritional benefits, farmed salmon are sometimes incorrectly portrayed as high in contaminants and antibiotics, leading to concern amongst some members of the public. Recent efforts to provide up-to-date science-based information are helping to reduce confusion and concern. A recent podcast by Dr. Stephanie Colombo entitled '*Debunking Nutritional Myths of Farmed Salmon*' is a good example (Aquaculture North America, Salmon Farming Inside and Out, March 8, 2024).

Contaminants – While a few early studies reported higher levels of contaminants in farmed salmon than in wild salmon, more recent studies have not confirmed this. The current consensus among scientists and regulators is that both farmed and wild salmon are safe to consume (Washington State Department of Health, undated), a conclusion shared by Dewailly et al. (2007) in their examination of contaminants in wild and farmed salmon and trout available for sale in Canada.

Antibiotic Use – Globally, the use of antibiotics in salmon and trout farming is declining. While there is still occasional use in some net-pen operations and land-based flow-through operations, they cannot be

used in land-based Recirculating Aquaculture Systems (RAS) as their use would destroy the bio-filters required to maintain system water quality. This is one reason that the David Suzuki Foundation (undated) considers closed-containment aquaculture a responsible alternative to open water net pen culture.

Environmental Footprint and Efficiency of Production

In its 2021 Sustainability Report, the Global Salmon Initiative compared the sustainability of farmed fish production (using Atlantic Salmon as its reference species) to other commonly farmed animals using six metrics. Notably, farmed salmon had the best performance in four of six metrics, and second best in the remaining two (Table 2). See Global Salmon Initiative (2021) for source data and analytical details.

Table 2. Efficiency of salmon production relative to chicken, pork, beef and lamb production, as measured by six different variables. See source for lists of assumptions and data sources. Source: Global Salmon Initiative *https://globalsalmoninitiative.org/en/sustainability-report/sustainable-food-systems*.

Criterion	Description	Salmon	Chicken	Pork	Beef	Lamb
Lowest carbon footprint*	Kg CO_2 equivalent per typical 40 gm serving of edible protein product.	0.6*	0.88	1.3	5.92	No Data
Most efficient land use	The amount of land needed in m^2, including for feed production, to produce 100 gm of edible protein	3.7	7.1	11	102	185
Best (FCR) Feed Conversion Efficiency	Amount of feed required in kg to increase animal's weight by 1.0 kg	1.1-1.5	1.7-2.0	2.7-5.0	6.0-10.0	4.0-6.0
Highest Edible Yield	Weight of edible meat divided by total body weight x 100	68%	46%	52%	41%	38%
High Protein Retention	Weight of edible protein divided by weight of protein in feed X 100	31%	34%	18%	15%	No Data
High Calorie Retention	Gain in edible calories divided by calories in feed X 100	25%	27%	16%	7%	No Data

*Author's note: The estimated carbon footprint for farmed salmon is based on the production of early life stages in land-based Recirculating Aquaculture Systems (RAS) and final grow-out in ocean net pens. This approach under-estimates the carbon footprint for salmon (or trout) raised from start to finish in land-based RAS. Land-based RAS offers other efficiencies including very efficient temperature control and proximity to markets.

The Global Salmon Initiative's assessment of the sustainability of salmon farming is not unique. According to the Canadian Aquaculture Industry Alliance, on November 7, 2023, the independent Coller FAIRR Protein Producer Index[1] (FAIRR Initiative 2023) stated that:

[1] The Coller FAIRR Index is the world's only comprehensive assessment of publicly traded animal protein producers on environmental, social and governance issues. Seven of the top ten companies are salmon farming companies, and the top and third positions are held by Mowi and Grieg Seafood, both of which have operations on both coasts of Canada. Canada's two other major salmon producers, Cermaq and Cooke Aquaculture, are privately held companies and not included in this Index but are recognized in other leading sustainability indices.

> *"Farmed-raised salmon producers are global sustainable food leaders. By all indicators, salmon farming was the most environmentally efficient form of large-scale animal production on the planet: lowest freshwater use, lowest carbon emissions, smallest environmental footprint".*

While modern salmonid (salmon and trout) aquaculture practices are widely recognized as sustainable and environmentally responsible by industry experts and fish production certification programs such the Aquaculture Stewardship Council, there are opportunities for improvement. When realized, these improvements will further increase sustainability, consumer confidence and social license. Examples of positive changes over the past few decades include significant reductions in the amount of fish meal and fish oil in commercial fish feeds and in the use of antibiotics, enhanced biosecurity, improved feed conversion efficiencies, increased energy efficiency, and improvements in effluent treatment.

Production Systems Potentially Applicable to Manitoba

There are two general types of aquaculture production systems, land-based and open water (net pen or cage culture) systems. Both have the potential for application in Manitoba.

Land-based systems offer the potential of greater control of rearing conditions and environmental impacts than open net pen systems. Early land-based systems were often connected directly to natural water bodies. Modern land-based systems are better isolated from natural water bodies, but still generate effluents that must be managed and can have impacts.

Open water systems involve the placement of rearing units (net pens or cages) directly into open water bodies, either freshwater or marine. These systems offer only limited control of rearing conditions and environmental impacts. However, if suitable locations are available, they can be economically attractive and generate relatively limited environmental impacts.

Pond Systems

The origins of pond culture date back at least 1000 years when species like carp were grown in Asia.

In North America, Rainbow Trout has been cultured for conservation purposes since the late 1800s. Commercial culture of the species began in the 1950s, with ponds being the primary culture system. Ponds were typically manmade, with water being fed from wells, springs, or surface sources. Historically, rearing densities were kept low because higher densities led to unacceptable water quality problems.

Pond design and technology has evolved considerably over the decades, and they are still used extensively today in some areas for the commercial culture some species (e.g., catfish in the U.S.). Present day use in salmonid culture in Canada is generally limited to hobby farms and smaller commercial operations offering pay-to-fish services.

Raceway Systems

The use of raceways for salmonid culture became common in the 1960s. Raceways are long, rectangular tanks, and can be made of a variety of materials. Water is introduced at one end and exits at the other with no recirculation or mixing. Their main advantages over ponds include greater ease of fish handling, the ability to achieve higher densities, and better control over water quality and effluents. Their main disadvantage is that water quality declines from the inflow end to the outflow end often resulting in uneven distribution of fish and ineffective use of rearing space. In addition, water velocities tend to be

very low, leading to the settling of solids throughout the unit and the need for additional cleaning effort. Raceway technology has evolved considerably over the years.

To address some of the disadvantages of conventional raceways, Burrows and Chenoweth (1970) developed the Burrows tank (or raceway) in the 1960s. At its simplest, a Burrows tank is a raceway modified to include a partial divider down the centre, or two or more parallel raceways sharing common dividing walls. In either case, the dividing walls stop short of both ends allowing the water to circulate around the divider(s), providing some of the benefits inherent in circular tanks described below. The design of Burrows tanks has evolved considerably since they were first developed. A modified version of a Burrows tank was used as the principal fish rearing unit in the Manitoba-Canadian Model Aqua-Farm.

Circular Tank Technologies

Circular tanks have been used in salmonid culture for decades. Modern circular tank designs offer several benefits relative to raceways including more uniform water quality, the ability to operate over a range of rotational velocities, and greater ease of cleaning (some designs can be virtually self-cleaning). While circular tanks (and other designs that induce circulating flows, including Burrows tanks) are generally considered better for fish than traditional raceways, fish handling can require more labour.

Open Water Net Pen/Cage Culture Technologies

This technology involves floating or suspending net pens or cages in freshwater or marine environments where suitable rearing conditions exist. Most of the global production of farmed Atlantic involves final grow-out in marine net pens. Similarly, virtually all the world's leading producers of Rainbow and Steelhead Trout (including Canada's) utilize either freshwater or marine net pens for final grow-out. While the capital and operating costs of such systems can be lower than modern land-based systems, their use is under scrutiny, putting pressure on producers to find ways to reduce associated negative impacts and to further explore land-based alternatives.

Recirculating Aquaculture Systems- RAS

RAS is a form of closed containment, land-based aquaculture that seeks to isolate the rearing environment from the natural environment to reduce or eliminate interactions between the two. RAS technology has existed since at least the early 1980s and has evolved considerably since then. While ongoing research can be expected to lead to further gains in efficiency and performance over time, future gains are likely to result from the combined effects of a few small improvements rather than from significant new technological breakthroughs (Stechey, pers. comm.). RAS technology can be used in both raceways and circular tanks.

In conventional land-based systems, water is generally used once prior to existing the system. With RAS technology, water is re-used many times and reconditioned with each pass using mechanical and biological filtration processes to remove waste feed and metabolic wastes (faeces, ammonia, carbon dioxide, etc.), and to add oxygen. Modern RAS can have reuse rates exceeding 99%, meaning that it is possible to raise fish on less than 1% of the water of traditional flow-through systems. The advantages and disadvantages of RAS are shown in Table 3.

Table 3. Advantages and disadvantages of RAS. Modified from Stechey and Gilbert (2004). Modifications and additions are italicized.

Advantages	Disadvantages
Greatly reduced water use	Higher capital costs
Year-round production potential	Higher operational expenses
Cost-effective control of temperature	Increased operational complexity
Very high yields per litre of water	Lack of standardized system
Increased operational control	Inconsistent performance / track record
Ability to make use of existing buildings	Weak investor / lender confidence
Numerous equipment suppliers	*Requires highly trained staff*
Products can be marketed as sustainable	*Mistakes can be costly*

Even though RAS technology has been employed successfully for decades, weak investor and lender confidence remain almost as significant an issue today as in 2004 when the above report was prepared. This is due to the number of failures that receive media cover, most of which can be attributed to inadequate business knowledge, flawed designs, or inadequate operator training (Stechey, pers. comm.).

Production Trends in Salmonid Aquaculture

Global Trends – Atlantic Salmon

Atlantic Salmon farming started on an experimental level in the 1960s, but became an industry in Norway in the 1980s, and in Chile, Canada, and Scotland in the 1990s. The industry has grown substantially in the past 40 years, and today approximately 70% of salmon produced worldwide is farmed with the biggest producers being Norway, Chile and the U.K. (Global Salmon Initiative, undated) (Figure 3). Atlantic salmon makes up most farmed salmonid production, followed by Rainbow Trout and Coho Salmon (Figure 4, FAO 2023). Since 2000, total farmed salmon production has increased from 1.2 million MT to over 3 million MT (Rosenstein and Drost, 2023). Despite this growth, total farmed salmonid production today is less than 1.5% of the combined production of common livestock species.

Figure 3. Global Atlantic Salmon farmed production by country, 2000–2020. (FAO, 2023).

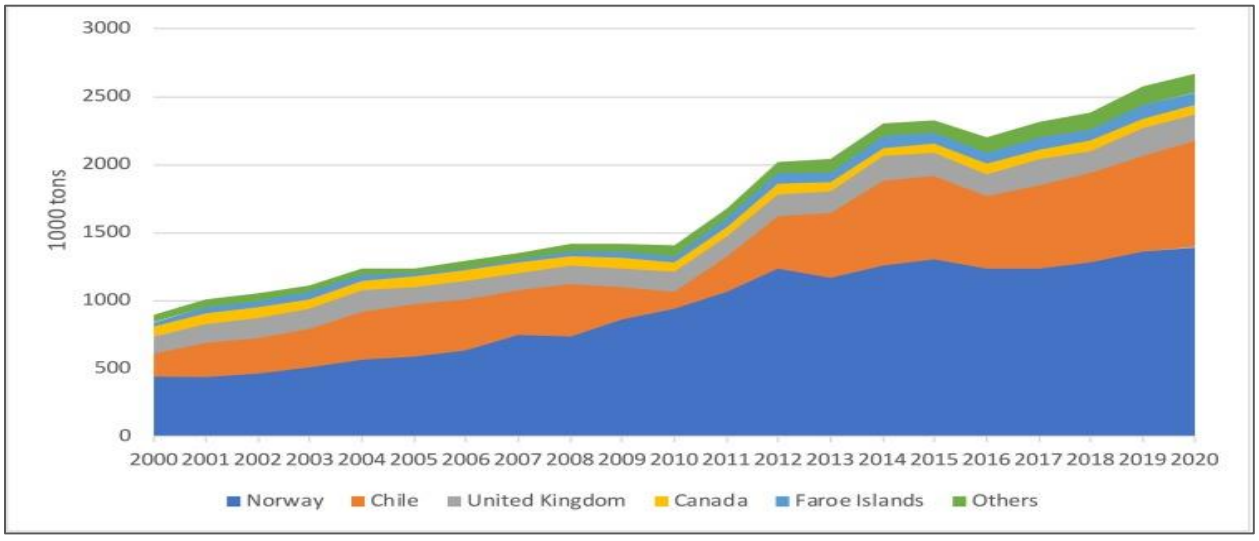
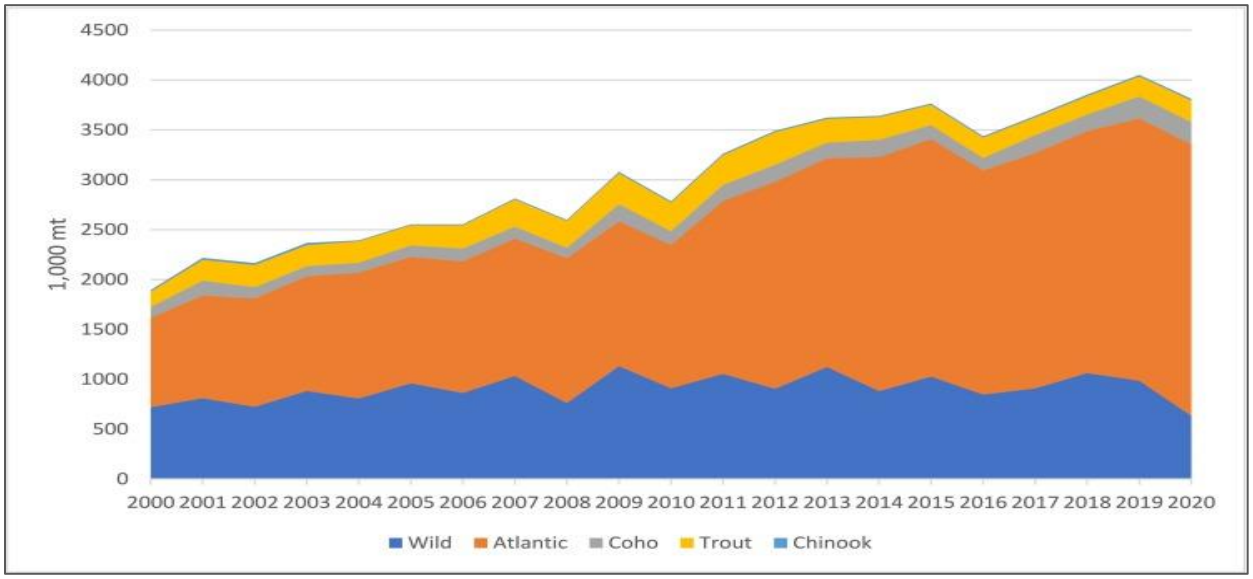


Figure 4. Global farmed salmonid production vs wild capture production by species, 2000–2020. (FAO 2023).



Global Trends – Rainbow Trout

Commercial farming of Rainbow Trout first began in the 1950s. Since then, global production has increased from about 4,400 MT to approximately 850,000 MT in 2018 (Seafish, undated). Most of this production is presently from freshwater systems (77%), primarily from net pens located in freshwater, and the balance of the production (23%) coming from net-pens located in marine and brackish waters (Figure 5). Rainbow Trout production by country is shown in Table 4.

Figure 5. Global Rainbow Trout Production – Locations and Volumes, 1960-2016. (Seafish, undated).

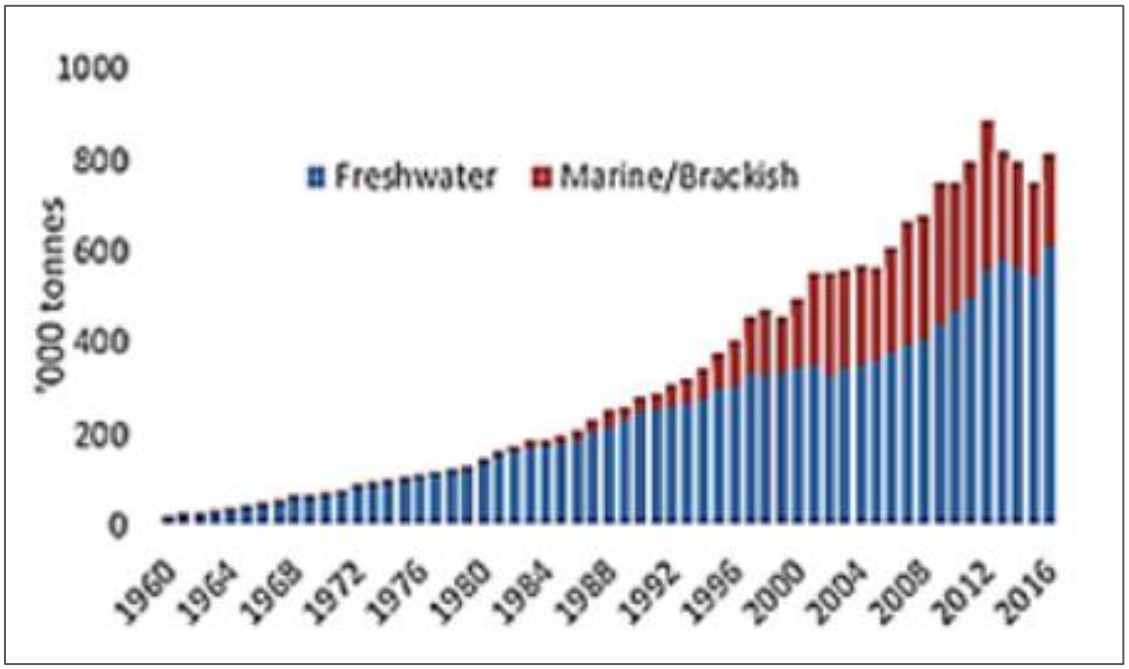


Table 4. Global Rainbow Trout production by country and culture system, 2018. (Seafish, undated).

Largest 10 Freshwater Producers (2018)		Largest Marine/Brackish Producers (2018)	
Country	**Volume (MT)**	**Country**	**Volume (MT)**
Iran	173,384	Chili	78,255
Turkey	103,192	Norway	68,216
Peru	55,030	Finland	11,119
China	38,606	Denmark	9,737
Russian	35,204	Turkey	9,235
Italy	32,825	Iran	6,300
France	26,100	U.K.	3,500
Columbia	23,038	Sweden	2,870
U.S.A.	22,370	Note: Freshwater production may include both land-based and net pen culture operations.	
Denmark	20,000		

Canadian Trends – All Salmonids

From 2107 to 2021, total reported aquaculture production of finfish in Canada averaged about 130,000 MT/year. More than 80% of this was from net-pen reared Atlantic Salmon operations on the east and west coasts. Rainbow and/or Steelhead Trout production amounted to less than 8% of the total.

Canadian Trends – Rainbow/Steelhead Trout

[2]Between 1997 and 2021, reported farmed production of Rainbow Trout in Canada ranged from about 4,400 MT in the mid-2000s to just over 10,500 MT in 2020 (Table 5). Based on size at harvest, some of this production could have been reported Steelhead Trout.

During this same period, reported farmed production of Steelhead Trout ranged from 0 MT in several years to a high of 6002 MT in 1999 (Canada.ca database). However, this estimate is unreliable as information from provinces with only one producer is not captured in the database. Total production in recent years likely approaches 2000-3000 MT/year, with Saskatchewan accounting for roughly 1000 MT/year (D. Foss, pers. comm.), Nova Scotia and Newfoundland accounting for close to 1000 MT/year (Rosenstein and Drost, 2023), and B.C. producing ~750 MT/year as recently as seven years ago.

Manitoba's production has never reached 1% of the Canada-wide total during this period.

During most of this period, Ontario accounted for more than 60% of Canada's total Rainbow Trout production, the majority of which was produced in net pen operations in Great Lake waters (Figure 6) and which, based upon harvest size, could be characterized as Steelhead Trout. Other jurisdictions that

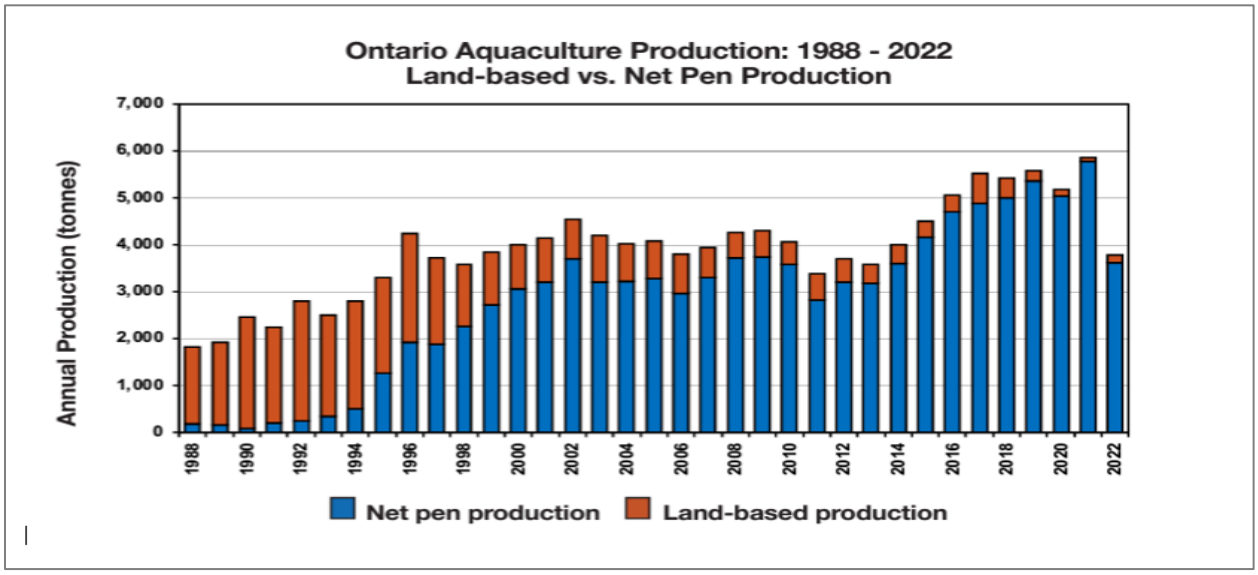
[2] Rainbow Trout and Steelhead Trout are the same species. Not all production of either form is reported in all years. Considering both forms, it is likely that combined production is underestimated by at least 2000 MT.

allow net pen culture include New Brunswick (Zone 1 – Bay of Fundy Drainage, triploids only), Newfoundland (Bay d'Espoir region); Nova Scotia (Bras d'Or Lakes area), Saskatchewan (Lake Diefenbaker) and British Columbia (both marine and freshwater).

Table 5. Canadian Farmed Rainbow Trout Production, 1997-2021. Numbers are MT of whole fish produced on-site and exclude hatcheries and processing. Numbers do not include the weight of fish identified as Steelhead Trout, whether produced in fresh or salt water. "ND" denotes no data provided. "X" denotes data suppressed for confidentiality purposes. Source: Canada.ca, *https://www.dfo-mpo.gc.ca/stats/aqua/aqua21-eng.htm*.

	NL	PE	NS	NB	QC	ON	MB	SK	AB	BC	Total
1997	14	x	33	550	667	3725	5	721	3	212	5930
1998	48	x	0	550	895	3580	14	875	x	60	6022
1999	10	x	0	550	1185	3850	4	875	x	100	6572
2000	0	x	0	550	982	4000	7	875	x	100	6514
2001	0	x	0	550	723	4135	16	989	x	100	6513
2002	0	x	0	550	603	4650	16	914	x	100	6833
2003	0	x	0	550	357	4200	10	x	x	136	5253
2004	0	x	0	400	333	4000	10	x	x	115	4858
2005	0	x	0	300	300	4075	11	x	x	171	4857
2006	0	x	0	x	ND	3800	x	x	x	274	4374
2007	0	x	118	300	ND	4100	21	x	x	505	5044
2008	ND	ND	x	500	379	4335	x	x	x	635	7932
2009	ND	ND	133	150	380	4375	x	x	x	523	7198
2010	ND	ND	91	150	337	4060	x	x	x	600	6844
2011	ND	ND	124	80	357	3385	x	x	x	64	5600
2012	ND	ND	113	142	420	3700	x	x	x	88	6077
2013	ND	ND	104	0	1262	3580	x	x	x	62	6695
2014	ND	ND	ND	ND	1143	4000	x	x	x	44	6698
2015	ND	ND	114	ND	953	4510	x	x	x	0	7062
2016	ND	ND	300	ND	1083	5060	x	x	x	1136	9507
2017	ND	ND	467	0	547	5530	x	x	x	33	8512
2018	ND	ND	343	0	481	5416	x	x	x	1190	8810
2019	ND	ND	840	0	435	5574	x	x	x	900	8801
2020	ND	ND	1991	0	359	5583	x	x	x	1154	10553
2021	ND	ND	376	0	463	5873	x	x	x	1177	9366

Figure 6. Rainbow Trout Production in Ontario by Production System. 1988-2022. (Canada.ca, undated).



Salmonid Culture History in Manitoba

The Early Years

The following history of aquaculture development in Manitoba is derived from '*A Guide to Intensive Aquaculture in Manitoba'* (Manitoba Water Stewardship, 2004).

Fish farming has been practiced in Manitoba since the late 1960s, beginning with experimental efforts in pothole lakes in the southwestern part of the province. Rainbow Trout quickly became the preferred species because of its hardiness and growth rate.

In the mid-1980s, AgPro Farms of Winnipeg established a grow-out operation that produced both Rainbow Trout and Arctic Char, and the Department of Fisheries and Ocean's Freshwater Institute began experimenting with Arctic Char. By the early 1990s, four private hatcheries were producing Rainbow trout in the 2-4 lb range for human consumption and were selling fingerlings and fertilized eggs primarily to unlicensed hobby farmers for stocking into private ponds.

Between 1999 and 2002, Rainbow Trout fingerling sales ranged from 172,000 to 196,000. During that same period, grow-out sales of Rainbow Trout increased from 4,260 kg (~4 MT) to 16,050 kg (~16 MT), and Arctic Char from 3,962 kg (~4 MT) to 47,000 kg (~47 MT).

By the early 2000s, a few "U-catch-em" businesses were in operation which provided fee-for-fishing opportunities in privately stocked ponds.

Present Day

At present, Manitoba has a very small commercial aquaculture sector with only one significant producer, Ridgeland Farms, which is currently transitioning its production from Arctic Char to Rainbow/Steelhead Trout (N. and P. Waldner, pers. comm.). The other significant producer, Watersong Farms, former home of the Manitoba – Canadian Model Aqua-Farm Initiative, which produced upwards of 100 MT of Rainbow/Steelhead Trout per year in its last few years of operation, discontinued operations in 2022 (R. Reimer, pers. comm.). Recent production and sales statistics are shown in Table 6.

A new 5,000 MT Arctic Char facility being developed by Sapphire Springs Inc. is presently under construction and is expected to be complete by summer 2025 and reach full production by late 2026 (C. LaFlèche, pers. comm.). This level of production, if achieved, would represent a 50% increase in the global production of farmed Arctic Char, presently estimated at 10,000 MT/year (LaFlèche, pers. comm.).

Candidate Species for Culture in Manitoba

Rainbow/Steelhead Trout and Arctic Char have both been farmed successfully in Manitoba for decades and culture practices are well-established. With proper facility design and husbandry practices, both species should be able to support profitable enterprises and significant growth.

However, there are other species that could be considered for culture. Modern RAS technology makes the culture of many other species entirely feasible from a technical perspective. For example, culture practices for Tilapia, hybrid Striped Bass, Channel Catfish and Barramundi are well-established, and the species have been grown successfully in RAS operations for several decades. Whether or not they could be grown profitably in Manitoba would depend on production costs, access to eggs or fingerlings, access

to markets, and the ability to provide a competitively priced product. Another species, Pacific White Shrimp, was being grown successfully in Ontario until recently; however, operations were discontinued when the CFIA restricted the import of larvae life stages from the U.S. due to a disease outbreak.

Table 6. Manitoba Aquaculture Statistics, 2020-2022 (Source: J. Eastman, Manitoba Agriculture**).**

		2020	2021	2022
No. of Eggs Imported	Rainbow Trout	0	10,000	50,000
	Arctic Char	170,000	150,000	1,050,000
	Brook Trout	0	0	0
	Other	0	5,000	0
No. of Fingerlings Imported	Rainbow Trout	46,890	0	100
	Arctic Char	0	0	0
	Brook Trout	0	0	0
	Other	0	0	0
No. of Eggs/Fry Purchased in Manitoba	Rainbow Trout	0	0	0
	Arctic Char	0	0	0
	Brook Trout	0	0	0
	Other	0	0	0
No. of Fingerlings Purchased in Manitoba	Rainbow Trout	0	400	0
	Arctic Char	208,000	0	0
	Brook Trout	0	0	0
	Other	0	0	0
No. of Fingerlings Sold	Rainbow Trout	0	0	0
	Arctic Char	31,000	0	0
	Brook Trout	0	0	0
	Other	0	0	0
No. of Kgs of Fish Sold	Rainbow Trout (Dressed viscera removed)	32,769	0	0
	Rainbow Trout (Fillets)	0	442	1,588
	Arctic Char (Round whole fish)	0	52,000	23,587
	Arctic Char (Dressed viscera removed)	0	0	907
	Arctic Char (Fillets)	20,000	0	22680
	Brook Trout		52,000	-
	Other	0		0
No. of Fingerling Clients		113	0	0

Culture practices for at least two other species are sufficiently well developed that they could be confidently grown to market size in RAS. These include Lake Whitefish (Chiasson, pers. comm., Drew, pers. comm., and Loftus, 2023), and Walleye (Aneshansley, pers. comm., Fischer, pers. comm., Johnson, pers. comm., and Kelsey, pers. comm.). Despite the feasibility of culture, it is not yet clear if either species can be grown to market size profitably. Key information fundamental to assessing growth rates and production costs is not yet available. Furthermore, broodstock development for both species has only recently begun, and reliable techniques to enable spawning at multiple times of year have not yet been developed. Until this is resolved, commercial production will not be feasible.

Key Document Review

This section highlights findings from a number of documents that are of particular relevance to the purpose of this report, including the proceedings of conferences or workshops aimed at identifying impediments to the growth of the industry, existing government policy and aquaculture growth

strategies, a market study, a report on the potential of aquaculture as an agricultural diversification strategy, a report on the state of closed-containment aquaculture technologies, and a report on Manitoba's experience with the Model Aqua-Farm initiative.

A. Spawning Aquaculture: Facilitator's Report on the Nov 23, 2005, Stakeholder Conference. Manitoba Rural Adaptation Council and Manitoba Agriculture, Food and Rural Initiatives.

Overview – This report describes the proceedings and recommendations from a meeting held at the Radisson Hotel in Winnipeg in November 2005, attended by approximately 40 people representing Manitoba's aquaculture sector. The purpose of the meeting was "*to begin assessing Manitoba's current opportunities and challenges for aquaculture as a potential diversification opportunity, conduct an initial assessment of the specific infrastructure requirements to enhance the sector, and discuss an action plan to move the agenda forward*".

Key Recommendations

1. That a producers' association be formed.
2. That the Manitoba government declare its commitment to aquaculture and that the agriculture ministry become the lead public sector supporting organization.
3. That the government establish a clear and comprehensive regulatory framework and provide access to technical advice on water quality, effluent management, and other environmental issues.
4. That the (then) Manitoba Rural Adaptation Council encourage the development of a program to enhance access to capital.
5. The academic institutions be encouraged to develop low-cost feed alternatives.

Priority Needs

Prior to the conference, participants were asked to rank 12 different infrastructure components (or needs) as to their potential importance to the growth of the sector. At least 85% of participants rated all 12 needs as either important, very important or critical. Three needs were deemed equally important and were collectively ranked in 8th position.

Average participant ranking of infrastructure components (%) from highest to lowest. The percentages for the 'not essential', 'somewhat important' and 'not sure' categories are not shown as even the lowest priority need was still identified as 'important', 'very important' or 'critical' by at least 85% of participants.

Rank	Needs	Important	Very Important	Critical
1	Access to Credit	7	14	75
2	Access to Marketing/Distribution Expertise/Resources	11	18	68
3	Access to Technical/Production Expertise	14	25	57
4	Access to Technical Advice on Water Quality, Effluent Management and other Environmental Issues	18	29	50
5	Access to Reliable Sources of Affordable Feed	14	32	46
6	Training and Education	18	39	36
7	Access to Processing Expertise and Resources	22	37	33
8	Risk Protection/Safety Nets	11	25	46
8	Access to Veterinary Services	21	43	25

8	Clear and Comprehensive Regulatory Framework	36	18	39
9	Networking with other Producers	32	46	14
10	Genetic Development	32	46	7

B. Spawning Aquaculture 2.0. Summary Report on the March 2, 2018, Aquaculture Stakeholder Conference. Final Draft. Manitoba Agriculture and Fisheries and Oceans Canada.

Overview – The purpose of this conference was: (1) to learn more about the state of the industry in Manitoba; (2) to identify and assess opportunities and challenges facing the development of the industry; and (3) to strengthen the foundation for future industry growth. By design, the final report did not provide a detailed analysis of the findings. Rather, it was intended to be used as a reference for future planning. The conference included three presentations, a panel discussion, break-out group discussions and approximately 100 participants.

The presentation most relevant to this report was entitled *Sustainable Aquaculture Development: the Manitoba Context*. It identified seven challenges hindering industry development.

Challenges to industry development identified in 2018 Manitoba Aquaculture conference.

Lack of knowledge/practical experience	Need for aquaculture support sectors
Absence of a local fish feed supplier	Absence of smart regulations /programming
Lack of access to financing	Lack of infrastructure
Lack on an industry champion.	

A panel consisting of four Manitoba aquaculture producers was asked a series of questions, two of which are highlighted below, along with the (paraphrased) responses.

What kind of support would be most beneficial?	A clear, enabling policy and regulatory framework that is efficiently communicated and implemented (3 of 4) Improved access to federal and provincial funding (3 of 4)[1]
What are /would be the most valuable partnerships?	Improved (local?) access to aspects of the value chain from fingerling supply to marketing (2 of 4) Local fingerling supply (1 of 4) Buyers (1 of 4)

In subsequent discussions, the following were also identified as important:

- Improved access to loan guarantees and crop/liability insurance
- Enhanced marketing support – better promotion / address misinformation
- Better access to fish health/veterinary services
- Better access to knowledge and training
- Lower utility costs
- Access to an association and/or network of practitioners

C. Aquaculture Development in Central Canada: Toward Realization of the Potential – Summary of Calgary and Orillia Sessions. March 2023. Dan Stechey, Canadian Aquaculture Systems Inc.

Overview – Industry session workshops were held in Calgary, AB and Orillia, ON to identify the problems limiting the growth of the industry and to propose solutions. Participants at each session were asked to identify issues faced by the industry and to rank them in order of importance. Despite identifying different sets of issues at the workshops, four common issues and priorities were identified.

High, medium and lower priority issues identified at the 2022 Calgary and Orillia workshops.

High Priority	Medium Priority
Need for an enabling regulatory environment	Technological advancement
Better access to capital	Education and Training

Other issues identified at both sessions but ranked lower or less consistently included:

Fish health	Brood stock development
First Nations/Indigenous community engagement	Research and development
Marketing support	

These findings were then used to develop a set of three strategic objectives and to identify a series of actions which need to be implemented to achieve those objectives. Three strategic objectives, which are at least in part relevant to the objectives of this report, are:

- Develop an enabling policy and regulatory framework,
- Enhance productivity, and
- Enhance confidence in aquaculture.

D. New Brunswick Finfish Aquaculture Growth Strategy. 2022. New Brunswick Department of Agriculture, Aquaculture and Fisheries.

Overview – The strategy was developed by the Government of New Brunswick following extensive consultation with stakeholders. It was endorsed by the Atlantic Canada Fish Farmers Association (2022) "*…for clearly recognizing the importance of salmon farming and for establishing an achievable and promising path forward…*". The strategy outlines seven themes identifies clear actions, priorities and milestones aimed at helping to grow both the freshwater and marine aquaculture industries. These seven themes are:

Land-based Aquaculture	Governance
Competitiveness and Science Support	Fish Health
Promotion and Advocacy	Strategic Infrastructure
Regulatory Efficacy[1]	

[1]Includes updating the province's 1989 Aquaculture Act and supporting regulations.

E. New Brunswick Rainbow Trout Aquaculture Policy. 2016. NB Departments of Energy and Resource Development and of Agriculture, Aquaculture and Fisheries.

Overview – The policy describes a process to simultaneously support the development of Rainbow Trout aquaculture and to mitigate risks to wild stocks. It was developed in recognition of the benefits that a thriving commercial aquaculture industry can provide while, and of the threats to native stocks because of intentional or unintentional introductions in the past. Policy mechanisms to achieve these purposes are clearly defined and include:

- establishing operational requirements for industry regarding the culture of rainbow trout, designed to prevent potential negative effects on native fish stocks without unduly impeding the aquaculture sector,
- providing a standardized inter-departmental mechanism for the review of rainbow trout culture licence applications,
- respecting federal and provincial acts, regulations, and policies related to conservation and aquaculture activities, and
- establishing two rainbow trout culture zones for New Brunswick

Subsequent sections of the Policy clearly describe the activities that will be permitted in each zone including, among other things, the use of triploids, whether cage culture is allowed or not, and compliance with closed containment standards.

F. Strategy for Sustainable Aquaculture Development in Ontario. 2009. Prepared by Dan Stechey, Canadian Aquaculture Systems Inc., for Northern Ontario Aquaculture Association.

Overview – According to the author, the Ontario aquaculture industry's ability to realize its considerable growth potential is contingent upon addressing matters related to the real and perceived effects of aquaculture on the environment and the effectiveness of aquaculture governance. Doing so will require that measures be taken to enhance public and investor confidence in the abilities and governments to manage the industry efficiently and sustainably.

The Strategy identifies three strategic objectives and lists actions necessary to achieve them.

Enabling Responsible Development	Upholding Public Confidence	Maintaining Healthy Ecosystems
- Regional economic development - Increased investment - Continued investment in R&D to develop technologies and practices that will improve productivity/sustainability. - Effective, efficient, and transparent policy and regulatory framework.	- Enhanced stakeholder and community engagement - Effective communication of objective information about the industry, its effects, and its products - Effective, efficient, and transparent policy and regulatory framework.	- Improved understanding of environmental effects - Best Management Practices validated by an independent audit function. - Demonstration of innovative technologies and practices for sustainable development

	- Effective, efficient, and transparent policy and regulatory framework.

The Strategy identifies 14 strategic actions and groups them into four categories as follow:

1. Structural initiatives, including a recommendation to form specific committees.
2. Policy and regulatory initiatives, including a recommendation to establish a comprehensive aquaculture policy for the province.
3. Operational initiatives, including a recommendation to develop a domestic rainbow trout broodstock program.
4. Social license initiatives, including a recommendation to develop and implement a communications strategy.

The Strategic Plan also includes an action plan that identifies which agencies should be involved in implementing each action and the targeted outcomes.

G. Ontario's Farmed Trout Sector Market Assessment and Growth Plan. November 2023. Prepared for the Ontario Ministry of Agriculture, Food and Rural Affairs by Rosenstein Marketing and Four Links Marketing.

Overview – The findings in this report were developed through a combination of quantitative and qualitative research. Quantitative research was based on the collection and analysis of secondary data and statistics from a variety of government and non-government sources. The qualitative research was derived from interviews with 24 individuals across 20 organizations, including processors, distributors, retailers, Indigenous groups, industry academics and trade associations. The authors noted that Rainbow Trout can be marketed as either Rainbow Trout or Steelhead Trout, the distinction currently being based on size and no longer on the rearing environment (freshwater or saltwater) as was the case in the past.

The key finding was that the consumer market could easily support a tripling of Ontario's farmed trout production over the next five years, through an approach which would involve:

- Capturing market share from salmon consumption in Canada (at present, salmon and trout account for 33% and 3%, respectively, of Canadian expenditures on seafood),
- Capturing market share from imports, especially from South America, and
- Exporting more trout to southeastern and southcentral markets in the U.S.

It is likely that the market for Manitoba farm-raised trout has similar upside potential (T. Drost, Four Links Marketing, pers. comm.).

The report also identified two industry trends that would be relevant to aquaculture producers in Manitoba, including:

- A shift towards more pre-package products and away from the seafood counter, and
- A preference for larger trout with fillets ranging from 1 to 3 pounds (450-1500 gm).

The report included findings from recent consumer fish and seafood research that would be useful in the development of marketing campaigns.

Three other important findings were that:

- Sustainability certification is a must,
- Price continues to be an issue with consumers, and
- Lack of consistent supply of product is a barrier to marketing.

Achieving competitive pricing with countries like Chile and Norway where final growout of Rainbow Trout production is completed in net pens will prove challenging.

H. The Scope and Potential of Aquaculture as a Diversification Strategy for Traditional Aquaculture Operations. 2004. Prepared for Agriculture and Agri-Food Canada and the Office of the Commissioner for Aquaculture Development by D. Stechey and E. Gilbert.

Overview – The number of family farms has been decreasing for decades. The consolidation of family farms into fewer, larger farms is negatively impacting the sustainability of those that remain, the survival of rural communities and traditional ways of life. Declining margins, when combined with an ever-shrinking work force as young people seek employment in urban centres, is accelerating this trend.

Agricultural diversification – the introduction of a wider range of output options within a traditional farming enterprise – is regarded as an effective strategy to reduce financial risk and increase margins. Aquaculture has been identified as one potential diversification strategy.

The authors note that the success of aquaculture as a diversification strategy will be influenced by how it is implemented.

> *In many parts of Canada, it is unlikely that an individual farmer who chooses to diversify into aquaculture will be successful. Constraints imposed by geography, economies of scale, infrastructure support and access to skills and knowledge would likely drive-up costs to the point that profits would be marginal*. *Successful diversification, however, can be greatly enhanced by incorporating a cluster approach to aquaculture development*.[3]
>
> *Porter (1991) defines a cluster as "a geographic concentration of competitive and mutually reinforcing businesses linked through vertical (buyer/supplier) and horizontal (common customers, technologies, etc*.) relationships*. Clusters are fundamental to productivity and international competitiveness."*

In the context of aquaculture, a cluster approach would entail the development of multiple farms within a geographic region…supported by centralized infrastructure providing essential products and services…including processing, marketing, supplies (including feed, specialized equipment, consumables, etc.) and other specialized services (e.g., fish health, training, etc.).

Some of the findings in this report were derived from input from stakeholder meetings held in Ontario, Manitoba, Saskatchewan and Alberta which were attended by almost 70 stakeholders.

[3] The cluster approach to agricultural diversification is particularly important to the scale of aquaculture operations that are likely to be incorporated into family-farms. A cluster approach is less critical to the economic viability of larger scale aquaculture enterprises such as the 5000 MT facility that is currently being developed by Saphire Springs. That said, such large facilities would still benefit from proximity to other related business.

I. Closed Containment Salmon Aquaculture. 2013. Report of the Standing Committee on Fisheries and Oceans. R. Weston (Chair). 41st Parliament, First Session.

Overview – This report was commissioned to assess the state and readiness of closed containment aquaculture technologies (and associated research and development needs) as a rearing technology that could be employed to avoid the perceived environmental impacts of net pen culture. Although the report is directed primarily at Atlantic Salmon farming, some of its findings are applicable to freshwater net pen operations. The report examines both ocean-based solid-wall containment systems and land-based Recirculating Aquaculture Systems, or RAS.

At the time of writing, several species, including tilapia, Coho Salmon, Rainbow Trout and Arctic Char had been grown profitably in RAS.

The report notes that RAS infrastructure offers several advantages relative to net pen culture including:

- Reduced risk of exposure to external environmental hazards,
- Reduced environmental impacts,
- Increased flexibility in siting, and
- The ability to command higher prices because their products can be marketed as environmentally sustainable.

Potential disadvantages or RAS infrastructure include:

- Higher capital costs,
- Higher operating costs.

The report includes an assessment of the economic viability of RAS operations and notes that viability depends in part on the species being reared and the price it can command and the scale of operation.

The report identified four critical needs:

- Ongoing financial support for applied R&D
- Continued support for demonstration projects
- Access to capital for private sector participants
- An urgent need for the above three needs to be implemented in the near future to enable Canada to take advantage of its inherent competitive advantages.

J. Manitoba – Canadian Model Aqua-Farm Initiative – Performance Monitoring and Management Final Report. Prepared for the Interprovincial Partnership for Sustainable Freshwater Aquaculture Development by D. Stechey and J. Eastman.

Overview – Support for the implementation of a Canadian Model Aqua-Farm (CMAF) was first recommended by the Inter-Provincial Partnership for Sustainable Freshwater Aquaculture Development in 2001. It was based on the Danish experience with a similar model fish farm program which served to overcome environmental concerns associated with aquaculture. The results of that program were accepted by industry, government, and non-government stakeholders, and facilitated the regulatory review and approval of new aquaculture development applications.

The following italicized text is taken directly from the report.

"*Those interested in farming often develop agri-business ventures by observing other operations, acquiring a basic understanding of operational and investment requirements, and then establishing their own facility. Throughout Canada, however, there is no standard land-based (aquaculture) model to emulate. Existing aquaculture ventures are decidedly variable in design and performance and, thus, there are few fundamental benchmarks for productivity or efficiency to rely upon. The development of a standardized farm model which addresses the basic technological, production, financial, environmental, and regulatory aspects of commercial aquaculture would be a milestone in Canadian aquaculture.*

A model farm is a production unit that integrates the most current technologies.

The objective was to prepare a design that would optimize both financial and environmental performance. Once thoroughly assessed and documented, model farm inputs and outputs become recognized as standards and are more readily accepted by regulatory agencies, thus facilitating site application and approval processes. The modular design would enable the facility to be easily duplicated.

The model farm initiative was intended to establish norms and baseline standards pertaining to the biological, technological, financial, and environmental sustainability of land-based freshwater aquaculture. A fundamental component of success would be the participation of provincial and federal regulatory officials in the environmental assessment of these technologies so that aquaculture applications based on the model farm could be recognized, understood, and accepted by the authorities. By incorporating a production and financial benchmarking program, the CMAF would also establish economic standards that could enhance investor confidence."

Manitoba was selected to receive model farm funding and Watersong Farms, near the town of Warren, was selected as the partner farm owner/operator. Design work was completed in 2008, and construction began in 2009. The first batch of production fingerlings was introduced into the system in fall 2010.

Due to a disease event that occurred in the seventh month of operations, the owner elected not to purchase additional cohorts of fish beyond cohorts 1 and 2. This compromised the production plan, and the venture never achieved the steady-state level of production that it was designed for. This compromised the ability to fully assess the biological and financial performance of the system, or to collect data on effluent characteristics under 'full load' that was of particular interest to regulators. As a result, the principal objectives of the initiative in relation to production, productivity, financial viability, and environmental sustainability, were not attained. While this was unfortunate, sufficient performance monitoring and management data were collected to suggest that the design performance was achievable. Project objectives were also not met in training and development. Despite this and the other shortcomings mentioned above, the initiative resulted in significant knowledge gains in site assessment, development planning, construction, commissioning and production performance, knowledge that would be invaluable if and when another model farm project is considered. The authors recommended that any future such initiatives be established in conjunction with educational institutions, research groups and/or community organizations.

Key Informant Interviews

Approximately 24 individuals were contacted during the preparation of this report to seek their opinions on the potential issues currently hindering the growth of the industry in Manitoba or in other parts of Canada, and/or on a variety of other matters or questions. Not all the feedback provided has been captured in this report. Some is and is reflected in the thinking behind the recommendations. In some cases, the feedback has been attributed to the individual(s) who provided it. In others, for reasons of confidentiality, it has not. The list of persons contacted is provided in Appendix 1.

Advances in Manitoba's Support for Commercial Aquaculture Following the 2005 and 2018 Aquaculture Conferences

1. Manitoba was selected for the Model Aqua-Farm program in 2006. Planning was initiated in 2007 and design work was completed in 2008. Construction was initiated in 2009 and the first batch of production fish were introduced into the system in 2010 (Stechey and Eastman, 2018).

   Although there were issues with the project which resulted in some objectives not being met, much was learned which has helped advance commercial aquaculture in the province, including:

   - Confirmation of the validity of the design of the model farm and the identification of areas for improvement
   - Significant knowledge gains in site assessment, the administration of approvals, regulatory gaps, development planning, construction and commissioning, production planning, project timing and duration, supporting business requirements and partner requirements.

2. The development of a variety of support documents including:
   - Aquaculture in Manitoba – What you Need to Know (Anonymous, undated).
   - The 2013 Fish Farm Technical Training Manual, which is essentially a step-by-step guide to operating the Model Aqua-Farm or a similar facility (Manitoba Agriculture, Food, and Rural Initiatives, March 2013).
   - Production of the 2018 Guidelines for Estimating Aquaculture Production Costs, a planning tool for persons interested in developing in starting up an aquaculture operation (Manitoba Agriculture, Food, and Rural Initiatives, 2018).
   - An enhanced web presence.

3. The development and delivery in 2018 of a 2.5-day training course designed to provide participants with an understanding and awareness of all aspects of fish husbandry and fish culture systems. The course was not intended to make participants experts in the design of intensive fish culture systems, but rather to enhance their understanding of such systems and their capacity to manage them (Stechey, Johnson and Beckman, 2018)

4. The explicit recognition of aquaculture in Manitoba's Protein Advantage Strategy, an important policy step (Government of Manitoba, 2019, 2022, undated).

5. A Zoom meeting entitled Aquaculture: Exploring Opportunities with Manitoba's Protein Industry (Invest Manitoba and Manitoba Agriculture, 2023).

Issues, Strategic Objectives and Recommendations

To address the challenges or issues that continue to constrain commercial aquaculture development in Manitoba, a total of 16 Recommendations has been identified, each of which is categorized under one of six Strategic Objectives.

Each Strategic Objective is important, and timely progress on each is important to achieving the overall goal of supporting the development of Manitoba's emerging commercial aquaculture sector.

Although it is difficult to prioritize the recommendations, three are particularly important. The first is Recommendation 1.1, which involves the designation of a Government Champion, who would provide the leadership and profile necessary to drive the timely development of a Strategy and Action Plan. The second is Recommendation 2.1, which would involve the development of a Provincial Aquaculture Policy that, in turn, would send a clear message of the Manitoba's intent to support the development of the sector and provide a framework under which all related policies, regulations, licenses, permits and procedures would fit. The third is Recommendation 4.1, which would involve the establishment of a new Model Aqua-Farm initiative, would give investors much of the knowledge and confidence required to achieve success and lenders the knowledge and confidence required to provide access to capital.

Several of the needs identified by stakeholders during the Manitoba workshops are not reflected in the recommendations. The first was a desire to develop a provincial Rainbow Trout broodstock. This is neither practical nor necessary at the present time because of the costs of doing so and the ready availability of good quality eggs or fingerlings from other sources. The second was an interest in developing a local fish feed manufacturing industry. This may be feasible in the future but is not practical at the present time given the small size of the sector.

Strategic Objective 1 – Designate a Government Champion and Develop a Strategy and Action Plan

Issue – At present, despite the efforts made over the past 15-18 years described in this report, there is little visible evidence within the Manitoba government of a high-level commitment to the promotion of the province's fledgling commercial aquaculture sector, and no strategy to facilitate its growth. The commissioning of this report is a step towards addressing that issue.

Achieving meaningful progress towards the growth of the province's commercial aquaculture sector will require that the province clearly commit to facilitating that growth. The need for an executive champion was identified in the workshop held in Manitoba in 2018 and was reiterated by many of the people interviewed during this project. Indeed, the absence of industry champions in Manitoba and in several other provinces was seen by many of the persons interviewed (including individuals from government, private, academic, and consulting service sectors) as a key factor constraining the growth of the industry.

Recommendation 1.1 – *Designate an executive level champion within government, preferably at the ADM level, with a mandate to work across ministries and with other levels of government, to oversee the development a strategy and action plan to facilitate the responsible and sustainable growth of the commercial sector. The action plan should have ambitious timelines, clear targets, deliverables and reporting requirements, and a commitment to review progress within three years. It should build upon other recommendations contained in this report. The government*

should demonstrate its commitment to this effort through a public announcement of its intent to complete the action plan within one year and to review progress at specified intervals.

Strategic Objective 2- Create an Enabling Policy and Regulatory Framework

Issue – The need for an enabling policy and regulatory framework to facilitate the responsible growth of the commercial aquaculture sector was identified in the workshops held in Manitoba in 2005 and 2018, in workshops held in Calgary and Orillia in 2022, in a number of documents prepared outside Manitoba, and by many of the individuals interviewed during the preparation of this report (see Appendix 1). The framework should be based on objective information, be clear, transparent, enabling, easily accessed, and efficiently administered.

The absence of a stand-alone Provincial Aquaculture Policy was highlighted as a particular issue.

Also highlighted was the need for greater clarity regarding some permitting/regulatory requirements, especially as related to the issuance of Drainage and Water Control Licenses (which govern the discharge of effluents). Establishing clear effluent standards would provide more certainty to entrepreneurs by allowing them to determine, during their design phase, if the predicted effluents from the scale of operation they are considering would meet requirements.

Additionally, the absence of an easy-to-find comprehensive document that clearly describes all relevant policy, regulatory and permitting requirements and provides up-to-date contact information was seen as problematic. The Fish Farming (Aquaculture) Program Policy (2013) and the Guide to Intensive Aquaculture in Manitoba (2004) documents are neither current nor comprehensive. A document entitled 'Aquaculture in Manitoba – What You Need to Know' (Anonymous, undated) was made available for review during the preparation of this report and, while a step in the right direction, lacks detail and current contact information, and is not available on the government website. Ontario's Application Guidelines for Cage Culture Facilities (2017) is an example of a more comprehensive, user-friendly document.

Recommendation 2.1 – *Manitoba should develop a stand-alone Provincial Aquaculture Policy that articulate the province's support for the sector, its intent to manage its growth in a way that ensures the protection of wild fish stocks and associated fisheries, and the effective management of effluents. It should identify the types of aquaculture systems that will be allowed and where, licensing and permitting requirements and the need to conform with other policies, legislation, and regulations.*

The explicit mention of aquaculture in the province's Protein Advantage Strategy and Action Plan is an important step toward recognition of its support for the sector. However, it lacks profile and needed policy detail, and is unlikely to advance the industry without supplementation. An explicit, stand-alone Provincial Aquaculture Policy that articulates the province's support for aquaculture would be welcomed by industry and would signal the province's commitment to potential investors, to relevant provincial ministries, to the federal and municipal governments and to key utilities.

Should Manitoba choose to proceed with the development of a Provincial Aquaculture Policy, there are at least two areas that require additional consideration.

The first relates to whether it will allow net pen culture for final grow-out. If it was to do so, it would need to determine where and how much would be allowed, what species would be permitted and under what conditions. It is important to note that the cost to produce market-sized Rainbow Trout (or Steelhead Trout) in freshwater net pens is presently lower than in land-based RAS infrastructure (J. Henry, R.J. Taylor, and D. Stechey, pers. comm.), and net pens are being used successfully to culture several species in several Canadian provinces. In Saskatchewan, for example, support for net pen culture appears to be strong and opposition very limited (D. Foss, pers. comm.; M. Tyree, pers. comm.). In other provinces, notably Ontario, there is some opposition to the practice (M. Chiasson, S. Naylor, D. Stechey, and R.J. Taylor, pers. comm.) Whether this stems from real or perceived environmental impacts, or from other considerations, is unclear. A decision to either allow or not allow net pen culture in Manitoba should be informed by a transparent and objective analysis of social, economic, and environmental factors.

The second area that warrants further consideration is the current prohibition on the farming of Walleye and Lake Whitefish, two species that support important commercial fisheries. The use of RAS culture technology from incubation through to harvest makes it entirely feasible to avoid any impacts on wild populations. As such, a policy decision would need to consider other factors.

Recommendation 2.2 – *Manitoba should update and review its regulatory framework, associated guidelines, and administrative procedures to ensure alignment with the policy decisions embedded in the Provincial Aquaculture Policy recommended above, to streamline where feasible and to provide greater clarity regarding the management of effluents. The current requirement to renew aquaculture licenses annually is an example of a requirement that may be amenable to streamlining.*

Recommendation 2.3 – *Manitoba should consolidate all relevant information pertinent to the establishment of a new aquaculture enterprise, or the expansion of existing ones, within a transparent, accessible, online document.*

Recommendation 2.4 – *Manitoba should consider a one window approach for the administration of the licensing and permitting process, with clearly identified points of contact. The staff responsible for administering the process should be knowledgeable about the process, should operate under clear service standards and should be committed to helping applicants navigate the regulatory process. They should also be able to refer clients to other staff with more technical expertise when required*.

Strategic Objective 3 – Enable Production Success through Access to Knowledge, Proven Designs and related Support Services

Issue – Several knowledge-related issues were identified during the preparation of this report that are limiting the ability of aquaculture entrepreneurs to develop profitable enterprises in Manitoba and elsewhere. These include but are not limited to a lack of access to suitably trained staff[4] and

[4] It is worth reiterating that the successful operation of Recirculating Aquaculture System (RAS) fish farms requires highly trained staff. These systems are technically complex, and success requires a good understanding of both fish culture basics and of RAS operation. Most of the growth in Manitoba's aquaculture sector will likely involve RAS.

ongoing training, to relevant aquaculture business planning expertise (including economic performance data), to standardized, proven designs of a scale suited to investors, including farmers, who wish to diversify their operations, and to information that would enhance regulator confidence.

Recommendation 3.1 – *Manitoba should invest in a new model aqua-farm initiative similar to that launched in 2008 that is no longer operating. It should build upon lessons learned from the first model aqua-farm initiative, from B.C.'s model aqua-farm experience, and from recent experience developing fish farms of similar size in other provinces. It would lead to the establishment of a standardized design for a modular system that would be easily shared and would generate positive cash flow. It would also enhance investor and lender confidence by allowing people considering investing in or working on a fish farm to visit an operating facility first-hand.*

The primary objective of the original Canadian – Manitoba Aqua-Farm initiative was to help farmers diversify their operations (See Key Document Review, Section J, for more information). This objective remains relevant today and, based on the number of farmers who expressed interest in the first Model Aqua-Farm, there is reason to believe that a new one could lead to significant uptake over the course of a decade. The cost for farmers who already own land and who have suitable vacant buildings which can house fish farming infrastructure makes this kind of venture more affordable than for someone who must also cover land purchase and building construction costs.

Recent experience in Ontario suggests that some of Manitoba's Indigenous communities would be interested in a new model aqua-farm initiative and in establishing similar sized operations in their communities. As a sustainable, resource-based activity, fish farming has the potential to support community income, prosperity, and food security goals. Further, many Indigenous communities have good access to capital making such projects more attractive.

*If Manitoba chooses to proceed with the establishment of a new Model Aqua-Farm initiative**, it is further recommended:***

- *that it be established in partnership with an academic institution with an existing agriculture program and an interest in developing an aquaculture program.[5] Doing so could facilitate training, the delivery of extension services, and research,*
- *that it be targeted to both the agricultural and Indigenous communities,*
- *that it be operated in such a manner that the original objectives of the program, which remain relevant today (see Stechey and Eastman, 2018), be achieved,*
- *that any new agreement be strengthened to better clarify partner expectations and obligations and key decision-making procedures,*
- *that all parties commit to operating the facility in a manner consistent with its objectives for a significant period of time (10 years is suggested, longer would be better), and*

[5] Two academic institutions, Assiniboine College's School of Agriculture and Environment and the University of Manitoba's Faculty of Agricultural & Food Sciences, are aware of this potential opportunity and would be interested in discussing it with the province should it decide to proceed.

- *that incubation and early rearing infrastructure be incorporated into the facility to reduce the costs and disease risks associated with importing fingerlings and to provide operators with more control.*

Should Manitoba wish to pursue this recommendation, one option would be to physically locate the new facility at or in association with an academic institution. The other would be to invest in necessary infrastructure upgrades at the existing model aqua-farm site (if that opportunity still exists) and to operate it in collaboration with an academic institution. The former option would be the more expensive of the two. Both options offer advantages and disadvantages.

Recommendation 3.2 – *Manitoba should support persons interested in starting or expanding aquaculture businesses by:*

- *enabling easy access to model aqua-farm design details and related investment and operational requirements, to operating and production plans, and to financial and operational performance data, and by*
- *facilitating access to professional support services for the development and/or review of business plans and facility designs.*

Recommendation 3.3 – *Manitoba, in collaboration with the federal government, academic institutions and industry associations, should develop and implement a plan to enhance support for Education, Training, Extension and Research that builds upon the opportunities created by the establishment of a new Model Aqua-Farm initiative, by:*

- *determining how best to further achieve some training and development objectives in a new model aqua-farm initiative, should one be implemented,*
- *creating a website where information on existing training programs, including on-line training, could be consolidated, and accessed, and by providing links to other sources of information, including culture manuals, etc.,*
- *working with partners to explore the feasibility of developing either a formal academic training program* such as *those offered at other academic institutions, or of developing and delivering shorter courses on priority topics for persons not interested in or able to participate in longer courses,*
- *developing and communicating Best Management Practices documents, and by*
- *exploring the feasibility of supporting the development of aquaculture R&D programs at local academic institutions.*

Recommendation 3.4 – *To the extent feasible, Manitoba should encourage the development of new aquaculture ventures in specific geographic clusters. Doing so would facilitate more efficient access to support services, including feed distribution, product shipping to processors, processing, specialized supplies, and fish health/veterinary services. This, in turn, could lead to lower costs by enabling economies of scale.*

Strategic Objective 4 – Enhance Access to Capital and Risk Management Funding.

Issue – The need for enhanced access to capital (or financing), risk management (or safety net) funding or programs was raised as a critical issue in the Manitoba aquaculture workshops held in 2005 and 2018, in the Calgary and Orillia workshops (Stechey, 2023), in the Strategy for the Sustainable Development of Aquaculture in Ontario (Stechey, 2009), and in the Report on Closed Containment Aquaculture issued by the Standing Committee on Fisheries and Oceans (Weston, 2013). It was also raised by most persons interviewed during the preparation of this report.

It was noted that banks, other lending institutions and investors are often reluctant to provide financing (both capital and operating) to support the development of aquaculture enterprises, particularly those involving the use of RAS technology as they are often seen as high risk. In recent years, this perception has been exacerbated by the number of high-profile failures that have been reported in the media. This is unfortunate. According to both D. Stechey and J. Henry (pers. comm.), RAS technology is proven and been used successfully for the commercial culture of some species for decades and, further, that most failures can be attributed to poor design, poor operator training, or a failure to properly account for all costs during business planning.

It was also noted that aquaculture enterprises are often unable to access federal agricultural or risk management program funding largely because the federal government does not formally recognize aquaculture as agriculture.

Similarly, awareness of and eligibility for some provincial funding programs is sometimes unclear. For example, LaFlèche (pers. comm.) noted that Sapphire Spring's proposal to develop a 5000 MT Arctic Char farm was initially deemed ineligible for funding under the Small Business Venture Capital Tax program. However, subsequent rule changes allowed access to the program.

Recommendation 4.1 – *Manitoba should take an active role in addressing lender and investor concerns about the risks of land-based aquaculture by addressing misinformation and providing access to objective information.*

Recommendation 4.2 – *Manitoba should further enhance investor and lender confidence by conducting a market analysis for Manitoba farmed fish and, once complete, by working with industry to develop a marketing strategy that identifies how best the province can support the development of the sector.*

Recommendation 4.3 – *Manitoba should capitalize on the opportunity provided by CCFAM to encourage the federal government to recognize land-based aquaculture as agriculture and to ensure its eligibility for federal agriculture funding programs, including loan programs, grants, seed funding, funding to support the adoption of green technology, and crop insurance/risk management programs. When doing so, it may also wish to encourage the federal government to consider transferring administrative responsibility for land-based agriculture from Fisheries and Oceans Canada to Agriculture Canada. Land-based aquaculture is agriculture.*

Recommendation 4.4 – *Manitoba should consider enhancing provincial financial support to the emerging aquaculture sector by ensuring access to existing programs and by considering the development of a new, dedicated funding program. Such a program could have parallels with its recently announced investments in the province's commercial fisheries totaling $4.0 million.*

Recommendation 4.5 – *Manitoba should develop an online document that provides easy access to up-to-date information on all potential funding sources.*

Strategic Objective 5 – Facilitate Timely Access to Power

Issue – Several people interviewed during the preparation of this report expressed concern with the length of time required to secure electrical upgrades at existing fish farms or at new farm operations. Significant delays could deter some from investing or could lead to delays in generating revenues for new projects that have been completed but cannot be operated at full capacity because of inadequate power. According to Stechey (pers. comm.), even model farm-sized operations located in rural areas would need electrical upgrades to operate.

Recommendation 5.1 – *The province of Manitoba should work with Manitoba Hydro to explore options to ensure that electrical upgrades are implemented in a timely manner.*

Strategic Objective 6 – Enhance Confidence and Social License Through Effective Communications

Issue – As a result persistent negative media coverage, some members of the public and some investors and lenders continue to express concern about the risks associated with fish farming, its environmental impacts and sustainability and the health benefits of farm raised fish. There is a need to counteract these perceptions by the transparent communication of factual information.

Recommendation 6.1 – *Manitoba should support the development of a communications strategy and action plan that identifies goals and objectives, audiences, products, and timelines for development. Consider hosting all products on a single, comprehensive, and easy-to-navigate government Aquaculture in Manitoba website. Communication products should be aimed at:*

- *addressing misinformation (this could include links to reputable 3rd party sources of independent information),*
- *improving investor and lender confidence in the industry,*
- *improving consumer awareness of the sustainability and nutritional benefits of Manitoba farmed seafood,*
- *facilitating transparent, one-stop access to relevant policy, regulatory, and licensing requirements (including contact information),*
- *enabling easy access to information on existing training programs, including on-line training, and to other information of interest to practitioners such as conferences, culture manuals, Best Management Practice documents and other technical information.*
- *Other ministry specific government websites should include links to this website.*

Many of these products could support marketing efforts by industry. By addressing misinformation and communicating positive messages about sustainability and healthy products, Manitoba would enable producers to dedicate more of their marketing effort to promoting sales.

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Appendix 1: List of Persons Contacted/Interviewed/Consulted

Note: In the interest of confidentiality, not all communications with some of the people identified below are specifically attributed to those individuals in the report.

Aneshansley, Ed. Ed-A Aquatic Design Services, LLC. Marblehead, MA.

Budiwski, Chris. School of Agriculture and Environment, Assiniboine Community College, MB. Note – Interactions were limited to email communications in which Mr. Budiwski indicated that the college may have an interest in supporting aquaculture development in the province.

Burdick, Brian. Senior Aquaculture Specialist, Fisheries and Oceans Canada, Ontario and Prairie Region. Peterborough, ON.

Chiasson, Marcia. Manager, Ontario Aquaculture Research Centre, Office of Research, University of Guelph, Elora, ON.

Drew, Tim. Manager, White Lake Fish Culture Station. Ontario Ministry of Natural Resources and Forestry, Sharbot Lake, ON.

Drost, Terry. President, Four Links Marketing Inc. Douglas, NB.

Eastman, Jeff. Industrial Development Consultant – Protein, Manitoba Agriculture, Winnipeg, MB.

Firkus, Tyler. Northern Aquaculture Demonstration Facility, University of Wisconsin-Stevens Point, WI.

Fischer, Greg. McMillen Jacobs Associates. Former manager of Stevens Point Aquaculture Demonstration Facility, University of Wisconsin at Stevens Point, WI.

Foss, Dean. General Manager, Wild West Steelhead. Lucky Lake, SK.

Hendrickson, Lorna. Regional Manager – Aquaculture, Fisheries and Oceans Canada, Ontario and Prairie Region.

Henry, Justin. Chief Technology Officer, Sapphire Springs, and owner, Henry Aquaculture Consult, Inc. North Vancouver, BC.

Hotson, Doug. Vice-President – Operations, Sapphire Springs, Winnipeg, MB.

Hore, Tim. Dean – Agriculture and Environment, School of Agriculture and Environment, Assiniboine Community College, Brandon, MB.

Johnson, Alan. North Central Regional Aquaculture Centre, Iowa Department of Natural Resources. Moravia, IA.

Kelsey, Kevin. Ed Weed Fish Culture Station, Vermont Fish and Wildlife Department, Grand Isle, VT.

Kroeker, Derek. Manager – Sustainable Fisheries Section, Manitoba Fisheries Branch, Ministry of Economic Development, Investment, Trade, and Natural Resources, Winnipeg, MB.

LaFlèche, Charles. Chief Financial Officer, Sapphire Springs, Winnipeg, MB.

Lee, Jeremy. President, Sustainable Fish Farming (Canada) Limited, and Chief Technology Officer, Sustainable Blue. Burlington, NS.

Naylor, Steve. Senior Regional Aquaculture Advisor, Fisheries and Oceans Canada, Ontario and Prairie Region. Guelph, ON.

Reimer, Rudy. Owners, Watersong Farms. Warren, MB.

Roberts, David. Chief Sustainability Officer, Sustainable Blue, Burlington, NS.

Scanlon, Martin. Dean, Faculty of Agricultural & Food Sciences, University of Manitoba, Winnipeg, MB. Note – Interactions were limited to short email exchanges in which Dr. Martin's indicated that his department has a potential interest in supporting aquaculture development in the province.

Sopuck, Robert D. Former Member of the House of Commons of Canada (Dauphin - Swan River – Neepawa and Dauphin and Swan River – Marquette ridings), Former Member of the Standing Committee on Fisheries and Oceans. Co-author of Closed Containment Aquaculture Report (Weston et al., 2013).

Stechey, Dan. President, Canadian Aquaculture Systems, Cobourg, ON.

Taylor, R.J. Managing Director, Ontario Aquaculture Association and Co-owner, Cedar Crest Trout Farms and Springhills Fish, Hanover, ON.

Tyree, Matt. Director of Fisheries, Saskatchewan Ministry of Environment, Saskatoon, SK.

Waldner, Noel. Ridgeland Aqua Farms, Springfield, MB.

Waldner, Peter. Ridgeland Aqua Farms, Springfield, MB.