



GEORGIA AQUACULTURE

DEVELOPMENT PLAN



UNIVERSITY OF
GEORGIA

About

The Georgia Aquaculture Development Plan was developed by the University of Georgia Aquaculture Working Group as part of a multidisciplinary effort to evaluate opportunities, challenges, and strategies for advancing aquaculture in Georgia. It assesses the status of aquaculture in the state and identifies opportunities, challenges, and strategic actions to support sustainable industry growth. Intended for policymakers, industry stakeholders, researchers, economic development professionals, and producers, this report provides a framework for advancing aquaculture in Georgia while supporting economic development, food security and environmental stewardship.

Authors

- **Mark Risse**, Marine Extension and Georgia Sea Grant, University of Georgia
- **Amrit Bart**, Department of Animal and Dairy Science, University of Georgia
- **Eugene Frimpong**, Marine Extension and Georgia Sea Grant, University of Georgia
- **Tom Bliss**, Marine Extension and Georgia Sea Grant, University of Georgia
- **Issmat Kassem**, Center for Food Safety, University of Georgia
- **Daniel Remar**, Department of Agricultural and Applied Economics, University of Georgia
- **Erin Arneson**, Marine Extension and Georgia Sea Grant, University of Georgia
- **Jay Shelton**, Warnell School of Forestry and Natural Resources, University of Georgia

Acknowledgements

The University of Georgia Aquaculture Working Group would like to acknowledge the many individuals, organizations, and agencies whose expertise, support and engagement contributed to the development of this report. Special appreciation is extended to the faculty, staff, and researchers of the University of Georgia, including representatives from Marine Extension and Georgia Sea Grant, the College of Agricultural and Environmental Sciences, the Warnell School of Forestry and Natural Resources, and other collaborating units who contributed their knowledge and perspectives throughout this initiative. The Working Group also recognizes the valuable input provided by aquaculture producers, seafood processors, distributors, industry organizations, community leaders and economic development professionals across Georgia.

Published July 2026

Table of Contents

Executive Summary	5
Section 1: Introduction and National Context.....	11
Introduction	11
Factors Influencing Demand	12
Domestic Production and Imports	13
U.S. Government's Role in Advancing Domestic Aquaculture.....	17
Section 2: Status of U.S. and Georgia Fisheries.....	20
Status of Wild Fisheries.....	20
Status of U.S. Aquaculture Production	22
Status of Georgia Aquaculture	23
Section 3: Aquaculture Systems and Environmental Considerations	26
Types of Aquaculture Systems	26
Water Resources	30
Land Topography	32
Soil.....	32
Climate.....	33
Ownership of the Resources	33
Waste Disposal	34
Permitting and Licensing	35
Zoning and Land Use Planning.....	36
Wildlife and Habitat Protection.....	36
Universal Requirements, Restrictions, and Rules	36
Section 4: Aquaculture Financing and Risk Mitigation	40
Changing Financing Environment	40
Funding Challenges	41
How Other States Support Aquaculture Financing	42
Securing Financing in the Early Stages of Business Development.....	44
Factors Outside the Business.....	44
Insurance and Risk Mitigation.....	45
Section 5: Supply Chain and Marketing	46
Seafood Demand	46
Seafood Supply	49
Aquaculture Supply Chain	52
Pricing.....	59

Linkages Between Producers and Markets	60
Constraints	63
Critical Mass.....	65
Section 6: Research, Training and Regulatory Support.....	66
Research and Development.....	66
Training and Education.....	67
State and Federal Agencies Involved in Georgia Aquaculture	67
Conclusion	73
References.....	75
Appendix A: State-wide Survey	81



Executive Summary

In December 2024, the U.S. National Science and Technology Council released the National Aquaculture Development Plan, emphasizing sustainable aquaculture as a key component of U.S. food systems. The plan highlights the nation's potential to lead in the production of fish, mollusks, crustaceans, and aquatic plants—as well as in conservation-driven practices. Multiple federal agencies are now supporting state-level efforts to expand aquaculture's benefits for public health, resilient communities, economic growth, and environmental quality.

Georgia is an ideal state for aquaculture expansion. It has a strong agricultural industry and considerable rural areas ripe for new economic development opportunities. Its transportation networks, processing capabilities, and access to markets provide economic advantages. Many communities in Georgia's rural and coastal areas are food desert zones and lack access to jobs and sustainable economic growth opportunities. Georgia also contains natural resources capable of sustaining a robust and diverse aquaculture expansion and could utilize aquaculture to promote greater protection of these resources.

In 2022, a self-initiated Aquaculture Working Group was formed by faculty and staff at the University of Georgia (UGA) to assess the university's potential role in facilitating aquaculture development in Georgia. These discussions led to the successful acquisition of a UGA Presidential Interdisciplinary Seed Grant. This grant is

designed to “address significant challenges to grow aquaculture in Georgia and to foster research, innovation, and partnerships with communities.”

The project team includes:

- **Mark Risse** | Director, *UGA Marine Extension and Georgia Sea Grant*
- **Amrit Bart** | Aquaculture Specialist, *UGA Animal and Dairy Sciences*
- **Eugene Frimpong** | Coastal Economic Specialist, *UGA Marine Extension and Georgia Sea Grant*
- **Tom Bliss** | Shellfish Research Lab Director, *UGA Marine Extension and Georgia Sea Grant*
- **Issmat Kassem** | Food Processing and Safety, *UGA Center for Food Safety*
- **Daniel Remar** | Economist and Marketing, *UGA Agricultural and Applied Economics*
- **Erin Arneson** | Seafood Specialist, *UGA Marine Extension and Georgia Sea Grant*
- **Jay Shelton** | Fisheries and Aquaculture, *UGA Warnell School of Forestry and Natural Resources*

This document is a product of the UGA Aquaculture Working Group and the Seed Grant initiative. A Georgia Aquaculture Conference in Athens in 2025 showcased the findings of this document and served as a platform for stakeholders to collaborate and advance aquaculture initiatives. Following the conference, strategic planning efforts have involved forming specialized working groups to develop actionable plans for the most promising aquaculture sectors. This coordinated approach aims to drive sustainable growth in Georgia’s aquaculture industry and position the state as a leader in the field.

The team found that Georgia, with its rich agricultural heritage, abundant natural resources, diverse markets, and advanced technology and food processing infrastructure, is well positioned to become a leader in sustainable aquaculture.

Six strategic categories have been identified for future growth:

1. **Guidance and Strategic Planning**
2. **Financial Support and Incentives**
3. **Research, Development, and Technology Transfer**

4. **Market Development and Consumer Engagement**
 5. **Infrastructure and Workforce Development**
 6. **Regulatory Compliance and Policy Development**
-

1. Guidance and Strategic Planning

A statewide coordinated effort is necessary to support aquaculture growth and development.

Key Actions

- **Establish a Georgia Aquaculture Working Group:**
The establishment of a non-governing aquaculture working group would play a critical role in shaping strategic policies to support the growth of Georgia's aquaculture industry. This group should include representatives from key state agencies, including the Georgia Department of Agriculture, the Georgia Department of Natural Resources, and the Georgia Department of Economic Development. Additionally, university faculty and staff with expertise in aquaculture research, outreach, and education should be involved. To ensure industry representation, the group should include producers from various aquaculture sectors, such as food fish, sport fish, shellfish and baitfish/ornamental fish. Other potential members could include state legislators from the Georgia House of Representatives and Senate, as well as representatives from the aquaculture technology sector. A key component of this initiative would be close collaboration with the Georgia Farm Bureau's Aquaculture Commodity Advisory Committee. This working group would help identify and develop specific aquaculture sectors in Georgia.
- **Leverage Existing Initiatives:**
Our research found that there are numerous existing efforts at the federal level, within the Department of Agriculture and the NOAA Sea Grant program, that are working to grow the domestic production of seafood. These should be leveraged to support the working group efforts. There are also several initiatives within the University System of Georgia, like the Institute for Integrative Precision Agriculture, to engage to advance sustainable aquaculture.

2. Financial Support and Incentives

To grow aquaculture production in Georgia, significant investments and access to capital will be required.

Key Actions

- **Address Funding Gaps:**

A major challenge is the lack of appropriate funding. The National Aquaculture Development Plan and NOAA's Guide to Federal Aquaculture Grants outline financial resources from federal partners like USDA, SBA, MBDA, and EDA. There are also significant venture capitalists and foundations interested in supporting new aquaculture ventures.

- **Integrate Funding Mechanisms:**

A statewide working group should:

- Adapt successful incentive programs from other agricultural sectors.
- Partner with state and local agencies to develop business planning and market feasibility studies for small-scale operations.
- Study financing models from other states and educate private investors through targeted campaigns and networking events.
- Foster public-private partnerships to share investment risks.

3. Research, Development, and Technology Transfer

With U.S. aquaculture encompassing inland ponds, offshore farms, recirculating systems, and aquaponics, Georgia must adopt modern tools and practices to stay competitive. Federal initiatives—such as NOAA's Aquaculture Collaboratives and USDA's Agricultural Genome to Phenome Initiative—offer valuable guidance for these advancements.

Key Actions

- Establish a centralized statewide information and technology hub.
- Utilize demonstration sites at institutions like UGA, Marine Extension and Georgia Sea Grant, North Georgia Technical College, Georgia Southern University and the GA DNR Go Fish Education Center.
- Engage the UGA Institute for Integrative Precision Agriculture to explore controlled-environment aquaculture.

- Prioritize research and bridge technology transfer gaps via a dedicated statewide mechanism such as a hub. Focus on allied advancements such as improved aquaculture feed production, water conservation and energy efficiency.
- Expand outreach through the UGA Cooperative Extension and Marine Extension and Georgia Sea Grant programs.

4. Market Development and Consumer Engagement

The National Aquaculture Development Plan calls for expanding domestic markets. Currently, most aquaculture products in Georgia are sold live or ice-packed. Greater integration with local seafood processing can enhance quality, freshness, and value addition.

Key Actions

- Launch consumer education and awareness programs to highlight the quality and sustainability of aquaculture products.
- Conduct market analyses to identify niche opportunities for species like catfish, rainbow trout, and tilapia.
- Analyze consumer demand, pricing dynamics, and regional preferences.
- Explore novel markets (e.g., public aquariums, pet food, pharmaceuticals, cosmetics, fishing lodges).
- Leverage existing processing infrastructure to develop value-added products.
- Improve distribution and direct marketing efforts through Georgia Grown, work with restaurants and chefs, agritourism efforts, and Destination Marketing Organizations.

5. Infrastructure and Workforce Development

A skilled workforce and modern facilities are essential for competitiveness. Federal initiatives—such as NOAA Sea Grant’s Aquaculture Hubs—demonstrate the benefits of collaborative infrastructure investment.

Key Actions

- Identify and prioritize deficiencies in both upstream (hatcheries, nurseries) and downstream (processing, cold storage) infrastructure.

- Collaborate with academic institutions to enhance workforce training and expand educational programs including fellowships and industry-based programs that provide on-the-job training to students.
- Develop targeted training and knowledge-sharing initiatives, including a potential blueprint for a Southeast Oyster Breeding Collaborative.

6. Regulatory Compliance and Policy Development

Regulatory uncertainty is a major barrier to aquaculture investment. The Strategic Plan to Enhance Regulatory Efficiency in Aquaculture (February 2022) calls for streamlined permitting, improved aquatic animal health management, and better regulatory tools.

Key Actions

- Improve interagency coordination to ensure cohesive policy implementation and resource sharing (handbook or guide for regulations).
- Form working groups to address regulatory challenges specific to freshwater and coastal aquaculture.
- Adapt national strategies to address Georgia's unique environmental, health, and legal requirements.

Georgia's natural and economic advantages make it a prime candidate for sustainable aquaculture leadership. Through integrated strategic planning, robust financial support, innovative research, targeted market development, modern infrastructure, and streamlined regulatory processes, the state can unlock significant economic and environmental benefits. By leveraging the growing support in Georgia for local food producers and tackling food insecurity with programs like Georgia Grown, aquaculture has the potential to take off at many different scales of market demand. These recommendations provide a roadmap for aligning local initiatives with national priorities and advancing Georgia's aquaculture industry into a leading role.



Section 1: Introduction and National Context

Introduction

The U.S. has seen a consistent rise in the demand for fish and seafood products, driven by increasing consumer awareness about the health benefits, evolving culinary preferences, and a growing population. U.S. per capita consumption reached 9.3kg in 2022 which is a 30% increase since 1990 (USDA, ERS 2024). Fish and seafood in American diets are celebrated for their rich nutritional profiles, distinct flavors, and adaptability in a wide range of culinary preparations. This surge in demand has necessitated a complex supply chain, blending domestic production with imports to sustainably meet the needs of the market.

As consumers become more health-conscious, they are increasingly turning to fish and other seafoods as lean sources of protein, vitamins, and minerals. The American Heart Association recommends consuming fish at least twice a week for heart health, further fueling the demand for these products. Additionally, the rise of various dietary trends, such as the Mediterranean diet and pescatarian diet has bolstered the popularity of fish and seafood as key components of balanced eating habits. Moreover, the versatility of fish and seafood in culinary applications contributes to their widespread appeal. From elegant seafood dinners to casual fish tacos, these products offer endless possibilities for chefs and home cooks alike. Their ability to complement

a variety of flavors and cuisines ensures their presence in diverse culinary traditions across the country.

To meet the current demand, the U.S. seafood market relies on a combination of domestic production and imports. While domestic fish contribute to the market by supplying fresh catch from coastal regions and inland waters, imports play a crucial role in supplementing supply, providing a diverse array of species year-round. U.S. seafood imports exceed exports by \$20.3 billion in 2023 (USDA, ERS 2024). The U.S. imported over 80% of seafood in 2021 (FATUS, 2023). While imports supplement supply and provide access to a diverse range of species, this dependence raises concerns about food security, economic vulnerability to fluctuations in global markets, and environmental sustainability. Developing domestic production systems is crucial not for ensuring a consistent supply of seafood and reducing reliance on international trade.

The growing demand for fisheries products in the U.S. reflects shifting consumer preferences towards healthier and more diverse food choices. As fish continue to occupy a prominent place on American diets, the industry must navigate a complex landscape of domestic production and international trade to meet the evolving needs of consumers while promoting sustainability and responsible stewardship of natural resources. Addressing these issues will require comprehensive management strategies, including regulations, ecosystem-based approaches, and sustainable farming practices, to ensure the long-term health and resilience of aquatic food systems.

Factors Influencing Demand

Four primary contributors to increasing demand for fisheries products in the U.S. include

1. **Population Growth:** The expanding population directly correlates with higher food demand, including fish and seafood. The steady growth of the U.S. population has resulted in increased consumption of fisheries products (Davis, 2024).
2. **Health-Conscious Consumers:** Consumers are recognizing that fish and shellfish provide high-quality protein, omega-3 fatty acids, vitamins, and minerals. Federal dietary guidance recommends seafood as part of a healthy eating pattern, including at least 8 ounces per week for adults. They also recommend 8–12 ounces per week for pregnant or breastfeeding women. For

children, FDA and EPA guidance emphasizes “Best Choices,” including salmon and trout. These health attributes, together with consumer perceptions of seafood as a healthier protein option compared with red meat, contribute to continued interest in seafood products (Valle de Souza et al., 2021).

3. **Cultural and Culinary Preferences:** Fish and seafood have deep-rooted significance in various cultural cuisines across the U.S. Different regions boast diverse culinary traditions that incorporate an array of fish and seafood dishes, thereby fostering demand for diverse products.

Domestic Production and Imports

In 2011, aquaculture surpassed natural fish production, reaching a peak of 96 million metric tons by 2023 (U.N. Food and Agriculture Organization, FAO 2023). Despite this global growth, aquaculture in the U.S. has stagnated, hovering around 300,000 metric tons valued at 1.3 billion dollars, ranking the nation 18th globally (NOAA, 2023).

The U.S., although a major importer of seafood, faced a trade deficit of 20.3 billion dollars in 2023 (USDA, 2024). To address this shortfall, the U.S. employs a comprehensive strategy, blending domestic production with international imports. Domestic aquaculture not only bolsters food security but also stimulates local economies and alleviates strain on wild fish populations (Anderson et al., 2020).

However, despite its crucial role, domestic aquaculture alone cannot satisfy the nation's appetite for fish. Consequently, the U.S. heavily relies on imports to bridge this gap and ensure a steady supply of seafood (Naylor et al., 2021). These imports encompass a wide variety of species from diverse global regions, highlighting the importance of sustainable sourcing strategies to meet consumer demands.

Sustainability and Environmental Considerations

With the burgeoning demand for seafood products, the aquaculture industry is increasingly prioritizing sustainability and environmental concerns. Practices aimed at minimizing ecological impact, such as improved feed efficiency and reduced pollution, are being implemented alongside efforts to bolster domestic production. The U.S. seafood market necessitates a blend of domestic production and imports, with sustainable practices emerging as pivotal for the industry's future.

The U.S. seafood market increasingly favors sustainably sourced, traceable products. While the country imports heavily from Canada, China, Chile, and Vietnam, it also exports much of its domestic production. Aquaculture—ranging from salmon to

shrimp—helps meet demand by applying new technologies to boost efficiency and output.

Environmental concerns drive efforts to reduce aquaculture's footprint through water conservation, responsible feed sourcing, and certifications such as ASC (Aquaculture Stewardship Council) and BAP (Best Aquaculture Practices). Government funding and regulatory frameworks support industry growth, though challenges like financing and disease management remain.

Consumers are choosing premium, sustainable seafood more often, with organic aquaculture gaining ground. Both retail and food service sectors fuel this demand, reinforced by certification programs like MSC and BAP. Population growth, health awareness, and shifting dietary preferences continue to shape U.S. consumption patterns. Meeting this demand will require a mix of domestic aquaculture and imports, with sustainable practices central to ensuring long-term supply and minimizing environmental impacts.

Advancements in Aquaculture Technology

Technology and innovations have improved productivity, efficiency, and sustainability in aquaculture. Major gains in farmed shrimp, salmon, and tilapia have been linked to hatchery seed production, improved feed formulations, automated labor-saving equipment, genetic improvements, vaccines, and better control of production processes. More recent advances in precision aquaculture include engineering innovations such as sensors, monitoring systems, automation, and data-supported management, while genomic tools are increasingly being applied to accelerate selective breeding and improve production traits. (Kumar & Engle, 2016; Antonucci & Costa, 2020; Houston et al., 2020)

The pursuit of sustainable and alternative feed sources for aquaculture has garnered significant interest. Research endeavors are concentrated on identifying alternative protein and lipid sources, such as insect-based feeds, algae, and single-cell proteins, aimed at diminishing dependence on conventional fish-based feed components (Hua et al., 2019).

The pricing of fish and seafood exerts a substantial influence on consumer demand, with affordability emerging as a critical factor, particularly for species perceived as premium or luxury items. Market dynamics, including supply-demand fluctuations, alongside variables such as weather events and trade policies, can significantly impact the availability and pricing of fisheries products.

Educating consumers regarding the advantages of fish and seafood consumption, sustainable sourcing practices, and responsible consumption habits can bolster demand. Highlighting the nutritional value, culinary versatility, and gastronomic experiences associated with various fish and seafood products can foster expanded consumer interest and diversified consumption patterns (Gupta et al., 2020).

Expanding on the Health Benefits of Consuming Fish and Seafood

Omega-3 fatty acids, encompassing eicosatetraenoic acid (EPA) and docosahexaenoic acid (DHA), are indispensable for brain development, cognitive function, and cardiovascular health. Their association with mitigating the risk of heart disease, supporting brain health across different life stages, and contributing to overall mental well-being underscores their significance (Calder, 2015).

Fish and seafood serve as exceptional sources of high-quality protein, in addition to furnishing essential vitamins and minerals, including vitamin D, vitamin B12, iodine, selenium, and zinc. These nutrients play pivotal roles in diverse bodily functions, encompassing bone health, immune system functionality, and energy metabolism (Burlingame et al., 2009).

Fish consumption holds advantages for pregnant women, as the omega-3 fatty acids support fetal brain and eye development. Moreover, it is recommended for older adults owing to its potential to mitigate the risk of cognitive decline and age-related macular degeneration (U.S. Food and Drug Administration & U.S. Environmental Protection Agency, 2024; Cederholm, 2017; Jiang et al., 2021).

These multifaceted dimensions collectively sculpt the demand for fisheries products in the U.S., propelling industry growth, sustainability endeavors, and innovation. Adhering to consumer preferences, upholding quality standards, and ensuring environmental stewardship stand as imperative pillars for fostering a resilient and thriving aquaculture sector.

Change in Species Preference

Change in species preference: Consumer preferences for fish and seafood species in the U.S. are influenced by taste, availability, price, health perceptions, sustainability, and cultural familiarity. Although the U.S. seafood market has a limited number of familiar species, there is growing interest among seafood educators, chefs, retailers, and sustainability groups in promoting lesser-known or underutilized species. However, underutilized species should not automatically be presented as more sustainable; their market potential depends on stock status, harvest limits, supply-chain access, consumer acceptance, and price. In the Northeast U.S., Acadian redfish

has been identified as an underutilized species with potential market opportunities, although recent climate-resilience assessments suggest caution in assuming long-term expansion potential (Farmery et al., 2020; Davis et al., 2023; Love et al., 2020).

Such shifts impact market dynamics, supply chains, and aquaculture production strategies. One significant driver of change is the growing awareness of sustainability and environmental concerns among U.S. consumers. This heightened consciousness has led to a preference for species sourced through sustainable fishing or farming practices, with lower environmental impact and reduced vulnerability to overfishing (Troell et al., 2014). In fact, a survey conducted by the Marine Stewardship Council (MSC) found that 67% of U.S. seafood consumers consider sustainability certifications when making purchasing decisions.

Culinary trends and cultural cuisine also play a pivotal role in shaping consumer preferences in the U.S. The popularity of diverse culinary traditions fosters exploration of new flavors, prompting a demand for a broader range of species beyond the traditionally consumed ones. For example, the growing popularity of sushi and other Asian cuisines has contributed to increased consumption of species like yellowtail and mackerel.

Furthermore, the availability and pricing of fish species exert considerable influence on consumer choices in the U.S. Seasonality, fishing quotas, and market forces affect the supply and cost of varied species, prompting consumers to adapt their preferences accordingly (Lynch et al., 2017). For instance, fluctuations in the availability of wild-caught salmon often lead consumers to opt for farmed alternatives during periods of scarcity.

Product innovation further amplifies these shifts by introducing U.S. consumers to new species or alternative forms of familiar species. The development of new processing techniques, convenience products, and value-added seafood items diversifies the range of species consumed and creates new market opportunities. For example, the increasing popularity of pre-marinated and ready-to-cook seafood products has contributed to the rising consumption of species like tilapia and pangasius.

This proactive approach enables the aquaculture sector to remain responsive to evolving consumer preferences while promoting environmental stewardship and economic resilience.

U.S. Government's Role in Advancing Domestic Aquaculture

NOAA, Sea Grant, and the U.S. Department of Agriculture (USDA) have had crucial roles in advancing aquaculture in the U.S. through various initiatives and programs. These organizations are pivotal in fostering the development of a sustainable and competitive aquaculture industry, which is essential for the nation's food security and economic growth.

NOAA and Sea Grant

Breeding, rearing, and harvesting animals and plants in various water environments is one of the most resource-efficient ways to produce protein. NOAA Fisheries supports innovative science and research, as well as federal policymaking and regulation, to grow sustainable aquaculture in the U.S. NOAA also supports science, policies, and regulations that allow communities to reap the social, economic, and environmental benefits of aquaculture, fostering responsible aquaculture that provides safe, sustainable seafood and creates employment and business opportunities in coastal communities.

NOAA and Sea Grant focus on enhancing sustainable aquaculture practices through comprehensive research and development efforts. Their initiatives aim to improve the efficiency and sustainability of aquaculture operations, ensuring that environmental impacts are minimized while productivity is maximized. Education and outreach are central to their missions, engaging in numerous activities designed to spread awareness about sustainable aquaculture practices and improve the skills and knowledge of individuals involved in the industry, from fish farmers to policymakers.

Additionally, NOAA and Sea Grant provide critical support for policy and regulation by offering scientific data and policy recommendations, they help shape regulatory frameworks that promote sustainable aquaculture practices while protecting natural resources. Their contributions ensure that regulations are based on science, fostering a balanced approach to industry growth and environmental stewardship.

USDA Aquaculture

The USDA, through its Research, Education, and Economics (REE) mission area, is responsible for creating a safe, sustainable, and competitive food and fiber system. This mission area integrates research, analysis, and education to support the aquaculture industry.

The National Institute of Food and Agriculture (NIFA) addresses national needs for aquaculture research, education, extension, and technology transfer. Established in 1985, the Regional Aquaculture Center (RAC) program is a cornerstone of NIFA's efforts, supporting aquaculture production across the U.S. NIFA also funds aquaculture extension educators through Cooperative Extension at Land Grant Universities, ensuring that cutting-edge research and best practices reach local communities. NIFA's research investments cover a diverse range of freshwater and marine aquaculture areas and species, contributing significantly to industry advancement.

The Economic Research Service (ERS) plays a critical role in providing monthly data on the domestic aquaculture industry and U.S. trade in aquaculture products. By anticipating trends and emerging issues, ERS conducts high-quality, objective economic research that informs and enhances public and private decision-making, helping stakeholders stay informed about the economic landscape of the U.S. and global aquaculture industry.

The National Agricultural Statistics Service (NASS) contributes by conducting both the Census of Agriculture and the Census of Aquaculture every five years. These censuses provide comprehensive pictures of the aquaculture sector at state and national levels. Annually, NASS publishes three aquaculture reports: the February Catfish Production Report, the July Catfish Processing Report, and the February Trout Production Report. These reports offer valuable insights into production trends and industry health.

The Agricultural Research Service (ARS) conducts intramural research and delivers technologies to improve domestic aquaculture production efficiency, animal health, nutrition, genetic improvement, and product quality. ARS research also focuses on minimizing the environmental impacts of aquaculture. Current projects under National Program 106 Aquaculture include studies on shellfish and a variety of freshwater and marine finfish farmed in diverse production systems.

The National Aquaculture Act of 1980 and the National Aquaculture Improvement Act of 1985 recognized that aquaculture has the potential to reduce the trade deficit in seafood products and meet national food needs. Therefore, these acts encouraged the development of aquaculture in the U.S.

To support the National Aquaculture Improvement Act of 1985, the Subcommittee on Aquaculture (SCA) was formed. This group serves as the federal interagency coordinating body to increase the overall effectiveness and productivity of federal aquaculture research, regulation, technology transfer, and assistance programs. The group has been functioning since before the National Aquaculture Act was signed into law in 1980. The SCA is a statutory subcommittee that operates under the Committee

on Environment of the National Science and Technology Council (NSTC) within the Office of Science and Technology Policy in the Executive Office of the President.

Collectively, the efforts of NOAA, Sea Grant, and the USDA support the development of a robust aquaculture industry in the U.S. Their integrated approach ensures sustainable production and economic growth, contributing to the nation's food security and the vitality of rural communities. These organizations play a pivotal role in advancing the science, education, and policy frameworks necessary for a thriving aquaculture sector.



Section 2: Status of U.S. and Georgia Fisheries

This section focuses on commercial fishery landings in the U.S., providing insights into the domestic production of fish and seafood. The status of both wild-caught and aquaculture production is examined, with a detailed focus on the aquaculture sector in Georgia.

Status of Wild Fisheries

On average, the U.S. harvests approximately 9.4 billion pounds of commercial fish and seafood annually, both edible and industrial varieties, valued at \$6 billion (NOAA 2024a). This makes the U.S. the 6th largest producer of wild fisheries (FAO 2024). More than half of the country's commercial wild fisheries come from Alaska, with Alaska (walleye) pollock being the country's largest in volume. The five most valuable commercial wild fisheries are crabs, lobsters, scallops, salmon, and shrimp (NOAA 2024a).

Georgia's commercial wild fisheries contribute less than 1% of U.S. commercial wild fisheries. In Georgia, shrimp and blue crab are the primary commercial wild fisheries in terms of weight and value.

Commercial fishery landings have decreased over the past decade (Figure 1). As a result, over 70% of the fish and seafood consumed in the U.S. are now imported to meet the increasing demand (Abaidoo et al., 2023).

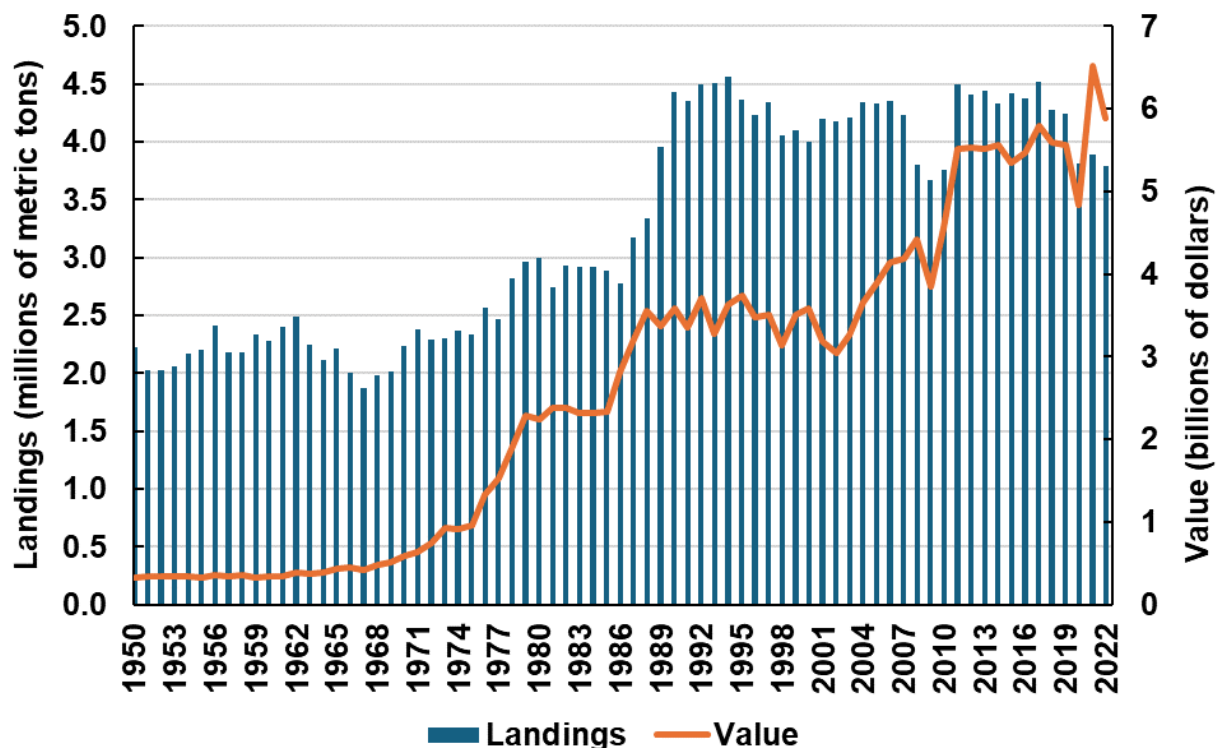


Figure 1 U.S. Commercial landings and value (Source: NOAA)

Numerous factors, mostly human-induced, contribute to this decline of wild fisheries. Unsustainable fishing practices, habitat degradation, and changing ecosystems affect the availability of wild fisheries. Pollution, habitat destruction, and climate change damage critical ecosystems like natural reefs and coastal wetlands, reducing fishery productivity. Climate change also alters marine ecosystems, affecting species distribution and abundance, and challenging reproduction and survival. Additionally, regulations, operational costs, inadequate commercial fishing infrastructure, an aging fleet, and a shrinking workforce are common reasons for the decrease in commercial fisheries landings.

Implementing protection and regulations to conserve wild fisheries is essential but can sometimes reduce the availability of certain species for commercial harvest. Here is why: setting sustainable fishing limits and quotas prevents overexploitation but may lead to lower catch levels than when the fishery was unmanaged. Additionally, measures like fishing restrictions, habitat restoration, fish stocking, and other conservation efforts to rebuild depleted populations often require limiting fishing activities. This allows fish populations to recover to sustainable levels, resulting in temporary reductions in the availability of certain species, impacting commercial

landings. Time restrictions for fishing seasons and catch limits vary by species because of specific life histories, reproductive strategies, and growth rates.

Balancing commercial fishery growth while maintaining healthy fisheries is crucial but complex. Expanding and promoting sustainable aquaculture can help address the supply-demand gap. Responsible aquaculture that prioritizes environmental stewardship, minimizes resource use, and ensures high-quality products can meet consumer demand while reducing pressure on wild populations. Collaboration between the aquaculture industry, fisheries management authorities, and conservation organizations is necessary to protect wild fish populations, support sustainable aquaculture, and ensure a steady supply of fish and seafood products for the market.

Status of U.S. Aquaculture Production

More than half of the fish and seafood imported into the U.S. comes from aquaculture (NOAA 2024b). Even so, aquaculture makes up only about 1.75% of the value and less than 10% of the weight of total U.S. fish production, and its growth has been relatively slow (Malone and Melstrom, 2021). Globally the U.S. is ranked 18 for aquaculture production (NOAA 2024b). The country produces about 567 million pounds (\$694 million) of freshwater aquaculture species like catfish and tilapia and 90 million pounds (\$430 million) of marine aquaculture species like oysters and clams (NOAA 2024b). Catfish, oysters, salmonids, and clams are the four most common aquaculture species in the U.S. (USDA-NASS 2019).

The Atlantic states hold the largest share of the total value of marine aquaculture (NOAA 2024b). Notably, oyster aquaculture is growing in the southern U.S. due to favorable environmental conditions, increased demand for their unique taste, their environmental benefits and the economic opportunities they provide for coastal communities.

There is increasing interest in shrimp farming in the U.S., driven by high demand for shrimp as a popular seafood item, but feasibility studies in different states are identifying several roadblocks. Successful shrimp farming requires suitable environmental conditions, access to clean water sources, and appropriate land for pond construction. Challenges include disease management, water quality management, feed availability, and competition from imported shrimp. Disease outbreaks, such as those from Early Mortality Syndrome (EMS), have historically posed significant challenges. The availability and cost of shrimp feed are critical

factors, making the development of sustainable, affordable alternatives essential for reducing environmental impacts and improving profitability.

Status of Georgia Aquaculture

Georgia's aquaculture sector is relatively small, with limited production compared to the larger volumes and economic impact of neighboring states like South Carolina (see sales data in Table 1). As of 2022, Georgia has about 79 aquaculture farms producing mostly catfish, trout, sports fish, other food fish, baitfish, crustaceans, mollusks, and ornamental fish (USDA-NASS 2022).

Stat	2017		2022	
	No. of Farms	Sales/Value (\$1,000)	No. of Farms	Sales/Value (\$1,000)
GA	108	7,437	79	4,019
SC	74	4,437	76	33,308
FL	636	72,178	766	191,098

*Table 1. Aquaculture sales in Georgia (GA), South Carolina (SC), and Florida (FL)
(Source: USDA-NASS, some data withheld for privacy)*

Georgia's aquaculture sector is about 98% freshwater, but it also includes diverse operations such as aquaponics and marine aquaculture.

- *Freshwater Aquaculture:* Georgia is renowned for its thriving freshwater aquaculture sector. Catfish, trout, bass, and tilapia are among the popular freshwater species farmed in the state. Georgia's abundant water resources, such as ponds, reservoirs, and rivers, provide an ideal environment for freshwater aquaculture operations.
- *Marine Aquaculture or Mariculture:* Along Georgia's coastal regions, marine aquaculture activities are prevalent. Oyster and clam farming is particularly prominent, with one oyster hatchery and several bivalve aquaculture farms

operating in the area. The potential for farming other marine species, such as shrimp and finfish, is also being investigated.

- *Aquaponics:* Aquaponics, a sustainable and integrated system that combines aquaculture and hydroponics, is gaining attention in Georgia. Aquaponics involves cultivating fish alongside plants in a symbiotic environment, where the waste produced by the fish provides nutrients for the plants. This closed-loop system allows for efficient resource utilization and year-round production.

There are several aquaculture research and development initiatives happening across the state. Universities, research institutions, and government agencies collaborate to improve aquaculture techniques, develop disease prevention strategies, enhance feed efficiency, and explore new species for cultivation.

Sustainable aquaculture practices are key to long-term growth and stability of aquaculture in Georgia. This includes minimizing environmental impacts, optimizing water and energy use, practicing responsible feed management, and prioritizing animal welfare. Sustainable practices help ensure the long-term viability of the industry and protect Georgia's natural resources. Sustainable aquaculture practices can offer several advantages over traditional terrestrial forms of meat production, such as livestock farming. Here are some reasons why aquaculture can be considered a better alternative:

1. *Reduced environmental impact:* Aquaculture can be designed to minimize habitat destruction, water pollution, and other negative environmental impacts associated with traditional livestock farming practices. Sustainable aquaculture systems aim to optimize resource use, reduce waste production, and limit the use of antibiotics and chemicals.
2. *Efficient resource utilization:* Aquaculture can be highly efficient in terms of resource utilization, such as land, water, and feed. Compared to terrestrial livestock production, aquaculture can require fewer resources and inputs to produce a similar amount of protein, making it more resource efficient.
3. *Potential for local production:* Aquaculture offers the opportunity for localized production, which can reduce the carbon footprint associated with the long-distance transportation of seafood. By establishing aquaculture operations closer to consumer markets, it is possible to reduce the energy consumption and environmental impact of food distribution.
4. *Control over production and quality:* Aquaculture provides the ability to control various aspects of production, including water quality, feed composition, and disease prevention. This control allows for consistent product quality,

traceability, and reduced reliance on wild fisheries. It is important to note that not all aquaculture practices are sustainable. The industry must adhere to responsible farming practices, environmental regulations, and continuous improvement to mitigate potential negative impacts and ensure the long-term viability of the sector.

In summary, Georgia can expand its aquaculture sector by taking advantage of its favorable geographic location, diverse water resources, aquaculture expertise, commitment to sustainability, and supportive regulatory framework. This expansion would significantly benefit the state's economy by creating jobs, supporting local businesses, and generating revenue through the sale of aquaculture products. By promoting sustainable practices, technological innovation, and collaboration among stakeholders, Georgia's aquaculture sector can meet the demand for high-quality seafood, bolster local economies, and contribute to the sustainable growth of aquaculture in the U.S.



Section 3: Aquaculture Systems and Environmental Considerations

This section dives into the diverse systems used in aquaculture, from traditional ponds and raceways to modern recirculating systems, aquaponics, and mariculture operations. It explains how species' biology, farmer goals, and available resources determine which systems are employed, often in sequence from hatchery to grow-out. Beyond production methods, the section also addresses critical environmental and operational factors, including water resources, land and climate influences, permitting and regulations, waste management, and wildlife protection, all of which shape the sustainability and growth potential of aquaculture in Georgia.

Types of Aquaculture Systems

Aquatic organisms are farmed in a variety of "systems" depending on each species' unique environmental and physiological requirements, and the location, resources, and objectives of the farmer (Table 2). In many cases, an aquaculture product will go through several systems throughout the production cycle. Most production cycles start at a hatchery, where broodstock is maintained to produce eggs and larvae, which ultimately become a product. Hatcheries require intensive water quality, feeding, and genetic management to produce the desired traits for farmers and consumers. From

the hatcheries, most farms use nursery and grow-out systems catered to the physiology of the species being produced.

Ponds

Open freshwater ponds are the oldest and most commonly used form of aquaculture. They utilize natural bodies of water, such as lakes, reservoirs, or constructed ponds, to cultivate fish or other aquatic species. These systems require access to abundant fresh or saltwater resources. In Georgia, pond-based aquaculture is the most practiced form of aquaculture. The state has numerous freshwater ponds that produce various fish species, such as catfish, bass, and tilapia. These ponds are typically constructed on land in many sizes and depths. They are filled with fresh water from natural sources or supplied through irrigation. Pond-based aquaculture offers several advantages, including the ability to control environmental factors, manage feeding and growth rates, and optimize production efficiency. A variation on pond systems includes tank aquaculture where large tanks can be used instead of constructing an in-ground pond.

Raceways

Raceways are designed to mimic rivers where water flows through a system. Cool water raceways are used for species such as trout and salmon that are adapted to cold flowing water. Warm water raceways have been used for other species such as sportfish, and shrimp, and are commonly employed at hatcheries. These systems use existing flowing streams or groundwater to create the optimal environment for the fish. The water is channeled through raceways or channels that provide a controlled environment for the cultured species. These systems can be completely enclosed. Enclosed systems require cooling, pumps, and filtration. Most cool water raceways are in the Appalachian foothills where cooler water streams are common.

Mariculture

Mariculture refers to aquaculture activities conducted in marine or saltwater environments, such as bays, estuaries, or offshore areas. It requires access to suitable coastal or offshore water bodies with appropriate water quality and salinity levels for the cultured species. Georgia's coastlines are ideally suited for shellfish farming. Our vast marshes and low coastal development compared to other states create ideal water quality for mariculture operations. Georgia's Atlantic coast is also not experiencing as much ocean acidification as other regions such as the northeast and Pacific coast states. There are over 500,000 acres of pre-approved federal waters that could be used for mariculture in Georgia. There are some limited mariculture operations within

Georgia state waters, for oysters and clams. These mariculture operations benefit from Georgia's nutrient-rich waters and favorable salinities and substrate for shellfish.

Cage or Net Pen

Cage aquaculture involves confining aquatic organisms within floating cages or net pens in natural or artificial water bodies. Cages or pens used in both fresh and saltwater environments to hold fish or other products and feed must be brought in to grow the organisms. This form of aquaculture requires access to suitable water bodies with adequate water quality, oxygen levels, and flow rates for the species being produced.

Recirculating Aquaculture Systems (RAS)

Recirculating aquaculture systems aim to minimize water usage and promote water reuse. These systems use recirculating aquaculture technology, where water is treated and reused, reducing the need for large water volumes. They can be built as closed aquaculture systems that would not interact with the natural environment. RAS systems are often used for species that have invasive potential or in areas where water availability is limited.

Aquaponics

An aquaponic system is a form of RAS that incorporates plant production with the production of other aquatic species. Aquaponics exist in several Georgia counties at small scales. Many are located at educational institutions where they are used for research and teaching. These systems are self-contained, have minimal discharge, and use 90% less water than traditional aquaculture. The systems do not need fertilizer, as the fish provide the plants with nutrients via excrement. Aquaponics allows for the expansion of aquaculture in regions with water usage restrictions and is well suited for more urban environments. Shortening the distance from producer to urban consumers, has the potential to lower food costs and provide fresh seafood and produce to urban areas, reducing transportation costs, and carbon footprint, and increasing freshness.

Type of Aquaculture System	Benefits	Type of Environment Needed	Agricultural output	Cons
Ponds	Controlled environment Easiest method	Pond with available water resources, ground, or surface waters	All inland non-river fish Catfish and mullet are common	Local water supply has to fit the fish's needs for pH, mineral composition, etc.
Raceways	No filtration needed Constant water flow	Cool rivers/streams run or an indoor high-power facility	River fish, Salmon, trout, etc.	Requires constant input or pumping for RAS systems
Mariculture	Large market High-Profit Margins Cleans water	Clean ocean water With the correct temperature, food, and pH	Oysters, clams, mussels, finfish, shrimp, crab	Multi-agency federal approval required High opportunity cost
Cage or net pen	The larger body of water can take less management	Suitable water body for the type of fish being farmed	Finfish, marine and inland fish	Requires permitting as it impedes boat traffic
Aquaponics	Highly efficient	Indoor facilities, filters, and careful monitoring	All types of inland fish, typically tilapia	The initial setup is complicated and expensive

Table 2: Characteristics of different types of aquaculture systems.

Water Resources

Managing water resources appropriately is important for any aquaculture system. It is important to consider water sources and water quality parameters to ensure sustainable production of aquatic species while minimizing impacts on the environment and other water users.

Water Quality

Water quality is crucial for the success of aquaculture operations. Maintaining optimal water conditions is essential for the health and growth of the cultured species. Factors such as temperature, dissolved oxygen levels, pH, ammonia, and nitrate levels are monitored to maintain a healthy environment for aquatic organisms. Table 3 provides recommended ranges for some key water quality parameters in freshwater fish aquaculture. Most of Georgia's fresh and saltwater resources fall within recommended ranges for parameters like temperature, dissolved oxygen, and pH. Regular water testing and appropriate management practices are employed to maintain a suitable environment in most aquaculture production systems.

Component	Lower Level (mg/L)	Upper Level (mg/L)	Georgia Average Level
Total Alkalinity	40	180	NA
Calcium	15	52	NA
Carbon Dioxide	0.1	5.0	NA
Chlorine	3.0	170	NA
Dissolved ds	7.0	170	126
Iron	0	0.7	0.01-2.2
Magnesium	3.5	14	NA
Nitrate	0.2	4.0	NA
Nitrite	0	1.0	NA
pH	6.7	8.3	NA
Sodium	6.0	85	NA
Sulfate	11	90	NA
Specific Conductance $\mu\text{S}/\text{cm}$	50	1100	NA

Table 3: Desired water quality parameters for aquaculture production.

Water Availability

While aquaculture uses a lot of water, compared to irrigated agriculture, it is efficient compared to most other food production systems. The water used in aquaculture production systems can come from either surface water systems such as rivers, streams, lakes, and ponds or from groundwater systems which require wells and pumping.

Most Georgia groundwater comes from the following aquifers: Principal Artesian (Floridan) Aquifer, Clayton Aquifer, Claiborne Aquifer, Cretaceous-Tertiary Aquifer, Shallow Sand (Coastal) Aquifer, and Paleozoic (Northwest) Aquifers (Figure 2). These aquifers provide essential freshwater resources for agriculture, industry, and public water supply.

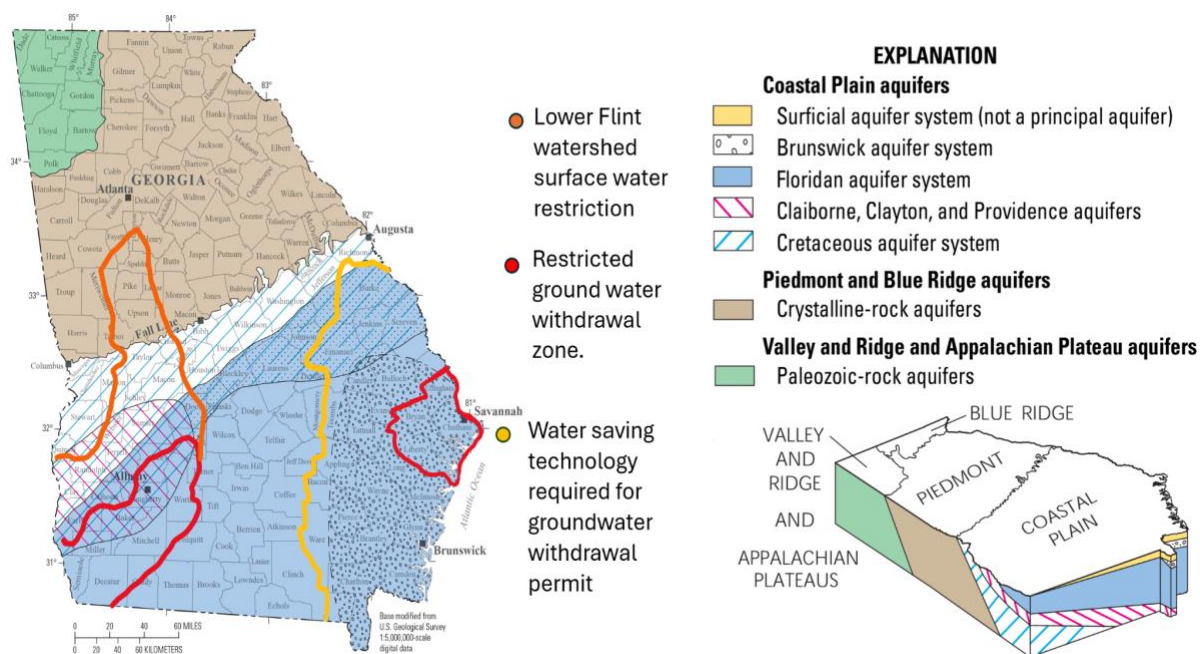


Figure 2: Georgia's primary aquifers.

Compared to other states, Georgia has abundant water resources. Surface water flows are constrained in some areas of the state; however, most rivers and streams have sufficient flow to support additional water use. The Floridan aquifer that underlies much of the state is one of the most productive aquifers in the U.S. The Georgia Department of Natural Resources,

Environmental Protection Division (EPD) requires water withdrawal permits for anyone using more than 100,000 gallons of water per day regardless of whether the water is withdrawn from surface or groundwater sources. These permits are relatively easy to get unless you are in certain parts of the state with water use restrictions identified in Figure 3. Since 2012, a moratorium has been placed on new groundwater withdrawal permits in southwest GA in the lower Flint River watershed due to drought conditions and high-water use for irrigation. Existing permit holders can still withdraw based on their permits, and deeper wells into lower aquifers are showing promising results for alternative water sources. In areas of drought, aquaponics presents an aquaculture opportunity by continuing to utilize the existing water, while also growing crops, and using less feed, water, and fertilizer per pound of output.

Land Topography

The topography of Georgia plays a significant role in determining the land available for aquaculture. Topography refers to the physical features and elevation of the land. The state exhibits diverse topographic characteristics, including coastal areas, plains, valleys, and mountainous regions. These different landforms offer both opportunities and challenges for aquaculture development.

Soil

Soil composition is another crucial factor to consider for aquaculture in Georgia. Soil classification determines water-holding capacities, drainage capabilities, and nutrient content. Georgia is known for its diverse soil types, ranging from sandy coastal soils to clayey soils in

the Piedmont region. The potential and management

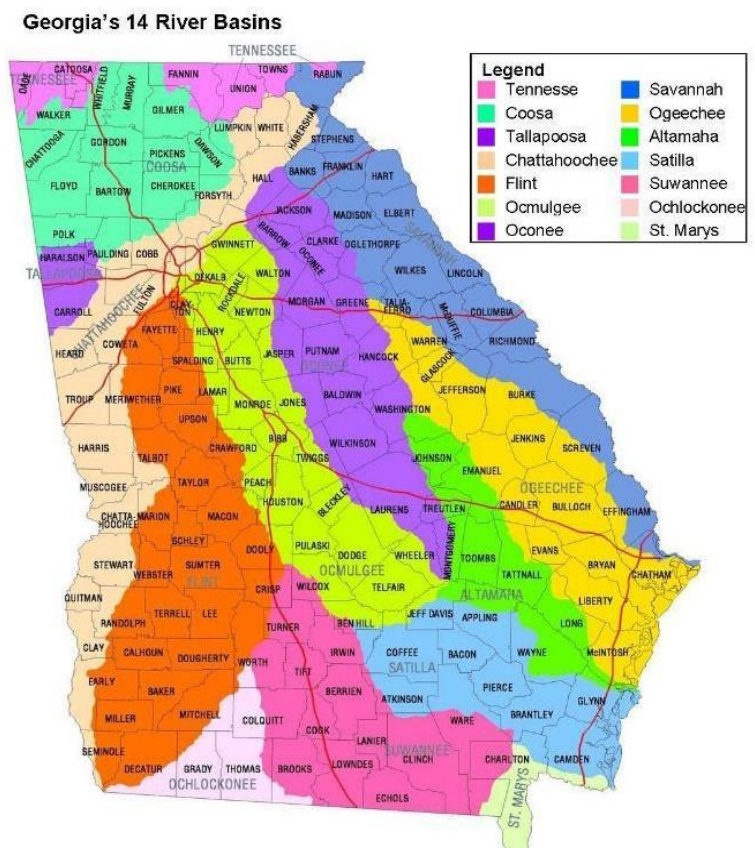


Figure 3: Georgia's primary river basins.

approaches for specific soils can impact the success of aquaculture operations using pond or outdoor systems.

Climate

Temperature

Temperature is an important climatic factor that influences aquaculture production and species selection. Georgia experiences a humid subtropical climate with mild winters and hot summers. The average temperature and the number of frost-free days are important considerations for determining suitable aquaculture species and production systems. For the most part, Georgia's long growing season and lack of long, hard freezes provide outdoor systems with a competitive advantage over most states located further to the north.

Rainfall

Rainfall patterns are crucial for maintaining water availability in aquaculture systems. Georgia's climate is characterized by moderate to high rainfall, with variations across different regions. Adequate and well-distributed precipitation is essential for replenishing water sources and sustaining aquaculture operations.

These aspects of land and climate provide important insights into the physical and environmental conditions that influence aquaculture in Georgia. Understanding topography, soil characteristics, temperature, and rainfall patterns must be considered in site selection, species adoption, and overall management of aquaculture systems.

Ownership of the Resources

Water Rights

Water allocation for aquaculture can be a contentious issue, especially in regions with competing demands for water resources. Determining the rights to water access and use for aquaculture operations requires clear regulations and policies to avoid conflicts and ensure fair distribution.

Riparian Rights

Georgia follows a riparian system, where landowners adjacent to a water source have certain rights to use the water. However, this system may not adequately address the needs of aquaculture operations that are located away from water bodies or involve multiple stakeholders accessing the same water source.

Permits for Water Use

Aquaculture farmers must obtain water use permits from regulatory agencies to withdraw and use water for their operations. The permitting process involves demonstrating the sustainable use of water resources, adherence to water quality standards, and mitigation of potential environmental impacts.

Waste Disposal

Waste disposal is an important aspect of aquaculture operations to ensure environmental sustainability. Aquaculture systems generate waste in the form of uneaten feed, feces, and other byproducts. Effective waste management practices are necessary to minimize environmental impacts and maintain water quality.

In Georgia, aquaculture producers employ various waste disposal methods, depending on the specific system and species being cultured. Some common waste disposal practices are identified below.

Sedimentation Ponds

Sedimentation ponds are designed to capture solid waste particles and allow them to settle at the bottom. This helps in reducing the number of suspended solids and organic matter in the water before it is discharged.

Biological Filtration Systems

Biological filtration systems, such as biofilters or constructed wetlands, use natural processes to break down organic waste materials. Beneficial bacteria and plants help in converting harmful substances into less toxic forms, improving water quality.

Nutrient Recycling

Some aquaculture systems incorporate nutrient recycling techniques, where the waste from one component (e.g., fish tanks) is utilized as a nutrient source for another (e.g., hydroponic vegetable production). This helps in minimizing waste discharge and maximizing resource utilization.

Aquaculture operations in Georgia must adhere to state and federal regulations regarding waste disposal. These regulations specify discharge limits, effluent quality standards, and best management practices to ensure the protection of water resources and surrounding ecosystems.

Other Innovative Technologies

Recently, there has been a focus on implementing innovative waste disposal technologies in aquaculture. These include biofiltration, recirculating aquaculture systems (RAS), and integrated multi-trophic aquaculture (IMTA), which aim to optimize waste management, enhance water quality, and improve the overall sustainability of aquaculture operations.

Some aquaculture systems implement opportunities for nutrient utilization, where waste products, such as fish feces, are used as fertilizers in agriculture or as feed for other organisms, such as insects or algae. By effectively utilizing waste nutrients, aquaculture producers can minimize waste disposal and create value-added products.

Permitting and Licensing

Aquaculture operations must comply with environmental regulations to protect water quality and minimize negative impacts on ecosystems. These regulations govern waste management, effluent discharge, the use of chemicals, and the prevention of disease outbreaks. Ensuring compliance with these regulations can be challenging and may involve additional costs for aquaculture farmers.

Obtaining permits and licenses for aquaculture operations can be complex and time-consuming. It often requires coordination with multiple regulatory agencies at the local, state, and federal levels, each with its requirements and procedures.

Zoning and Land Use Planning

Zoning regulations and land use planning determine where aquaculture operations can be established based on their compatibility with existing land use. These regulations aim to prevent conflicts with other land uses, protect sensitive ecosystems, and maintain the aesthetic and recreational value of certain areas. These regulations can vary across different jurisdictions and may not always consider the unique needs of aquaculture businesses. Streamlining zoning and land use regulations to include provisions for aquaculture can facilitate industry growth and development.

Balancing the interests of different stakeholders, such as landowners, environmental groups, and local communities, is crucial in developing zoning regulations that support responsible and sustainable aquaculture practices. Public input and stakeholder engagement can help identify suitable locations for aquaculture operations and address concerns.

Wildlife and Habitat Protection

Aquaculture operations must consider potential impacts on endangered or protected species and their habitats. Regulatory agencies may require environmental assessments and the implementation of measures to mitigate any adverse effects on wildlife and habitats.

Aquaculture farmers are encouraged to adopt best management practices that minimize the ecological footprint of their operations and ensure the preservation of biodiversity. These practices include responsible feed and nutrient management, prevention of organism escapes and introductions of non-native species, and habitat restoration efforts.

Universal Requirements, Restrictions, and Rules

Georgia's abundant natural resources all fall under environmental rules and regulations from Georgia's Department of Natural Resources (GA DNR). Georgia lacks a central authority on fish Aquaculture permits for both sport and consumption. Permits for aquaculture capture, harvest, transport, sales, and processing come from a patchwork of different departments such as the GA DNR Georgia Wildlife Resources Division, GA DNR Coastal Resources Division, GA DNR Environmental Protection Division, and GA Department of Agriculture. The patchwork of agencies administering

permits creates a confusing permitting space for current and potential farmers attempting to produce a sustainable seafood supply chain. All of these departments are state level agencies and there are still federal regulations with Agencies such as the U.S. Army Corp of Engineers, which regulates navigable waters, that every farmer must follow. No truly universal system exists for aquaculture farmers or enforcement.

Exotic Fish Aquaculture Rules

GA DNR does not allow exotic animals to be grown without a closed system or special permitting process. This restriction prohibits pond aquaculture from growing species not identified in Georgia in 1992.

The aquaculture techniques described below are for all open-system aquaculture. These systems rely on a constant supply of fresh or salt water from rivers, aquifers, ponds, or lakes. Organisms not contained in an isolated system of a pond or lake could result in populations developing in other parts of the state downstream of their outflows. However, pond aquaculture rarely sees this kind of movement as the ponds are isolated, and excess water or water changes are not released directly into lakes or streams. While it is permitted to grow fish in completely isolated systems, proving that a system will stay completely isolated to GADNR is challenging and usually results in permits not being given for the aquaculture of exotic species. Table 4 lists the species considered native to Georgia that are allowed to be grown in open systems without additional permits. Any other fish not native to Georgia as of 1992 needs a wild animal license to farm and sell. If it can be procured, this license must be renewed annually, making investment risky, with annual reviews that can financially ruin an aquaculture farm.

Freshwater Aquaculture Type	Fish species currently legal to farm in GA
Aquaponics, Pond Aquaculture, Cage Aquaculture	1. Channel catfish 2. Largemouth bass 3. Crappie 4. Bluegill 5. Redear sunfish 6. Hybrid sunfish 7. Hybrid bass 8. Golden shiner 9. Fathead minnow 10. Goldfish 11. Koi 12. Common carp 13. Freshwater drum 14. Smallmouth buffalo 15. Red drum 16. Gizzard shad 17. Threadfin shad 18. Yellow perch 19. Mosquitofish
Cool water Raceway	20. Rainbow, brown, and brook trout

Table 4: Georgia DNR list of approved species for aquaculture production (as of 2026).

Conserving the Environment: Waste Product and Recycling

Aquaculture, as with any other form of agriculture, creates waste. Minimizing waste is crucial to garnering community support. Non-edible fish waste is already reused for other value-added products from seafood processors that receive mostly imported fish. Only farmers that do their processing would have to worry about this issue.

Permitting Process

Georgia's aquaculture permitting process is complicated and involves multiple state agencies. Some permits contain arbitrary restrictions, harvesting fish for the game

requires a permit, and only gives the farmer or proprietor 15 days to complete the harvest after approval. The harvester also needs to have a separate permit just to grow the aquaculture game. Streamlining the permit process would drastically reduce the administrative burden on farmers and make it easier for new farmers to establish operations. Permitting and regulations of aquaculture should be based on public and ecological health research and recommendations by professionals in the field. Exotic fishes that cannot survive in the wild in Georgia provide great aquaculture expansion potential.



Section 4: Aquaculture Financing and Risk Mitigation

Aquaculture development depends not only on biology and markets but also on access to financing, effective risk management, and coordinated policy support. This section reviews current financing trends, lessons from other states, and opportunities to strengthen Georgia’s financial ecosystem to support aquaculture growth.

Changing Financing Environment

Historically, financing options for aquaculture in Georgia and other states were limited, often relying on traditional sources such as personal savings, bank loans, or government grants. However, there has been a noticeable shift in the financing environment, driven by diversification of funding sources, increased interest in sustainable finance, and expanding public-private partnerships that align economic and environmental goals.

Diversification of Sources

The range of financing mechanisms available to aquaculture ventures has expanded. Beyond traditional lending, entrepreneurs now have access to venture capital, private equity, crowdfunding, and impact investment funds focused on sustainability.

Crowdfunding uses online platforms that allow individuals and organizations to raise funds from a large pool of contributors interested in sustainable aquaculture

initiatives. This approach provides access to capital and builds a community of stakeholders invested in project success.

Impact investing targets projects that generate both financial returns and positive social and environmental outcomes, aligning well with the sustainable and socially responsible nature of aquaculture.

Sustainable Finance and Insurance Tools

Investors and financial institutions increasingly prioritize aquaculture projects that demonstrate environmental responsibility, social impact, and long-term viability. This trend aligns with growing consumer demand for sustainable seafood products.

Aquaculture insurance products have also improved, mitigating risks from disease outbreaks, natural disasters, or market fluctuations. Insurance coverage provides financial security to investors and lenders, making aquaculture projects more attractive for financing.

The U.S. Department of Agriculture's Risk Management Agency (RMA) offers subsidized insurance through private providers, including the Shellfish Crop Insurance Program, the Aquaculture Dollar Plan for Clams, and Whole-Farm Revenue Protection. These products are not yet available in Georgia, though neighboring states such as South Carolina and Florida participate (USDA, 2024). Expanding eligibility to include Georgia producers could reduce financial risk and increase investor confidence.

Public-Private Partnerships and Government Incentives

Collaborations between the public and private sectors are emerging to promote aquaculture financing. These partnerships leverage the strengths and resources of both sectors to provide financial support, technical expertise, and infrastructure development for aquaculture projects.

Governments at the state and federal levels may offer incentives to promote aquaculture, including tax credits, grants, loan guarantees, and regulatory support to attract private investment and stimulate industry growth.

Funding Challenges

Despite these opportunities, aquaculture in Georgia faces significant funding challenges. The absence of dedicated financing mechanisms, high start-up costs, and

limited investor familiarity with aquaculture create barriers for new and expanding operations.

Start-Up Costs

Aquaculture enterprises often require substantial capital for land preparation, pond or tank systems, filtration and feeding technology, and stock purchases. These high upfront costs make entry difficult, particularly for small or minority-owned businesses (Georgia Department of Agriculture [GDA], 2024).

Working Capital

Beyond initial investments, operations need consistent cash flow for feed, maintenance, and labor. The cyclical nature of aquaculture harvests can lead to uneven income streams, making it difficult to service loans under traditional agricultural lending models.

Infrastructure and Technology Upgrades

Georgia's producers report challenges accessing capital for technology improvements, such as automated feeding systems or water quality monitoring tools, which could improve efficiency and biosecurity.

Access to Loans and Grants

While programs like the USDA Farm Service Agency's (FSA) Noninsured Crop Disaster Assistance Program (NAP) and the Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish (ELAP) offer limited coverage, they remain underutilized in Georgia due to lack of awareness and administrative complexity (USDA, 2024).

Addressing these funding challenges requires tailored financial tools, improved outreach, and stronger alignment among agencies that support agricultural and aquacultural enterprises.

How Other States Support Aquaculture Financing

States across the U.S. have different approaches to financing aquaculture projects, including special funding programs, research grants, loans, or tax incentives specific to the aquaculture sector. The differences in approaches are motivated by regional priorities, available resources, and industry development.

- South Carolina: Through the South Carolina Agribusiness Loan Fund (SC ALF), administered by Catawba Regional, producers—including aquaculture farmers—can access up to \$400,000 in low-interest financing for expansion and equipment (South Carolina Department of Agriculture, 2023).
- Louisiana: The Louisiana Department of Agriculture and Forestry (LDAF) offers a revolving loan fund and small business assistance program that supports aquaculture through the Louisiana Agricultural Finance Authority. The state also launched a grant program to support oyster growers, farms, hatcheries, and nurseries (Petrolia, 2023).
- Alabama: The Coastal Alabama Fisheries Fund (CAFF) is a pilot loan program providing financing to oyster farmers and harvesters in coastal Alabama. Loans can be used to purchase shell, seed, spat, or equipment. Both bottom culture and water column projects are eligible.
- Alaska, Maryland, and North Carolina have created loan programs to help growers finance shellfish seed purchases and equipment (Hill & Collins, 2024).

Many states also invest in research and development initiatives, supporting innovation, technology adoption, and sustainable practices that drive industry growth and attract private investment. Grants may fund infrastructure such as hatcheries, processing facilities, and water treatment systems, reducing financial burdens and enabling producers to invest in critical infrastructure.

Other state programs provide financial assistance for training, education, and marketing initiatives, recognizing that long-term viability depends on a skilled workforce and market diversification. These targeted investments in infrastructure and innovation yield both economic and environmental benefits.

Collaboration with financial institutions is increasingly common. Banks and credit unions in aquaculture-focused states offer specialized loan products tailored to aquaculture operations. These partnerships, often facilitated by industry associations and state agencies, have improved access to capital and risk management tools.

Georgia can draw from these examples to evaluate how public and private financing mechanisms might support its aquaculture development goals. Partnerships among agencies, financial institutions, and industry groups could help foster innovation, expand markets, and strengthen economic resilience.

Securing Financing in the Early Stages of Business Development

In the initial stages of aquaculture development, securing financing can be challenging due to several factors, including the lack of established operations and limited financial history. However, there are options available to support aquaculture projects during this phase.

- *Start-Up Business Loans:* Some financial institutions offer loans specifically designed for new ventures, including aquaculture. These loans cover expenses such as equipment, infrastructure, and working capital and typically require a detailed business plan and financial projections.
- *Grants and Incentives:* Governments, nonprofits, and research institutions may offer grants to support early-stage development, feasibility studies, and technology adoption.
- *Angel Investors and Venture Capital:* Entrepreneurs may seek funding from angel investors or venture capital firms in exchange for equity or profit shares. These investors are often drawn to innovative aquaculture projects and can also provide expertise and guidance.

Factors Outside the Business

Accurate information on aquaculture gear, equipment, and infrastructure is essential for farmers and lenders to assess the financial needs of a project. Farmers should gather cost estimates from suppliers, manufacturers, or experienced aquaculturists, and leverage industry networks for insights into equipment pricing and operational requirements.

- *Financing Options:* Various financing avenues are available, including traditional business loans, equipment leasing, and supplier-provided in-house financing tailored to aquaculture. Farmers should compare terms, interest rates, and repayment schedules to select the most suitable option for their operation.
- *Depreciation and Resale Value:* Understanding the expected lifespan, depreciation, and potential resale value of equipment helps farmers plan for long-term costs, replacements, or business exit strategies.

By combining accurate cost estimates with appropriate financing strategies, farmers can develop sound business plans, secure funding, and strengthen the long-term sustainability of their aquaculture operations.

Insurance and Risk Mitigation

Improved aquaculture insurance products now help mitigate risks from disease, natural disasters, and market fluctuations. These tools provide financial security to investors and lenders and make aquaculture projects more attractive for financing.

The USDA Risk Management Agency offers four main insurance programs available in various states and counties, though not yet in Georgia (USDA, 2024). Neighboring states such as South Carolina and Florida participate.

- *Shellfish Crop Insurance Program*: Provides yield-based coverage for containerized oysters produced for the half-shell market, covering named storms, excessive heat or freeze during low tide, and low salinity from rainfall.
- *Group Risk Plan Oysters*: Covers widespread county-level oyster production losses, offering up to 90% of expected yield.
- *Aquaculture Dollar Plan Clams*: Provides inventory-based stock mortality insurance covering perils such as oxygen depletion, disease, freeze, hurricanes, salinity changes, and storm surge. Coverage is available from 50% to 75%.
- *Whole-Farm Revenue Protection*: Offers a safety net for all farm commodities under one policy, protecting against loss of revenue from aquaculture or other farm products due to natural causes. Coverage is available from 50% to 85% for farms with up to \$17 million in insured revenue.

Additional federally supported risk mitigation programs, such as the USDA Farm Service Agency's Noninsured Crop Disaster Assistance Program (NAP) and Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish (ELAP), offer limited coverage and remain underutilized in Georgia due to lack of awareness and administrative complexity (USDA, 2024).



Section 5: Supply Chain and Marketing

Seafood Demand

The demand for seafood plays a significant role in the processing and marketing of aquaculture products. Understanding seafood demand helps aquaculture businesses identify target markets, develop product offerings, and implement effective marketing strategies. Some key factors related to seafood demand are highlighted below.

Consumer Preferences

Consumer preferences for seafood can vary based on taste, texture, price, convenience, cultural popularity and health considerations. Aquaculture businesses need to assess and respond to these preferences to meet market demand effectively. There are additional factors that complicate the issue around consumer preference for aquaculture products, such as misinformation and unwillingness to try a species again after a distasteful experience. Two examples of these complications here in Georgia are tilapia and clams. Amongst many U.S. consumers, Georgia included, tilapia has garnered a negative reputation as a distasteful fish (Haspel, 2016; York, 2011). However, several other cultures perceive tilapia favorably, including, South American, East Asian, and African. With large immigrant populations residing

throughout Georgia, there is enough demand to counter the lack of support among other consumer groups. Clams are another example of how regional/cultural differences in food preferences can affect demand. Clams are a top aquaculture product grown in Georgia; however, the majority of harvests are exported out of state. Whereas clams have rarely been on the menu in the South, they have been a popular food item in New England for centuries (even millennia). However, with the increase in popularity of fresh seafood at raw bars and seafood restaurants, local/regional demand for clams should continue to grow in the state (Remar, D., 2015).

Wild Versus Farmed

When it comes to seafood, the results can vary on whether consumers prefer wild-caught seafood over farm-raised (aquaculture). Preference is largely contextual, but the limited research on the topic shows consumers have more negative perceptions towards aquaculture products and favor wild-caught (Gempesaw, 1995; Claret, et al. 2014). Consumers often find it difficult to visualize or contextualize what ‘farm-raised’ seafood looks like, especially if raised or grown inland. Consumers frequently associate the phrase farmed or farm-raised with traditional agriculture-practices. Implementing education into marketing may help alleviate some of this challenge.

Health Benefits

There is a rising need for healthy food in the U.S. and seafood is often associated with numerous health benefits due to its high protein content, omega-3 fatty acids, and other essential nutrients. Seafood and the omega-3 fatty acids they contain are of particular importance for child neural development (O’Connor et al, 2025). Three components that may help drive local seafood demand are food insecurity, food scarcity and an increase in consumer health consciousness. According to 2022 census data, over 13% of the population in Georgia is food insecure, with higher rates occurring in rural communities where there are often food deserts (Benez-Secanho, Miner and Dwivedi 2021). Through the right processing and distribution networks, there is a wonderful opportunity for aquaculture products to provide affordable and nutritional protein options for Georgians experiencing hunger, food insecurity, and limited access to fresh food. Sales to institutions such as schools and hospitals as well as non-profit food shelves could be essential market partners. The other significant driver pertaining to seafood’s health benefits is the growing consumer base focused on personal health consciousness (Rana & Paul, 2020). Furthermore, many consumers, when dining away from home, actively seek out (and return to) establishments that serve healthy foods and are often willing to pay more for them (DiPietro, Remar, & Parsa, 2016). Aquaculture products that promote their health

benefits can attract health-conscious consumers and cater to related market segments.

Culinary Trends

Culinary trends and preferences can influence seafood demand. For example, the popularity of sushi and other seafood-based dishes at restaurants has increased demand for specific species like salmon and tuna. It is recommended that farmers monitor culinary trends and build relationships with chefs. Chefs often understand what customers want and can create demand through their innovation. Farmers can choose to adapt their production accordingly. Additionally, chefs may choose to develop dishes around a high quality product, which may drive local demand.

Zoos and Aquariums

Another potentially lucrative, but often overlooked buyer for aquaculture products are zoos and aquariums. There are over 350 locations across the country, each one accommodating a wide variety of aquatic species. Each species with its own unique dietary needs. Zoos and aquariums need to source tens of thousands of pounds of fish, live or frozen, annually. However, the majority of this feed is sourced from commercial fisheries outside the U.S. and is often wild caught. The feed, in recent times, has become scarce, expensive, and environmentally unsustainable. In response, zoos and aquariums are actively seeking alternative feed sources that are both sustainable and cost-effective. Domestic aquaculture products could fill this gap. One of the greatest opportunities here in Georgia would be to connect the Georgia Aquarium, the country's largest indoor aquarium, with local growers who could satisfy their large volume demand and consistent needs.

Recreation and Sport

Another outlet that constantly needs fish, specifically live fish, are recreation and tourism operations that offer fishing activities. Throughout the state, there are several hunting-fishing lodges that offer stocked ponds, lakes, or rivers for their guests to fish, as well as public facilities such as the Go Fish Education Center in Perry, Ga. There is also a small market for live fish for home ponds and gardens.

Pet Food and Fertilizers

Another potential, albeit secondary market for aquaculture products are pet food and fertilizer manufacturers. The demand in this case though is mostly for aquaculture byproducts, such as fish bones, skin, or fileted carcasses. This established market for

seafood byproducts presents an opportunity for aquaculture growers to gain additional revenue by maximizing the utility of the whole species they produce.

Seafood Supply

The supply of both aquaculture and wild-caught seafood impacts the processing and marketing dynamics of seafood products. In Georgia, the seafood supply has yet to meet the demand, according to local processors and wholesalers. Below are key considerations related to seafood supply.

Wild Fisheries

The availability and sustainability of wild-caught seafood can impact the overall seafood supply. Overfishing, regulatory measures, environmental factors and seasonality may all affect the abundance and availability of certain species. Aquaculture can help supplement the seafood supply by providing a reliable source of fish and shellfish, stabilizing supply dynamics and increasing year-round seafood demand.

Aquaculture Production

The growth of aquaculture internationally has contributed to an increase in the overall seafood supply. Aquaculture allows for controlled and efficient production of various species, reducing reliance on wild-caught fisheries. As aquaculture practices continue to develop and expand, it has the potential to play a significant role in meeting seafood demand.

Import and Export

Seafood is often traded globally, with countries importing and exporting different species to meet domestic demand and access new markets globally. Aquaculture products can be both imported and exported, depending on the comparative advantages of different regions in terms of production capabilities, cost-efficiency, and market demands of specific species.

Balancing Act

Looking forward, it will be important to balance between wild-caught seafood and aquaculture-produced seafood in the overall seafood supply. As aquaculture continues to grow, the proportion of aquaculture products in the market has increased, reaching

a more balanced distribution with wild-caught seafood. In fact, just recently the U.N.'s FAO announced that for the first time ever, more aquatic animals were farmed than fished. This shift signifies the importance and potential of aquaculture in meeting seafood demand sustainably.

Aquaculture businesses in Georgia should consider both the demand and supply factors in the seafood industry to make informed decisions regarding processing and marketing strategies. By aligning their product offerings with consumer preferences, monitoring seafood supply dynamics, and staying abreast of market trends, aquaculture businesses can position themselves effectively, strategize supply chain partnerships and capitalize on the opportunities in the processing and marketing of domestic seafood products.

International Sourcing

When sourcing seafood internationally there are several factors to consider. One of the most important considerations is the social and environmental costs and risks associated with imported seafood. Within the global seafood supply chain, there have been ongoing instances of lack of regulatory oversight, overfishing, use of antibiotics in feed, environmental degradation and pollution, fraud, as well as forced labor, and slavery (Fox et al., 2018; Nakamura et al., 2018).

U.S. dependence on imported seafood provides a strain on regulatory agencies to uphold food security and food safety. Therefore, Georgia aquaculture businesses have the opportunity to alleviate international inspection burdens by supplying safe, domestic seafood products.

Seasonality

Seasonality is often considered for wild-caught fisheries, but it can also play a role in aquaculture production. Seasonality in aquaculture refers to the variation in production levels and availability of certain species due to natural factors, such as temperature, water quality, and breeding patterns. These factors influence the timing and duration of production cycles, as well as the availability of specific aquaculture products in the market. Depending on the species, seasonality may be essential to maintain a high-quality product. Below are some comparisons between wild-caught and farmed species in Georgia that may be limited by seasonality.

Finfish

Some warm-water fish species, such as catfish or tilapia, may experience slower growth or reduced activity during colder months, limiting their production capacity.

On the other hand, cooler water species like trout may thrive in Georgia's colder seasons.

Similarly, some wild-caught species of fish may have limited availability due to seasonal variations in their natural habitats. By farming these species in aquaculture systems, producers can overcome seasonal limitations and supply the market with a consistent and reliable source of fish throughout the year.

Shrimp

Wild-caught shrimp in Georgia may have a specific season during which they are abundant and can be harvested. However, shrimp farming in controlled environments, such as indoor recirculating systems or pond aquaculture, enables year-round production of shrimp. This ensures a stable supply of shrimp in the market, reduces the pressure on wild shrimp stocks, and provides economic opportunities for farmers throughout the year.

Oysters

Oysters are subject to seasonal variations in growth and quality. In Georgia, oysters typically experience slower growth during the colder months and may exhibit favorable changes in flavor and texture. Moreover, wild-harvested oysters in Georgia are not allowed to be harvested during the summer, because they are out of the water twice a day at low tide. In the summer heat, this poses a human health risk for food-borne *Vibriosis*. However, oyster aquaculture techniques such as off-bottom farming or wet-storage depuration, and harvest protocols specific to each season, can extend the harvest season and provide a more consistent supply of high-quality, safe oysters throughout the year.

Crawfish

Crawfish, also known as crayfish or freshwater lobsters, are generally more active during the warmer months. Their reproduction and growth rates are influenced by water temperature and the availability of food. In Georgia, crawfish farming is primarily conducted during the spring and summer months when water temperatures are optimal for their growth and reproduction.

By understanding the biological seasonality of distinct species and utilizing aquaculture techniques, Georgia's aquaculture industry can strategically diversify its production to meet consumer demand throughout the year and complement wild-caught fisheries by supplying seafood during seasonal gaps in fishery harvests. This can contribute to the stability and growth of the seafood industry while promoting sustainable practices and reducing pressure on wild fish populations.

Aquaculture Supply Chain

The process of bringing aquaculture products from the farm to the table involves several essential steps. The process can vary depending on the specific product and value chain.

Step 1: Aquaculture Harvest

The aquaculture producers are responsible for rearing and harvesting aquatic species. They ensure that the products meet quality standards and are safe and ready for distribution down the supply chain. Aquaculture products are harvested from the farm or aquaculture facility involving methods such as netting, seining, trapping, or hand-picking, depending on the species and farming system. Once the fish or shellfish are harvested, they are prepared for distribution, which usually means the next stop is a processing facility. Very few products are shipped live, and most products require some sort of processing and reliable cold storage distribution. However, many producers in Georgia lack the capabilities to process their own aquaculture products on site.

Step 2: Processing Infrastructure

After harvesting, the products may undergo processing at a specialized facility. Processing can include cleaning, grading, sorting, fileting, packaging, and sometimes value-added processing like smoking, marinating, or freezing. The processing stage of aquaculture products may involve multiple processors and several stakeholders depending on the desired end product and end consumer.

Processing Facilities and Technology

Processing facilities play a vital role in transforming raw aquaculture products into value-added seafood products. These facilities may specialize in processing shrimp, oysters, or multiple species. Processing facilities utilize various technologies and equipment to efficiently process and transform raw aquaculture products into market-ready seafood. These can include state-of-the-art machinery for fileting, skinning, portioning, and packaging, as well as specialized equipment for processes such as oyster shucking or shrimp peeling. The adoption of advanced processing technology can enhance productivity and improve product quality in processing operations. However, depending on where market demand is and where specialized facilities or infrastructure exist, certain aquaculture products may be exported to other states or countries for processing. There are over 200 seafood processors and wholesalers throughout Georgia, with most facilities located in the metro Atlanta area and fewer along the coast. Though a large volume of the seafood that is processed in

these Georgia facilities is imported, there is sufficient capacity among stakeholders to accept aquaculture products that are produced within the state of Georgia. By having in-state harvesters that are closer to the processing facilities, it allows for better control over the quality, freshness, and value addition of the products.

Value-Added Processing

In addition to basic processing tasks such as cleaning and packaging, seafood processing facilities may also engage in value-added processing. This involves further processing the seafood products to create value-added or convenience products such as breaded fish filets, smoked salmon, marinated shrimp, or pre-packaged seafood meals. Value-added processing can help diversify product offerings, cater to specific market demands, and increase profitability.

Exporters/Wholesalers

Depending on the market demand and distribution channels, exporters or wholesalers may be involved in the processing stage. They facilitate the transportation and sale of processed aquaculture products to various markets, which can include other states or even international destinations.

Step 3: Food Safety and Quality Assurance

Ensuring the quality and safety of aquaculture products is of paramount importance to maintain consumer confidence and meet regulatory requirements. Quality assurance involves implementing processes, policies, and standards throughout the production and distribution chain. Processing facilities implement rigorous quality control measures to monitor and assess the freshness, taste, texture, and appearance of seafood products. They also adhere to food safety regulations and standard operating procedures to prevent contamination and ensure the safety of the end consumers.

Several federal and state policies and agencies that participate in quality assurance in the aquaculture industry are provided below.

Food Safety Regulations

Aquaculture products are subject to food safety regulations at the local, state, and federal levels. These regulations set standards for handling, processing, packaging, and labeling of products to ensure consumer safety. In the U.S., the Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) play significant roles in regulating and enforcing food safety standards.

HACCP and Food Safety Plans

Seafood Hazard Analysis and Critical Control Point (HACCP) plans and other food safety plans are integral components of food safety and quality assurance during seafood processing. These systematic approaches involve identifying potential hazards, establishing control measures, monitoring procedures, and corrective actions to significantly reduce food safety risks in the final product, and protecting consumers. Seafood HACCP plans are required by the FDA (21 CFR part 123) and by some third-party certification programs.

Testing and Inspection

Quality assurance and food safety/GMPs involves regular testing and inspection of aquaculture products and the processing environment for parameters such as microbiological safety, chemical residues, product composition, and sensory attributes. Testing may be conducted by independent laboratories, government agencies, or internal quality control departments. Before distribution, aquaculture products undergo quality control and inspection procedures to ensure they meet industry standards and regulations. This includes assessing factors such as freshness, size, appearance, proper labeling and compliance with other food safety requirements.

Traceability Systems

Traceability systems are important for ensuring product integrity, consumer confidence, and managing food safety incidents and investigations. These systems enable the tracking of aquaculture products from farm to table, including information on production practices, origin, handling, and processing. By implementing traceability systems, stakeholders can quickly identify and respond to any quality or safety issues that may arise and comply with the FDA Food Safety Traceability Rule. The Food Safety Traceability Rule fulfills the Food Safety Modernization Act 204(d) and requires sortable spreadsheets to be provided to the FDA within 24hr of request for a specified list of food types including seafood. Depending on the size of the operation, traceability information systems can greatly assist in regulatory compliance.

Collaboration with Government Agencies

In Georgia, state agencies, such as the Georgia Department of Agriculture, Georgia Department of Natural Resources, and local health departments, are responsible for enforcing regulations, conducting inspections, and ensuring compliance with quality and safety regulations. Each agency specializes in enforcement of either production facilities, processing facilities, retail establishments or restaurants. These agencies

may provide guidance, support, and oversight to help inform future aquaculture industry growth.

Certification and Accreditation

Various certification programs and accreditation bodies validate product quality, adherence to specific food manufacturing standards, or seafood sustainability. These certifications demonstrate the commitment of a facility to quality, safety, and sustainability practices, which can enhance consumer confidence. Examples include the Aquaculture Stewardship Council (ASC) certification, Best Aquaculture Practices (BAP) certification, and organic certification programs. These certifications help establish credibility, demonstrate sustainability practices, and open-up access to markets that prioritize certified products. Good Aquaculture Practices (GAQPs), while not usually regulatory in nature, do provide crucial guidance for final product quality assurance. GAQPs describe general principles and applications encompassing production, processing, and handling practices that aim to minimize risks, maintain product integrity, enhance sustainability and ensure traceability.

Market Access Requirements

Different markets, wholesalers and retailers all may have their own suite of quality and safety requirements that aquaculture products must meet to become approved suppliers. These requirements may include processing certifications (e.g., Global Food Safety Initiative), adherence to specific production standards (e.g., organic, sustainable), and compliance with import regulations. Understanding and meeting these market access requirements is essential for expanding market reach and securing prices that support the viability of an aquaculture business.

Collaboration and Partnerships

Quality assurance in aquaculture often involves collaboration among various stakeholders. Producers, processors, regulatory agencies, research institutions, and industry associations work together to establish and uphold quality standards, share best practices, and address emerging challenges. Strong partnerships and information exchange enhance the overall quality assurance efforts in the industry. By adhering to quality assurance policies and working closely with relevant agencies, aquaculture producers can uphold high standards of product quality, safety, and consumer satisfaction.

Product Packaging and Labeling

Proper packaging is essential to ensure the freshness and quality of aquaculture products during transportation and storage. Packaging materials may vary depending on the product type and distribution requirements, such as trays, bags, or boxes

vacuum-sealed bags, modified atmosphere packaging, or other suitable containers. Labeling is also important for providing essential information about the product. Some information is federally required such as allergen labeling. Other information may be optional but helpful for consumers, such as educational information about the species. Labels commonly include country of origin, species name, certifications, nutritional information, and handling instructions.

Step 4: Labor Components

Skilled Workers

Aquaculture processing facilities require skilled labor to perform tasks such as filleting, packaging, quality control, and operating processing machinery. Skilled workers may include trained fish cutters, oyster shuckers, shrimp processors, and machine operators. Some roles can be trained on the job. Other roles require prior education. There has been an increase in demand for workers skilled in information technology, computer programming and other engineering-related tasks.

Local Workforce

Processing facilities often employ a local workforce from the surrounding communities. These workers may have experience in seafood processing or related industries, and they contribute to the local economy and job market.

Seasonal or Migrant Workers

Depending on the specific aquaculture products and harvest cycles, processing facilities may also employ seasonal or migrant workers during peak production seasons. These workers may come from different regions or countries and may have specialized skills in seafood harvesting or processing.

Support Staff

Apart from the processing workers, processing facilities also require support staff for various functions such as administration, management, maintenance, and logistics.

Distribution Workforce

The infrastructure of aquaculture processing is also influenced by market access and distribution networks. Processing facilities need to have efficient logistics and transportation systems to ensure the timely and efficient delivery of products to retailers, wholesalers, or export destinations. They may collaborate with distributors, transportation companies, and cold storage facilities to facilitate the smooth flow of seafood products from the processing facility to the end consumer.

The demographics of the workforce in aquaculture processing facilities can be influenced by factors such as workforce availability, skills required, and labor regulations. It is important to ensure that any and all workforce is trained in proper food handling and safety practices to maintain product quality and safety standards.

Step 5: Distribution and Logistics

The distribution of aquaculture products involves fundamental stakeholders who play important roles in ensuring that the products reach their intended markets.

Distributors/Wholesalers

Distributors or wholesalers are key intermediaries in the distribution process. They purchase aquaculture products from the producers or processors and then distribute them to retailers, restaurants, seafood markets, and other buyers. Distributors often have established networks and logistics capabilities to efficiently transport and store the products until they reach the end consumers.

Transportation and Logistics

The transportation of aquaculture products requires careful planning and coordination to maintain product quality and freshness. Logistics companies handle aspects such as route planning, refrigerated transportation, temperature monitoring, and timely delivery to ensure that products reach their destinations in optimal condition. Aquaculture products are transported from the processing facilities to distribution centers, retailers, or other buyers. This involves coordinating logistics, including choosing the right transportation mode (truck, air, or sea), optimizing routes, and ensuring timely delivery.

Storage and Cold Chain Management

Aquaculture products require proper storage conditions, especially maintaining a cold chain to prevent spoilage and maintain freshness. Cold storage facilities and refrigerated transportation are used to keep the products at appropriate temperatures throughout the distribution process. Maintaining the cold chain is crucial to preserve the freshness and quality of aquaculture products. This involves using refrigerated distribution facilities, refrigerated trucks or containers, and temperature monitoring systems to keep the products at appropriate temperatures throughout the distribution process.

Inventory Management

Effective inventory management systems are essential to track the quantity and condition of aquaculture products at various stages of the distribution process. This

helps optimize storage, minimize waste, and ensure that products are available when needed.

The distribution of aquaculture products can occur at various levels, including local, regional, national, and even international markets. The specific distribution channels and geographic reach depend on factors such as product type, market demand, logistics infrastructure, and marketing strategies.

Step 6: End Users

Retailers

Retailers, such as grocery stores, seafood markets, and specialty shops, are crucial in making aquaculture products available to consumers. They purchase products from distributors or wholesalers and display them for sale to the public in stores or online. Retailers may also handle additional processing, such as filleting or portioning, to meet consumer preferences. Final product presentation, pricing, and customer service at the retail store can influence frequency of purchases by consumers.

Restaurants and Food Service Providers

The food service industry, including restaurants, hotels, catering services, and institutional cafeterias, also plays a significant role in the sale of aquaculture products. These establishments source seafood from distributors or directly from aquaculture producers and incorporate them into their menus or food offerings.

Online Platforms and Direct Sales

With the rise of e-commerce and direct-to-consumer models, online platforms have become increasingly important in the distribution of aquaculture products. Online seafood marketplaces, direct sales platforms, and subscription services provide consumers with convenient access to a wide range of aquaculture products, often sourced directly from producers or processing facilities.

Conclusion

Efficient and well-managed operations are crucial for maintaining the quality, safety, and marketability of aquaculture products as they move through the various stages of the supply chain. Collaboration among stakeholders, adherence to industry standards, and ongoing monitoring helps ensure consistent high-quality products are being produced. The infrastructure and operations of seafood processing facilities are critical for adding value to aquaculture products, ensuring quality and safety, and meeting market demands. Continuous investments in infrastructure, technology, and a skilled workforce are essential to maintain competitiveness and capitalize on the

opportunities in the seafood industry. Finally, effective and well-managed distribution operations are vital for connecting aquaculture producers with retailers, institutions and restaurants, ultimately reaching consumers' tables.

Pricing

Pricing is a critical factor in the success of aquaculture products in the market. Several factors influence the pricing of aquaculture products in Georgia, including production costs, market demand and supply dynamics, competition, and product quality.

Competition with Domestic and International Production and Wild Caught Fisheries

Aquaculture products from Georgia may face competition from products originating from other states or other countries, as well as wild-caught seafood. Pricing dynamics are influenced by factors such as transportation costs, production volumes, quality, and market preferences. Aquaculture products from different states may vary in terms of species, production methods, and market positioning. Factors such as proximity to markets, production efficiency, branding, and quality standards can impact the competitiveness of Georgia's aquaculture products against those from other states. Georgia Aquaculture products may also be competing in the market with imported aquaculture products. Imported products tend to be priced lower because of factors such as, economies of scale, labor costs, and differing regulatory oversight.

Wild-caught seafood, including fish, shrimp, and shellfish, continues to be a significant competitor to aquaculture products. Wild-caught seafood is often associated with unique flavors, sustainability, and a sense of naturalness. Georgia Aquaculture products need to be differentiated by their attributes such as freshness, consistency, environmental sustainability and overall quality to compete effectively in the marketplace.

Cost of Production

The cost of production, including inputs such as feed, labor, energy, and infrastructure, is a significant factor in pricing. Efficient production practices, economies of scale, and cost management strategies can help aquaculture producers maintain competitive pricing while ensuring profitability.

Price competitiveness is influenced by the cost of production, including feed, labor, infrastructure, and regulatory compliance. Efficient production practices, economies

of scale, and value-added product differentiation can help aquaculture producers in Georgia achieve competitive pricing and market positioning.

Market Demand and Supply

The pricing of aquaculture products is influenced by market demand and supply dynamics. Factors such as consumer preferences, trends, seasonal variations, and overall market conditions play a role in determining the pricing of Georgia aquaculture products. Producers need to monitor market trends and adapt their pricing strategies accordingly.

Market Channels

The choice of market channels, such as direct sales to consumers, restaurants, wholesalers, or retailers, can also influence pricing. Each channel has its cost structure, profit margins, and pricing expectations, which aquaculture producers need to consider when determining the appropriate pricing strategy.

Branding and Marketing

Effective branding and marketing efforts can influence consumer perception and willingness to pay for aquaculture products. Premium-quality products with certifications, eco-labels, or value-added products often command higher prices in the market. Building a strong brand image, that differentiates the unique selling points of Georgia Aquaculture products can support higher pricing and market competitiveness.

Georgia aquaculture producers need to stay informed about market trends, consumer preferences, and pricing strategies employed by competitors. Regular market analysis, customer feedback, and collaboration with industry stakeholders can help in making informed decisions regarding pricing strategies to enhance the competitiveness of Georgia's aquaculture industry.

Linkages Between Producers and Markets

Establishing strong linkages between aquaculture producers and markets is essential for the success and sustainability of Georgia's aquaculture industry. These linkages involve the flow of products, information, and relationships between producers, processors, distributors, and consumers. Here are some key points to consider:

Marketing

By fostering strong linkages between producers, retailers, restaurants and other markets, Georgia's aquaculture industry can enhance market opportunities, and contribute to the economic growth of the sector. Collaborative market research, and targeted marketing efforts can help effectively reach and satisfy consumer demands. Continuous efforts to educate and engage consumers enhance consumer trust, meet consumer preferences for transparent sourcing, and potentially capture a niche market that values local, sustainably produced seafood.

Market Access and Promotion

Aquaculture producers and distributors work to establish relationships with retailers, restaurants, and other buyers to ensure market access. They also engage in marketing and promotional activities to create awareness and generate demand for aquaculture products. This may include participation in trade shows, advertising campaigns, or collaborations with culinary professionals to highlight the quality and versatility of the products.

Collaborative Producer Marketing

Supporting the marketing efforts of Georgia's aquaculture products can help increase consumer awareness, demand, and economic viability. Collaborative marketing initiatives involving multiple aquaculture producers can help pool resources, increase marketing reach, and create a unified presence in the market. This can include joint branding, promotional campaigns, and participation in industry events and trade shows that showcase the quality and sustainability of Georgia's aquaculture products.

Product Differentiation

Differentiating aquaculture products based on their unique qualities, such as sustainability, traceability, and superior quality, can help create market advantages. Highlighting the local origin and responsible production practices of Georgia's aquaculture products can resonate with consumers who value supporting local producers and sustainable food systems. Implementing clear labeling and transparency systems can provide consumers with confidence in Georgia's aquaculture products while making them easily identifiable in the marketplace.

Consumer Education and Preferences

Market Research and Consumer Preferences

Conducting market research to understand consumer preferences, trends, and demands can help guide producers in deciding which market channels to pursue and

aligning their products and packaging with market expectations, thereby improving competitiveness. This includes understanding consumer preferences for certain species, processing methods, packaging, and price points. For example, consumers may be seeking the convenience of a fish that is marinated and ready to cook. Consumer awareness regarding the origin and processing of seafood products varies. While some consumers actively seek information about the source and processing methods of their seafood, others may have limited knowledge or may not prioritize this information when making purchasing decisions. However, there is a growing trend of consumers showing interest in knowing the origin, sustainability, and quality of their food, including seafood.

Certifications and Labels

Obtaining certifications and labels that demonstrate adherence to specific standards, such as organic, sustainable, or environmentally friendly practices, can enhance marketability. These certifications reassure consumers about the quality and sustainability of the products and can open doors to markets that prioritize such certifications. To address consumer demand for transparency, it is important to establish clear and informative labeling practices. This can include indicating the specific farm or aquaculture operation where the product was produced, as well as information about the processing facilities involved.

Promoting Consumer Awareness and Engagement

Educating consumers about the benefits of consuming locally produced seafood and the sustainable practices employed by Georgia's aquaculture industry can enhance consumer engagement and support. Additionally, engaging consumers through educational events, farm tours, and interactive experiences can foster a sense of connection between producers and consumers, increasing consumer loyalty. It may also encourage consumers to make more informed choices and develop preferences for other locally sourced products. Appropriate consumer education and communication efforts will reduce product confusion and facilitate growth in market demand of Georgia seafood products.

Direct Market Channels

Establishing effective direct market channels is crucial for connecting aquaculture producers with consumers. These channels can include direct sales to consumers through on-farm markets, farmers' markets, community-supported agriculture (CSA) and fisheries (CSF) programs, and online platforms. Additionally, partnerships with local restaurants, seafood retailers, and distributors can help expand market reach and access a wider consumer base.

Farm to Table Movement

One of the largest economic sectors that's been experiencing considerable growth, both nationally and within Georgia, is the hospitality and tourism industry, especially the restaurant and food service segment. With over 20,000 eating and drinking establishments across the state, Georgia is strengthening its position as a food destination. From a national perspective, consumer demand for locally sourced food has increased significantly over the past twenty years. Also referred to as the farm-to-table movement, the desire for consumers to know more about where their food comes from has been a growing factor in their purchase decisions. Nowhere else can this movement be more observed than in the food and beverage industries. Various research, including from the National Restaurant Association, has continuously shown that consumers not only seek out restaurants that source ingredients locally, but they also are willing to pay more for local food items on a menu, as well as recommend and revisit restaurants that feature local food offerings (Remar et al., 2016; Remar et al., 2022).

Consumer demand for local food is also relevant when comparing domestically produced (not just U.S. processed) seafood to imported seafood. Therefore, the opportunity is great for aquaculture producers in Georgia to capitalize on the consumer demand for local food, from both a state and national level.

Constraints

Aquaculture operations in Georgia may face certain constraints that can impact their growth and productivity.

Regulatory and Permitting Challenges

The aquaculture industry is subject to various regulations and permitting requirements, which can sometimes be complex and time-consuming to navigate. These regulations may include environmental regulations, water use permits, zoning restrictions, and health and safety standards. Compliance with these regulations can pose challenges and may require significant time, resources, and expertise.

By addressing these regulatory issues and implementing supportive measures, Georgia can create an enabling environment for the aquaculture industry to thrive. Collaboration among government agencies, industry stakeholders, research institutions, and educational bodies is crucial for developing effective policies,

fostering innovation, and ensuring the sustainable growth of Georgia's aquaculture sector.

Limited Access to Capital

Access to capital and financing options can be a constraint for aquaculture operations, especially for small-scale farmers or entrepreneurs. Obtaining funding for infrastructure development, equipment, research, and development, and working capital can be challenging. Limited financial resources can hinder the expansion or modernization of aquaculture facilities and limit the adoption of advanced technologies.

Infrastructure Limitations

The availability of suitable infrastructure, such as access to water resources, transportation networks, processing facilities, and cold storage, can impact the viability and efficiency of aquaculture operations. Limited infrastructure in certain regions may restrict the establishment or expansion of aquaculture farms.

Market Access and Distribution Channels

Gaining access to profitable markets and establishing efficient distribution channels can be a constraint for aquaculture producers. Market competition, pricing dynamics, and the ability to reach and engage with target consumers can pose challenges. Developing effective marketing strategies and securing reliable distribution networks are crucial for successful market penetration.

Environmental Considerations

Aquaculture operations must carefully manage their environmental impact to ensure sustainability and minimize negative effects on ecosystems. This includes addressing concerns such as water quality, waste management, and the potential for interactions with wild fish populations. Compliance with environmental regulations and implementing responsible practices, such as proper site selection and monitoring, are essential to mitigate these constraints. Collaboration with industry stakeholders and researchers can help in making informed decisions regarding waste management and water quality.

Disease and Health Management

Aquaculture farms may face challenges related to disease outbreaks and the health management of cultured species. Disease prevention, early detection, and effective treatment strategies are vital for maintaining the health and productivity of aquaculture operations. Collaborating with veterinary experts, implementing biosecurity measures, and staying updated on best practices can help address these constraints.

Access to Knowledge and Technical Expertise

Keeping up with advancements in aquaculture techniques, technologies, and research is crucial for the industry's growth. Access to knowledge, technical training, and expert guidance can be a constraint for farmers, especially those who are new to aquaculture or lack resources for continuing education. Support from research institutions, extension services, and industry associations can help address this constraint by providing educational programs and resources.

Critical Mass

Critical mass refers to the minimum scale of production necessary for aquaculture operations to be economically viable and sustainable. Achieving critical mass allows producers to benefit from economies of scale, improved operational efficiencies, and increased competitiveness in the market. It involves reaching a sufficient production volume to meet market demand, cover production costs, and generate profits.

In the context of Georgia's aquaculture industry, reaching critical mass may require enough aquaculture farms and facilities, adequate infrastructure, and supportive policies and regulations. By achieving critical mass, the industry can attract investment, foster innovation, and establish a robust supply chain that ensures consistent product availability and market stability.



Section 6: Research, Training and Regulatory Support

Research and Development

Encouraging research and development (R&D) in aquaculture is essential for innovation, improved production techniques, and addressing environmental and economic challenges. Allocating resources and funding for research programs can drive industry growth and sustainability. Both the USDA and NOAA offer a variety of funding opportunities to support aquaculture R&D, which can lead to advances in practices, increased efficiency, and the development of sustainable production methods.

State agencies can further support R&D by partnering with academic institutions, research organizations, and industry stakeholders. These collaborations can foster advancements in production techniques, disease management, environmental sustainability, and product diversification. By promoting knowledge exchange, state agencies contribute to the long-term growth and competitiveness of Georgia's aquaculture sector.

Adequate funding is critical for R&D initiatives, which may include improving breeding techniques, developing disease-resistant strains, optimizing feed formulations, and exploring innovative production systems. Without sufficient funding, research is limited in scope and pace, hampering the industry's ability to overcome challenges and seize emerging opportunities.

Partnerships among aquaculture farmers, government agencies, and academic institutions facilitate technology transfer, adoption of best practices, and evidence-based decision-making. Collaborative projects can address industry-specific needs and provide scientific support for operational improvements.

Training and Education

Providing training and educational programs tailored to the aquaculture industry's needs can enhance the skills and knowledge of farmers and industry professionals. Workshops, seminars, and vocational training courses cover production techniques, business management, environmental stewardship, and regulatory compliance.

Government agencies and industry associations can play a crucial role in disseminating information, resources, and guidance to aquaculture farmers. Regular communication channels, workshops, and online platforms can facilitate information exchange, address concerns, and keep farmers updated on the latest developments in regulations and industry practices.

State and Federal Agencies Involved in Georgia Aquaculture

State Agency Support

State agencies play a crucial role in providing resources, information, and assistance to aquaculture operators, facilitating the development of the sector, and ensuring regulatory compliance.

Awareness and Education

State agencies can engage in educational initiatives to raise awareness about the benefits and opportunities of aquaculture among farmers, entrepreneurs, and the public. This includes organizing workshops, seminars, and training programs to provide information on best practices, regulatory requirements, and market opportunities.

Technical Assistance

State agencies can offer technical assistance to aquaculture operators, especially those who are new to the industry or facing specific challenges. This may involve guiding

site selection, farm design, water quality management, species selection, and production techniques. By offering expert advice and support, state agencies can help ensure that aquaculture operations are conducted efficiently, economically, and in compliance with relevant regulations.

Permitting and Licensing

State agencies play a critical role in the permitting and licensing processes for aquaculture operations. They can streamline and simplify the permitting procedures, ensuring that the process is transparent, efficient, and responsive to the needs of aquaculture operators. Clear guidelines and assistance in navigating the regulatory requirements contribute to a favorable business environment for the aquaculture industry.

Market Development

State agencies can assist in market development for Georgia's aquaculture products. This can involve collaborating with industry associations, trade organizations, and retailers to promote local aquaculture products and increase their visibility in domestic and international markets. State agencies can facilitate networking opportunities, trade shows, and marketing campaigns to connect aquaculture producers with potential buyers and consumers.

Collaboration and Coordination

State agencies should strive for effective coordination and collaboration among different departments and agencies involved in aquaculture regulation and promotion. This ensures a cohesive and integrated approach to addressing the needs and challenges of the industry. By working together, state agencies can maximize their collective impact and provide comprehensive support to the aquaculture community.

Overall, state agency promotion plays a vital role in creating a favorable environment for the growth and development of Georgia's aquaculture industry. Through awareness building, technical assistance, market development, and research support, state agencies can help foster a sustainable and thriving aquaculture sector in the state. Learn about some of the key state agencies involved in Georgia aquaculture below.

Georgia Department of Natural Resources

The Georgia Department of Natural Resources (DNR) oversees aquaculture management and regulation through its Wildlife Resources Division, Environmental Protection Division, and Coastal Resources Division. Together, these divisions support

responsible industry growth by improving permitting processes, ensuring environmental protection, and fostering collaboration among regulators, researchers, and producers.

Wildlife Resources Division

The Wildlife Resources Division (WRD) supports the development of Georgia's aquaculture industry while safeguarding natural resources. Over time, the division has modernized its approach to regulation and industry support. WRD's emphasis on efficiency, education, and science-based management has improved how aquaculture operations are permitted and monitored, promoting industry growth that is both practical and sustainable. Below are some key activities and impacts provided by WRD.

- *Program expansion and support:* WRD has broadened its aquaculture programs to assist producers with technical guidance, permitting, and compliance. These programs help new operators understand regulatory expectations early in the process, reducing permitting delays and ensuring operations are established responsibly.
- *Streamlined permitting:* The division has simplified application procedures and improved coordination with other agencies. These changes have shortened review timelines and made the process more transparent and predictable for applicants.
- *Environmental stewardship:* WRD developed best management practices that address water quality, waste management, and habitat protection. These guidelines help producers minimize environmental impacts and align their operations with state conservation goals.
- *Research and data collection:* The division has supported research on species suitability, disease management, and environmental performance of aquaculture systems. Findings from these studies inform future permitting standards and help identify low-impact, high-yield production models suited to Georgia's conditions.
- *Collaboration and stakeholder engagement:* WRD regularly partners with other agencies, universities, and industry groups to share information and align policy with on-the-ground realities. This collaborative approach helps identify challenges early and promotes more coordinated solutions.
- *Education and outreach:* The division conducts workshops and provides training to aquaculture operators and the public. These efforts increase understanding of sustainable practices and improve compliance with state regulations.
- *Regulatory updates:* WRD periodically reviews and updates aquaculture rules to reflect advances in science, technology, and production methods, ensuring that policies remain relevant and effective.

Environmental Protection Division

The Environmental Protection Division (EPD) is responsible for safeguarding Georgia's air, water, and land resources. In the context of aquaculture, the division focuses on maintaining water quality, managing waste, and enforcing environmental compliance. Through stronger environmental review, clearer standards, and improved coordination, EPD has made Georgia's aquaculture oversight more effective, balancing resource protection with industry development. Below are some key activities and impacts provided by EPD.

- *Environmental impact assessments:* EPD now requires more comprehensive assessments for proposed aquaculture facilities, ensuring potential effects on water quality, habitat, and wildlife are understood and mitigated before projects are approved. This upfront review reduces the likelihood of environmental damage and regulatory violations later.
- *Water quality monitoring and standards:* The division enforces stringent water quality standards and requires operators to monitor and report water quality data such as dissolved oxygen and nutrient levels. Regular monitoring promotes transparency and ensures aquaculture activities do not degrade surrounding ecosystems.
- *Waste management oversight:* EPD developed regulations to reduce nutrient runoff and sedimentation from aquaculture operations. These policies encourage the adoption of best management practices that protect nearby waterways and improve operational efficiency.
- *Enforcement and compliance:* The division conducts inspections and ensures facilities adhere to permit conditions. These actions maintain accountability and promote a culture of continuous improvement among aquaculture operators.
- *Interagency collaboration:* EPD coordinates with the DNR, the U.S. Environmental Protection Agency, and other partners to align permitting and monitoring standards. This coordination reduces duplication and ensures a consistent regulatory framework across state and federal levels.

Coastal Resources Division

The Coastal Resources Division (CRD) manages Georgia's coastal and marine environments, including aquaculture activities that occur in tidally influenced waters. Its policies emphasize sustainable development, habitat protection, and stakeholder involvement. CRD's permitting and monitoring framework has created a more predictable, science-driven process for coastal aquaculture, allowing the sector to

grow responsibly while maintaining healthy marine ecosystems. Below are some key activities and impacts provided by CRD.

- *Coastal aquaculture permitting:* CRD developed a comprehensive review process for proposed coastal aquaculture sites. This ensures that projects are appropriately located to avoid sensitive habitats, navigation channels, and recreational areas. The process also provides greater clarity to applicants and helps prevent conflicts among coastal users.
- *Zoning and siting guidance:* The division uses coastal zoning and mapping tools to guide where aquaculture can occur, helping balance economic opportunity with environmental integrity and community values.
- *Environmental monitoring:* CRD conducts long-term monitoring of coastal water quality and habitat health. The resulting data inform adaptive management and allow early detection of potential impacts from aquaculture operations.
- *Stakeholder engagement:* The division regularly solicits input from producers, local governments, and conservation organizations. This participatory process builds trust, increases transparency, and leads to more widely supported management decisions.
- *Research and innovation:* CRD supports pilot projects and collaborations that test new gear types, species, and techniques suited to Georgia's coastal environment. These research initiatives help identify methods that enhance productivity while minimizing environmental impacts.

Georgia Department of Agriculture

The Georgia Department of Agriculture (GDA) plays a key role in promoting, regulating, and marketing aquaculture products within the state. GDA's combined focus on regulation, marketing, and technical support strengthens the commercial side of Georgia aquaculture and connects producers to growing markets. Below are some key activities and impacts by GDA.

- *Regulatory oversight:* GDA developed and enforces licensing, inspection, and food safety requirements for aquaculture facilities. Clearer rules and updated compliance standards help operators meet both state and federal expectations.
- *Marketing and promotion:* The department promotes Georgia aquaculture products through trade shows, branding campaigns, and market development programs. These efforts raise consumer awareness and expand opportunities for producers domestically and internationally.
- *Research and technical support:* GDA collaborates with universities and industry organizations to fund studies on production efficiency, disease control, and

product quality. By sharing technical information and best practices, the department helps operators improve profitability and resilience.

Federal Agencies

Several federal agencies contribute to the development and oversight of aquaculture in Georgia, including the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Agriculture (USDA), and the U.S. Fish and Wildlife Service (USFWS). Below are some key activities and impacts by federal agencies.

- *Regulatory oversight:* Federal agencies establish national standards for aquaculture permitting, food safety, and resource protection. These frameworks help ensure consistency across states and provide guidance for sustainable growth.
- *Research and development funding:* NOAA, USDA, and other federal partners fund research on production efficiency, disease prevention, and sustainable practices. This investment drives innovation that directly benefits Georgia producers.
- *Financial assistance:* Programs such as USDA Rural Development provide grants and loans for infrastructure, training, and business planning, helping new and existing operations expand responsibly.
- *Collaborative initiatives:* Federal agencies work with state regulators, universities, and industry organizations to harmonize policies and address shared challenges, from environmental management to market access.

Federal involvement brings vital funding, research, and coordination that help Georgia's aquaculture sector adopt new technologies and compete in national and international markets.



Conclusion

Georgia is uniquely positioned to emerge as a leader in sustainable aquaculture in the U.S. As national demand for seafood continues to grow, driven by population expansion, evolving consumer preferences, and increased awareness of health and sustainability, the need to strengthen domestic production has never been more critical. Aquaculture represents a strategic opportunity for Georgia to address this demand while supporting economic development, enhancing food security, and protecting natural resources.

This plan demonstrates that Georgia possesses many of the key assets required for aquaculture growth, including abundant water resources, diverse production environments, strong research institutions, and access to major markets and transportation networks. At the same time, the state faces identifiable challenges, such as regulatory complexity, limited access to financing, infrastructure gaps, and the need for greater consumer awareness, that must be addressed to fully realize this potential.

The findings across all sections of this document highlight that successful aquaculture development depends on a coordinated, systems-based approach. Biological, environmental, financial, regulatory, and market components are deeply interconnected. Progress in one area, such as research innovation or market development, must be matched by advancements in infrastructure, workforce development, and policy alignment to achieve meaningful and sustained growth.

The six strategic priority areas outlined in the Executive Summary provide a comprehensive roadmap for action:

- 1. Strengthening statewide coordination and long-term planning**
- 2. Expanding access to capital and financial tools**
- 3. Advancing research, technology transfer, and innovation**
- 4. Building strong markets through consumer engagement and branding**
- 5. Investing in infrastructure and workforce capacity**
- 6. Streamlining regulatory frameworks and improving interagency collaboration**

Together, these priorities reflect a shared vision: a resilient aquaculture industry that supports producers, benefits communities, and aligns with Georgia's broader agricultural and environmental goals.

Importantly, aquaculture also offers solutions beyond economic growth. It can play a meaningful role in addressing food insecurity, particularly in underserved rural and urban communities, by providing access to affordable, high-quality protein. It can reduce reliance on imported seafood, strengthen domestic supply chains, and contribute to environmental stewardship through sustainable production practices.

The path forward will require continued collaboration among state and federal agencies, academic institutions, industry stakeholders, and local communities. Building partnerships, fostering innovation, and maintaining a clear, unified strategy will be essential to overcoming barriers and capturing emerging opportunities.

In conclusion, aquaculture in Georgia is not simply an agricultural expansion, it is an opportunity to build a more sustainable, diversified, and resilient food system. With deliberate investment, strategic coordination, and continued stakeholder engagement, Georgia can position itself at the forefront of aquaculture development in the United States, delivering lasting economic, environmental, and social benefits for the state and its communities.

References

1. Anderson, J. L., Asche, F., & Garlock, T. (2020). Aquaculture: Its role in the future of food. In *Aquaculture economics and management*. Emerald Publishing. <https://www.emerald.com/books/book/11657/chapter/81583129/Aquaculture-Its-Role-in-the-Future-of-Food>
2. Abaidoo, E., Malone, T., & Melstrom, R. T. (2023). Fish demand in the U.S. Great Lakes region in the face of seafood mislabeling. *Aquaculture Economics & Management*, 27(4), 666–692.
3. Antonucci, F., & Costa, C. (2020). Precision aquaculture: A short review on engineering innovations. *Aquaculture International*, 28(1), 41–57. <https://doi.org/10.1007/s10499-019-00443-w>
4. Benez-Secanho, F. J., Miner, J., & Dwivedi, P. (2021). Using advanced spatial statistical analyses to determine socio-economic constructs of fresh food availability in Georgia, United States. *Journal of Agriculture and Food Research*, 6, 100204.
5. Burlingame, B., Nishida, C., Uauy, R., & Weisell, R. (2009). Fats and Fatty Acids in Human Nutrition: Introduction. *Annals of Nutrition & Metabolism*, 55(1/3), 5–7. <https://www.jstor.org/stable/48514089>
6. Calder, P. C. (2015). Omega-3 fatty acids and inflammatory processes. *Nutrients*, 7(9), 690–708.
7. Cederholm, T. (2017). Fish consumption and omega-3 fatty acid supplementation for prevention or treatment of cognitive decline, dementia or Alzheimer's disease in older adults—Any news? *Current Opinion in Clinical Nutrition and Metabolic Care*, 20(2), 104–109. <https://doi.org/10.1097/MCO.0000000000000350>
8. Claret, A., Guerrero, L., Ginés, R., Grau, A., Hernández, M. D., Aguirre, E., & Rodríguez-Rodríguez, C. (2014). Consumer beliefs regarding farmed versus wild fish. *Appetite*, 79, 25–31.

9. Davis, A. G., Staudinger, M. D., Mills, K. E., & colleagues. (2023). Identifying New England's underutilized seafood species and evaluating their market potential in a changing climate. *Frontiers in Marine Science*.
<https://doi.org/10.3389/fmars.2023.1226219>
10. Davis, C. G., & Rexroad, C. E. (2024). *U.S. seafood imports expand as domestic aquaculture industry repositions itself*. U.S. Department of Agriculture, Economic Research Service, Amber Waves. DOI: <https://doi.org/10.22004/ag.econ.343334>.
11. DiPietro, R. B., Remar, D., & Parsa, H. G. (2016). Health consciousness, menu information, and consumers' purchase intentions: An empirical investigation. *Journal of Foodservice Business Research*, 19(5), 497–513.
12. Food and Agriculture Organization. (2023). *The state of world fisheries and aquaculture 2023*.
13. Food and Agriculture Organization. (2024). *The state of world fisheries and aquaculture 2024*.
14. Florida Department of Agriculture and Consumer Services. (2024). *Florida aquaculture review council annual report*.
15. Fox, M., Mitchell, M., Dean, M., Elliott, C., & Campbell, K. (2018). The seafood supply chain from a fraudulent perspective. *Food Security*, 10, 939–963.
16. Farmery, A. K., van Putten, I. E., Phillipov, M., & McIlgorm, A. (2020). Are media messages to consume more under-utilized seafood species reliable? *Fish and Fisheries*, 21(4), 844–855. <https://doi.org/10.1111/faf.12467>
17. Froehlich, H. E., Gentry, R. R., & Halpern, B. S. (2018). Global change in marine aquaculture production potential under climate change. *Nature Ecology & Evolution*, 2(11), 1745–1750. <https://doi.org/10.1038/s41559-018-0669-1>
18. Georgia Department of Agriculture. (2024). *Georgia agriculture and agribusiness overview*.
19. Gempesaw, C. M., Bacon, J. R., Wessells, C. R., & Manalo, A. (1995). Consumer perceptions of aquaculture products. *American Journal of Agricultural Economics*, 77(5), 1306–1312.
20. Gupta, S., Chakraborty, D., & Saha, S. (2020). Nanotechnology in aquaculture: A potential tool for enhancing sustainable production. In *Nanotechnology in*

sustainable aquaculture (pp. 1–26). Springer.

21. Haspel, T. (2016, February 4). The “food movement” is small? Not from where we sit, it isn’t. *The Washington Post*.
https://www.washingtonpost.com/lifestyle/food/the-food-movement-is-small-not-from-where-we-sit-it-isnt/2016/02/04/cd20150c-cb75-11e5-a7b2-5a2f824b02c9_story.html
22. Hill, A., & Collins, B. (2024). *State shellfish aquaculture funding programs: Examples and options for Georgia’s oyster farming industry*. University of Georgia.
23. Houston, R. D., Bean, T. P., MacQueen, D. J., Gundappa, M. K., Jin, Y. H., Jenkins, T. L., Selly, S. L. C., Martin, S. A. M., Stevens, J. R., Santos, E. M., Davie, A., & Robledo, D. (2020). Harnessing genomics to fast-track genetic improvement in aquaculture. *Nature Reviews Genetics*, 21, 389–409.
<https://doi.org/10.1038/s41576-020-0227-y>
24. Hua, K., Cobcroft, J. M., Cole, A., Condon, K., Jerry, D. R., Mangott, A., Praeger, C., Vucko, M. J., Zeng, C., Zenger, K., & Strugnell, J. M. (2019). The future of aquatic protein: Implications for protein sources in aquaculture diets. *One Earth*, 1(3), 316–329. <https://doi.org/10.1016/j.oneear.2019.10.018>
25. Jiang, H., Shi, X., Fan, Y., Wang, D., Li, B., Zhou, J., Pei, C., & Ma, L. (2021). Dietary omega-3 polyunsaturated fatty acids and fish intake and risk of age-related macular degeneration. *Clinical Nutrition*, 40(12), 5662–5673.
<https://doi.org/10.1016/j.clnu.2021.10.005>
26. Kumar, G., & Engle, C. R. (2016). Technological advances that led to growth of shrimp, salmon, and tilapia farming. *Reviews in Fisheries Science & Aquaculture*, 24(2), 136–152. <https://doi.org/10.1080/23308249.2015.1112357>
27. Li, S., & Kallas, Z. (2021). Meta-analysis of consumers' willingness to pay for sustainable food products. *Appetite*, 163, 105239.
28. Louisiana Department of Agriculture and Forestry. (2024). *Seafood and aquaculture programs summary*.
29. Love, D. C., Asche, F., Conrad, Z., Young, R., Harding, J., Nussbaumer, E. M., Thorne-Lyman, A. L., & Neff, R. (2020). Food sources and expenditures for seafood in the United States. *Nutrients*, 12(6), 1810.

30. Lynch, A. J., Cooke, S. J., Deines, A. M., Bower, S. D., Bunnell, D. B., Cowx, I. G., ... Nguyen, V. M. (2017). *Invisible fisheries: Assessing global freshwater fish biodiversity and conservation*. Fisheries Ecology and Conservation Laboratory. <https://doi.org/10.1016/j.gloenvcha.2017.10.005>
31. Malone, T., & Melstrom, R. T. (2021). Theme overview: The economics of U.S. aquaculture. *Choices*, 36(4).
32. Marshall, J., Malone, T., & Melstrom, R. T. (2021). The economics of United States aquaculture data visualization. *Choices*.
33. Nakamura, K., Bishop, L., Ward, T., Pramod, G., Thomson, D. C., Tungpuchayakul, P., & Srakaew, S. (2018). Seeing slavery in seafood supply chains. *Science Advances*, 4(7), e1701833.
34. Naylor, R. L., Hardy, R. W., Buschmann, A. H., et al. (2021). A 20-year retrospective review of global aquaculture. *Nature*, 591, 551–563. <https://doi.org/10.1038/s41586-021-03308-6>
35. NOAA. (2023). *U.S. aquaculture overview*.
36. NOAA. (2024a). *Fisheries of the United States*.
37. NOAA. (2024b). *Current status of seafood*.
38. O'Connor, L. E., Spill, M. K., Saha, S., Balalian, A., Davis, J. S., & MacFarlane, A. J. (2025). Seafood and neurocognitive development in children: A systematic review. *Advances in Nutrition*.
39. Petrolia, D. R. (2023). *Economic report on oyster aquaculture in Louisiana*. Louisiana Sea Grant. <https://www.laseagrant.org/wp-content/uploads/AOC-Econ-Report-Petrolia-Aug15-2023-Final.pdf>
40. Rana, J., & Paul, J. (2020). Health motive and the purchase of organic food: A meta-analytic review. *International Journal of Consumer Studies*, 44(2), 162–171.
41. Remar, D. (2015). Oyster bars. In K. Albala (Ed.), *The SAGE encyclopedia of food issues*. SAGE Publications.
42. Remar, D., Campbell, J., & DiPietro, R. B. (2016). The impact of local food marketing on purchase decisions and willingness to pay in a foodservice

- setting. *Journal of Foodservice Business Research*, 19(1), 89–108.
43. Remar, D., Sukhu, A., & Bilgihan, A. (2022). The effects of environmental consciousness and menu information on the perception of restaurant image. *British Food Journal*, 124(11), 3563–3581.
 44. South Carolina Department of Agriculture. (2023). *South Carolina agribusiness loan fund program description*.
 45. Thong, N. T., & Solgaard, H. S. (2017). Consumer food motives and seafood consumption. *Food Quality and Preference*, 56, 181–188.
 46. Troell, M., Naylor, R. L., Metian, M., Beveridge, M., Tyedmers, P. H., Folke, C., Arrow, K. J., Barrett, S., Crépin, A.-S., Ehrlich, P. R., Gren, Å., Kautsky, N., Levin, S. A., Nyborg, K., Österblom, H., Polasky, S., Scheffer, M., Walker, B. H., Xepapadeas, A., & de Zeeuw, A. (2014). Does aquaculture add resilience to the global food system? *Proceedings of the National Academy of Sciences, 111*(37), 13257–13263. <https://doi.org/10.1073/pnas.1404067111>
 47. Troell, M., Naylor, R. L., Metian, M., Beveridge, M., Tyedmers, P. H., Folke, C., et al. (2014). Does aquaculture add resilience to the global food system? *Proceedings of the National Academy of Sciences*, 111(37), 13257–13263. <https://doi.org/10.1073/pnas.1404067111>
 48. U.S. Department of Agriculture. (2024). *Risk management agency: Aquaculture insurance and risk management tools*.
 49. U.S. Department of Agriculture, Farm Service Agency. (2024). *Disaster assistance programs for aquaculture producers*.
 50. U.S. Department of Agriculture, Economic Research Service. (2024). *Aquaculture and seafood trade data*.
 51. U.S. Department of Agriculture, National Agricultural Statistics Service. (2019). *Census of aquaculture*.
 52. U.S. Department of Agriculture, National Agricultural Statistics Service. (2022). *Census of aquaculture*.
 53. U.S. Food and Drug Administration & U.S. Environmental Protection Agency. (2024). *Advice about eating fish*. U.S. Food and Drug Administration.

54. Valle de Souza, S., Quagrainie, K., Knudson, W., & Athnos, A. (2021). *Go FISH: U.S. seafood consumers seek freshness, information, safety, and health benefits. Choices: The Magazine of Food, Farm, and Resource Issues*, 36(4).
<https://doi.org/10.22004/ag.econ.316610>
55. Virginia Marine Resources Commission. (2023). *Virginia aquaculture advisory board annual summary report*.
56. Witkin, T., Dissanayake, S. T., & McClenachan, L. (2015). Opportunities and barriers for fisheries diversification: Consumer choice in New England. *Fisheries Research*, 168, 56–62.
57. York, H. (2011, May 19). In defense of tilapia. *The Atlantic*.
<https://www.theatlantic.com/health/archive/2011/05/in-defense-of-tilapia/238859/>

Appendix A: State-wide Survey

As part of developing this strategic plan, we conducted an online survey targeting Georgia county extension agents to assess the scope of aquaculture activities within the state and to evaluate the extent of their engagement with aquaculture operators. The survey included 10 questions aimed at understanding county representation, the presence of aquaculture, agents' involvement with operators, the types of aquaculture systems used, the species raised, and the challenges encountered by operators. Additionally, we gathered contact information for aquaculture operators and assessed agents' interest in educational initiatives, as well as their interest in the Georgia aquaculture conference scheduled for September 2024. The survey questionnaire was divided into three sections: background information, farm details, and interest in future workshops. The survey was administered between July 11 and July 30, 2024, with reminders sent on July 17 and July 22, 2024. The survey collected responses from 54 County Extension Agents across Georgia, covering 61 counties.

Survey results

Aquaculture presence varied by county. Out of the 54 agents who participated, only 15, or 27.8%, reported having aquaculture facilities in their county or region (Figure 1). The pond system was the predominant type of aquaculture system in 12 counties (Table 2). Five counties had recirculating or closed systems, two counties had aquaponics systems, and another two counties had flow-through systems. Treutlen County was unique in having both on-bottom and off-bottom systems not related to shellfish aquaculture (see Table 2 and refer to the Excel spreadsheet for more details). In total, 9 agents provided estimates indicating that Georgia has approximately 94 ponds, 2 cages, 3 aquaponics systems, 7 flow-through systems, and 7 recirculating systems (Table 3). The most raised species in Georgia include catfish, baitfish, ornamental fish, and trout (Table 4). Twelve agents reported that they have some level of involvement with aquaculture operators, primarily offering technical assistance (Table 1). The majority (45%) of responding agents identified high operational costs as the top challenge faced by aquaculture operators in their county, followed by issues such as market price fluctuations, predators and diseases, limited access to credit and farm insurance, and competition and regulations (Table 5). Nearly all responding agents expressed interest in educational initiatives to enhance their knowledge of aquaculture in Georgia.

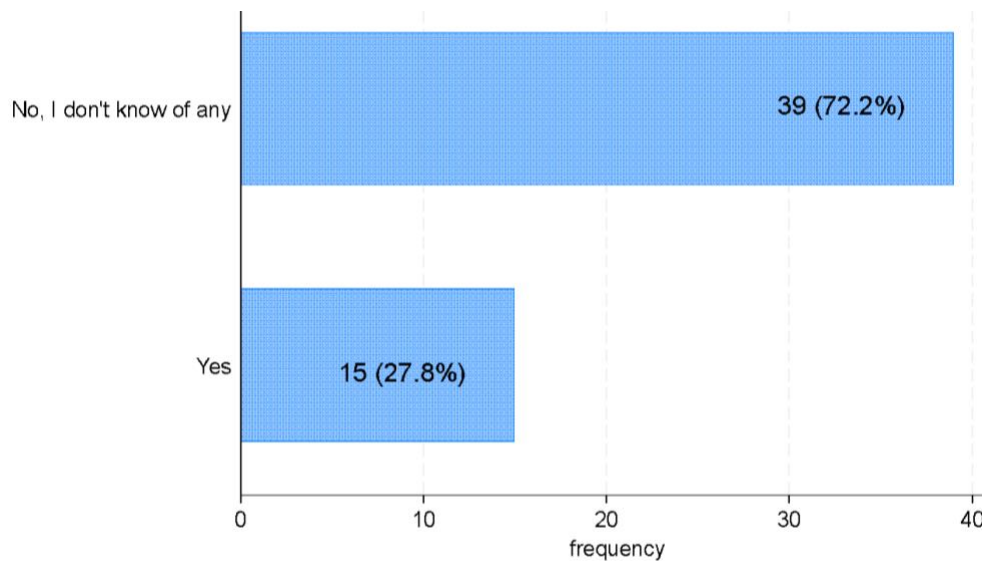


Figure 1. Presence of aquaculture facilities

Table 1: Agents' involvement with aquaculture operators

Ways involved	Responses
I have offered technical assistance to aquaculture operators	4
I organized or facilitated meetings for aquaculture stakeholders	1
I have helped establish connections between aquaculture operators and researchers	2
I have not been involved to date	5
Other involvement (please specify)	
Assisted clients in counties with no agent	1
I managed the UGA Cohutta Fisheries Center for Warnell. This facility is currently owned/controlled by USFWS, but is not operational	1

I talk with them routinely and have been with them on pond visits	1
Minimal advising for some producers	1
Reached out to offer assistance	1

Table 2: Types of aquaculture systems available

Aquaculture system	Number of counties
Finfish aquaculture	
Pond systems	12
Cage and net pen systems	1
Flow -Through or Single-Pass systems	2
Recirculating /Closed systems	5
Aquaponic systems	2
Other (please specify)	
Shellfish aquaculture	
On-bottom systems	1
Off-bottom systems	1
Other (please specify)	

Table 3: Number of aquaculture systems available

Aquaculture system	Number of systems
Finfish aquaculture	
Pond systems	94
Cage and net pen systems	2
Flow -Through or Single-Pass systems	7
Recirculating /Closed systems	7
Aquaponic systems	3
Other (please specify)	
Shellfish aquaculture	
On-bottom systems	
Off-bottom systems	
Other (please specify)	

Table 4: Type of species raised

Species	Responses
Finfish	
Tilapia	
Catfish	9
Trout	3
Baitfish	7
Sportfish/Ornamental fish	7
Other (please specify)	
Brim	1
Grass Carp	2
Eel	1
Shellfish	
Oysters	
Clams	
Mussels	
Other (please specify)	
**Alligator	1

Table 5: Issues faced by aquaculture operators; rank (1 to 10)

Topic/Issue	Rank
Lack of access to credit	7 (by 27% of respondents)
Lack of access to farm insurance	6 (by 45% of respondents)
Lack of market for aquaculture products	7 (by 27% of respondents)
High cost of operations	1 (by 45% of respondents)
Market price fluctuations	4 (by 36% of respondents)
Competition	8 (by 27% of respondents)
Predators and diseases	5 (by 27% of respondents)
Regulations	8 (by 27% of respondents)

Other (please specify)
