National Program 106 Aquaculture Annual Report for 2021

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.*

Mission: The mission of National Program (NP) 106, Aquaculture, is to conduct research and deliver technologies that improve domestic aquaculture production efficiency and product quality while minimizing impacts on natural resources.

The aim of the ARS Aquaculture Program is to support a safe and affordable domestic supply of seafood products for 330 million U.S. consumers that is produced in a healthy, competitive, and sustainable aquaculture sector; a sector supported by almost 3000 aquaculture farmers producing more than $1.5 billion farm gate value worth of goods annually. In 2019 the USDA National Agricultural Statistics Service (NASS) published the 2018 Census of Aquaculture updating these statistics for the first time since 2013. The report details many features of aquaculture in the United States, and shows that since 2005, the overall number of farms has dropped (from about 3093 to 2932 from 2013 to 2018). However, sales in 2018 increased to over $1.51 billion from 2013 level of $1.37 billion.

In fiscal year 2021 the ARS Office of National Programs contributed to many federal aquaculture activities, including:

- Leadership in the National Science and Technology Council (NSTC) Subcommittee on Aquaculture provided by an ARS Co-Chair, Executive Secretary and the Chair of the Science Planning Task Force developing the National Strategic Plan for Aquaculture Research;

- Assistance provided to USDA APHIS towards the development of the National Aquaculture Health Plan and Standards;

- Partnering with HeroX and NASA to award a prize challenge entitled, "Protecting the Natural Flavor of Catfish". A total of 589 participants from 48 countries formed into 29 teams making 85 submissions, with the top six prizes awarded;

- Contributing to Theme Teams led by the USDA Office of the Chief Scientist towards implementing the USDA Science Blueprint: A Roadmap for USDA Science from 2020 to 2025;

- Co-organizing the 2020 48th United States-Japan Natural Resources Aquaculture Workshop, presenting an overview on ARS Aquatic Animal Health research on pests, pathogens and mitigation strategies;

- Advising the USDA NIFA funded Agricultural Genomes to Phenomes Initiative, including invited field day presentations on Stakeholder Driven Research and Aquaculture;

- Partnering with USDA NIFA, National Oceanic and Atmospheric Administration (NOAA) and Harbor Branch Oceanographic Institute to publish a special issue of the Journal of the World Aquaculture Society containing 14 articles that describe the State of the Art for marine finfish aquaculture.

- Partnering with the USDA Office of the Chief Scientist to organize a series of virtual listening sessions titled, "***Aquaculture is Agriculture: USDA's Role in supporting Farmers of Fish, Shellfish and Aquatic Plants***." A white paper having 21 authors from 12 USDA Agencies or Offices details the USDA programs and summaries and input received from stakeholders, available online.

- Forming an interagency Federal Working Group in response to Congressional Guidance that will explore opportunities for reducing ocean acidification through the farming of seaweeds and seagrasses;

- Representing USDA on the OSTP Interagency Council for Advancing Meteorological Services Committee;

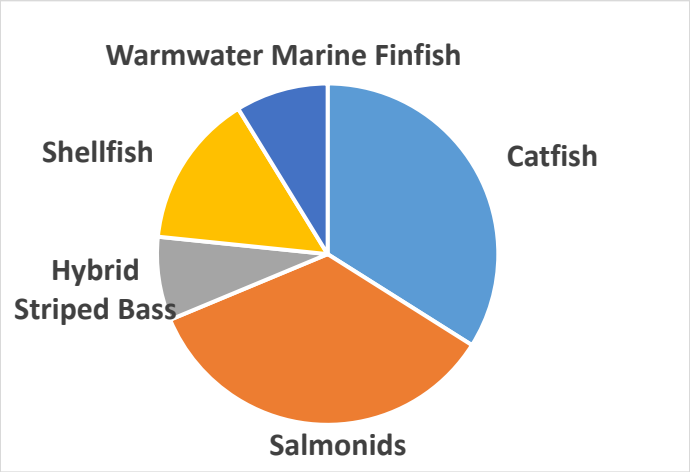
- Partnering with NOAA and USDA NIFA to respond to the Food and Agriculture Organization of the United Nations (FAO) Code of Conduct for Responsible Fisheries Questionnaire;

- Engaging with the Bureau of Labor and Statistics regarding inclusion of aquaculture products in the Producer Price Index; and

- Leading a team of U.S. aquaculture professionals that drafted the aquatic pathogen section of the Agricultural Biorisk Compendium.

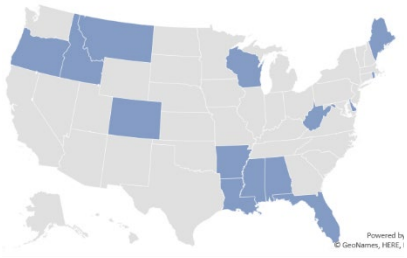
Fiscal year 2021 was the second year of externally-reviewed five-year project plans (2020- 2024) that fall under the six Components of the 2020 – 2024 Aquaculture National Program Action Plan which are:

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; and
5. Developing Marine Finfish Seedstocks.
6. Developing Sustainable Aquaponic Production Systems *(new)*



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

In 2021 NP106 conducted research at 11 main laboratories on 15 project plans including approximately 42 ARS scientists and University or private cooperators on 15 congressionally mandated agreements. During fiscal year 2021, ARS base funding for aquaculture research was approximately $47 million, not including approximately $166K from incoming grants and agreements.



Although project plans guide most of the efforts of the laboratories, we remain flexible to respond to unanticipated challenges and opportunities. NP 106 research covers the spectrum from fundamental to applied research and is focused on solving problems through long term high impact research. The 2020-2024 NP106 Action Plan was approved in 2018 and amended in 2019 and 2021 in response to new funding provided for research in warmwater marine finfish and aquaponics.

2021 NP 106 Technology transfer activities are summarized in **Table 1** below.

Mechanism	# New
Peer Reviewed Journal Articles	71
Material Transfer Research Agreements	5
Material Transfer Agreements	3
Invention Disclosures*	3
New Patent Applications Filed	3

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	
Advising and Mentorship	
Students and Post-Docs (ARS and Non-ARS)	20
Scientists Serving as Advisors	1
Adjunct or Other Appointments	1
Student Targeted Outreach	
Student related outreach activities - # of activities (Presentations to schools, Science fair participation, Student tours/visits to ARS locations)	5
Student related outreach activities - # of student participants (Presentations to schools, Science fair participation, Student tours/visits to ARS locations)	30
Other Outreach	
Other Outreach Activities - # of activities	12
Other Outreach Activities - # of student participants	31
Other Outreach Activities - # of non-student participants	1937

In 2021, NP 106 scientists participated in research collaborations with scientists in the following countries:

CANADA:

- Collaborating with researchers at the University of Ontario Institute of Technology to determine the metabolic and physiologic changes in a selected line of ARS rainbow trout to metabolize plant proteins.

DENMARK:

- Conducting collaborative research with Technical University of Denmark to provide information on peracetic acid used in aquaculture.

GERMANY:

- Collaborating with researchers at the Leibniz-Institute of Freshwater Ecology and Inland Fisheries to study the toxicity/effectiveness of peracetic acid to fish and the effectiveness of this compound to control pathogens on fish.

NORWAY:

- Collaborating with researchers at Benchmark Genetics to determine the feasibility of selectively breeding Nile tilapia for resistance to *Streptococcus* species and other tilapia pathogens.
- Collaborating with researchers in the Fish Health Department of Nofima to establish the importance of the potent disinfectant peracetic acid to the global aquaculture industry.
- Collaborating in the CtrlAQUA project, 7-year research initiative run by Nofima, to make closed-containment aquaculture systems a reliable and economically viable technology and identify biological solutions for producing Atlantic salmon.

PORTUGAL:

- Collaborating with researchers at the University of Coimbra on non-invasive methods for the detection of enteritis caused by dietary plan proteins.

EUROPEAN UNION:

- To foster future collaboration, the Conservation Fund Freshwater Institute Research Director, affiliated with the National Center for Cool and Cold Water Aquaculture Research, joined the advisory panel of iFishIENCi (Intelligent Fish Feeding Through Integration of Enabling Technologies and Circular Principles, a European Union Horizon 2020 project involving numerous diverse scientists and industry partners.

PERSONNEL

New scientists in NP 106 in 2021:

Dr. Bernarda Calla, Research Molecular Geneticist, joined the Forage Seed and Cereal Research Unit, Corvallis, Oregon.

Dr. Thomas Delomas, Shellfish Quantitative Geneticist, joined the National Cold Water Marine Aquaculture Center Shellfish Genetics Lab, Kingston, Rhode Island.

Dr. Brian Ott, Fish Biologist Researcher, joined the Warmwater Aquaculture Research Unit, Stoneville, Mississippi.

Dr. Timothy Pfeiffer, Research Fish Biologist, joined Warmwater Aquaculture Research Unit, Stoneville, Mississippi.

Dr. Mark Polinski, Research Immunologist, joined National Cold Water Marine Aquaculture Center, Franklin, Maine.

Dr. Ross Reid, Postdoctoral Researcher, joined National Center for Cool and Cold Water Aquaculture, Kearneysville, West Virginia.

Dr. Bradley Richardson, Research Fish Biologist, joined Warmwater Aquaculture Research Unit, Stoneville, Mississippi.

PROMINENT AWARDS

The following scientists in NP 106 received prominent awards in 2021:

Dr. Craig Tucker, along with lead author **Dr. Claude Boyd** and their co-authors**,** received the best paper award for 2020 in the category of review article entitled "Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges" for the Journal of the World Aquaculture Society.

Drs. Kenneth Davis, Phillip H. Klesius, Chorn E. Lim, Yniv Palti, and Craig S. Tucker were identified in the top 2% of scientists worldwide across 22 scientific disciplines.

Dr. Bart Green was invited to give a presentation (virtually) at the Aquaculture Africa Magazine Flagship Webinar: "Biofloc Aquaculture – For Fish Farmers or Wizards?", Johannesburg, South Africa.

Seen here on the left is the Governor of Arkansas Asa Hutchinson presenting the award.

Dr. Andrew "Drew" Mitchell, retired ARS scientist from the Stuttgart National Aquaculture Research Center in Stuttgart, Arkansas, was honored with the National Aquaculture Association's 2021 Joseph P. McCraren Award for Distinguished Lifetime Contributions to U.S. Aquaculture.

RESEARCH RESULTS

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

Component 1: IMPROVING THE EFFICIENCY AND SUSTAINABILITY OF CATFISH AQUACULTURE

Problem Statement 1A: Improve Catfish Aquaculture Production Efficiency

Industry utilization of spawning aid. More than half of U.S. catfish aquaculture produces a hybrid between channel catfish females and blue catfish males. Hybrid production depends on induced ovulation in females, and producers traditionally utilized carp pituitary extract or a synthetic peptide based on a mammalian reproductive hormone to induce ovulation. ARS scientists in Stoneville, Mississippi, developed a synthetic peptide based on the chicken and catfish gonadotropin hormone releasing hormone (GnRH II), and helped producers test it on farms during the 2020 spawning season. The success of the new GnRH II on farms led to its use in 2021 by all eight producers that supply the U.S. catfish industry with hybrid catfish fingerlings, and six of the eight producers used GnRH II exclusively for hybrid production.

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

Using stock rotations to mitigate proliferative gill disease. Proliferative gill disease (PGD) in channel and hybrid catfish is a devastating disease caused by *Henneguya ictaluri*, a parasite present in nearly all catfish ponds during springtime. PGD is associated with catastrophic losses with a mortality rate of more than 90 percent. ARS researchers in Stoneville, Mississippi, found that *H. ictaluri* myxospores (the infective stage of the parasite) matured in channel catfish from 14 to 20 weeks after becoming infected, but hybrid catfish showed no myxospore development after the same period of exposure. This suggests that PGD infection will not persist in hybrid catfish, and shows that strategic rotations between channel and hybrid catfish in ponds could be a viable management strategy to reduce the incidence of PGD in commercial catfish operations.

Component 2: IMPROVING THE EFFICIENCY AND SUSTAINABILITY OF SALMONID AQUACULTURE

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

Improved fillet yield and body weight in rainbow trout. The proportion of edible meat (fillet yield) on a carcass is of major economic importance and breeding animals with superior fillet yield can improve production efficiency and profitability. Animals must be slaughtered to measure fillet yield directly, so it cannot be measured in breeding animals. However, developing genetic gains for fillet yield are possible using information, including genome information, from siblings of fish that are potential breeders. ARS researchers in Leetown, West Virginia, compared the accuracy of genetic merit predictions for fillet yield between the family-based selective breeding—which used information about family relationships—and genomic selection, which used information about family relationships and genomic information. The genomic selection model increased the accuracy of genetic merit predictions for fillet yield by 50 percent, indicating that the use of genomic selection can enhance genetic improvement for the fillet yield trait and further enhance the efficiency and sustainability of rainbow trout aquaculture.

Reducing early maturation in Atlantic salmon. The development of land-based recirculating aquaculture system (RAS) fish farms for producing market-size Atlantic salmon is becoming a significant growth area in U.S. aquaculture. However, the RAS environment can support the production of unacceptable levels of early maturing salmon that are considered a downgraded product, resulting in lost revenue. ARS funded scientists in Shepherdstown, WV, investigated how RAS water temperature affected early maturation in Atlantic salmon post-smolts. Findings indicated that raising salmon in lower temperatures reduced the prevalence of early maturation by 38 percent. These findings will assist farmers in lowering early maturation, thereby increasing the economic viability of their operations.

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

Recycled water use affects rainbow trout disease susceptibility and survival. Fish farmers often re-use water to conserve freshwater resources, but re-use is associated with reduced water quality that in turn is often blamed for disease outbreaks. More information is needed about risk levels associated with short or long-term re-use water exposure, including how risks are associated with genetic traits and vaccine response. ARS researchers at Leetown, West Virginia, collaborated with researchers at Virginia Institute of Marine Science and Virginia Tech to study how two commercial breeds of rainbow trout vaccinated against infectious hematopoietic necrosis virus responded to exposure to re-used water. They found chronic re-use water exposure increased risk of death more than 46-fold and that these risks varied with the genetic makeup of the trout. This research demonstrated the importance of mitigating effects of poor water quality and improving fish genetics to reduce disease loss.

Resistance to infectious hematopoietic necrosis virus in rainbow trout. Infectious hematopoietic necrosis (IHN), a viral disease of salmonid fishes, causes significant mortality and economic losses in aquaculture. Improving resistance to IHN through traditional, family-based selective breeding has shown promise, but is limited since IHN resistance cannot be measured in potential breeders. ARS researchers in Leetown, West

Virginia, used disease resistance data from a commercial rainbow trout breeding program to compare the accuracy of genetic merit and family-based selective breeding. They found genome-enabled breeding strategies improved the accuracy of an individual's genetic merit for IHN resistance by 15 percent. These results indicate that genome-enabled breeding can be more effective than traditional, family-based selection in improving the resistance of rainbow trout to the IHN virus.

Component 3: Improving the efficiency and sustainability of hybrid striped bass aquaculture

Problem Statement 3A: Enhance Hybrid Striped Bass Aquaculture Production

Sticky fish eggs thwarted by milk. Hybrid striped bass eggs become extremely sticky after they are fertilized. In a hatchery, this results in the eggs clumping together, which limits availability of oxygen and enables fungal infestations. Both problems can destroy an entire batch of eggs. Fish farmers typically use tannic acid treatments to prevent egg adhesion, but it is costly and, if left too long, will form a hard layer on the surface, which can prevent embryos from hatching. ARS researchers in Stuttgart, Arkansas, investigated 12 candidate compounds to prevent stickiness and found that 10 percent whole milk treatment was the most effective strategy. As a result, the largest commercial hybrid striped bass hatchery immediately began using milk for their 2020 production; in 2021, the hatchery exclusively used the milk to prevent clumping and successfully produced 80.9 million larvae using methods developed by ARS.

Component 4: Enhancing Shellfish Production

Problem Statement 4A: Enhance Shellfish Aquaculture Production

A multi-state oyster herpesvirus detection program. The Ostreid herpesvirus 1 (OsHV-1) has significantly harmed Pacific oyster production around the globe. The first United States detection was in 1995 in Tomales Bay, California, and a more virulent microvariant strain previously detected in other countries was found in San Diego Bay, California, in 2018. Recognizing the risk of regional spread, a multi-state sentinel program was initiated by ARS researchers in Newport, Oregon, and their collaborators to monitor the prevalence and disease development of OsHV-1 in naïve and genetically uniform hybrid oysters planted at commercial farms in California, Oregon, and Washington. A second group of oysters selected for OsHV-1 tolerance was planted for comparison in San Diego and Tomales Bay. Oyster mortalities were almost 100 percent for both families in San Diego Bay where the microvariant was present. Mortalities also occurred in Tomales Bay, but survival was higher for the tolerant family. Mortality events occurred during high seawater temperature spikes and followed peak virus levels. This information enables researchers to establish a consistent protocol for a more extensive OsHV-1 monitoring program.

Component 5: Developing Marine Finfish Seedstocks

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

Algae oil in fish diets is a viable alternative to fish oil. Competition for the limited supplies of long-chain, omega 3 fatty acids, or "fish oil", used in the production of farmed fish feeds has created the need to identify alternative sources of long-chain, omega 3 lipids. Vegetable oils have proven to be insufficient in providing the nutritional requirements for normal growth and well-being of marine finfish and do not provide the heart healthy nutrients valued by U.S. seafood consumers. ARS funded researchers in Fort Pierce, Florida, and their collaborators demonstrated that oils from algae can produce the same long chain omega 3 fatty acids found in fish oils. These findings provide an alternative lipid source that will increase the capacity for raising high-quality marine finfish aquaculture products and meeting the nutritional needs of U.S. seafood consumers.

Nutritional value of new feed ingredients for Florida pompano. The rising costs and ecological impacts of farmed fish feeds have necessitated the search for new and less expensive ingredients to ensure the profitability of U.S. aquaculture farms. ARS funded researchers in Fort Pierce and Tallahassee, Florida, determined that the nutritional needs of Florida pompano can be met by clam byproducts and hemp fibers that are biproducts of the textile industry. Both products are plentiful and provide growth-promoting and healthy nutrients, which indicates they should make very good supplements to marine finfish feeds. These findings have been provided to fish feed manufacturers for the development and marketing of more sustainable fish feeds, and for creating alternative revenue streams for other industries.

Additional Accomplishments

Breeding Nile tilapia for disease resistance does not affect harvest weight. Fish growth is economically important for farmers, so the relationship between growth and other traits that affect performance is paramount. ARS scientists in Auburn, Alabama, and industry stakeholders demonstrated that resistance to *Streptococcus (S.) iniae* and *S. agalactiae* is heritable, and used these findings to develop improved lines of tilapia with increased resistance to these diseases. They examined data from eight generations of selective tilapia breeding, including survival following *S. iniae*/*S. agalactiae* infection, and did not find any significant associations between harvest weight and survival. These finding suggest that selectively breeding for disease resistance will not reduce tilapia harvest weight, and support using multi-trait selection as a potential strategy to balance growth and disease resistance.