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Agricultural Utilization Research Institute

Minnesota Aquaculture:

Opportunities & Challenges

2020/2021

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EXECUTIVE SUMMARY

Globally, aquaculture is one of the fastest-growing food industries. The key drivers are technological developments, increased production, and growing understanding of the health benefits of fish consumption. As populations grow, there's an even greater need for a sustainable source of protein that can keep pace with demand.

Since 2016, according to the Food Agriculture Organization of the United Nations, aquaculture has served as the primary source of fish available for human consumption. Bolstering the U.S. food fish aquaculture industry could, therefore, offer long-term food security benefits. Concurrently, positioning Minnesota aquaculture as environmentally friendly, sustainable and healthy could help more local producers gain market awareness and market share.

Only about one in five Americans are considered frequent fish and seafood purchasers. This may be changing, however. Despite the COVID-19 pandemic, the fish and seafood sector saw record sales across multiple categories. As more Americans gravitate toward fish and seafood, with many citing health benefits as an incentive, opportunities may exist for Minnesota's aquaculture industry to become an even greater resource for supplying fresh, unique products to these consumers. In a survey that was part of this research initiative, for instance, Minnesota consumers indicated that their purchases of fish in either grocery stores or restaurants may increase, particularly for select species.

As other research has shown there is still significant debate over which species would be most successful in Minnesota. Atlantic salmon, Arctic char, shrimp, trout, walleye and yellow perch appear to have promise, among others. Through this study, over 40% of respondents reported a likeliness to purchase shrimp and walleye more frequently if Minnesota-raised options were available. Similarly, nearly 40% indicated their purchase of salmon would increase as well.

Consumers also indicated a willingness to pay more for fish and shrimp products with certain aspects. Over a third reported they would pay more for products raised in Minnesota and those sustainably raised, and nearly half agreed they would pay more for fish products that benefit the state's economy. Fifty-seven percent, however, said that being able to locate Minnesota raised fish at retail is a potential barrier to purchase (57%), and knowing how to cook it could also be a prohibitive factor (47%).

Minnesota has a rich history of fishing, but it wasn't until the 1980s that interest in developing an aquaculture industry escalated. While many food fish aquaculture businesses have since launched across the state, not all have prospered. Now, as consumer demand for locally grown fish increases, food fish producers and those with aligned interests in growing the aquaculture industry across the state, are looking for solutions to improve viability.

The State of Minnesota recognizes aquaculture (privately raising fish or other aquatic life) as agriculture, considering farmed fish to be a type of livestock. The Minnesota Department of Agriculture (MDA) therefore provides development assistance, with regulatory authority residing within the Department of Natural Resources (DNR). Several other organizations work actively to further the aquaculture industry such as the Minnesota Aquaculture Association (MNAA), Minnesota Sea Grant, the Great Lakes Aquaculture Collaborative (GLAC) and the University of Minnesota.

In order to better understand impediments to the growth of Minnesota's aquaculture industry, experts have identified several significant hurdles. These challenges include pairing species with effective production systems, developing disease management protocols, identifying cost-effective fishmeal alternatives, navigating complex and changing regulatory systems, having ready access to meaningful market research, obtaining financing and establishing economically viable operations.

Fish nutrition varies by species, but many carnivorous farm-raised fish need a source of protein in their diet. Traditionally, fishmeal has been this source of protein, but high demand and limited

supply have caused the price of this feed to increase significantly. Currently, there's a push to find alternative aquaculture feeds. Through significant research efforts, scientists have already identified some promising alternative sources of protein, such as soybeans — a Minnesota-grown crop that could align with this need.

Fish and seafood waste from the aquaculture sector also present a value-add opportunity for producers and is a more environmentally conscious way of sourcing fish to be used in fishmeal, or feed, because it doesn't rely on wild stocks.

Also, without question, greater market research is needed to help producers realistically gauge supply and demand for the species they intend to produce. Some studies are currently underway, and more are needed.

But beyond the work already in progress, what else holds promise for further establishing – and growing – the aquaculture industry's success?

Figure 1. **Commercial fishing on Lake of the Woods. (Source: Dobie, John, n.d.)**

Recommendations

To address industry challenges and maximize opportunities, the following action steps are recommended for consideration.

Educate

- Compile research on key markets and realistically gauge supply and demand for the species intended to be produced.
- Fully define the economics of growing, processing and marketing products.
- Further determine, as an industry, the purchase decision-making of customers, price sensitivity and industry growth potential.
- Provide operation-specific technical support to producers to help them gain best practices knowledge.
- Conduct production risk assessments and develop mitigating protocols based upon findings.
- Learn from other states to establish Minnesota-based university preparatory training for future production and leadership talent.

Finance

- Nurture an investment environment more favorable to stimulating innovation and market development, by exploring increased access to capital, particularly for developing sustainable products for new or existing markets.
- Consider financial support through tax incentives, grants or special economic zones.
- Invest in research and development.
- Adequately fund research to fill information gaps, particularly within understanding consumer perceptions and demand, as well as further exploration of optimal business models, best practices, and technical efficiencies.

RECOMMENDATIONS

Figure 2. Aerial view of the Superior Fresh greenhouse and fish house in Hixton, Wisc., (Source: Superior Fresh, 2021)

- Provide financial resources to support onsite assistance to manufacturers to further encourage production refinements and innovation.

Collaborate and Support

- Support the efforts and expand the impact of the Minnesota Aquaculture Association to help shape vision, policies and success within the industry, ensuring the organization encompasses members from all dimensions of the aquaculture value chain.
- Complete a thorough Minnesota aquaculture plan that details the opportunities, challenges and strategies needed to grow the industry through a defined path forward.
- Determine ways to more effectively bring fish processors, chefs, retailers and wholesalers into the aquaculture industry discussion.
- Foster industry and academic partnerships to support a strong research and development environment.
- Sponsor additional Minnesota-specific forums for sharing of best practices, such as the one held in 2017 that encompassed opportunities, challenges, trends and innovations.

Build Consumer Awareness and Demand

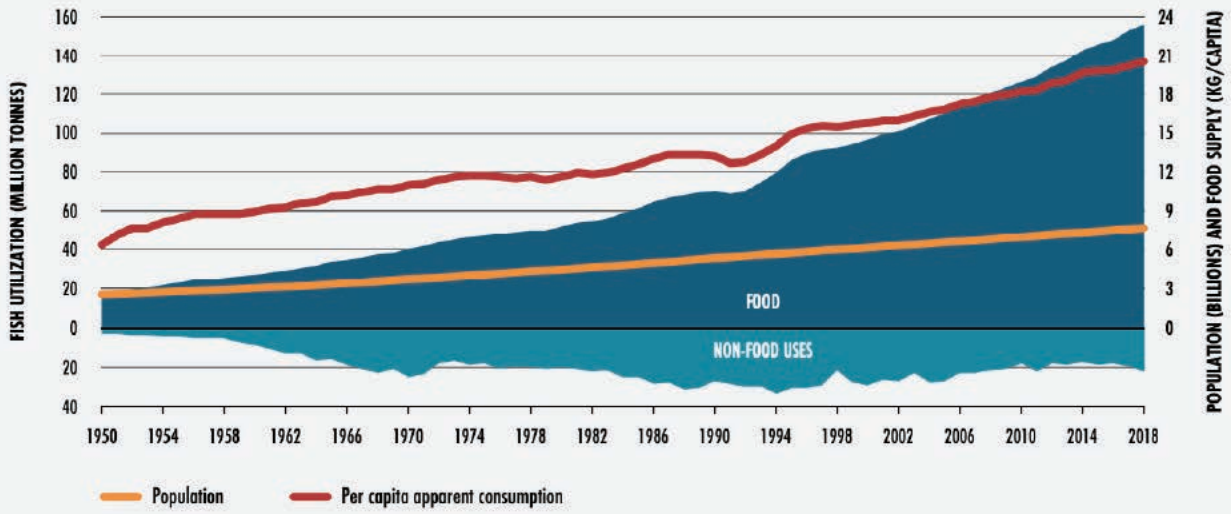
- Proactively shape awareness, attitudes and understanding of the availability of Minnesota farm-raised fish, and its inherent benefits among consumers, retailers/ restaurants, and the agricultural communities.
- Accurately position aquaculture operations and products in Minnesota whenever feasible as being environmentally friendly, a good source of protein, sustainable and energy efficient.

- Ensure clear point of purchase information through accurate nutritional and source labeling.
- Establish a website that provides clear information about food fish aquaculture products available in Minnesota and how to cook and prepare them, among other information to improve consumer knowledge base and comfort.
- Aggressively raise the industry's media profile about Minnesota aquaculture developments and economic potential.

Mitigate Potential Barriers

- Consider viewing aquaculture waste as an agricultural waste stream rather than industrial waste to simplify regulatory efforts.
- Leverage Minnesota's corn, soybean and wheat crops — and potentially other resources — to reduce the price of feed and the aquaculture industry's reliance on forage fish, while also creating market demand for crops in which the state is one of the nation's primary producers.
- Create a clear, positive regulatory environment for sustainability and permitting. Streamlining regulations and fostering proactive and collaborative engagement between government, academia and industry would be beneficial.
- Ensure adequate resources for fish disease detection and control, as well as introduction of new innovative treatments.
- Support continued advances in technology for facilities (RAS, bio-filters, thermal regulation, energy efficiency, water conservation, waste treatment, etc.).
- Streamline water quality regulations and develop a centralized location where food fish farmers can easily access the most up-to-date information.
- Consider hiring a state aquaculture coordinator to work closely with the University of Minnesota Extension Service, Sea Grant, the Minnesota Department of Natural Resources, the Minnesota Department of Agriculture and the Minnesota Pollution Control Agency to help ensure producers are up to date on everything from best management practices to regulatory information and markets.

AQUACULTURE FROM A GLOBAL PERSPECTIVE



Note: Excludes aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants.

Figure 3. **World fish utilization as compared to population and per capita apparent consumption (Source: FAO. 2020. The State of World Fisheries and Aquaculture 2020, p. 4. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en).**

Globally, aquaculture is one of the fastest-growing food industries. Technological developments, increased production, and a better understanding of the health benefits of fish are all said to be driving the increase. Per capita food fish consumption — fish eaten directly by humans — is also on the rise worldwide, reaching 20.3 kilograms (approximately 45 pounds) in 2017, which is up from nine kilograms (approximately 20 pounds) in 1961.[1]

"In 2017, fish accounted for about 17% of total animal protein, and 7% of all proteins, consumed globally," according to the Food Agriculture Organization. "Moreover, fish provided about 3.3 billion people with almost 20% of their average per capita intake of animal protein."

The FAO's The State of World Fisheries and Aquaculture 2020 report noted that from 1961-2017, the "average annual growth rate of total food fish consumption" outpaced the world's annual population growth rate. Data from that period also show that the average annual growth rate of total food fish consumption increased more than nearly all other animal proteins — except poultry. While these figures describe total food fish consumption, they still account for the significant role aquaculture plays in providing animal protein for people around the globe.[1]

"At the global level, since 2016, aquaculture has been the main source of fish available for human consumption," according to the FAO's The State of World Fisheries and Aquaculture 2020 report. "In 2018, this share was 52%, a figure that can be expected to continue to increase in the long term."

With the global population expected to reach nine billion by 2050, the World Bank expects the need for animal protein to continue increasing. Aquaculture, in particular, is viewed as an efficient and sustainable solution for keeping pace with world protein demand.[2]

Projections indicate that aquaculture production will reach approximately 120 million tons by 2030 — an increase of 32% from 2018. Inland finfish aquaculture remains the most popular globally, with approximately 51 tons produced in 2018. That same year, total inland aquaculture — which includes finfish, crustaceans and other aquatic animals — reached around 57 tons, accounting for 62.5% of the world's farmed food fish production.[1]

Overall, economists view aquaculture as a valuable production method capable of supplying protein to a growing population while protecting natural resources, creating new jobs and achieving global food security.[2]

Key Takeaways

As the world population continues to grow, organizations like the Food Agriculture Organization (FAO) of the United Nations expect the need for animal protein to increase. Aquaculture, in particular, is viewed as a sustainable way to keep pace with the growing demand for protein.

In 2018, aquaculture was the leader in fish production for human consumption, according to FAO estimates. Aquaculture production is expected to reach approximately 120 million tons by 2030, according to FAO.

NATIONAL FISH AND SEAFOOD TRENDS

Domestic Production/Demand

While the U.S. recognizes the important role aquaculture can play in preserving wild stocks and providing food security, it still lags behind other nations in food fish production.[3] Among industry-leading countries such as China, Indonesia, India, Vietnam, and Bangladesh, the U.S. ranks 17th.[4] As of 2018, the U.S. was the "leading global importer of fish and fishery products"[5] which, has contributed to the $16.8 billion seafood trade deficit.[4] Many experts view aquaculture as a way to bolster domestic fish production while also preserving wild stocks.[5] Currently, more than half of the fish and seafood the U.S. imports are products of aquaculture.[4]

> *"Consumers have been increasing [Atlantic salmon] consumption by about 7% a year for the last decade in the U.S., even with increasing prices."*
>
> Steve Summerfelt,
> Chief Science Officer,
> Superior Fresh[6]

Individual states are beginning to realize the economic opportunity that exists in building up an aquaculture industry, according to Ed Aneshansley, senior aquaculture engineer for McMillen Jacobs Associates.

> *"The demand for healthy protein sources is growing on a global scale, and Recirculation Aquaculture System (RAS) Technology offers a locally grown, sustainable solution. The shift from wild caught to farm raised seafood is already tipping in this direction and the demand will continue to grow in the future."*
>
> Ed Aneshansley,
> Senior Aquaculture Engineer,
> McMillen Jacobs Associates[7]

The U.S. aquaculture industry was valued at nearly $1.5 billion in 2018, with freshwater and saltwater production contributing $707 million and $397 million, respectively. This represents 21% of U.S. seafood and fishery products by value. While the overall value of the industry increased, combined production decreased to 626 million pounds in 2017, down 1.2% from the previous year.[4]

Key Takeaways

The U.S. lags behind other nations in food fish production, ranking 17th among industry-leading nations.

Aquaculture, in particular, is viewed as a sustainable way to keep pace with the growing demand for protein.

The federal government and many individual states recognize the role food fish aquaculture could play in restoring natural habitats and providing food security.

However, the number of food fish farms nationwide declined from 2013-2018, as did sales. In 2017, U.S. fish farmers produced 625.7 million pounds of fresh and saltwater aquaculture, a decrease of 7.8 million pounds from 2016.[4]

Understanding the Preferences/Interests of American Consumers

Times are changing, and so are Americans' preferences for fish and seafood. Despite the COVID-19 pandemic, new data presented during the National Fisheries Institute's Global Seafood Marketing Conference in February 2021 revealed record U.S. fish and seafood sales across multiple categories during 2020. Frozen seafood sales reached $7 billion, followed closely by fresh at $6.7 billion, according to a SeafoodSource press release citing data from IRI Worldwide. Salmon once again generated the highest sales in the fresh seafood department, followed by crab, shrimp, lobster, catfish, tilapia, cod, scallops, tuna and trout. Meanwhile, tuna remained the dominant species as a shelf-stable item and shrimp led the frozen category.[9]

Demographics-wise, the data revealed that Baby Boomers gravitated toward shelf-stable fish and seafood during 2020, while other generations, including millennials, Gen Z and some Gen Xers didn't "engage" or purchase as much of the industry's product. While the industry attracted many new consumers in 2020, the data showed that households with annual incomes of more than $100,000 still generally purchase more, and families with lower incomes tend to buy fewer fish and seafood products. With the pandemic driving a sales increase across the sector, leaders within the industry said it's important to evaluate how to get consumers to continue cooking seafood at home to maintain growth across all categories.[9]

This trend of increasing fish and seafood consumption, however, isn't new. In 2018, U.S. consumers ate 16.1 pounds of commercial fish and shellfish per capita, a notable trend after consumption peaked in 2004 with per capita consumption reaching 16.6 pounds of edible meat and began a steady decline after 2009, according to the Fisheries of the United States 2018 Report published by NOAA Fisheries. Seventy-six percent of the U.S. fish and seafood catch was distributed as fresh or frozen food, 17% was used in fish meal and oil, 3% was repurposed as fresh or frozen bait and animal food, 2% was canned, 1% was cured, and around 1% was used in canned animal food.[4]

> *"Estimated U.S. per capita consumption of fish and shellfish was 16.1 pounds (edible meat) in 2018. This was an increase from the 16 pounds consumed in 2017."*[4]

American consumers aren't alone in this trend. A 2018 online consumer survey for Cargill Animal Nutrition polled adults to better understand the animal protein supply chain. According to the Feed4Thought survey, 44% of American and British consumers said they started incorporating more fish into their diet during the previous five years.[10] Of those who had done so, nearly 75% said they did it for health reasons.

"I think people are going to continue to consume animal protein," Cargill's Chief Executive Officer Dave MacLennan told Bloomberg in a 2021 article. "We believe they're going to consume more fish over time. We're making investments in fish feed and in fish processing. That is a key part of our future strategy."[11]

In early 2021, Cargill, a food corporation based in Minnetonka, Minnesota, announced its intention to begin producing and processing seafood products.[11] The company is already one of the world's foremost fish feed producers and currently focuses on producing sustainable feeds by using "plant-friendly ingredients" and finding "ways to reuse by-products" that would normally be discarded.[12] While the company isn't currently invested in the seafood supply chain, it is actively seeking out opportunities.[11]

Although the Feed4Thought survey showed a promising upward trend in fish and seafood consumption, a different survey conducted by the Food Marketing Institute (FMI) found that nearly half of all Americans rarely if ever eat fish or seafood. However, those who eat fish and seafood value product quality and taste/flavor.[13]

The Power of Seafood survey conducted by FMI asked a statistically representative sample of U.S. grocery shoppers about their purchasing habits to better understand the nationwide market for fish and seafood. People who eat fish or seafood, according to the study, are more likely to be male, live alone, have a college degree and make more than $100,000 per year compared to non-fish

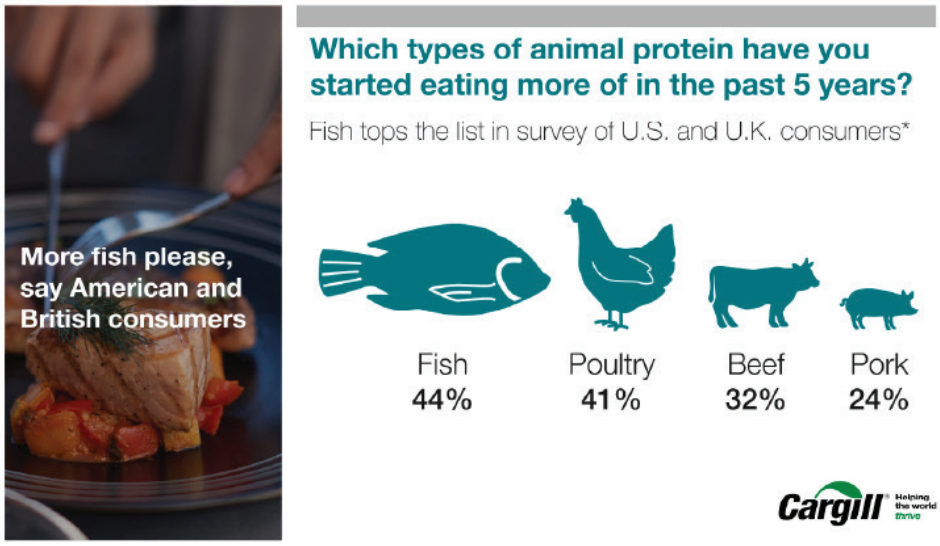


Figure 4. **The findings from Cargill's Feed4Thought survey illustrated above show that fish is among the top animal proteins U.S. and U.K. consumers added to their diets in the five years prior to 2018 (Source: Cargill, 2018).**

and seafood consumers. These shoppers also spend more per week on groceries than those who don't eat fish and seafood. Those who said they eat fish and seafood two or more times per week reported spending $143 each week on groceries. Meanwhile, less frequent consumers, who eat fish and seafood at least once a month, reported grocery bills of around $129 per week.[13]

Fish and seafood consumers, according to the survey, are willing to shop around for a quality product but admit that a reasonable price could lead them to make an "impulse" purchase.[13] A 2019 survey by Blue Circle Foods of primary decision-makers and shoppers also indicated that price is the leading determinate of their fish or seafood purchasing decisions.[14] While 42% of respondents from *The Power of Seafood* survey indicated that total price does influence their purchasing decisions, 58% and 42% said product quality and the taste or flavor, respectively, were also primary determinants. Eighty-five percent of shoppers also indicated that the freshness of fish or seafood has a significant impact on their consumption levels.[13]

> *"When you're looking at a protein price for fish, local fish farms have to compete with the international market. Farm-raised Atlantic salmon filet can be on sale for as low as $7.99 a pound. Wild-caught sockeye can sell for $9.99 a pound. That is the realistic price that local farmers are competing with. Some producers are finding unique, local markets, or partnering with local restaurants that are willing to pay more for a local, quality product."*
>
> Sean Sisler, Fisheries Program Consultant, Minnesota Department of Natural Resources[15]

The Power of Seafood survey respondents' shopping baskets were diverse, as they reported purchasing everything from shrimp and salmon to freshwater fish. Fish and seafood purchasing habits were relatively evenly distributed in terms of fresh versus frozen products. Forty-four percent of respondents said they sometimes purchase frozen fish or seafood and 33% indicated they buy it often. Of those who purchase fresh fish or seafood most frequently, 28% said they prefer to select from offerings at the counter, whereas 24% gravitated toward a self-serve option. Meanwhile, of the consumers who sometimes buy fresh fish or seafood, 43% preferred self-serve, while 37% selected items directly from the meat/seafood counter.[13]

Shrimp was the most popular frozen option among respondents to *The Power of Seafood* survey, while salmon was the favorite fresh fish and tuna was the leading canned option. Most fish and seafood consumers said they tend to purchase familiar products in the grocery store, but 39% said they like to try new types of seafood at restaurants.[13] This could indicate that restaurants can help lead the way in introducing different species to the fish and seafood consumer, and/or those who are not comfortable trying to prepare less familiar options.

Demographic Differences Among Fish and Seafood Consumers

The Power of Seafood survey indicated that only about one in five Americans are considered frequent fish and seafood consumers — a group food fish producers need to understand further.[13]

A 2017 nationwide survey of people who eat fish for at least three or more meals each week looked at the regional and demographic differences in self-caught and total fish consumption. Based on the results, researchers estimated that there are approximately 17.6 million high-frequency fish consumers in the U.S., or around 5% of the population. Among all respondents, shrimp, tuna and salmon were the most sought-after species, accounting for 50% of total consumption.[16]

Men and women reported eating statistically similar amounts of fish when body weight was considered. Total fish consumption was high among both "Black, non-Hispanic" and "Other, non-Hispanic groups," but the former (the "Black, non-hispanic") demographic reported eating the most on average compared to all races and ethnicities, at 124 grams per day.[16] In the West-North Central region, which includes Minnesota, the mean consumption was about 108 grams per day.[16]

About 10% of survey respondents reported eating self-caught fish. Based on this finding, researchers estimated that there are between 1.9 and 2.8 million frequent fish and seafood consumers who are also part of the recreational fishing population in the U.S.[16]

Overall, the survey revealed notable demographic differences among two categories of high-frequency, self-caught fish consumers. "The first, an ethnically diverse, lower-income and education cohort that may be consuming self-caught fish for subsistence purposes, and the second, a higher income and education cohort likely to be more of an avid recreational angler rather than subsistence angler."[16]

Researchers extrapolated that an estimated 660,000 people in the U.S. exclusively eat self-caught fish. While the majority of those individuals reported eating self-caught freshwater fish, anglers in coastal areas also added marine species to their plates. Among the exclusively self-caught anglers, eight species including trout, freshwater bass, salmon, cod, crappie, carp, catfish and perch represented more than 80% of their total consumption.[16]

According to the Minnesota Department of Natural Resources, the state's approximately 1.2 million licensed anglers had 5,400 fishable lakes and more than 18,000 miles of fishable rivers and streams to choose from.[17] The average Minnesota angler spends 15 days per year fishing, and walleye, northern pike, muskie, panfish, bass, crappie and trout are among the most sought-after catches.[17]

For those in the aquaculture industry, experts agree that information on consumer demographics and preferences can help gauge the market for their product.

Key Takeaways

U.S. consumers are eating more fish and seafood than in previous years.

Still, nearly half of all Americans report rarely eating fish or seafood.[12]

Fish and seafood consumers shop around for a quality product at a good price.

Price, taste or flavor, and freshness are primary purchasing decision determinants.

Consumers tend to stick with familiar fish and seafood options when grocery shopping, but are more willing to try something new at restaurants.

Shrimp, salmon and tuna were among the most popular grocery store options.

Current Consumer Landscape in Minnesota

Food fish is a diverse category in Minnesota from its legendary walleye to shrimp and trout. Besides wild caught fishing that goes back many generations, commercially viable fish farm opportunities have been expanding as an interest area in recent years, creating employment, economic impact and growth for related sectors in the form of fish feed, fish health and byproducts.

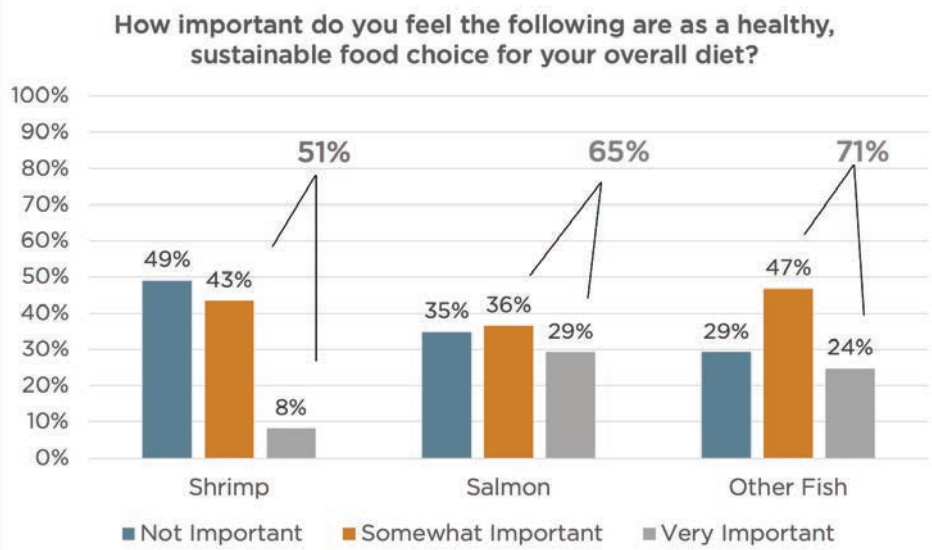


Figure 5. The graph shows that consumers who participated in the AURI Food Fish Consumer Survey consider seafood a healthy, sustainable choice for their overall diet (Source: AURI Food Fish Consumer Survey, 2020).

To better understand current consumption behaviors, perceptions of food fish and industry development, and market potential, a consumer survey was conducted in October-November 2020 with Minnesotans who are primary purchasers of food at grocery stores and restaurants.

More consumers reported eating chicken, beef, and pork at least once a week than any kind of fish. However, just because it is consumed less frequently does not mean consumers underestimate its significance as a healthy, sustainable food. The majority of those surveyed recognized the importance of consuming either shrimp, salmon, or other fish as a part of a balanced, nutritious diet.

Furthermore, when reporting on the frequency of which they order fish or shrimp at a restaurant, fewer than one-fifth of consumers indicated they never do, suggesting opportunities for growth of the food fish industry continue to exist within consumer markets.

Interest in buying fish for consumption is an important metric. Understanding the extent to which Minnesota's food fish industry has actual growth potential, however, is equally critical from a local economic standpoint.

When it comes to fish raised within the state, consumers indicated that their purchases in either grocery stores or restaurants could potentially increase, particularly for select species. Over 40% reported a likeliness to purchase shrimp and walleye more frequently if Minnesota raised options were available. Similarly, just under 40% indicated their purchase of salmon would increase as well.

Wherever it originates from, understanding the decision-making factors among purchasing consumers is important to ensure the product is meeting their needs and demand is maintained. In a ranking of importance with five being extremely important and one being not at all important, the factor with the highest rating by consumers was taste and flavor. Food safety, aroma and odor, and appearance were the next highest rated factors.

These findings underscore the importance of maintaining standard practices regarding safety of the product as well as producing one that is high quality. It's worth noting that consumers said that they most trust government, stores and fish operations when it comes to assuring the safety of the food fish they buy.

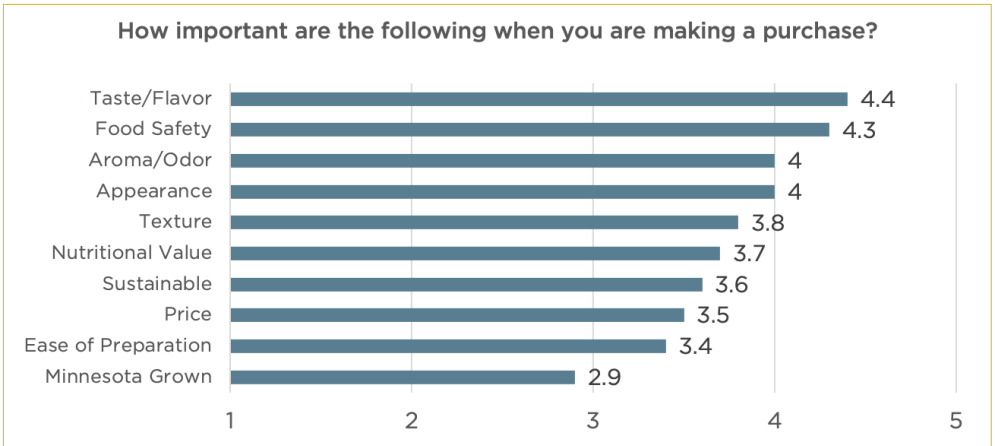


Figure 6. The bar graph above illustrates how important taste and flavor are to consumers when making purchasing decisions (Source: AURI Food Fish Consumer Survey, 2020).

Consumers are aware of the significance of raising fish in a healthy environment and are more likely to purchase if they know their food is safe. This was further emphasized with the finding that nearly two-thirds read the product labels on fish and shrimp while grocery shopping, indicating a desire for further information on their purchase.

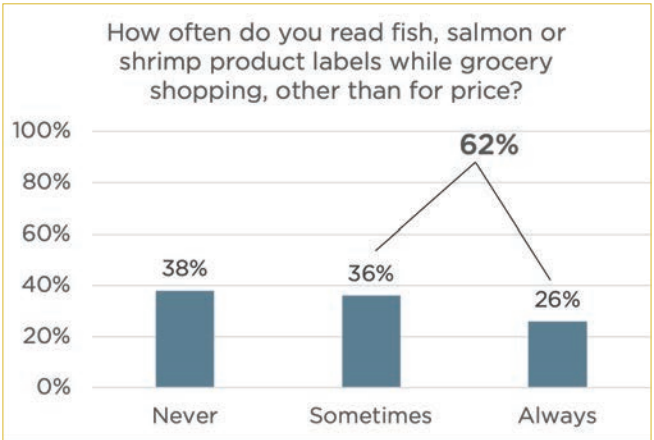


Figure 7. **The majority of consumers who participated in this research indicated that they "sometimes" or "always" check fish, salmon or shrimp product labels for information other than price while grocery shopping (Source: AURI Food Fish Consumer Survey, 2020).**

Consumers also indicated a willingness to pay more for fish and shrimp products with certain aspects. Over a third reported they would pay more for those raised in Minnesota and those sustainably raised, and nearly half agreed they would pay more for fish products that benefit the state's economy. Fifty-seven percent, however, said that being able to locate Minnesota raised fish at retail is a potential barrier to purchase (57%), and knowing how to cook it could also be a prohibitive factor (47%).

Perceptions of fish raised in Minnesota were generally positive. The majority of consumers agreed that eating Minnesota-raised fish, salmon or shrimp is safer to eat than other fish options, as well as more sustainable. There was also a general belief among consumers that locally raised fish would be higher quality. Given the importance placed on the quality and safety of fish when making a purchase, it is likely Minnesota food fish would see higher demand in grocery stores and restaurants than options that did not possess these perceived qualities.

In addition to generally positive perceptions of fish originating in Minnesota, consumers felt similarly about the commercial operations of fisheries and fish farms. Agreement levels were high regarding the benefits of these businesses, with most understanding that commercially regulated fisheries are good for the local economy.

Other benefits consumers agreed with most included operations being a safe and clean method of obtaining fish and providing products with high nutritional value. These findings indicate that while food safety and quality are a top factor when making a purchase of fish, Minnesota consumers are generally confident

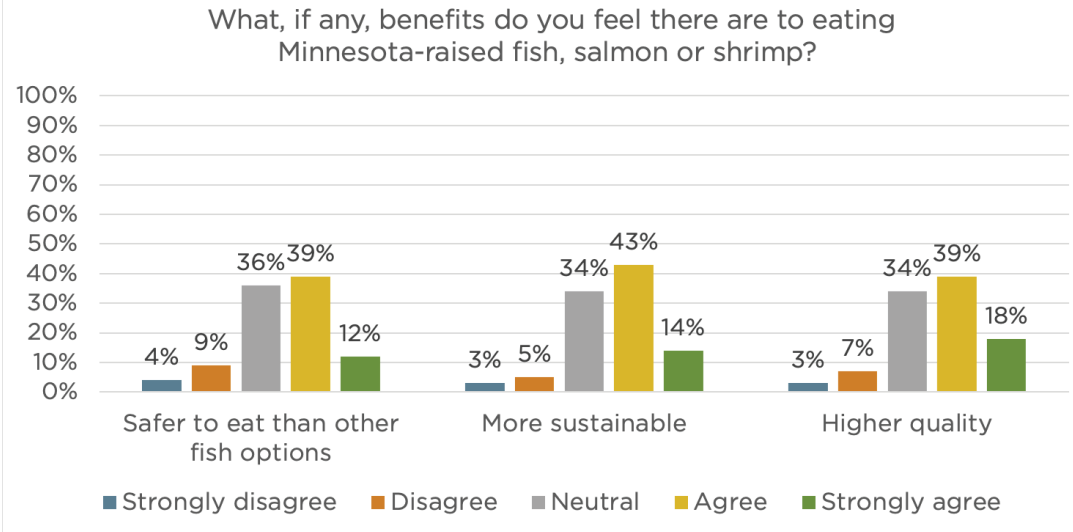


Figure 8. **The majority of consumers surveyed agreed that eating Minnesota-raised fish, salmon or shrimp is beneficial because the products are: 1) Safer to eat than other fish options; 2) more sustainable; 3) higher quality (Source: AURI Food Fish Consumer Survey, 2020).**

products raised in Minnesota fisheries or fish farms would meet these expectations.

As findings illustrate, Minnesota consumers care about their food and its origin. Products that benefit the economy, are produced in sustainable ways and, of course, are high quality are all important factors they consider when making a purchase. Further educating consumers on what they are buying and eating can raise confidence in their purchasing decisions.

In keeping with this information, consumer research has shown nearly half of the market reported interest in learning more about commercially regulated fisheries or fish farms in Minnesota. Education about safety protocols, sustainability, and how these operations support the state economy are all factors that could lead to increased demand in Minnesota raised fish.

Key Takeaways

Minnesota consumers recognize the health benefits of incorporating fish and seafood into their diets.

The frequency in which Minnesotans order shrimp or fish at restaurants suggests opportunities for growth exist within consumer markets.

Consumers indicated they would potentially increase the amount of fish or seafood they purchase at the grocery store or restaurants if it's Minnesota-raised.

The survey revealed consumers are also willing to pay more for products raised in Minnesota or sustainably raised.

Nearly half of respondents indicated they are interested in learning more about Minnesota fish farms.

Producers have an opportunity to educate consumers about safety precautions, sustainability and how Minnesota-raised fish benefit the economy.

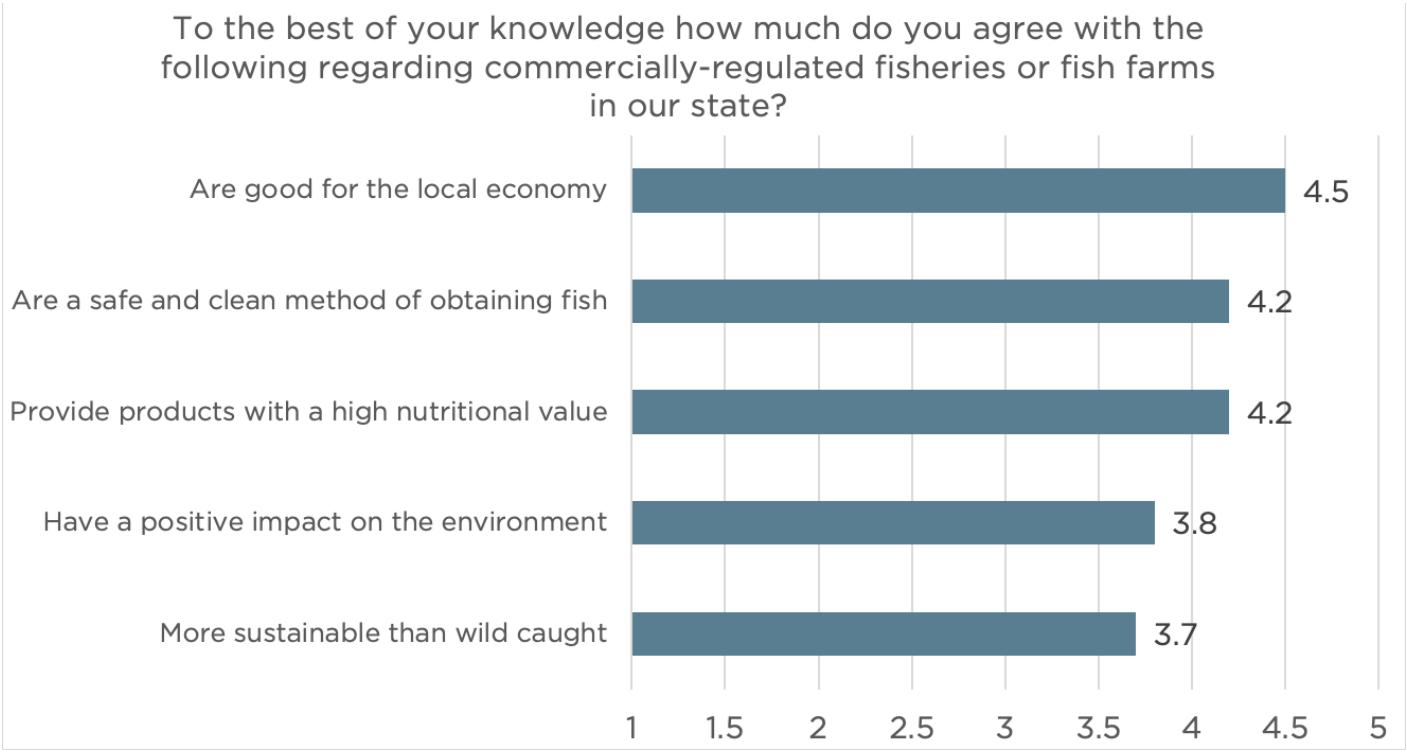


Figure 9. The bar graph above illustrates how much consumers who participated in this survey agreed or disagreed with statements regarding commercially regulated fisheries or fish farms in Minnesota (Source: AURI Food Fish Consumer Survey, 2020).

Nutritional Benefits

Fish is an excellent source of protein, and evidence suggests there are significant health benefits to incorporating it into a balanced diet. The U.S. Department of Health and Human Services (HHS) and the U.S. Department of Agriculture (USDA) highlights seafood, including fish and shellfish, in the 2015-2020 Dietary Guidelines for Americans, recommending the general public consume at least eight ounces per week. Fish and seafood are considered nutrient-dense proteins, meaning they contain vitamins, minerals and other naturally occurring components known to produce positive health outcomes.[18]

Fewer calories are consumed with fish or seafood, while still meeting the recommended number of daily proteins. Both fish and seafood are also considered low in total and saturated fats.[19] The American Heart Association recommends maintaining a diet where no more than 5-6% of calories per day come from saturated fats, found in many other animal-based products such as pork, beef, lamb and poultry with the skin on. Lean meats like fish and seafood are considered healthy alternatives.[20]

> *"Strong evidence ... has shown that eating patterns that include seafood are associated with reduced risk of CVD [cardiovascular disease], and moderate evidence indicates that these eating patterns are associated with reduced risk of obesity."*
>
> 2015-2020 Dietary Guidelines for Americans[18]

Fat content varies by species, but generally, the leanest fish tend to have a lighter color, while darker meat is found in fattier fish.[19] One type of fat that plays a role in reducing the risk of heart disease and stroke is omega-3 fatty acids, which are "almost exclusively found in aquatic organisms."[19]

Fish can't produce omega-3s but obtain them through their diet. Forage fish, which are smaller and typically eaten by larger species, consume microalgae, which is a source of omega-3s. For larger, carnivorous species, such as salmon, those smaller fish are a source of omega-3s.[21] The two omega-3 fatty acids found in fish are eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), and while the body can convert small amounts of the third type of omega-3 fatty acid — alpha-linolenic acid (ALA) — into the other types, food is the most efficient source of these nutrients.[22] Fattier species typically have higher levels of omega-3 fatty acids, but non-fried fish, in general,

Sea Grant

Seafood Health Facts
www.seafoodhealthfacts.org

Fat Content in Common Fish and Shellfish

To get a general idea of the fat content of most fish species, look at the color of the flesh. The leanest species such as cod and flounder have a white or lighter color, and fattier fish such as salmon, herring, and mackerel usually have a much darker color. The fat content of fish and shellfish can vary depending on when and where they are caught and other factors. To assist you in comparing common seafood choices the following table groups a variety of fish and shellfish according to their average amount of total fat and percent calories from fat.

SEAFOOD PRODUCT	FAT CONTENT *per 3 ounce cooked*
Herring, Mackerel, Sardines, Salmon (Atlantic, Coho, Sockeye and Chinook)	High Fat (10 grams or more)
Bluefish, Catfish, Rainbow Trout, Swordfish	Medium Fat (5 to 10 grams)
Tilapia, Halibut, Mussels, Ocean Perch, Oysters, Pacific Rockfish, Salmon (Chum, Pink)	Low Fat (2 to 5 grams)
Crab, Clams, Cod, Flounder/Sole, Haddock, Hake, Lobster, Mahi-mahi, Pollock, Scallops, Shrimp, Tuna	Very Low Fat (less than 2 grams)

Source: https://www.seafoodhealthfacts.org/seafood-nutrition/patients-and-consumers/seafood-nutrition-overviewnce

Figure 10. **The infographic above categorizes common fish and shellfish products based on fat content (Source: Delaware Sea Grant, 2020).**

is considered one of the best sources of this polyunsaturated fat.[19] Much like wild-caught fish, the omega-3 levels of farm-raised fish are also dependant upon their diet. Currently, the nutrients in feed come from plants, grains and fishmeal, the latter of which usually consists of by-catch products. New, more sustainable feeds that do not rely on fish by-catch, are being developed and are explained more thoroughly in the "Fish Nutrition" section of this report.[23]

Atlantic salmon is a fattier fish considered to be "well-adapted for growth in cool and cold environments," and is just one promising species for the Minnesota food-fish industry.[24] It was once unclear whether farm-raised Atlantic salmon retained the healthy omega-3 fatty acids that make the product particularly attractive to consumers during the baking process. However, a promising 2011 study conducted by the Grand Forks [North Dakota] Human Nutrition Research Center found that baking farm-raised Atlantic salmon to the recommended temperature of 145 degrees Fahrenheit does not result in "toxic omega-3 oxidation byproducts." Researchers found that baking the fish reduced the presence of those byproducts, meaning it retained the omega-3 fatty acids that make Atlantic salmon a healthy choice for consumers.[25]

Sea Grant

Seafood Health Facts
www.seafoodhealthfacts.org

Omega-3 (EPA+DHA) Levels in Common Fish and Shellfish

Health organizations suggest an EPA+DHA intake of at least 250 to 500 milligrams per day. The American Heart Association recommends 1000 milligrams of EPA+DHA per day for patients with coronary heart disease, and two meals of oily fish per week for people without heart disease.

SEAFOOD PRODUCT	HEART HEALTHY	OMEGA-3s *per 3 ounce cooked*
Farmed: Salmon (Atlantic) ***Wild:*** Herring (Atlantic & Pacific), Salmon (King), Mackerel (Pacific & Jack)	♥♥♥♥♥	>1,500 milligrams
Canned: Salmon (Pink, Sockeye & Chum), Mackerel (Jack) ***Wild:*** Mackerel (Atlantic & Spanish), Tuna (Bluefin)	♥♥♥♥	1,000 to 1,500 milligrams
Canned: Sardines, Tuna (White Albacore) ***Farmed:*** Trout (Rainbow) ***Wild:*** Salmon (Pink, Sockeye, Chum & Coho), Swordfish ***Wild & Farmed:*** Mussels, Oysters	♥♥♥	500 to 1,000 milligrams
Breaded: Fish Sticks ***Canned:*** Tuna (Light) ***Wild:*** Tuna (Skipjack), Pollock (Alaskan), Rockfish (Pacific), Crab (King, Dungeness & Snow), Lobster (Spiny), Snapper, Grouper, Flounder/Sole, Halibut (Pacific & Atlantic), Ocean Perch, Squid (Fried) ***Wild & Farmed:*** Clams	♥♥	200 to 500 milligrams
Farmed: Tilapia, Catfish ***Surimi Product:*** Imitation Crab ***Wild:*** Scallops, Lobster (Northern), Crab (Blue), Cod, Haddock, Mahimahi, Tuna (Yellowfin), Orange Roughy ***Wild & Farmed:*** Shrimp	♥	< 200 milligrams

Source: USDA National Nutrient Database for Standard Reference
https://www.seafoodhealthfacts.org/seafood-nutrition/patients-and-consumers/omega-3-epadha-levels-common-fish-and-shellfish

Figure 11. **The infographic above categorizes common fish and shellfish products based on their omega-3 (EPA+DHA) levels (Source: Delaware *Sea Grant, 2020).***

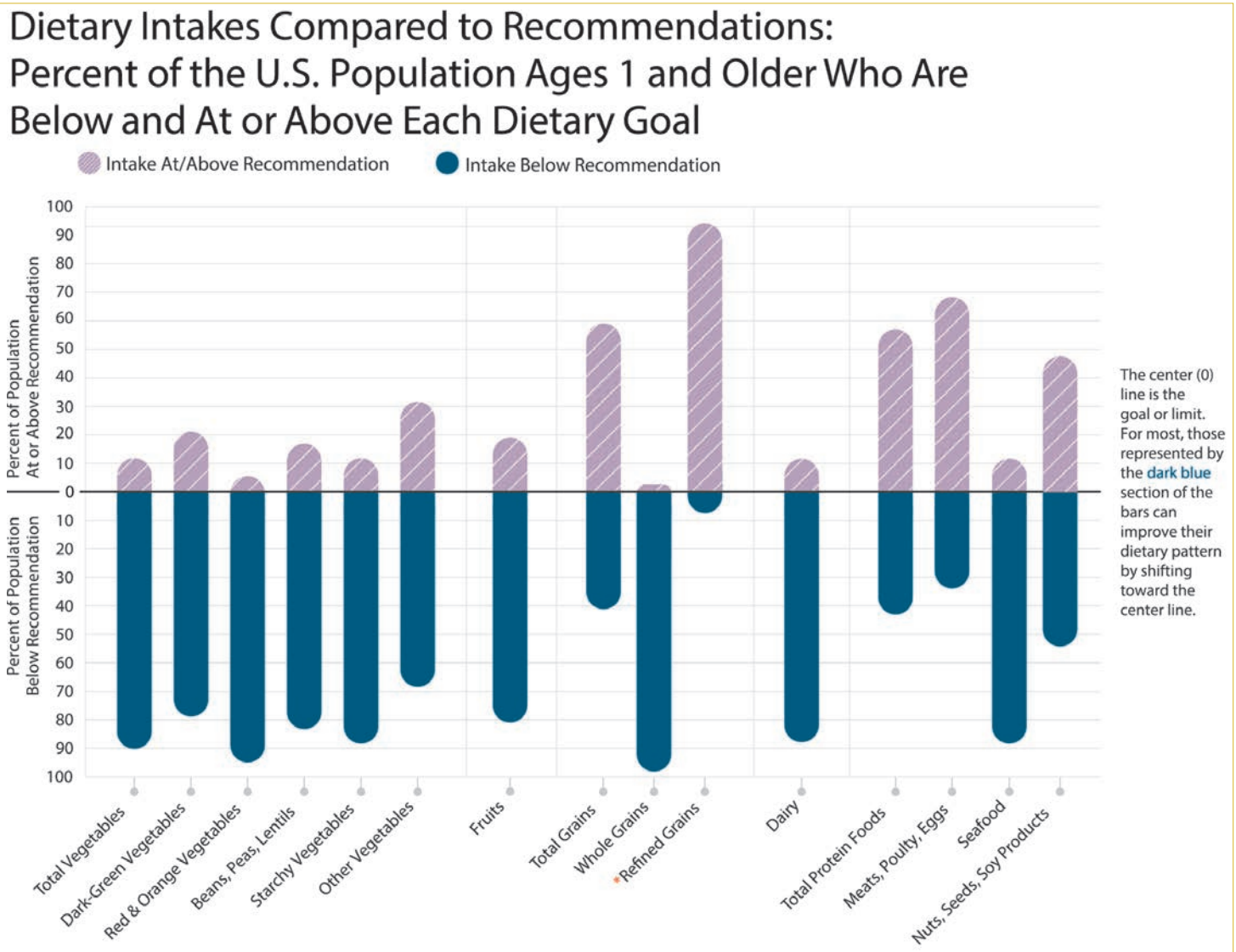


Figure 12. **The graph above shows the recommended dietary intakes compared to the percent of Americans ages one and older who are at or above the dietary goals (Source: U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020-2025).**

> *"We know how to cook a hamburger; we know how to cook pork; we know how to cook chicken. And what do people eat most of the time? That's what they're eating. But if you had a good fish recipe and could start eating it once or twice a week — that's a healthy choice."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

While national dietary guidelines recommend that Americans incorporate at least two servings of fish and seafood into their diets each week, the *What We Eat in America* National Health and Nutrition Examination Survey found that, on average, people aren't necessarily doing that. Overall, the study found that Americans across all age-sex groups consume less than the recommended amount of fish and seafood per week.[27]

> *"If you could substitute [fish for] one meal a week of meat you're healthier. If they [consumers] know the health benefits, I think people will pay the cost."*
>
> Steve Summerfelt, Chief Science Officer, Superior Fresh[6]

There is evidence that consumer attitudes are changing. Two recent surveys suggest that individuals are beginning to consider the health benefits of fish or seafood when shopping for groceries. In a 2019 survey conducted by Blue Circle Foods, 84% of primary household shoppers indicated that they believe "fish and other seafood is an important part of a balanced diet."[14] Meanwhile, 51% of grocery shoppers surveyed by the Food Marketing Institute said they look for "heart healthy" options when choosing fish or seafood.[13]

Key Takeaways

The HHS and USDA's 2015-2020 Dietary Guidelines for Americans recommends that consumers eat at least eight ounces of fish or seafood per week.

On average, Americans are still consuming less than the recommended amount of fish and seafood each week.

Fish and seafood are excellent sources of protein and provide significant health benefits.

Fish is a good source of omega-3 fatty acids, unsaturated fats, vitamins and minerals, among other things.

While U.S. consumers appear not to be eating enough fish or seafood, shoppers view both as part of a balanced diet.

Shoppers consider fish and seafood "heart-healthy" options.

Figure 13. Farm-raised Superior Fresh Atlantic salmon is pictured above as part of a sushi dish. The Wisconsin-based farm feeds its fish a non-GMO, organic diet free of pesticides and antibiotics (Source: Superior Fresh, n.d.).

MINNESOTA: AN EVOLVING AQUACULTURE INDUSTRY

Minnesota's Rich Fishing History

Minnesota has a rich fishing history — one that has impacted both the state's economy to varying degrees over the years and its recreational lifestyle.

Excavations of prehistoric sites in and around early settlements in Minnesota have unearthed artifacts that appear to have been chipped stone fishhooks. Approximately 3,000 years ago, the Dakota fished the area's many lakes, streams, and rivers, angling, netting, or spearing depending upon season. Years later, the Ojibwe arrived, choosing to use large birchbark canoes and nets made from twisted and knotted strands of willow bark to catch lake trout, whitefish, and sturgeon. In winter, they speared fish through holes chopped in the ice.[28]

Fish was a diet staple for not only the Dakota and Ojibwe, but the French fur traders and settlers who came to Minnesota from such origins as Scandinavia. Many of Minnesota's early settlements were, in fact, built on the shores of rivers or lakes, not just for access to a water source, but also to gain fish used for food.

Today, though fish can be found in most grocery stores, restaurants and online. Minnesota continues to be known nationally and internationally for its recreational fishing opportunities, with as many as two million anglers casting their lines into Minnesota waters each year.

Figure 14. **Covering fish with ice at the Booth Fish Company in Warroad, Minn., (Source: Dobie, J., n.d.).**

> *"Everyone should believe in something. I believe I'll go fishing."*
>
> Henry David Thoreau

According to the Minnesota DNR, there are 11,842 lakes (5,400 of which are fishable) — and more than 18,000 miles of streams and rivers, featuring such species as walleye, largemouth and smallmouth bass, northern pike, muskie, sauger, crappie, bluegill, perch, sturgeon, catfish, lake trout, brook trout, brown trout, rainbow trout, steelhead, splake, salmon, burbot and whitefish, just to name a few.[17]

Concurrent with sport fishing, commercial fishing had early beginnings as well — particularly on Lake Superior. Annual catch rates varied over the years, according to the DNR, but the all-time record occurred in 1915, when almost 10,000 tons of fish were harvested out of Duluth alone. By the 1920s, catches began to decrease for numerous reasons including over-harvest, the accidental introduction of the sea lamprey from the Atlantic Ocean, pollution and other factors.[27]

According to Great Lakes Now, an initiative of Detroit Public Television and PBS, some feel that the modern era of commercial fishing began around 1954, when the U.S. and Canada signed a treaty agreeing to work cooperatively to address Great Lakes issues. "One creature was the catalyst that brought them together: the sea lamprey. [As a result] the Great Lakes Fishery Commission was born. Ontario and the Great Lakes states began collaborating to solve the sea lamprey problem and share scientific information to preserve and enhance the fisheries."[29]

Interest in growing Minnesota's food fish industry on a commercial basis continued. The Minnesota Department of Agriculture (MDA) was designated the lead agency for aquaculture development in the late 1980s when interest in fish farming was escalating. The State of Minnesota recognized aquaculture (privately raising fish or other aquatic life) as agriculture, considering farmed fish to be a type of livestock — hence, MDA's logical involvement.

While MDA's Marketing Services Division provided development assistance, regulatory authority stayed with the DNR where it continues to reside today. Fish farms were required to obtain a license from the DNR and, when needed, a discharge permit from the Pollution Control Agency (PCA). When aquaculture development decreased in the late 1990s, there was less need for MDA's oversight and the Marketing Division reprioritized its focus on the marketing of other agricultural products.[30]

Several other organizations work actively to further the aquaculture industry. The Minnesota Aquaculture Association (MNAA) was re-established in 2019 to promote the long-term sustainability and economic growth of the Minnesota aquaculture, aquaponics and bait industries, while minimizing environmental impacts to the natural resources of the state. MNAA is supported by industry members, scientists, volunteers and volunteer board members.

Minnesota Sea Grant also helps further aquaculture interests. A national network of 34 university-based programs, Sea Grant's mission is to enhance the practical use and conservation of coastal, marine, and Great Lakes resources in order to create a sustainable economy and environment. As an example, the Great Lakes Aquaculture Collaborative (GLAC) is comprised of Sea Grant extension educators, science communicators, fisheries biologists, economists, and aquaculture specialists from Minnesota, Michigan, Wisconsin, Illinois, Indiana, Ohio, Pennsylvania, and New York, with a goal of supporting an environmentally responsible, science-based, competitive, and sustainable aquaculture industry in the region.

Figure 15. Processing fish at the Booth Fish Company in Warroad, Minn. (Source Dobie, J., n.d.).

Key Takeaways

Known as the Land of 10,000 Lakes, Minnesota has a rich history of fishing, but it wasn't until the 1980s that the state took more serious interest in developing the fish farming industry.

Since the 1980s, the Minnesota Department of Natural Resources has served as the regulatory authority for aquaculture operations. Meanwhile, because farmed fish is considered a form of livestock, the Minnesota Department of Agriculture plays a key role in helping develop the industry statewide.

Numerous organizations including the Minnesota Aquaculture Association, Minnesota Sea Grant and the Great Lakes Aquaculture Collaborative have worked to further develop the industry.

Figure 16. Arctic char fingerlings at the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility (Source: UW-Stevens Point Northern Aquaculture Demonstration Facility, 2019).

State Commercial Aquaculture Development

Although the food fish industry in Minnesota is in its infancy and remains relatively small, aquaculture, in general, is not new to the state. Historically, Minnesota's commercial fish farmers have focused on rearing baitfish and fish for stocking ponds. Valued at nearly $2.4 million, the state had the nation's second-largest baitfish industry in 2013, with 22 farms and more than 15,000 water surface acres dedicated to production. As of the 2018 Census of Aquaculture, other states, including Arkansas, Ohio, and Wisconsin have surpassed Minnesota in total baitfish sales.[8]

Despite a successful baitfish industry, food fish aquaculture production still lags in Minnesota. In 2013, the state had 13 documented food fish farms with total sales of more than $1.7 million, compared to neighboring Wisconsin's 67 farms with revenue upwards of $2.4 million. By 2018, the number of food fish farms in Minnesota dropped to 12.[8]

> *"Minnesota is one of those states that, given the resources available and its proximity to some decent seafood markets, it should be a major aquaculture producing state."*
>
> Carole Engle, Aquaculture Economist and Co-owner of Stone-Engle Aquatic$ LLC[32]

The aquaculture census does define food fish production and sales by species for each state, but for Minnesota, where the industry is still limited, the datasets don't clearly illustrate a trend. As of the latest census of aquaculture, Minnesota reported two tilapia farms, two trout farms and eight yellow perch farms. The number of tilapia and trout farms in Minnesota decreased from 2013 to 2018, while yellow perch producers increased from five to eight during that same period. Since there aren't

very many farms producing each species mentioned, the USDA withheld total sales to "avoid disclosing data for individual farms."[8]

> *"This lack of growth implies that there are internal kinds of things in Minnesota that are severe and strong constraints to growth. If you look at just total sales, Minnesota has gone down. It's not just the number of farms and total production; total sales have decreased."*
>
> Carole Engle, Aquaculture Economist and Co-owner of Engle-Stone Aquatic$ LLC[32]

Additionally, there are experts who say the data from the census is not definitive, as it doesn't necessarily distinguish food fish from fish raised for stocking purposes. Sean Sisler, fisheries program consultant for the Minnesota Department of Natural Resources, explained that 100-150 aquaculture licenses are issued each year, but the majority of those are used for stocking purposes to support the game fish industry.

> *"Only a fraction of the aquaculture licenses focus on food production. Between 10 and 20 licenses a year are focused on raising fish for food production. Many are either aquaponics systems or people raising shrimp."*
>
> Sean Sisler, Fisheries Program Consultant, Minnesota Department of Natural Resources[15]

Also, as Greg Fischer, Assistant Director of the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility pointed out, different states define "fish farms" in different ways.

> *"A fish farm in Wisconsin could be defined as someone with a pond that has fish in it. It may not be somebody making a living at fish farming. Out of over 2,000 fish farms registered in Wisconsin, I know there's probably only 50-100 fish farms that are making some kind of income that helps support their operators. There's probably 50 of them that this is what they do for a full-time occupation and living."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

While Alabama, Arkansas, Louisiana and Mississippi have helped establish a positive reputation for farm-raised catfish, and contribute roughly $4 billion to each state's economy per year, regionally, neighboring Wisconsin has served as an example of what Minnesota's food fish industry could become.[33] As of 2018, Wisconsin had two catfish, three Atlantic salmon, six tilapia, 13 yellow perch, 26 trout and three "other" food fish farms. Total sales in Wisconsin declined to $2.26 million in 2018, down approximately 7% from 2013.[8]

The breakdown of sales by species included incomplete data, so it's difficult to extrapolate what led to that decline. The two species with complete datasets included yellow perch and trout. Sales for yellow perch remained stable over the five-year period, bringing in $173,000 in 2018 and $172,000 in 2013. For trout, revenue declined by 22% from $1.9 million in 2013 to $1.6 million in 2018.[8] The census, however, doesn't indicate whether the food fish farms producing yellow perch or trout were also rearing other species, suffered a disease outbreak or experienced any other factors that could contribute to this decline.

Looking to the future, division director at the Minnesota Department of Agriculture, Paul Hugunin, acknowledged the growth potential of the food fish industry in Minnesota. As the demand for healthy protein sources increases, he said there will be growing interest within the state to meet it.

> *"Minnesota's challenges will be 1) our climate and how can we compete with warm weather states, 2) successfully navigating water regulations, and 3) the history of unsuccessful aquaculture business 25 years ago on Minnesota's Iron Range. Minnesota does have the advantage, however, of growing an abundance of fish feed sources like soybeans."*
>
> Paul Hugunin, Division Director, Minnesota Department of Agriculture[34]

Interviews with other industry experts echoed these challenges, but also revealed practical solutions to address many of the most pressing issues aquaculture food fish farmers in Minnesota face.

Wisconsin: Progress to Watch

Figure 17. Figure 17. University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility staff (Source: Narayan Mahon, 2019).

Although Wisconsin's food fish industry is still relatively young, experts often point to it as a model for Minnesota aquaculturists. Wisconsin's food fish industry is ahead of other Great Lakes states, according to Minnesota Sea Grant Fisheries specialist, Don Schreiner, who partially attributed its success to having an aquaculture program built into the university system.

> *"Many challenges exist in this industry. If you are successful in raising the capital to permit and build your facility, you still need to find qualified personnel to operate and manage it. We are creating a whole new sector of agriculture with unique technological and biological demands that require unique qualifications and skill sets that are hard to find."*
>
> Ed Aneshansley, Senior Aquaculture Engineer, McMillen Jacobs Associates[7]

The University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility (NADF) has been training students in aquaculture for 20 years and serves as an example of what could happen in Minnesota. Students at the University of Wisconsin-Stevens Point, according to Greg Fischer, get hands-on experience with recirculating systems, pond aquaculture, and raceways — raising everything from salmon to walleye before graduating. Fischer said companies like Superior Fresh, Riverance LLC, Atlantic Sapphire and even some smaller farms are quick to hire students out of NADF's program.

> *"We're one of the few that offer this type of training in the Midwest. I think more universities and colleges are trying to catch up to us, but we've been doing this for 20 years now."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

About 90% of students who come out of the NADF program find immediate job placements, according to Fischer. Still, the aquaculture

industry doesn't have enough skilled workers entering the field. Fischer said many of the facilities coming on-line, including the traditional family-owned operations, are having trouble finding aquaculture specialists to hire. If Minnesota were to have a major producer like the Wisconsin-based aquaponics farm Superior Fresh, he said the demand for a highly skilled aquaculture workforce would certainly exist.

> *"Aquaculture is growing more worldwide than I've ever seen it in 30 years of doing this, and it's definitely here in the United States. For the university students that we're training, we have people waiting to hire them — we really can't train them fast enough."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

Superior Fresh is considered an industry leader, producing Atlantic salmon, steelhead trout and organic leafy greens. The company was founded on the premise of restoring some of Wisconsin's land to its natural state while also building a sustainable agriculture business. With that mission in mind, the company has flourished and now supplies retail partners like Lunds and Byerlys, Cub Foods, Festival Foods, Kwik Trip and more.[35]

"We're still expanding," said Steve Summerfelt, chief science officer at Superior Fresh. "We are increasing salmon production from not quite 200,000 pounds to 1.5 million pounds a year and our leafy greens from two million pounds a year to five or six million pounds."

Superior Fresh grows fish and organic leafy greens in separate buildings using a decoupled aquaponics system, which makes it easier to regularly disinfect the hydroponic portion.[35] This production method is beneficial to operators as it makes surpassing food safety standards much easier.[36] Additionally, by growing leafy greens in a greenhouse, crops are protected from insects, among other things, and pesticides aren't necessary.

Superior Fresh produces 100% USDA-certified organic leafy greens, meaning they are free of pesticides, synthetic fertilizers and growth hormones, genetically modified organisms, as well as artificial preservatives, colors, and flavors. Meanwhile, the fish eat a well-balanced, non-GMO diet of fishmeal and fish oil. Another benefit to Superior Fresh's efficient setup, according to their website, is that the company can produce "the same amount of food on six acres that a traditional farm produces on 100 acres."[35]

As the first landlocked Atlantic salmon farm in the U.S., Superior Fresh has an advantage with Midwestern consumers looking for fresh fish. In 2018, the U.S. imported 844.5 million pounds of fresh and frozen salmon.[4]

"Today's salmon is mostly coming from Chile and Norway, but some of it is coming from northern Canada, so there's a large carbon footprint," Summerfelt said. "That's a lot of food miles and a lot of costs to get that salmon here."

From a marketing perspective, Superior Fresh positions itself as a locally grown, sustainable business. The company's mission is to "grow food that is healthy, responsibly produced, and accessible to everyone," which, according to a recent consumer survey, really speaks to what shoppers are looking for when purchasing fish.[35] A Wisconsin study found that consumers prefer locally, wild-caught or farm-raised fish over an imported alternative, which bodes well for Superior Fresh and other aquaculture farms in the region.[37] Superior Fresh uses its blog to highlight how fish farming, and aquaponics, in particular, is a more environmentally friendly choice for consumers who might inherently associate "wild-caught" with freshness.

"One of the benefits of raising salmon on land is that it can be done virtually anywhere —adjacent to major markets to supply local, fresh salmon, eliminating the need to transport the fish over long distances and vastly reducing its carbon footprint," Superior Fresh's website notes. Since Superior Fresh is committed to reducing its carbon footprint, the company focuses on supplying fish and leafy greens to distributors in the Midwest year-round.[35]

Summerfelt added that consumer education can play a significant role in addressing common misconceptions about farm-raised fish and establishing trust among shoppers. The Wisconsin study found that many consumers were uncertain about some of the benefits of local, farm-raised fish, but still trusted state "fish farmers' ability to keep fish safe to eat as compared to the ability of government agencies, grocery stores, and non-local fish farmers."

In a 2020 Minnesota survey conducted by Russell Herder for this study, shoppers expressed different levels of confidence and trust in those entities. This finding underscores an opportunity for industry leaders to educate the public about their products and dispel any misconceptions consumers may have about the freshness of farmed fish compared to wild-caught.[37]

"I would say that, more than anything, if consumer education was funded it would help the existing industry," Summerfelt added. "The commercials for milk have been successful. There are marketing campaigns that can really work and it's going to be good for us as a society to eat more fish."

Superior Fresh uses its website as a platform to educate consumers about the controlled environment its fish are raised in, as well as steps it takes to ensure they remain healthy and disease-free. Meanwhile, the company also addresses the common misconception that wild-caught is fresher or more sustainable, noting that endangered species or marine mammals are unintentionally killed as a result of some fishing practices. The benefits of land-based systems, Superior Fresh

Figure 18. **Atlantic salmon fingerling at the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility (Source: Narayan Mahon, 2019).**

Figure 19. Atlantic salmon fingerlings at the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility (Source: UW-Stevens Point Northern Aquaculture Demonstration Facility, 2019).

asserts, include water conservation, a controlled growing environment, and a guarantee that farm-raised fish won't negatively impact wild stocks.[35]

> *"Good marketing is very important; it's how we sell at a premium. People like Wisconsin fish, produced in the Midwest within a 400-mile radius, and we have a great story because it's sustainable."*
>
> Steve Summerfelt, Chief Science Officer, Superior Fresh[6]

Additionally, the company's certifications are displayed prominently on the website, showing consumers that Superior Fresh's fish are considered a healthy "Best Choice" by Monterey Bay Aquarium Seafood Watch, "Best Aquaculture Practices" (BAP) certified, and "Salmon Welfare" and "Non-GMO" certified by A Greener World.[29] Overall, Superior Fresh has served as a success story in the industry, and specifically in the Midwest, where there are very few large-scale land-based fish farms.

Key Takeaways

The baitfish industry has been successful in Minnesota, but food fish aquaculture hasn't shown as much growth.

Only a fraction of the Minnesota aquaculture licenses issued each year are actually for food fish production, according to the DNR.

Minnesota's food fish aquaculture industry is still in its infancy.

Neighboring Wisconsin's food fish industry, while still growing, could serve as a model for other Great Lakes states, including Minnesota.

Consumer education has been key to industry growth in states like Wisconsin.

Minnesota could learn from this awareness building to increase food fish sales.

INDUSTRY CHALLENGES

Although the U.S. aquaculture industry has grown significantly over the last 35 years, there are still many hurdles to overcome. Some of these challenges include pairing species with effective production systems, developing disease management protocols, identifying cost-effective fishmeal alternatives, navigating complex and changing regulatory systems, obtaining financing and establishing economically viable new businesses.[38]

> *"Investments will be made where the opportunity exists."*
>
> Carole Engle, Aquaculture Economist and Co-owner of Engle-Stone Aquatic$ LLC[32]

Technology

To compete with global leaders in the aquaculture industry, experts say the U.S. needs to prioritize research and development. Currently, much of the funding for research is distributed through NOAA's Sea Grant Marine Aquaculture grant program. These grants fund research on everything from economic modeling to production systems.[39] In the National Strategic Plan for Federal Aquaculture Research, members of the Interagency Working Group on Aquaculture (IWGA), which is comprised of leaders from several federal agencies, identified areas of research and development needed to help U.S. businesses compete on a global level.[3]

One of the most significant challenges for the industry is pairing fish species with the most effective production system. This requires a complete understanding of fish physiology and stressors that can inhibit the health and well-being of aquatic organisms. "Achieving the desired partitioning of nutrients into the competing systems of muscle development, digestive metabolism, health maintenance and reproductive development is critical for improving productivity and reducing cost and waste."[3]

As a result, research has focused on identifying commercially viable species, as well as developing and introducing practices that reduce waste and make production more efficient.[3]

Members of the IWGA also acknowledged the need for improving the performance and efficiency of production systems. The development of systems that require less water and energy are key to making aquaculture more commercially viable in the U.S. Experts also recommended prioritizing research on effluent treatment technologies to reduce or eliminate the amount of waste discharged from aquaculture facilities. "There is significant potential to adapt current commercial technologies and engineering solutions from other sectors of the economy, such as municipal wastewater treatment, manufacturing, medicine, information technology, and energy that can be integrated into aquaculture systems to improve productivity and efficiency."[3]

Understanding Aquaculture Production Systems

There are a wide variety of food fish farming methods, each of which comes with its own set of challenges. Before selecting a production system, food fish farmers look at variables such as species, climate, water sources, land resources and initial investment, among other things.

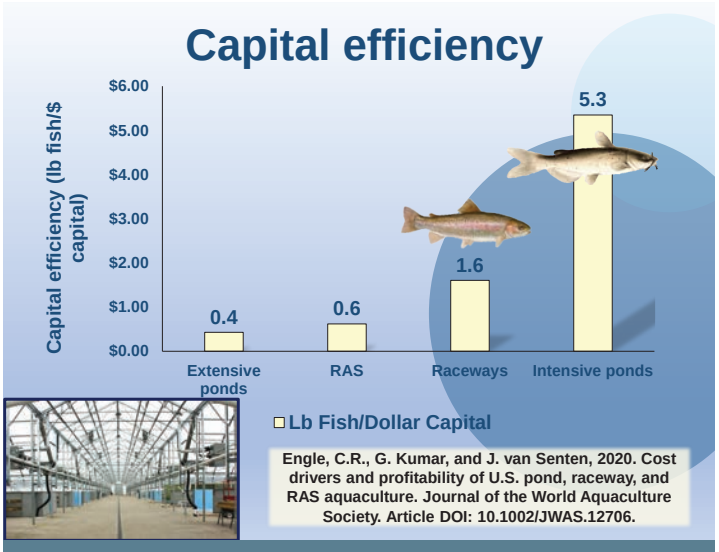


Figure 20. **The graph above shows the capital efficiency of various types of aquaculture production systems including, extensive ponds, Recirculating Aquaculture Systems, raceways and intensive ponds (Engle et al., 2020).**

While fish farming methods vary, all fall into three main categories: open aquaculture, semi-closed aquaculture and closed aquaculture.[24] Operators choose which system will work best for their business based on various factors, including, but not limited to biological feasibility, regulations, and financial resources.

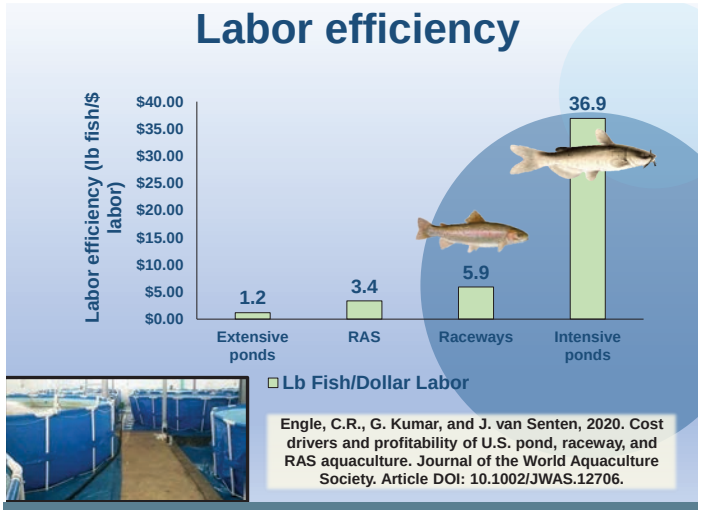


Figure 21. The graph above shows the labor efficiency of different types of aquaculture production systems including, extensive ponds, Recirculating Aquaculture Systems, raceways and intensive ponds (Engle et al., 2020).

Launching an aquaculture business requires significant research when selecting a system because there are multiple factors that can influence what will work best for various operations. Experts suggest the most successful aquaculture operators start small and scale their business as they gain experience and a better understanding of the market.[40]

OPEN AQUACULTURE

With open aquaculture, production densities mirror that of natural stocks and generally don't exceed it. This category also doesn't require as much maintenance as semi or closed aquaculture.[40] Ponds, net pens, bottom and off-bottom culture are all forms of open aquaculture. Bottom and off-bottom aquaculture are typically production methods for shellfish, such as oysters, clams and mussels.[41]

Ponds

There are a wide variety of ponds, but there are two main categories: natural and man-made. Generally, ponds require a large amount of land and a viable water source. Natural ponds are existing bodies of water that cannot be drained, which makes harvesting fish more difficult. Man-made ponds are generally smaller, constructed bodies of water that are manually filled and drained for harvest.[42] Both categories vary greatly, and consist of everything from "simple, low-tech extensive ponds to sophisticated hyper-intensive ponds where farmers have significant control over the rearing process and pond conditions and production per hectare is very high."[41]

Launching a pond aquaculture operation is relatively economically feasible, but the cost can vary depending on whether ponds are natural or man-made. In the 1996 Walleye Culture Manual, researchers noted that finding a natural pond of the proper size and depth, among other features needed for a successful aquaculture operation, can be difficult. Fish farmers in Minnesota often lease ponds from farmers in the west-central part of the state who have land located in riparian zones — or areas located near bodies of water.[43]

Since access to natural ponds is limited, many farmers opt for man-made ponds, which are constructed using soil liners that consist of 20% or more clay to efficiently hold water. The type of soil used to construct man-made ponds does influence the cost, but experts note that using a plastic pond liner further increases the initial investment.[24] Ponds rely on groundwater, as well as surface water to a lesser degree. For an efficient source of groundwater, experts recommend drawing from a well that has water "near the surface to reduce pumping cost."[44]

Chris Weeks, an aquaculture extension specialist at Michigan State University, added that commercial operators in Minnesota could benefit from evaluating a map of the state's Department of Natural Resources' (DNR) map of spring-fed water sources. By doing so, he said, new businesses can properly evaluate whether a site would support pond or raceway aquaculture. After reviewing the Minnesota DNR's Spring Inventory Map, Weeks suggested during a 2017 food fish aquaculture workshop that the southern part of the state, particularly the Rochester area, could be a profitable area for aquaculture businesses.[24]

Researchers from the University of Wisconsin Stevens Point added that pond aquaculture is a good option for first-time fish farmers because it "provides a higher level of buffering capacity for operational or management mistakes."[45]While ponds are an economically viable option for new aquaculture operators, fish also benefit.

Figure 22. **Feeding time for young salmon at the Ocean Systems, Inc. pens in Puget Sound. This was the first facility to raise salmon in captivity in the United States (NOAA Central Library Historical Fisheries Collection, 1971).**

Unlike other aquaculture systems such as tanks or raceways, ponds provide an environment for fish to grow at lower densities, which can lead to "lower stress, faster growth and lower transmission of disease."[42]

Research shows that rearing fish in a larger volume of water reduces the amount of physiological stress incurred, which can affect health and survival rates.[46] Cool to warm water species such as bass, walleye, yellow perch and panfish are the most common species farmed in ponds. Ponds don't support cold-water fish because water temperatures fluctuate too much during the summer months.[42]

Ponds are used for fish farming worldwide, but many experts who attended a 2017 food fish aquaculture workshop hosted by the Minnesota Sea Grant program suggested that this method of fish farming may not be efficient in colder climates. Chris Hartleb, director of the Northern Aquaculture Demonstration Facility at University of Wisconsin-Stevens Point, estimated that seasonal growth would limit Minnesota's pond operations to approximately "120-200 days per year and a two-year production cycle for most food-fish species." So, while ponds provide an environment for farmed fish to grow quickly and under less stress compared to other forms of aquaculture, Minnesota's cold climate could significantly limit the growing season.[24]

Net Pens

Net pens, usually made of wood, mesh, or netting, are cages submerged below the water's surface that hold fish in a designated area as they grow. "Net pens can be in marine waters to farm species such as salmon and trout or freshwater to farm species such as tilapia and trout," according to the Monterey Bay Aquarium.[41] Water flows openly through net pens, and because they are submerged in a marine or freshwater environment so do "waste, chemicals, parasites and disease." As a result, this method of open aquaculture is considered a "high-risk" system among some fish and seafood sustainability organizations.[47]

Canada has been successful with net pen aquaculture in northern Lake Huron, with seven operations producing more than 5,000 tons of

rainbow trout each year.[48] The net pens used in Canada operate year-round and are either attached to a pier or float within the nearshore zone. During the winter months, operators use heaters and bubblers to prevent the net pens from incurring ice damage and send divers to monitor the fish.[49]

Meanwhile, Michigan — which has access to four of the five Great Lakes, including Erie, Huron, Michigan and Superior — has faced public opposition to allowing fish farming operations in those waters. Several bills, introduced in the Michigan state legislature between 2015 and 2016, aimed to bolster the aquaculture industry by allowing fish farming facilities to operate in the U.S. waters of the Great Lakes. Those bills, however, were met with opposition from the public, as well as several state government agencies. Because of the open water flow, public concern focused on the potential for disease spread from farmed fish to those in the wild, as well as pollution and excessive phosphorus discharge.[50]

During a 2018 conference, Michigan Sea Grant experts addressed public concerns regarding net-pen aquaculture. In the U.S., fish farming is highly regulated in the same way the nation's fish hatcheries are, according to Michigan Sea Grant, and successful management practices can reduce negative effects on the environment, as well as the potential for disease spread. Experts from Michigan Sea Grant explained that while the public expressed concerns over phosphorus waste from farmed fish contributing to harmful algal blooms, digestible fish diets could help reduce the amount of phosphorus waste expelled.

Referencing a study conducted by Fisheries and Oceans Canada, experts explained that farmed fish that receive just enough phosphorus in their diets "excrete only small amounts of dissolved phosphorus."[48] Too much dissolved phosphorus or other nutrients like nitrogen can cause algae to grow too fast for the ecosystem, resulting in harmful algae bloom. Harmful algae bloom limits the amount of oxygen in the water, which can kill fish and sometimes make humans who come in contact with contaminated water or fish very ill.[51] The particulate phosphorus released by fish typically settles at the bottom of a body of water and is primarily consumed by animals living on the lake floor. Michigan Sea Grant noted that the majority of the waste produced by net pen methodology is particulate phosphorus, making it a "low" threat to the surrounding ecosystem.[48]

With Canada as an example, Michigan's Departments of Agricultural and Rural Development, Environmental Quality and Natural Resources also provided recommendations on how to safely establish commercial net pen aquaculture operations in 2016. Some of those recommendations included using certified disease-free fish, only farming fish that are native species to the Great Lakes to avoid adding an invasive species and using triploid fish to protect the genetic makeup of wild fish.[52]

The use of all-female triploids, researchers suggest, is a solution to reduce the risk of farmed fish escaping the net pens, reproducing with wild populations and altering their genetics.[53] Unlike a diploid fish, which has two sets of chromosomes — either XX (female) or XY (male) — triploids have three sets of chromosomes and, as a result, are sterile. Scientists produce triploids by feeding female fry, which have XX chromosomes, male hormones — reversing the sex of the fish. By doing so, the genetically female fish produces sperm with only XX chromosomes. When scientists use sperm from these fish to fertilize an egg, it produces a triploid, or a fish with three sets of chromosomes.[53] As a result, if a triploid fish raised in a net pen were to escape, it would not be able to reproduce with fish in the wild.

Hartleb suggested the negative perception of net pen aquaculture could be one of the most significant barriers to launching a successful commercial operation in Minnesota. He noted that while net pen aquaculture requires a much lower initial investment, it may not be a practical option for Minnesota because a sustainable business would require a large body of water.[24] According to Michigan Sea Grant, net pen aquaculture is not currently legal in the U.S. waters of the Great Lakes, a hurdle that would also hinder Minnesota's aquaculture industry.[54]

From 1988 until 1995 Minnesota Aquafarms Inc. experimented with net pen aquaculture in some of the state's abandoned iron ore pits. Former mine pits in Minnesota's Iron Range gradually fill with water and are occasionally used by surrounding communities for drinking water. When Minnesota Aquafarms Inc. began using these pits for net pen salmonid aquaculture, controversy erupted over whether the operation would degrade water quality in mine pits used for drinking water. During its seven years in business, the operation produced an estimated 4.4 million pounds of fish, but the mounting concern over water quality and regulatory hurdles ultimately forced Minnesota Aquafarms Inc. into bankruptcy.[55] Although this operation wasn't successful for a variety of reasons, Hartleb suggested it does demonstrate some of the major challenges net pen operations would face in Minnesota.[24] The negative public perception of net pens coupled with the inability to use net pens in Lake Superior could make using this farming method in Minnesota more problematic.

SEMI-CLOSED AQUACULTURE

Semi-closed aquaculture systems are capable of raising fish at higher densities than open aquaculture, meaning greater production outputs are possible. However, semi-closed aquaculture requires much more maintenance, and as a result, is a more significant time commitment. Semi-closed systems are often more costly, as, "sophisticated culture methods are employed such as pumping water, providing supplemental or continuous aeration, and adding commercial feeds."[40]

Raceways

Flow-through raceways are an example of semi-closed aquaculture and consist of land-based systems that allow for water exchange between natural waterways and fish farms.[24] These systems are most commonly used for rearing cold water species, such as rainbow trout, and are occasionally used to produce warm water fish like catfish and tilapia. Compared to ponds, raceways have several advantages that make them more appealing for food fish farmers.[56] Traditional raceways are capable of producing a higher quantity of fish, depending on the available space. Grading, or the practice of sorting fish of the same age and species based on size, is also much easier in a raceway. This process sorts out any fish that do not fit within the preferred specs of both processors and grocery stores. By grading more efficiently, operators not only make their product more marketable, but they also improve feeding practices by better estimating the most suitable size of feed in relation to the fish.[57] Although disease spreads more quickly in a raceway because of the density of fish, compared to a pond, it's much easier to detect disease and there are fewer chemicals required for treatment. By having a better sense of fish growth and mortality, operators who use raceways can also more accurately estimate inventory.[56]

Most raceways consist of concrete or earthen channels, but the arrangement of these tanks depends on which of the two general types of raceways is used: parallel or series. In parallel raceways, fairly shallow water flows through channels that run parallel to one another — entering through one side, flowing through the area where fish are contained and exiting on the opposite end. Series are more common, and in those systems, water flows through multiple raceways before being discharged.[42] The water that initially enters a series system provides oxygen for the fish, but as that water flows through the channel, the fish remove oxygen from the water.[56] "The oxygen content will always be higher at the inlet and lower at the outlet, which also gives a different environment depending on where each fish is swimming."[58]

To replace the oxygen lost before the water proceeds to the next raceway, operators use a "terraced configuration."[41] The configuration creates a waterfall effect, forcing water from the previous raceway to drop approximately 18-24 feet to reach the next raceway, replacing any lost oxygen.[42] Floating raceways, though less common, are placed in existing bodies of water and have similar entry and exit points on opposite sides.[42] While operators can produce higher densities of fish in floating raceways, these systems "require ponds and built floating docks attached to fish cages," and are costly to implement.[24]

One of the most significant challenges with raceways is sourcing high-quality water and

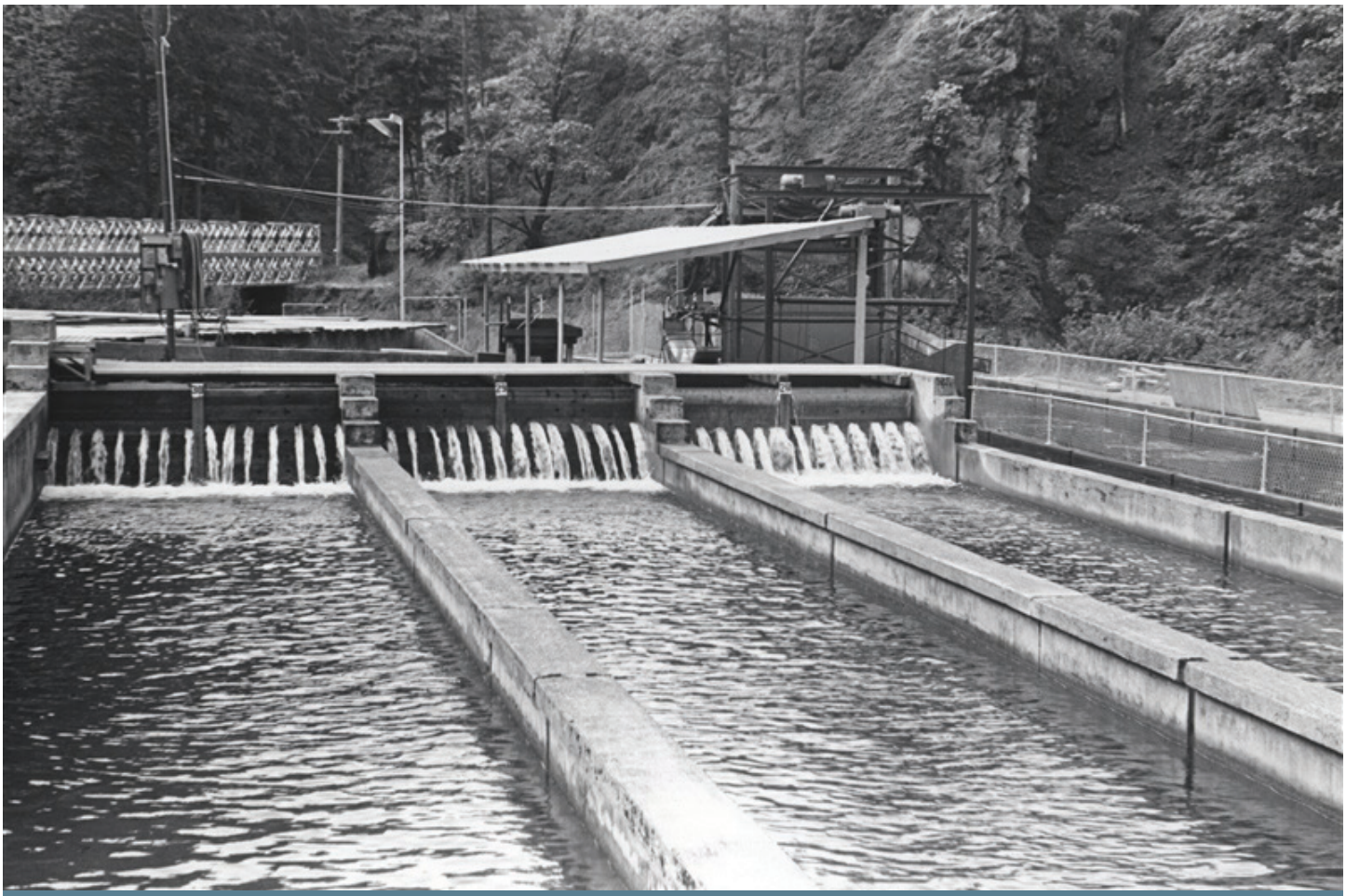


Figure 23. The raceway at Little White Salmon Hatchery in Cook, Wash., (Williams, B., NOAA Central Library Historical Fisheries Collection, 1968).

finding suitable topography. Flow-through raceway systems usually rely on natural springs as a source of water and gravity, rather than a pump, to move the water from one end to the other.[24] Suitable topography with an 8-10% slope is needed to ensure water is flowing properly and a pump isn't needed. This continual flow helps replace oxygen removed by the fish and maintain a consistent water temperature.[42]

With flow-through raceways, treating wastewater as it leaves the system is important to prevent the spread of disease, as well as the contamination of natural waterways.[41] Because flow-through raceways can support higher densities of fish, cleaning these systems and removing the high volume of discharge can be a challenge.[42] At the end of a raceway, excess solids, such as feed and feces, are removed from the channel using suction. From there, the waste empties into a sedimentation basin which uses gravity to remove solids before the treated water is discharged into a natural waterway.[59] Operators also have to periodically clean raceways, as some of the waste settles at the bottom.[59] If left untreated, fish discharge or waste can add dissolved phosphorus and nitrogen, among other things, to natural waterways.

"Fish waste adds phosphorus and nitrogen to a stream, and as fish waste decomposes in receiving streams, it can use up the dissolved oxygen that wild fish and aquatic life depend on," according to the Wisconsin Department of Natural Resources. "All aquaculture systems should be designed to incorporate best management practices that will collect all settleable solids prior to discharge."[44]

Figure 24. ne-year-old walleye swim in a Recirculating Aquaculture System at the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility (Source: UW-Stevens Point Northern Aquaculture Demonstration Facility, 2019).

To prevent fish discharge from affecting water quality, flow-through raceway operators must ensure the body of water where the waste is dispelled has a strong enough flow to absorb any added nutrients, thus maintaining water quality.[44] Food fish industry experts note that because water from flow-through raceways re-enters natural springs or other bodies of water, farmers usually have to apply for discharge permits and are required to adhere to the specific water laws in the state in which they operate.[24]

While Idaho has been successful in using flow-through systems to raise rainbow trout, and so has the Minnesota-based Driftless Fish Company, some experts suggest that the amount of natural spring water required may limit the viability of this method.[24]

CLOSED AQUACULTURE

Recirculating Aquaculture Systems (RAS)

Recently, technological developments have drastically increased the capabilities of closed aquaculture systems. Recirculating aquaculture systems (RAS) and aquaponics are examples of closed systems, both of which are considered less of an environmental threat than semi or open systems. Additionally, these systems have the potential to produce higher yields, but with greater opportunity comes a higher cost. Closed aquaculture requires precise management and operators must provide, "nutritionally complete rations, continuous aeration or oxygenation, biological filtration and waste management" for their fish stocks.[40]

> *"The technology with these recirculating aquaculture systems (RAS) has moved forward and advanced in the last five years or so, and I think that's really important because they have minimal environmental impact. In Minnesota and the rest of the Great Lakes states, there is a lot of opposition to using public waters for aquaculture. This is important because the recreational fisheries in this state bring in about $2.5 billion in economic value. In contrast, the food fish aquaculture industry brings in approximately $1.7 million. If aquaculture is to succeed, it will need public acceptance to do so."*
>
> Don Schreiner, Fisheries Specialist, Minnesota Sea Grant[60]

RAS are an increasingly popular form of closed aquaculture, in part because of the level of optimization available to operators. Some of these sophisticated systems can reuse 80-90% of the water held in the tanks[24] — one of the many capabilities that make RAS an environmentally friendly option.[42]

"Consequently, these systems greatly diminish the amount of water required to produce fish, which is often a problem for sustaining land-based aquaculture systems," Steve Summerfelt, director of aquaculture systems research with the Conservation Fund's Freshwater Institute, said during a 2017 Minnesota food fish workshop.[24]

In recirculating systems, a mechanical filter is used to remove solid waste such as excess feed and fecal matter from the tank. Wastewater from the tanks then goes through a sedimentation filter where gravity is used to separate solid particles and water, with the solid particles settling on the filter. Ammonia and nitrates, produced by fish during digestion, are removed as the water passes through a biological filter.[61] Operators must closely monitor water quality to maintain the health and wellbeing of the fish, so before the water is returned to the tanks, aeration or oxygenation must occur.[40]

Fish need a constant supply of dissolved oxygen (DO) to survive and if levels dip too low it can cause physiological stress on the fish.[62] The amount of oxygen needed depends upon the species because fish adapt to their natural habitats. Wild salmon, for instance, live in faster flowing water where oxygen levels are frequently replenished, whereas other species have adapted to calmer, less oxygenated waters.[63] When fish become stressed as a result of lower levels of DO, they typically eat less and become more susceptible to disease, both of which can lead to "decreased growth rates and mortality."[62]

In closed aquaculture, aeration or oxygenation systems are used to maintain water quality. "When the water has been through the fish tanks, the oxygen content has been lowered, typically down to 70%, and the content is reduced further in the biofilter. Aeration of this water will typically bring the saturation up to around 90%, in some systems 100% can be reached."[58] Aeration is a process that uses different forms of technology — including paddlewheels, floating surface and vertical pump aerators, among others — to increase the level of dissolved oxygen and distribute it throughout ponds, recirculating or flow-through systems.[62]

Oxygenation systems are used in high-density aquaculture when aeration equipment can't keep up with the level of oxygen consumption by the fish.[64] Oxygen cones and low-head oxygenators are just two examples of these types of systems.[42] Both use similar principles to inject oxygen back into the water. "Water and pure oxygen are mixed under pressure whereby the oxygen is forced into the water."[58] Typically, fish farmers will need to evaluate which process is most effective for their operation.

While the customization opportunities available with RAS are part of what makes them advantageous, these systems also address some of the environmental concerns associated with other categories of aquaculture. For instance, pollution and the effect that can have on wildlife is a significant concern for consumers. Using these systems to recirculate water reduces the number of pollutants discharged, which could negatively impact the environment if left unregulated.[24]

Unlike semi-closed and open aquaculture, RAS aren't as limited by location because most of these systems are housed indoors. Still, as Ed Aneshansley, senior aquaculture engineer for McMillen Jacobs Associates, explained, identifying the appropriate resources for water and discharge can still present a challenge.

> *"Even with a recirculation facility, there still is a significant water volume requirement and a pretty large discharge requirement, as well. Those resources require permitting and a lot of upfront work to get a site ready. That's a huge bottleneck."*
>
> Ed Aneshansley, Senior Aquaculture Engineer, McMillen Jacobs Associates[7]

Although these systems still need a reliable source of quality water, RAS compared to other aquaculture systems substantially reduces the chance of farmed fish escaping and breeding with wild populations.[41] Operating indoors also eliminates the possibility of predators negatively impacting a farmer's stock.[24]

For food fish producers in the Midwest, Summerfelt added that RAS could make rearing species that require warm water year-round more economically feasible. Recirculating warm water in and out of the tanks not only conserves energy but also provides more opportunity for Midwest farmers to produce a wider variety of species.[24]

Figure 25. **Atlantic salmon swim in a Recirculating Aquaculture System at the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility (Source: UW-Stevens Point Northern Aquaculture Demonstration Facility, 2015).**

"Minnesota and Wisconsin are ideal environments for raising rainbow trout, salmon (Atlantic and Coho), and Arctic Char in RAS," Summerfelt said. "Not only are there plentiful freshwater resources but the groundwater ranges from 8-10 degrees Celsius (46-50 degrees Fahrenheit) north to south, which is ideal for such cold-water fish."[24]

While there are many benefits to RAS, one of the most significant barriers to entry in this methodology is cost. "The capital expenses for a RAS are about 80% higher than traditional ocean net-pen systems, but the gap is narrowing," Summerfelt explained. The initial investment cost for RAS makes the barrier to entry quite high, and with very few successful businesses for investors to look to for a proof of concept, many operators are unable to secure funding for the technology. Summerfelt explained that some U.S. operators have purchased systems from Europe in order to secure a loan through the Bank of Denmark.[24]

> *"I don't think technology is a challenge. I think people are challenged by getting a good technology provider and capital that's patient. When you first start, you're never that good, so it helps to have a patient investor and a realistic business plan, but you've got to have consumers buying it."*
>
> Steve Summerfelt, Chief Science Officer, Superior Fresh[6]

In addition to the initial investment, experts agree that launching a food fish business using a RAS system requires careful planning and research. Choosing a profitable species based on the market, as well as having an experienced engineering firm design the system to meet

the needs of the fish, plays a critical role in the success of a business. Beyond that, maintaining these complex systems requires expertise and training, as well an emergency system to consistently monitor the tanks.

> *"You've got to have knowledgeable people running these systems, who know how to raise a fish, understand the biology of fish, plus the engineering and maintenance of the systems."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

While the initial capital cost for RAS is quite high, according to experts, continued technological advances could make the return on investment worthwhile, as fish "tend to be healthier and survive better than they might in other aquaculture systems."[24]

Aquaponics

Aquaponics is a unique food production method that uses RAS to rear fish and a hydroponics system to grow plants — usually vegetables — without using soil. In aquaponics, instead of discarding the ammonia excreted by fish, the wasted by-product is used. Ammonia build-up can be toxic to fish in RAS, so operators have to replace approximately 10% of the water daily. However, in aquaponics systems the nutrient-rich water goes from the RAS to a biofilter where "the bacteria can grow and convert ammonia to nitrates and organic wastes to carbon dioxide." From there, the nutrient-rich water is transferred to the hydroponics tank where plant roots are submersed in it.[65]

The plants absorb "nitrogenous and mineral products"[66] produced by the fish and purify the water before it returns to the fish tanks.[67] This is particularly beneficial for operators, as it reduces water usage and the cost of water filtration.[36] Additionally, operators can collect solid waste from the fish and plants, repurposing it as fertilizer that can serve as an additional source of income.[68]

While aquaponics systems can be coupled or decoupled, a few studies have found that fish production remains stable with both, but the latter yielded higher plant growth.[36] Coupled or closed-loop systems use one RAS and pump water from the fish tank to a filtration system and on to the plant unit where the non-toxic nutrients are removed, further purifying the water before it returns to the fish tank.[42] These systems "work on the premise that the incoming feed to the fish provides [sic] the exact nutrient requirements for the plants being grown." For coupled systems, consistent feed is a critical component for ensuring production remains on track. Because these systems are dependent on the balance of multiple variables, it's more difficult to address problems like diseased fish because that, in turn, affects the plants.[68]

Decoupled systems are typically easier to scale up for commercial operations,[36] because "they separate the water and nutrient loops of both the aquaculture and hydroponics unit from each another and thus provide a control of the water chemistry in both systems."[69] Plants and fish typically have different optimal water quality requirements, such as pH and temperature, so decoupling the systems allows operators to address these needs separately.

Ultimately, decoupled systems provide a wider selection of products for the operator to choose from when determining which fish or plants to grow. Tilapia, channel catfish, rainbow trout, perch, Arctic char, and largemouth and striped bass are the most common types of fish reared in aquaponics systems,[65] but University of Wisconsin Stevens Point is currently evaluating research to determine whether walleye would be suitable as well.[42]

With coupled systems specifically, operators are usually limited to rearing warm water fish, such as tilapia, because most crops require water temperatures between 65- and 80-degrees Fahrenheit. Much like plants, different species of fish have a range of optimal temperatures,[68] and decoupled systems allow operators to raise cold water species like salmon or walleye, while still maintaining the warmer water temperature needed for growing plants.[36] While adjusting water temperature to meet the needs of fish and plants is possible with a decoupled system, heating or cooling the water could increase the energy costs of an operation.

Figure 26. USDA certified organic leafy greens grown at Superior Fresh in Hixton, Wisc., using an aquaponic model. (Source: Superior Fresh, 2021).

Aquaponics systems are particularly attractive because they are sustainable, viewed favorably by consumers, efficient and yield multiple end products. There are, however, several challenges for operators to consider before choosing this type of system. The initial investment for an aquaponics system is quite high, especially for those looking to build a commercial operation. Additionally, operators must have a thorough technical training on the equipment and grasp the needs of both fish and plants. An understanding of the market is also a key factor, as production should be based on consumer demand.[65]

While aquaponics is still a relatively new method, experts suggest that decoupled systems could be promising for fish farmers in the upper Midwest. Still, with many aquaponics businesses just getting started, researchers said it's still unclear whether these systems can serve as a significant form of food production.[24]

Key Takeaways

There are a variety of fish farming methods, presenting inherent challenges and opportunities.

Producers must consider all of the variables including, but not limited to species, climate, financial capacity, water and land resoures before selecting a method.

Generally, open aquaculture, which includes ponds and net pens, tend to be more affordable but may incur limitations.

Researchers identified ponds as a potential option for Minnesota producers looking to rear cool to warm water species. Net pens are generally less publicly supported and it's not legal on Lake Superior. Net pen aquaculture, however, has been explored in abandoned Minnesota mine pits.

Semi-closed aquaculture systems are usually capable of raising fish at higher densities, but often require more maintenance than a closed system.

Raceways which are an example of a semi-closed aquaculture system, require a significant water source and suitable topography.

Recent technological advancements have drastically increased the capabilities of closed aquaculture systems, such as recirculating aquaculture systems (RAS) and aquaponics.

These systems are housed indoors, making them particularly attractive to food fish farmers in colder regions where the weather could limit production. The upfront capital expenses for these systems, however, are often the most significant barrier to entry for food fish producers.

Disease Control and Detection

Disease outbreaks and even "low-level incremental losses" can be devastating for fish farms — and the bottom line. There are steps, however, that food fish farmers can take to minimize the possibility of a disease outbreak.[70] Experts suggest a proactive approach to disease prevention is more cost-effective than treating sick fish.[70]

"Vaccination is the most effective method of combating disease and currently there are a number of vaccines commercially available for use in fish."[71] Fish vaccines are typically delivered through injection or immersion. Injection is a very time-consuming method of vaccination, and involves handling the fish, which can cause physiological stress.

Immersion is a less stressful method of vaccination for the fish but is often limited to smaller species.[72] Due to these constraints, researchers have started exploring oral vaccination delivery methods that would be suitable for fish of all sizes.

There are several ways producers can proactively approach disease management beyond vaccinating farmed fish. Knowing the signs and symptoms of a sick fish, as well as developing and maintaining biosecurity measures are key to managing or preventing disease outbreaks.

Role of Stress in Disease

Stress can play a significant role in fish health and is often "caused by placing fish in a situation that is beyond its normal level of tolerance." Various chemical, biological, physical and procedural stressors can negatively affect a fish's natural "protective barriers." Stressors can trigger a fight or flight response, where the animal appears to be adapting to a situation, but in reality, may be using up its energy trying to respond to new conditions. This can lead to exhaustion, leaving the fish more susceptible to disease or death. When there is a disease outbreak, there are a multitude of factors that contribute to how each fish responds to disease-causing organisms.[70]

Figure 27. An inside look at Superior Fresh's greenhouse in Hixton, Wisc., where it grows several varieties of lettuce using an aquaponic model (Source: Superior Fresh, n.d.).

HOW STRESS AFFECTS 'PROTECTIVE BARRIERS'

Mucus

Mucus is a physical and chemical barrier that protects fish from disease-causing organisms. Stress can decrease the effectiveness of the mucus' chemical makeup, which is normally capable of killing pathogens.[70]

Scales and Skin

Scales and skin provide a physical barrier that protects the fish and, when damaged, can serve as an entry point for bacteria and other pathogens. This physical barrier is usually damaged during handling or fighting among fish. Fish with parasite infestations can also lose scales, often resulting in bacterial infections. Physiological stressors and bacterial infections are often a lethal combination for fish.[70]

Inflammation

Inflammation acts as a protective barrier by fending off and attempting to destroy invasive bacteria, viruses or other toxins. Stress, especially from cold temperatures, can decrease the effectiveness of this protective barrier, eliminating a critical first line of defense for the fish.[70]

Antibodies

Antibodies are proteins the body produces to fend off pathogens. When a fish first comes in contact with a disease-causing organism these antibodies form, fend off the pathogen and then protect the fish from future exposure to it. Temperature stress and prolonged stress can negatively affect the speed and effectiveness of a fish's antibody response, leaving it vulnerable to invaders.[70]

The key takeaway is that fish all have natural protective barriers that can fend off "invaders" if they are in a low-stress environment. Stressors, as described above, can weaken the fish's ability to naturally protect itself. Maintaining "good water quality, good nutrition and sanitation" are vital to protecting the health and well-being of fish stocks.[70]

Fish diseases vary by species, but there are some common signs that could indicate illness. If fish aren't consuming as much feed, operators should first check to make sure oxygen levels and temperature are at optimal levels. Fish that reduce their food intake, despite optimal water quality, should be evaluated by a health specialist. Changes in behavior, such as fish gathering around the water's surface or near aerators, rubbing against the bottom of a tank or swimming slowly could also indicate disease. Other indicators of disease include, "fin erosion, skin ulcers or discoloration, white fuzzy patches, bumps, open sores, and cloudy or swollen eyes." Lastly, discovering a dead fish is an immediate indicator that at least one fish, and maybe more, was diseased.[73]

> *"If producers call me, it's usually about how to walk through a fish health risk assessment. They say, 'Here's my facility; here's the species,' and I say, 'All right, here's the three things you need to be worried about and here's how you address them.'"*
>
> Nicholas Phelps, Director, Minnesota Aquatic Invasive Species Research Center, University of Minnesota[74]

Operators should immediately quarantine or isolate any fish that show signs of disease, as this can protect the rest of the stock.[75] From there, it's important to find an aquatic health specialist who can easily, "recognize fish parasites by microscopy and the ability to culture and identify bacteria, fungi, and viruses." Fish specialists usually ask a series of questions to get a better sense of what disease could be affecting the stock. Producers should have information on hand about recent stocking activity, how the fish are behaving and whether there are any visible signs of disease, among other things.[73] Fish diseases fall into three main categories — viral, bacterial and parasitic — and should be diagnosed by an aquatic health professional.

"Diagnosis of a bacterial disease should be verified by a fish health specialist, and appropriate bacterial tests should be run to determine which antibiotic will be effective."[76] The fish specialist can then recommend an FDA-approved antibiotic, which can range from a medicated feed to a prescription injection or immersion.[77] Chemicals and drugs

used to treat food fish are regulated by the FDA and EPA, and very few are authorized or approved for use.

> *"Food fish are extremely restricted in antibiotics. We don't use any of them but even with sanitation, we have a step where we have to sanitize the eggs and we use a formula that we can only buy from the one company in the country that's approved to sell it for food fish, even though it's very similar to other products."*
>
> Chad Hebert, Owner and Operator, The East Phillips Indoor Urban Farm Project[78]

Those treatments that are authorized must be used according to the label or as directed by a fish specialist.[73] Treatment is used to delay the progress of the pathogen and give the fish's immune system an opportunity to fight it. Experts note that treatment won't eliminate a pathogen all together, and it could still return when the medication wears off.[70]

Figure 28. Rainbow trout with a skeletal deformity (Source: Nicholas Phelps, 2021).

Importance of Biosecurity

Disease is one of the leading causes of economic loss among food fish farmers, partially because outbreaks can spread rapidly. "Each year in the U.S., millions of dollars in losses to fish producers are attributed to infectious diseases."[75] Implementing basic biosecurity practices can, however, help food fish farmers minimize the risk of introducing a disease to their stocks.[79]

> *"Biosecurity measures are important not only when bringing new fish into a facility; these measures are also important for reducing overall numbers of potential pathogens in a given system, and to avoid transferring pathogens from one system to another."*[76]

The goal of biosecurity management is to prevent a disease or disease-causing organisms such as parasites, fungi, viruses or bacteria, from coming in contact with fish stocks. Biosecurity risks can vary based on species and the technology used for production, among other things, so there's not a single solution to prevent the spread of disease.[75] If proper biosecurity measures are implemented, indoor recirculating aquaculture systems (RAS) are the easiest systems to keep pathogen and disease-free.[24] Experts encourage those new to the industry to consult with an aquatic health specialist to identify the specific risks and preventative measures,[75] as prevention is "more rewarding and cost-effective than [the] treatment of dying fish."[70]

Disease Transmission

Understanding the five primary ways fish diseases spread is one of the first steps to mitigating risk. In aquaculture, the transmission of diseases usually occurs through direct exposure, ingestion, contaminated water, and contact with fomites or vectors.

Direct contact, which is the most common cause of transmission in aquaculture, occurs when disease-causing organisms from an infected fish enter an otherwise healthy fish "through the skin, open wounds, mucous membranes, or gills."[75] Fish diseases can also spread when other infected fish or contaminated feed is ingested. Feed that isn't stored properly is particularly susceptible to contamination.[76] If a diseased fish dies and isn't promptly removed, other fish may then feed off of it, which could lead to a larger outbreak within the tank. Experts also note that, "Ingestion of water contaminated with waste products from infected fish also may serve as a transmission route."[75]

Feces, mucus, reproductive fluids or urine expelled from a diseased fish can also contaminate water, which can contribute to the spread of pathogens to other locations. "Shipping water often contains high numbers of bacteria and may also contain parasites or other pathogens."[76] In some cases, though less common, experts have traced disease spread to contaminated droplets of water or aerosols.

Fomites and vectors facilitate disease spread in similar ways, with disease causing organisms coming in contact with something that can carry pathogens to different locations. Inanimate objects that come into contact with pathogens and can spread them to production sites are known as fomites. Any equipment that isn't properly disinfected — including everything from nets, buckets, hoses, and even clothes or shoes worn by operators — can serve as a fomite.[75]

Vectors, on the other hand, are living organisms that can carry pathogens from one site to another in various ways. Animals such as birds, rodents, leeches and even humans are examples of vectors.[76] "Animals may transfer fish diseases between locations by carrying the pathogen on their body or feet, or by dropping fish or fish parts at other locations. Rodents and birds may carry some fish pathogens in their feces or urine, contaminating the environment or fish feeds."[75] People can also serve as vectors, with their hands, arms or other body parts transferring pathogens from tank to tank as during fish handling.[76]

Mitigating the Risk of Introducing Diseases

Implementing biosecurity measures is recommended, as experts note this can

reduce the risk of disease-causing organisms coming in contact with fish stocks. The most successful biosecurity programs begin with a risk assessment, where the operator identifies specific areas or processes that could contribute to disease transmission. With those risk factors in mind, fish farmers can begin developing effective processes that address those risks and train employees, so everyone is following the same biosecurity protocols.[79]

> *"Good biosecurity measures will reduce the risk of catastrophic losses from infectious disease and low-level losses that, over time, can also greatly affect the bottom line."*[76]

With open aquaculture, risk reduction is more difficult because contact with wild fish increases the potential for disease spread. Net pens, for instance, are typically densely stocked, which is a physiological stressor for fish and can make them more vulnerable to disease.[75] Since these are open systems, disease can then spread to wild populations of fish as well. Pesticides and other antibiotics are the most common way to prevent disease spread in these systems, but experts note that these chemicals also inevitably affect wild fish because of the open water flow.[80]

Figure 29. **Parasite infection seen in the skeletal muscle of a yellow perch (Source: Nicholas Phelps, 2021).**

For closed and semi-closed systems, however, the greatest risk for disease transmission occurs when fish are moved, whether that includes the introduction of new fish or current stocks being moved within or out of an aquaculture facility.[75] For fish farmers, one of the most important factors in mitigating the risk of disease transmission is doing thorough research to ensure a reputable supplier is selected. Consulting with an aquatic health specialist before purchasing stock can help a fish farmer know what diseases that species is most susceptible to, as well as the best ways to maintain fish health. Experts recommend that operators ask suppliers where their fish came from, whether any disease issues have been observed and the extent to which the fish underwent "health examinations, disease testing, or treatments."[79] Some suppliers offer fish that are certified as disease-free, and thus are the preferred option when sourcing fish or eggs.[75]

Reputable suppliers will be able to provide information about fish health,[79] and if information is unavailable, operators should quarantine new stock for four to six weeks before introducing them to current stock.[75] "Fish in quarantine should be sampled for specific diseases of concern at the beginning and end of the quarantine period and at any time that disease signs develop."[79]

Quarantines should take place in a different location than where current stocks are housed and utilize separate equipment to further reduce the possibility of any type of cross contamination. Additionally, experts recommend that, "Any water effluent on or off the farm from the quarantine area should be managed to avoid contaminating water sources or fish production areas."[75] Quarantines are one of the most important biosecurity measures a fish farmer can take because it allows ample time for observation and protects current fish stocks.

General maintenance is another factor that contributes to making sure fish stocks remain healthy once they arrive at a facility. Maintaining water quality, removing dead or dying fish, providing a well-balanced diet and keeping detailed health records, all play a role in keeping stocks healthy.

Water quality is an important factor for maintaining fish health, and so it is also a critical consideration when developing biosecurity measures for an aquaculture facility. Poor water quality is one of many physiological stressors that can make fish more susceptible to disease. Ideal water chemistry varies by species, but in general, operators monitor temperature, as well the level of dissolved oxygen, ammonia, and nitrate in the water. When selecting a water source, experts recommend using pathogen-free groundwater, which can be found in wells and springs. If groundwater isn't an option, surface water sources can be used, but must go through a stringent disinfection process.[75] All water, however, should go through a testing process to ensure it's safe to use.[79]

"If even a small amount of unsafe water is used (e.g., surface water used to prime a well pump), the entire water supply should be considered unsafe. Similarly, water used to ship fish should not be poured into the system."[79]

Ultraviolet (UV) sterilization and ozonation are the most common techniques used for removing disease-causing pathogens from unsafe water sources, particularly with recirculating aquaculture systems (RAS). With ultraviolet sterilization, the water passes through a glass or quartz sleeve that's emitting UV light at a wavelength capable of killing organisms that would be harmful to fish.

Ozone disinfection systems are more complex than UV sterilization systems and also more dangerous, as small amounts of the highly reactive molecule can kill fish. Ozone can also be toxic for humans, so fish farmers often have to consult specialists before using one of these systems. "The ozone oxidizes (i.e., reacts with and breaks down) dissolved and suspended molecules, as well as molecules within and on pathogens in the water." Afterward, the water must pass through a carbon filtration system to remove the ozone before being transported back to a tank.[76]

Providing a well-balanced diet can also help keep fish stocks healthy and build up their disease resistance. Feed should be securely stored in a cool, dry environment, as this can reduce the chance of mold.[67] Live feed is also

common with certain species and must be tested before they're fed to the fish stock.[79] Loss of appetite is commonly an early indicator of disease with fish, so operators must continually monitor and keep detailed records of food intake.[79] Along with feed conversion records, health records can serve as an indicator and help operators detect disease. For instance, noting when new fish are introduced gives an operator a frame of reference if a disease outbreak occurs. This can also indicate where some biosecurity risks still exist.[75]

Lastly, promptly removing and properly disposing of dead or dying fish can help prevent a disease outbreak. As previously mentioned, diseased fish can contaminate the water and if a fish dies and isn't removed right away, other fish in the tank may resort to cannibalism. After a fish dies, operators may want to contact an aquaculture health specialist to perform a necropsy to identify any potential for disease among the remaining stock. Once removed from the tank, dying fish should be humanely euthanized and disposed of in accordance with local laws.

Figure 30. A Superior Fresh staff member holds up an Atlantic salmon raised using an aquaponic model (Source: Superior Fresh, n.d.).

Implement a Cleaning Protocol

In addition to the preceding steps, stringent cleaning protocols can minimize the possibility of infectious disease transmission by fomites. Sanitation involves removing visible debris from equipment — including, but not limited to, buckets, nets, waders and boots — by scrubbing them. Fish farmers should then apply disinfectant to all surfaces for the recommended time listed on the bottle of the cleaning agent. Preferred cleaning methods and agents often vary by state, so operators have to do thorough research beforehand. Some of the common cleaning agents used in aquaculture include chlorine, iodine, Virkon® Aquatic, alcohol and hydrogen peroxide, among others. After equipment comes into contact with the cleaning agent for the recommended amount of time, it should be rinsed and dried, preferably in the sun.[79]

Beyond equipment, experts recommend that, because employees can serve as vectors, disinfection protocols should be in place to prevent disease spread. In large facilities, employees are often assigned to a certain work area to avoid cross-contamination. Facilities can also place stations equipped with foot baths and showers, as well as areas for hand washing, equipment and vehicle disinfection, in strategic locations. If employees receive thorough training on when and how to use these disinfection stations, that can also play a critical role in keeping fish stocks healthy.[79]

Overall, understanding and implementing clear biosecurity measures can help reduce the chances of a catastrophic loss, and even more periodic losses. Even steps such as carefully monitoring water quality and knowing the signs of a sick fish can make a significant difference in quickly recognizing a problem when it occurs.

Key Takeaways

For food fish aquaculture, disease outbreaks can be devastating, and treatments are limited.

Knowing the signs and symptoms of diseases can help producers detect illnesses early on and isolate sick fish.

Understanding the way fish diseases spread can help producers mitigate the risk of a devastating outbreak.

There are at least five primary ways fish diseases spread: direct exposure, ingestion, contaminated water, and contact with fomites or vectors.

Implementing biosecurity measures can reduce the risk of a disease-causing organism coming in contact with fish stocks.

Every aquaculture facility is different, so experts recommend that producers conduct a biosecurity risk assessment and develop a protocol based upon it.

Fish Nutrition

Identifying sustainable feeds is another hurdle the aquaculture industry faces, as many traditional feeds put pressure on wild fisheries and are sold at a price point that could significantly affect input costs — especially for small businesses.

Farmed fish, like those in the wild, require a balanced diet to keep them growing and healthy. While aquaculture is considered an efficient way "to convert feed to edible protein," researchers are still exploring and developing economically viable fish food alternatives.[81] The ultimate goal is to identify feeds that would maintain the human health benefits, while also allowing the industry to increase production without negatively impacting wild stocks.[82]

Fish nutrition in the wild varies by species, as some carnivorous fish such as salmon eat other, smaller fish and insects, and herbivorous fish subsist on plants. Many aquaculture facilities at least partially rely on fishmeal, which usually comes in the form of small pellets, to feed their stocks a well-balanced diet.[83]

"Nutritionists who design feed for fish have to account for about 40 essential nutrients," according to NOAA Fisheries. These essential nutrients include vitamins, minerals, amino acids and fats — all of which contribute to making fish and seafood nutritious dietary options for humans.[72] Unfortunately, traditional fishmeal is costly because it often consists, at least partially, of "wild-caught bony, oily, forage fish such as anchovy, herring, mackerel, and sardines."[83]

In 2018, aquaculture accounted for 46% of the world's fish

production, according to the Food and Agriculture Organization (FAO) of the United Nations.[1] So as the aquaculture industry and, in turn, the demand for aquafeed, grows, so does the demand for the forage fish used in fishmeal.[84] While many of these forage fish have shorter life spans and are known to reproduce quickly,[81] scientists warn that demand, "will eventually surpass ecological supply of forage fish."[84] Seventeen percent of the U.S. fish catch was reduced to fishmeal and oil in 2018 alone.[4]

The U.S. uses quotas and catch limit systems to maintain and regulate wild stocks but doing so also causes the supply of forage fish to remain constant even as the demand increases. As a result, the price of fishmeal and fish oil has increased over the last decade.[81] The cost of feed can "account for about 40-70% of the variable cost of finfish and shrimp culture," which often makes it difficult for those in the aquaculture industry to scale up their businesses.[3]

> *"Global fishmeal and fish oil production have remained steady in recent years at five million metric tons (MT) [approximately 5.5 million tons] of fishmeal and one million MT [approximately 1.1 million tons] of fish oil annually, according to IFFO, The Marine Ingredients Organisation. But aquaculture's demand for these ingredients is growing steadily."*
>
> James Wright,
> Global Aquaculture Alliance[85]

Since using forage fish in aquafeed is no longer a cost-effective option, research is underway to determine how to produce feeds that offer the same nutritional benefits. In 2007, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Agriculture (USDA) launched the Alternative Feeds Initiative, which aims to identify ways to reduce the amount of fishmeal and fish oil incorporated into aquafeeds.[81]

"Potential alternative ingredients already in use include soybeans, barley, rice, peas, canola, lupine, wheat gluten, corn gluten, other various plant proteins, yeast, insects and algae," according to NOAA Fisheries.[81]

Soybeans for Aquafeed

The Marshall, Minnesota-based feed company, Midwest Ag Enterprises is just one company making strides in identifying alternative ingredients. Using soybeans, Minnesota's second-largest cash crop, Midwest Ag Enterprises developed a new high-protein soy concentrate that can be used as aquafeed.

> *"Soybean meal is considered to be one of the most suitable and stable supplies of an alternative ingredient for replacing fish meal [sic] in commercial fish feeds. Compared to other grains and oilseeds, soybeans are promising because of their high protein content, high digestibility and good amino acid profile."*
>
> NOAA[82]

Together with the Agricultural Utilization Research Institute (AURI), Midwest Ag Enterprises developed a process to remove indigestible components of the soy product, NutriVance, such as fiber and complex sugars. These components, "inhibit nutrient absorption in animals that have a single-chambered stomach."[86] Products like NutriVance are especially important for providing protein and other nutrients for carnivorous fish species, such as rainbow trout, while also reducing the cost of fishmeal and the pressure on wild fish stocks.[87]

A nutrition study of the product found that "NutriVance can be used to replace up to 25% of soybean meal and soy protein concentrate in a practical diet for rainbow trout juveniles without sacrificing growth performance, feed utilization and nutrient retention."[88] The product reduced the cost of the aquafeed by eliminating the need for incorporating forage fish into the meal, and also helped the fish grow to a consistent size.

Scaling up the use of soy-based aquafeeds like this will not only benefit Minnesota's soybean farmers, but also the state's aquaculture industry. Mike Ziebell, general manager of the Minnesota-based trū Shrimp, told AURI in 2016 that a mix of soybeans, wheat and fishmeal is used to cultivate the company's shrimp.

> *"Over 40% of the shrimp's diet is soy based and the other 11% is red meat. So, we have two major commodities right at the doorstep of Minnesota. We've essentially brought this technology to Minnesota and brought the shrimp to the feed."*
>
> Michael Ziebell, CEO,
> The trū Shrimp Company[89]

Taurine

As part of the Alternative Feeds Initiative, NOAA and the U.S. Department of Agriculture identified the nutrient taurine as an aquafeed ingredient that can reduce the nation's reliance on forage fish.

"Taurine is a key nutrient needed to make plant proteins nutritionally similar to other animal proteins," according to NOAA Fisheries. Many animals need the amino acid taurine for proper development, as it aids in fat digestion and eyesight development, among other things.[90]

Taurine can be produced synthetically but is also found naturally in certain animal products, as well as in algae. In the wild, forage fish eat algae and produce taurine naturally, whereas carnivorous fish cannot create this nutrient and must obtain it by eating smaller fish.

While taurine wasn't an approved aquafeed ingredient here in the U.S. until 2017, Canada and many European countries were using it to feed farmed fish stocks for years prior. Using taurine in addition to plant proteins in aquafeed can reduce the nation's dependence on forage fish for fishmeal. This, in turn, can also significantly reduce the price of aquafeed. "Using fish feed with taurine will cost farmers less than half of what it costs to feed fish to other fish," according to NOAA Fisheries.[90]

These are just a few of the research and development efforts underway to reduce the nation's dependence on forage fish for feed. Exploring alternative ingredients ranging from insects to seaweed, scientists have discovered a wide variety of substitutes for forage fish. In addition to these advancements, researchers are studying everything from improving feed use to "timing dietary needs with developmental stages."[81]

Figure 31. **Farm-raised Atlantic salmon grown by Superior Fresh in Hixton, Wisc. (Source: Superior Fresh, 2021.)**

OPPORTUNITIES FOR SEAFOOD WASTE IN MINNESOTA

Fish waste contains high levels of nutrients when used as a livestock feed, plant fertilizer or soil amendment which is a process used centuries ago. However, handling and processing the fish waste into a stable form for storage and further utilization comes at a high cost and can be a process challenge.

Stabilizing fish waste after processing for further utilization is a necessity for value-added seafood production. Fish waste requires drying or stabilizing as an emulsion prior to utilizing as a possible feed ingredient or fertilizer. Separation of fish oil can also pose a potential for adding value when the appropriate markets are identified such as pet food diets due to the high levels of omega-3 and omega-6 fatty acids.

Livestock, poultry, aquaculture, and pet food are all market opportunities for fish waste. Fishmeal can come from various sources and is often a by-product of fish processing and rendering. ensures stabilization of the product along with drying and milling. Fishmeal ranges from 44-65% crude protein on a dry matter basis. Aquaculture diets rely heavily on fishmeal as a primary ingredient. Along with being a good source of protein, fishmeal also contains very low fiber which is beneficial when developing a nutrient dense pet food. Secondly, as the pet food industry continues to focus on highly digestible sources of protein and energy there continues to be a growing demand for meat-based ingredients.

Fish waste emulsions are often referred to as “fish silage” and is a practice that has been used for decades by the seafood industry. Fish silage in this case is not a solid feed for livestock like corn silage but rather a flowable fish emulsion stabilized with acid. A common document which outlines the process can be found at the Food and Agricultural Organization of the United Nations, titled Fish Silage: Fish Silage (fao.org). Fish silage is a more dilute nutrient form of fishmeal although it can be fed to livestock with the proper equipment.

Fish emulsions are also commonly used as fertilizer for a variety of plant growth applications including lawns, plants, and vegetables. A typical fish emulsion may contain 2% nitrogen, 1% di-phosphorus pentoxide (P_2O_5), and 1% potassium oxide (K_2O). However, fish fertilizers can also come in a dried hydrolyzed from which is typically more nutrient dense and will contain greater nutrient levels such as 4% nitrogen, 2% P_2O_5, and 2% K_2O.

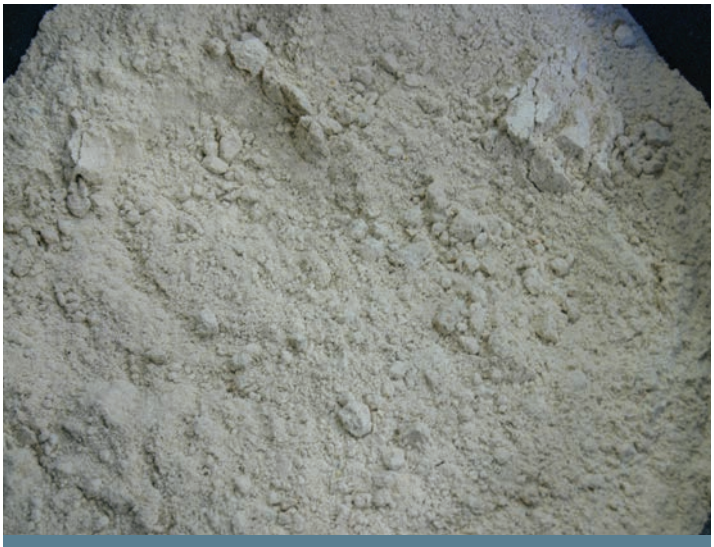


Figure 32. Dried fish waste for swine feed applications (not milled) (Source: AURI, 2020).

Figure 33. Dried and milled fish waste blended in a typical swine nursery feed (ample shown is prior to pelleting) (Source: AURI, 2020).

Conventional, and organic crop production is possibly the largest potential market based on volume for hydrolyzed and fish emulsions. Due to the organic nature of fish fertilizer along with the macro and micronutrients fish fertilizer provides for crop production it can be a critical crop nutrient when broadcast or applied as a foliar feeding.

Lastly, seafood waste from arthropods such as shrimp present another growing opportunity in Minnesota with the increase of shrimp production. The outer protective shell provides opportunities for developing biobased polymers derived from the chitin within the shell. Chitin, which is the exoskeleton from crustaceans such as shrimp or scales of fish, may present binding opportunities for the livestock feed, pharmaceutical applications as drug carriers and human food applications as well.

Key Takeaways

Fish nutrition varies by species, but many carnivorous farm-raised fish need a source of protein in their diet.

Traditionally, fishmeal has been this source of protein, but high demand and limited supply have caused the price of this feed to increase significantly.

Because fishmeal is costly and at least partially consists of forage fish, there's a push to find alternative aquaculture feeds.

Through significant research efforts, scientists have already identified some promising alternative sources of protein, such as soybeans, insects, algae and seaweed, among others mentioned above.

Figure 34. Fish silage (emulsion) (Source: AURI, 2020).

Figure 35. Fish silage (emulsion) after treatment (Source: AURI, 2020).

Fish and seafood waste from the aquaculture sector present a value add opportunity for producers.

Livestock, poultry, aquaculture, and pet food are all market opportunities for fish waste.

Regulations and Policy

Many regulations set forth by the state and local government are in place to protect the environment, as well as consumers. While these laws apply to U.S. aquaculture producers, foreign imports don't always face the same stringent regulations — a factor that often makes it difficult for domestic producers to compete with.[24]

> *"Can the rest of the world continue to flood our markets with substandard product at very, very low prices? That's probably the biggest challenge that we have. How much longer can they do that? How much longer will the government allow it?"*
>
> Michael Ziebell, CEO, The trū Shrimp Company[89]

In the U.S. alone, there are more than 1,300 state and federal regulations in place for the aquaculture industry.[91] Many experts, including Carole Engle, an aquaculture economist and co-owner of Engle-Stone Aquatic$ LLC., agree that while regulations are necessary to bolster consumer confidence in the product, too many regulations can be detrimental to industry growth.

> *"When you talk about aquaculture and making a profit, this is a worldwide industry. This isn't something that is just done in Minnesota or the United States. Most of our seafood is imported and if we can't compete on price with the imported product, then we're going to have to compete for people's attitudes toward locally grown fish."*
>
> Don Schreiner, Fisheries Specialist, Minnesota Sea Grant[60]

A study on the Norwegian salmon industry that's referenced in The Costs of Regulations on U.S. Baitfish and Sportfish indicated that too many regulations can actually put limits on the economic competitiveness of the aquaculture industry.[91] While the Food and Agriculture Organization of the United Nations estimates that the aquaculture production will reach 109 million tonnes (more than 120 million tons) by 2030, one study found that industry growth may be related to the regulatory framework each country has in place.[92] Looking at 95 developed and developing countries, the authors of that study noted that stringent environmental regulatory frameworks were "negatively related to aquaculture growth."[93]

"Our empirical results suggest that stricter environmental regulations in developed countries have contributed to lower growth rates and that these countries are falling behind emerging and developing economies that have more lenient environmental regulations."[93]

Out of the 95 countries examined in this study, researchers determined that the U.S. has the third most stringent aquaculture regulations, a factor that could relate to the industry's slow growth rate.[93] A separate article published in the journal Nature, notes that the governments of many Asian countries, as well as Norway and Chile, have helped facilitate the growth of the aquaculture industry, whereas in the U.S. and many European Union member states have impeded it.[94]

"In very few countries, such as Norway, has strict environmental regulation allowed the sector to expand by coordinating governing institutions to support planned aquaculture growth," the article notes. "Uneven regulation has led to disparities in investment and trade, with only a few export nations selling into major net seafood importing markets such as the USA and European Union."[94]

In fact, NOAA's Fisheries of the United States 2018 report found that U.S. freshwater and marine aquaculture production was 626 million pounds in 2017, a 1.2% decrease from the previous year.

> *"The U.S. imports nearly all of the seafood its citizens consume … Most of it comes from developing nations that have very little governance and regulatory structure."*
>
> Food-Fish Aquaculture in Minnesota[24]

Freshwater aquaculture production, which is primarily what would occur in Minnesota, was responsible for 543 million pounds of fish in 2017, down 3.6 million pounds from the year prior.[4] The U.S. aquaculture industry has called for a re-evaluation of current regulations, citing that some rules are "redundant" and often "inefficient."[91] "Major compliance categories include: 1) environmental management; 2) food safety; 3) legal and labor standards; 4) interstate transport of aquatic products; 5) fish health; and 6) culture of commercially harvested species."[95]

In Minnesota, the permitting and licensing process is determined by the Department of Natural Resources (DNR). Joseph E. Morris, an Iowa State professor and director of the North Central Regional Aquaculture Center, noted that compared to Iowa, Minnesota fish farmers must navigate more regulations. Not all producers in the state, however, feel that the regulations are too stringent.

> *"I don't think the regulations are insurmountable. I do think that operators have to also think in terms of sustainability. Water is a very sensitive subject to people, especially in Minnesota, so producers have to be very mindful of building a system that is sustainable in any stretch of the imagination."*
>
> Michael Ziebell, CEO, The trū Shrimp Company[89]

Food fish operators in Minnesota must apply for an annual aquatic farm license, which costs $210 per year, in order to hatch, raise, rear and culture aquatic life in their facility. This license covers "ponds, vats, tanks, raceways, and other indoor or outdoor facilities that an aquatic farmer owns or has the right to use," according to the DNR's website. Each facility is also subject to an initial inspection fee of $300 and an additional fee of the same amount if a public wetland or rearing pond is part of the operator's aquatic farm license. Additionally, operators are also responsible for a pond acreage fee. For this fee, the DNR charges aquaculture producers $15 for every 10 acres of licensed waters — natural or artificial — meaning this applies to everything from natural ponds to raceways and RAS.[96]

> *"I can only say [the regulators] are incredibly helpful, straightforward, and just the relationships have been wonderful there. When it comes to business, they're some of the most useful resources I have."*
>
> Chad Hebert, Owner and Operator, The East Phillips Indoor Urban Farm Project[78]

Before bringing any aquatic life into the facility, operators are required to submit a letter to their regional fisheries manager, requesting to add each species intended for production to the farm license. "Species of aquatic life must be approved and listed on your list of licensed waters, before they are brought into your licensed waters," according to the DNR.[96]

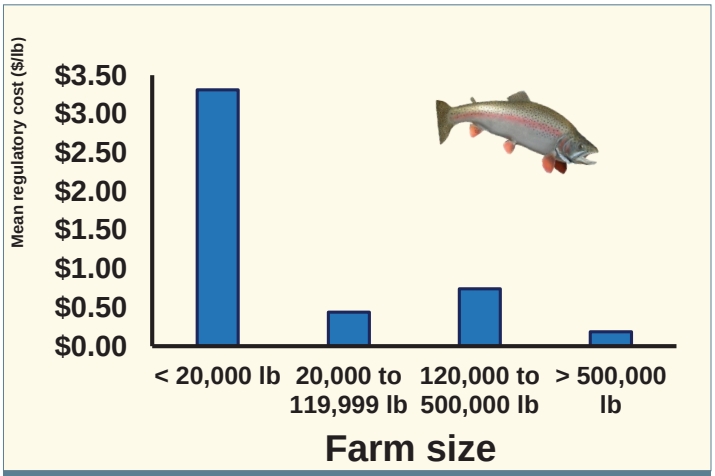


Figure 36. **The graph above shows average regulatory costs based on farm size (Source: Engle, C.R., J. van Senten, and G. Fornshell. 2019. Regulatory costs on U.S. salmonid farms. Journal of the World Aquaculture Society 50(3):522-549. doi.org/10.1111/jwas.12604.).**

Each species falls into one of three categories: indigenous (only fish from Minnesota or a contiguous state); nonindigenous; or exotic (species not indigenous to the U.S.). Nonindigenous and exotic species have more stringent regulations, as those have the potential to threaten native fish species. Operators working with nonindigenous species are required to situate their ponds outside of 25-year flood plains to prevent escapes. For producing a high-risk nonindigenous or exotic species, the DNR may require operators to use closed systems.[96]

Lastly, water appropriation permits are required for facilities that use more than "10,000 gallons per day or one million gallons per year." This $150

permit is needed for the removal, withdrawal or transport of water from one point to another for an aquaculture facility. Any salmonoid or catfish facility that discharges effluent or liquid waste into public water also has to undergo a fish health inspection and certification. Operators transferring any species between locations must also have a health inspection performed.[96]

In accordance with federal laws, Minnesota fish farmers must also comply with the U.S. Environmental Protection Agency's (EPA) regulations, many of which pertain to water quality. The National Pollutant Discharge Elimination System program (NPDES) was established under the Clean Water Act and regulates aquaculture operations that discharge pollutants into U.S. waterways. Facilities that raise warm or cold-water fish and discharge effluent 30 days out of the year are required to obtain a NPDES permit,[97] which outlines "pollutant monitoring and reporting requirements."[98]

> *"There's discharge permits and things that have to be approved, but if people do it, we can do this in a very sustainable and environmentally-friendly way. We've proven that we can do it safely and effectively without impacting natural resources. It's probably going to take some regulatory-type changes where some of the laws are rewritten or opened up a little more to allow that to happen a bit better."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

As part of the NPDES program, any fish farm or hatchery that produces 100,000 pounds of product per year "in a flow-through, recirculating, net pen or submerged cage system" must also comply with the Concentrated Aquatic Animal Production Facilities (CAAP) guidelines.[99] These guidelines, however, do not apply to facilities raising cold water species that produce less than 20,000 pounds of product each year and use less than 5,000 pounds of feed during the "month of maximum feeding." Facilities that operate closed ponds that only produce discharge when there's excess runoff or produce less than 100,000 pounds of warm water species per year are also exempt.[97]

Operators who must comply with CAAP guidelines are required to report if the facility uses an "investigational new animal drug (I)" or an approved drug but does not follow the instructions on the label. This is in place to prevent the drugs from being discharged into waterways. Flow-through raceways and RAS operators must also meet certain solids control, materials storage, structural maintenance, record keeping, and training requirements as outlined in the CAAP guidelines. Net pen operators have similar requirements that focus on feed management, waste collection, maintenance, record keeping and training, among other things.[99]

Aquaculture facilities that use tanks or ponds must also comply with EPA regulations established under the Safe Drinking Water Act (SDWA). "While some aquaculture facilities use holding structures in natural, open water bodies and rely on natural water circulation for water replenishment, many facilities use closed systems (e.g., tanks or ponds) and accumulate wastewater and sludge that must be removed," according to the EPA. The SDWA specifically applies to aquaculture facilities that dispose of liquid waste in an on-site well, seepage pit or similar mechanism. Facilities, however, only need a permit if waste disposal wells could endanger drinking water.[98]

Any aquaculture facility that uses pesticides should verify that the product is registered with the EPA as required under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA also establishes that any facility that misuses pesticides — which includes using pesticides at an unregistered site or using more than the recommended amount of the product — could face EPA "enforcement action."[98]

With regulations in place at the federal and state level, some producers new to the industry have found it difficult to determine what is relevant to their farm. Amy Schrank and Don Schreiner with Minnesota's Sea Grant program said aquaculture laws at the state and federal level can change periodically, meaning producers have to make sure they are complying with the most up-to-date information. The problem, they said, is that while Minnesota's Department of Natural Resources serves as the state-level regulator, there isn't a central location where food fish farmers can find all of the current laws in one place.

Schreiner said the Department of Agriculture would be the most logical fit, suggesting the agency maintain an up-to-date webpage with federal and state aquaculture regulations, much like it would do for other various arms of the agriculture industry.

> *"Part of the problem when we hear complaints about regulations is that producers don't have a clear understanding of what regulations apply and what the real costs are."*
>
> Amy Schrank, Minnesota Sea Grant[100]

In Michigan, a report identified similar industry constraints while also noting several areas where the state government can update regulations to improve how the sector operates. As part of the study, researchers recommended the state overhaul its regulations to clarify performance standards for facility operators. Adopting a set of best management practices, according to the report, could help food fish farmers comply with regulations and state-defined performance standards.[101]

> *"To achieve a thriving sector, a structure is required that includes regulatory framework clarity … defined performance standards to articulate regulatory constraints, and operator compliance to those regulations through best management practices."*
>
> Aquaculture in Michigan: Roadmap through Regulations[101]

Lower priced foreign imports, coupled with federal and state regulations, according to some industry experts, can make it difficult for food fish farmers in the U.S., especially small businesses, to compete.[24] A new state aquaculture plan being proposed in Minnesota could help provide a roadmap for permitting certainty. Stakeholders and regulatory officials will need to collarborate to develop workable solutions.

National Legislation

Recently, national legislation was introduced to bolster the U.S. aquaculture industry, while also making regulations more navigable. Representatives Collin Peterson (D-Minn.) and Steven Palazzo (R-Miss.) introduced the bipartisan Advancing the Quality and Understanding of American Aquaculture (AQUAA) Act to the U.S. House on March 11, 2020.[102] This legislation is considered the companion bill to the Senators Roger Wicker (R-MS), Brian Schatz (D-HI) and Marco Rubio (R-FL) introduced to the Senate in September 2020. Both pieces of legislation primarily focus on developing an offshore aquaculture industry in the U.S., which aligns with President Donald Trump's 2020 executive order on American Seafood Competitiveness.

While the focal point of the AQUAA Act is offshore aquaculture, land-based operators would also benefit.[103] The legislation aims to establish an Office of Marine Aquaculture within the National Oceanic and Atmospheric Administration, which would be responsible for streamlining the federal permitting process, making it more efficient and affordable.[102] The AQUAA Act would also "establish a research and technology grant program to fund innovative research and extension services focused on improving and advancing sustainable domestic aquaculture."

With this piece of the legislation in mind, many land-based aquaculture operators are speaking out in favor of the bill. The owners of Simply Shrimp and trū Shrimp, both Minnesota-based companies, have expressed support for the bill. "Simply Shrimp supports the AQUAA Act as an opportunity to shape the future of aquaculture for the betterment of the industry and the environment. We need this. Thanks to Rep. Peterson for leading the effort to create research and development opportunities to expand the domestic markets of American-grown shrimp," Paul Damhof, owner of Simply Shrimp told Lakeland Broadcasting.[104]

Additionally, the bill is designed to create a market for soybeans, which can serve as an aquafeed. Soybeans are the second-largest cash crop in Minnesota, and in a press release from Peterson's office, Bill Gordon, president of the American Soybean Association, praised the bill, noting that it "provides economic opportunity for soybean farmers."

Figure 37. A Superior Fresh team member releases fish from a net into the water (Source: Superior Fresh, n.d.).

The House and Senate bills were referred to committee, but if passed, could provide greater opportunities for the U.S. aquaculture industry. As one of the fastest growing forms of food production, the sponsors of each bill are positioning this legislation as an opportunity for economic advancement, while also providing food security for the nation.

Key Takeaways

The state and federal governments have regulations in place for aquaculture to protect the environment and consumers.

Aquaculture producers, however, often have to compete with imports and those producers don't always face the same regulations, giving them a competitive advantage over U.S. food fish farmers.

Industry leaders have called for the government to adopt a set of best management practices and streamline the regulation process.

Some experts suggest having a state agency like the Minnesota Department of Agriculture maintain a list of up-to-date regulations and serve as a resource for food fish producers.

National legislation was recently introduced in the U.S. House and Senate to establish an Office of Marine Aquaculture within NOAA to streamline the federal permitting process.

Although the bills primarily focus on marine aquaculture, several Minnesota producers have spoken out in favor of the legislation because of the potential it has to shape the future of the industry domestically.

Meanwhile, a new state aquaculture plan is being discussed for stakeholder development, in order to provide a roadmap for success.

Proof of Concept Hurdles

Obtaining financing is another significant barrier to entry and can prevent businesses from scaling up production. Beyond the cost of permitting, businesses have to acquire financing for everything from equipment to energy costs.

> *"The Minnesota investment community is hardly aware of aquaculture, and the little bit they know of it is negative."*
>
> Clarence Bischoff, President and Founder, Bluewater Farms[105]

Greg Fischer, Assistant Director and Program Manager of the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility estimated that building a facility capable of producing year-round and supplying a large enough volume to the market would require an initial investment of $20-40 million. In addition to the upfront cost of a facility, he said the level of specialization required to run a food fish farm from an industry outsider's perspective, can make it seem like a risky investment.

> *"You've got to have knowledgeable people that are running the systems and know how to raise the fish. You've got to have strong marketing people and you got to have a strong market."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

With aquaculture, lenders and insurance companies want to see a "proof of concept" before moving forward. "This makes obtaining startup funds or loans for expansion challenging since it remains difficult to demonstrate success, especially in aquaponics," explained Chris Hartleb, director of the Northern Aquaculture Demonstration Facility at the University of Wisconsin Stevens Point.[24] With little to no market research available, it's difficult for new aquaculture businesses and potential investors to evaluate risk.

> *"Marketing information is in short supply; there's no question about that. You have to have folks who are able to see the opportunities, develop their markets, move in and convince somebody to buy their product compared to somebody else's."*
>
> Carole Engle, Aquaculture Economist and Co-owner of Engle-Stone Aquatic$ LLC[32]

During the 2017 Food Fish Aquaculture in Minnesota Workshop, Carole Engle, co-owner of Engle-Stone Aquatic$ LLC, explained that many aquaculture businesses fail because the company's leadership fails to do thorough research and understand the business before pursuing it. Each new business, according to

industry experts, should compile research on key markets and realistically gauge supply and demand for the species it intends to produce.[24]

> *"Be realistic. This isn't an easy business, and you need to have some correct assumptions on production, growth rate, production cost and sales price. Your business plan has to be proofed well, and if it doesn't make money, don't do it!"*
>
> Steve Summerfelt, Chief Science Officer, Superior Fresh

Engle added that information on the 10-year average and minimum price of the species, price fluctuations, consumer base, key markets, and how it performs in supermarkets are all critical for understanding how a business will perform long-term. Aquaculture, she said, would benefit from a standardized enterprise budget analysis "so that the industry can manage cash flow and risk with good estimates for scales of production of different species in different systems."

Industry experts suggested that in addition to careful planning, many of these fledgling businesses could benefit from government subsidies, tax credits, or even support from a foundation that could offer guidance.[24] In the NOAA Research and Development Vision Areas: 2020-2026, one of the objectives is to "provide economic research and associated outreach programming to aquaculture businesses" to help bolster the industry.[106]

In January 2021, the University of Minnesota Sea Grant program announced a three-year study aimed at determining "the potential for a sustainable food-fish aquaculture industry in Minnesota." The study will gather data that will help guide prospective food-fish farmers as they decide what species and production systems will set their businesses up for financial success. Additionally, the research team plans to survey consumers and restaurateurs to get a sense of preferences and gauge their willingness to pay for locally grown fish or seafood.

Having market information on production costs, consumer demand and price points for various species will allow prospective farmers to more accurately estimate potential profit margins.[107]

Amy Schrank, project lead and University of Minnesota Sea Grant fisheries and aquaculture extension educator, said in a press release that this data will be useful for food fish farmers as they apply for loans to launch their businesses. Once the study is complete, Schrank added that the University of Minnesota Sea Grant program plans to share its findings with "the food fish aquaculture industry, policymakers and the public" through a series of discussions.[107]

The U.S. is one of the top three seafood markets in the world, and advancements in technology, disease management, fish nutrition, regulatory policies and market research, among others, will help bolster the nation's marine and freshwater aquaculture industry. As the U.S. and other countries work to rebuild wild stocks, aquaculture is expected to become an increasingly important method of producing enough protein to feed the growing population, while also providing jobs for the American workforce. With this in mind, experts are pushing for research and development in these key areas to help the U.S. meet the increasing demand for aquaculture products.[39]

INABILITY TO COMPETE WITH IMPORTS

While some Minnesota food fish businesses have been successful, some have not survived. In 2010, Minnesota was home to North America's second-largest tilapia producer, MinAqua Fisheries.[108] When MinAqua Fisheries launched in 1997, it had buy-in from more than 300 crop farmers and represented a $4.5 million investment.[109] Tilapia is a warm-water species, so MinAqua Fisheries used the heat generated by a nearby sugar beet processing facility to warm the water for the Recirculating Aquaculture System (RAS) it used for rearing fish. The company also utilized local ingredients such as soy and corn for feed pellets.[108] Despite its environmentally friendly approach, MinAqua Fisheries couldn't compete with imports.[10]

MinAqua Fisheries primarily sold live tilapia — partially because it's worth about 40% more alive — to "Asian markets in Toronto, Calgary, Vancouver, Chicago, and Minneapolis."[108] Input costs such as feed and energy made it difficult for the company to compete with producers in Asia, Central and South America who can raise tilapia in outdoor ponds at a lower cost. That allows those imports to dominate the frozen fish market, effectively driving the competition out of business. After operating at a loss for several years, MinAqua Fisheries filed for bankruptcy in 2013.[109]

> *"I think a lot of failures in the industry result from people not being prepared to run a business. Raising fish is much more difficult than most people think it is."*
>
> Don Schreiner, Fisheries Specialist, Minnesota Sea Grant[60]

Whether it's competition from imports, regulatory hurdles or business plans that don't add up, several Minnesota food fish businesses have faced similar fates. Still, many industry experts remain hopeful that recent innovations, such as aquaponics, can help Minnesota overcome challenges like the state's cold climate and drive the industry forward.[24]

Key Takeaways

Obtaining financing for a new or expanding aquaculture business can be difficult because there's limited market research available.

Many lenders and insurance companies want to see a "proof of concept," which is a challenge because it remains difficult to demonstrate success in the industry.

Off-take agreements are critical with buyers in advancing investment.

Many new aquaculture businesses fail because leadership doesn't do thorough research.

Limited market research makes evaluating risk a challenge.

Experts say the industry could benefit from government subsidies, tax credits or even support from a foundation that could offer guidance.

RESEARCH CURRENTLY UNDERWAY

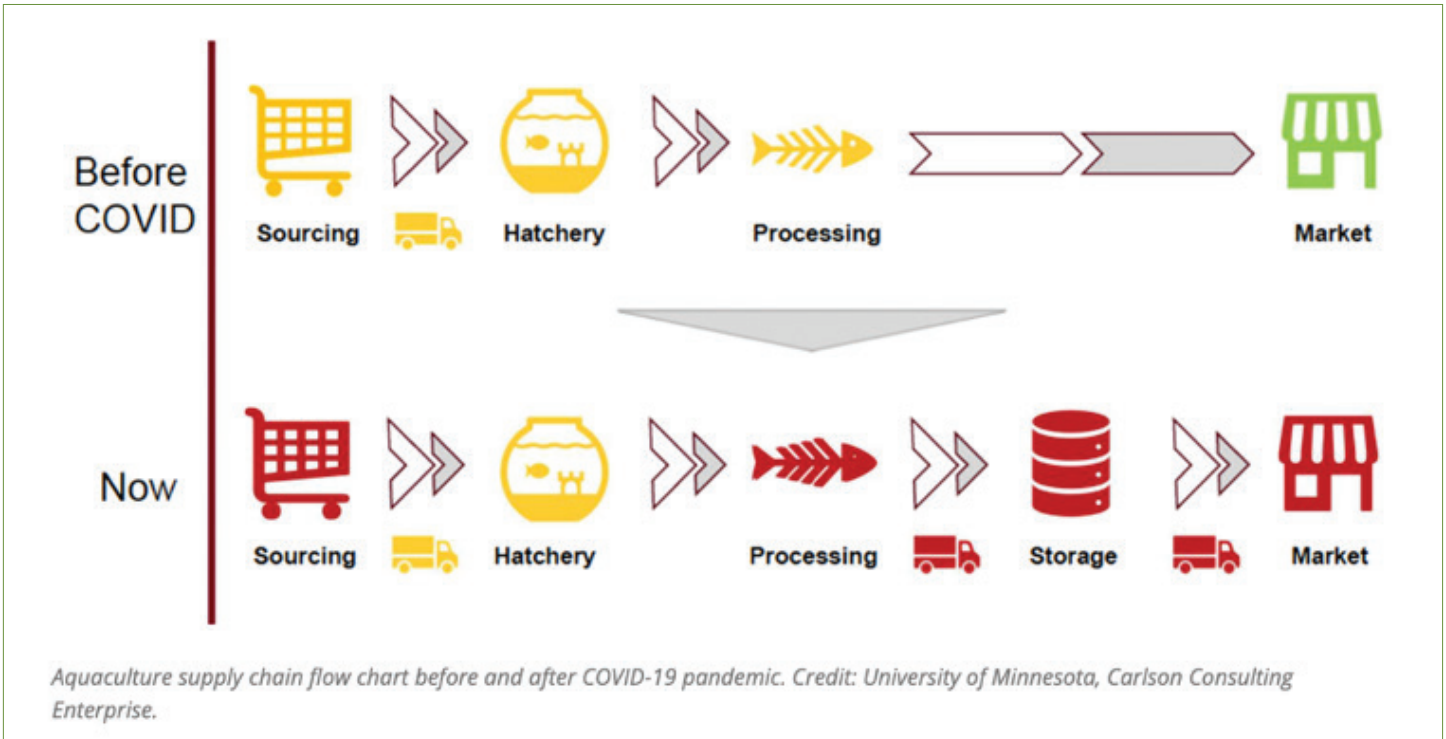
Leaders within Minnesota are already making significant strides to better understand the extent to which the aquaculture industry can develop. The Great Lakes Aquaculture Collaborative (GLAC) received a $1 million grant in 2019 to explore the potential of the region's aquaculture industry. Currently, Great Lakes states are unable to meet consumer demand for fish and seafood, so Minnesota Sea Grant is leading a three-year project focused on supporting sustainable aquaculture in the region. Illinois, Indiana, Michigan, New York, Ohio, Pennsylvania, Wisconsin, and Minnesota are all involved in this collaborative effort.[110]

> *"The goal of the [GLAC] project is to foster relevant, science-based initiatives that support aquaculture industries in the Great Lakes region that are environmentally responsible, competitive and sustainable."*
>
> Amy Schrank, Minnesota Sea Grant[100]

As part of the first phase of the project, Minnesota Sea Grant is working in collaboration with a multi-disciplinary group of experts to establish a formal way for Great Lakes states to share the latest scientific research and data. Phase two, which launched in 2020, seeks to identify the most prevalent barrier to entry within the industry and assess ways to overcome these challenges.[110]

> *"What information do producers need to be successful? What information do consumers need to feel that they understand aquaculture?"*
>
> Amy Schrank, Minnesota Sea Grant[100]

Currently, there is a lack of information on consumers' willingness to pay for various aquaculture products, specifically those from the Great Lakes region. Phase two will also include a study that evaluates consumer preferences for species, as well as characteristics like fresh or frozen, farm-raised or wild-caught, imported or domestically raised, and whether sustainable practices influence purchasing decisions.[111]



Aquaculture supply chain flow chart before and after COVID-19 pandemic. Credit: University of Minnesota, Carlson Consulting Enterprise.

Figure 39. Aquaculture supply chain flow chart before and after the COVID-19 pandemic (Source: University of Minnesota, Carlson Consulting Enterprise, 2020).

Researchers plan to conduct experimental auctions, which is an economics technique "used to identify how consumers evaluate and value specific attributes of a product." Afterward, researchers plan to use online surveys to conduct "discrete-choice experiments."

The findings from these experiments will provide a snapshot of how consumers choose from local aquaculture products versus those raised elsewhere. It will also provide insight into how advertising could sway consumers toward Great Lakes products.[112]

In addition to the GLAC research, Minnesota Sea Grant is undertaking a food fish supply chain project which "seeks to identify viable scenarios for the effective processing and distribution of commercial fish and aquaculture products in Minnesota." Working with a team of graduate students from the University of Minnesota, Carlson Consulting Enterprise (CCE), Minnesota Sea Grant is analyzing each step raw fish undergoes before reaching the consumer. This project aims to help commercial fishermen and aquaculture farmers in Minnesota by identifying ways to effectively lower the overall cost and time it takes to get a product to consumers.[113]

Most recently, the team toured aquaculture farms on Minnesota's North Shore to better understand fish processing and get a sense of the obstacles producers face in getting their product from farm to market. Findings from this work are expected in 2021.[113]

Key Takeaways

Great Lakes states currently aren't meeting consumer demand for fish and seafood.

Market research is underway, focusing on providing insight into how consumers in the region select fish and seafood products.

Research is also needed to identify the most common barriers to entry for food fish aquaculture businesses and determine how to overcome those challenges.

A study is analyzing the food fish supply chain and identifying ways to make the process more efficient and cost-effective. Both studies will provide much-needed market information that food fish aquaculture producers in Minnesota currently lack.

PROGRESS AND PROJECTIONS

During the last 10 years, experts say increasing consumer demand for locally grown food and advances in aquaculture production strategies have paved the way for the growth of the food fish industry in Minnesota.[24] Aquaculture economist Carole Engle noted that the uptick in demand for local food, specifically in the northern tier of the U.S., could bode well for Minnesota's fledgling aquaculture industry.

> *"On a scale of one to 10, I think whether Minnesota deserves or should have an aquaculture industry is a 10. There's no reason it shouldn't happen here, and we need it here — clearly, there's demand."*
>
> Nicholas Phelps, Director, Minnesota Aquatic Invasive Species Research Center, University of Minnesota[74]

While there is still significant debate over which species could be the most successful in Minnesota, experts identified Atlantic salmon, Arctic char, shrimp, trout, walleye and yellow perch as the most promising.[24] In her opinion, Engle said trout may have the most potential in Minnesota because there's already an established market.

"I would think trout in Minnesota could probably not be as big as Idaho, but certainly the scale of North Carolina," Engle said. The market starts to attract more businesses and supply chain companies, she added, when production increases and clusters of farms begin to develop.

Greg Fischer, the assistant director and program manager at the University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility (NADF) agreed, noting that the rainbow trout industry is currently thriving in Wisconsin, but Atlantic salmon is an up-and-coming species in the region. While demand for Atlantic salmon exists, Engle suggested it could be difficult to compete with imports, specifically from Norway and Chile, because those countries are very efficient producers.

> *"Rainbow trout is by far our biggest success right now in Wisconsin. We have more trout farms that are successful, but the up-and-coming one now is Atlantic salmon. Atlantic salmon is taken over with groups like Superior Fresh that are large commercial farms with some outside support. They're going to be over one and a half million pounds of annual production of Atlantic salmon after this year."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

Walleye is another species Carole Engle suggested has great potential in the state, but farm-raised would need to compete with the wild-caught supply. Regionally, significant research is underway to make walleye a viable species to raise in recirculating aquaculture systems. The NADF is exploring ways to trigger out-of-season spawning to make walleye eggs, fry and juveniles available year-round.[114]

"The capability to spawn walleye out of season in a controlled aquaculture setting is paramount to bringing commercial walleye production to fruition in the U.S.," Greg Fischer said in a Wisconsin Sea Grant blog post.[114] "We have got to have eggs year-round for this to be commercially acceptable. This newest project will allow us to move this species into the commercial aquaculture production sector in the Midwest."

Beyond determining the best species and production systems for Minnesota food fish farms, Nicholas Phelps, director of the Minnesota Aquatic Invasive Species Research Center at the University of Minnesota, said "every step in the supply chain needs to be expanded." Phelps said aquaculture can learn a lot by looking at other industries that have grown from nothing. Other industries, he added, have found markets and financing, developed economic models, and navigated the regulatory system.

> *"Think about each compartment of the supply chain. Who's involved? How can they make it better? Is it a value-added product? If so, how can we make salmon, for instance, more palatable for Minnesotans?"*
>
> Nicholas Phelps, Director, Minnesota Aquatic Invasive Species Research Center, University of Minnesota[74]

Paul Hugunin, division director at the Minnesota Department of Agriculture, expressed a similar view, noting that aquaculturists should do thorough research to learn as much as they can from similar businesses in other states.

> *"Connect with other industry groups (beef, soybeans, dairy, etc.) in Minnesota and take note of their experiences. Explore forming a state research and promotion council. This will help you better identify the challenges you will face."*
>
> Paul Hugunin, Division Director, Minnesota Department of Agriculture[34]

Many states, like Arkansas, have developed successful aquaculture industries with the support of an association. These organizations typically create a sense of unity and help members determine common objectives. The participants of a 2017 Minnesota food fish aquaculture workshop expressed interest in establishing association that could push policies to help promote industry growth.[24] Just a few years later, in 2019, Clarence Bischoff, president of Bluewater Farms, and other industry leaders launched the Minnesota Aquaculture Association, with the mission of growing the state's "aquaculture, aquaponics and bait industry while minimizing environmental impacts to the natural resources of the state."[115]

Aquaculture economist Carole Engle added that an association comprised of producers who understand industry challenges and are willing to devote time to address them can be key to positive change. Producers, she said, can then identify the most important issues and begin pulling together resources from the university level to the state department of agriculture to work toward a solution.

> *"For an industry to develop they're going to need support from the Department of Agriculture. States that have strong aquaculture industries have very engaged departments of agriculture."*
>
> Carole Engle, Aquaculture Economist and Co-owner of Engle-Stone Aquatic$ LLC[32]

With a state association in place, experts agreed that developing a state aquaculture plan to highlight the path forward and provide resources for new businesses is the next step for Minnesota.[24]

> *"The freshwater food fish industry doesn't have any resources. I think the State of Minnesota, the legislature, and the University of Minnesota has to commit to building this industry."*
>
> Michael Ziebell, CEO, The trū Shrimp Company[89]

Ed Aneshansley, senior aquaculture engineer for McMillen Jacobs Associates, added that financial support from the state through tax incentives or special economic zones could also help new aquaculture businesses get started. With the creation of a state aquaculture plan, Bischoff said he hopes more resources will be available to assist new fish farms.

> *"What I hope could come out of a state plan is a document that supports the creation of an aquaculture center at the University of Minnesota or some other campus."*
>
> Clarence Bischoff, President and Founder, Bluewater Farms[105]

Additionally, hiring a state aquaculture coordinator to "work closely with [the] University of Minnesota Extension, the University of Minnesota Sea Grant Program, MNDNR and the Minnesota Pollution Control Agency," could, according to experts, help ensure producers are up to date on everything from best management practices to regulatory information.[24]

> *"There should be somebody within a state agency who understands the needs of the industry and is working to develop an economically and environmentally sustainable future."*
>
> Nicholas Phelps, Director, Minnesota Aquatic Invasive Species Research Center, University of Minnesota[74]

Overall, experts agreed there's significant potential for a food fish industry in Minnesota. Much of the progress is dependent on current producers developing a united front to push for state-level policies and research that could bolster the industry.

FARM-RAISED SHRIMP

The trū Shrimp Company, based in Balaton, Minn., spent the last four years researching and developing a "commercial-scale, shallow-water indoor shrimp farming technology."[116] Michael Ziebell, CEO of The trū Shrimp Company, said he sees this new technology as an industry disruptor.

"The idea of growing shrimp indoors is not a new idea, but our technology is very new," said Michael Ziebell, CEO of The trū Shrimp Company. "We're the first people in the world to commercialize a shallow water technology. So, getting people to invest in new technology in this market is probably the greatest challenge."

Currently, the U.S. shrimp market is dominated by imports, with this commodity alone accounting for 27.7% of the total value of all edible aquaculture imports. In 2018, the U.S. imported 1.5 billion pounds of shrimp — that's 68.6 million pounds more than the previous year.[4]

There's no doubt a demand for shrimp exists, but with so much of the supply coming from other countries, traceability is a major issue. "Less than 1% of the shrimp that come into the United States are inspected by the FDA," Ziebell explained. "There is no traceability through the supply chain, and shrimp is among the most mislabeled seafood products in America."

The trū Shrimp Company, Ziebell added, was built on the idea that American consumers are growing more conscious about the quality and source of their food supply. By raising shrimp indoors using their Tidal Basin™ technology, Ziebell said the company has total control of the shrimp diet — which is more than 40% soy-based — and their growing environment, therefore ensuring product safety.

"People may think of us as being shrimp farmers, but we're actually water chemists more than anything because, to the shrimp, the water is everything," Ziebell added. "We're capital intense, but our product is far superior and is consistent."

The Tidal Basin™ technology constantly monitors water conditions, ensuring

Figure 40. **A member of the trū Shrimp team holds a harvested shrimp at the company's Balaton, Minn., facility (Source: trū Shrimp Company, 2020).**

temperature, water flow and oxygen levels are all at appropriate levels. It also "recreates the natural ocean currents, focusing on reducing stress and creating an environment where shrimp can thrive. This technology is also stackable, minimizing the amount of space needed for a shrimp farm, and nearly 100% of the water used in these systems is recycled," according to the company's website.[116] Looking to the future, Ziebell said the company would like to co-locate one of its harbors next to an ethanol plant.

> *"An ethanol plant consumes a great deal of energy and it all goes up the smokestack in steam. Well, we could harness that steam engine to power our harbor."*
>
> Michael Ziebell, CEO, The trū Shrimp Company[89]

Consumers will no longer have to be near the ocean to eat fresh shrimp, Ziebell added, because this indoor-based technology can be installed anywhere. While the trū Shrimp's Balaton-based facility is already producing shrimp, the company is looking to scale up production to meet demand.

> *"The potential lies in becoming a domestic producer of shrimp aquaculture. We have a pilot facility we call Balaton Bayreef that's capable of producing 45,000 pounds of shrimp a year."*
>
> Michael Ziebell, CEO, The trū Shrimp Company[89]

Trū Shrimp is currently raising capital to build its first full-scale facility in Madison, S.D. As trū Shrimp scales up production, the company projects it can capture a significant share of the U.S. shrimp market.[116]

Figure 41. **Fresh, farm-raised trū shrimp on display at Almanac Fish Seafood Counter in St. Paul, Minn. (Source: trū Shrimp Company, 2020).**

BLUE WATER FARMS

The Welch, Minnesota-based Bluewater Farms is another company working to grow the aquaculture industry in the state. Blue Water Farms is currently working to develop a land-based Recirculating Aquaculture System (RAS) capable of rearing Minnesota's state fish, the walleye.[117]

"There is a market for walleye," said Clarence Bischoff, president and founder of Bluewater Farms. "Almost everybody knows it's a good fish."

Seafood Source noted that walleye is "widely regarded as the best-tasting freshwater fish."[118] These elusive fish are sought after by Minnesota anglers, and, according to John Downing, director of Minnesota's Sea Grant program, are by far the most popular species in fish recipes published by or about Minnesotans.[24]

> *"I think walleye has the potential to be equal to or greater than the current trout market. Walleye is widely recognized as a better product."*
>
> Clarence Bischoff, President and Founder, Blue Water Farms[105]

When chefs add this fish to their menu, they need a dependable supply of walleye, and neither U.S. nor Canadian aquaculture facilities have started producing the fish commercially.[119] Because of this, a lot of the walleye in restaurants and grocery stores throughout the region is imported from Canada.[114]

"Currently, with [the] exception of a few small producers that serve local niche markets, walleye in commerce is obtained from capture fisheries from numerous inland lakes in the western provinces of Canada, a portion of Lake Erie, and a few other tribal fisheries in Michigan, Minnesota, and Wisconsin," according to a North Central Regional Aquaculture Center Technical Bulletin.[119]

Walleye's popularity, regional name recognition and limited supply make it a high-value species that usually sells for $6-12 per pound in a retail setting.[119] A local producer like Blue Water Farms also has the potential to disrupt the current market with a sustainably raised product.

> *"If you talk to most Minnesotans, there's no other fish but walleye."*
>
> Joseph E. Morris, Iowa State Professor, Director, North Central Regional Aquaculture Center[120]

Figure 42. Aerial shot provides a bird's eye view of the Blue Water Farms facility in Welch, Minn. Blue Water Farms is working to develop a sustainable system for producing walleye (Source: Red Wing Port Authority, 2021).

Key Takeaways

There is still significant debate over which species would be most successful in Minnesota.

Experts suggest Atlantic salmon, Arctic char, shrimp, trout, walleye and yellow perch are the most promising. Farm-raised, in some instances, would need to compete with wild-caught supply.

For aquaculture to grow in Minnesota, experts suggest producers who understand the industry should play a key role in identifying challenges and addressing them.

The state association, according to experts, can help by presenting a united front and pulling together resources to work toward solutions that address common challenges.

For the industry to grow, producers need support from the state, particularly the Minnesota Department of Agriculture.

Experts suggest hiring a state aquaculture coordinator to provide support and resources would help ensure producers are up to date on everything from best management practices to regulatory information.

A new state aquaculture plan being proposed in Minnesota could help provide a roadmap for developing workable solutions.

MARKET OPPORTUNITIES

For the food fish industry, research shows that clear, transparent communication may play a significant role in reaching the intended audience. Positioning Minnesota aquaculture products as environmentally friendly, sustainable and healthy, according to experts, could help them gain favor over imports.

> *"I think there really needs to be focused marketing that promotes locally-sourced fish and that those fish are raised in an environmentally sustainable way. For example, biosecurity measures are in place that prevent the release of pathogens from the facility. Private aquatic life is prevented from being released into the environment and effluent is monitored for the level of nutrients and there are not adverse plumes in the environment due to the release of excessive nutrients."*
>
> Sean Sisler, Fisheries Program Consultant, Minnesota Department of Natural Resources[15]

A 2016 survey titled "The Untapped Potential of Story to Sell Seafood" revealed that consumers find the concept of "storied fish" appealing. "Storied fish" is defined as seafood or fish that, "tells a story about its journey from water to table." Often, companies and restaurants will use this information to give consumers a better sense of where the product came from and how it was raised.[121]

> *"For some reason, fish is always looked at a little differently. When you go to a restaurant, you don't normally ask the waitstaff, 'Well, where did this cow come from or where did this pig come from?' But when you order fish, you ask, 'Where did that come from? Is it wild-caught or farm-raised?'"*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

Researchers asked U.S. consumers to identify what types of labels resonated most with them. Shoppers considered products characterized as environmentally and socially friendly important, which experts said indicates that "stories" have to speak to the values of the consumer base. In fact, 61% indicated that "sustainably produced" labels were important to them.[121]

"Interestingly, more specific eco-and socially-responsible labels did not always garner as high support as the values those labels represent," the survey report noted.[121] "For example, compared to 60% of respondents noting 'sustainably produced' as an important product label, only 33% said the sustainable seafood certification label, Marine Stewardship Council (MSC), was important."

For Minnesota producers, this research shows that transparency about the production process could boost consumer confidence in the product. Successfully telling a product's story in a way that leverages the consumer's values has the potential to give the state's food fish farmers a competitive advantage.[121] Still, researchers who conducted this survey suggested that individual markets could benefit from conducting additional market research on the most effective ways to use labels, packaging and menus.[121]

WHOLESALE PERSPECTIVE: FISH GUYS

The St. Louis Park-based wholesale fish and seafood supplier, The Fish Guys, has played a critical role in providing fresh, sustainable fish and seafood to Midwest restaurants and retailers since 1993. While The Fish Guys do import some of their product, they source it from trusted fishing and farming partners and use sustainable processing practices.[122]

"Our ozone water-purification system, a green initiative that significantly reduces chemicals, allows us to organically clean and sanitize our product throughout the processing phase for increased food safety assurance," The Fish Guys website notes.[122]

The company carries more than 1,000 different products, many of which are cut-to-order and distributed to the region's top chefs.[122] In an effort to encourage local restaurants to buy sustainable fish and seafood, The Fish Guys partnered with the James Beard Foundation's Smart Catch Program. Smart Catch is an educational program for chefs to help them add fish and seafood that's caught or farmed in an environmentally friendly way to their menus. As part of the Smart Catch program, The Fish Guys and other suppliers help onboard new

Figure 43. **Sushi made with sustainably sourced seafood (Source: Monterey Bay Aquarium, 2021).**

restaurants and promote "diverse, traceable, sustainable, and delicious seafood options."[123]

> *"We are very fortunate in the Twin Cities, to have a very unique demographic when it comes to food. That's what makes our business, I think, a little more valuable and special because of what we have in place. We have great James Beard Award-winning chefs; we have places like Kowalski's [Market], Lunds & Byerlys and The Fish Guys — all working in a sustainable manner."*
>
> Chad Hebert, Owner and Operator, The East Phillips Indoor Urban Farm Project[78]

Beyond their reach within the restaurant industry, The Fish Guys have a role in making sure consumers have access to sustainably raised fish and seafood. Locally, the grocery store Lunds & Byerlys has partnered with The Fish Guys as part of its sustainable seafood program.[124]

"Led by the highly experienced and trusted team of Mike Higgins and Brent Casper, The Fish Guys source whole fish so their skilled team can fillet them to our exact specifications," Tres Lund, Lunds & Byerlys president and CEO, wrote in the Spring 2017 edition of Real Food.[124] "Their commitment to exceptional quality is matched by their care and commitment to searching the globe for new fisheries that meet our Responsibly Sourced guidelines."

Lunds & Byerlys also partners with other sustainable seafood leaders, such as the Global Aquaculture Alliance, Monterey Bay Aquarium Seafood Watch and Alaska Seafood. Consumers can easily identify these products by the "Responsibly Sourced" logo the grocer uses in their fish and seafood department.[124]

For food fish producers in Minnesota, working with a wholesale partner like The Fish Guys is a way to get sustainable fish and seafood products on consumers' plates in restaurants or at the dinner table.

RETAIL ENGAGEMENT: WHOLE FOODS

Whole Foods Market, Inc., an American multinational supermarket chain with 500 stores in North America, is known for its organic selections and being "a purpose-driven company that aims to set the standards of excellence for food retailers."[125] The organization prides itself on offering responsibly farmed or sustainable wild-caught fish and seafood. As explained on the company's website, the grocer's fish and seafood "...is traceable, and we work hard to source it only from responsibly managed farms and abundant, well-managed wild fisheries."

Mike Kilgore, a seafood coordinator for Whole Foods, oversees fish and seafood for 75 stores across nine states and Ontario. "In 2020, seafood was in the top grossing category within our region consistently. It's one of those items that I think people have traditionally relied upon restaurants to cook for them. [With many closed due to the pandemic] they still want to eat it and now they're venturing out into cooking it themselves. But I think seafood is one of those really delicate items that people are scared of because it's not as forgiving as beef or poultry where you can be off by a few degrees. I think unfortunately that's intimidating to a lot of people."[126]

To help any consumer hesitancy, Kilgore says Whole Foods is continually educating its team members and adding signage. The grocery stores also work to increase shopper knowledge about quality. "Consumer awareness is important. Anything we can do to educate the consumer about the need for a sustainable practice, the high quality of the product, the benefits of it. There is still that slight stigma of farmed fish and the bad rap it gets from the products coming out of places like China and Thailand. If we educate people about the high quality that is being produced, that would be beneficial."[126]

As Whole Foods observes on its website, "With a dwindling supply of wild seafood in our oceans, farm-raised seafood is playing a more important role than ever. When it's done right, farmed seafood provides a reliable year-round source of high-quality seafood you can trust."

"With wild fish, there can be a flavor difference, but the seasonality comes and goes. Farming is becoming much more viable. One of the top items that we sell across the board is farmed Atlantic salmon," Kilgore says, adding that the stores also retail such fish as farmed tilapia, rainbow trout out of Wisconsin, and striped bass from Baja, Mexico. "It is pretty tough to get products through the Whole Foods quality certifications."[126]

Kilgore's advice to producers? "Make it as clean a product as possible, be able to accept any feedback, work in a positive light and not just look to cut corners to make the cheapest, biggest fish you can.

"Years ago, for instance, we found that the majority of the farmed tilapia was being given a drug that stunted its growth. That allowed them to harvest consistently sized fish. We realized that was not an ethical way to do it, so we didn't have any farmed tilapia for quite some time until we had producers that got on board and saw the benefits of harvesting fish the right way and treating it responsibly."[126]

One of the struggles Kilgore says he faces in the Midwest is a lack of sufficient local producers. "I have one that I work with right now in Wisconsin for rainbow trout. I love working with them - they have wonderful quality water, and they treat their fish right. The more local and sustainable we can get within our stores the better," he indicates, adding, "Things that are regionally driven make the most sense . . . something like walleye is great, trout. I think those are really good ones to go after."[126]

RESTAURANTS: JAMES BEARD FOUNDATION'S SMART CATCH PROGRAM

With the help of the James Beard Foundation's Smart Catch Program, restaurants have played a significant role in "increasing the seafood sustainability supply chain," while also educating consumers.[123] In October 2018, chef and vice president of development for The Fish Guys, Tim McKee, used National Seafood Month to raise awareness about sustainable seafood among local chefs. Acting as a "disciple" of the James Beard Foundation's Smart Catch Program, McKee started reaching out to other chefs and asking them to add at least one sustainably sourced seafood item to the menu during October. More than 140 area chefs signed on, adding stickers to their doors to indicate to diners that they were participating.[127]

> *"The producers who have been successful are the ones who have been able to leverage the sustainability model and make partnerships with restaurants that can sell at a high value and can advertise that these [fish] are Minnesota grown."*
>
> Sean Sisler, Fisheries Program Consultant, Minnesota Department of Natural Resources[15]

The Smart Catch Program is one that Minnesota's food fish farmers can tap into. Created by philanthropist Paul G. Allen, the Smart Catch Program "provides training and support to chefs so they can serve seafood fished or farmed in environmentally-responsible ways. By becoming a Smart Catch Leader and earning the Smart Catch seal, chefs give consumers a simple way to identify and support their restaurants." With more than 70 participating restaurants in the Twin Cities area alone, food fish farmers in Minnesota could sign on to serve as suppliers. The Fish Guys, a seafood importer based in St. Louis Park, Minn., is already a supplier for the Smart Catch program, meaning they are committed to onboarding participating restaurants and promoting sustainable seafood within their community.[123]

Katherine Miller, the James Beard Foundation's vice president of impact, told the Star Tribune that, since its inception in 2015, the Smart Catch program has grown from 60 participating restaurants in Seattle[128] to more than 500 in 44 states.[128] She credited chefs like McKee for reaching out to colleagues and getting them on board with the program. "No one has jumped on it [the Smart Catch program] the way that [the Twin Cities] has. This is, by far, the biggest response by a chef community in a single city," Miller told the Star Tribune.[127]

Key Takeaways

Consumers increasingly want to know where their seafood is coming from and how it was raised.

Research suggests transparency and a product's "journey" from water to table can boost consumer interest.

Studies have shown U.S. consumers are interested in sustainably raised products but don't always know what types of labels or certifications indicate that.

Researchers suggested individual markets conduct additional research to determine local consumers' understanding of labels, packaging and menus.

Wholesalers, grocers and restaurants all play important roles in reaching consumers.

These sectors are very much connected and could help educate consumers about Minnesota-grown fish and seafood.

CONSUMER EDUCATION

The majority — about 90% — of fish and seafood consumed by Americans is imported.5 As a result, educating consumers about the value of buying locally raised fish can help reduce the seafood trade deficit and improve traceability. With imports, there's a complex supply chain that consists of harvesting or catching fish, processing it and shipping it to a seafood distributor like a grocery store or restaurant.[129]

Blockchain technology is leading the way in making fish and seafood more traceable. Fishcoin and IBM's Food Trust are just two cutting-edge products making the fish and seafood industries more transparent. Fishcoin specifically "incentivizes supply chain stakeholders to share data from the point of harvest to the point of consumption."[130] Meanwhile, the IBM "Food Trust" technology will allow consumers to see where and how the fish on their table was raised, as well as how it got there. Producers can also benefit from this technology, as it could bolster consumer confidence in their product and demonstrate the benefits of buying local, farm-raised products.[131] While blockchain is most well-known for financial transactions, many see the technology potentially helping provide information about the food to table journey of fish and seafood.[132]

There are also plenty of other ways to educate consumers about the benefits of locally, sustainably raised fish. One study suggests that providing clearer information about a product can improve fish and seafood sales.[121]

> *"For Minnesota, I think marketing is also really important to let people know that, for example, buying a walleye from a farm in Minnesota is a better option than importing a fish from somewhere else, like Canada or even overseas."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

One recent improvement to fish and seafood traceability includes adding labeling to help consumers easily identify products that are certified as sustainably raised.[129] Of the 1,300 U.S. consumers surveyed as part of the "Future of Fish" study, 63% said they found the idea of storied fish — or "seafood that tells a story about its journey from water to table" — appealing.[121] Consumers said labels that indicated the fish or seafood is hormone-free, antibiotic-free, humanely raised or harvested, produced in the U.S., produced locally or wild-caught resonated the most with them. With this, researchers suggested that the fish and seafood industry clearly link labels to the values of the consumer base.[121]

> *"The industry needs to be getting out more positive images of fish farms."*
>
> Bret Shaw, Associate Professor and Environmental Communication Specialist, Division of Extension, University of Wisconsin-Madison[133]

Studies have also shown that consumers generally prefer to purchase locally grown or raised food. Researchers have noted that the public is often motivated to buy local, both to support the economy and because the food is more traceable.[134]

> *"The local food demand has really increased in the northern tier of the U.S., and I would guess that's true of Minnesota. It's true in Wisconsin, Chicago, and all of the major markets around there."*
>
> Carole Engle, Aquaculture Economist and Co-owner of Engle-Stone Aquatic$ LLC[32]

A 2019 survey of Wisconsin consumers, aimed at better understanding the perceptions of local farm-raised fish, revealed similar findings. Generally, this survey found that consumers were most interested in wild-caught fish but would prefer to purchase a product harvested in Wisconsin over an import, regardless of whether it was wild-caught or farm-raised.

> *"People have these notions that if it's farm-raised, it's bad. We have to change that, and we're working on it. The bigger question here is, should we be spending time and money trying to raise fish in captivity just like we do with other animals? Some of our fish populations in the wild cannot sustain the harvest that we've had or any more harvests. There's a lot of fish populations already in peril. Aquaculture may be the answer to help lessen the harvest on some of these populations."*
>
> Greg Fischer, Assistant Director, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility[26]

Figure 44. **Salmon fry, or young fish, are seen swimming in a first-feed tank where they begin to eat on their own (Source: Superior Fresh, n.d.).**

Consumers also indicated that they trust Wisconsin fish farmers more than government agencies, grocery stores and non-local fish farmers to keep their food safe. With that finding, researchers suggested that fish farmers could play an important role in communicating the measures taken to keep the environment safe and the fish healthy.[37]

> *"Most people probably picture muddy pools or clinical-looking tanks. The fish farming situations that I have encountered were quite clean and not like the stereotypes that may be out there."*
>
> Bret Shaw, Associate Professor and Environmental Communication Specialist, Division of Extension, University of Wisconsin-Madison[133]

To gauge consumer concerns over aquaculture, researchers also asked respondents to indicate whether they "disagree," are "neutral," or "agree" that the following are concerns of Wisconsin farm-raised fish: contain contaminants, can cause environmental problems, are risky to eat, and are low quality. The majority of respondents selected "neutral" for each of the possible concerns, indicating there is a lack of awareness regarding aquaculture in the state. With this finding in mind, researchers suggested aquaculturists in the state have an opportunity to educate the public about the food safety and production processes in place to protect the environment.[37]

> *"Consumers wonder, 'What are those fish eating? Are they just packed tightly in tanks eating each other's waste?' Of course, not, but public perception and education are critical. I think what helps people move toward farm-raised is producers talking about how products are locally raised here in Minnesota or other states in the Midwest."*
>
> Amy Schrank, Minnesota Sea Grant[100]

Many fish farms in the region already use their websites as a tool to educate consumers and assure that their product is sustainably raised. For instance, Superior Fresh has a "How We Raise Our Fish" website section that explains everything from the incubation period to harvest. The company explains its aquaponics system in detail, noting that fish and plants are grown in separate buildings, operators control all the inputs, such as food, and the conservation of water during the process. Superior Fresh also lists all of its certifications, explains what each one means and uses images of the labels for consumer familiarization.[35]

> *"I would love to see more consumer education because we're trying to expand our sales, and it helps if people trust salmon and know how to cook it."*
>
> Steve Summerfelt, Chief Science Officer, Superior Fresh[6]

Wisconsin Sea Grant's "Eat Wisconsin Fish" website provides an example of how to educate the public about locally produced food fish. They provide illustrations of fish commercially raised or harvested in Wisconsin, as well as information on health benefits and resources for consumers to make informed purchasing decisions. The site also gives consumers the tools to take the next step and discover where to purchase locally raised fish by providing an interactive map of commercial and retail suppliers.[135]

> *"Younger generations want local fish, healthier and more sustainably raised food. Maybe we just need to target certain audiences and try to educate them."*
>
> Steve Summerfelt, Chief Science Officer, Superior Fresh[6]

In the Wisconsin consumer survey, researchers found that people who considered fish difficult to prepare ate it less often.[37] The "Eat Wisconsin Fish" website also presents easy recipes for different types of fish that aim to make cooking something new less daunting. For consumers looking for tips on preserving fish, the website provides printable information on planking, canning, freezing, pickling and smoking.[135]

> *"If you think about it, outside of a fish fry, what's an iconic Minnesota or Wisconsin fish dish? One of the things we learned is that people want fish recipes to be simple to make."*
>
> Bret Shaw, Associate Professor and Environmental Communication Specialist, Division of Extension, University of Wisconsin-Madison[133]

The newly launched "Eat Midwest Fish" website, which aims to educate consumers about sustainable aquaculture in the north central region, takes a similar approach. There, consumers can find information about where to purchase locally grown fish and seafood from the 12 states in the region, as well as "how to source and cook these products." Much like the "Eat Wisconsin Fish" site, "Eat Midwest Fish" provides nutritional information and uses step-by-step videos to demonstrate simple ways to prepare popular fish and seafood options.[136] While Paul Hugunin, division director of the Minnesota Department of Agriculture (MDA), said the agency will do all it can to promote locally grown fish, it likely won't take the same approach.

> *"It's more likely the MDA would support the aquaculture industry by including it in our existing marketing efforts such as our Minnesota Grown Program for smaller producers, Farm to School efforts, our many national and international market development activities, and our various AGRI grant programs like the value-added grant program. In addition, if fish producers wanted to form a check-off funded research and promotion council like other commodities we could help them through that process."*
>
> Paul Hugunin, Division Director, Minnesota Department of Agriculture[34]

Overall, Aquaculture Economist and Co-owner of Engle-Stone Aquatic$ LLC Carole Engle explained that consumer outreach and education should emphasize that the product is fresh, locally and sustainably grown and complies with U.S. regulations.[24] It's particularly important that this messaging is available in the retail environment, as many consumers said they "trust and rely on information from the grocery store environment almost as much as they value information from family and friends when it comes to their seafood selections."[136] Data also suggests that brands can utilize online marketing and should consider having chefs tell the story of their seafood to consumers, as this can influence purchasing decisions.[136]

ARKANSAS

Known as the birthplace of the warm water aquaculture industry, Arkansas has been in the fish business since the 1940s. While the state's first commercial fish farms raised goldfish, Arkansas fish farmers have diversified over the years.[137] In the late 1950s, at least two farms were selling catfish (Ictalurus punctatus), and by the 1960s "Arkansas had 4,500 acres in catfish production and three processing plants." While there was a brief downturn in the mid-1970s, by the next decade technological developments made year-round production possible.[138]

Arkansas embraced aquaculture early on, establishing its Catfish Farmers of Arkansas association in 1975. The association is composed of catfish producers, industry-related businesses, and research and education personnel, all of whom have an invested interest in the success of the industry.[139]

> *"I think it's important to have a strong aquaculture association. I spent a long time in Arkansas, of course, and the Catfish Farmers of Arkansas is a very strong association."*
>
> Carole Engle, Aquaculture Economist and Co-owner of Engle-Stone Aquatic$ LLC[32]

Arkansas, however, isn't alone in having a strong association lobbying on behalf of food fish

farmers. When the U.S. began importing and marketing basa and tra (Pangasius sp.) from Vietnam as "catfish" in the late 1990s, domestic producers suffered and jumped into action. "The U.S. catfish industry was successful in obtaining legislation stipulating that only fish from the Ictaluridae family can be labeled as 'catfish' in the United States."[138]

While Arkansas has the highest per capita catfish consumption in the U.S., there's a robust market for this product nationwide, and particularly with states along the Mississippi River.[138] After federal legislation was passed, several of the states with strong catfish markets went on to pass statutes on labeling requirements. Six states, including Alabama, Arkansas, Louisiana, Kansas, Mississippi and Tennessee, passed labeling laws.

While each state's laws are slightly different, there were two primary approaches. Some states require catfish to receive one of the following four labels: "Farm-Raised Catfish," "River or Lake Catfish," "Imported Catfish" or "Ocean Catfish."[140] Other states used the taxonomic rank to determine which fish can receive a "catfish" label. All catfish fall under the order Siluriformes and are broken down from there into 34 families. U.S. food fish farmers raise catfish in the Ictaluridae, so many state legislatures have prohibited the sale of certain "catfish" that don't fall within this family to protect domestic catfish producers.[140] In Arkansas, even restaurants have to comply with the labeling law, meaning a "catfish sandwich" has to be labeled as "imported" on the menu if it's not a domestic, farm-raised catfish.[141]

"We think it's good for the consumer," Jeremy Robbins, vice president of The Catfish Institute, told the Arkansas Democrat Gazette.[141] "There is far [sic] more imported catfish and catfish-like species coming into the United States than is produced [sic] here in the United States. But unfortunately, the methods that are used to raise them overseas in Asia and Vietnam are not up to par with how we raise the fish here in the United States."

This is just one-way states like Arkansas are bolstering their food fish industry, while also educating consumers and providing a simple way for them to make informed purchasing decisions. Having various well-organized state associations and resources like the Catfish Farmers of America and The Catfish Institute has helped the domestic catfish industry compete.

Additionally, industry trade groups like The Catfish Institute have helped educate consumers about catfish farming and its benefits. This trade group provides information on everything from fish farming techniques to what it takes to become a U.S. Farm-Raised Catfish Certified Processor. For consumers new to cooking catfish, there are even e-cookbooks available for download.[33] Beyond that, media reports, articles produced by the Arkansas Farm Bureau and Arkansas Grown magazine have contributed to educating consumers about farm-raised catfish.[24]

Key Takeaways

The majority of fish and seafood consumed by Americans is imported — contributing to the country's $16.8 billion trade deficit — and often difficult to trace.

Studies have shown that providing clear information about a fish or seafood product can improve sales.

Minnesota aquaculture producers can provide locally-sourced protein with a traceable water-to-table story.

Through blockchain technology, clear labeling, menu indicators and business websites, Minnesota producers can improve consumer awareness of local, sustainably raised fish and seafood.

Studies have shown that consumers don't always know how to prepare fish, and eat it less often as a result.

Websites like "Eat Midwest Fish" and "Eat Wisconsin Fish" not only provide information on the health benefits of fish but also show consumers simple steps to prepare it.

RECOMMENDATIONS: WHAT SHOULD HAPPEN NEXT

Though in existence for a number of years, food fish aquaculture continues to experience unrealized economic potential in Minnesota. The primary challenges, among others, include competition with offshore imports and warm weather states, successfully navigating the regulatory environment, lack of sufficient market and technical knowledge, financing for start-ups and expansions, and consumers' awareness of locally raised food fish and their willingness to purchase such product over cheaper imports.

Primary research and interviews with industry experts echoed these challenges, but also revealed practical solutions to address many of the most pressing issues aquaculture food fish farmers in Minnesota face. To address the challenges and maximize opportunities, the following action steps are recommended for consideration.

EDUCATE

Some aquaculture businesses across the U.S., and perhaps in Minnesota, have failed because leadership did not undertake the technical research and market analysis necessary to fully understand aquaculture before pursuing it. Guidance should be provided to equip new and existing food fish businesses with the information they need to succeed.

> For each business, compile research on key markets and realistically gauge supply and demand for the species intended to be produced.
>
> Fully define the economics of growing, processing and marketing the products.
>
> Further determine, as an industry, the purchase decision-making of customers, price sensitivity and industry growth potential.
>
> Update State Aquaculture Plan with current industry protocols.

Consumer education could also play a significant role in industry growth. Raising product awareness is important for long term success, as is establishing trust and purchasing interest among shoppers, and dispelling any misconceptions buyers have. Such education could stimulate demand and allow producers to align with buyer needs. [See Build Consumer Demand recommendations]

Training is also essential to ensure food fish operations are run efficiently, profitably and sustainably. As in states such as Wisconsin, Minnesota educational institutions could become a vital resource for preparing industry talent and shaping the skills and mindsets necessary for industry development.

> Provide operation-specific educational support to producers to help them gain best practice knowledge on the job.
>
> Conduct production risk assessments and develop mitigating protocols based upon findings.
>
> Learn from other states to establish Minnesota-based university preparatory training for future production and leadership talent. A technically trained and widely available workforce must be available.

FINANCE

Obtaining financing can be a significant barrier to entry within the industry and can prevent established and fledgling businesses from scaling up production. Beyond the cost of permitting, businesses have to acquire financing for everything from equipment to energy costs. But particularly with aquaculture businesses, lenders and insurance companies understandably want to see "proof of concept," making startup funds or loans for expansion challenging if that information is not in place. Further, the Minnesota investment community may not have a deep awareness of the industry, and the little they have heard could be negative.

> Nurture an investment environment more favorable to stimulating innovation and market development, by exploring increased access to capital, particularly for developing sustainable products for new or existing markets.

Consider financial support through tax incentives, grants or special economic zones.

Invest in research and development.

Adequately fund research to fill information gaps, particularly within understanding consumer perceptions and demand, as well as further exploration of optimal business models, best practices, and technical efficiencies.

Provide financial resources to support onsite assistance to manufacturers to further encourage production refinements and innovation.

COLLABORATE AND SUPPORT

Further development of an environmentally responsible and sustainable food fish aquaculture industry in Minnesota will take an informed, thoughtful and collaborative approach among numerous stakeholders. Experienced producers, government agencies and technical experts must play a key role in identifying challenges, presenting a united front and working toward solutions that address common challenges. Doing so could create a valuable innovation ecosystem between academia, nonprofits and the private sector that encourages knowledge sharing and, potentially, joint ventures. A more open and collaborative environment made possible through stakeholder dialogue could ultimately accelerate innovation and product development.

Support the efforts and expand the impact of the Minnesota Aquaculture Association to help shape vision, policies and success within the industry, ensuring the organization encompasses members from all dimensions of the aquaculture field.

Complete a thorough Minnesota aquaculture plan that details the opportunities, challenges and strategies needed to grow the industry through a defined path forward.

Determine ways to bring fish processors, chefs, retailers and wholesalers more effectively into the aquaculture industry discussion.

Foster industry and academic partnerships to support a strong research and development environment.

Leverage new technologies that reduce the cost of production and give Minnesota-grown fish a competitive advantage over imports.

Sponsor additional Minnesota-specific forums for sharing of best practices, such as the one held in 2017 that encompassed opportunities, challenges, trends and innovations.

BUILD CONSUMER AWARENESS AND DEMAND

Clear education and product information should play a significant role in successfully growing the buyer market for Minnesota raised food fish. Positioning Minnesota aquaculture products as environmentally friendly, sustainable and healthy, could help gain purchasing favor over imported, competitive product and promote fish that are raised locally in an environmentally sustainable way. Consumers want to be informed about where products are coming from. As has been successfully proven in other states, grocers, restaurants, producers and government entities all have a part in informing them.

Proactively shape awareness, attitudes and understanding of the availability of Minnesota farm-raised fish, and its inherent benefits among consumers, retailers/restaurants, and the financial and agricultural communities by undertaking a consumer education campaign to educate buyers about the health benefits of eating fish, different locally available species and how to cook them.

Accurately position aquaculture operations and products in Minnesota whenever feasible as being environmentally friendly, a good source of protein, sustainable and energy efficient.

Ensure clear point of purchase information through accurate nutritional and source labeling.

Establish a website that provides clear information about food fish aquaculture products available in Minnesota and how to cook them, among other information.

Aggressively raise the industry's media profile about Minnesota aquaculture developments and economic potential.

Collaborate with other regional producers to establish a better understanding of the regional consumer landscape.

MITIGATE POTENTIAL BARRIERS

There are numerous factors within this complex industry that could benefit from further discussion, clarification and possible reformulation.

Consider viewing aquaculture waste as agricultural waste rather than industrial waste to simplify regulatory efforts.

Create a clear, positive regulatory environment for sustainability. Streamlining regulations and fostering proactive and collaborative engagement between government, academia and industry would be beneficial.

Ensure adequate resources for fish disease detection and control, as well as introduction of new innovative treatments.

Support continued advances in technology for facilities (RAS, bio-filters, thermal regulation, energy efficiency, water conservation, waste treatment, etc.).

Leverage Minnesota's soybean crops — and potentially crops, such as wheat and other ag product resources — to reduce the price of feed and the aquaculture industry's reliance on forage fish, while also creating market demand for a crop in which the state is one of the nation's primary producers.

Consider hiring a state aquaculture coordinator to work closely with the University of Minnesota Extension Service, Sea Grant, the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency to help ensure producers are up to date on everything from best management practices to regulatory information.

APPENDIX

Survey Report

Food Fish Consumer Survey
March 2021

auri
Agricultural Utilization Research Institute

Contents

ABOUT AURI
The Agriculture Utilization Research Institute (AURI) has a mission to foster long-term economic benefit for Minnesota through value-added agricultural products. AURI helps businesses and entrepreneurs pursue innovative opportunities in biobased products, renewable energy, coproducts and food. This includes conducting extensive research about potential industries and supply chains that could bring additional jobs and economic stability to the state, in addition to advancing the agricultural field. Market expansion and process improvement are also impactful services AURI offers to the Minnesota agricultural industry.

Executive Summary

BACKGROUND
Food fish comprise a diverse category in Minnesota from its legendary walleye to trout. Besides wild caught fishing, which goes back many generations, commercially viable fish farm opportunities have been expanding as an interest area in recent years, creating employment, economic impact and growth for related sectors in the form of fish feed, fish health and byproducts. AURI retained research and strategic communications firm, Russell Herder, to undertake a consumer survey to better understand current fish consumption behaviors in Minnesota, perceptions of the food fish industry and market potential. The research findings will ultimately exist as part of a larger guide to serve as a resource and educational tool for decision makers, industry, academia and others to expand market opportunities in Minnesota, resulting in a positive shift in public perception, and serving to inspire successive projects with stakeholders' partners.

OBJECTIVES
This research:

Informs and supports expansion of current work in the field;

Creates actionable information for Minnesota aquaculture producers and related businesses;

Identifies consumer demand and perceptions within Minnesota markets; and

Determines necessary purchase drivers to grow the industry.

METHODOLOGY
To gain statistically reliable consumer insights, Russell Herder undertook a statewide telephone survey, on behalf of the Agricultural Utilization Research Institute, to assess market demand, current perceptions and purchasing barriers of food fish grown and/or sold in Minnesota. The surveying company completed a total of 352 interviews were completed with adult Minnesotans for a statistical reliability of +/-5.3 percent at the 95 percent confidence level. The survey sample took into consideration appropriate geographical distribution, age, income, race, etc. The surveys were conducted by phone between November 23 and December 2, 2020.

KEY FINDINGS
Respondents indicated they consume chicken and beef on a more regular basis than fish, with approximately half of consumers saying that they eat these meats more than once per week. Conversely, only three percent report eating salmon at this frequency, six percent consume shrimp and 11 percent eat other fish more than once per week.

Consumers feel fish is good for a healthy diet to a far great extent than they are buying it. In fact, nearly two-thirds agree salmon (65%) and other fish (71%) are either somewhat or very important as a healthy, sustainable food choice.

Consumers most trust government, grocery stores and commercial fish producers when it comes to assuring the safety of the food fish they buy.

Consumers have little awareness of which breeds of fish are currently raised in Minnesota, but 46% are interested in learning more – especially online or at the place of purchase. Walleye and trout are the species most commonly perceived as being commercially raised local fish, with 50 percent identifying walleye and 36 percent saying trout. However, nearly one-fourth (22%) of consumers are unable to name any locally raised species, indicating a lack of awareness. Almost half (46%) of consumers indicate that they are interested in learning more about fish that are commercially raised in Minnesota.

There is strong potential for increasing purchase of Minnesota grown fish. Consumers say that they would not only buy more but could pay additional. If Minnesota-raised salmon was available in either restaurants or grocery stores, 37 percent of consumers report they would be either somewhat or very likely to increase their purchase of such. Similarly, 40 percent feel their purchase of shrimp would increase and 41 percent indicate their purchase of walleye would increase if raised and available in Minnesota.

Flavor is the factor rated as the highest priority when purchasing fish.

Nearly two-thirds (62%) of consumers indicate that they sometimes or always read the product label for information (beyond price) when making a purchase of salmon, fish or shrimp while grocery shopping.

Those who would be willing to pay more for Minnesota-raised fish place the greatest importance on nutritional value, sustainability and being locally raised. Over half (57%) of consumers agree that eating Minnesota-raised fish, salmon or shrimp is more sustainable, and 51 percent feel such would be safer to eat than other fish options.

Eight in 10 (82%) consumers agree that commercially regulated fisheries or fish farms in Minnesota are good for the local economy. Seventy percent feel that these businesses would provide products with a high nutritional value, and over half (56%) agree such would have a positive impact on the environment. Furthermore, nearly half (46%) of consumers report that they are willing to pay more for food fish products that would benefit the state's economy.

APPENDIX

Survey Report

The top three perceived barriers to purchasing Minnesota-raised salmon, shrimp or other fish were overall quality (70%), taste (66%) and smell (58%). As well, 57 percent say that being able to locate Minnesota-raised fish and seafood products in stores or restaurants is a potential barrier to purchase (57%) and knowing how to cook it could also be a prohibitive factor (47%).

Those who would pay more for Minnesota-raised fish and seafood products are more likely to agree that commercially regulated fisheries and fish farms have a positive impact on the environment. Just over half (55%) agree commercially regulated fisheries or fish farms in Minnesota are a more sustainable method than wild caught.

RECOMMENDATIONS
Advance awareness, attitudes and understanding of the availability of Minnesota farm-raised fish and shrimp, by undertaking a consumer education campaign.

Share information about Minnesota aquaculture operations — when applicable — as environmentally friendly, healthy, sustainable, and energy efficient.

Clarify the economic advantages of expanding the aquaculture industry.

Ensure clear point-of-purchase information through accurate nutritional and source labeling, utilizing tools such as QR codes to increase traceability or identity preservation.

Establish centralized online information that provides detail about food fish aquaculture products available in Minnesota.

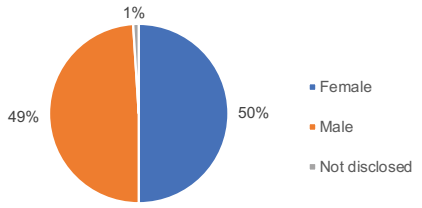
Increase the industry's profile of Minnesota aquaculture developments and the economic potential success could bring.

Food Fish Consumer Survey Findings 5

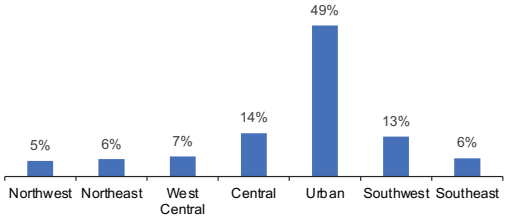
Demographics

Food Fish Consumer Survey Findings 6

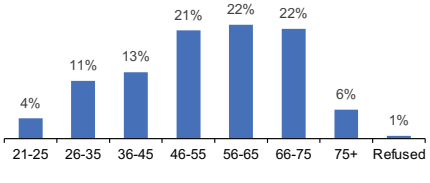
Of the 352 respondents interviewed, 49 percent identified as male, and 50 percent identified as female. Fewer than one percent preferred not to disclose their gender identity.



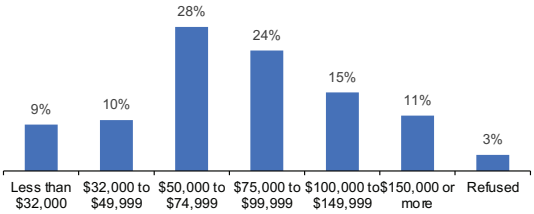
Forty-nine percent of consumers surveyed resided in the metro area of Minnesota. Fifty-one percent lived in regions other than urban. *(A breakdown of region, by county, available in appendix)*



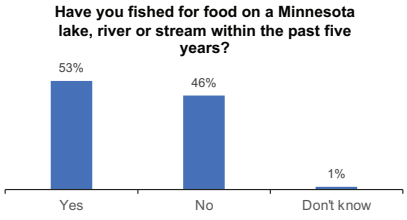
Twenty-eight percent of respondents were ages 45 or below. Sixty-five percent were between the ages of 46 and 75, and six percent were over 75.



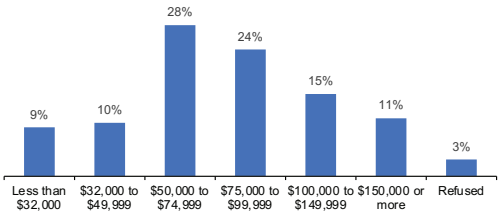
Nineteen percent of respondents reported an annual household income of $49,999 or less. Fifty-two percent reported their annual income to be between $50,000 and $99,999. Twenty-six percent reported annual income over $100,000, and three percent refused to answer.



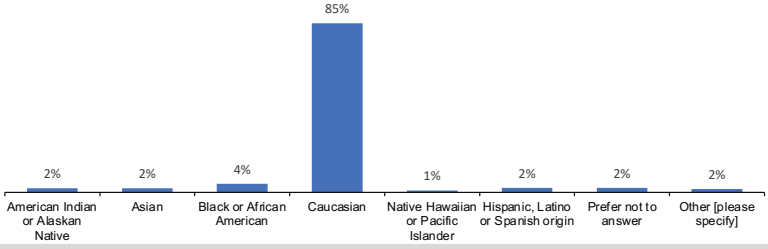
Just over half (53%) of consumers said that they have fished for food in Minnesota waters within the past five years and 46 percent said they have not.



Nineteen percent of respondents reported an annual household income of $49,999 or less. Fifty-two percent reported their annual income to be between $50,000 and $99,999. Twenty-six percent reported annual income over $100,000, and three percent chose not to answer.



Eighty-five percent of those interviewed indicated that they were Caucasian. Four percent reported they were Black or African American. Those who were Asian, American Indian or Alaskan Native, and Hispanic, Latino or Spanish origin comprised two percent each of the total respondents. One percent reported being Native Hawaiian or Pacific Islander. Two percent preferred not to answer and another two percent selected other. *(Other responses available in Appendix)*



APPENDIX

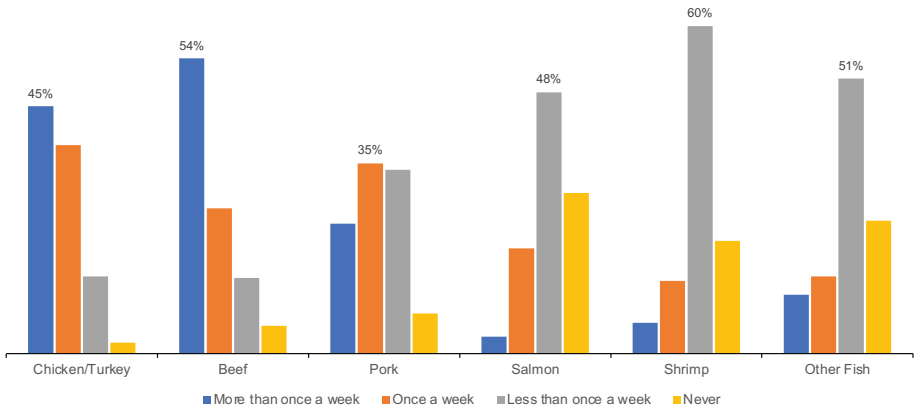
Survey Report

Findings

Consumption and Purchasing Behaviors
Over half (54%) of consumers reported having eaten beef more than once a week within the last twelve months. Similarly, nearly half (45%) reported they had eaten chicken more than once a week. Fewer indicated consuming pork at that frequency, with 35 percent saying they had eaten it just once a week.

Nearly one-fourth (22%) of all respondents reported having salmon once a week or more within the last twelve months. Comparably, 25 percent indicated they had eaten other fish at least once a week or more and 19 percent reported consuming shrimp at this frequency. However, of the options listed, salmon received the highest percentage (30%) of respondents indicating they had not consumed it at all within the past twelve months.

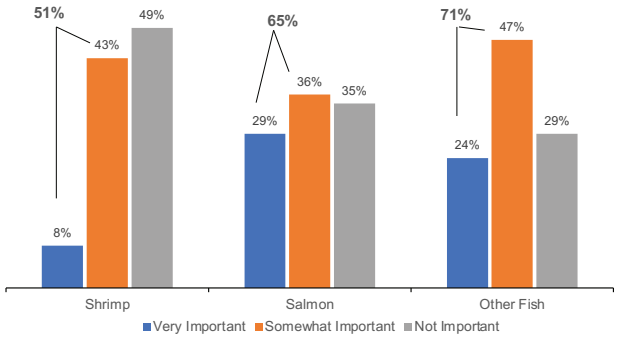
Within the past 12 months, how often have you eaten the following?



Awareness of the health benefits of eating fish is an important consideration.

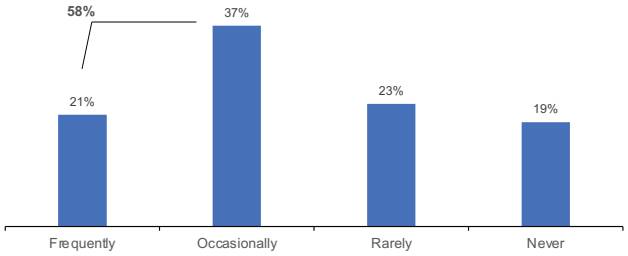
Nearly two-thirds (65%) felt salmon is either somewhat or very important as a healthy, sustainable food choice for their overall diet. Furthermore, 71 percent felt other fish are somewhat or very important additions to their diet as well. However, almost half (49%) of consumers indicated that they believe shrimp is not important as a healthy, sustainable food.

How important do you feel the following are as a healthy, sustainable food choice for your overall diet?



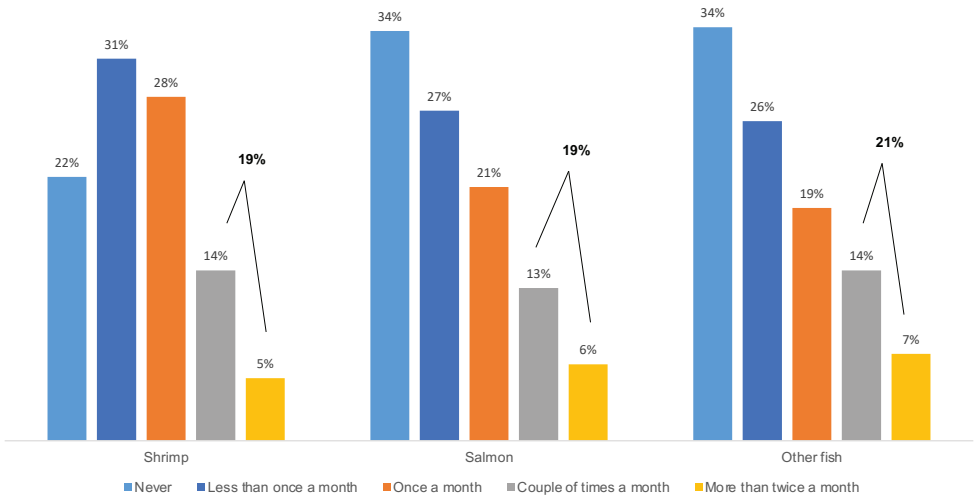
When asked how often they order fish, shrimp or salmon at a restaurant, 21 percent reported they do so frequently, and another 37 percent do occasionally. Less than one-fourth (23%) do so rarely and even fewer (19%) reported they never order fish, shrimp or salmon.

When you order food from a restaurant, how often do you order fish, shrimp or salmon?



Approximately one in five consumers indicated that they purchase fresh or frozen shrimp (19%), salmon (19%) or other fish (21%) from the grocery store more than once a month. However, over one-third (34%) reported they never buy salmon or other fish, while 22 percent reported never buying shrimp.

How often do you buy the following at a grocery store, either fresh or frozen?

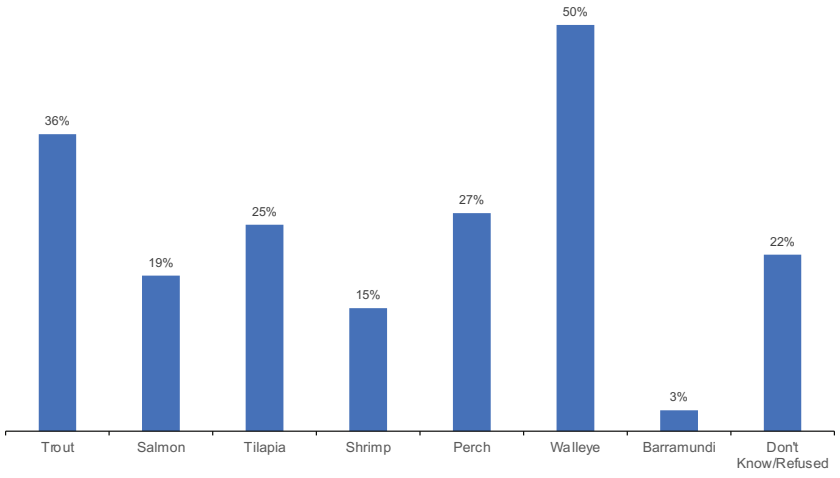


APPENDIX

Survey Report

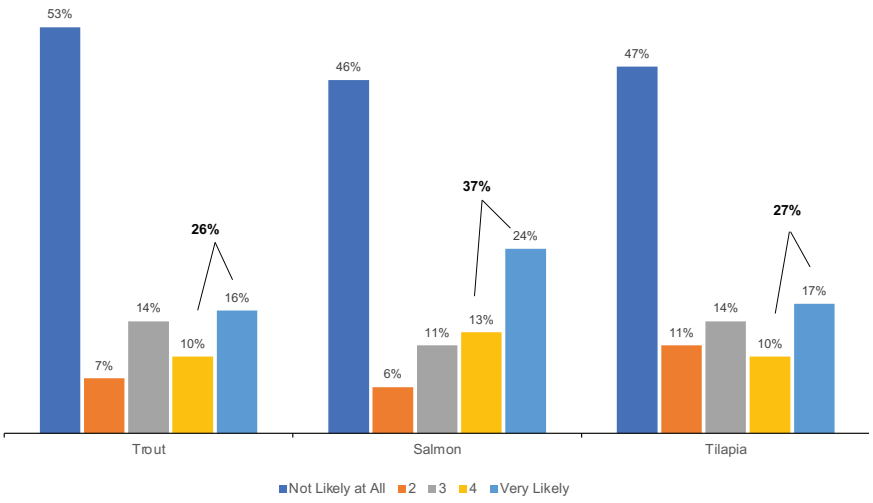
Minnesota-Raised Fish: Awareness and Demand
When asked to identify which species of fish they thought were commercially raised for food in Minnesota, consumers chose walleye most frequently at 50 percent. Over one-third (36%) also identified trout as a species commercially raised in Minnesota, and over a quarter (27%) identified perch. Fewer respondents believed that salmon (19%), tilapia (25%), and shrimp (15%) are species commercially raised in Minnesota. Nearly one-fourth (22%) did not know or chose not to answer the question, potentially an opportunity to further educate consumers of the commercial food fish market potential in this state.

Which of these species of fish do you believe are commercially raised for food in Minnesota?



Nearly one-fourth (24%) of consumers reported that they would be very likely to increase their purchases of salmon if a Minnesota-raised option were available in a grocery store or restaurant they frequent. An additional 13 percent indicated they would be somewhat likely to do so. Twenty-six percent reported that if Minnesota-grown trout were available in a grocery store or restaurant, they would be likely to somewhat likely to increase their purchases of such. Similar responses were seen for tilapia with 27 percent reporting their purchasing behaviors would likely increase.

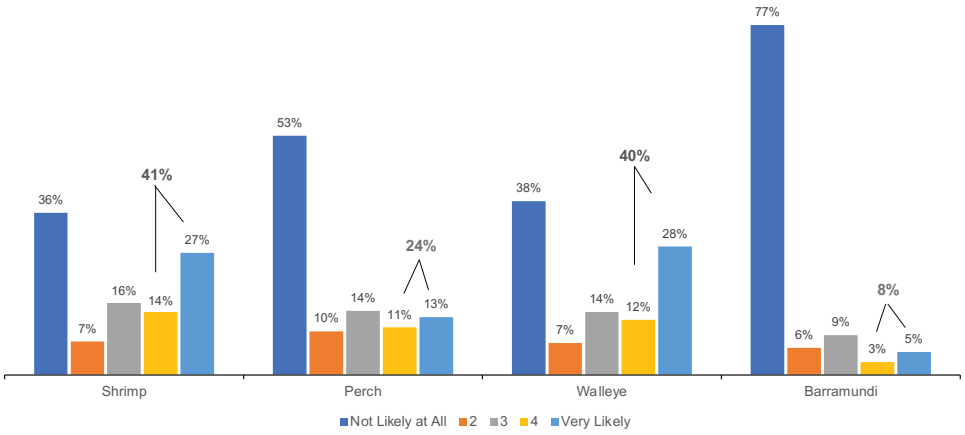
How likely is it that you would increase your purchase of Minnesota grown fish, if it were available in a grocery store or restaurant you frequent?



In addition to salmon, shrimp (41%) and walleye (40%) were the two species that yielded the highest percentage of consumers reporting that they would be somewhat or very likely to increase their purchases of such, if Minnesota-grown options were available in grocery stores and restaurants.

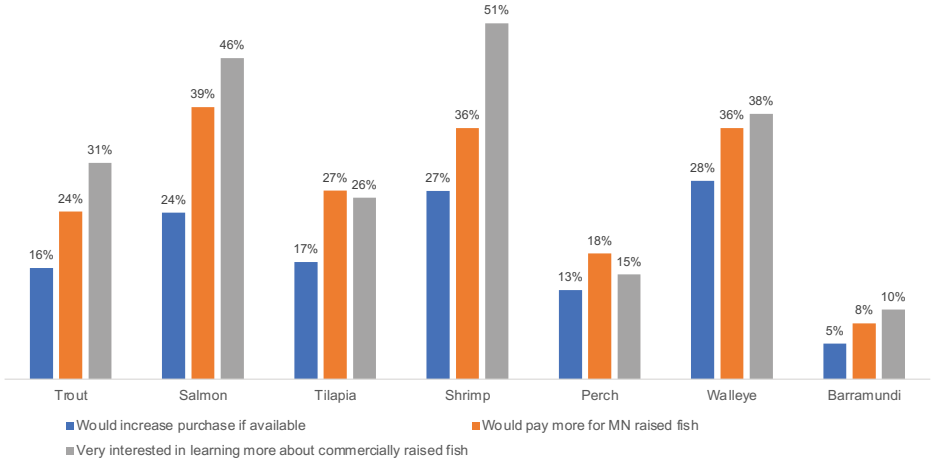
Twenty-four percent felt that the availability of Minnesota-grown perch would increase their purchasing of such. Similarly, Only eight percent of consumers indicated they would not be at all likely to increase their purchases of Minnesota-grown barramundi.

How likely is it that you would increase your purchase of Minnesota-grown fish, if it were available in a grocery store or restaurant you frequent?



Market potential for Minnesota-raised fish and seafood products exists. Consumers who indicated they are very interested in learning more about fish commercially raised in Minnesota had higher percentages report that they would be very likely to purchase Minnesota trout (31%), salmon (22%), shrimp (51%) and walleye (38%) if such were available. These higher percentages identify consumer preferences and fish and seafood species with the highest market potential.

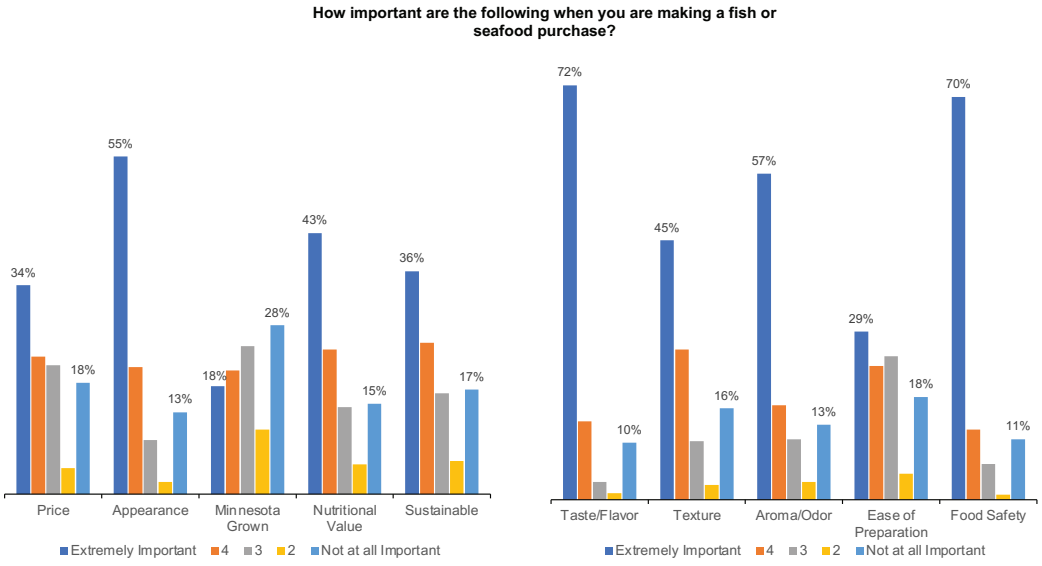
Very likely to increase purchase of Minnesota grown fish if it were available



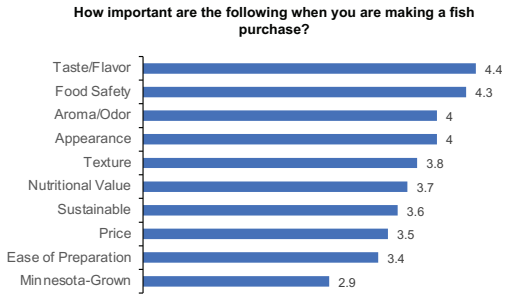
APPENDIX

Survey Report

Purchasing Preferences and Decision-Making Factors
When asked how important various factors are when making a fish or seafood purchase, the strongest drivers were taste/flavor (72%), food safety (70%), aroma/odor (57%), and appearance (55%).



Furthermore, when averaging the importance scores, with one being not at all important and five being extremely important, taste/flavor was the top ranked factor with an average score of 4.4. Factors seen as less important by consumers include price (3.5), ease of preparation (3.4), and Minnesota-grown (2.9).



When comparing the average ratings of importance of these factors, there were differences seen across the various segments of respondents. Those who had indicated they would pay more for Minnesota-grown fish and seafood products placed more importance on nutritional value (4.1), sustainability (3.9) and, of course, Minnesota-grown (3.5). Interestingly, Minnesota origin still received the lowest average score on importance within this group.

Those who had indicated they would be very interested in learning more about commercially raised fish and seafood products in Minnesota rated every factor as more important than the overall total scores.

How important are the following when you are making a fish purchase?
(1 not at all important – 5 extremely important)

	Total Avg	Would pay more for MN fish	Very interested in learning more	Fished in MN
Taste/Flavor	4.4	4.6	4.9	4.5
Food Safety	4.3	4.5	4.7	4.3
Appearance	4	4.2	4.5	4.1
Aroma/Odor	4	4.2	4.4	4.1
Texture	3.8	4	4.3	3.9
Nutritional Value	3.7	4.1	4.4	3.8
Sustainable	3.6	3.9	4.1	3.5
Price	3.5	3.6	3.6	3.5
Ease of Preparation	3.4	3.6	3.8	3.3
Minnesota-Grown	2.9	3.5	3.1	2.9

Purchasing opinions varied between men and women. Overall, women tended to rank each of the factors as more important, particularly food safety, texture, nutritional value, sustainability, ease of preparation and being Minnesota-grown. Nearly half of women (45%) ranked sustainability as an extremely important factor when making a purchase, while only 28 percent of men felt the same.

How important are the following when you are making a fish purchase? (1 not at all important – 5 extremely important)		
	Male	Female
Taste/Flavor	4.3	4.5
Food Safety	4.1	4.5
Appearance	3.9	4.1
Aroma/Odor	3.9	4.1
Texture	3.6	4
Nutritional Value	3.5	4
Sustainable	3.4	3.8
Price	3.4	3.6
Ease of Preparation	3.2	3.6
Minnesota-Grown	2.7	3.1

While taste and flavor had the highest average importance rating for nearly all the income brackets, food safety rated the highest for individuals with an annual household income of less than $32,000, with an average score of 4.2 compared to 4.1 for taste and flavor.

Price and ease of preparation were considerably less important factors to those who reported a household income over $150,000 than for all other income segments. Similarly, as household income levels increased, the importance of Minnesota-grown fish or seafood products decreased.

How important are the following when you are making a fish purchase? (1 not at all important – 5 extremely important)						
Annual Household Income	Less than $32,000	$32,000 to $49,999	$50,000 to $74,999	$75,000 to $99,999	$100,000 to $149,999	$150,000+
Taste/Flavor	4.1	4.3	4.5	4.2	4.6	4.3
Food Safety	4.2	4.3	4.4	4.2	4.4	4.1
Appearance	4	3.9	4.1	3.9	4.2	4
Aroma/Odor	4	3.9	4.1	3.9	4	4
Texture	3.5	3.9	3.9	3.7	4	3.7
Nutritional Value	4	4.1	3.8	3.4	3.7	3.6
Sustainable	3.6	4.1	3.7	3.3	3.4	3.7
Price	3.5	3.5	3.7	3.5	3.5	2.8
Ease of Preparation	3.6	3.4	3.5	3.3	3.5	2.9
Minnesota-Grown	3.3	3	3.1	2.7	2.8	2.5

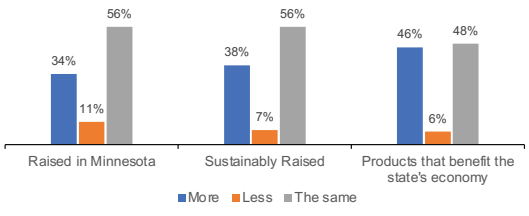
To provide a degree of context regarding buyer price sensitivity, consumers interviewed were asked whether they felt they would be willing to pay more, less or the same for fish, salmon or shrimp with certain attributes. It should be noted that for the purposes of this study, the question was asked without actual pricing comparisons, relying instead on perceptual responses.

The majority of consumers interviewed (56%) reported they would pay the same amount for fish or shrimp regardless if it were raised in Minnesota or if it was sustainably raised. However, nearly half (46%) also reported they would be willing to pay more for products that would benefit the state's economy. Just over one-third indicated they would pay more for fish or shrimp raised in Minnesota (34%), or those raised sustainably (38%). In comparison to the overall totals, a markedly higher percentage of those who said they would pay more for fish and seafood products raised in Minnesota said they would be very likely to increase their purchase of Minnesota-grown salmon (39%), tilapia (27%) and walleye (36%), if it were available.

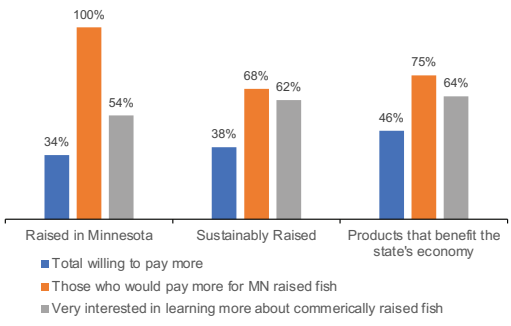
In comparison to the overall totals, those who reported they are very interested in learning more about commercially raised fish and seafood products in Minnesota were also more likely to be willing to pay more for fish or shrimp raised in Minnesota (54%), sustainably raised (62%), and products that benefit the state's economy (64%). Sixty-eight percent of those who indicated that they would pay more for fish or shrimp raised in Minnesota also indicated they would pay more for sustainably raised fish or shrimp. Three-fourths (75%) of these individuals reported they would be willing to pay more for products that benefit the state's economy as well.

Interestingly, those who indicated they had fished in Minnesota for the purposes of food within the last five years were less likely to be willing to pay more for either sustainably raised fish (35%) or products that benefit the state's economy (45%) when compared to overall totals of 38 percent and 46 percent, respectively.

Would you be willing to pay more, less or the same for fish, salmon or shrimp with these attributes?



Willing to pay more for fish with these attributes

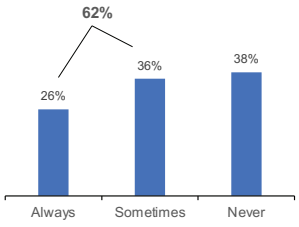


APPENDIX

Survey Report

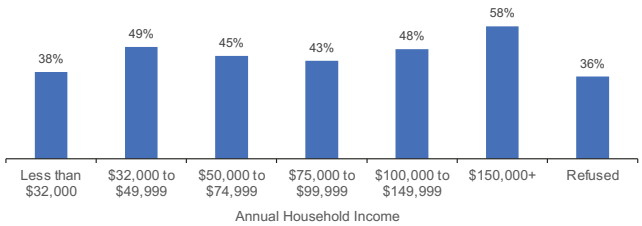
Sixty-two percent of consumers reported that they either sometimes or always read the labels while grocery shopping for fish, salmon or shrimp.

How often do you read fish, salmon or shrimp product labels while grocery shopping, other than for price?



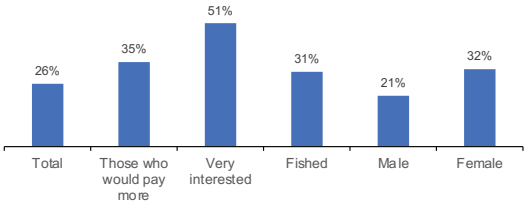
While the percentage of individuals who indicated that they would be willing to pay more for fish or shrimp raised in Minnesota and raised sustainably remained fairly consistent regardless of annual household income, there was a noticeable difference in the percentage that indicated a willingness to pay more for products that benefit the state's economy. Only 38 percent of those who have an annual income of less than $32,000 reported a willingness to pay more for these products. On the other hand, of those who reported an annual income of $150,000 or more, 58 percent indicated a willingness to pay more for products that are beneficial to the Minnesota economy. This identifies an opportunity to increase demand of Minnesota-grown fish or shrimp by educating consumers on how it benefits the state.

Willing to pay more for products that benefit the state's economy



When looking at the various segments, the survey identified certain groups as being more likely to read labels when purchasing fish, salmon, or shrimp. While only one-fourth (26%) of total respondents reported they always read the label, over one-third (35%) of those who are willing to pay more for Minnesota-grown fish or shrimp do so. Over half (51%) of those who indicated they are very interested in learning more about commercial fish or seafood operations in Minnesota reported they always read the label. The segment that is less likely than others to read the label were men, with only 21 percent reporting they always do so.

Always read the label



Food Fish Consumer Survey Findings

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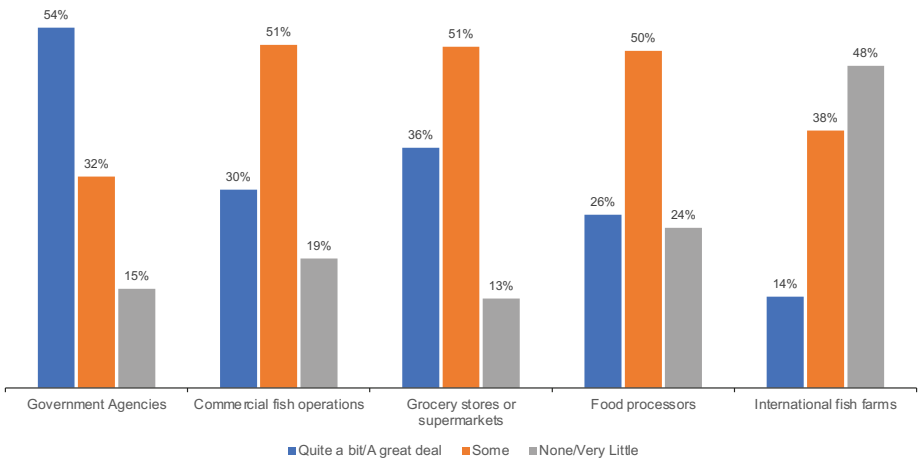
Information and Benefits of Minnesota-Raised Fish

Consumers have distinct opinions about who they trust to keep the fish and seafood they buy safe. The entity engendering the most trust by the majority (54%) were government agencies. Over half reported having some trust in commercial fish operations (51%), grocery stores or supermarkets (51%), and food processors (50%). The least trust related to international fish farms, with nearly half (48%) reporting they had none or very little belief in their willingness to keep food fresh and safe.

How much do you trust the following entities to keep the fish sold in restaurants and stores safe?



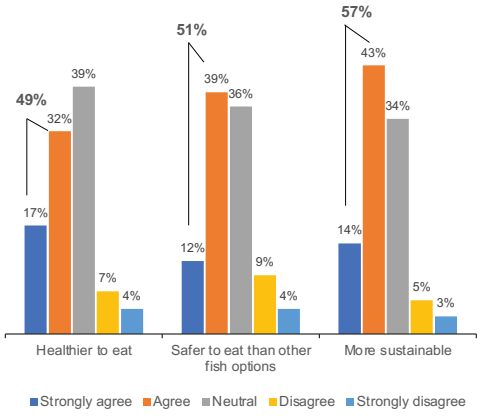
Food Fish Consumer Survey Findings

22

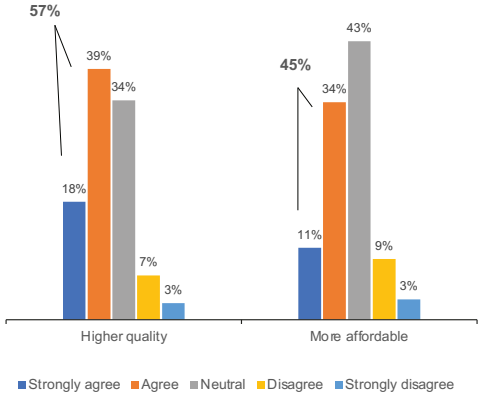
Fifty-seven percent of consumers agreed that eating Minnesota-raised fish, salmon or shrimp is more sustainable, and 51 percent agreed it would be safer to eat than other fish options. Nearly half (49%) also agreed that such would be healthier to eat.

Comparably, 57 percent also agreed that Minnesota-raised fish, salmon, or shrimp would be higher quality. However, there was less confidence in Minnesota-raised products being more affordable, with 43 percent feeling neutral about it.

What, if any, benefits do you feel there are to eating Minnesota-raised fish or shrimp?



What, if any, benefits do you feel there are to eating Minnesota-raised fish or shrimp?

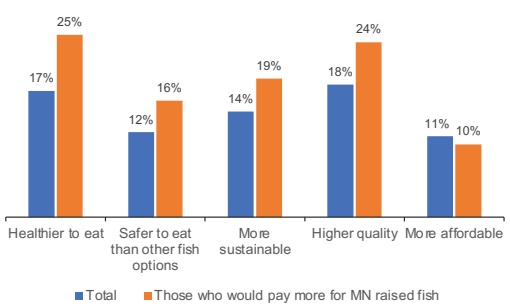


Overall, those who would pay more for fish or shrimp raised in Minnesota and those who are very interested in learning more about commercially raised fish were more likely to agree with the benefits of eating Minnesota-grown product. While just 17 percent of total consumers strongly agreed that eating Minnesota-grown fish or shrimp was healthier to eat, one-fourth (25%) of those who would pay more and nearly one-third (31%) of those who are very interested in learning more strongly agreed with this sentiment.

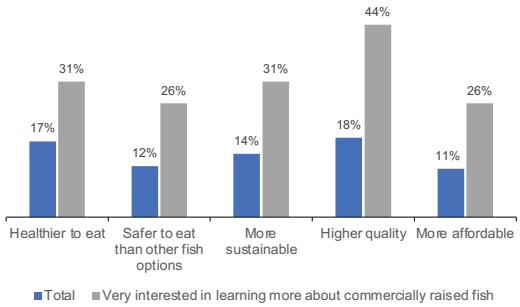
Similarly, a higher percentage of both groups strongly agreed eating Minnesota-grown fish or shrimp would be safer to eat than other fish options, with those who pay more being four percentage points higher than the overall and those who are very interested in learning more 14 percentage points higher. This trend continues for almost every other benefit listed, suggesting those who would pay more for Minnesota-raised fish or shrimp and those who are interested In learning more about commercially raised fish in Minnesota feel more confident in the benefits of eating Minnesota-grown fish or shrimp.

However, interestingly, those who indicated they would pay more for fish or shrimp raised in Minnesota were less likely than the total percentage of respondents to strongly agree such would be more affordable, with only 10 percent indicating such.

Strongly agree about the benefits of eating Minnesota-grown fish



Strongly agree about the benefits of eating Minnesota-grown fish

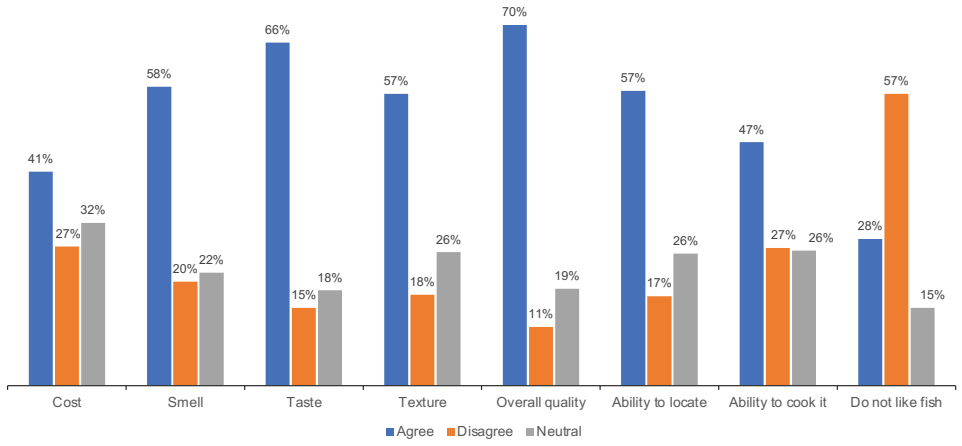


APPENDIX

Survey Report

Potential Barriers
When asked about barriers to purchasing Minnesota-raised salmon, shrimp or other fish, only 28 percent said that they had a dislike for fish. The potential barriers identified most frequently included overall quality (70%), taste (66%), smell (58%), texture (57%), and ability to locate (57%). These findings align with the previous responses suggesting taste/flavor is the most important factor when making a purchase. Similarly, food safety, aroma, appearance, and texture where among the top factors affecting this decision. (*Other responses available in Appendix)*

Are any of the following barriers to you, if you were to consider purchasing Minnesota-raised salmon, shrimp or other fish?



Food Fish Consumer Survey Findings 25

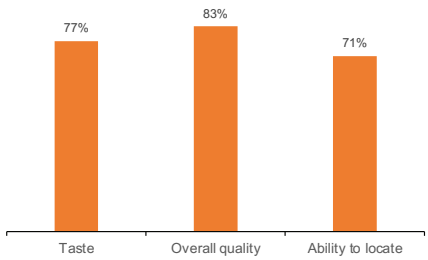
There were minimal differences across audience segments regarding barriers to potentially purchase Minnesota-raised salmon, shrimp, or other fish. The three obstacles that did show slight differentiation, when compared to those who would pay more for fish or shrimp raised in Minnesota, those who were very interested in learning more about commercially raised fish or shrimp in Minnesota, and those who had fished for food in Minnesota within the last five years were taste, overall quality and ability to locate.

While just two-thirds (66%) of consumers agreed that taste could be a barrier to purchase, more than three-fourths (77%) of those willing to pay more for fish or shrimp raised in Minnesota felt taste could be a barrier. Quality was also more important to this audience, with 83 percent identifying it as a possible barrier to purchase compared to just 70 percent of the total audience.

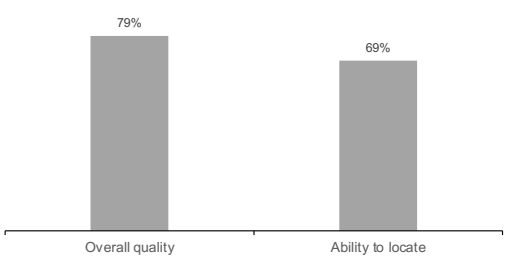
Furthermore, those who are very interested in learning more about commercially raised fish in Minnesota were also more likely to agree to overall quality being a barrier, with 79 percent in agreement. This data suggests overall quality may be more important to those who are willing to pay more for Minnesota-raised fish or shrimp and those who are very interested in learning more about commercially raised fish than the total population.

Respondents indicated the ability to locate Minnesota-raised salmon, shrimp, or other fish as a potential barrier to purchase by just over half (57%) of total respondents, but by over two-thirds of those who would pay more for Minnesota-raised fish or shrimp (71%) and those who are very interested in learning more about commercially raised fish in Minnesota (69%). This could be indicative that those who are willing to pay more or are more interested in learning about Minnesota-raised fish or shrimp believe Minnesota-raised fish and seafood products are scarcer, causing them to be willing to pay more or seek further information on such.

Barriers to purchasing Minnesota-raised salmon, shrimp or other fish among those who would pay more for Minnesota-raised fish



Barriers to purchasing Minnesota-raised salmon, shrimp or other fish among consumers very interested in learning more about commercially raised fish

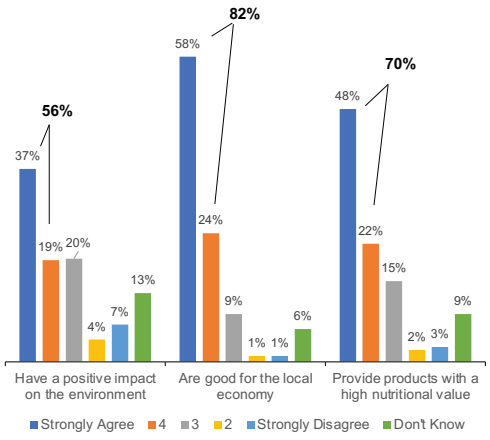


Food Fish Consumer Survey Findings 26

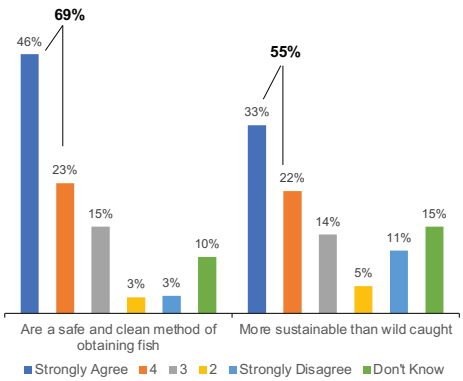
Positive Benefits
The majority (58%) of consumers strongly agree that commercially regulated fisheries or fish farms in Minnesota are good for the local economy. Seventy percent either agreed or strongly agreed that these businesses provide products with a high nutritional value, and over half (56%) agree or strongly agree they would have a positive impact on the environment.

Over two-thirds (69%) agreed or strongly agreed that commercially regulated fisheries or fish farms in Minnesota are a safe and clean method of obtaining fish. Just over half (55%) feel such operations are a more sustainable method than wild caught.

To the best of your knowledge how much do you agree with the following regarding commercially-regulated fisheries or fish farms in Minnesota?

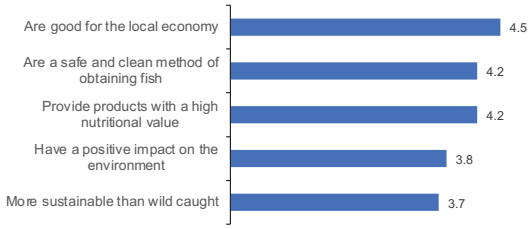


To the best of your knowledge how much do you agree with the following regarding commercially-regulated fisheries or fish farms in Minnesota?



When asked to what level they agreed with the following statements, with one being strongly disagree and five being strongly agree, there was the highest level of acceptance that commercially regulated fisheries and fish farms are good for the local economy. The statement with the least acceptance was that fisheries and fish farms are more sustainable than wild caught, with a score of 3.7. Based on previous data, nearly half (46%) indicated they would pay more for products that benefit the state's economy, therefore leading to the conclusion that the belief these farms are good for the economy will increase market demand.

To the best of your knowledge how much do you agree with the following regarding commercially-regulated fisheries or fish farms in our state?



Those who would pay more for Minnesota-raised fish or shrimp averaged a higher level of agreement with the perception that commercial fish positively impact on the environment.

Furthermore, those who were very interested in learning more about commercially raised fish in Minnesota were in stronger agreement that commercial fisheries are more sustainable than wild caught. They also were more likely to agree that commercially regulated fisheries provide products with a high nutritional value and are a safe, clean method of obtaining fish.

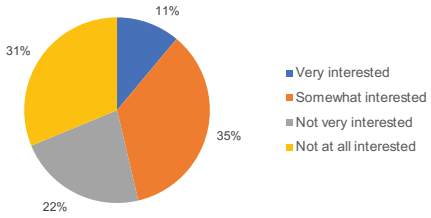
How much do you agree with the following regarding commercially regulated fisheries or fish farms in our state?
(1 strongly disagree – 5 strongly agree)

	Total Avg	Would pay more for MN fish	Very interested in learning more	Fished in MN
More sustainable than wild caught	3.7	3.9	4.4	3.8
Have a positive impact on the environment	3.8	4.1	4	3.9
Provide products with a high nutritional value	4.2	4.4	4.5	4.3
Are a safe and clean method of obtaining fish	4.2	4.4	4.5	4.3
Are good for the local economy	4.5	4.6	4.6	4.6

APPENDIX

Survey Report

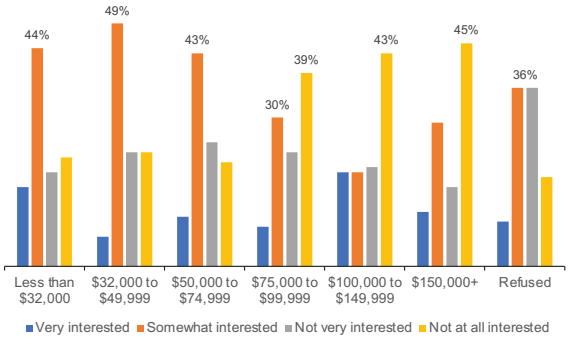
How interested would you be in learning more about fish that are commercially raised in Minnesota?



According to the results, almost half (46%) of consumers indicated they are somewhat or very interested in learning more about fish commercially raised in Minnesota.

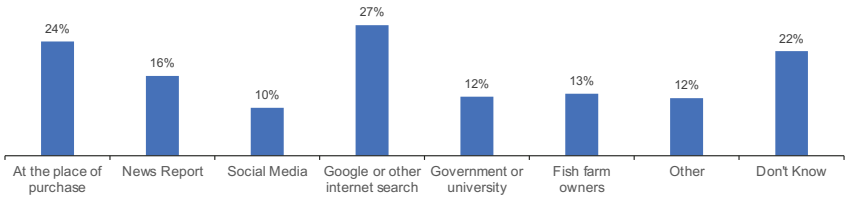
There was a notable shift in opinion as annual household income levels increased. While 44 percent of those with an annual income of less than $32,000, nearly half (49%) of those with an income between $32,000 and $49,999, and 43 percent of those with an income between $50,000 to $74,999 indicated they were somewhat interested in learning more, a higher percentage (39%) reported being not at all interested once income levels reached $75,000 or higher. This pattern continued with 43 percent of those with an annual income between $100,000 and $149,999 and almost half (45%) of those with an income at or above $150,000 reporting they are not at all interested in learning more about this subject.

Interest in learning more about fish that is commercially raised in Minnesota



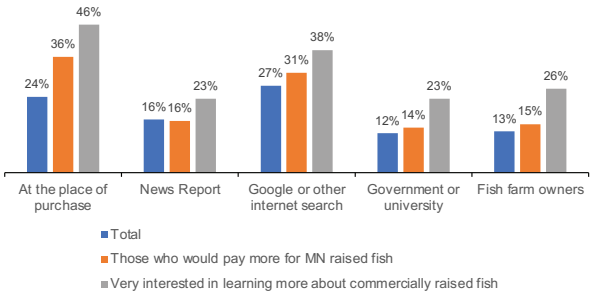
When asked where they would like to receive information about Minnesota fish farmers and commercial operations, the highest percentage (27%) reported that Google or other internet search would be preferred. The second most popular option was at the place of fish purchase (24%). (*Other responses available in Appendix)*

From where would you like to learn more about fish that is commercially raised in Minnesota?



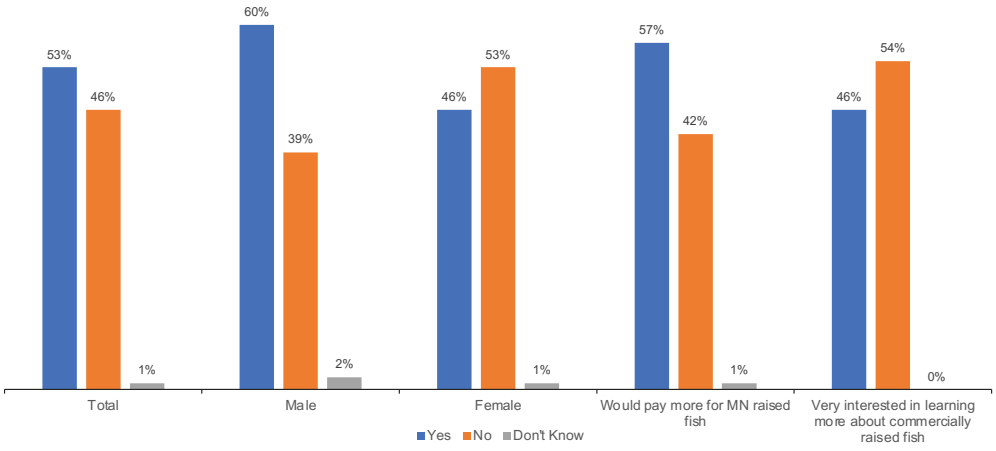
Those who would pay more for Minnesota fish or shrimp and those who were very interested in learning more about commercially raised fish in Minnesota both had a higher percentage who prefer to receive this information at the place of purchase, with 36 percent and 46 percent respectively reporting such. There was also a considerably higher percentage of those who were very interested in this information preferring to receive such from news reports at 23 percent compared to just 16 percent of overall respondents. Comparably, over one-third (38%) would like to receive this information via a Google or other internet search versus just 27 percent of the total population. Government or universities, and fish farm owners were also identified as reasonable sources.

Where would you like to receive this information



Those who would pay more for Minnesota-raised fish or shrimp were slightly more likely to have fished for food within the past five years, with 57 percent reporting having done so. Those who identified as male were also slightly more likely than the total population to have done so at 60 percent reporting they had.

Have you fished for food in Minnesota within the past five years?



Recommendations

APPENDIX

Survey Report

Findings from this study shed new light on consumer opinions about food fish purchasing and preferences – information that should serve to provide guidance to the aquaculture industry in Minnesota. More in-depth recommendations will be included in the upcoming, more extensive AURI food fish report; however, the following are offered as considerations based upon consumer study research results.

EDUCATE
Proactively advance awareness and understanding of the availability of Minnesota farm-raised fish and shrimp, and the inherent benefits for consumers, retailers/restaurants, and the financial and agricultural communities by undertaking a public education and outreach campaign.

Accurately position aquaculture operations and products in Minnesota, whenever feasible, as being environmentally friendly, a good source of protein, sustainable and energy efficient.

Emphasize the economic advantages of expanding the aquaculture industry within Minnesota across all educational touchpoints.

COMMUNICATE
Ensure clear point-of-purchase information through accurate nutritional and source labeling. To reassure consumers of the safety of the product, indicate such on the labels and emphasize the local aspect to increase credibility and trust.

Establish a centralized online destination that provides clear information about food fish aquaculture products available in Minnesota and how to cook them, among other information.

Highlight the health benefits of food fish products on labels, advertising, the aquaculture website, and point-of-purchase materials to remind consumers of this healthy alternative to other meat products.

PROMOTE
Aggressively raise the industry's profile about Minnesota aquaculture developments and the economic potential of success.

Position Minnesota aquaculture products as environmentally friendly, sustainable and healthy as compared to imported, competitive products, and promote fish raised locally in an environmentally sustainable way.

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Appendix

Food Fish Consumer Survey Findings 34

Breakdown of region by Minnesota county [page 7]

Northwest	Northeast	West Central	Central	Urban	Southwest	Southeast
Beltrami	Aitkin	Becker	Benton	Anoka	Big Stone	Blue Earth
Clearwater	Carlton	Clay	Cass	Carver	Chippewa	Brown
Hubbard	Cook	Douglas	Chisago	Dakota	Cottonwood	Dodge
Kittson	Itasca	Grant	Cow Wing	Hennepin	Jackson	Faribault
Lake of the Woods	Koochiching	Otter Tail	Isanti	Ramsey	Kandiyohi	Filmore
Mahnomen	Lake	Pope	Kanabec	Scott	Lac Qui Parie	Freeborn
Marshall	St. Louis	Stevens	Mille Lacs	Washington	Lincoln	Goodhue
Norman		Traverse	Morrison		Lyon	Houston
Pennington		Wilkin	Pine		McLeod	Le Suer
Polk			Sherburne		Meeker	Martin
Red Lake			Stearns		Murray	Mower
Roseau			Todd		Nobles	Nicollet
			Wadena		Pipestone	Olmstead
			Wright		Redwood	Rice
					Renville	Sibley
					Rock	Steele
					Swift	Wabasha
					Yellow Medicine	Waseca
						Watonwan
						Winona

Are you… *[Other responses, page 8]*

- Other
- Pali Pali
- Italian
- Native American
- Something else

APPENDIX

Survey Report

Are any of the following barriers if you were considering a purchase of Minnesota-raised salmon, shrimp or other fish? *[Other responses, page 25]*

- I would need it to be delivered because of disability
- Method of storage, either frozen, and the location.
- I would need to know how it is raised and the mercury content because I know that fresh water fish has high mercury content so I would need more information about that.
- Freshness if it wasn't raised in pens no antibiotics no disease
- Size of packaging
- It depends on who does it if the Indians up north are doing it and then the commercial people I would
- The fact we don't have a real ocean the lack of salt water
- I specifically purchase wild caught fish
- Packaging
- Said nothing about catfish
- My husband doesn't like it
- Prefer wild caught
- Appearance in the package or the meat shelf where ever you get from
- Available in the are where I'm at
- Availability living in the rural area
- Mercury in the lakes
- Safety
- Walleye will have to travel to get it
- I'll catch it
- Price
- Physical ability
- Safety of the product
- Allergic to sodium phosphate
- My wife doesn't like fish
- Do not cook
- Freshness
- Freshness
- Mercury level
- I would be real worried about the mercury content if it was wild caught
- The location to having it available and not going 45 mins away to find it
- Me being a fisherman and catching my own fish rather than buying it from a store
- Fish allergy
- It has to be not farmed
- Packing
- Environmental impact of the fish farming
- How they were raised and what they look like
- There are no salmon or fish raised in Minnesota. There's certain types of salmon on the borders of Minnesota but they're not raised in a farm.
- The quality
- Turned off by phrase 'organic'
- Freshness
- None
- Traveling distance
- Availability and awareness
- The fact that wild caught fish are more sustainable
- Fish allergy
- Vegetarian.

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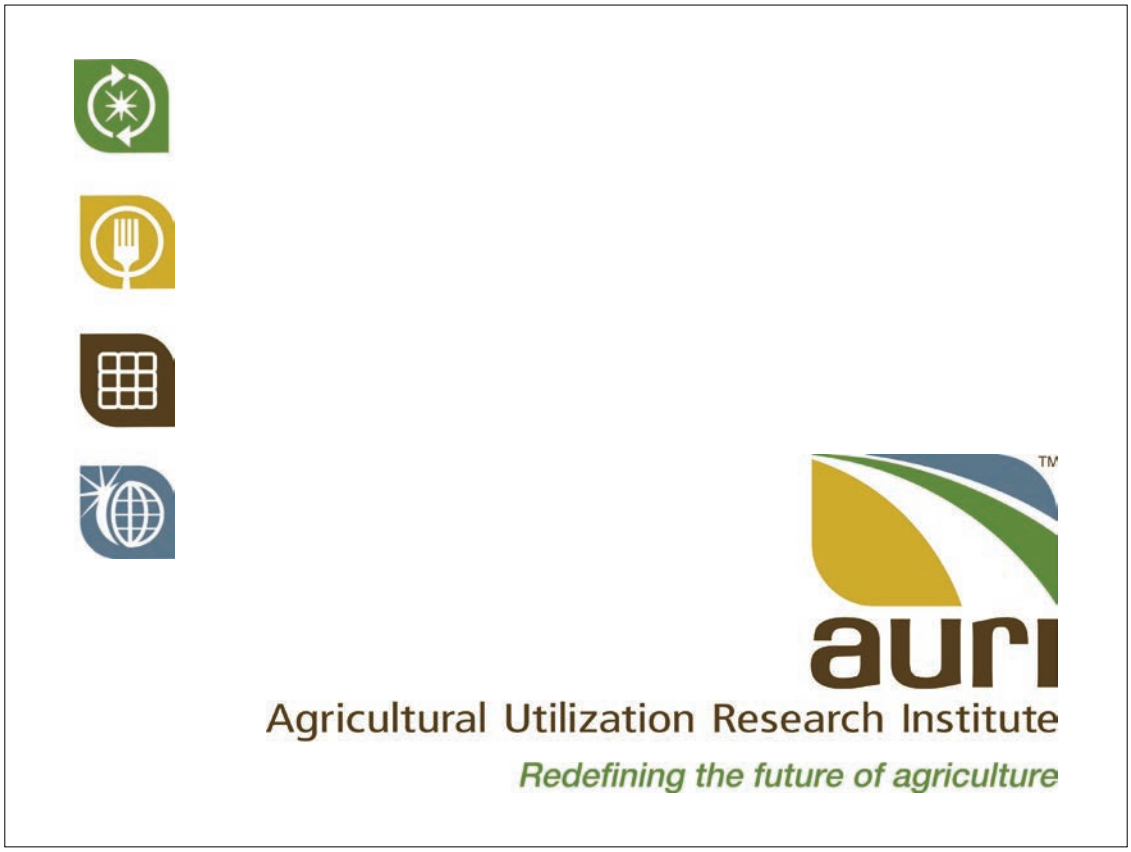
From where would you like to learn information about Minnesota fish farmers? *[Other responses, page 29]*

- I don't do social media and get most of my information from TV or radio
- Sent to my house
- Any of them
- Email
- The State of Minnesota
- The grocery stores
- Journals peer review type of stuff
- I don't want to learn more
- An email
- Not interested. Do not like any kind of fish or shrimp
- News paper
- DNR
- Advertise how they raise and sell them
- University of Minnesota
- Nowhere
- Public knowledge

Food Fish Consumer Survey Findings 38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