National Program 106 Aquaculture Annual Report for 2016

The **vision** for ARS aquaculture research and technology transfer is *a thriving domestic industry based on improved genetic stocks and scientific information on biotechnologies and management practices to ensure a high quality, safe supply of healthful seafood and aquatic products.*

Mission: The mission of the Aquaculture National Program is to conduct high quality, relevant, fundamental and applied aquaculture research, to improve the systems for raising domesticated aquaculture species, and to transfer technology to enhance the productivity and efficiency of U.S. producers and the quality of seafood and other aquatic animal products.

The aim of the ARS Aquaculture Program is to support a safe and affordable domestic supply of seafood products for the 330 million U.S. consumers that is produced in a healthy, competitive, and sustainable aquaculture sector; a sector supported by more than 3000 aquaculture farmers producing in excess of $1.35 billion worth of goods annually. In 2013 the USDA National Agricultural Statistics Service published the Census of Aquaculture updating these statistics for the first time since 2005. 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 4300 to 3090) and the sales have increased from just over $1 billion to over $1.37 billion in 2013.

Fiscal year 2016 was the second year of externally-reviewed five-year project plans (2015-2019) that fall under the five major components of the National Aquaculture Action Plan which are:

1. Selective Breeding, Directed Reproduction, and Development of Genomic Tools
2. Nutrient Requirements and Alternative Sources of Protein and Lipid
3. Health of Aquatic Animals
4. Sustainable Production Systems
5. Product Quality and New Products

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. NP 106 scientists published more than 170 articles over the past two years in peer-reviewed scientific journals.

National Program 106 involves efforts in 10 different locations on 20 projects performed by approximately 87 scientists (47 ARS scientists and ~40 collaborating scientists). During fiscal year 2016, ARS base funding for aquaculture research was approximately $28 million not including $700K incoming funds from grants and agreements. Technology transfer activities included 1 new patent filed, 1 new CRADA, 16 Material Transfer Agreements (MTAs) and 3 Material Transfer Research Agreements (MTRAs).

The patent filing led by Dr. Frederick Barrows describes a new method and apparatus to produce aquatic feed products with altered physical characteristics that addresses the needs of the aquaculture industry. First, the aquafeed produced by the new method contains

significantly reduced amounts of total carbohydrates as compared to conventional feed. Second, it has a texture similar to natural feeds such as sardines, which is appealing to fish accustomed to consuming natural feeds and consequently can lead to an increase in feed consumption. Third, the product does not disintegrate upon soaking in water as quickly as traditional feeds do, but holds its texture and dry mass for more than 24 hrs. Consequently, the product has application to slow feeding aquatic animals like shrimp, abalone, grazing species of fish (rudderfish or Kysoids), and sturgeon - in addition to traditional fish stocks. The increased water stability of the new product also contributes to the preservation of tank water quality.

Recently ARS developed Material Transfer Research agreements in our Technology Transfer portfolio to not only allow the transfer of materials, but to facilitate joint research between the provider and the recipient of the materials. This instrument does not convey rights to negotiate exclusive licenses to any intellectual property arising from the research, however it is intended as an early stage opportunity for proof of concept that may lead to more extensive research that would be conducted under a CRADA. Scientists in the Aquaculture Program are increasingly using this mechanism to transfer technologies to industry.

In 2016 NP 106 scientists participated in research collaborations with scientists in: Azores, Belgium, Brazil, Canada, China, Denmark, France, Germany, Japan, Norway, Russia, and Thailand.

Personnel in NP 106

***New additions to the NP 106 team in 2016 are*:**

***The following scientists retired from the ranks in NP 106*:**
Rick Barrows, Small Grains, Bozeman, Montana. The distinguished record of service of Dr. Barrows is recognized world-wide and he will be missed in NP 106. Dr. Barrow's achievements are well documented in more than 130 scientific publications and in many awards, including several Special Service Awards from the U.S. Fish and Wildlife Service; ARS Pacific West Area Senior Research Scientist award of 2012; an ARS Outstanding Technology Transfer Award; and the highest award conferred by the United States Aquaculture Society, the 2016 Distinguished Lifetime Achievement Award.

Research Results
The following section of the report summarizes the specific high impact research results addressing objectives in the current National Program Action Plan.

Selective Breeding, Directed Reproduction, and Development of Genomic Tools

Atlantic salmon
Improved resistance to seal lice in Atlantic salmon. Current strategies to mitigate sea lice infestations require expensive chemical treatments ($750,000 per farm per production cycle in Maine). ARS researchers in Franklin, Maine, determined that there is a heritable component to

the ability of Atlantic salmon to resist sea lice infestation, indicating the potential for improvement through selective breeding. In cooperation with an industry partner, a panel of genetic markers was developed that will be used to increase the efficiency of selective breeding for sea lice resistance. Utilization of improved salmon germplasm will increase the profitability and sustainability of cold water marine aquaculture in the United States and provide quality seafood products to U.S. consumers.

Catfish

Sire strain affects blue × channel catfish progeny performance in commercial settings. Hybrid catfish created by mating blue and channel catfish are the preferred fish produced by the U.S. farm-raised catfish industry, which relies primarily on the D&B and Rio Grande strains of blue catfish. ARS scientists in Stoneville, Mississippi, examined the influence of blue catfish sire strain (D&B vs. Rio Grande) on hybrid catfish embryo production and fingerling performance under commercial hatchery conditions. Average testis weight, an indicator of reproductive efficiency, was higher in Rio Grande fish compared with that of D&B fish. However, D&B hybrids exhibited higher rates of mean survival, production, and growth efficiency compared with Rio Grande hybrid catfish fingerlings reared in earthen ponds. This research demonstrates the potential of exploiting genetic differences between strains to increase production on commercial farms.

Cryopreservation of catfish sperm. Use of cryopreserved sperm is critical to development of improved catfish germplasm and preservation of genetic material from catfish breeding populations. ARS scientists in Stoneville, Mississippi, continue to improve sperm cryopreservation techniques in collaboration with scientists at Louisiana State University and an industry partner. To date sperm from 260 blue catfish from four strains has been preserved to maintain the genetic diversity of blue catfish populations. Spawning trials demonstrated that cryopreservation reduced blue catfish sperm motility by 50% compared to fresh sperm. However, cryopreserved and fresh sperm did not differ in the percentage of viable embryos observed 48 hours after fertilization. Availability of cryopreserved blue catfish sperm will improve the efficiency of hybrid catfish production.

Eastern oyster

Using genetics to improve the eastern oyster for commercial production. Improving the eastern oyster through genetics and breeding is expected to make it more economically feasible to produce on a commercial basis. ARS scientists in Kingston, Rhode Island, and their collaborators conducted field trials to evaluate the growth, mortality, and yield of six mass-selected oyster populations at five farm sites with varied environmental conditions. Significant genetic and environment interactions were detected for mortality and yield, and peak mortality at each site coincided with the most prominent oyster pathogen at that site. Selected varieties generally performed best at their native site, and some varieties exhibited above average performance at multiple sites. Characterization of interactions between oyster varieties and the environments in which they are raised will enhance current breeding efforts that aim to increase production efficiency and profitability of shellfish farming while improving the quality and availability of shellfish products to U.S. consumers.

Rainbow Trout

Using genomics to improve disease resistance in rainbow trout. Bacterial cold water disease (BCWD) of rainbow trout is a continuing challenge to the American aquaculture industry, accounting for up to 39 percent losses in hatchery stocks. ARS researchers in Leetown, West Virginia, aimed to improve disease resistance in fish using genome-based breeding instead of traditional pedigree-only breeding and have shown that the genome predictions are substantially better at selecting traits that confer resistance to BCWD over successive generations of fish. Using this new process of genomic selection should reduce the amount of time, money, labor, and the number of fish needed to achieve the same level of improvements. Applying a similar genomic selection strategy to improve other commercially important animal traits, including resistance to other diseases, increased fillet yield, or improved carcass quality offers opportunities to increase farm productivity, enhance product quality, improve animal welfare, and the overall sustainability of rainbow trout production systems.

A DNA-based tool for managing trout production. In salmonid aquaculture, family-based selective breeding programs rely on accurate pedigree information for selecting the best breeding animals. In addition, breeding companies that provide eggs to grow-out farmers need a way to trace a fish's pedigree from the farm back to the breeding population of origin to help resolve issues associated with suboptimal production by identifying genetic strain of origin. ARS researchers in Leetown, West Virginia, developed a new, inexpensive DNA-based assay and demonstrated that it can be used to rapidly and effectively analyze parentage with 100 percent accuracy and assigning production fish back to their population of origin with 97 percent accuracy. ARS has made this new assay available to Troutlodge, Inc., the largest trout breeding company in North America, and is currently being offered as a commercial product by the Center for Aquaculture Technologies, Inc., an aquaculture biotechnology company. This assay provides a means for breeding companies to trace fish genetics as part of a strategy to resolve issues associated with suboptimal production efficiency.

Tilapia

Selective breeding in Nile tilapia for disease resistance. Intensification of tilapia production has resulted in disease outbreaks that negatively affect commercial fish farmers, one common bacterial pathogen impacting production is *Streptococcus iniae*. Control and prevention of *S. iniae* can be difficult and requires enhanced management practices, use of antibiotics, and vaccination. Selective breeding for resistance to disease is a complementary strategy, but its potential was previously unknown. ARS scientists in Auburn, Alabama, in collaboration with industry stakeholders demonstrated that resistance to *S. iniae* is moderately heritable, indicating that it should be possible to develop improved tilapia populations that are more resistant to disease. The long term goal of this research is to provide fish farmers with a more resistant stock of tilapia as an additional management tool for reducing production losses due to Streptococcus spp.

Nutrient Requirements and Alternative Sources of Protein and Lipid

Catfish

Improving the diet of commercial catfish. Farm-raised catfish have the highest economic value of any domestic aquaculture industry; in 2013, 605 farms produced more than 350 million

pounds of food-sized fish valued at more than $350 million in farm gate value alone. Fish feeds constitute half the cost of production; therefore, understanding the nutrient requirements of this fish is essential to controlling diet costs, maximizing production potential and maintaining the competitiveness of this industry. Catfish feeds are plant-based and can feature high levels of phytate or phytic acid, a compound that binds iron and other minerals, making them unavailable to fish. ARS scientists in Auburn, Alabama, and Stuttgart, Arkansas, collaborated with colleagues at Auburn University and demonstrated that coating feed with the enzyme phytase, which destroys phytate, could boost the uptake of iron and other key nutritional minerals. Scientists also showed that fish given the phytase-treated diet had higher red blood cell and hemoglobin counts, increased growth rates, and a greater ability to convert iron and other minerals in the digestive tract into useable forms that can be deposited into the blood stream. Phytase is currently used in poultry and swine diets to destroy phytate. These results suggest that phytase-amended diets could improve both the health and production of farmed catfish.

Development of cost-effective feeding strategies to maintain body weight of market-size hybrid catfish during harvest delays. Several circumstances, such as off-flavor, oversupply of fish in the market, or low fish prices, can cause delays in harvesting market-size fish in catfish production. Delays in harvest increase the risk of fish losses and diminish production efficiency and profitability. Issues associated with harvest delays are exacerbated in hybrid catfish as they feed more aggressively and grow faster than channel catfish. Researchers at Mississippi State University in Stoneville, Mississippi, examined effects of no feeding, maintenance feeding (feeding once weekly) and refeeding on production and processing characteristics of market-size hybrid catfish. Results show feeding once weekly can generally maintain fish body weight, and no feeding or feeding once weekly for two months does not affect survival but significantly reduces fillet yield. These data provide catfish producers with information that can be used to minimize production losses in events of long-term harvest delays.

Evaluation of processing yield in catfish fed alternative protein sources. Diet composition and feeding regimes can affect fillet yield in farm-raised catfish. Soybean meal represents the main source of dietary protein in traditional catfish diets, but increased pricing of soybean meal dramatically increased feed costs. ARS and Mississippi State University researchers in Stoneville, Mississippi, examined the effects of substituting soybean meal with other, less expensive dietary protein sources (cotton seed meal, corn distillers dried grains with solubles, corn germ meal, peanut meal, and porcine meat and bone meal) on growth and fillet yield of farm-raised catfish. The results demonstrated soybean meal could be completely replaced with cheaper sources of dietary protein with no effect on growth or fillet yield of channel catfish. This information enables catfish feed producers to alter diet compositions and thus lower feed costs for farmers.

Identify additives that improve growth performance. High feed costs have forced producers to look for feed additives that have the potential to reduce production costs of raising catfish. ARS scientists in Stoneville, Mississippi, conducted research with a ß-adrenergic agonist (BAA) that was shown to improve growth, feed efficiency, and dressout percent in cattle. A BAA was identified that reduced fillet fat in channel catfish. However, visceral fat was not affected by feeding BAA. Survival, dressout percent, growth, and feed efficiency were also not affected by feeding BAA. The BAA was also tested in hybrid catfish and it was also shown to reduce fillet

fat. Survival, dressout percent, growth, and feed efficiency were similar between treated and untreated fish. The BAA tested in these studies do not appear to improve channel catfish or hybrid catfish production efficiency, however they demonstrate the potential to modify fillet composition. .

Rainbow Trout

Evaluation of algal sources of omega-3 fatty acids to replace fish oil in trout feeds. Fish oil is derived from capture fisheries such as sardines and menhaden, and has been the traditional source of omega-3 fatty acids in feeds for farmed fish such as trout. However, the limited availability of fish oil from natural resources is currently limiting the expansion of aquaculture production, which aims to provide healthy protein sources to a growing global population. ARS researchers in Aberdeen, Idaho, determined the nutrient digestibility, palatability, and functionality of a number of new commercial sources of algae that are high in omega-3 fatty acids. All algal products exhibited high digestibility of omega-3 fatty acids, with no effect on feed intake, and minimal effect on feed manufacturing. Identifying alternative sources of omega-3 fatty acids for aquaculture feeds that do not reduce production efficiency or product quality, such as these algae, will decrease our dependence on ocean-harvested fish and remove production barriers to increasing the availability and sustainability of this heart- and brain-healthy protein source.

New feed processing technology results in better water quality for fish farms. Feeding fish with traditional feeds results in fecal particles that are very fine and difficult to settle or remove by filtration in flow-through or recirculating aquaculture systems. Fish feeds are traditionally held together in a pellet with carbohydrate based binders. ARS researchers in Aberdeen, Idaho, developed a new method that does not require carbohydrates. This new technology, which has been patented, results in fish producing larger and more durable feces that can be more easily removed from the water, thus improving water quality by reducing nutrients in the effluent. Adoption of this new processing technology will enhance the water quality of aquaculture production.

Shrimp

Insect meal is a viable protein ingredient for white shrimp diets. Over 90% of farmed shrimp rely on high protein diets containing high percentages of marine fish meal. Future growth and profitability within the shrimp aquaculture sector is dependent upon continued improvements in diet efficiency and formulation; specifically a reduction in fish meal. A potential candidate ingredient for fish meal replacement is the black soldier fly (*Hermetia illucens*) which has been evaluated as a possible organism for use in bioconversion of manure and food compost to reduce waste residue and has received a great deal of interest for use as a protein source in other animal industries. ARS researchers in Stuttgart, Arkansas, in collaboration with Kentucky State University tested six diets containing graded levels of black soldier fly larvae meal as replacements for protein from menhaden fish meal which were fed to juvenile shrimp and compared to shrimp fed a control diet. Shrimp fed the control diet with the highest percentage of fish meal had the highest weight gains compared to all other diets. However, reasonable growth, up to 95% to 100% of the maximum final weight, weight gain, specific growth rate, and food conversion, could be obtained if replacement of fish meal by black soldier fly larvae meal was limited to less than 25% of the diet. The research also revealed that

addition of limiting amino acids to the replacement diets could significantly improve shrimp growth when fed diets with higher percentages of this insect meal.

Striped Bass

Fish meal in hybrid striped bass diets can be replaced with high-protein, low-antigen soy varieties. Replacing fish meal as a protein source in fish feeds has the potential to reduce an aquaculture farmer's reliance on fish meal and increase the availability of farmed fish products. ARS researchers in Stuttgart, Arkansas, and collaborators at several institutions [University of Arkansas (UA) at Pine Bluff; UA at Fayetteville; ARS Trout-Grains Project, Hagerman, Idaho; and the U.S. Fish and Wildlife Service Fish Technology Center, Bozeman, Montana] previously conducted nutrient digestibility studies in hybrid striped bass using three novel varieties of non-genetically modified soybeans containing higher protein and lower anti-nutritional factors than traditional soybean. Recently, these varieties were used to replace all the fish meal in a typical commercial hybrid striped bass feed in a performance trial to assess growth, body composition, intestinal health, immunological response to soy antigens, and resistance to disease. Results indicate that fish meal can be entirely replaced by high-protein, low-antigen soybean meals when formulated on an available amino acid basis and supplemented with limiting amino acids.

Taurine supplementation is not needed to support growth of hybrid striped bass fed all-plant-protein diets. The amino acid based nutrient taurine is often conditionally limiting in fish when they are fed feeds composed of plant protein sources. ARS researchers and their collaborators at the U.S. Fish and Wildlife Service Fish Technology Center Bozeman, Montana, and Texas A&M University conducted a performance trial where they fed hybrid striped bass plant-based feeds formulated with graded levels of taurine to determine the effectiveness of supplementing with taurine to support growth. At the end of the trial it was determined that taurine supplementation is not required for rearing hybrid striped bass on plant-based protein diets. However, muscle saturation and liver data suggested there is some benefit to low dietary inclusion levels (< 1%) to maximize body stores, especially since taurine is a relatively inexpensive feed additive.

Tilapia

Tilapia whole-body amino acid profile is a robust nutrient target for optimizing commercial diets. ARS researchers and collaborators at Kentucky State University evaluated the use of the tilapia whole body amino acid profile as a nutrient target for optimizing commercial tilapia diets instead of using the nutrient profile of current commercial diets typically containing fish meal. Fish meal in the commercial diet was completely replaced with different ratios of poultry by-product meal and soybean meal. Amino acids were supplemented to match the levels measured in the original fish meal. Results showed that the more the diet nutrient profile diverged from the nutrient profile of whole body tilapia, the poorer the diet performance. This work is a critical discovery in developing diet formulas for testing combinations of novel alternative ingredients to replace fish meal in commercial diets for tilapia.

Utilization of distiller's dried grains with solubles (DDGS) as a potential replacement for fish meal in tilapia diets. Tilapia became the most-produced food-fish in the world for the global marketplace in 2015. There are several important reasons for this dramatic increase in production, one being its acceptance of diets containing plant-protein ingredients. However, as

production has increased, prices paid to producers have decreased. As feed costs represent approximately 35-55% of variable costs to tilapia producers, formulating nutritious, but less expensive diets may assist producers in maintaining profitability. Historically, distiller's dried grains with solubles (DDGS), was a by-product of the distillery industry. Ethanol production in the United States has undergone significant expansion within the last 10 years as a result of rising energy costs and mandates for biofuel use in the U.S. Energy Acts of 2005 and 2007. Increased ethanol production has subsequently led to increased production of DDGS, and production in the United States has almost quadrupled since 2005. With the abundance of DDGS in the United States, it has been proposed as a protein source for use in aquaculture diets due its relative low cost per unit protein basis, and absence of anti-nutritional factors found in other plant-based ingredients. ARS researchers in Stuttgart, Arkansas, demonstrated that a substantial amount of the fish meal in typical tilapia fry diets can be replaced with DDGS, when combined with poultry by-product meal and supplemental amino acids (methionine and lysine). Growth of tilapia fed the diets containing DDGS was slightly less than fish fed the fish meal diet, but average fish growth was high regardless of which diet was fed. DDGS replacement of fish meal in tilapia diets can be substantial when diets are carefully formulated. This will result in less expensive diets for tilapia, particularly hatchery, the stage of fish which use diets with high percentages of fish meal.

Health of Aquatic Animals

Catfish

An oral vaccine for enteric septicemia of catfish increases profitability. *Edwardsiella ictaluri* is the causative agent for enteric septicemia of catfish, a highly fatal systemic infection that is responsible for significant economic losses in the catfish industry. Researchers from Mississippi State University in collaboration with ARS scientists in Stoneville, Mississippi, conducted commercial field trials with a previously patented oral vaccine to prevent septicemia. Vaccination was shown to dramatically improve fish production, resulted in improved animal health and growth rates, and in commercial fish farm trials increased gross sales by approximately $3,000 per acre for channel catfish and $2,000 for hybrid catfish (i.e., a 30 percent to 50 percent increase over sales for non-vaccinated fish populations). In 2015, more than 90 million fingerlings were vaccinated on six commercial operations.

Developed in vitro methods to screen parasiticides against Ich. *Ichthyophthirius multifiliis*, commonly called Ich, is a severe ciliate parasite that can infect most freshwater fish worldwide resulting in heavy economic losses for aquaculture. Currently available parasiticides to control this parasite are limited. Ich is an obligated parasite, requires a fish host to survive and cannot be cultured in vitro. *Tetrahymena thermophila* is a free living protozoa that thrives in water similar to Ich and can be easily cultured in large quantities within a short period of time. ARS scientists in Auburn, Alabama, evaluated whether *T. thermophila* could be used to screen potentially effective parasiticides against Ich. The results demonstrated that the parasiticides that killed *T. thermophila* would kill Ich, thus the in vitro method using *T. thermophila* can be used to screen novel parasiticides effective against Ich.

Reproducible waterborne disease model for virulent Aeromonas hydrophila. The catfish industry in the Southern United States has been greatly impacted by motile Aeromonas

septicemia disease caused by virulent *Aeromonas hydrophila*, with losses of approximately three million pounds of market-size fish annually since 2009. ARS scientists in Auburn, Alabama, developed a reproducible disease model and demonstrated that portals for bacterial entry are a prerequisite for infection via waterborne exposure. The waterborne disease model will facilitate urgently-needed studies of prevention and treatment.

Rainbow trout

Genetic diversity of Flavobacterium psychrophilum isolates from the United States determined by multilocus sequence typing. Bacterial cold water disease (BCWD) is a frequent cause of freshwater farmed trout loss, and genetic diversity of the pathogen is poorly understood. ARS researchers in Leetown, West Virginia, in collaboration with scientists at the College of Veterinary Medicine, Michigan State University, and French National Institute for Agricultural Research, identified 96 isolates of *F. pyschrophilum* recovered from rainbow trout, coho salmon, and Chinook salmon that originated from nine States. Multilocus sequence typing (a molecular technique used to characterize DNA sequences) was used to identify 34 types of the bacteria that clustered into five groups. A specific sequence was commonly associated with BCWD outbreaks on rainbow trout farms. This information improves our understanding of genetic diversity and strains associated with bacterial disease outbreaks, which will help direct the development of targeted vaccines, and improve a farmer's ability to select disease-resistant rainbow trout.

***Yersinia ruckeri* lipopolysaccharide is necessary and sufficient for eliciting a protective immune response in rainbow trout.** A highly effective vaccine was developed in the 1970's to prevent infection caused by the bacterial pathogen *Yersinia ruckeri*. The unusual success of this vaccine has led to the use of *Y. ruckeri* vaccination as a model system for better understanding immersion vaccination which is preferred by producers. While much has been learned regarding host response to *Y. ruckeri* vaccination, the bacterial components necessary for eliciting this protective response remain unclear. ARS scientists in Leetown, West Virginia, have demonstrated that highly purified *Y. ruckeri* lipopolysaccharide (LPS) alone is a highly potent immunogen and is sufficient for eliciting a strong protective response. We also created a defined *Y. ruckeri* mutant lacking LPS and used this mutant to demonstrate that LPS is an essential component of the whole cell vaccine. Together these results suggest that LPS is the only cellular component contributing to the protective response elicited by the *Y. ruckeri* bacterin vaccine. We propose that the exceptionally high potency of *Y. ruckeri* LPS accounts for the unusual success of this vaccine when delivered by immersion. This work contributes to a better understanding of *Y. ruckeri* vaccination by identifying the bacterial factors necessary for eliciting a protective response.

Genome sequencing of *Lactococcus garvieae* strain PAQ102015-99, an outbreak strain identified from cultured rainbow trout in the northwestern United States. *L. garvieae*, the causative agent of lactococcosis, is a commercially important pathogen of farmed rainbow trout. ARS scientists in Leetown, West Virginia, have recently identified an outbreak of lactococcosis at a commercial trout aquaculture facility in Washington State and have determined the draft genome sequence of a representative strain. This information will be critical for the development of strain-specific diagnostics and for the identification of virulence factors and surface characteristics.

Sustainable Production Systems

Atlantic salmon

Atlantic salmon can be raised to market weight in land-based systems using sustainable diets. The use of alternative protein sources in fish feed continues to increase as concerns persist surrounding the availability and cost of using ocean-harvested fish as protein and oil in fish feed. Furthermore, commercial farms are beginning to use land-based systems that recirculate water and allow production of market-size Atlantic salmon in highly controlled environments. Researchers at The Conservation Fund's Freshwater Institute in Shepherdstown, West Virginia, showed that a novel fishmeal-free diet fed to Atlantic salmon in recirculation aquaculture systems resulted in greater waste production, but equal salmon growth, feed conversion, and survival compared with a traditional fishmeal-based diet. These findings were adapted to larger-scale salmon production, for which ARS provided the first evidence that Atlantic salmon can be effectively raised to market size while consuming a fish meal-free diet in a commercially relevant land-based system. This research provides strategies for infrastructure and rearing that are expected to increase Atlantic salmon production efficiency, alleviate environmental impacts of fish that escape land-based farms, and reduces reliance upon capture fisheries.

Catfish

Impact of grading hybrid catfish fingerlings on processing. Hybrid catfish grow rapidly but not uniformly, pond harvests often include individual fish weighing over five pounds while others are less than a pound. This is undesirable for processors who pay a discounted price for both larger and smaller fish. ARS scientists at Stoneville, Mississippi, found that food conversion and mean weight at harvest were not affected by grading fingerlings. However, the proportion of fish above and below the processor-preferred size range was decreased when fingerlings were graded. Stocking well-graded fingerlings is an important aspect of producing a uniform population of harvest-sized fish, as a result most farmers are now purchasing graded fingerlings.

Pacific oyster

Models of burrowing shrimp population dynamics can be used to advance integrated pest management. Burrowing shrimp are a problem for the U.S. West Coast shellfish aquaculture industry as they cause oysters to sink under the surface of the sediment and die. ARS researchers in Newport, Oregon, monitored shrimp populations, quantified annual patterns of shrimp recruitment to West Coast estuaries and built an age based population dynamics model for these shrimp by quantifying the amount of lipofuscin, a pigment in their brains. Though recruitment of small young-of-the year shrimp varies widely from year to year and from estuary to estuary, the age based model suggested that there was also consistent and relatively high natural mortality of older shrimp after recruitment. Though the chemical treatment program in Washington State continues to be difficult to permit, developing a good monitoring plan that includes recruitment indices may focus efforts on developing an integrated pest management program with alternative treatments for shrimp recruits with shallow burrows, allowing the industry to control them before they become a significant issue.

Product Quality and New Products

Catfish

Improving the shelf life of fresh catfish fillets. Improving the shelf life of fresh catfish fillets is of great economic importance to catfish, retail food, and food service industries. Louisiana State University scientists collaborated with ARS scientists in New Orleans, Louisiana, to evaluate the use of water soluble chitosan to improve the shelf life of refrigerated catfish fillets. Results indicated catfish fillets treated with water soluble chitosan had the lowest lipid oxidation and inhibited yeast and mold counts more than the other treatments during the 20 days in refrigerated conditions. They demonstrated that water soluble chitosan product, combined with vacuum tumbling, can be effective at reducing yeast and mold and lipid oxidation in catfish fillets during refrigerated storage.

Where best to check for off-flavor in catfish fillets. The objective was to evaluate what part of the catfish fillet should be used to check for off-flavor in an effort to reduce the number of off-flavor fish in the market place. ARS scientists in New Orleans, Louisiana, processed catfish into fillets and then each fillet was cut vertically and horizontally into 4 portions and analyzed for the off-flavor compounds 2-methylisoborenol (2-MIB) and geosmin, and fat content. Results indicated no trend was observed to support the hypothesis that portions of the fillet had higher concentrations of off-flavor compounds than other portions. There was little difference in the concentration of 2-MIB and geosmin within the fillet with current analytical techniques; therefore, any part of the fillet can be used for evaluating off flavors.