National Program 106 Aquaculture Annual Report for 2020

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.

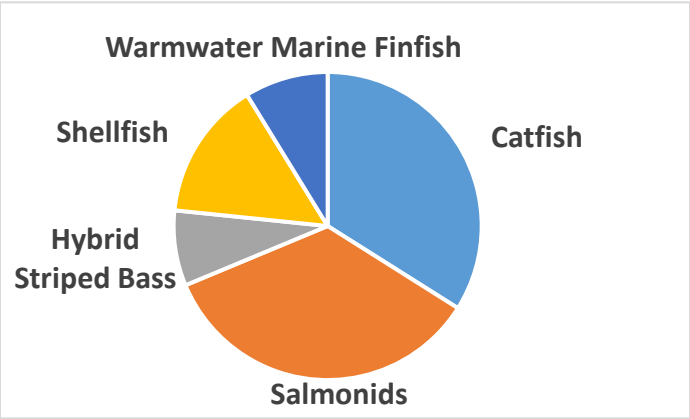
The aim of the ARS Aquaculture Program is to support a safe and affordable domestic supply of seafood products for 330 million U.S. consumers that is produced in a healthy, competitive, and sustainable aquaculture sector; a sector supported by almost 3000 aquaculture farmers producing more than $1.5 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 2020 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 and Executive Secretary and the Chair of the Science Planning Task Force developing the National Strategic Plan for Aquaculture Research;
- In collaboration with the Office of the Secretary, forming and leading the USDA Working Group on Aquaculture to meet USDA requirements of the President's Executive Order on Seafood Competitiveness and ensure customer service to aquaculture stakeholders;
- Provided consultation to USDA leadership towards including aquaculture in implementation of the Coronavirus Aid, Relief and Economic Security (CARES) Act through Coronavirus Food Assistance Program (CFAP) and CFAP2;
- Led HeroX and NASA to conduct a prize challenge entitled, "Protecting the Natural Flavor of Catfish";
- Contributed to the Theme Teams led by the Office of the Chief Scientist towards implementing the USDA Science Blueprint: A Roadmap for USDA Science from 2020 to 2025;
- Administered the Aquacontacts listserv on behalf of USDA National Institute of Food and Agriculture during their relocation to Kansas City and recruitment of new National Program Leaders;
- Engaged with the Bureau of Labor and Statistics regarding inclusion of aquaculture products in the Producer Price Index; and
- Assembled a team of U.S. scientists to develop the aquatic pathogen section of the Agricultural Biorisk Compendium.

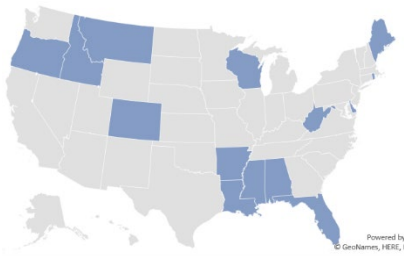
Fiscal year 2020 was the first year of externally-reviewed five-year project plans (2020- 2024) that fall under the five Components of the 2020 – 2024 Aquaculture Action Plan which are:

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.



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

In 2020 NP106 conducted research at 10 main laboratories on 14 project plans including approximately 36 ARS scientists and University or private cooperators on 15 congressionally mandated agreements. During fiscal year 2020, ARS base funding for aquaculture research was approximately $41 million, not including approximately $750K from incoming grants and agreements.



Although these 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 in response to new funding provided for research in warmwater marine finfish.

2020 NP 106 Technology transfer activities are summarized in **Table 1** below.

Mechanism	# New
Peer Reviewed Journal Articles	60
Trade Journals	3
Book/Book Chapters	1
Material Transfer Research Agreements	26
Material Transfer Agreements	10
Invention Disclosures*	2
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)	29
Scientists Serving as Advisors	3
Mentorships	2
Adjunct or Other Appointments	8
Student Targeted Outreach	
Student related outreach activities - # of activities (Presentations to schools, Science fair participation, Student tours/visits to ARS locations)	18
Student related outreach activities - # of student participants (Presentations to schools, Science fair participation, Student tours/visits to ARS locations)	414
Other Outreach	
Other Outreach Activities - # of activities	23
Other Outreach Activities - # of student participants	720
Other Outreach Activities - # of non-student participants	3,528

In 2020, NP 106 scientists participated in research collaborations with scientists in the following countries:

BELGIUM:

- Conducting collaborative research with Faculty of Veterinary Medicine at Ghent University to identify the host-derived factors that govern susceptibility of fish to columnaris disease.

BRAZIL:

- Conducting collaborative research to evaluate clays for treating or preventing bacterial diseases of fish and shellfish including *Aeromonas hydrophila*, *Flavobacterium columnare*, and *Vibrio parahaemolyticus*.

CANADA:

- Collaborating with the Aquatic Omics Laboratory at the Ontario Technology University, to process and analyze tissue samples taken from five strains of rainbow trout raised on a fishmeal protein control diet and a diet where fishmeal is completely replaced with sustainable protein derived from soybeans.

CHINA:

- Collaborating with researchers at Nanchang University to analyze metatranscriptomics and proteomic interaction related to the intestinal microbiome of selected and non-selected fish reared on plant and fishmeal-based feeds.
- Working with scientist from Yangtze River Fisheries Research Institute, Chinese Academy of Fishery Sciences to characterize gender-specific regulation of hepcidin in yellow perch.
- Conducting collaborative research with Jinan University to evaluate and develop effective parasiticides for controlling and preventing parasite *Ichthyophthirius multifiliis* in cultured fish and study fish immune responses against parasites.

DENMARK:

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

FINLAND:

- Working with scientist from the University of Jyväskylä on genetic techniques to manipulate *Flavobacterium columnare*.

FRANCE:

- Working with scientists from INRA (National Institute for Agricultural Research), on genetic techniques to manipulate *Flavobacterium columnare*.

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, *Ichthyophthirius multifiliis*, *Ichthyobodo necator*, *Flavobacterium columnare* and *Saprolegnia spp*. on fish.

JAPAN:

- Collaborating with the Japan Fisheries Research and Education Agency to examine the effects of recent changes in ocean climate on oyster condition, gametogenesis and spawning in both countries.

NORWAY:

- Collaborating with researchers at the Nord University to utilize commercial and ARS selected strains of trout to characterize intestinal microbial populations and correlate these populations with host intestinal immunological cell populations, both qualitatively and quantitatively.
- Conducting collaborative research with Akvaforsk Genetics Center to determine the feasibility of selectively breeding Nile tilapia for resistance to Streptococcus species and other tilapia pathogens.
- Conducting collaborative research with Benchmark Genetics Norway AS 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.

PERU:

- Collaborating with researchers at the Universidad Nacional Agraria and the aquaculture egg producing company Ovaseed to evaluate rainbow trout stocks reared in different environmental settings and determine if lines of fish can be developed for improved growth under these conditions.

PORTUGAL:

- Collaborating with researchers at the University of Coimbra to analyze metabolomics and proteomic interaction related to the intestinal microbiome of selected and non-selected fish reared on plant and fishmeal-based feeds.
- Collaborating with researchers at the University of Coimbra located to analyze the metabolome of tissues from selected and non-selected rainbow trout at early and late stages of development.

THAILAND:

- Conducting collaborative research with Chulalongkorn University to develop and validate new molecular assays for detecting the fish pathogen *Flavobacterium columnare* and determine the genotypes of this bacterium in Thailand aquaculture species.

UGANDA:

- Working with the National Agricultural Research Organisation, Aquaculture Research & Development Centre to assist in formulating feeds and setting up a selection program for tilapia in eastern Africa using localized resources

PERSONNEL

New scientists in NP 106 in 2020:

Dr. Michael Deshotel, Research Microbiologist, joined Harry K. Dupree Stuttgart National Aquaculture Research Center, Stuttgart, Arkansas.

Dr. Neil Thompson, Research Geneticist, joined Forage Seed and Cereal Research Unit, Newport, Oregon.

In 2020 the following NP 106 scientists retired:

Dr. Dehai Xu, Research Parasitologist, Aquatic Animal Health Research, Auburn, Alabama.

Dr. Craig Tucker, Research Leader, Warmwater Aquaculture Research Unit, Stoneville, Mississippi.

Mr. Terry Bates, Fisheries Biologist, Warmwater Aquaculture Research Unit, Stoneville, Mississippi.

The distinguished record of these scientists is recognized world-wide and they will be missed.

PROMINENT AWARDS

The following scientists in NP 106 received prominent awards in 2020:

Dr. Bart Green, Kevin Schrader, Steven Rawles, Carl Webster and Matthew McEntire, co-authors for an article entitled: *Channel catfish production in biofloc technology systems* was one of the ten most read articles in the first half of 2020, in the publication Global Aquaculture Advocate.

Dr. Keshun Liu, received the American Oil Chemists' Society (AOCS) Protein and Co-Products Division Life Time Achievement Award.

Dr. David Straus, received an award for his paper being recognized as one of the most read in *Reviews in 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

Release of the Delta Select strain of channel catfish. Improved catfish germplasm in aquaculture will reduce production costs and allow U.S. catfish farmers to remain competitive in the global seafood market. ARS researchers in Stoneville, MS, developed the "Delta Select" strain of channel catfish through three generations of genetic selection, leading to a 25 percent increase in growth rate and 0.9 percent increase in carcass yield compared to the non-selected Delta Control line that originated from the same population. Approximately 90,000 head (180,000 pounds) of 2-year-old Delta Select strain catfish were released to industry, providing U.S. farmers access to improved catfish germplasm that will make them more efficient and profitable.

An alternative aquafeed protein source improves growth and immune responses**.** Frass is a byproduct of the fly larval meal industry and is composed of larval excrement, shed exoskeletons, and residual feed of the flies. ARS researchers in Auburn, AL, evaluated diets containing black soldier fly frass as partial replacements for soybean meal, wheat short (the fine bran particles, germ and particles separated in commercial flour milling), and corn meal. Experimental diets were fed to fingerling catfish and tilapia and the results demonstrated that final weight gain was significantly increased. Additionally, tilapia fed frass diets exhibited increased survival against two important pathogens, *Flavobacterium columnare* and *Streptococcus iniae*. Based on these findings, frass derived from the larvae of black solder flies has potential as an alternative source of protein in aquafeeds or as an ingredient enhancing palatability and growth.

Catfish diets and feeding strategies affect meat yield. During the production and harvest cycle, catfish farmers are sometimes unable to sell market weight catfish for processing if there is a lack of demand. Feeding fish during this time allows the fish to grow larger than the preferred size for processing. If feed is withheld during this time, the fish mobilize muscle tissue for energy, reducing fillet yield. In either case, the price paid to farmers is reduced. ARS researchers in Stoneville, MS, worked in cooperation with Mississippi State University fish nutritionists and determined that hybrid catfish fed once or twice weekly for 4 months remained in the preferred size range for processing but had reduced fillet yield. Thirty days of full feeding were needed to restore fillet yield to normal levels in fish fed once or twice weekly for 4 months. These results allow the catfish farming industry to develop feeding strategies that minimize production costs and maximize profits.

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

Pyranopyrans are potential bacteriocidal compounds against fish pathogens. Disease losses in catfish aquaculture can cost up to $100 million, so reducing or eliminating bacterial pathogens is critical to the success of the industry and improving fish health and welfare. ARS researchers in Oxford, MS, Stoneville, MS, and Villanova University modified the chemical structures of natural compounds produced by a certain species of fungus to produce novel compounds. *In vitro* experiments with these novel compounds, pyranopyrans, demonstrated that they possess significant antibacterial activities against certain species of fish pathogens. Combatting disease with alternative efficacious natural or natural-based compounds is very acceptable to the

catfish industry, which has access to only a few approved therapeutants and is striving to limit the use of antibiotics.

A rapid assay for *Flavobacterium columnare*. Columnaris disease is caused by the bacterium *Flavobacterium columnare* and affects almost all finfish aquaculture industries in the United States and worldwide. Previous research established the existence of four distinct genetic groups within the species *F. columnare*; however, there were simple or inexpensive methods to assign an unknown isolate to one of the four groups. Knowing which group is causing outbreak informs decisions on disease treatment strategies. ARS researchers in Auburn, AL, developed a molecular assay to quickly assign an isolate to a genetic group, demonstrating the assay is rapid, sensitive, and specific for genotyping *F. columnare*. The assay is inexpensive and can be used by any laboratory with basic molecular capabilities to determine which genetic group(s) are responsible for disease outbreaks. It is currently in use by commercial and academic laboratories.

Component 2: IMPROVING THE EFFICIENCY AND SUSTAINABILITY OF SALMONID AQUACULTURE

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

Genome-enabled breeding tools for Atlantic salmon. The number of U.S. commercial Atlantic salmon farming operations is expected to increase 5-fold over the next 3 years, and demand for genetically improved stocks will increase dramatically. ARS researchers in Franklin, ME, and Leetown, WV, created an improved genome reference sequence for the North American Atlantic salmon and developed the first DNA chip that enables the use of genomic information in breeding strategies. This DNA chip is publicly available and in use by commercial breeding programs. Genomic enabled breeding is estimated to improve selection accuracy by up to 50 percent, depending on the trait, therefore increasing the pace of genetic improvement and reducing costs of breeding programs.

Improved method to measure starch content and gelatinization. Starch is an important component of various food and feed products. Starch gelatinization is important during processing starch-containing foods or feeds; the degree of starch gelatinization (DSG) affects physiochemical and sensory properties of starchy products and their susceptibility to enzymatic digestion and so affects their nutritional availability for humans and animals. ARS researchers in Hagerman, ID, recently developed an improved method for simpler and more accurate measurement of total starch and gelatinized starch *in situ* for wet and dried products. This provides a valuable new tool for food and feed researchers to study the role of starch in food and feed products.

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

A bacteriophage for preventing disease in rainbow trout. Bacteriophages (phages) are viruses that infect and kill bacteria, self-replicating in high numbers in the process. Used against disease-causing microbes, phages are excellent candidates for the prevention or treatment of bacterial diseases. ARS researchers at Leetown, WV, identified a new phage that kills *Yersinia ruckeri,* the rainbow trout pathogen. This phage is unique; in addition to killing its bacterial host by infection, it also binds to and degrades lipopolysaccharide, a large carbohydrate structure that covers the surface of some bacteria and reduces the effectiveness of the trout immune system. By trimming off this protective layer, the phage renders *Yersinia ruckeri* susceptible to the trout immune system, preventing its survival inside its fish host.

Component 5: Developing Marine Finfish Seedstocks

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

A draft genome sequence for Florida pompano. The lack of available genome information is a hurdle in implementing state-of-the-art selective breeding strategies for many aquaculture species, including Florida pompano. ARS funded researchers at Ft. Pierce, FL, established a complete draft genome of the Florida pompano, using a hybrid sequencing method and a novel bioinformatics workflow. This draft genome will improve farm production and profitability and enhance breeding strategies by allowing researchers to identify genes associated with aquaculture production efficiency and product quality.

Nutritional requirements of Florida pompano broodstock. Quality broodstock diets increase reproductive success and seedstock quality, leading to increased hatchery success, on-farm efficiencies, and profitability. The lack of optimal diets for Florida pompano broodstock (especially during the spawning season) continues to present an obstacle to commercial production, because nutritional status is a powerful determinant of egg quality and the successful development of eggs and larvae. ARS-funded researchers at Ft. Pierce, FL, employed comprehensive and quantitative lipid analysis to determine different egg and larval lipid compositions and identify lipid requirements for larval development and successful reproduction of Florida pompano. Hatchery managers and marine finfish producers will benefit from efficiencies associated with meeting optimum nutritional needs for reproduction and successful seedstock production.