Carlson Consulting Enterprise

Carlson School of Management

University of Minnesota

Fall 2020 Project:

Minnesota Sea Grant:

Lake Superior Commercial Fishing

and Aquaculture Supply Chains in Minnesota

By

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1. Overview

The Carlson Consulting Enterprise (hereinafter referred to as CCE) is a management consultancy and academic program housed in the Carlson School of Management at the University of Minnesota's Twin Cities campus. CCE students, faculty, and staff collaborate in teams to address significant business and organizational challenges for corporate, nonprofit, and public sector entities. Since 2002, CCE has partnered with over 100 organizations on over 300 projects to provide hands-on learning opportunities for high-caliber MBA and undergraduate business students, and deliver results and recommendations for clients.

Minnesota Sea Grant (hereinafter referred to as MNSG) is part of the National Oceanic and Atmospheric Administration's (hereinafter referred to as NOAA) National Sea Grant College Program, which supports 34 university-based programs in coastal states throughout the United States, Puerto Rico, and Guam. Sea Grant receives funding through the NOAA Office of Oceanic and Atmospheric Research and the University of Minnesota. MNSG partners with local, regional, and national organizations and is an integral member of the Great Lakes Sea Grant Network. MNSG supports the four main focus areas of the National Sea Grant College Program, which includes Sustainable Fisheries and Aquaculture (SFA).

CCE and MNSG partnered during the fall 2020 semester (September-December) to develop viable scenarios for the effective processing and distribution for the commercial fishing and aquaculture industries in Minnesota. The goal of the project was to obtain a better understanding of the fisheries supply chain in Minnesota. Major objectives were to: 1) explore how best to mitigate the present COVID-19 pandemic situation, 2) determine methods to prolong shelf life of fish products to provide supply chain flexibility, 3) explore cooperative business components, such as processing and distribution, and 4) address future uncertainties in the supply chain for Minnesota seafood products. Supply chain is defined as the procurement, processing, preservation, transport, and sale of a product. Essentially, the supply chain includes all steps from procurement until the product reaches the consumer. This project covered each step of the supply chain except transportation and sale of the product.

This paper reports the research, findings, and recommendations for supply chain needs for both the Lake Superior commercial fishing (hereinafter referred to as commercial fishing) and aquaculture industries that resulted from the partnership work by CCE and MNSG. First, the project objectives and scope are provided as an overview of the project. Then, details of the challenges and recommendations within this project are discussed. The paper ends with frequently asked questions about the project. Although there are some similarities between the research, findings, and recommendations for the commercial fishing and aquaculture industries, their supply chain needs are quite different. Thus, the paper is organized to separately report the recommendations for each of these two industries.

2. Project Objectives and Scope

Project Objectives

MNSG engaged a student team from CCE to study the commercial fishing and aquaculture supply chains in Minnesota. The purpose was to understand how best to improve supply chain resiliency, flexibility, and sustainability. Further, the team was charged with developing recommendations for innovative ways that producers in both commercial fishing and aquaculture could target other consumers to increase their reach.

Project Scope

- Determine the current customer base for the commercial fishing industry
- Create a comprehensive understanding of current supply chain activities for the main species in the commercial fishing industry
- Understand current supply chain activities for the aquaculture industry
- Identify challenges associated with each supply chain activity in both the commercial fishing and aquaculture industries
- Investigate the difficulties of raising various species in the aquaculture industry
- Determine key gaps in each part of the supply chain for both industries
- Recognize barriers in each industry that present challenges to new methods
- Recommend innovative solutions to address the challenges in both the commercial fishing and aquaculture industries

- Suggest additional ideas for future supply chain designs in both the commercial fishing and aquaculture industries in Minnesota to build and sustain supply chain resiliency

3. Research Methods

Commercial Fishing

Interviews: CCE student consultants gathered information from a variety of resources. The Minnesota commercial fishing industry is small, and little data and information about the industry have been published. Therefore, most of the information used to conduct this project comes from personal interviews with key stakeholders in the industry. Key stakeholders interviewed were: MNSG staff who are coauthors of this report: Amy Schrank and Donald Schreiner, six Minnesota Lake Superior commercial fishers, three North Shore restaurants, two Minnesota Department of Natural Resources (hereinafter referred to as MNDNR) Lake Specialists, Red Lake Nation Fishery General Manager, owner of Interlaken Fisheries and Superior Fish Guys, and additional MNSG staff.[1]

Secondary research: Literature reviewed by the student consultants include the MNDNR Annual Commercial Fisheries Summary from 2015 to 2019,[2] Minnesota DNR regulations,[3] 2018-2021 Strategic Plan of the University of Minnesota Sea Grant College Program, 2020 Lake Superior Commercial Fishing Statutes,[4] and numerous online articles regarding the commercial fishing industry.[5]

Aquaculture

Interviews: CCE student consultants gathered information from a variety of resources. Similar to the commercial fishing industry, the Minnesota aquaculture industry is small and very little data and information about the industry are published. Therefore, most of the information collected for this study came directly from interviews with key stakeholders in Minnesota. Key stakeholders interviewed were: MNSG staff including coauthors of this report: Amy Schrank and

[1] All names withheld for privacy reasons
[2] Available upon request from the Minnesota DNR
[3] See details at https://www.dnr.state.mn.us/regulations/index.html
[4] See details at https://www.revisor.mn.gov/statutes/cite/97C.835
[5] Specified in the footnotes through the report

Donald Schreiner, 12 Minnesota-based producers,[6] six industry experts at the University of Minnesota, MNDNR, Minnesota Aquaculture Association, Global Aquaculture Alliance, Cargill, and InCity Farms.[7]

Secondary research: Literature that was reviewed includes Food-Fish Aquaculture in Minnesota Synthesis from the April 2017 Workshop,[8] MNDNR regulations, 2018-2021 Strategic Plan of the University of Minnesota Sea Grant College Program, MNSG Rapid Response Project Narrative,[9] 2020-07-14 Market Study proposal narrative through milestones, as well as numerous online articles[10] regarding the aquaculture industry.

4. Needs Assessment

Commercial Fishing

Table 1 summarizes information collected by CCE student consultants for a needs assessment for the commercial fishing industry. The needs were identified from independent research as well as in-person visits with multiple fishers on the North Shore. Information in the "current state" and "recommendations" columns are expanded upon later in this paper.

Current State[11]	Desired State	Recommendation[12]
Aging industry players	Flow of new entrants	Make the industry more profitable so new entrants are attracted to the industry
Supply and demand mismatch	Supply and demand efficiencies	Facebook page and eventual co-op

[6] Including 4 current aquaculture producers, 3 future aquaculture producers (planning stage), 2 previous aquaculture producers (shut down this year), and 3 current aquaponics producers
[7] All names withheld for privacy reasons
[8] By Sharon M. Moen, Donald R. Schreiner, Jessica Coburn, Nicholas Jacob, 26-27 April 2017
[9] By Schrank et al., 06-01-2020
[10] Specified in the footnotes through the report
[11] Current state is expanded upon in Section 5 "Supply Chain Findings"
[12] Recommendations are expanded upon in Section 6 "Recommendations"

Fishers receive a low price for their product	Fair price for fishers that allows them to make a living from commercial fishing	Cost calculator to assist fishers' negotiating capabilities
Lack of preservation options	Feasible preservation technologies to help even out seasonal supply variations	Investment in vacuum packing technology
Lack of processing labor	Strategic partnerships to eliminate processing bottleneck	Explore potential processor/distributor partnerships to provide labor during the supply-intensive peak (November) season
Monopoly in the roe export market	Additional buyers to support competitive pricing	Explore potential processor/distributor partnerships to provide additional roe processing options

Table 1. Commercial fishing needs assessment.

Aquaculture

Table 2 summarizes the needs assessment conducted by student consultants. The identified needs are based on independent research and interviews with local producers and industry experts. The "current state" and "recommendations" columns are expanded upon later in the paper.

Current State[13]	Desired State	Recommendation[14]
High loss of embryo and postlarvae during transportation from suppliers	Local embryo and postlarvae sourcing to reduce losses during transportation	Advocate for multi-channel sourcing as well as developing local suppliers
High mortality rate during grow-out caused by lack of	Improved operational and biological knowledge	Streamline producer education through MNSG and

[13] Current state is expanded upon in Section 5 "Supply Chain Findings"
[14] Recommendations are expanded upon in Section 6 "Recommendations"

operational and biological knowledge		University of Minnesota; develop biology student consulting projects and other education options
High energy costs in winter	Improved awareness and knowledge of facility energy consumption	Provide detailed energy consumption comparison and pros/cons for each facility type
Strict regulations without enough explanation	More transparent regulations and understanding among local producers	Communicate regulations with explanations as to why they are needed in Minnesota
Some producers closing due to change in demand	Contingency plan for demand change	Options for new revenue streams for producers
Less optimal investment and profit margin caused by inexperienced business planning	Improved investment and business operations decisions	Cost calculator to aid producers' understanding of investment decisions; business student consulting projects
Few producers for each species, while producers of each species face different operational challenges	Group of similar-sized producers who are interested in collaborating	Entice new industry entrants; use university resources to address operational challenges; "test-run" small-scale cooperation and/or partnerships

Table 2. Aquaculture needs assessment.

5. Supply Chain Findings

Commercial Fishing Findings

1. Aging industry players

   Many of the commercial fishers are approaching retirement without apprentices to continue their fishing operations after they retire. In order to obtain a commercial fishing license in Minnesota, fishers must have participated in an apprenticeship under a

commercially licensed fisher and own the necessary equipment.[15] The population along the North Shore, like much of rural Minnesota, is generally shrinking. Many of today's licensed Lake Superior fishing businesses have been passed down within families and have been in operation since the North Shore was settled in the late 1800s. Younger generations are choosing other career paths, as demonstrated by the low number of apprentices. An estimated 75% of commercial fishing license holders for Lake Superior are close to retirement.[16]

2. Supply and demand mismatch due to seasonality

   Cisco comprise the predominant commercial harvest in Minnesota's portion of Lake Superior. Local demand for freshly caught fish is high and fishers struggle to provide adequate supply during the prime spring/summer tourist season. Cisco spawn in November and are much easier to catch in large quantities, drastically increasing local supply when compared to the rest of the year. The high demand for Cisco eggs (roe) drive the large increase in November Cisco harvest. The roe is valuable when processed into caviar. In November fishers find themselves with more fish flesh (fillets) than they can process and sell locally. Most fishers are not connected to other markets, and long-term preservation of fillets has not been explored, so they struggle with excess supply and extremely low prices for the flesh. Figure 1 outlines the differences in supply chain challenges for fillet and roe seasons. Red icons indicate areas of great concern, yellow icons indicate mild concern, and green icons indicate well-functioning areas of the supply chain. As shown, processing and finding buyers are great concerns in the roe supply chain, while fishing harvests are a mild concern in the fillet supply chain.

[15] The authors used data from *Minnesota DNR Annual Commercial Fisheries Summary* from 2015 to 2019
[16] The authors used data from *Minnesota DNR Annual Commercial Fisheries Summary* from 2015 to 2019

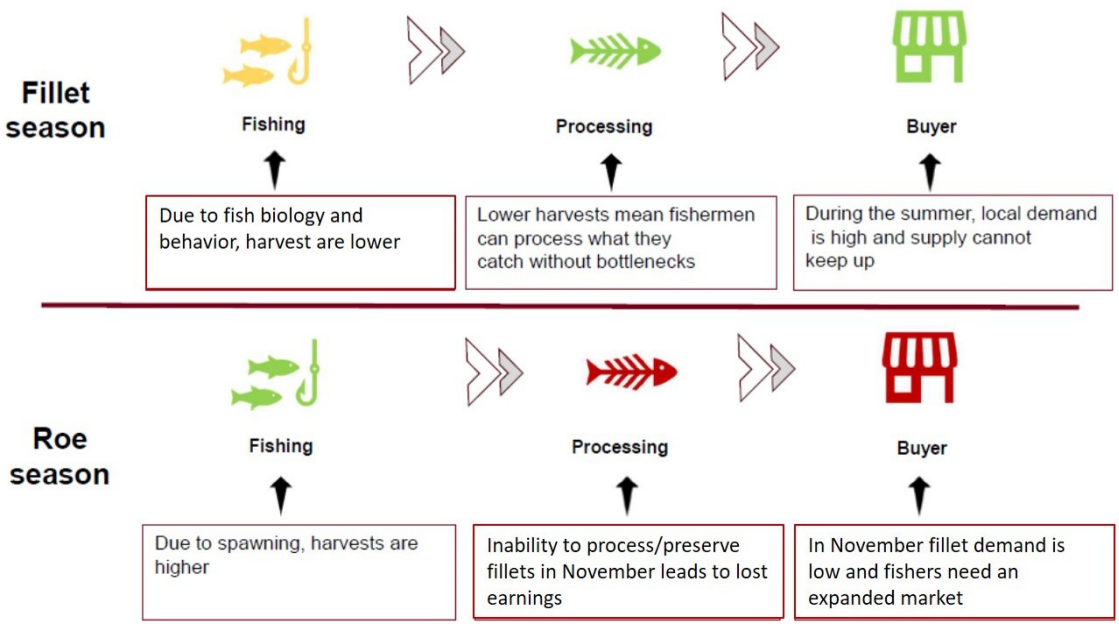

Figure 1. Supply chain for fillet and roe season.

3. Fishers receive a low price for their product

   The dockside price (defined as the whole, unprocessed fish) for Cisco has been declining since its peak of $0.89 per pound in 2017, as noted in Figure 2.[17] During the 2020 roe season, fishers reported receiving only $0.60 per pound dockside. One of the stated reasons for the decrease was that, due to the COVID-19 pandemic, the sole local buyer who processed fish for roe had shut down his processing facility. Other reasons reported for the decrease in dockside price are the absence of a local market for roe. Roe makes the fish more valuable, therefore the ability to process and use the roe is a key factor in determining dockside price in the fall roe season.

[17] The authors used data from *Minnesota DNR Annual Commercial Fisheries Summary* from 2015 to 2019 to illustrate Exhibit 4

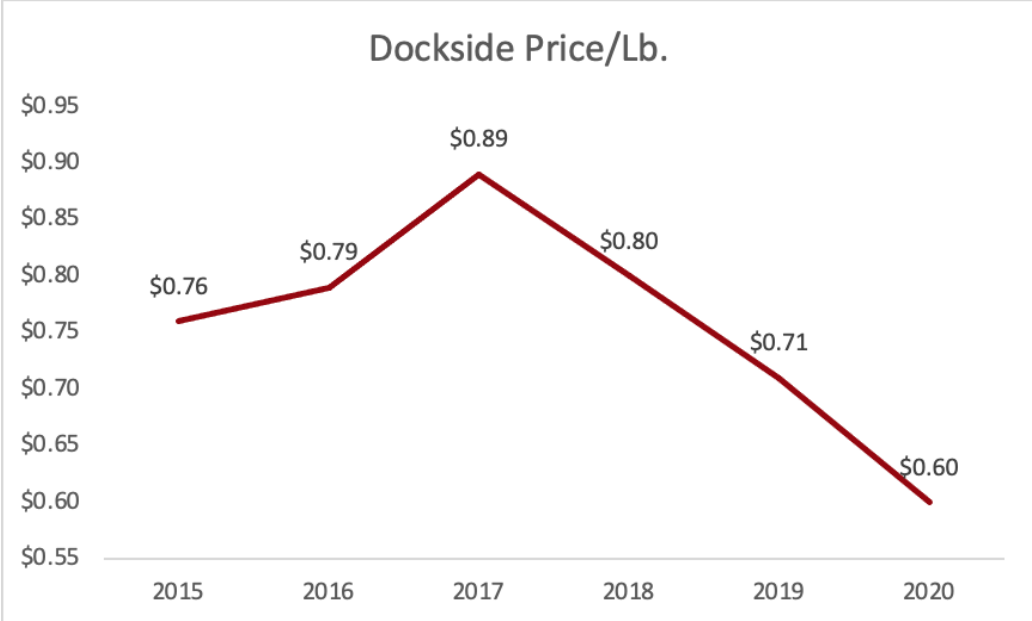

Figure 2. Dockside price of Cisco from 2015 to 2020.

4. Lack of preservation options

   The highest demand for Cisco is in its fresh state. Fresh, unfrozen, unprocessed fish must be consumed within a few days. When local demand drops, preserving the fish extends the usable life of the product and opens up the possibility of transporting and selling in other markets. The most viable preservation options include vacuum packing, freezing, and smoking the product. Most fishers lack the financing and infrastructure required for purchasing and holding the equipment for these preservation methods. Some fishers have vacuum packing technologies, but these are limited in number.

5. Lack of processing labor

   Many of the fishers who were interviewed noted a lack of local labor to process the fish. Processing is done by hand and is time-consuming and physically tiring. In past years, they hired migrant workers during roe season to help with processing. However, recent changes in immigration laws resulted in fewer available and interested workers. Without additional labor, fishers had to spend more time processing fish and, as a result, less time actually fishing.

6. Monopoly in the roe export market

Roe is very profitable when processed into caviar and sold in international markets.[18] The price fishers get for roe is often 10 times the price they receive for flesh.[19] Locally, roe does not have great value. Turning roe into caviar requires expensive processing equipment as well as Food and Drug Administration (hereinafter referred to as FDA) approval of processing facilities. During our research, we identified only one roe buyer with the necessary equipment, FDA approval, and access to an international market. Local fishers sell whole fish that they cannot process (due to limited labor availability) to this buyer at the dockside price. Fishers have not negotiated a higher price for the fish/roe due to the monopoly this buyer has in the area.

Aquaculture Findings

1. High loss of embryo and postlarvae during transportation from suppliers

   Local producers of shrimp, Rainbow Trout, and some other major species in the Minnesota aquaculture industry do not currently have capabilities to produce postlarvae and embryos, respectively. Nor are there currently any alternative local (within state or upper Midwest) sources. Based on interviews with local producers in October 2020, shrimp postlarvae are sourced mainly from Texas and Louisiana, while trout embryos are sourced from Hawaii. Local producers state that both species suffer significant loss rates due to the long-distance sourcing: First, death of up to 80%[20] of postlarvae and embryos occur due to turbulence during transportation because both are extremely fragile. Second, local shrimp and trout producers source from one supplier each, and do not currently have alternative suppliers. During 2020, due to the COVID-19 pandemic, many postlarvae and embryo suppliers stopped their operations, resulting in Minnesota producers closing their operations.

2. High mortality rates during grow-out caused by the lack of operational and biology knowledge

[18] *Why Is Caviar So Expensive? | How Much Is Caviar? | Caviar's Real Price*, by Derek Leavitt, Feb 12th 2020
[19] *Why Is Caviar So Expensive? | How Much Is Caviar? | Caviar's Real Price*, by Derek Leavitt, Feb 12th 2020
[20] Estimation from local producers

Daily operations of aquaculture facilities are complicated. The design of aquaculture systems, quality of fish feeds, and status of dissolved oxygen, temperature, salinity, hardness, ammonia, nitrite and pH, all require very close monitoring by operators.[21] In other words, "everything can go wrong during day-to-day operations."[22]

Meanwhile, some producers have insufficient operations and biological knowledge to maintain an aquaculture production system. Even experienced producers expressed that they struggle to "do it right." This is linked with high mortality rates during both the hatching and growth stages of the fish.

Most producers expressed a desire for on-site help from people trained in aquaculture to "have a look and tell us what went wrong." Producers find it challenging to sift through massive amounts of information found online. Some information seems contradictory to "industry common sense" or their current practices, and they do not know which information is correct (or incorrect) or most important.

3. High energy costs in winter

Due to Minnesota's winter conditions, energy costs are one of the largest concerns for producers with indoor operations. The interviewed aquaponics producers - growing both aquatic species and plants - chose to produce in greenhouses in order to save the expenses of lighting for vegetable growth. However, if not properly designed, heat loss in greenhouses is relatively high.[23] Based on interviews during December 2020, producers need to bring in additional resources to heat the water in order to maintain the proper water temperature for fish in the aquaponics systems. This resulted in unexpectedly high energy costs for these producers.

[21] *Aquaculture: Challenges and Promise*, By: Peter J. Allen (Department of Wildlife, Fisheries and Aquaculture; Mississippi State University) & James A. Steeby (Thad Cochran National Warmwater Aquaculture Center, Mississippi State University) © 2011 Nature Education

[22] Most producers who were interviewed expressed this

[23] *GREENHOUSES Heating, Cooling and Ventilation*, John Worley, Professor, Department of Poultry Science, University of Georgia, Feb 23, 2009

Also worth noting is the difficulty in changing facility and operating system designs once established. Thus, once the inefficient energy systems are built, the producers will likely suffer high energy costs for an extended time.

4. Misunderstanding and lack of clarity in permitting

   Producers believe the Minnesota aquaculture industry is highly regulated, particularly in comparison to neighboring states. Minnesota producers complained about the complexity of state regulations, and expressed a lack of understanding of the reasons for permit costs. A direct comparison of regulations and permit costs between states is not simple because of highly dynamic fee structures, different compositions among fee packages, regulation complexity, social license and political realities. There are a variety of permits and licenses required to operate an aquaculture farm in Minnesota that depend on farm size, production system, use of private or public waters, and species reared. For example, a large-scale, flow-through production system that uses public waters in Minnesota requires a National Pollutant Discharge Elimination System (hereinafter referred to as NPDES) permit.[24] Other potential costs Minnesota producers might incur, depending on their operation, include: aquatic farm license, initial inspection for all licensed facilities, initial inspection of each public wetland (rearing pond), pond acreage fee, water appropriation permit, and/or an annual fish health inspection if the farm discharges effluent to public waters.[25]

5. Some producers closing due to change in demand

   Minnesota food-fish producers are mostly producing high-quality, high-price products. As a result, the target market for producers is mainly fine dining restaurants, which charge end consumers more than $25 on average for a meal.[26] During 2020, due to the COVID-19 pandemic, upscale restaurants significantly reduced or stopped purchasing

[24] See details at: https://www.pca.state.mn.us/water/wastewater-permit-fees
[25] See details at: https://www.dnr.state.mn.us/fishing/commercial/af.html
[26] Calculated based on client information on local producer websites

from aquaculture producers due to restricted indoor dining[27] and demand was limited for carry-out meals from these upscale restaurants.

Due to the significant decrease in demand from these restaurant buyers, producers experienced a resulting decrease in revenues and an oversupply of product.[28] Producers were not prepared for this shift, and some reported giving away their product because of their inability to continue to maintain it live and its extremely short storage shelf life.

6. Less optimal investment and profit margin caused by inexperienced business planning

   Similar to the daily operations, business planning for the aquaculture industry is also complicated. The industry requires substantial initial investment. Finding locations, designing systems, and purchasing facilities are costly early activities that occur well before any production takes place or any profits can be made. However, most of the interviewed producers did not consider the cost-effectiveness of each investment.[29] Some producers bought cheap supplies during initial setup of operations and had to upgrade them very soon,[30] while some producers invested in facilities that they later determined were unnecessary. In general, inexperienced business planning appeared to be related to struggles or even closure of some producers.

7. Few producers for each species, while producers of each species face different operational challenges

   The Minnesota aquaculture industry is small relative to its counterparts in marine coastal states. Minnesota has only two or three producers for each species (e.g., shrimp, trout). Each producer interacts separately with suppliers and buyers, with little awareness of

[27] Multiple governor's orders regarding indoor dining in Minnesota during 2020, see an example from the December 2020 order at: *Frequently Asked Questions: Bars, Restaurants, and Other Places of Public Accommodation INFORMATION ON RECENT EXECUTIVE ORDERS FOR THE HOSPITALITY INDUSTRY AND ITS REGULATORY AGENCIES*, 12/24/2020

[28] *Supply Chain Effects of Restaurant Closures*, by Eva Koronios, Industry Research Analyst, Apr 17 2020

[29] One aquaponic producer (interviewed in November 2020) claimed to be far from breakeven after operating for 8 years, while other producers interviewed had difficulty calculating investments and payback

[30] An industry expert from InCity Farms (interviewed September 2020) said that small producers sometimes follow large-scale producers when purchasing facilities, without considering the suitability for their small operations. For example, automated processing will cause the loss of up to 10% of fish yield, which is affordable for large operations but not for small producers with profit margins of less than 10%

what others in their industry may be doing. Additionally, each producer is fairly small in terms of total production, and therefore, has limited bargaining power with suppliers and buyers. Producers also face diverse operational challenges which need to be addressed individually.

6. Recommendations

Commercial Fishing Recommendations

6.1 Seasonality Solution

One of the main problems in the commercial fishing industry is the supply and demand mismatch that occurs seasonally. In the fillet season, which is the entire year excluding November, there are low to moderate supplies of fish, sufficient processing capacity, and enough demand to meet supply. Conversely, in the roe season (November), fish supply is very high, and fishers do not have sufficient capacity to process as many fish as they are able to catch.[31] Therefore, fishers fish less than they are able to because processing is a bottleneck.

Additionally, in November, the fish contain valuable roe (fish eggs) which can be sold for a much higher price than fillets. Although there is international demand for roe, there is currently only one roe buyer in the region, creating a monopoly. Some fishers choose not to work with the buyer because they believe they are underpaid for their product. Therefore, some fishers waste their valuable roe rather than sell it at a low price. Further, in roe season, many local restaurant buyers have closed for the winter, so there is minimal local demand for fillets. This means that fishers catch the most fish when their market is limited, and therefore, they sell their fish (and sometimes roe) at very low prices.

A solution to the problem of surplus fish in November may be overcome by partnering with a willing processor/distributor. A potential partnership between North Shore fishers and a willing processor/distributor might provide a preliminary solution to the seasonal supply surplus and processing bottlenecks. In addition to processing and marketing fillets in November, adding

[31] All commercial fisheries in the Lake Superior area are one-person or one-family operations, which lack the labor for processing fish quickly

additional roe buyers may increase competition and potentially increase the price fishers may receive for their product.

The next step in this solution is to explore the willingness of potential processors/distributors to meet with Lake Superior fishers and determine if a partnership model is feasible. Such a partnership/arrangement would stabilize the commercial fishing industry and create a more resilient supply chain, while ideally providing a win-win opportunity for both parties.

6.2 Increased Profit Solution

A significant problem threatening the economic sustainability of the commercial fishing industry is that most fishers are not able to make a full-time living from fishing. Low returns on financial and labor investments, seasonal employment, the necessity of a second job, and the nature of the hard work of fishing mean that the industry is relatively unattractive to possible new entrants. The low inflow of industry participants, combined with an aging population of fishers and few apprentices, pose a threat to the long-term survival of the industry.

One way to address this sustainability issue is to enable fishers to get a high enough price for their product so they can make a living from fishing. Empowering fishers with the information they need to negotiate for higher prices for their fish and roe may provide an avenue toward improved economic sustainability.

A solution that may assist fishers is to develop a breakeven cost calculator (Figure 3) available on a website or as an app. Producers enter information such as license cost, permit cost, fuel cost, equipment cost, labor cost, and pounds of harvest to determine their break-even price, that is, how much they need to charge per pound of unprocessed fish to be profitable. If producers calculate how much money they need to charge per pound to break even, they have a reasonable starting point for negotiating with buyers.

Expenses:	
License(s)	$3,000
Permit(s)	$1,000

Fuel	$8,000				
Equipment	$10,000				
Labor	$50,000				
Total	$72,000 /	Harvest	80,000 =	Price per pound	$0.90

Figure 3. Breakeven cost calculator.

6.3 Supply and Demand Mismatch Solution

There is a significant supply and demand mismatch in the industry that varies seasonally and is driven by a lack of coordination among buyers and sellers. While the industry may not yet be mature enough for a formal co-op, a Facebook group page to connect buyers and sellers can be a first step toward greater coordination in the industry (Figure 4).

The purpose of a Facebook group page is twofold. First, fishers can post information about their excess supply, and restaurant or consumer buyers can contact them with interest to purchase. Second, potential restaurant or consumer buyers can post when they are looking to buy and can then coordinate with potential sellers. A Facebook group page enables fishers to connect with additional buyers that they might not otherwise find. Through this informal bidding system of fishers offering product and buyers making offers to purchase, fishers can choose to sell to the buyer offering the highest price.

We propose that a Facebook group page for the commercial fishing industry be established that includes local restaurants, grocery stores, and commercial fishers invited as group members. Allowing these parties to invite others into the group will help the group to grow in size, increasing the involvement of both buyers and sellers. Once the Facebook page is set up and buy-in is achieved through conversations and an invitation, the page should be more or less self-sufficient and not require significant maintenance or resources. As a consideration, due to the

geographical distances between docksides, there could be one Facebook group established per fishing zone.[32]

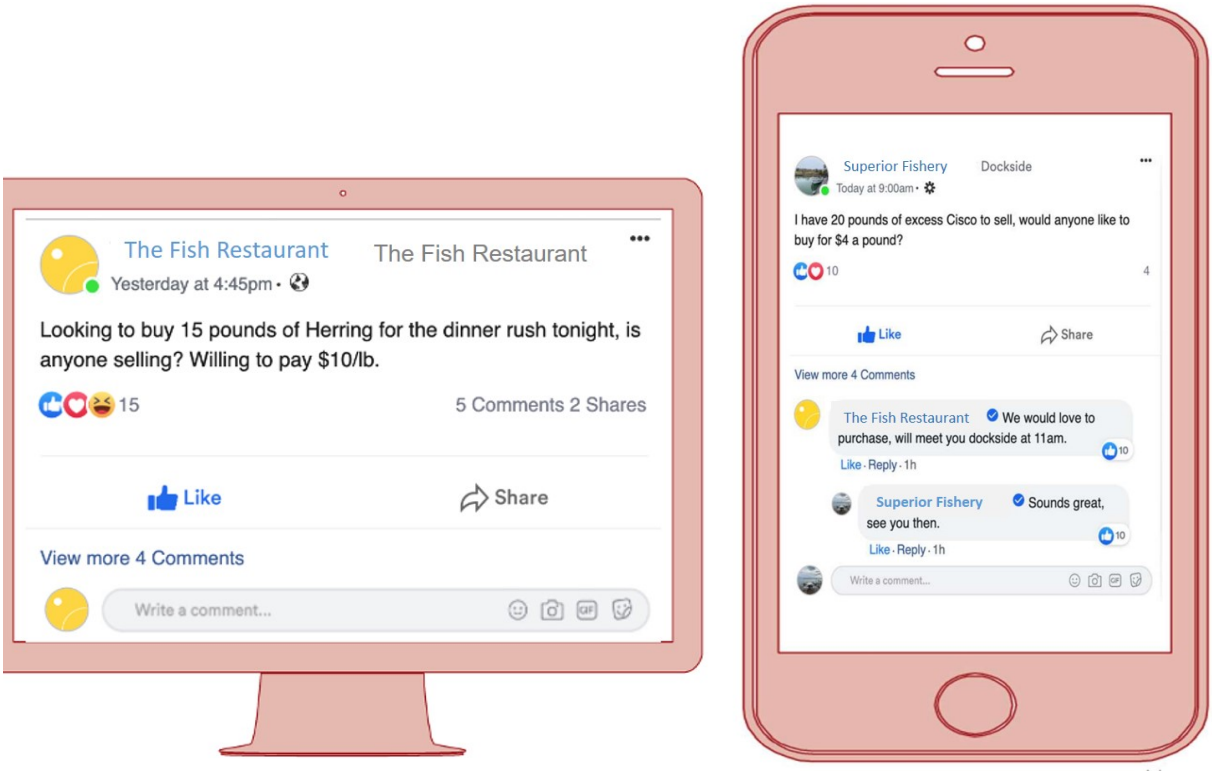

Figure 4. Sample posts in Facebook group.

6.4 Preservation Solution

Unlike a straightforward manufacturing environment where supply on a given day is known and predictable, fish harvests depend on fish behavior, weather conditions and other factors that can vary day to day. Because of this, a preservation solution can help even out supply levels so that there is a steadier level of supply each day. With a preservation solution such as vacuum packing, fishers are able to sell fresh, unfrozen fish from one to three days after they are caught. With vacuum packing, refrigerated fillet shelf life increases by three days and when frozen increases by one year. Vacuum-packed "perishable foods can maintain their freshness and shelf

[32] The Lake Superior commercial fishing area has three zones. Zone one is from French River to the Encampment River. Zone two is from Encampment River to Poplar River. Zone three is from Poplar River to Grand Portage

life three to five times longer than they naturally might."[33] This serves to both even out daily supply levels and to enable fishers to sell fillets at a higher price than non-vacuum packed fillets. Pricing information could not be verified but was repeated by many of the North Shore fishers. Further, vacuum packing provides a high-quality product because it preserves flavor, moisture, and weight, and it prevents freezer burn and discoloration when frozen.[34]

An industry standard commercial vacuum packing machine costs approximately $3,000 to $4,000 per machine.[35] Outside funding could be pursued to cost-share or purchase a vacuum packer depending on the assessed cost-benefit of providing machines to the industry. We recommend that between three and five of the commercial fishers with the greatest harvest to quota ratios be prioritized to cost-share on a vacuum packing machine. This prioritization will ensure that the machine is going where the need for processing capabilities is the greatest. Additionally, we recommend that participating fishers are required to have an apprentice or partner to ensure that an additional machine is put to use.

Aquaculture Recommendations

6.5 Improve Sourcing for Postlarvae and Embryos

Minnesota producers of both shrimp and Rainbow Trout report suffering high mortality rates for postlarvae and embryos caused by long-distance transportation from their source. Additionally, producers often use a single supplier source and, because this supplier stopped shipping during 2020, some small-scale producers chose to close or downsize their operations. Producers of each species reported during interviews that they plan to begin raising their own postlarvae and embryos in the future. These producers further stated that once their own demands for postlarvae or embryos are met they would be willing to sell their excess supply to other local aquaculture producers. Researchers from the University of Minnesota are also currently working to develop

[33] *VACUUM PACKAGING IS A TOOL FOR SHELF LIFE EXTENSION OF FISH PRODUCT*, by Patil, A & Chogale, Narendra & Pagarkar, A & Koli, J. & Bhosale, Bhaskar & Sharangdhar, S & Gaikwad, Bhavesh & Kulkarni, G.N., 2020

[34] *VACUUM PACKAGING IS A TOOL FOR SHELF LIFE EXTENSION OF FISH PRODUCT*, by Patil, A & Chogale, Narendra & Pagarkar, A & Koli, J. & Bhosale, Bhaskar & Sharangdhar, S & Gaikwad, Bhavesh & Kulkarni, G.N., 2020

[35] Average price point found for machines similar to those currently owned by North Shore commercial fishers at https://www.ultrasourceusa.com/ultravac-225-chamber-vacuum-sealer.html

fish embryo cryopreservation technologies. This new technology is mainly focused on species preservation since it can help to ensure against loss of aquatic species due to reproductive failures, environmental degradation, or invasive species proliferation.[36] This technology is useful for producers as well because it has the potential to preserve postlarvae and embryos for operations and to allow year-round availability of embryos.[37]

First, because most shrimp and Rainbow Trout producers currently source embryos from a single supplier, we recommend they develop knowledge and relationships to allow sourcing from multiple suppliers. Using multiple sources may increase some costs, such as higher prices per unit, due to smaller orders sizes for each supplier or higher total transportation costs, but it can reduce supply chain risks associated with supplier failures (e.g., poor quality, failure to deliver) and higher levels of supplier power.[38]

Second, local producers may soon[39] be producing postlarvae and embryos. In interviews, they expressed a willingness to sell their excess supply to other aquaculture businesses after their own needs are met. This provides a potential local source for small-scale producers. This may help reduce the high mortality rate of the postlarvae and embryos that occur during long-distance transportation. This type of local sourcing further serves to enhance cooperation among the producer community, which is likely to have additional benefits including knowledge transfer and economies of scale regarding sourcing.

Third, the embryo cryopreservation technology development and related research at the University of Minnesota may increase the effectiveness of suppliers. However, since this is still an emerging technology, we recommend MNSG encourage local producers to work closely with researchers and/or monitor their progress to share the research results so producers better understand the opportunities and risks associated with the technology before going all-in.

[36] *Behind UMN research, a "cool" breakthrough in cryopreservation*, by Sydney Baum-Haines, July 17, 2017
[37] Based on interviews with University of Minnesota researchers Kieran Smith and Marc Tye
[38] *Benefits and Risks of Single Sourcing*, by North Carolina State University Supply Chain Resource Cooperative, November 11, 2004
[39] One trout producer interviewed aims to start producing trout embryos in 2021

6.6 Encourage New Revenue Streams

Prior to the 2020 sharp decline in demand for aquaculture products due to the COVID-19 pandemic, local producers were able to sell all their output fresh and distribute immediately after harvest. However, during the pandemic, many restaurants closed and some producers had no contingency plan for selling their product elsewhere, nor the capacity for preserving and storing their product for future sales. There was significant waste among some producers because fresh fish has an extremely short shelf life, and the window for producers to find new buyers was too small.

While the demand decrease caused by the COVID-19 pandemic may not occur again, producers may struggle with future demand shifts caused by other reasons. To help them better prepare for unknown future risks and challenges, we recommend encouraging producers to explore new revenue streams by way of creating new products, applying new business models, and establishing relationships with new buyers.

a. New products

Local producers can consider introducing new value-added products that are based on processing fish (or other seafood) into other products. For example, smoked fish is an effective way to increase product value with limited investment in new equipment but with risk associated with contamination; fish oil significantly increases product value, but requires large processing investments and probably does not apply to currently grown species; fish meal and fish cake are additional options, but both destroy value compared to the original fish fillets. See Table 3 for details of these value-added products.

New Product	Equipment	License	Value Added	Risks
Smoked Fish	Smoker: $2K-$50K. Vacuum sealer: $300-$3K	Retail license	~75%	High risk of contamination during processing
Fish Oil	Cooker, Press, Centrifuge, Evaporator	Standards imposed by purchasing entity or third-party to check for purity	Varies, for some species >100%	Not applicable for most Minnesota species, need to build and maintain

				relationship with large buyers
Fish Meal	Cooker, Press, Evaporator, Centrifuge, Dryer, Grinder	Standards imposed by purchasing entity	Destroy value: ~$0.65 per pound, lose ~80% yield	Lots of equipment needed
Fish Cake	Fishcake maker, Blender, Fryer	Food handler's license, standards imposed by purchasing entity	Destroy value: ~$4 per pound, with investment in other ingredients	Very small market in the United States

Table 3. Examples of new value-added products.

As many of the new value-added product options require different types of investments, it is worth noting that these investments introduce new risks for producers. Producers, when considering cost effectiveness, market size, and risks of each investment, can use the cost calculator described under "Other Recommendations" (below) to learn about the payback period.

b. New business model - fee fishing

Aquaculture producers who use ponds for their business can generate new revenue streams by adding fee fishing to their business model. With the closure of traditional entertainment options caused by the COVID-19 pandemic, consumers are craving socially distanced, family friendly, weekday and weekend activities. Pond fishing fits these needs for the local or regional community.

Producers can charge entrance fees for consumers to fish at their production ponds. More revenue can be generated by charging consumers for the fish caught as well as the follow-up cleaning, processing, and transportation. Two producers[40] initiated fee fishing at their facilities in 2020 and charge 200% more per pound than they were getting from restaurants. One producer made 50% more revenue through fee fishing compared to traditional restaurant sales.

c. Find new buyers

[40] One in Minnesota and one in Wisconsin

Most aquaculture producers report that they have been selling their product exclusively to local fine dining restaurants. To further develop supply chain resilience in terms of downstream buyers, producers can expand their business sales channels both locally and nationally.

We recommend MNSG or the Sea Grant Great Lakes Aquaculture Collaborative (hereinafter referred to as GLAC) post a producer map on its website, including producer addresses and contact information. Also, inform relevant groups like the Minnesota Aquaculture Association (hereinafter referred to as MNAA) of the map's availability to producers. A marketing effort can remind potential buyers that there are options to purchase directly from producers. This aligns with local and global trends among consumers to have more information and understanding of the sources of their food. MNSG can also feature stories or new products of local producers to help raise the awareness of shop locally.

Producers can also investigate options for working with national buyers such as Walleye Direct[41] and Local Catch[42] during periods of low local demand. The prices per pound of product will likely be relatively lower than restaurants' direct purchases, but this may be a way to use inventory that might otherwise become waste.

6.7 Introduce Co-op Model Once Industry Matures

Due to the low number and small size of Minnesota aquaculture producers, a robust co-op is not an option during 2020. Potential benefits of a co-op include helping local producers improve their bargaining power with suppliers and buyers (customers), expanded market access and broader market opportunities, reduced costs, improved product or service quality, and as a result, increased income.[43] Due to these potential benefits, we recommend introducing a co-op model once the aquaculture industry matures.

[41] https://www.walleyedirect.com/
[42] https://localcatch.org/
[43] *Aquaculture Cooperative Establishment and Management Guide*, Daniel Burden, Extension Value-added Agriculture and the Agricultural Marketing Resource Center, Iowa State University, 17 October 2014

Minnesota currently has a limited number of small-size and middle-size producers, and very few producers for each particular species. The challenges and needs for each producer size and each species can be unique. Co-ops tend to function most effectively when members share similar size and similar challenges (for example, similar species). As new producers enter the industry, a group of similar-sized producers can be formed as the first step toward establishing a successful co-op. Enticing new industry entrants may require tactics such as sharing more information on environmental benefits of the industry, free training and boot camps, and assisting the funding for licenses.

One challenge identified during interviews with small-size producers is that they lack familiarity with working as a group within their industry. We recommend MNSG initiate test-runs of small-scale cooperation and partnerships in order to determine which types of cooperation are most effective and to help producers understand the benefits of working together.

Other Recommendations

6.8 Enhance Educational Materials

General knowledge of aquaculture operations, biology, and business are among the key challenges shared among Minnesota producers across different species. This complex, wide-ranging, and developing industry is currently served by a variety of information outlets, but there is no consensus on which sources of information are most useful or contain the best general knowledge. Some information sources are not reliable and their suggestions may be untested and unproven; some information is only relevant to a particular type of aquaculture or species. Sifting through the available online information is difficult and discouraging for new entrants. Thus, we recommend enhancing educational materials on associated official (e.g., Sea Grant) websites in order to improve local producers' operational and biological knowledge and business decisions. Three suggestions are outlined below.

a. Training content

A more intuitive layout of relevant content will help both current producers and potential industry entrants navigate among useful information. Currently, there is a wealth of knowledge about aquaculture on MNSG and GLAC official websites. However, about

70% of the videos are research-related and only 6% are directly linked to aquaculture day-to-day operations.[44] We recommend MNSG and GLAC reorganize and categorize their current content in a way that is more easily understood (Table 4), while identifying and filling any information gaps regarding daily operations.

		Shrimp	Perch	Perch
Short videos for operational questions	Selecting a system and facility			
	Maintenance and upkeep			
	Introducing larvae/embryos			

Table 4. Example of website content.

b. Cost Calculator

A preformatted calculator (Figure 5) can assist producers in understanding the financial impact of various investments. Using the calculator, producers can calculate the payback period of investments as well as the potential impact of setting a variety of prices. The impacts of relevant costs and income, such as utility costs and the changes in yield, are built into the calculation effects.

Costs:		**Income:**	
Equipment	$50,000	Fish price per pound	$4 per pound
Permit(s)	$2,000	Annual output	19,000 pounds
Labor cost change (+/-)	-$30,000	Weight yield change with new equipment	-5%
Utility cost change (+/-)	$10,000		
• It will take 1.77 years to cover the equipment cost if product price is unchanged. • Product price needs to be raised by $2.88 per pound if you aim to cover the cost in one year.			

[44] Among MNSG videos on MNSG YouTube channel (https://www.youtube.com/user/MNSeaGrant/videos) in the last three years

Figure 5. Sample cost calculator.

c. University Resources

We recommend continued collaboration with the University of Minnesota to provide a variety of types of support to local producers. We share a few examples here.

Operational and biological knowledge needed by producers may be deliverable via an on-site aquaculture boot camp[45] designed to help new entrants understand basic information about the industry. Online webinars[46] covering specific aspects of the aquaculture industry can help both new entrants and established producers learn more on particular topics. Biology students trained in aquaculture could conduct field trips to individual farms and provide consulting programs to address common questions and challenges during operations.

In terms of business knowledge, MNSG can facilitate creating a bridge between producers and business school students with options to develop business student consulting programs for those engaged in or interested in the aquaculture industry. Students can assist with analyzing costs, pricing, and cash flow for producers, and can provide justification (or disapproval) for a variety of investment options. MNSG can also assist with marketing and communication programs for local producers, encourage producers to join local industry networks, and consider employing a dedicated intern to manage social media in order to increase exposure of local aquaculture to potential buyers.

6.9 Raise Awareness of Energy Efficiency

Energy is one of the largest operating costs among local producers and therefore points to important considerations while creating a business plan. If not designed properly Minnesota producers using indoor systems can incur significant energy costs during winter.

[45] Example from University of Wisconsin - Stevens Point (https://www.uwsp.edu/cols-ap/nadf/Pages/Aquaculture-Boot-Camp.aspx)
[46] Examples from GLAC (https://greatlakesseagrant.com/aquaculture/webinars/)

We recommend developing producer awareness surrounding energy costs and energy efficiencies during business planning. For example, although greenhouses can decrease the need to use grow lights during certain seasons, traditional insulated building structures tend to perform better in terms of reserving heat. Further, high-pressure sodium (HPS) lighting systems are less expensive to purchase, but light-emitting diode (LED) lighting systems are more energy-efficient in the long run.[47] These types of factors (i.e., purchase price versus cost of longer-term use) are sometimes overlooked during business planning. Through increased awareness of these costs, as well as awareness of the difficulties in transitioning to different systems later, producers can be aided in making more cost-effective decisions.

6.10 Shed Light on Regulatory Costs

The Minnesota aquaculture industry is highly regulated. Industry awareness that addresses explanations for and a deeper understanding of the applicable regulations may be beneficial.

We recommend that MNSG work with Minnesota Pollution Control Agency (hereinafter referred to as MPCA) and MNDNR to identify ways to clearly communicate the step-to-step processes of applying for and obtaining necessary permits. Producers are currently receiving second-hand misinformation, resulting in a variety of misunderstandings regarding local regulations. In addition to step-by-step process guidance, explanations of the purpose for various regulations may serve to reduce misunderstandings and improve industry and environmental knowledge. Further, aquaculture producers and other industry participants who feel fees are unreasonable should be encouraged to contact the appropriate agency to express their concern and gain a better understanding of the issue.

7. Conclusions

Commercial Fishing

The Minnesota commercial fishing industry is crucial to the culture and livelihood of the North Shore but is plagued by a variety of problems that threaten its profitability and long-term sustainability. Problems include aging industry players, a supply and demand mismatch, low

[47] *The Great LED Grow Lights Vs HPS Grow Lights Debate*, Devin Martinez, October 3, 2013

prices for the fishers' products, a lack of preservation options, processing labor, and a monopoly in the roe export market. However, solutions for these problems may be feasible with participation of industry players and with assistance from MNSG and other organizations.

The problem of aging industry players can be addressed by making the industry more profitable so that new entrants are attracted into the industry. We recommend that the supply and demand mismatch could be addressed by the creation of market efficiencies through encouraging collaboration via a Facebook group page and eventually a co-op as the industry becomes more stable. Fishers' profits are inhibited by receiving a low price for their product, and so a cost calculator can help fishers' negotiating capabilities with their buyers by providing them with suggested starting points for the price of their product. The lack of preservation options in the industry reduces the amount of sellable catch during peak season. Obtaining funds to support investment into vacuum packing technology can allow fishers to sell more of their catch by extending the freshness window by three to five days and much longer if frozen. Similarly, a lack of processing labor causes bottlenecks during the peak harvest season. A strategic partnership with a willing processor/distributor during the roe season that enhances profitability among all parties could provide much-needed labor to process and market surplus product while increasing job opportunities. Lastly, the current monopoly in the roe export market can be remedied by the addition of other roe buyers into the market.

Aquaculture

The Minnesota aquaculture industry is in an early developmental stage. There are a small number of producers and their key challenges vary. Supply chain challenges such as single supplier sourcing of postlarvae and embryos and lack of alternative revenue streams are important for a few of the producers. For these supply chain challenges, we recommend producers diversify their postlarvae and embryo sourcing through multi-supplier and local sourcing. We also encourage new revenue streams, value added products, and once the industry matures, introducing a co-op model to strengthen producer standing in the industry.

We note that many of the observed supply chain challenges are symptoms of a greater underlying issue regarding producer knowledge and experience. Because the Minnesota aquaculture industry is relatively new, general knowledge of operations, biology, business planning, and regulations are key challenges shared among local producers. Therefore, along with our supply chain recommendations, we also recommend efforts to increase knowledge management in the industry. For example, websites that can be developed or improved by MNSG, GLAC and MNAA could help local producers to increase their knowledge in particular areas of need. Continued collaboration among MNSG and various departments at the University of Minnesota could provide continuous business and operational support for producers, while collaboration among MNSG, MPCA, and/or MNDNR could foster improved understanding of Minnesota's strict regulations. Bolstering general knowledge among key players in this industry will provide a more stable foundation on which current and future producers can thrive.

8. Next Steps

Proposed next steps from this study

Commercial Fishing

- Facilitate discussion among potential processors/distributors and commercial Cisco fishers
- Explore development of a cost calculator and business seminar to help commercial fishers understand their costs, earnings, and product value
- Create an online tool (e.g., Facebook page) to connect fish sellers and buyers
- Procure funding to purchase (i.e., cost-share) vacuum packing machines for the top Cisco producer in each zone

Aquaculture

- Enhance educational materials on official (i.e., Sea Grant) websites to improve local producer operational knowledge and business decisions
- Explore development of a cost calculator and business seminar to help local producers understand the financial impact of investments
- Work closely with University of Minnesota to introduce continuous business and operational support for producers

- Work with MPCA and/or MNDNR to foster improved understanding of Minnesota's aquaculture regulations
- New industry entrants to improve awareness of energy efficiency during business planning
- Established producers to share knowledge and practices with other producers on small scale projects in order to test and work towards a co-op model

Future studies/projects to pursue

- Encourage producers to attend aquaculture boot camps and webinars to help both established and new producers better understand the foundational knowledge of the aquaculture industry
- Assist with development of a marketing campaign to help local producers sell directly to end consumers

Appendix: Frequently Asked Questions

1. Who are the key buyers for commercial fisheries?

   Local restaurants, local grocery stores, individual local consumers, Interlaken Fisheries International.

2. What is the definition of dockside price?

   The price per pound of a whole, unprocessed fish caught straight from a lake. Also referred to as "in the round."

3. How do permits and licenses work on Lake Superior?

   There are 25 authorized commercial fishing licenses for Lake Superior in Minnesota. Fishers must have a license to fish in any of Lake Superior's commercial fishing zones. Under those licenses, fishers must apply for permits to fish for specific commercial fisheries. Commercial fishing license owners must apply for a permit to fish Cisco during November.

4. What is causing the large decline in dockside prices?

   Due to the scope of the project, we were unable to identify the reasons for the steady decline in dockside prices. But based on interviews, some producers mentioned that they do not want to "ruin relationships with the current buyers" by raising prices.

5. What are the 'zones'?

   There are three management zones in Minnesota's portion of Lake Superior. Zone one runs from the French River to Encampment River. Zone two starts at Encampment River and runs to the Poplar River. Zone three runs from Poplar River to the Canadian border.

6. Are buyers willing to accept vacuum-packed products?

   Yes, fishers report that they are able to sell fillets when vacuum packed.

7. What are NPDES and SDS?

National Pollutant Discharge Elimination System and State Disposal System**.**

8. What agency regulates NPDES permits?

   Minnesota Pollution Control Agency (MPCA) and Environmental Protection Agency (EPA).