United States Department of Agriculture

Agricultural Research Service

National Program 106
Aquaculture
Annual Report for Fiscal Year 2024

Introduction

Aquaculture is the production of aquatic organisms under controlled conditions throughout part or all their lifespan. In 1980 Congress declared "*… that aquaculture has the potential for reducing the United States trade deficit in fisheries products, for augmenting existing commercial and recreational fisheries, and for producing other renewable resources, thereby assisting the United States in meeting its future food needs and contributing to the solution of world resource problems. It is, therefore, in the national interest, and it is the national policy, to encourage the development of aquaculture in the United States.*" In response to this declaration, the ARS National Program for Aquaculture (NP 106) is focusing on research that supports the production of quality seafood products for human consumption.

Aquaculture production is growing because demands for healthy seafood products are increasing even as stocks of wild-caught seafood are dwindling from overfishing and other factors. Developing technologies that reduce production costs while maintaining or improving product quality will help U.S. aquaculture producers meet increasing demands. Producers, processors, and breeders need systems that maximize aquatic animal production, reduce environmental impacts, increase market competitiveness, sustain producers, and earn consumer confidence.

Aquaculture research is important for informing the development of science-based environmental policies that:

- Sustain aquaculture production while maintaining healthy and productive freshwater, coastal, and marine ecosystems, including offshore ecosystems
- Protect special aquatic areas
- Rebuild overfished wild stocks
- Restore populations of endangered species
- Restore and conserve freshwater, coastal, and marine habitats
- Balance competing uses of aquatic environments
- Create employment and business opportunities in rural inland, coastal, and urban communities
- Enable the production of safe and sustainably produced seafood and other products.

Research conducted in NP 106 supports commercial aquaculture production to ensure that a healthy, competitive, and sustainable aquaculture sector can produce an abundant, safe, healthy, and affordable supply of aquatic products. In 2022, NP 106 work advanced the efforts of more than 3,453aquaculture farms contributing $4billion to the US economy and supporting 22,000 jobs.

Since the 1980s, capture fisheries production has been static and shows no signs of increasing. The *2020–2025 Dietary Guidelines for Americans* notes that Americans are consuming less than recommended amounts of seafood and recommends that they double their seafood intake. Domestic aquaculture production could displace seafood imports (of which 50 percent are produced through aquaculture), meet increasing demands for seafood, and become the most readily available source of safe and sustainable seafood. In fact, aquaculture is now the source for about half of all fish produced for human consumption, and its contribution will increase as global demands for seafood increase. Currently, only 7 percent by weight and 24% by value of the US domestic seafood production is from aquaculture.

In 2023, the total value of imported seafood by US consumers was $22.5 billion, making it one of the top three seafood markets worldwide. Yet, U.S. marine and freshwater aquaculture production ranked 18th worldwide, producing 298,336 metric tons with a farm gate value approaching $1.8 billion. As a result, more than 79 percent of the seafood consumed in the United States (by value) is imported, resulting in more than a $20 billion trade deficit.

Table 1: Components of the ARS Aquaculture National Program and states with record of production of each component (2023 Aquaculture Census).

Component	Farm Gate ($1,000)	Live Weight (1,000 pounds)	States
Catfish	479,994	354,068	Alabama, Arkansas, California, Georgia, Louisiana, Mississippi, Missouri, North Carolina, Texas
Salmonids	134,114 [a]	48,197 [a]	Idaho, Maine, Pennsylvania, North Carolina, Washington, California, Colorado, Georgia, Kentucky, Michigan, Missouri, New York, Oregon, Utah, Virginia, West Virginia, Wisconsin
Basses and Baitfish	73,467	13,295	Arkansas, North Carolina, Maryland, Virginia, New York, South Carolina, Louisiana, Mississippi, Florida, Texas, Massachusetts
Mollusks and Crustaceans	751,201	227,800	Alabama, Alaska, Arkansas, California, Connecticut, Delaware, Florida, Hawaii, Kentucky, Louisiana, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oregon, Rhode Island, South Carolina, Texas, Virginia, Washington
Marine Warmwater Finfish	N/A	N/A	Louisiana, Mississippi, Florida, Texas, Alabama
Aquaponics	N/A	N/A	Arizona, California, Florida, Hawaii, New York, Wisconsin,

Tilapia	51,247	14,990	Florida, California, Alabama, Arizona, Hawaii, Idaho, North Carolina, Ohio, Texas

[a] Sales data available only for trout.

This report communicates research and technology transfer highlights supporting the US Aquaculture Industry from ARS scientists and their support staffs working in the Aquaculture National Program (NP106) from October 1, 2023, through September 30, 2024. Additional information can be found in individual project annual reports located here.

The ***vision*** for ARS aquaculture research and technology transfer is *to enable science-based use of our natural resources to meet the seafood demands of a growing global population.*

The ***mission*** of NP106 is to conduct research and deliver technologies that improve domestic aquaculture production efficiency and product quality while minimizing impacts on natural resources.

The ***goal*** of NP106 is to foster and support a globally competitive, science and technology driven aquaculture sector that meets increasing demands for aquatic products that are affordable and meet high standards for safety, quality, and environmental stewardship while providing new opportunities for profitability and economic growth.

The aim of NP106 is to support a safe and affordable domestic supply of seafood products for 330 million U.S. consumers. Seafood products should be produced in a healthy, competitive, and sustainable aquaculture sector that is supported by approximately 3,453 aquaculture farmers producing more than $1.9B farm gate value worth of goods annually. In December 2024, the USDA National Agricultural Statistics Service (NASS) published the 2023 Census of Aquaculture updating national aquaculture statistics for the first time since 2018. The report details many features of aquaculture in the United States, including top producing states and species, which are the primary focus of ARS aquaculture research.

Office of National Programs

In fiscal year (FY) 2024 the ARS Office of National Programs (ONP) contributed to many federal aquaculture activities:

- Providing leadership in the National Science and Technology Council (NSTC) Subcommittee on Aquaculture was provided by an ARS Co-Chair, Executive Secretary and the Chair of the Science Planning Task Force on developing and reporting progress towards the National Strategic Plan for Aquaculture Research.
- Partnering with NOAA and Japanese colleagues to co-organize the 2024 United States-Japan Natural Resources Aquaculture Workshop in Ise, Japan.
- ONP staff and the Bigelow Laboratory for Ocean Sciences' Center for Seafood Solutions led an interagency Federal Working Group that identified opportunities for reducing ocean acidification and producing agricultural products through the farming of seaweeds and seagrasses in a report entitled "Farming of Seagrasses and Seaweeds: Responsible Restoration & Revenue Generation".

- Partnered with Texas A&M University to estimate economic impacts of bird predation on redfish aquaculture.
- Co-sponsored the Aquaculture Information Exchange with NOAA and NIFA.
- Partnered with the University of Connecticut to develop and disseminate nursery production and cryopreservation techniques for seaweeds.
- Partnered with the National Animal Germplasm Program and other academic, government, and private sector institutions to develop a national framework for conserving and using aquatic genetic resources to enhance resiliency.
- Represented USDA on the Ocean Policy Committee on behalf of Dr. Jacobs-Young.

2020 – 2024 Strategic Planning Cycle

FY 2024 was the fifth and final year of externally-reviewed 5-year project plans (2020 – 2024) that fall under the six components of the 2020 – 2024 Aquaculture National Program Action Plan:

1. Improving the Efficiency and Sustainability of Catfish Aquaculture
2. Improving the Efficiency and Sustainability of Salmonid Aquaculture
3. Improving the Efficiency and Sustainability of Hybrid Striped Bass Aquaculture
4. Enhancing Shellfish Aquaculture
5. Developing Marine Finfish Seedstocks
6. Developing Sustainable Aquaponic Production Systems

Research themes include genetic improvement, reproduction and development, growth and nutrition, fish health and well-being, production systems, and product quality.

2025 – 2029 Action Plan and Project Planning

In FY 2024, the 2025 – 2029 Aquaculture National Program Action Plan was completed and project plans were reviewed by the Office of Scientific Quality Review. The components of the new plan retain the themes of the previous plan and include:

1. Improving the Efficiency and Sustainability of Catfish Aquaculture
2. Improving the Efficiency and Sustainability of Salmonid Aquaculture
3. Improving the Efficiency and Sustainability of Bass and Baitfish Aquaculture
4. Enhancing Molluscan and Crustacean Aquaculture
5. Developing Marine Finfish Seedstocks
6. Developing Sustainable Aquaponic Production Systems
7. Enhancing Tilapia Aquaculture Production

This new Action Plan reflects new and/or expanded program directions that are a result of new funding and guidance provided by the Congress and/or redirecting current capacities. For example, Component 3 has been expanded to include largemouth bass and baitfish, Component 4 now includes research on crawfish, and Components 5-7 were developed after the 2020-2024 NP106 Action Plan was first published. Specific examples of new directions are listed below.

Component 1: Catfish

- Developing data management and bioinformatic applications to aid in the genomic selection of channel, blue, and hybrid catfish for improved growth and carcass yield traits
- Developing ante and postmortem strategies that improve the efficiency of processing and quality and consistency of catfish products

Component 2: Salmonids

- Implementing precision agriculture technologies to quantify new fish metrics associated with growth, disease status, and/or well-being in aquaculture production systems to increase efficiencies and profitability by defining phenotypes contributing to performance, developing methods for monitoring them, and strategies to improve performance through breeding and management practices
- Determining the susceptibility of North American Atlantic salmon selected for performance to new and emerging pathogens and developing strategies to improve their health
- Optimizing production efficiency in recirculating aquaculture systems (RAS) by developing breeding strategies and management practices that ensure the productivity and profitability of raising fish in RAS while maintaining high standards of animal well-being
- Reducing or eliminating off-flavor in salmonids

Component 3: Basses and Baitfish

- Developing genetic improvement strategies for largemouth bass
- Developing strategies to remove pests from baitfish harvests

Component 4: Mollusks and Crustaceans

- Improving prevention and control strategies for bacterial and parasitic diseases of crawfish and shrimp
- Applying genome-enabled selection to breed Pacific oysters for resistance to the oyster herpes virus microvariant-1
- Integrating quantitative genetics, molecular biology, and physiology to advance genetic improvement in eastern oysters produced on the Atlantic and Gulf of Mexico coasts

Component 5: Marine Warmwater Finfish

- Developing year-round spawning strategies for captive broodstock, larval culture methods for seed production, and genetic improvement technologies to optimize production efficiency

Component 6: Aquaponics

- Optimizing the integration of plant and fish production in aquaponic systems

Component 7: Tilapia

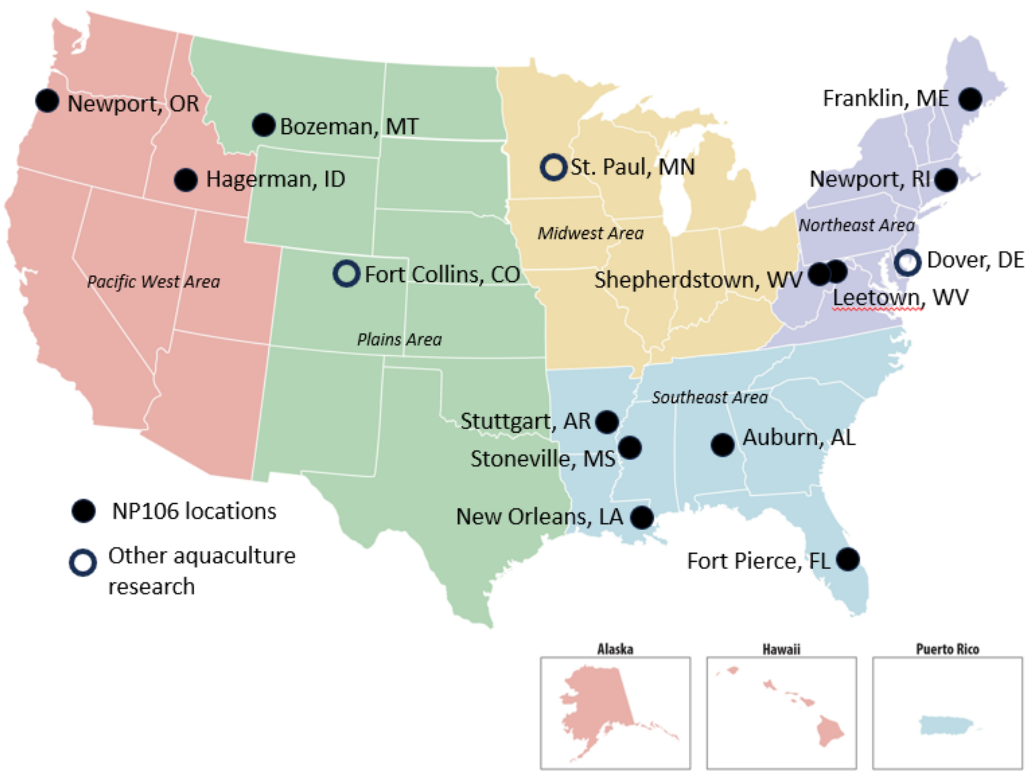
- Breeding tilapia for disease resistance and characterizing pathogens

In 2024, NP106 scientists developed fifteen new project plans that align with one or more components of the 2025-2029 NP106 Action Plan. Each plan was reviewed by one of four external peer-review panels and rated as requiring "No Revision, Minor Revision, Moderate Revision or Major Revision." These new projects are being revised to address reviewer comments and will be initiated in fiscal year 2025.

Although project plans guide most of the efforts of the laboratories, we remain flexible to respond to unanticipated challenges and opportunities. NP106 research covers the spectrum from fundamental to applied research and is focused on solving problems through long-term, high-impact research.

Research Capacity

In 2024, NP106 conducted research at 10 main laboratories on 14 project plans including approximately 66 ARS scientists and University or private cooperators on 15 congressionally mandated agreements. During FY 2024, ARS base funding for aquaculture research was approximately $57M, not including approximately $571K from incoming grants and agreements. The map below identifies NP106 research locations and other ARS locations conducting research directly relevant to aquaculture.



Technology Transfer

2024 NP106 New Technology transfer metrics are summarized in **Table 1** below.

Mechanism	**# New**
Peer Reviewed Journal Articles	78
Book Chapters	1
Material Transfer Research Agreements	7
Material Transfer Agreements	14
New Patent Invention Disclosures	4

Outreach

NP 106 scientists were also active in serving on committees and as advisors/mentors for undergraduate and post-doctoral students and serving as adjunct/affiliate faculty members as outlined in **Table 2** below.

Advising, Mentorship and Outreach Activities	**# of Participants**
Advising and Mentorship	
Students and Post-Docs (ARS and Non-ARS)	11
Mentorships	7
Scientists Serving as Student Advisors	3
Adjunct or Other Appointments	11
Student Targeted Outreach	
Student related outreach activities - # of activities (Presentations to schools, science fair participation, student tours/visits to ARS locations)	9
Student related outreach activities - # of student participants (Presentations to schools, science fair participation, student tours/visits to ARS locations)	1,629
Other Outreach	
Other Outreach Activities - # of activities	4
Other Outreach Activities - # of student participants	1,120
Other Outreach Activities - # of non-student participants	2,022

International Collaborations

In 2024, NP106 scientists took part in research collaborations with scientists in the following countries:

AUSTRALIA: ARS researchers in Auburn, Alabama, and collaborators at Auburn University are using molecular approaches to identify latent viruses and potential coinfections in industry reared catfish.

DENMARK: ARS researchers in Stuttgart, Arkansas, continued collaborating with scientists at the Technical University of Denmark in Hirtshals on research designed to provide information on peracetic acid used in aquaculture. Collaboration has taken place since 2007.

FRANCE: Collaboration between ARS researchers at Stoneville, Mississippi, and the National Institute for Agricultural Research, France. The overall objective of the informal collaboration is to gain a better understanding of immunity in catfish.

GERMANY: ARS researchers in Stuttgart, Arkansas, continued collaborating with scientists at the Leibniz-Institute of Freshwater Ecology and Inland Fisheries in Berlin on research designed to study the toxicity/effectiveness of peracetic acid to fish and the effectiveness of this compound to control pathogens on fish. Collaboration has taken place since 2007.

INDIA: ARS researchers in Auburn, Alabama and Stuttgart, Arkansas, are collaborating with scientists at the Karnataka Veterinary, Animal and Fisheries Sciences University, Nitte University Centre for Science Education & Research, and the Central Agricultural University to characterize lytic bacteriophages for use as therapeutants against Aeromonas species.

NORWAY: ARS researchers in Auburn, Alabama, are conducting collaborative research with Benchmark Genetics Norway AS. The goal of the research is to determine the feasibility of selectively breeding Nile tilapia for industry relevant pathogens and identifying the mechanisms of resistance.

NORWAY: ARS researchers in Stuttgart, Arkansas, continued collaborating with scientists in the Fish Health Department of Norwegian Institute of Food, Fisheries and Aquaculture Research (NOFIMA) on research designed to establish the importance of the potent disinfectant peracetic acid to the global aquaculture industry. Collaboration has taken place since 2007.

NORWAY: Beginning in 2022, The Conservation Fund's Freshwater Institute (TCFFI) personnel are collaborating with The Arctic University of Norway (UiT) to contribute and develop RAS expertise and research towards “CandRAS”, a 7-year project funded by the Norwegian Research Council. Contributions by TCFFI personnel involve collaboration on the design, execution, evaluation, and reporting of experiments in RAS salmon production to address specific areas identified as challenges by RAS salmon producers. A significant component of this collaboration also involves providing expertise and advice on aquaculture employee education, as well as individual university-level courses. The collaboration also involves short-term visits of personnel and potential exchange of students to support mutual US-Norwegian interests to develop and expand a successful Atlantic salmon RAS industry. Most recently, TCFFI has been working with UiT to establish a CandRAS-funded doctoral course of study for TCFFI Research Support Specialist Christine Lepine.

NORWAY: An ARS Scientist located in Leetown, West Virginia, met with scientists from the Institute of Marine Research (IMR) Bergen, Norway on May 13-16, 2024. Six diagnostic fish health biomarkers were measured in Atlantic salmon experimentally infected with Piscine Orthoreovirus-1 (PRV-1) that causes heart and skeletal muscle inflammation (HSMI) disease. The scientists discussed further collaboration, and an extended work stay evaluating additional biomarkers and developing non-lethal sampling methods with the goal of improved detection of infectious diseases in salmonid fish. No external funding source and No Formal Agreement.

SOUTH KOREA: ARS researchers in Stuttgart, Arkansas, have continued collaborating with iNTRON Biotech Inc to evaluate the efficacy of bacteriophages to treat and prevent infections caused by *S. iniae* and *A. hydrophila*. We have completed the in vitro testing of the bacteriophages and aim to complete the *in vivo* (disease model challenges) by the end of FY24.

Personnel

In Memoriam

Regrettably, in 2024 NP106 lost our colleague ***Dr. Guangtu Gao***, who was a scientist at the National Center for Cool and Cold Water Aquaculture in Leetown, West Virginia from 2009 – 2023. Dr. Gao's achievements included de-novo assemblies of reference genomes for rainbow trout and North American Atlantic salmon, and corresponding discovery of single nucleotide polymorphisms and creating high-density genotyping arrays for these species. His impact spanned private, public and academic sectors on five continents and is documented in over 120 scientific publications.

New scientists in NP106 in 2024:

Dr. Louis Plough joined the Pacific Shellfish Research Unit, Newport, Oregon as Research Leader.

Dr Erin Legacki joined the National Cold Water Marine Aquaculture Center, Franklin, Maine.

Dr. Caitlin Older joined the Warmwater Aquaculture Research Unit, Stoneville, Mississippi.

Dr. Geoffrey Waldbieser became the Research Leader of the Warmwater Aquaculture Research Unit, Stoneville, Mississippi.

Dr. Nicholas Romano joined the National Warmwater Marine Finfish Unit, Fort Pierce, Florida as Research Leader.

Prominent Awards

The following scientists in NP 106 received prominent awards in 2024:

Dr. Brian Bosworth and Dr. Geoff Waldbieser of the Warmwater Aquaculture Research Unit in Stoneville, MS received the Federal Laboratory Consortium's (FLC) Impact Award for their research on producing a line of superior line of channel catfish called Delta Select.

Dr. Benjamin LaFrentz of the Aquatic Animal Health Research Unit in Auburn, AL received the American Fisheries Society Fish Health Section Award of Excellence for his achievement of excellence as the Awards Committee Chair.

Research Results

The following section summarizes the specific research results addressing objectives in the current NP106 Action Plan.

Component 1: Improving the Efficiency and Sustainability of Catfish Aquaculture

Problem Statement 1A: Improve Catfish Aquaculture Production Efficiency

New catfish line out-performs again. U.S. catfish farmers need lower production costs to compete in the global seafood market. ARS released the Delta Select line of channel catfish, which has improved growth and meat yield compared to other channel catfish lines. to fish farmers in 2020. After the Delta Select line release, ARS researchers at Stoneville, Mississippi, continued two more generations of Delta Select breeding and produced a Delta Select line that is 75 percent larger than other population at 18 months old. This line showed the same level of meat yield and an improved resistance to disease. In response to continued performance improvement, positive feedback, and stakeholder requests, ARS released 150,000 Delta Select catfish to 8 of the 12 major catfish hatcheries in May 2024. The Delta Select line represented roughly half of the catfish fry produced at commercial hatcheries in spring 2024.

Controlling disease vectors in catfish production systems. In the late 1990s, the parasite *Bolbophorus damnificus* was identified as a cause of reduced profitability in commercially raised catfish in the southeastern United States. The life cycle of this parasite involves the American white pelican, aquatic snails, and fish. Control strategies developed by ARS researchers in Stoneville, Mississippi, have focused on eradicating snail hosts from the culture environment. Previous studies demonstrated that four weekly low-dose treatments of copper are as effective as a single high-dose treatment. However, in a commercial setting, applying multiple treatments across large farms is logistically difficult. ARS researchers at Mississippi State University developed a mechanized system for delivering granular copper sulfate that enables the precise application of a targeted dose along pond margins in a single pass. This innovation increases the safety margins of copper sulfate treatments and dramatically facilitates treatment application.

Developing techniques to understand the pond microbial community. Catfish aquaculture ponds are highly influenced by their microbial communities, which can impact dissolved oxygen and ammonia concentration, fish flavor, and catfish pathogens. ARS researchers at Stoneville, Mississippi, isolated DNA from catfish pond water and used a new DNA sequencing technology to identify the bacterial species present. The team discovered 1,488 genera of bacteria in the ponds and found that samples became more diverse as the catfish production season came to an end in the autumn. These data also indicated that different isolation techniques are needed to find bacteria responsible for the nitrogen cycle and that are useful for monitoring and predicting the pond's ability to assimilate ammonia. The experiments demonstrated the feasibility of this approach to measure the distribution of catfish pond microbes to correlate the microbial populations with conditions that optimize fish production.

Relevant Publications:

Older, C.E., Richardson, B.M., Wood, M.L., Waldbieser, G.C., Ware, C., Griffin, M.J., Ott, B.D. 2023. Evaluating nanopore sequencing for microbial community characterization in catfish pond water. Journal of the World Aquaculture Society. 55:289-301. https://doi.org/10.1111/jwas.13002.

Older, C.E., Yamamoto, F.Y., Griffin, M.J., Ware, C., Heckman, T.I., Soto, E., Bosworth, B.G., Waldbieser, G.C. 2023. Comparison of high-throughput sequencing methods for bacterial microbiota profiling in catfish aquaculture. North American Journal of Aquaculture. 86:39-54. https://doi.org/10.1002/naaq.10309.

Improving commercial hybrid catfish production. Hybrid (channel crossed with blue) catfish constitute a significant portion of U.S. catfish production, but manual labor is needed to obtain and mix sperm and eggs and then efficiently culture the embryos to hatching stage. ARS researchers at Stoneville, Mississippi, worked with commercial hatcheries to demonstrate that a single-step fertilization of eggs in water that contained Fuller's earth (a clay product used to reduce egg stickiness) was as efficient as fertilization in water with Fuller's earth added afterward. This can save significant time during the short window of opportunity for hybrid production. The researchers also found that reducing the amount of sperm used by 75 percent did not affect fry production rates. This can significantly reduce the number of blue catfish males required for hybrid production and free broodstock holding ponds for rearing more hybrid fry, thus increasing production efficiency on commercial catfish farms.

Additional Problem Statement Publications:

Asche, F., Garlock, T., Camp, E., Guiillen, J., Kumar, G., Llorente, I., Shamshak, G. 2022. Market opportunities for U.S. aquaculture producers: The case of Branzino. Marine Resource Economics. 37(2):221-233. https://doi.org/10.1086/718437.

Bosworth, B.G., Waldbieser, G.C., Engle, C., Kumar, G. 2023. Effects of sex ratio, broodfish stocking density, and postspawn broodfish holding-pond density on reproductive efficiency in pond-spawned channel catfish. North American Journal of Aquaculture. 86:130-140. https://doi.org/10.1002/naaq.10321.

Gerhart, B.J., Mischke, C.C., Llen, P.J. 2023. Growth, condition factor, and survival of juvenile channel (*Ictalurus punctatus*), blue (*I. furcatus*), and hybrid (*I. punctatus* x *I. furcatus*) catfish at moderate and high temperatures. Journal of the World Aquaculture Society. 55:302-311. https://doi.org/10.1111/jwas.13038.

Ghosh, K., Hanson, T., Robinson, D., Bugg, W., Chatakondi, N., Kumar, G., Jeffers, C.D., Dunham, R.A. 2022. Economic Effect of Hybrid Catfish (Channel Catfish × Blue Catfish) Growth Variability on Traditional and Intensive Production Systems. North American Journal of Aquaculture. 84(1):25-41. https://doi.org/10.1002/naaq.10211.

Hegde, S., Kumar, G., Engle, C., Avery, J., Johnson, J., Aarattuthodiyil, S., Van Senten, J. 2022. Production economic relationships in intensive U.S. catfish production systems. Aquaculture Economics & Management. 26(3):314-331. https://doi.org/10.1080/13657305.2022.2038720.

Kumar, G., Engle, C., Van Senten, J., Sun, L., Hedge, S., Richardson, B.M. 2023. Resource productivity and costs of aquaculture practices: Economic-sustainability perspectives from U.S. catfish farming. Aquaculture Economics & Management. 574:739715. https://doi.org/10.1016/j.aquaculture.2023.739715.

Ott, B.D., Torrans, E.L., Allen, P.J. 2022. Design of a Vacuum Degassing Apparatus to Reduce Nitrogen Supersaturation and Maintain Hypoxia in Well-Water. North American Journal of Aquaculture. https://doi.org/10.1002/naaq.10263.

Ott, B.D., Chisolm, D.O., Griffin, M.J., Torrans, E.L., Allen, P.J. 2023. Effect of hypoxia duration and pattern on channel catfish (*Ictalurus punct*atus) neuropeptide gene expression and hematology. Journal of Comparative Physiology. 193:631-645. https://doi.org/10.1007/s00360-023-01521-5.

Ott, B.D., Torrans, E.L., Griffins, M.J., Allen, P.J., Duke, M.V., Peterson, B.C., Scheffler, B.E., Hulse-Kemp, A.M. 2024. Hypothalamic Transcriptome Response To Simulated Diel Earthen Pond Hypoxia Cycles In Channel Catfish (*Ictalurus punctatus*). Physiological Genomics. https://doi.org/10.1152/physiolgenomics.00007.2024.

Problem Statement 1B: Reduce the Impacts of Disease in Catfish Aquaculture

Flavobacterium covae is the predominant species of columnaris-causing bacteria in the U.S. catfish industry. Columnaris disease is one of the largest contributors to disease losses for catfish farmers in the southeastern United States. The term ‘columnaris-causing bacteria’ (CCB) has been coined in reference to the four recently described species that cause columnaris disease: *Flavobacterium columnare*, *F. covae*, *F. davisii*, and *F. oreochromis*. Historically, *F. columnare*, *F. covae*, and *F. davisii* have been isolated from columnaris disease cases in the catfish industry. However, the CCBs most severely impacting the industry and their virulence in channel catfish were not known. ARS researchers in Auburn, Alabama, and university collaborators determined the species of CCB implicated in 259 columnaris disease cases in Mississippi and Alabama. The results demonstrated that *F. covae* is the predominant CCB impacting the catfish industry and these data were supported by laboratory infection experiments demonstrating *F. covae* causes more mortality in catfish than *F. columnare* and *F. davisii*. Collectively, these results demonstrate *F. covae* is the predominant CCB in the U.S. catfish industry and research aimed at developing new prevention and control strategies targeting this bacterial species should be more effective in combatting columnaris.

Relevant Publication:

LaFrentz, B.R., Khoo, L.H., Lawrence, M.L., Petrie-Hanson, L., Hanson, L.A., Baumgartner, W.A., Hemstreet, W.G., Kelly, A.M., Garcia, J.C., Shelley, J.P., Johnston, A.E., Bruce, T.J., Griffin, M.J. 2024. *Flavobacterium covae* is the predominant species of columnaris causing bacteria impacting the channel catfish (*Ictalurus punctatus*) industry in the southeastern USA. Journal of Aquatic Animal Health. 36:3-15. https://doi.org/10.1002/aah.10207.

Additional Problem Statement Publications:

Aksoy, M., Eljack, R.M., Aksoy, J., Beck, B.H. 2023. Frass from black soldier fly larvae, *Hermetia illucens*, as a possible functional dietary ingredient on channel catfish feed. Fishes. 8(11):542. https://doi.org/10.3390/fishes8110542.

Bosworth, B.G., Koshy, M., Ware, C., Yamamoto, F., Byars, T., Griffin, M., Wise, D. 2024. Susceptibility of delta select and delta control channel catfish lines to experimental *Edwardsiella ictaluri* and *Edwardsiella piscicida* infection. North American Journal of Aquaculture. https://doi.org/10.1002/naaq.10338.

Older, C.E., Griffin, M.J., Richardson, B.M., Waldbieser, G.C., Reifers, J.G., Goodman, P.M., Ware, C., Gatlin Iii, D.M., Wise, D.J., Yamamoto, F.Y. 2023. Influence of probiotic and prebiotic supplementation on intestinal microbiota and resistance to *Edwardsiella ictaluri* infection in channel catfish (*Ictalurus punctatus*) following florfenicol administration. Journal of Fish Diseases. 47(4):e13910. https://doi.org/10.1111/jfd.13910.

Quiniou, S., Bengten, E., Boudinot, P. 2024. Costimulatory receptors in the Channel catfish: CD28 family members and their ligands. Immunogenetics. 76:51-67. https://doi.org/10.1007/s00251-023-01327-3

Sankappa, N.M., Kallappa, G.S., Boregowda, K., Ramachandra, N.M., Suresh, P.K., Balakrishna, D.S., Ballamoole, K.K., Thangavel, S., Sahoo, L., Lange, M.D., Deshotel, M.B., Abernathy, J.W. 2024. Novel lytic bacteriophage AhFM11 as an effective therapy against hypervirulent *Aeromonas hydrophila*. Scientific Reports. 14:16882. https://doi.org/10.1038/s41598-024-67768-2.

Sankappa, N.M., Lange, M.D., Aksoy, M., Eljack, R.M., Kucuktas, H., Beck, B.H., Abernathy, J.W. 2024. Transcriptome analysis and immune gene expression of channel catfish (*Ictalurus punctatus*)

fed diets with inclusion of frass from black soldier fly larvae. Frontiers in Physiology. 14:1330368. https://doi.org/10.3389/fphys.2023.1330368.

Stilwell, J., Camus, A., Ware, C., Walker, C., Stanton, J., Leary, J., Khoo, L., Wise, D., Waldbieser, G.C., Griffin, M. 2023. Influence of channel catfish (*Ictalurus punctatus*) and channel x blue catfish (*I. furcatus*) hybrids on myxozoan community composition in catfish aquaculture ponds. North American Journal of Aquaculture. 85:242-251. https://doi.org/10.1002/naaq.10293

Wise, A.L., LaFrentz, B.R., Kelly, A.M., Liles, M.R., Griffin, M.J., Beck, B.H., Bruce, T.J. 2024. Coinfection of channel catfish (*Ictalurus punct*atus) with virulent *Aeromonas hydrophila* and *Flavobacterium covae* exacerbates mortality. Journal of Fish Diseases. 2024:e13912. https://doi.org/10.1111/jfd.13912.

Zhang, D., Zu, G., Thongda, W., Li, C., Ye, Z., Zhao, H., Beck, B.H., Mohammed, H., Peatman, E. 2023. Early divergent responses to virulent and attenuated vaccine isolates of *Flavobacterium covae* sp. nov. In channel catfish, *Ictalurus punctatus*. Fish and Shellfish Immunology. 144:109248. https://doi.org/10.1016/j.fsi.2023.109248.

Problem Statement 1C: Improve Catfish Product Quality

Problem Statement Publications:

Dupre, R.A., Smith, B., Lloyd, S.W., Trushenski, J. 2024. Improved quantification of geosmin and 2-methylisoborneol in farmed fish using stable isotope dilution GC-MS. Journal of Agricultural and Food Chemistry. https://doi.org/10.1021/acs.jafc.3c08130.

Component 2: Improving the Efficiency and Sustainability of Salmonid Aquaculture

Problem Statement 2A: Improve Salmonid Aquaculture Production Efficiency and Ensure Product Quality

Using artificial intelligence for rapid, real-time evaluation of fish fillet color. The color of salmon fillets is an important quality influencing consumer choice, so salmon producers expend considerable effort to ensure their products have the fillet color that appeals to retail and wholesale customers. However, traditional methods used to quantify the color of salmon fillets are time-consuming, subjective, and often unreliable. Extramural ARS scientists in Shepherdstown, West Virginia, used a state-of-the-art, one-stage convolutional neural network model to develop an artificial intelligence

(AI)-enabled handheld device for rapid, accurate, objective, and real-time color evaluation of salmon fillets. Known as ‘FilletCam AI’, this technology saves producers and processors time and effort and provides a reliable and efficient assessment of fillet color.

Compost derived from aquaculture waste solids. The economic viability of land-based fish farms using recirculating aquaculture system (RAS) technologies can be supported by research that converts farm waste materials into marketable products. Converting waste solids into compost products can provide farmers with additional revenue and prevent waste from potentially impacting the environment. Extramural ARS scientists in Shepherdstown, West Virginia, developed protocols to convert aquaculture solids to compost and demonstrated that compost derived from aquaculture solids is not toxic to plants, has very low concentrations of heavy metals and human pathogens, and contains little to no PFAS (i.e., below the limit of quantification, and for the most part below the level of detection). These results will assist RAS farmers with developing additional revenue by producing marketable compost and will assure RAS farmers and customers regarding the safety and quality of aquaculture solids-derived compost.

Problem Statement Publications:

Ahmed, R.O., Ali, A., Leeds, T.D., Salem, M. 2023. RNA-Seq analysis of the pyloric caecum, liver, and muscle reveals molecular mechanisms regulating fillet color in rainbow trout. BMC Genomics. 24:579. https://doi.org/10.1186/s12864-023-09688-5.

Crouse, C., Knight, A., May, T., Davidson, J., Good, C. 2023. Performance, processing yields, and fillet composition of specific United States diploid and triploid rainbow trout (*Oncorhynchus mykiss*) lines reared in a semi-commercial scale freshwater recirculating aquaculture system. Aquaculture Reports. 33:101794. https://doi.org/10.1016/j.aqrep.2023.101794.

Davidson III, J., Schrader, K., May, T., Knight, A., Harries, M.D. 2023. Evaluating the feasibility of feeding RAS-produced Atlantic salmon (*Salmo salar*) during the depuration process: Effects on fish weight loss and off-flavor remediation. Journal of Applied Aquaculture. https://doi.org/10.1080/10454438.2023.2259892.

Delomas, T.A., Hollenbeck, C.M., Matt, J.L., Thompson, N.F. 2024. Microhaplotypes generate higher breeding value accuracy compared to SNPs for imputation-based breeding strategies. Aquaculture. 586:740779. https://doi.org/10.1016/j.aquaculture.2024.740779.

Freij, K., Cleveland, B.M., Biga, P. 2024. Maternal dietary choline levels cause transcriptome shift due to genotype-by-diet interactions in Rainbow Trout (*Oncorhynchus mykiss*). Comparative Biochemistry and Physiology, Part D: Genomics and Proteomics. 49:101193. https://doi.org/10.1016/j.cbd.2024.101193.

Gao, G., Waldbieser, G.C., Ramey, Y.C., Zaho, D., Pietrak, M.R., Stannard, J.A., Buchman, J.T., Scheffler, B.E., Peterson, B.C., Palti, Y., Rexroad III, C.E., Long, R., Burr, G.S., Milligan, M.T. 2023. The generation of the first chromosome-level de-novo genome assembly and the development and validation of a 50K SNP array for the St. John River aquaculture strain of North American Atlantic salmon. G3, Genes/Genomes/Genetics. jkad138. https://doi.org/10.1093/g3journal/jkad138.

Habte-Tsion, H.M., Hawkyard, M., Sealey, W.M., Bradshaw, D., Meesala, K., Bouchard, D. 2024. Effects of fishmeal substitution with mealworm meals (*Tenebrio molitor* and *Alphitobius diaperinus*) on the growth, physiobiochemical response, digesta microbiome, and immune genes expression of

Atlantic salmon. Aquaculture Nutrition. 2024(1). Article 6618117. https://doi.org/10.1155/2024/6618117.

Hargrove, J.S., Delomas, T.A., Powell, J.H., Hess, J.E., Narum, S.R., Campbell, M.R. 2023. Efficient population representation with more genetic markers increases performance of a steelhead (*Oncorhynchus mykiss*) genetic stock identification baseline. Evolutionary Applications. 17(2):e13610. https://doi.org/10.1111%2Feva.13610.

Hong, J., Ortiz, J.G., Sealey, W.M., Small, B.C. 2023. Effects of dietary arachidonic acid supplementation in low fishmeal and fish oil-free diets on growth performance, inflammatory response, gut histology, and non-specific immunity in sub-adult rainbow trout, *Oncorhynchus mykiss*. Aquaculture. 580. Article 740272. https://doi.org/10.1016/j.aquaculture.2023.740272.

Idenyi, J.N., Abanikannda, M., Huber, D.H., Gannam, A., Sealey, W.M., Eya, J.C. 2023. Genome-wide insights into whole gut microbiota of rainbow trout, *Oncorhynchus mykiss*, fed plant proteins and camelina oil at different temperature regimens. Journal of the World Aquaculture Society. 55(2). Article e13028. https://doi.org/10.1111/jwas.13028.

Kajbaf, K., Overturf, K.E., Kumar, V. 2024. Integrated alternative approaches to select feed-efficient rainbow trout families to enhance the plant protein utilization. Scientific Reports. 14. Article 3869. https://doi.org/10.1038/s41598-024-54218-2.

Legacki, E.L., Peterson, B.C., Boggs, A. 2023. Using skin mucus for the identification of ovulation biomarkers in North American Atlantic salmon (*Salmo salar*). Aquaculture. https://doi.org/10.1016/j.aquaculture.2023.739717.

Owens, C.E., Powell, M.S., Gaylord, T., Conley, Z.B., Sealey, W.M. 2024. Investigation of the suitability of 3 insect meals as protein sources for rainbow trout (*Oncorhynchus mykiss*). Journal of Economic Entomology. 117(4):1254-1260. https://doi.org/10.1093/jee/toae037.

Weber, G.M. 2023. Effects of IGF1 on in vitro ovarian follicle maturation in rainbow trout (*Oncorhynchus mykiss*). Fishes. 8(7):367. https://doi.org/10.3390/fishes8070367.

Welker, T.L., Barrows, F.T. 2023. Improved fecal particle size profile in rainbow trout fed feeds containing different ratios of animal meal and plant protein concentrates: Effect on nitrogen and phosphorus partitioning. North American Journal of Aquaculture. 86(1):84-94. https://doi.org/10.1002/naaq.10315.

Welker, T.L., Overturf, K.E. 2023. Effect of dietary soy protein source on effluent water quality and growth performance of rainbow trout reared in a serial reuse water system. Animals. 13(19). Article 3090. https://doi.org/10.3390/ani13193090.

Problem Statement 2B: Reduce the Impacts of Disease in Salmonid Aquaculture

A novel test for detecting risk factors in salmonoid fish health. Fish farmers need faster methods to assess animal health and wellbeing. ARS researchers at Leetown, West Virginia, and collaborators from St. George's University and a private company found seven proteins present in rainbow trout that correlate with bacterial infection. The researchers developed a test to detect these proteins that can be completed in 2 hours or less and only requires a small amount of blood from fish. The test is commercially available, providing fish farmers with a fast method to assess rainbow trout and Atlantic salmon health during production.

Relevant Publication:

Wiens, G.D., Marancik, D.P., Chadwick, C.C., Osbourn, K.E., Reid, R.M., Leeds, T.D. 2023. Plasma proteomic profiling of bacterial cold-water disease resistant and susceptible rainbow trout lines and biomarker discovery. Frontiers in Immunology. 14. https://doi.org/10.3389/fimmu.2023.1265386.

Characterizing genetic regulation of IHNV disease resistance in rainbow trout. Infectious hematopoietic necrosis (IHN) is a disease of salmonid fish that is caused by the IHN virus (IHNV). Under intensive aquaculture conditions, IHNV can cause significant mortality and economic losses. Currently, there is no proven and cost-effective method for IHNV control. In collaborative research with multiple institutions and industry, ARS researchers in Leetown, West Virginia, found that genetic resistance to IHNV is controlled by the inheritance of several moderate-effect quantitative trait loci (QTL) and many small effect loci in three commercial rainbow trout breeding populations that are widely used by the U.S. aquaculture industry. The trait was found to be moderately heritable, indicating that selective breeding can be used to improve resistance to IHN disease in commercial rainbow trout populations.

Additional Problem Statement Publications:

Abraham, T., Yazdi, Z., Littman, E., Shahin, K., Heckman, T.I., Quijano Cardé, E., Nguyen, D., Hua, R., Soto, E., Adkison, M., Veek, T., Mukkatira, K., Richey, C., Kwak, K., Mohammed, H., Ortega, C., Avendaño-Herrera, R., Hyatt, M.W., Keleher, W., Welch, T.J. 2023. Detection Of *Lactococcus* spp. in environmental samples and wild fish from Four Lakes in Southern California. Journal of Aquatic Animal Health. 35(3):129-198. https://doi.org/10.1002/aah.10188.

Cain, K.D., Polinski, M.P. 2023. Infectious Diseases of Coldwater Fish in Fresh Water. In: Woo, P.T.K., Subasinghe, R.P., editors. Climate Change on Diseases and Disorders of Finfish in Cage Culture. 3rd edition. Oxfordshire, London: CAB International. p. 76-124.

Cisar, J.O., Wang, X., Woods, R.J., Cain, K.D., Wiens, G.D. 2024. Structural and genetic basis for the binding of a mouse monoclonal antibody to *Flavobacterium psychrophilum* lipopolysaccharide. Journal of Fish Diseases. Article e13958. https://doi.org/10.1111/jfd.13958.

Graf, J., Testerman, T., Varga, J., Donohue, H., Vieira Da Silva, C., Schiffer, M. 2023. *Pseudomonas aphyarum* sp. nov., *Pseudomonas fontis* sp. nov., *Pseudomonas idahonensis* sp. nov. and *Pseudomonas rubra* sp. nov., isolated from in, and around, a rainbow trout farm. International Journal of Systematic and Evolutionary Microbiology. 73(12):006201. https://doi.org/10.1099/ijsem.0.006201.

Palti, Y., Vallejo, R.L., Purcell, M., Gao, G., Shewbridge, K., Long, R., Setzke, C., Fragomeni, B., Cheng, H., Martin, K., Naish, K. 2024. Genome-wide association analysis of the resistance to infectious hematopoietic necrosis virus in two aquaculture rainbow trout strains confirms oligogenic architecture with several moderate effect quantitative trait loci. Frontiers in Genetics. 15:1394656. https://doi.org/10.3389/fgene.2024.1394656.

Polinski, M.P., Gross, L., Marty, G.D., Garver, K.A. 2022. Heart inflammation and piscine orthoreovirus genotype-1 in Pacific Canada Atlantic salmon net-pen farms: 2016-2019. BMC Veterinary Research. https://doi.org/10.1186/s12917-022-03409-y.

Rounsville, T., Polinski, M.P., Marini, A., Turner, S., Vendramin, N., Cuenca, A., Pietrak, M.R., Peterson, B.C., Bouchard, D. 2024. Rapid differentiation of infectious salmon anemia virus avirulent (HPR0) from virulent (HPR) variants using multiplex RT-qPCR. Journal of Veterinary Diagnostic Investigation. 36(3):329-337. https://doi.org/10.1177/10406387231223290.

Thunes, N.C., Evenhuis, J., Lipscomb, R.S., Perez-Pascual, D., Stevick, R.J., Birkett, C., Ghigo, J., Mcbride, M.J. 2024. Gliding motility proteins GldJ and SprB contribute to *Flavobacterium columnare* virulence. Applied and Environmental Microbiology. 206(4). https://doi.org/10.1128/jb.00068-24.

Vallejo, R.L., Pietrak, M.R., Milligan, M.T., Gao, G., Tsuruta, S., Fragomeni, B.O., Long, R., Peterson, B.C., Palti, Y. 2024. Genetic architecture and accuracy of predicted genomic breeding values for sea lice resistance in the St John River aquaculture strain of North American Atlantic salmon. Aquaculture. 586:740819. https://doi.org/10.1016/j.aquaculture.2024.740819.

Component 3: Improving the Efficiency and Sustainability of Hybrid Striped Bass Aquaculture

Problem Statement 3A: Enhance Hybrid Striped Bass Aquaculture Production

Hybrid striped bass fed an all-plant protein diet grown successfully to market size. Commercially formulated feeds for hybrid striped bass typically contain about 10-20 percent marine fish meal, an expensive and limited animal protein source. Although hybrid striped bass can be grown to market size equally well on combined animal-plant protein-based (fishmeal-free) and fishmeal-based feeds, growth to market size has not been evaluated when fish are fed an all-plant protein-based feed. ARS researchers at Stuttgart, Arkansas, in collaboration with an ARS researcher at Oxford, Mississippi, and a U.S. Fish and Wildlife Service scientist in Bozeman, Montana, formulated a fishmeal-based and an all-plant protein-based feed and compared hybrid striped bass performance when grown to market size in earthen ponds managed according to industry standards. Results showed that fish fed the all-plant protein-based feed grew equally well as those fed the fishmeal-based feed.

Problem Statement Publications:

Andersen, L.K., Abernathy, J.W., Farmer, B.D., Lange, M.D., Mcentire, M.E., Rawles, S.D. 2024. Gene expression profiles of white bass (*Morone chrysops*) and hybrid striped bass (*M. chrysops* x *M. saxatilis*) gill tissue following *Flavobacterium covae* infection. Comparative Immunology Reports. 6:200144. https://doi.org/10.1016/j.cirep.2024.200144.

Farmer, B.D., Straus, D.L., Deshotel, M.B., Fuller, S.A., Reading, B.J., Meinelt, T. 2023. Antiparasitic effects of peracetic acid on striped bass infested with *Trichodina* spp. North American Journal of Aquaculture. 86:287-294. https://doi.org/10.1002/naaq.10332.

Fuller, S.A., Abernathy, J.W., Sankappa, N., Beck, B.H., Rawles, S.D., Green, B.W., Rosentrater, K.A., McEntire, M.E., Huskey Jr, G., Webster, C.D. 2024. Hepatic transcriptome analyses of juvenile white bass (*Morone chrysops*) when fed diets where fish meal is partially or totally replaced by alternative protein sources. Frontiers in Physiology. 14. Article 1308690. https://doi.org/10.3389/fphys.2023.1308690.

Green, B.W., Rawles, S.D., Gaylord, T., Schrader, K., McEntire, M.E., Webster, C.D. 2023. Performance of phytase-treated fishmeal-free and all-plant protein diets in pond production of market sized hybrid striped bass. Aquaculture. 577. Article 740006. https://doi.org/10.1016/j.aquaculture.2023.740006.

Rajab, S., Andersen, L.K., Kenter, L.W., Berlinsky, D.L., Borski, R.J., Mcginty, A.S., Ashwell, C.M., Ferket, P.R., Daniels, H.V., Reading, B.J. 2024. Combinatorial metabolomic and transcriptomic analysis of muscle growth in hybrid striped bass (female white bass *Morone chrysops* x male striped bass *M. saxatilis*). BMC Genomics. 25:580. https://doi.org/10.1186/s12864-024-10325-y.

Straus, D.L., Abernathy, J.W., Kelly, A.M., Quintero, H.E., Freeze, T., Williams, R.S. 2024. Initial investigations into the production of triploid sunshine bass using temperature shock. North American Journal of Aquaculture. 86:234-241. https://doi.org/10.1002/naaq.10329.

Component 4: Enhancing Shellfish Aquaculture

Problem Statement 4A: Enhance Shellfish Aquaculture Production

Reducing the cost of genetic improvement in aquaculture. Many shellfish breeders cannot implement state of the art genetic improvement technologies due to high implementation costs. ARS researchers in Newport, Oregon, and Kingston, Rhode Island, and collaborators at Texas A&M Corpus Christi developed a new, cost-effective genotyping platform that facilitates using genomic selection to breed for more rapid genetic gains in a number of species and increase farmer access to genetically improved animals.

Relevant Publication:

Guo, X., Puritz, J., Zhenwei, W., Proestou, D.A., Allen, S., Small, J., Verbyla, K., Zhao, H., Haggard, J., Chriss, N., Zeng, D., Markey Lundgren, K.R., Allam, B., Bushek, D., Gomez-Chiarri, M., Hare, M., Hollenbeck, C., Lapeyre, J., Liu, M., Lotterhos, K., Plough, L., Rawson, P., Rikard, S., Sallient, E., Varney, R., Wikfors, G., Wilbur, A. 2023. Development and evaluation of high-density SNP arrays for the eastern oyster *Crassostrea virginica*. Marine Biotechnology. https://doi.org/10.1007/s10126-022-10191-3.

Non-destructive tissue sampling method for eastern oyster. ARS scientists in Kingston, Rhode Island, developed an anesthesia and biopsy protocol for routine use in experimental physiology, pathology, and genetics research. Age did not affect the ability to sample or oyster survival; however, multiple biopsies one week apart did reduce survival slightly. This method offers an effective technique for sampling tissue from live eastern oysters and has important implications for advancing genetic improvement through precision phenotyping and genomic selection.

Additional Problem Statement Publications:

Bruce, T.J., Abernathy, J.W., Tripp, N., Barnes, N., Harrison, C.E., Oladipupo, A.A., Krol, J.D., Wise, A.L., Warg, J.V., Stoeckel, J.A. 2023. White spot syndrome virus (WSSV) in Alabama red swamp crayfish (*Procambarus clarkii*). Journal of Fish Diseases. 47(2):e13873. https://doi.org/10.1111/jfd.13873.

Delomas, T.A., Willis, S.C. 2023. Estimating microhaplotype allele frequencies from low-coverage or pooled sequencing data. Bioinformatics. https://doi.org/10.1186/s12859-023-05554-z.

Dumbauld, B.R., Mc Intyre, B.A. 2023. Influence of seagrass on juvenile Pacific oyster growth in two US west coast estuaries with different environmental gradients. Aquaculture Environment Interactions. 15:287-306. https://doi.org/10.3354/aei00466.

Proestou, D.A., Sullivan, M.E., Markey Lundgren, K.R., Ben-Horin, T., Witkop, E.M., Hart, K.M. 2023. Understanding *Crassostrea virginica* tolerance of *Perkinsus marinus* through global gene expression analysis. Frontiers in Genetics. https://doi.org/10.3389/fgene.2023.1054558.

Proestou, D.A., Delomas, T.A., Sullivan, M.E., Markey Lundgren, K.R. 2024. Sex-specific gene expression in eastern oyster gonad and mantle tissues. Invertebrate Biology. 143(1):e12418. https://doi.org/10.1111/ivb.12418.

Puritz, J., Guo, X., Hare, M., He, Y., Hillier, L., Jin, S., Liu, M., Lotterhos, K., Minx, P., Modak, T., Proestou, D.A., Rice, E., Tomlison, C., Warren, W., Witkop, E., Zhao, H., Gomez-Chiarri, M. 2023. A second unveiling: haplotig masking of the eastern oyster genome improves population-level inference. Molecular Ecology Resources. https://doi.org/10.1111/1755-0998.13801.

Sutherland, B.J., Thompson, N., Surry, L.B., Gujjula, K., Carrasco, C.D., Chadaram, S., Lunda, S.L.,

Langdon, C.J., Chan, A.M., Suttle, C.A., Green, T.J. 2024. An amplicon panel for high-throughput and low-cost genotyping of Pacific oyster. G3, Genes/Genomes/Genetics. Article jkae125. https://doi.org/10.1093/g3journal/jkae125.

Thompson, N., Agnew, M.V., Calla, B., Burge, C.A. 2024. Assessing selection potential for Pacific oyster (*Crassostrea gigas*) to a North American OsHV-1 µvar: Comparing two experimental assay methods. Aquaculture. 590. Article 741076. https://doi.org/10.1016/j.aquaculture.2024.741076.

Component 5: Developing Marine Finfish Seedstocks

Problem Statement 5A: Develop Marine Finfish Seedstocks Optimized for Aquaculture Production Efficiency

Year-round spawning of California yellowtail. Marine finfish aquaculture has been hindered by a limited, year-round supply of juveniles, so more juveniles are needed for consistently restocking and maintaining farm operations at an economical scale. ARS researchers at Fort Pierce, Florida, and collaborators at Hubbs Sea World Research Institute in San Diego, California, established out-of-season spawning techniques and methods for rearing California yellowtail larvae, which extended the spawning season by 5 months. This research provides another tool to increase product availability for California yellowtail by extending the amount of time high-quality seedstock can be accessed.

Economic scenarios indicate profitability for marine aquaculture in the US. Increased interest in marine fish farming in the United States has led to a need for fundamental economic information on production of candidate species for commercialization in various production systems. ARS funded scientists at Virginia Tech University conduced economic analyses that determined costs were lowest for net pen production, followed by ponds, with production costs in recirculating aquaculture systems being greater. The analyses indicated profitability for production of redfish, striped bass, cobia, red snapper, and seriolid species such as California yellowtail in net pens and profitable production of redfish, hybrid drum, black sea bass, and cobia in ponds. Due to a lack of comprehensive data on growout production of marine finfish species in the US, there is a strong need for production trials conducted under near-commercial conditions with an endpoint of market-sized fish. Generation of this data will allow for an enhanced ability to develop economic optimization models to guide prospective producers.

Relevant Publication:

Engle, RE, Boldt, NC, van Senten, J, Schwarz, M. Estimating growout production costs of commercial-scale marine finfish production in southern tier US States. Journal of the World Aquaculture Society volume 55 Issue 4 2024 https://doi.org/10.1111/jwas.13075

Additional Problem Statement Publications:

Chin, L., Mejri, S., Wills, P., Stuart, K., Drawbridge, M. 2023. Influence of broodstock nutrition on egg quality and fatty acid composition in California Yellowtail. North American Journal of Aquaculture. 86:3-16. https://doi.org/10.1002/naaq.10318.

Pfeiffer, T.J., Baptiste, R.M., Wills, P.S. 2024. Fine solids removal by foam fractionation in a low-salinity recirculating aquaculture system for red drum juveniles, *Sciaenops ocellatus*. North American Journal of Aquaculture. https://doi.org/10.1002/naaq.10345.

Yamamoto, F.Y., Ellis, M., Bowles, P.R., Suehs, B.A., Carvalho, P.L., Older, C.E., Hume, M.E., Gatlin Iii, D.M. 2022. The supplementation of a commercial prebiotic, probiotic or their combination affected the production performance and intestinal microbiota of red drum *Sciaenops ocellatus* L. but did not modulate plasma innate immune response. Aquaculture. https://doi.org/10.3390/ani12192629.

Component 6: Developing Sustainable Aquaponic Production Systems

Problem Statement 6A: Optimize Aquatic Animal Species Production Systems for Aquaponics

Publications:

James, J., Dahl, S., Teichert-Coddington, D., Kelly, A., Creel, J., Beck, B.H., Butts, I., Roy, L. 2024. Cohabitation of red swamp crayfish (*Procambarus clarkii*) and Pacific white shrimp (*Litopenaeus vannamei*) cultured in low salinity water. Aquaculture Reports. 36:102081.

https://doi.org/10.1016/j.aqrep.2024.102081.

Padeniya, U., Davis, D., Liles, M.R., LaFrentz, S.A., LaFrentz, B.R., Shoemaker, C.A., Beck, B.H., Wells, D.E., Bruce, T.J. 2023. Probiotics impact resistance to *Streptococcus iniae* in Nile tilapia (*Oreochromis niloticus*) reared in biofloc systems. Journal of Fish Diseases. 46:1137-1149. https://doi.org/10.1111/jfd.13833.

Problem Statement 6B: Optimize Plant Production Systems for Aquaponics

Problem Statement Publications:

Romano, N., Webster, C.D., Datta, S.N., Pande, S.J., Fischer, H., Sinha, A., Huskey Jr, G., Rawles, S.D., Francis, S. 2023. Black soldier fly (*Hermetia illucens*) frass on sweet-potato (*Ipomea batatas*) slip production with aquaponics. Horticulturae. 9. Article 1088. https://doi.org/10.3390/horticulturae9101088.

Problem Statement 6C: Optimize the Integration of Fish and Plant Production Systems

Problem Statement Publications:

Kalvakaalva, R., Prior, S.A., Smith, M., Runion, G.B., Ayipio, E., Blanchard, C., Wall, N., Wells, D., Hanson, T.R., Higgins, B.T. 2022. Direct greenhouse gas emissions from a commercial pilot-scale aquaponics system. Journal of the ASABE. 65(6):1211-1223. https://doi.org/10.13031/ja.15215.

Kalvakaalva, R., Smith, M., Ayipio, E., Blanchard, C., Prior, S.A., Runion, G.B., Wells, D., Blersch, D., Adhikari, S., Prasad, R., Hanson, T., Wall, N., Higgins, B.T. 2023. Mass-balance process model of a decoupled aquaponic system. Journal of the ASABE. 66(4):955-967. https://doi.org/10.13031/ja.15468.

Kalvakaalva, R., Smith, M., Prior, S.A., Runion, G.B., Ayipio, E., Blanchard, C., Wells, D., Blersch, D., Adhikari, S., Prasad, R., Hanson, T., Higgins, B.T. 2023. Life cycle assessment of a decoupled biofloc aquaponics facility across seasons. Journal of Cleaner Production. 429:139356. https://doi.org/10.1016/j.jclepro.2023.139356.

Additional Research

Publications:

Anantapantula, S.S., Wilson, A.E. 2023. Most treatments to control freshwater algal blooms are not effective: Meta-analysis of field experiments. Water Research. 243(5):120342. https://doi.org/10.1016/j.watres.2023.120342.

Andersen, L.K., Reading, B.J. 2023. A supervised machine learning workflow for the reduction of highly dimensional biological data. Artificial Intelligence in the Life Sciences. 5:100090. https://doi.org/10.1016/j.ailsci.2023.100090.

Baylous, H.R., Gladfelter, M.F., Gardner, M.I., Foley, M., Wilson, A.E., Steffen, M.M. 2024. Indole-3-acetic acid promotes growth in bloom-forming Microcystis via an antioxidant response. Harmful Algae. 133:102575. https://doi.org/10.1016/j.hal.2024.102575.

Boudry, P., Allal, F., Aslam, L., Bargelloni, L., Bean, T.P., Brad-Fudulea, S., Brieuc, M.S., Calboli, F.C., Gilbey, J., Haffray, P., Lamy, J., Morvezen, R., Purcell, C., Prodohl, P.A., Vandeputte, M., Waldbieser, G.C., Sonesson, A.K., Houston, R.D. 2021. Current status and potential of genomic selection to improve selective breeding in the main aquaculture species of International Council for the Exploration of the Sea (ICES) member countries. Aquaculture Reports. 20:100700. https://doi.org/10.1016/j.aqrep.2021.100700.

Buley, R.P., Gladfelter, M.F., Fernandez-Figueroa, E.G., Wilson, A.E. 2023. Complex effects of dissolved organic matter, temperature, and initial bloom density on the efficacy of hydrogen peroxide to control cyanobacteria. Environmental Science and Pollution Research. 30:43991-44005. https://doi.org/10.1007/s11356-023-25301-4.

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