Aquaculture (NP106) Annual Report for 2012

Vision: The vision for ARS aquaculture research and technology transfer is to support a thriving domestic industry based on improved systems developed through research and application of better genetic stocks, improved diets and nutrition, enhanced aquatic animal health and consistent water quality. Our program supplies scientific information on processes, 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 primary aim of the ARS Aquaculture Program, as described in the National Program 106 Action Plan, is to help develop and ensure an abundant, safe, and affordable supply of seafood products within a healthy, competitive, and sustainable aquaculture sector. This sector is supported by over 4,300 aquaculture farmers that produced in excess of $1 billion dollars worth of goods in 2005 (NASS, 2005 Census of Aquaculture).

Fiscal year 2012 was the third year of externally-reviewed five-year project plans. Although these project plans guide most of the efforts of the laboratories, we remain flexible enough to respond to additional problems and opportunities. NP106 research is spread across the spectrum from fundamental to applied, aiming to solve problems through long term high impact research. NP106 published over 100 articles over the past two years in peer-reviewed scientific journals.

NP106 People in 2012

We welcomed David Marancik, DVM, Ph.D. into ARS as a post-doc with the National Center for Cool and Cold Water Aquaculture in Leetown, West Virginia. In Stoneville, Mississippi, Craig Tucker, a familiar presence as the Mississippi State University Director of National Warmwater Aquaculture Center, moved across the hall to become the Research Leader of the Catfish Genetics Research Unit. With the closure of the Chestertown, Maryland, Aquatic Animal Health Research Unit, (Auburn, Alabama, North facility) Joyce Evans moved to the Catfish Genetics Research Unit in Stoneville, Mississippi. Peter Bechtel moved from the Alaskan project on fishery co-products, to the Southern Regional Research Center in New Orleans, Louisiana, to lead the new project on adding value and developing new products for catfish. Joining Peter on the project is the research chemist John Bland, coming to aquaculture from the Formosan Subterranean Termite Research Unit in New Orleans. Dunhua Zhang also joined the Aquaculture program from the Formosan Subterranean Termite project, moving to the Aquatic Animal Health Research Unit in Auburn, Alabama.

Several scientists have retired or left from USDA/ARS. Chhorn Lim retired in January 2013, after an extremely productive 25 years in nutrition and fish health with ARS. Mark Camara left the Newport, Oregon, Shellfish Genetics worksite (at the Oregon State University Hatfield Marine Research Laboratory) for a position in New Zealand.

Barry Hurlburt continues in New Orleans but has moved from the aquaculture project into the peanut allergen project.

Awards and Recognitions:
Scientists in the Aquaculture National Program were well recognized nationally and internationally over the past year, with many invited presentations. The following scientists in the Aquaculture National Program were recognized with prominent awards:

Frederic Barrows, Trout Grains Project, Aberdeen, Idaho:
2012, USDA/ARS Pacific West Area, Scientist of the Year

Frederic Barrows, Trout Grains Project, Aberdeen, Idaho:
2012 Excellence in Aquaculture Award, Illinois Soybean Association

Kevin Schrader, Natural Products Utilization Research Unit, Oxford, Mississippi, and John Davidson and Steve Summerfelt, Conservation Fund Freshwater Institute, Shepherdstown, West Virginia:

2012 Aquacultural Engineering Society Best Paper Award:
Schrader, K.K., Davidson, J., Summerfelt, S.T. (2010). Evaluation of ozonation on levels of the off-flavor compounds geosmin and 2-methylisoborneol in water and rainbow trout Oncorhynchus mykiss from water recirculation aquaculture systems. Aquacultural Engineering. 43, 46-50

Craig Tucker, Catfish Genetics Research Unit, Stoneville, Mississippi:
2012 Aquaculture Achievement Award, Delta Council

National Program 106 involves efforts in 9 units at 111 different locations on 20 projects performed by nearly 100 scientists (46 ARS scientists and an equal number of collaborating scientists). Technology transfer activities included invention disclosures including a large number of attenuated bacterial strains, several new and ongoing Cooperative Research and Development Agreements (CRADA) and over 20 new and ongoing Material Transfer Agreements (MTA). These agreements cover transfer of Atlantic salmon germplasm to commercial producers, supply of rainbow trout families to university, industry and State hatchery collaborators, development of vaccine and vaccination methodologies and transfer of specific pathogens strains for vaccine work. A number of additional activities to transfer technologies to other scientists and to industry partners were also completed. Among the outstanding examples is the ongoing effort to improve hybrid catfish production at Stoneville, Mississippi, where scientists are working closely with a number of hatchery

operators in the Mississippi Delta region having tremendous success increasing the number of hybrid fry produced across the industry. Another example is the rapid development of numerous fish diets including new ingredients. The Trout Grains project has worked with multiple collaborators to improve, develop and test new ingredients, leading to new feed formulations and opportunities for ingredient manufacturers.

Across the program, researchers maintained beneficial collaborations with a number of international investigators and laboratories. Canada and Norway lead the list in terms of the active collaborations. Work ranges across cooperation on salmon breeding efforts and information sharing on recirculating aquaculture systems with Canadian counterparts to exchange with the Norwegian Aquaculture Protein Center on feed processing and with NOFIMA (Norwegian Institute of Food, Fisheries and Aquaculture Research) on fish health and well-being in recirculating systems. Our aim is to form real partnerships that have benefit to the United States and to cooperating countries. These relationships increase the depth of our intellectual capital with original ideas from different perspectives. We had a 10 day tour of facilities in West Virginia and the Southern states, Alabama, Mississippi, and Arkansas by potential new cooperators, in fish health and feed development areas, from the National Agricultural Research Agency in Brazil, EMBRAPA. In addition ARS scientists traveled to Brazil, China, Norway, and other countries to make presentations and develop new collaborative opportunities.

Funding: During fiscal year 2012, total funding for Aquaculture research was approximately $33.4 million. Balancing the continuous need for additional funding with the maintenance of our core mission is a constant challenge and the resulting dialog is a big part of the innovative process. These additional funds have come from grants, other government agencies, foundations and industry. The National Center for Cool and Cold Water Aquaculture (Leetown, West Virginia), Trout-Grains project (Hagerman, Idaho), Catfish Genetics Research Unit (Stoneville, Mississippi), Aquatic Animal Health Research Unit (Auburn, Alabama), the shellfish habitat utilization lab (Hatfield, Oregon), and the National Cold Water Marine Aquaculture Center (Franklin, Maine) and the Freshwater Institute (Shepherdstown, West Virginia) all received extramural funds.

Research Results

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

Genetic and Genomic Resources

Third generation of selectively bred yellow perch reach market size four months sooner
High performers of yellow perch strains were identified, tagged, genotyped, and selectively bred by ARS researchers at Milwaukee, Wisconsin, and their University of Wisconsin at Milwaukee partners. As a result of two generations of selection, the time needed to reach market size has been reduced from eleven to seven months. Faster

growth to market size will enable producers to have multiple production cycles in a single year, which increases profitability of commercial yellow perch aquaculture operations. Additionally, genetic differences in resistance to viral hemorrhagic septicemia virus have been demonstrated and will enable further genetic improvement in disease resistance.

Reducing the use of fish oil in salmonids feeds

Feed is the highest variable cost in aquaculture production, with fish oil being one of the most expensive feed ingredients. Fish oil in trout feed is the primary source of the healthy omega-3 fatty acids EPA and DHA found in trout fillets. Scientists with the Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, evaluated the ability of several families of rainbow trout to convert plant oils into long chain omega-3 fatty acids and store them in their tissues. The study clearly demonstrated that genetic variation exists between families for this ability. Rearing rainbow trout improved for this trait should maintain the beneficial fatty acids currently found in trout fillets while reducing feed costs and the industry's current reliance on fish oil.

Rainbow trout selected for growth on plant-based feeds have increased tolerance for soy's anti-nutritional factors

Fishmeal is an expensive component of many trout diets. To reduce the reliance on fishmeal based feed, scientists with the Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, have selectively bred a strain of rainbow trout that grows faster and more efficiently when fed a fishmeal-free, plant-based diet. The improved fish have adapted parts of their intestinal tract to utilize a plant-based diet more efficiently without developing the intestinal inflammation observed with conventional strains of rainbow trout when fed such diet. Increasing our understanding of how trout adapt to being fed plant-based diets will aid in the continued development of improved strains of trout.

Production and evaluation of hybrid catfish using various strains of blue catfish

Hybrid catfish production (female channel catfish crossed with a male blue catfish) has expanded greatly in the United States over the past 5 years. While channel catfish strains have been well characterized over several decades, little information is available on blue catfish germplasm regarding production traits, especially in channel x blue hybrid catfish offspring. ARS scientists with the Catfish Genetics Research Unit in Stoneville, Mississippi, have obtained blue catfish from several geographic sources (strains) and initiated a program to determine the effects of blue catfish strain and individual within strain on hybrid offspring growth and fillet yield. Significant effects of individual male and female parent on offspring performance were identified and importantly, these effects were additive. This result means that the effect of parent on offspring performance is predictable and improvements will be cumulative. Based on results of these trials, blue

catfish germplasm that produces superior performing hybrid offspring will be identified and released to the industry.

Atlantic salmon selected for increased growth and weight released to industry
Commercial salmon producers in the Eastern United States are legally required to culture stocks certified to be of North American origin. Therefore they use stocks that are only a few generations removed from wild, unselected stocks with relatively poor performance under farming conditions. ARS researchers at the National Cold Water Marine Aquaculture Center at Franklin, Maine, are selectively breeding salmon of North American origin for faster growth and evaluated the growth of salmon from their breeding program in commercial sea cages in collaboration with industry. A salmon line selected for increased growth, more than 50% larger than unselected control fish, has been generated and germplasm was released for commercial production. Genetic gain has been 7-10% per generation. Utilization of improved germplasm will increase the profitability and sustainability of coldwater marine aquaculture in the United States while providing a quality seafood product to U.S. consumers.

Evaluation of channel x blue and purebred channel catfish performance from 4 commercial farms
Channel x blue hybrid catfish production and use by the catfish industry have increased substantially in the last 3 to 5 years, however channel catfish females that cross well to form hybrids and blue catfish breeds with superior farmed performance have not yet been identified. ARS scientists with the Catfish Genetics Research Unit in Stoneville, Mississippi, are working to determine the effects of channel catfish strain, and female within strain, on hybrid offspring growth and carcass yield. This project will provide information to determine which strains produce superior hybrid offspring, how much differences in offspring performance are due to differences in individual female parent, and if purebred channel offspring performance is predictive of hybrid offspring performance. This information is key to producers as they develop breeding plans to improve hybrid catfish performance.

Genetic mapping of stress response to handling in rainbow trout
Under typical fish farming conditions, fish are routinely exposed to crowding, handling and similar stressors. How fish respond to such stressors impacts their growth, feed efficiency, immune response, and reproductive development. Through genetic mapping approaches ARS researchers at the National Center for Cool and Cold Water Aquaculture (NCCCWA) at Leetown, West Virginia, identified 8 chromosomal regions linked to stress response in rainbow trout and are measuring genetic variation for this trait within and between populations. This research will improve our understanding of the

physiology of the stress response as well as provide a more rapid and accurate way to identify rainbow trout best able to perform well under routine farming stressors.

Animal Performance, Well-being and Efficiency

Controlling sexual maturation in farmed fish

The long periods of time required for most farmed fish to reach sexual maturity significantly slows genetic improvement and impedes fingerling production. Kisspeptins are newly recognized proteins that naturally control when animals enter puberty. Scientists from the Stuttgart National Aquaculture Research Center in Stuttgart, Arkansas, showed that sexually immature male white bass entered puberty more quickly and that adult female white bass had larger ovaries containing more mature eggs following administration of kisspeptins. Together these findings highlight the potential of kisspeptin treatment in fish to accelerate and help control reproductive timing. This will speed breeding and improve year-round reproductive potential.

Sex steroids linked to muscle degradation in rainbow trout

Sexual maturity affects growth and meat quality in most terrestrial livestock but little is known about their actions in fish. Understanding how sex steroids affect muscle growth and quality will enable development of strategies for more efficient fillet production. ARS researchers at the National Center of Cool and Cold Water Aquaculture at Leetown, West Virginia, discovered increased rates of muscle protein degradation occur in sexually maturing rainbow trout with high sex steroid levels, even when feeding rate is high. Subsequent studies indicated that estrogens, but not androgens, act directly in muscle to reduce protein retention by both increasing rates of protein degradation and decreasing rates of protein synthesis. These data demonstrate that harvesting before sexual maturation and sex steroid exposure should result in the most efficient production of high quality fillets in the rainbow trout.

Development of a non-lethal and rapid method for reliable identification of gender in yellow perch

Yellow perch females grow faster than males, so aquaculture producers would like to separate yellow perch by gender. Despite this difference in size, it is difficult to distinguish the sex of immature animals without causing harm or death to the animal. To address this, ARS researchers at Milwaukee, Wisconsin, developed criteria that enable gender identification in yellow perch, based upon the coloring and shape of the external reproductive openings, with an accuracy exceeding 97%. This non-lethal method provides a useful and practical tool that will enable aquaculture producers and researchers to sort sexes for 1) development and management of broodstocks (breeding stock) prior to, and during, breeding; 2) conducting multi-tank replicate experiments aimed at

studying gender-specific differences in yellow perch; and 3) identification of the fastest growing individuals of each sex in yellow perch broodstock genetic-selection programs dedicated to developing improved growth performance in this species. The criteria developed for gender identification in yellow perch are easy and inexpensive.

Evaluation of a vertebrate gonadotropin releasing hormone to induce ovulation in catfish

Production of hybrid catfish has expanded substantially in the United States over the past 5 years; however, availability of hybrid fingerlings still does not meet the demand. ARS researchers at the Catfish Genetics Research Unit in Stoneville, Mississippi, are working to improve efficiency of hybrid catfish production through better control of ovulation and stripping of high quality eggs. A synthetic spawning hormone has been tested and found to perform as well as the mammalian hormone analog which is currently used in commercial hybrid catfish production. The synthetic hormone also improved synchronization of ovulation, improving the number of eggs ovulated by each female, and higher numbers of fry were produced compared to the mammalian form of the hormone. Increased production efficiency of hybrid fry should lower the cost of hybrid fry production in the U.S. catfish industry.

Regulators of feed efficiency in catfish

Factors that control feed efficiency are not well understood in catfish. Therefore ARS scientists in Stoneville, Mississippi, conducted research to investigate the role of mitochondrial respiratory chain enzyme activities on low and high Feed Efficient (FE) families of catfish. Mitochondrial complex enzyme activities showed that the activities of the liver mitochondrial complexes (I, II, III, and IV) were all lower in the low FE family compared to the high FE family. Enzyme activities of the muscle and gene expression from the liver and muscle are currently being evaluated. Understanding how the mitochondrial respiratory chain controls feed efficiency will help researchers develop strategies to improve feed efficiency in catfish.

Nutrient Requirements, Nutrient Composition of Feedstuffs, and Expanding Alternative Ingredients

Use of alternative feed ingredients to reduce production costs of catfish

The prices of soybean meal and corn, the two most commonly used traditional feed ingredients in channel catfish diets, have increased dramatically in recent years. Using less-expensive alternative feed ingredients to partially replace soybean meal and corn would reduce feed cost. Scientists at Mississippi State University (MSU) at Stoneville, Mississippi, investigated the use of alternative feedstuffs corn gluten meal, distillers dried grains with solubles, and cottonseed meal, as replacements for soybean meal and corn in

diets for pond-raised channel catfish. Up to 50% of the soybean meal in channel catfish diets may be replaced by a combination of these ingredients without markedly affecting the physical quality of feed pellets, fish growth, processed yield, and body composition. The results also show that corn can be reduced to a level of about 15-20% without affecting fish performance.

Summer diets for hybrid striped bass

High daily summertime feeding rates can result in concentrations of ammonia in pond water that are toxic to hybrid striped bass. In response, farmers may curtail feeding or switch to a lower protein feed, both of which reduce production. With input from Mississippi-based hybrid striped bass producer, Nature's Catch, scientists at the Stuttgart National Aquaculture Research Center, Stuttgart, Arkansas, demonstrated that a diet with higher digestible protein and fat that was supplemented with deficient amino acids, maximized growth and nutrient retention and reduced ammonia waste production. Fish feed manufacturers are using new digestibility coefficients, recently developed at this lab, in their diet formulations for hybrid striped bass, feeding the new summer diet formulation, and improving summer production.

Organic ingredients can substitute for fish meal in fish feed

The USDA is currently developing standards for organic aquaculture production. Agricultural products for use in fish feeds that will meet these organic standards are sought as substitutes for fish meal. A scientist from the Stuttgart National Aquaculture Research Center, Stuttgart, Arkansas, in collaboration with scientists from Kentucky State University, Frankfurt, Kentucky, showed that tilapia fry fed a diet formulated with organic soybean meal and organic yeast, and supplemented with specific amino acids grew as well as tilapia fry fed a fishmeal based diet. Identifying organic agricultural products that can substitute successfully for fish meal in fish diets that meet the standards for an organic label is an essential step towards achieving organic aquaculture production.

Developed a method to recover high value co-products from grain-based ethanol production

There is increasing production of fuel ethanol from grains in the United States and the primary co-product is corn distiller's dried grains with solubles (DDGS). The quantity of this relatively low value product is also increasing and is used primarily in cattle but its use for feeds is limited due to an imbalance of nutrients. Scientists with the Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, developed a new processing method that will produce more consistent, higher protein DDG and two new products, a protein and a mineral source with improved nutrient profiles. Feeding trials with rainbow trout demonstrated that both products are highly digestible, which is vitally important to

the trout industry. This new process can be easily added to the existing process and it 1) reclaims valuable phosphorus and protein from the solubles and 2) separates the nutrients into distinct products, thus increasing the overall flexibility, economic value, and sustainability of ethanol production**.**

New protein source for aquafeeds developed from almond processing waste

Approximately 2 billion pounds of almonds are produced in the United States each year and approximately 25% is considered waste in the form of broken pieces and fine particles and is fed to cattle. Scientists with the Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, in collaboration with U.S. based Adaptive Bio-Resources LLC, developed a process to partition this waste into several new products for both the human food and aquafeed markets. Trout feeding studies have demonstrated high digestibility and palatability for the ~60% protein almond meal. Identifying and developing new sources of plant-based protein for aquafeeds will increase the profitability and sustainability of aquaculture production and increase the value of co-products.

Improving Health

Development of a live attenuated vaccine and in-pond vaccination platform to protect catfish against enteric septicemia of catfish

A new vaccine and vaccine delivery platform have been developed resulting in exceptional protection against Enteric Septicemia of Catfish (ESC). Based on experimental pond studies conducted under conditions similar to the commercial production setting, vaccination increased survival, fish size, and feed consumption while improving the feed conversion ratio by approximately 40.4%. The improved feed conversion could represent a 30% reduction in feed costs, while improved production efficiencies in vaccinated fish increased gross sales over 100%. Similar results were obtained over two years of field testing. Field and laboratory research is being conducted as part of the USDA licensing process for live attenuated vaccines.

Parasite vector for a bacterial pathogen in channel catfish

There is limited information on whether parasites act as vectors to transmit pathogenic bacteria in fish. Scientists at the Aquatic Animal Health Research Laboratory at Auburn, Alabama, conducted studies with *Ichthyophthirius multifiliis* (Ich, parasite) and *Edwardsiella (E.) ictaluri* (bacterium) to determine the interactions between the parasite, the bacteria, and the catfish. This study provided evidence that the parasite, Ich, can carry *E. ictaluri* into channel catfish. The parasite, when exposed to *E. ictaluri* bacteria could pass the bacteria to channel catfish. The transmission ability of parasites is particularly important at fish farms because the introduction of parasites either from wild fish or from

other farms could unintentionally involve the introduction and/or transmission of bacterial diseases.

Vaccines developed to protect tilapia against Streptococcosis

Streptococcosis is a hyperacute systematic disease that affects both cultured and wild fish species in various aquatic environments (freshwater, estuarine, and marine). ARS researchers at Auburn, Alabama, developed attenuated vaccines to protect tilapia against both *Streptococcosis agalactiae* and *Streptococcus* (*S.*) *iniae*. The attenuated *S. iniae* vaccine offered tilapia 100% protection for over 2 months post vaccination. In addition, the attenuated *S. iniae* vaccine offered 78% to 100% protection against multiple isolates of *S. iniae*. The use of these vaccines will protect tilapia against streptococcosis, and decrease the economic losses caused by strep induced mortality affecting the aquaculture industry**.**

Identification of the causative agent of a significant disease outbreak in farmed rainbow trout and development of an autogenous vaccine

Emerging pathogens are a significant threat to U.S. Aquaculture. An ARS researcher at Leetown, West Virginia, isolated a new gram positive bacterial pathogen causing significant loss of rainbow trout in North Carolina. The pathogen was found to be similar to *Weissella* sp. Associated with recent disease outbreaks in farmed rainbow trout in both China and Brazil; this is the first report of this pathogen in the United States. At the request of stakeholders, the National Center of Cool and Cold Water Aquaculture developed and validated an effective autogenous vaccine which is now in commercial production and in use at North Carolina farms affected by this pathogen. Early pathogen detection and the rapid development and implementation of a vaccine are aiding control efforts and reduce the likelihood of further pathogen dissemination in the United States.

Release of disease resistant germplasm to the rainbow trout industry stakeholders

Bacterial cold water disease, caused by *Flavobacterium psychrophilum*, is a widely-distributed and economically-important disease that results in elevated mortality and deformity rates in rainbow trout aquaculture. Currently there are only limited chemotherapeutics, and no commercial vaccines, available for control or prevention of the disease. ARS researchers at the National Center for Cool and Cold Water Aquaculture at Leetown, West Virginia, have developed the ARS-Fp-R rainbow trout line through multiple generations of genetic selection for improved disease resistance, and have demonstrated the line has superior resistance to the bacterium in laboratory challenges and field trial evaluations. The release of 80,000 embryos from 52 pedigreed families to Clear Springs Foods Inc. (Buhl, Idaho) and Troutlodge Inc. (Sumner, WA), and approximately 50,000 embryos from 43 families to the Utah Division of Wildlife Resources, will allow industry and government stakeholders to propagate or introgress the line and produce future generations of fish with improved disease resistance.

Bacterial binding sites influence susceptibility to columnaris disease

Columnaris is a major fish bacterial disease causing significant losses to the aquaculture industry. New research suggests that bacterial binding sites in the gills were stimulated in response to columnaris exposure. ARS scientists in Stuttgart, Arkansas, demonstrated dramatic evidence of differential immunity to columnaris after exposing fish to the bacteria and examining the quantity of binding sites in the gills of two different families of channel catfish. They determined that one family was susceptible to the disease, while the other was completely resistant. The quantity of binding sites in the gill was strongly increased in the columnaris-susceptible family, but the catfish protected from columnaris disease had reduced binding sites present in the gills. The nutritional status of the fish also had an effect, with a far greater amount of binding sites in the gill of unfed fish relative to well-fed fish. These findings will be applied to develop screening techniques for enhancing resistance to columnaris.

Pharmacokinetics of florfenicol in channel catfish

Researchers from Mississippi State University, College of Veterinary Medicine (MSU-CVM) at Stoneville, Mississippi, conducted pharmacokinetic studies of florfenicol in catfish. These studies along with laboratory and field efficacy studies were pivotal in obtaining Food and Drug Administration (FDA) approval for the use of florfenicol medicated feed to treat *Flavobacterium* (*F*.) *columnare* and *Edwardsiella ictaluri* infection in catfish. In addition, these studies along with one conducted by the United States Fish and Wildlife Service in Bozeman, Montana, cleared the way for approval of florfenicol to treat *F. columnaris* infection in all freshwater-reared warmwater fish. The drug is prescribed under a veterinary feed directive and has been shown extremely effective in controlling bacterial infections in warmwater fish.

The development of molecular test for the detection of significant catfish pathogens in environmental and tissue samples

Disease is one of the leading causes of fish loss and poor yields in catfish production. Researchers from Mississippi State University (Mississippi Agricultural and Forestry Experiment Station, MAFES and College of Veterinary Medicine, CVM) have developed and validated assays for the detection and quantification of a number of significant agents causing serious disease in channel catfish. The assays provide reliable methods for the detection and quantification of pathogens in pond environments and are being used for rapid diagnostic evaluations and evaluation of treatment efficacies associated with recommended disease management strategies and research. Using this technology, risk assessment models for proliferative gill disease (PGD) have been developed and are being used by diagnostic services to mitigate losses during catfish pond stocking and restocking programs. Additionally, a bacterial assay for the causitive agent of motile aeromonas septicemia is currently in use in our and other laboratories to confirm the presence/absence of the emerging virulent strain of *Aeromonas hydrophila* in suspect

cases. In addition to their diagnostic benefits, these assays provide a means to conduct epidemiological and environmental studies and evaluate how management strategies alter pathogen loading rates in commercial catfish ponds. This information will be used to optimize disease management practices aimed at maximizing production efficiencies and economic returns.

Identification of a new species of trematode affecting production efficiencies of catfish
Recently, ponds of catfish with reduced growth and feed intake were examined for disease. Snails were collected and found to be releasing a trematode parasite, previously thought inconsequential to catfish health. Challenges with actively shedding snails demonstrated this trematode can infect channel catfish, and cause mortality. Molecular analysis identified this parasite as *Drepanocephalus* (*D.*) *spathans*, a digenetic trematode known to parasitize the double-crested cormorant. Based on the high numbers of *D. spathans* infected snails collected from commercial catfish ponds, this trematode species is likely a significant pathogen of channel catfish and has been included in disease monitoring efforts.

Production Systems and Products

Lower water exchange rates save money without negative impacts on health and performance of Atlantic salmon
Water availability and cost of water use are two key variables for fish production in recirculating aquaculture systems, so one research goal is to minimize the rates of water exchange while maintaining excellent conditions for fish. Atlantic salmon were reared by ARS researchers at Leetown, West Virginia, for 6 months in replicated water recirculating systems operated with either high water exchange (97.5% of system flow recirculated, i.e. 2.5% new water added each day) or low water exchange (99.75% of system flow recirculated, 0.25% new water added each day). Fish performance, health and welfare were measured. By study's end, no significant differences were determined in growth, survival, and other fish health outcomes even though the low water flushing treatment operated with 10-times less water use. Though significant differences in a variety of water quality parameters were noted, none of these parameters was outside acceptable ranges for raising salmonids. This study illustrates that Atlantic salmon perform well in recirculating systems with low water exchange and demonstrate that farmers with limited water resources can compete in salmon production.

New cascade column and low-head pump combination reduces the energy requirement for producing fish in water reuse systems
Construction and operation costs of recirculating aquaculture systems is a major impediment to adoption of these recirculating aquaculture system technologies. Scientists at the Conservation Fund Freshwater Institute, working with ARS researchers

at Leetown, West Virginia, developed a sidewall box containing a forced-ventilated cascade column and low-head axial flow pump to provide a new high water flow and low lift method of gas exchange just outside of the culture tank. Water and air flow rates were measured, plus energy consumption, dissolved oxygen and carbon dioxide transfer rates and efficiencies. The novel application was found to reduce electric and oxygen costs by as much as 50% compared to more conventional partial water reuse technology. The sidewall box cascade column and low-head pump can be integrated into the design of much larger recirculating aquaculture systems to improve gas control, provide culture tank rotation, and reduce total power requirements and the carbon footprint of these systems.

Biofloc technology systems reduce the intensity of common off-flavors in channel catfish

Pre-harvest off-flavors described as "earthy-musty" in catfish that are produced in earthen ponds continue to present problems for this industry. A novel, highly intensive, static water production system, called the biofloc technology production system, produces high yields of channel catfish. ARS researchers at the Natural Products Utilization Research Unit, Oxford, Mississippi, and the Stuttgart National Aquaculture Research Center, Stuttgart, Arkansas, with a scientist at the University of Arkansas-Pine Bluff, Arkansas, demonstrated that the biofloc technology production system also inhibited the growth of common blue-green algae responsible for producing off-flavor compounds, and that the intensity of off-flavor problems were reduced in catfish grown in these systems. This discovery provides catfish producers with an alternative to using earthen ponds to grow catfish and provide an on-flavor, high-quality product to consumers.

Development of an improved aerator for the catfish industry

Paddlewheel aerators have been used for aeration in aquaculture for over 30 years. They transfer a lot of oxygen to the water but also move a large volume of water which spreads the aeration effort over the entire pond volume. Thus, a great deal of equipment and a large amount of power is required to prevent low dissolved oxygen (DO) conditions in commercial ponds. ARS researchers at Stoneville, Mississippi, have developed a new aerator, the Power Tube Airlift (PTA) which can concentrate DO into a small zone of water in a pond using less energy than traditional methods. At a 20-ft sparger water depth preliminary testing indicates that the PTA has an oxygen transfer rate aeration efficiency approximately equal to a 10-hp paddle-wheel aerator. Fewer moving parts and improved efficiency would reduce the costs associated with repair and maintenance, and lower power (electricity) consumption, respectively. Two commercial-scale PTAs have been installed in an 8-acre catfish production pond for onsite field testing, and field trials on commercial farms are expected to begin in FY 2013. This invention has a patent application currently pending with the U.S. Patent and Trademark Office.

Development and validation of split pond production systems to increase production efficiency of catfish

Most United States aquaculture production comes from large earthen ponds. Disadvantages of traditional pond production are the need for continuous management of pond oxygen concentrations, sporadic algae-related fish off-flavors, losses to avian predators, difficulties in disease control, inefficient fish harvesting, and lack of tight control of water quality. Scientists from Mississippi State University (MSU) at Stoneville, Mississippi, have addressed these constraints by modifying ponds to physically separate the fish-holding function from the life-support and waste-treatments functions. A commercial scale system, called the "split pond" has been developed and validated at Stoneville, Mississippi. The split pond is constructed by dividing an existing earthen pond into two unequal sections with an earthen levee and then linking the two sections with water flow. Validation studies indicate that the split-pond is easy to manage and that fish production can be tripled compared to traditional ponds. Based on research in this project, split ponds have been widely adopted by the catfish farming industry. More than 1,000 acres of commercial ponds have been built with at least an additional 1,000 acres under construction or planned construction.

Intensive production of hybrid catfish

ARS researchers at Stoneville, Mississippi, have completed three years of research on the intensive production of channel catfish female X blue catfish male hybrids (hybrid catfish) using 0.25-acre ponds at the National Warmwater Aquaculture Center in Stoneville and 1-acre ponds under contract at the Delta Western Research Center in Indianola, Mississippi. Speeding time to harvest and improving efficiency of feed conversion to flesh are critical for improving profitability of catfish production. Research has demonstrated that hybrid catfish can tolerate a slightly lower dissolved oxygen (DO) concentration in the morning than channel catfish. They also have a greater tolerance to common diseases affecting catfish, resulting in a greater feed intake through spring and fall when diseases are more common. Due to an overall greater feed intake, fish grow faster and reach harvest size sooner. It appears that with an adequate DO concentration (a minimum of 2.5 mg/L in the morning) fish density has little effect on growth rates at least up to stocking rates of 11,000 fish per acre. Continued adoption of hybrid catfish by the industry is expected to result in increased profits (reduced production costs) due to faster growth (reduced production cycle), increased survival, and improved feed conversion ratios.