North Central Regional Aquaculture Center

Fact Sheet Series

Introduction to Aquaculture in the North Central Region

Introduction

Aquaculture is defined by the Food and Agriculture Organization of the United Nations (FAO) as "the breeding, rearing, and harvesting of fish, plants, algae, and other organisms in all types of water." Since aquaculture encompasses a myriad of species produced in multiple types of systems and in multiple waters (e.g., fresh, salt, brackish), it is often the most correct word to use when describing farming in water. Simply saying "fish farming" leaves out significant aquatic crops that are farmed.

For sake of this publication, the terms North Central Region (NCR) and Midwest both pertain to 12 states (Table 1) that coincide with the North Central Regional Aquaculture Center (NCRAC). NCRAC is a Midwest aquaculture administrative unit funded through USDA National Institute of Food and Agriculture (USDA NIFA) that was established by Congress in 1987 following the Food Security Act of 1985. In the most recent United States Department of Agriculture National Agriculture Statistics Service (USDA NASS) Census of Aquaculture, the Midwest had 271 aquaculture farms reporting, representing 9.2% of the nation's 2,932 farms (Table 2). Farm-gate sales for those 271 farms was 2.8% ($42.7 million USD) of the $1.52 billion in total US sales.

It is federal law to participate in the U.S. census. However, the census only captures aquaculture farms that produced and sold at least $1,000 in 2018, and it is also likely that some larger farms are occasionally overlooked. The number of small-scale start-up farms in the North Central Region may have been considerably higher than what was reported as USDA NASS may not have had the contact data for new producers. Thus, it is important for aquaculture associations and Extension specialists to notify producers when USDA NASS conducts their National Agricultural Classification Survey. The survey consists of a multi-year agriculture census mail list which helps to identify agriculture operations so that every producer can be counted in the upcoming census.

Table 1. Midwestern states, accompanying USDA NIFA land-grant colleges and universities within the states, and notation of available aquaculture Extension personnel at the universities.

State	Land-Grant College or University
Illinois	University of Illinois
Indiana	Purdue University*
Iowa	Iowa State University*
Kansas	Haskell Indian Nations University | Kansas State University
Michigan	Bay Mills Community College | Keweenaw Bay Ojibwa Community College | Michigan State University* | Saginaw Chippewa Tribal College
Minnesota	Fond du Lac Tribal and Community College | Leech Lake Tribal College | Red Lake Nation College | University of Minnesota* | White Earth Tribal and Community College
Missouri	Lincoln University* | University of Missouri*
Nebraska	Little Priest Tribal College | Nebraska Indian Community College | University of Nebraska
North Dakota	Cankdeska Cikana Community College | North Dakota State University | Nueta Hidatsa Sahnish College | Sitting Bull College | Turtle Mountain Community College | United Tribes Technical College
Ohio	Central State University* | The Ohio State University*
South Dakota	Oglala Lakota College | Sinte Gleska University | Sisseton Wahpeton College | South Dakota State University
Wisconsin	College of Menominee Nation | Lac Courte Oreilles Ojibwa Community College | University of Wisconsin

*Denotes at least partial full-time equivalent dedicated to aquaculture/aquaponic Extension or outreach in the state as of publication. Some additional assistance is available through non-land grant universities in the Midwest. Examples of non-land grant universities that provide aquaculture assistance include Southern Illinois University-Carbondale and University of Wisconsin-Stevens Point. Contact your local county Extension office to find assistance in your state.

Table 2. Farm-gate value of aquaculture products sold by type and quantity – U.S and Midwest states. States are listed in alphabetical order. Adopted from the USDA NASS Census of Aquaculture 2018.

	Total		Foodfish		Sportfish		Baitfish	
Geographic Area	**Farms**	**Sales ($1,000)**	**Farms**	**Sales ($1,000)**	**Farms**	**Sales ($1,000)**	**Farms**	**Sales ($1,000)**
United States	2,932	$ 1,515,680	1,071	$ 715,978	264	$ 39,350	168	$ 32,778
Illinois	26	$ 4,080	19	-	16	$ 2,861	6	-
Indiana	13	$ 3,403	6	-	9	-	1	-
Iowa	13	$ 3,828	6	-	4	$ 115	6	$ 124
Kansas	4	$ 1,003	4	$ 745	4	-	3	-
Michigan	28	$ 3,090	20	$ 1,843	12	$ 814	4	$ 267
Minnesota	19	$ 3,971	12	-	7	$ 1,700	9	$ 1,583
Missouri	26	$ 7,672	17	$ 5,096	8	$ 570	11	$ 982
Nebraska	21	$ 2,761	18	$ 2,343	7	$ 319	4	-
North Dakota	-	-	-	-	-	-	-	-
Ohio	59	$ 6,658	33	$ 2,677	29	$ 1,543	14	$ 2,131
South Dakota	3	-	2	-	1	-	2	-
Wisconsin	59	$ 6,249	45	$ 2,260	16	-	7	$ 2,038

*Percentage is calculated only based on published data and as such may lead to underreporting. Some data is withheld within states for confidentiality purposes.

Congress established the National Aquaculture Act of 1980 which includes the language "It is, therefore, in the national interest, and it is the national policy, to encourage the development of aquaculture in the United States." Other Acts and amendments have occurred since. During the following years, aquaculture became the fastest-growing segment of US agriculture. There has been assistance to promote the growth of aquaculture in terms of federally funded research and Extension programs over the last few decades.

Several factors have contributed to a reversal in this trend in recent decades. For example, shortly after mandates for ethanol in gasoline supplies were put into place many years ago, the cost of a ton of catfish (*Ictalurus punctatus* and *I. punctatus* x *I. furcatus* hybrid) feed more than doubled. Although feed prices have stabilized somewhat since, the US catfish industry declined by more than 50% in less than two decades. We have seen a slight rebound by the US catfish industry and moderate, if any, increase in other sectors of US aquaculture. The main caveats being the expansion of coastal shellfish industries and the recent investments in land-based salmonid culture.

Globally, the US currently ranks 16th in aquaculture production, representing only approximately 0.7% share of total production. Industry observers cite high capital requirements, excessive and/or redundant regulations, difficulty obtaining farm financing, and unfair competition from imported products as continuing threats to industry survival, let alone expansion. In addition, in recent years all of US agriculture has seen a shift in the way meat and produce products are produced, marketed, and sold. This appears to be especially true given the global pandemic caused by the novel coronavirus disease (COVID-19).

Aquaculturists in the NCR produce considerably less volume than some other regions of the US, although there is strong historical presence in individual Midwestern states. Multiple Midwest states have second and third generation family farms, proving the region can be both competitive and sustainable in aquaculture. A quick calculation from Table 2 reveals the total number of farmers who produce food fish, sportfish, and baitfish (362 farms) are greater than the total number of farms in the Midwest (271 farms). A difference of 91 farms indicates these farms fall under multiple categories, and they reported values in multiple locations in the census survey.

A small number of farms in the region also produced crustaceans, ornamental fish, and miscellaneous aquaculture products. In the Midwest, it is very common for one producer to supply more than 10 different species to wholesale or retail markets, and collectively there are greater than 30 species produced and sold. Usually, this is a retail producer whose primary business is as a pond and lake management company. In looking at the final row of Table 2, it can be noted that the Midwest has a considerable portion of all US sportfish and baitfish farmers (42.8% and 39.9%, respectively), but commands less than 25% of the sales in these industries.

There are also more than eight different production systems used to culture aquatic animals in the Midwest. The major production systems used in the region include ponds, recirculating aquaculture systems (RASs), flow-through raceways, and aquaponics, and to a much lesser extent biofloc systems and cage or net pens. The systems are described below. Many species may be cultured in multiple systems, although not all species can be cultured in all production systems. This leads to further complex situations when attempting to identify optimal growth conditions, average growth and survival, feed conversion ratio, costs of production, among others for a particular species and production system.

The only two NCR states that showed growth in the number of farms between the 2013 and 2018 Census of Aquaculture were Illinois and Indiana, adding three and six producers respectively. Kansas and Nebraska were the only two states in the region that did not have any changes in the number of farmers between 2013 and 2018. Interestingly, sales increased by over $6 million in the region even though the number of farmers in the Midwest dropped considerably from 336 to 271 between 2013 and 2018.

Business considerations and marketing of aquaculture products

Potential buyers, such as wholesale customers, brokers, and direct retail customers should be evaluated prior to developing a business plan. There are several free websites dedicated to assisting with the development of a business plan, and one popular website is www.agplan.umn.edu. This living document should be updated as knowledge, vision, and experience within the industry changes. There are Small Business Development Centers, private consultants, and Extension specialists throughout the country that can assist and review business plans for those who are interested in starting an aquaculture business.

Utilizing publicly available production and economic data is common when first developing a business plan in addition to an assessment of the seafood markets. However, it is important to note that university research often yields data that are higher or better than what is commonly found on a commercial farm. Replicated research is designed with the goal of holding all factors constant by adjusting only the predetermined variable(s). In addition, research studies usually use systems that are smaller than commercial scale, and there is usually at least one graduate student who will intensely oversee the study to ensure the trial is a success. Prospective aquaculturists should talk to other farmers and Extension specialists to get a better idea of true values that should be expected when developing a business plan. Modest and conservative production numbers are important and focusing on the higher side for variable and fixed costs is recommended. Just like any venture, the business usually costs much more to get started and takes longer to get to full production than original optimistic projections would suggest.

Marketing aquaculture products can be a complex and challenging process. A single species may be sold at any stage of growth (i.e., egg, fry, small fingerling, advanced fingerling, adult/broodstock), and both your business plan and production system should be designed with this in mind. It is not uncommon for a business plan and production system to originally be developed as only a grow out facility but then be adapted to selling smaller fish, i.e., fingerlings, due to demand from markets. As an example, a business plan and production system may have been developed to only provide adult tilapia (e.g., *Oreochromis spp.*) to local markets, but there may be a previously unknown market for fingerlings (younger fish) to be sold for algae control in ponds. If not originally part of the business plan, the farmer must evaluate the feasibility and economics of selling multiple sized fish to multiple markets.

For example, in the tilapia example, actual production, for at least part of the year, is likely to be impacted as additional fingerlings will need to be purchased/produced to meet the demand for algae control. If the farmer does not plan accordingly, tilapia originally destined as a food fish may be sold off early for algae control, leaving the final density of fish per gallon of water at the food fish stage lower than originally intended due to fewer fish being retained on the farm. If additional fingerling systems are built and used during the spring/summer to provide tilapia fingerlings for the summer algae control market, then the farmer may possibly have systems not used year-round. This becomes more complex as a farmer adds more species to their farm.

The farmers that get their tilapia to the food market still must navigate distinct market chains. According to Love et al. (2020), US adults consume 63% of seafood, by weight, at home. Additionally, 39% of seafood was purchased, but not necessarily consumed, at food service venues such as restaurants (Love et al. 2020). Restaurants, in turn, may purchase product directly from producers or through foodservice distributors. Conversely, some aquaculture producers use direct sales to the public to move some or all their production.

The local foods movement, slow food movement, farm-to -fork and farm to cafeteria initiatives, USDA organic standards, craft brew pubs, and other similar trends are expanding, with many past the stage of being a fad and becoming firmly established. A single species and size may end up at several locations depending on a farmers' location, interests, and market demand. Many farmers in the Midwest will say that moving their product is not difficult, and that if they produced more, they could sell it. Marketing is only one facet that an aquaculture business must consider.

Animal welfare concerns, influenced by advocates such as Temple Grandin, are also a factor that impacts markets and production systems. As consumers are becoming more aware of where their food is grown, how it is grown, and how the animals these products come from are treated, there has been a slow but positive shift in public perception of US aquaculture products. Aquaculture farmers build and maintain their systems to decrease stress on the animals. A well-built system takes into consideration water source and quality, tank and filtration design, heating/cooling systems, reliable electricity, exclusion of pathogens and predators as much as possible, among others. A fish is prone to becoming sick if it is stressed and will not eat and will either perish or have its growth severely impacted. A fish that does not grow well cannot lead to an economically, biologically, and socially viable business.

Additionally, a proposal for a new business must consider where it will be located. Rural areas are generally more supportive of agriculture, and the land is usually much cheaper. However, it can be difficult to find labor for specialized agriculture such as aquaculture, and the distance to market, or at least to a major highway, may prove prohibitive. Although we may hear about those who are firm believers in NIMBY (not in my backyard) when it comes to aquaculture, there are also several regions of the country where US farm-raised aquaculture has established a very positive perception. One example is the US farm-raised catfish industry in the Mississippi Delta. These farms are in rural areas and often significantly positively impact an otherwise economically depressed area by directly and indirectly providing jobs and supporting their community. Social license to operate in an area, exceptional marketing skills, and a highly productive system are all vital to any aquaculture operations.

Markets for aquaculture producers continue to grow in the US. For consumers interested in the local foods movement and farm-to-fork, food fish are produced in almost every state in the Midwest and can usually be purchased live or on ice, ensuring the product is extremely fresh and produced locally. Some producers in the region process their own product and can provide fresh-never frozen or frozen products locally as well. For consumers interested in the slow food movement, most US aquaculture producers are small-scale farmers just trying to produce enough product at a fair price to provide consumers with a healthy protein source they can cook in their home while also providing a modest income for their families. For consumers interested in farm to cafeteria, most producers in the Midwest are too small to produce enough quantities on their own. However, with the assistance of Cooperative Development Centers and a continued interest in this movement, more regionally produced aquaculture products may be possible for cafeterias. The price point is likely the most significant hurdle for these groups. Similarly, some potential farmers are interested in providing fish for the Friday night fish fry, a common meal in the Midwest during Lent. However, most restaurants, churches, and others are purchasing significant quantities of fish during this time, and cost is likely to be the most important factor, especially if the fish is sold as "all you can eat".

Consumption of aquaculture products in the US is also steadily increasing. The top seafood commodities ranked by per capita consumption (pound per person) include shrimp, canned tuna, salmon, and tilapia. Except for tuna, aquaculture has grown to become the primary source for these favorite commodities. According to the FAO, in 2012 aquaculture production (66 million tons) surpassed beef production (63 million tons) on a global basis. We now eat more seafood raised on farms than harvested from the wild

(Figure 1). It is widely recognized that aquaculture will need to continue its current expansion trend to meet the protein demands of a growing global population (Figure 2). Americans eat approximately 5 billion pounds of seafood annually, and the United States and Japan are usually the top seafood importers.

The health benefits of omega-3 fatty acids, found in many aquaculture species, have been widely recognized. These include prevention of cardiovascular disease, improvement of visual acuity, and fortification of mental health. For this reason, the American Heart Association recommends at least two 4 oz. (113 g) servings of seafood that are high in omega-3 fats per week. On average, Americans are not meeting these recommendations. The health benefits from seafood consumption apply to adults and children alike. Additionally, growing fish has a significantly lower greenhouse gas emission impact than all other meat proteins. Further future research through life cycle assessments are likely to show similar results.

The diverse economic impacts of aquaculture production on local and regional scales are becoming more understood and appreciated with various economic sectors benefiting from fish and shellfish farming. Globally, 20.5 million people were engaged in aquaculture in 2018, of which 388,000 were in North and South America. In Arkansas, baitfish and sportfish industries were also found to support sectors such as automotive and equipment repair and maintenance, couriers, and messengers (such as FedEx and UPS), and highway construction and maintenance. Aquaculture increased employment in hospitals, real estate, and educational sectors in Pennsylvania because of additional household spending. The US catfish industry generated $1.91 billion in total economic contribution in 2019 (Hegde et al. 2021). Industries that benefit from farmed rainbow trout (*Oncorhynchus mykiss*) sold for recreational purposes include gasoline stations, bait shops, grocery stores, and sporting goods stores. Additionally, in most states that have a significant fishery, the sale of fishing licenses to be able to catch stocked fish is the primary source of revenue for their respective Departments of Natural Resources (DNRs). The recreational fishery market is an exceptional avenue for many producers in the Midwest.

Significant industries in the Midwest such as baitfish, ornamental fish, and sportfish for stocking private or public waters have their own marketing and regulatory

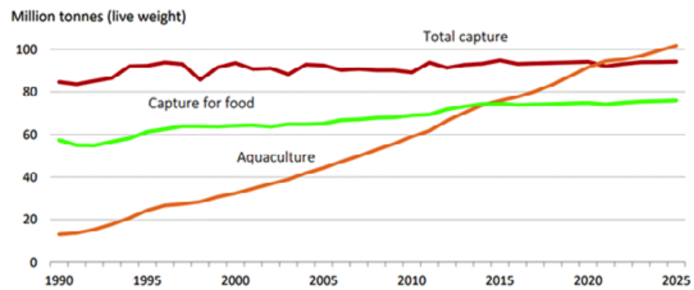

Figure 1. World aquaculture and wild capture fisheries production from 1990 to 2025 (real and projected). Source: OECD-FAO Agricultural Outlook 2017-2026.

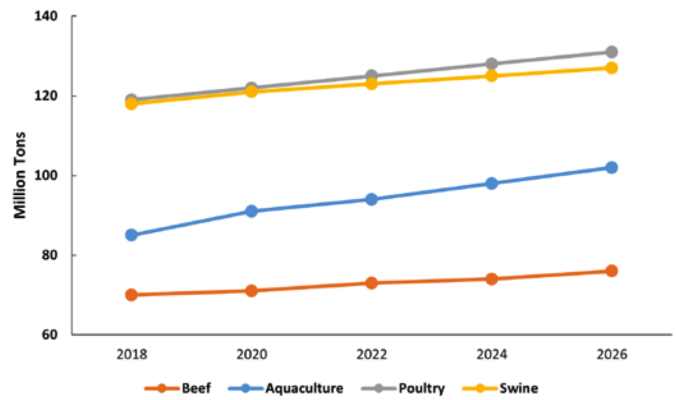

Figure 2. Global projections from the Food and Agriculture Organization of the United Nations for production of beef, aquaculture, poultry, and swine from 2018 to 2026.

considerations. Depending on the species, area produced, and other factors, a baitfish or ornamental fish operation may require significant time to navigate regulatory hurdles. Additionally, it may take significant time to market and sell their product. Most successful producers of baitfish and ornamentals have long-term relationships with their customers and loyalty can command a premium. When attempting to break into established markets, producers should keep in mind that little, if any, market share may be available, and competing on price alone will be difficult. This applies to food fish producers and virtually any other type of aquaculture. Understanding available and potential markets (and market segments) is as important as understanding production methods, systems, and each fish species' idiosyncrasies.

The regulatory complexities facing new aquaculture operations must also be considered during the planning process. For example, in Ohio there are several regulatory agencies that a producer must comply with, and the costs of complying with those regulations should be incorporated into a business plan. There are local, state, and federal regulatory agencies that demand attention. Researchers at Virginia Tech have worked to quantify regulatory costs on many segments of US aquaculture, such as baitfish and sportfish (pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/AREC/AREC-219/AREC-225.pdf). In Ohio, the Ohio Department of Agriculture must approve the importation of an aquaculture product, including eggs, to ensure the species does not contain any harmful pathogens which could endanger animals already in Ohio. Ohio DNR's Division of Wildlife must review the species, system, and location of the farm, and the department will approve the permit if these are deemed acceptable.

One of the Division of Wildlife's primary concerns is working with the aquaculture farmers to allow seafood production in the state without risking the release of potentially invasive (sometimes referred to as Aquatic Invasive Species [AIS]) or nuisance species into Ohio's public waters. The Ohio Environmental Protection Agency (EPA)also may be involved if the scale of the production system is large and leads to a considerable amount of feeding and discharge of water from the facility. Depending on scale and location, the US Corps Army of Engineers also may need to approve the operation to be within compliance. The Food and Drug Administration (FDA) inspects seafood processing facilities, so anyone planning to process (gut, scale, fillet, de-head, etc.) a seafood product must be certified in Seafood Hazard Analysis of Critical Control Points (HACCP). State agencies that inspect local food processors may also be involved. Each state has different regulations, and some regulations change frequently. "It is important to talk to regulators in the states where the product is produced and transported to for the most up-to-date information. NCRAC's website (www.NCRAC.org) has a State Import Regulations section which may also be useful.

Figure 3. Example of a yellow perch levee pond culture facility in the Midwest. Photo by Matthew Smith, Ohio State University.

Other considerations for aquaculture

In addition to being diligent in business plan development and marketing and promotion of aquaculture products, a keen sense of biology and even a rudimentary understanding of chemistry are necessary for a successful culturist. Most farmers do their own digging, plumbing, welding, electrical, and troubleshooting as doing the work oneself will lead to significant savings up front. However, these activities require skill and are extremely dangerous (see NCRAC FS 127). If the farmer is inexperienced and not properly trained, they may pay more to fix mistakes, or they may be seriously injured or even killed. Good aquaculture practices also involve ensuring good aquatic animal health, a well-designed system and proper care and maintenance to limit stress on the animals, utilization of high-quality feeds that meet the nutritional requirements of the species raised, adequate monitoring and management of water quality, good record keeping, and humane slaughtering or transporting upon harvest. Although there are a significant number of free publications available online and in print, there is little substitution for hands-on experience when it comes to learning aquatic animal behaviors, testing water quality, and maintaining a production system. Additionally, it may be difficult to quantify, but there is real economic value in the aquaculture learning curve.

Current production systems in the North Central Region

There are several production systems used in the Midwest, and it is not uncommon to hear of hybridization between systems. There are numerous cultured species and system configurations; however, not every species grows as well in each system. Additionally, the economics of a system, species, and market must be understood prior to spending money on infrastructure. Landing pages for many of the Extension publications mentioned below are available in the Suggested Readings and Websites section of this publication.

Pond culture (Figure 3) is the oldest and most popular aquaculture production system worldwide. Pond culture systems should be designed specifically for aquaculture, as there are general recommendations in terms of soil characteristics, construction dimensions, and volumes of water available for use. It is important to understand the effects of the watershed surrounding the farm and how nutrient runoff may impact the pond nutrient load. Several Extension publications are available regarding recommendations for pond culture (SRAC 101, SRAC 102, and SRAC 103).

Recirculation Aquaculture Systems (RASs) (Figure 4) are being considered by aquaculturists due to technological advances, increased pressure from regulatory agencies, and an overall belief that they are more environmentally sustainable. In the US, most RASs are built indoors and generally consist of some sort of tank to contain the cultured animals, several filters to clean the water and ensure water quality is optimal to decrease stress on the animals, and a source of oxygen for both the animals and beneficial bacteria in the filters. A RAS uses at least one pump to circulate the water from the culture tank through the filters and back. Often, gravity is used whenever possible to decrease circulation costs. While >85% of RAS water is recycled, water needs to be added to replace water lost to backwash, evaporation, and spillage. Essentially, RAS often is described as a larger version of a small home aquarium. Several Extension publications are available regarding desired recommendations for RASs (SRAC 451, SRAC 452, SRAC 453 and NCRAC FS 125).

Raceways (Figure 5) are often used in rainbow trout production in a few North Central Region states. Single-use or serial raceways typically consist of rectangular culture tanks where clean water flows in one end and then is discharged from the raceway at the other. After being discharged, the water is not returned to the raceway, unlike in a RAS. Raceways are common in areas where there are large quantities of high-quality spring water. After passing through settling ponds or other appropriate treatment options, water is returned to the watershed. Several Extension publications are available regarding overview and desired recommendations for raceway systems (e.g., Fornshell 2011; McGee and Cichra 2002).

Aquaponics (Figure 6) is not a new production system concept, and over the last few decades these systems have exploded in popularity. Aquaponics is being increasingly adopted by the public for self-consumption, as well as rural and urban farmers, faster than research can be conducted to generate design, management recommendations, and economic analyses. Aquaponic systems in the Midwest are

Figure 4. Example of a tilapia recirculating aquaculture system within a greenhouse in the Midwest. Photo by Matthew Smith, Ohio State University.

Figure 5. Example of a rainbow trout raceway system in the Midwest. Photo by Matthew Smith, Ohio State University.

Figure 6. Example of a tilapia coupled aquaponics system within a greenhouse in the Midwest. Photo of Roothouse Aquaponics in Ohio. Photo by Matthew Smith, Ohio State University.

similar to RASs in that these are usually are built indoors, consist of a culture tank and filters, and require oxygen to be provided for the bacterial community and aquatic animals. The difference is the inclusion of a hydroponic (plant culture) component that commonly acts as an additional filter as well as a revenue generator to support cash flow. The hydroponic component of the system may be located within greenhouses or entirely indoors under controlled lighting. The marriage between aquaculture and hydroponics frequently finds its way into schools as part of a science, technology, engineering, and math (STEM) focus. Teachers can work with students to teach them about the biology of the system (including the bacterial communities that liberate nutrients from uneaten food and animal waste), the design and water flow of the system, as well as the economics involved. Several Extension publications are available regarding desired recommendations for aquaponics (NCRAC Technical Bulletin 124 and 125, SRAC 454, SRAC 5006, and SRAC 5009).

Figure 7. Example of a saltwater shrimp biofloc system within a hoop house. Photo by Andrew Ray, Kentucky State University.

Figure 8. Example of cage culture. Photo by Michael Masser, Texas A&M University.

Biofloc systems (Figure 7) are increasing in popularity in the North Central Region. Most systems in the Midwest are saltwater systems primarily used to produce Pacific white shrimp (*Litopenaeus vannamei*). In biofloc systems, the goal is to convert wastes from the culture animals into microbial based protein that can be consumed by species such as tilapia and shrimp. The micro-organisms in the water tend to aggregate and form clumps with organic matter, or bio-flocs that can be filtered and consumed by some fish and shrimp. Protein use can increase two- to three-fold when raising species that can graze on biofloc in addition to their regular feed. The culture tank usually has just one filter attached to it, if any, and the main job of the filter is to keep the amount of floc in the desired range. Rather than using a pump to move the water from the culture tank and through a series of filters to remove solids and improve water quality, biofloc systems rely on bacteria's ability to attach to the floc, which is suspended in the tank by vigorous aeration. There has been increased interest in the US in hybridizing RAS and biofloc systems for optimal production, control, and costs. In the Midwest, round swimming pools are the tank of choice for culturing shrimp in biofloc systems. The bacteria in the tanks help to break down ammonia into relatively non-toxic forms and the floc is an additional food source for the shrimp. Salt can be a relatively expensive component of biofloc systems, and maintaining high water quality, including proper ionic balance, is necessary. A few Extension publications are available regarding biofloc systems (Rode 2014; SRAC 4503).

Cage/net pen culture (Figure 8) is a system that is not as widely popular in the North Central Region but can play a very significant role on a farm. For example, in some Midwest states, rainbow trout may be retained in cages in natural or semi-natural spring-fed ponds that are cool and clear year-round. They may also be used in abandoned quarries. Recreational ponds, spring-fed ponds, or quarries may not be constructed in a way that is best for production (e.g., they may be too deep or large to harvest) but floating cages in these ponds/quarries allow for production with easy feeding and harvest. Cage culture also works best in ponds that have decent wind exposure, which helps exchange the water in the cage with surrounding pond water, limiting the stress on the animals and increasing the oxygen in the cage. Several Extension publications are available (NCRAC 110, SRAC 160, SRAC 161, SRAC 162, and SRAC 163).

Species commonly cultured

The NCR produces and sells more than 30 different aquatic animal species. Finfish are most common, although crustaceans (mostly saltwater shrimp and freshwater prawn [*Macrobrachium rosenbergii*]) are produced in some states. Some fish, such as tilapia, are very adaptable and can be cultured in tanks, ponds, biofloc systems, and aquaponics facilities. Other require very specific culture conditions. At one time, members of NCRAC (including researchers, Extension professionals, and industry stakeholders) were asked what three species/taxa had the most potential for success in the region in the near future. Walleye (Sander vitreus)/saugeye [also referred to as hybrid walleye] (♀ *Sander vitreus* X ♂ *Sander canadensis*) was mentioned first, yellow perch (*Perca flavescens*) second, and for third place, there was a tie between largemouth bass (*Micropterus salmoides*) and trout/salmonids (*Salmonidae*). For anyone starting an aquaculture operation, it is important to understand relevant regulations for specific species and their culture operations. Regulations on which species can be cultured in any state are determined at the federal or state level, so contacting a state association and local regulators is important prior to culturing any species. "It is also possible that a species may only be produced within a certain part of a state.

Review and conclusion

Aquaculture is an extremely exciting, diverse, and interesting segment within agriculture, but a thorough review and understanding of the biology and business model being considered is critical. Aquaculture will continue to expand since one in seven people consume seafood every day. Reach out to your state, species, or system aquaculture associations and other producers in your area. Use available Extension publications and videos to learn more. Consider the objectivity of informational sources and the applicability to your particular situation.

Mention of trade names is for descriptive purposes only and does not imply endorsement or approval by the Iowa State University or NCRAC to the exclusion of other products that may also be suitable.

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Resources

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USDA

United States Department of Agriculture

National Institute of Food and Agriculture

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