National Program 106 Aquaculture Annual Report for 2013

The vision for ARS aquaculture research and technology transfer is *to support 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 primary aim of the ARS Aquaculture Program, as described in the National Program 106 (NP 106) Action Plan, is to develop and ensure an abundant, safe, and affordable supply of seafood products for the over 330 million U.S. consumers produced in a healthy, competitive, and sustainable aquaculture sector, a sector supported by more than 4,300 aquaculture farmers producing in excess of $1.3 billion worth of goods annually.

Fiscal year 2013 was the fourth 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. NP 106 research is spread across the spectrum from fundamental to applied, aiming to solve problems through long term high impact research. NP 106 published well over 100 articles over the past two years in peer-reviewed scientific journals.

Over the summer and early fall, ARS and the National Institute of Food and Agriculture (NIFA) together held a number of aquaculture stakeholder meetings. Most were conducted by webinar, a new format for us, and one facilitated workshop on catfish held in person in Stoneville, Mississippi, with participation from across the catfish growing regions. Inputs from these workshops and from the many written comments were considered and incorporated into the ARS aquaculture action plan and will inform NIFA leadership, too.

NP 106 People in 2013

In April 2013, Carl Webster, Ph.D. was hired as the new Research Leader/Center Director at the Harry K. Dupree Stuttgart National Aquaculture Research Center. Carl came to us from Kentucky State University and will continue research on aquaculture nutrition. He has already stimulated great teamwork at the center and initiated a series of written outreach materials, including a quarterly newsletter and an article in *World Aquaculture* magazine (December 2013).

In May 2013, we welcomed Dina Proestou, Ph.D. into ARS as a new scientist and part of the National Cold Water Marine Aquaculture Center. Dina's research is focused on oysters and the genetics of disease resistance; she is located in Rhode Island at University of Rhode

Island (URI). Dina completed her Ph.D. and a post-doc at URI. Dina came to ARS from the Environmental Protection Agency in Kingston, Rhode Island.

Several scientists have retired from USDA/ARS. Phil Klesius retired in January 2014, after an extremely productive 42 years of Federal service with ARS. Phil served as Research Leader of the Aquatic Animal Health Research Unit and Location Coordinator in Auburn, Alabama, for 26 years. Among Phil's many accomplishments, he published over 177 refereed papers, produced 16 patents and developed the only commercially available live attenuated fish vaccines in the United States. Gary Banowetz who was the Research Leader for the West Coast oyster efforts also retired at the end of 2013. Though Gary's research was focused on forage and grasses as a plant physiologist, he worked in fish health early in his research career.

Awards and Recognitions:
Scientists in the Aquaculture National Program were well recognized nationally and internationally over the past year, with many invited presentations. Dr. Ben LaFrentz from the Aquatic Animal Health Research Unit in Auburn, Alabama, was recognized by the publisher Wiley and the editors of the *Journal of Fish Diseases* as one of the journal's top peer-reviewers. A headquarters post-doctoral research associate program award went to Ken Overturf (Hagerman, Idaho) for *Enhancing aquaculture sustainability by improving plant oil utilization* and Peter Bechtel (New Orleans, Louisiana) for *Postharvest processing to add value to catfish*.

Over the past couple of years there has been a clear upward trend in the external funds awarded to ARS aquaculture scientists, through competitive grants, Foundation supported research, Cooperative Research and Development agreements (CRADAs) and the newer mechanism of Material Transfer and Research agreements (MTRAs). In new awards just this year there have been funds of over $550,000 coming into ARS aquaculture research, with Aquatic Animal Health Research Unit, The Trout-Grains project out of Aberdeen, Idaho, and the National Cold Water Marine Aquaculture Center attracting the most agreements and funding. Our close research partner, The Freshwater Institute, in Shepherdstown, West Virginia, also initiated a number of new research agreements.

National Program 106 involves efforts in 11 different locations on 23 projects performed by nearly 100 scientists (46 ARS scientists and an equal number of collaborating scientists). Technology transfer activities include a number of invention disclosures, 4 new patent applications, and 9 new Material Transfer Agreements (MTAs). 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. Collaborative research and development based on the bacterial coldwater disease resistant strain of rainbow

trout from the National Center for Cool and Cold Water Aquaculture has expanded with several labs and producers.

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.

Funding: During fiscal year 2013, total funding for Aquaculture research was approximately $30 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.

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

Increasing production of healthy omega-3 fatty acids in rainbow trout

The increase in price is making fish oil too expensive to include at desired levels in aquaculture feeds. Scientists at the Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, have determined that genetic variation exists between families for the ability to produce and deposit fish oils in flesh. During the last year they have measured the variation among families and validated methods for measuring fatty acid levels in live fish. This methodology provides the ability to improve fish oil content in filets through breeding, and ultimately produce a fish with greater health benefits to humans.

High survival of bacterial cold water disease resistant rainbow trout line in farm trials

Bacterial cold water disease (BCWD) is a frequent cause of farmed trout loss. ARS researchers at Leetown, West Virginia, have developed a BCWD resistant rainbow trout line, through multiple generations of genetic selection for improved disease resistance. Three consecutive years of performance testing of these fish were carried out under farm conditions. In five completed trials to date, in which non-select fish were diagnosed with BCWD, survival of the select line has been 95% from initial feeding through the early rearing phase. This was significantly greater than non-selected fish grown together. In addition to greater survival, the select line had a smaller percentage of fish that tested positive for the pathogen that causes BCWD. These findings support the release of germplasm to stakeholders and the continued evaluation of the select genetic line in large-scale production trials.

Genetic improvement for bacterial cold water disease (BCWD) resistance in diploid fish also benefits triploid fish production

Fish can be susceptible to many diseases such as bacterial coldwater disease (BCWD). Triploid fish, or fish with 3 sets of chromosomes, are sterile, or unable to reproduce. Therefore, triploids are often grown in situations where reproduction must be avoided, such as release into natural systems. Also, triploids grow to a larger size, and have better fillet quality than normal diploids (with 2 sets of chromosomes) during the normal reproductive periods, when fillet quality is typically poorer; however, they can be more susceptible to the BCWD disease. ARS researchers at Leetown, West Virginia, have previously shown family-based genetic selection can be used to rapidly improve resistance of trout to BCWD, increasing survival rate in laboratory challenges from 30% initially, up to 80% in just two generations. However, this selection was based on normal diploid fish. Now the researchers have demonstrated that selection for improved disease resistance in diploid fish can translate into improved disease resistance as triploids. Therefore, the improved line of BCWD-resistant trout they developed is of value to producers of both diploid and triploid rainbow trout used for both food production and recreational stocking purposes.

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

Commercial culture of channel catfish x blue catfish hybrids continues to increase, but little is known concerning the genetic contributions from the blue catfish. ARS scientists with the Warmwater Aquaculture Research Unit in Stoneville, Mississippi, conducted two studies in which blue male catfish were mated to female channel catfish to determine how to best improve growth and carcass yield of hybrid catfish offspring through selective breeding. In the first study, blue male catfish from a single strain were mated to multiple channel catfish females and hybrid offspring were measured for growth and carcass yield. Progeny were reared in communal ponds and parentage was determined by inheritance of DNA markers. In the second experiment a similar experimental design was used, but 10 males from each of 5 blue catfish strains were used in matings. Results of both studies demonstrated a significant effect of the female parent on growth and carcass yield, and substantial and predictable effects of blue catfish males on growth and carcass yield of hybrid offspring. This information is critical to efficient selection of purebred blue and channel catfish parents to improve performance of hybrid offspring.

Animal Performance, Well-being and Efficiency

Yellow perch females are more valuable than males

Females yellow perch are larger fish and the smaller fish are males that typically fail to thrive. Gender identification is extremely difficult until fish mature, which can take up to two years. This makes it difficult to separate fish for efficient production, managing brood stock for reproduction and it inhibits genetic improvement efforts. Scientists at our ARS Dairy Forage and Aquaculture Research Unit in Milwaukee, Wis., along with colleagues have developed criteria, based on the shape and color of the external reproductive openings, to identify the gender of yellow perch during early growth stages. The gender identification algorithm provides a systematic way to reliably identify males from females, ranging from about three inches and above in total length. The process is quick, easy and involves a check list of questions: the size of the fish, the shape of specific parts and other criteria to

distinguish males from females. The method is more than 97% accurate and provides a useful and practical tool to cost-effectively sort males from females so it can be used to develop and manage yellow perch brood stocks, conduct experiments targeting gender-specific differences, and to identify the fastest growing females and males for genetic programs to improve growth performance.

Chronic nitrate exposure impacts health and well-being of farmed rainbow trout
Maintaining the health and well-being of cultured fish is an important part of cost effective and high quality production. The effects of nitrate nitrogen (a byproduct of the breakdown of the highly toxic ammonia and nitrite nitrogen) on fish health have, until recently, been considered minor. Through ARS-funded research at The Freshwater Institute's Conservation Fund in Shepherdstown, West Virginia, juvenile rainbow trout were grown in systems, half that were maintained with elevated nitrate nitrogen concentrations and the other half at lower concentrations. Over the three-month study period, rainbow trout growth was not negatively impacted by the high nitrate treatment; however, survival was lower. Rainbow trout swimming behavior was also significantly different between treatments, with more erratic swimming in the high nitrate treatments. This study provided strong evidence that high normal nitrate levels (e.g. 80-100 mg/L) can have chronic health and well-being impacts on juvenile rainbow trout. For the U.S. rainbow trout industry, these results provide valuable water quality guidance to limit the impacts of nitrate nitrogen on farmed fish populations.

Effects of male to female ratio and broodfish density on spawning success in pond-spawned channel catfish
Channel catfish are reproduced by placing mature male and female catfish in spawning ponds, the fish mate in spawning containers placed in the ponds and farmers collect egg masses periodically. Improving efficiency of pond spawning would improve profitability of catfish farming. ARS scientists with the Warmwater Aquaculture Research Unit in Stoneville, Mississippi, conducted two studies to determine if spawning success could be improved by altering the ratio of male and female broodstock in the spawning pond. A stocking ratio of 1 male to 1 female brood channel catfish (currently the industry standard) was compared to a ratio of 1 male to 4 females. Both treatments had a stocking density of 1,000 pounds (lbs) per acre. The 1:4 stocking ratio produced fewer spawns and fewer fry per acre than the 1:1 ratio so farmers would *not* benefit from decreasing the male to female ratio to 1 to 4. In another study, broodstock were stocked at a male to female ratio of 1:2 at stocking densities of 1,000 lbs per acre (current industry practice) and 2,000 lbs per acre. Broodfish stocked at 2,000 lbs per acre produced approximately twice as many spawns and fry per acre. Therefore farmers could benefit by stocking broodfish ponds at higher stocking densities than commonly used.

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

Fish meal-free diets developed for Coho salmon and Yellowtail
Fish meal has been the primary protein ingredient in fish feeds for decades but increasing demand and static supply is driving the search for alternative ingredients to support expansion of aquaculture production. Scientists with the Small Grains and Potato

Germplasm Research Unit in Aberdeen, Idaho, applied research and technology developed with rainbow trout to two popular marine species, Coho salmon and yellowtail (amberjack). Feeding studies with each species demonstrated that as long as all essential nutrients are supplied in a balanced diet, fish meal is not needed for optimal growth and health of the fish. Reducing or eliminating the dependence of aquaculture feeds on expensive marine harvested ingredients will increase profitability and sustainability of aquaculture.

Salmon growth in freshwater and seawater on fishmeal and marine-free diets
Atlantic salmon producers require knowledge about optimum salinity and feed formulations to lower production costs. Salmon were cultured by ARS researchers at Franklin, Maine, in either freshwater or seawater on a standard fish meal or marine-free diet. Water source had no effect on growth, but fillet color was higher for fish grown in seawater and salmon fed the marine-free diet had lower omega-3 fatty acids compared to the fish fed the fishmeal diet. Atlantic salmon can be successfully cultured in a wide range of salinities, but proper diet formulation is needed to insure product quality.

Use of alternative feed ingredients to reduce production costs of catfish
The prices of soybean meal, the most commonly used traditional protein source in channel catfish diets, have increased dramatically in recent years. Using less-expensive alternative feedstuffs to partially replace soybean meal would reduce feed cost. Scientists at Mississippi State University at Stoneville, Mississippi, investigated the use of hydrolyzed feather meal as a partial replacement for soybean meal in diets for pond-raised channel catfish. Results demonstrate that hydrolyzed feather meal may replace about 20% soybean meal in catfish feeds without marked impact on fish growth performance when prices are favorable. However, caution should be taken when using hydrolyzed feather meal because it reduces carcass and fillet yield.

Proper combination or ratio of linoleic and linolenic acid to improve growth and health of all male hybrid tilapia
Published information indicates that tilapia have a dietary requirement for linoleic (LA, n-6) series fatty acids (FAs). The optimum levels of n-6 FAs reported were 0.5% and 1% for redbelly and Nile tilapia, respectively. It has been reported that linolenic (LN, n-3) series FAs are also dietarily essential for tilapia, but the optimum ratio of n-6 to n-3 and its effect on growth and health is unknown. Thus, this study evaluated the effects of various combinations of dietary LA and LN on growth, blood cells, immune response and disease resistance of all-male hybrid tilapia (Oreochromis niloticus x O. aureus) to *Streptococcus iniae* challenge. Results confirmed that either LA or LN alone at 1.0% of the diet meets the dietary essential FA requirement of hybrid tilapia. Linoleic acid alone, however, appeared to promote better growth than LN alone. Provided that the diet contained 0.5% LA or higher, dietary LN at levels ranging from 0.25 to 2% can be included in tilapia diet without affecting their performance.

Amino acid supplementation improves hybrid striped bass growth
Hybrid striped bass grow better when fishmeal-free diets are supplemented with amino acids. When fishmeal in fish feed is replaced with plant proteins, fish performance often declines because of imbalances in essential nutrients and intestinal dysfunction caused by anti-

nutritional factors in plant ingredients like soybean meal. When ARS scientists at Stuttgart, Arkansas, used the concentrations and ratios of three essential amino acids found in hybrid striped bass muscle to supplement practical fishmeal-free soybean meal-based diets, superior fish growth and nutrient retention was achieved. Because the concentrations of amino acids used were higher than those currently targeted by feed mills, this information allows feed mills to formulate more efficient fishmeal-free, soybean-based diets for hybrid striped bass, thereby reducing production costs and dependence on ocean-derived protein ingredients.

Improving Health

Kaolinitic clay protects fish from columnaris disease

Columnaris disease, caused by the bacterium *Flavobacterium columnare*, is a costly disease of many commercially grown fish species, including channel catfish. Despite its importance, few preventatives or therapies exist for this disease. In this study, a type of clay called kaolin was evaluated for the prevention of columnaris disease. ARS scientists in Stuttgart, Arkansas, demonstrated that addition of kaolin to the water significantly improved the survival of channel catfish that were experimentally challenged with the disease, and protected the gills from damage by the bacteria. Data suggests that kaolin works by binding to the bacteria, thereby preventing it from attaching to the fish and initiating disease. Kaolin is a novel, non-antibiotic treatment to increase survival rates in catfish hatcheries.

Copper sulfate effectively controls fungus on and increases survival of sunshine bass eggs

Fungus in sunshine bass hatcheries can cause decreased hatch rates of bass eggs and decrease profits. A collaborative study with ARS scientists in Stuttgart, Arkansas, and Keo Fish Farm, Inc. (Keo, Arkansas) addressed sunshine bass egg mortality from fungal growth. This study determined the optimum concentration of copper sulfate needed to prevent fungus from destroying the eggs while allowing the hatched larvae to thrive. This finding has led to improved larval survival and reduced time and effort in the hatchery, having an immediate economic benefit to the farmer with this inexpensive treatment. The majority of the industry is now using this treatment.

New diagnostic test detects a serious bacterial disease of rainbow trout

Bacterial cold water disease, caused by *Flavobacterium psychrophilum*, is a widely-distributed and economically-important disease that results in elevated mortality in rainbow trout aquaculture. ARS researchers at Leetown, West Virginia, developed a highly sensitive polymerase chain reaction (PCR) assay to accurately measure small amounts of this pathogen in fish tissue. The test recognizes a unique gene sequence that is only found in *F. psychrophilum*. The assay successfully identified more than 200 different isolates collected from farms where fish suffered from the disease. The assay was used to quantify bacterial numbers in experimentally and naturally infected rainbow trout tissues. Assay protocol and DNA standard have been distributed to government and university fish health researchers to enhance efforts to detect and control bacterial cold water disease.

Survey of parasites associated with catfish aquaculture
Mississippi State University scientists have conducted a survey of myxozoan parasites associated with catfish aquaculture. Myxozoan parasites have two distinct life stages, one stage in a worm host and another in a fish host, that until recently were thought to be unrelated parasites. Using molecular techniques, the stages of myxozoan parasite life cycles have been isolated and genetically characterized using molecular biology techniques. This survey has identified at least nine different myxozoan parasites in catfish ponds. In addition, two entire myxozoan life cycles have been molecularly confirmed, linking the parasite released by the worm to the parasite found in the catfish. Moreover, this work has also identified and genetically characterized a previously undescribed myxozoan parasite from catfish, although the worm residing stage associated with this myxozoan has not been determined. The effects these previously uncharacterized myxozoan parasites have on catfish production is currently unknown and will be a focus of future research.

Disease outbreak linked to water chemistry
Columnaris is a deadly fish disease that is caused by a bacteria (*Flavo-bacterium columnare*) that attaches to a fish's gills or skin (bacterial attachment). If we can stop the bacteria from attaching to the fish, we can prevent the fish from getting sick. Columnaris disease cannot be induced in some labs, and one possible explanation could be the water source. ARS scientists in Stuttgart, Arkansas, and Stoneville, Mississippi, found dramatic differences in catfish mortality after exposing fish to the columnaris bacteria in well-water from the two labs. Further investigation indicated bacterial attachment was 2000-fold less in softer waters with tannins. An additional study manipulated the calcium and tannin concentration in the waters to study their effects on the disease. The results suggest calcium is a key regulator of bacterial attachment. The study reveals the mechanisms of bacterial pathogenicity; this greater understanding will lead to further advances in controlling this disease.

Production Systems and Products

Development of an improved aerator for the catfish industry
Supplemental aeration is used by all catfish producers and it is critical to maintain dissolved oxygen at levels that support high densities of catfish grown in production ponds, especially when oxygen levels drop on warm summer nights. Paddlewheel aerators have been used for aeration in aquaculture for over 30 years and while they transfer oxygen to the water efficiently, they also move a huge volume of water so the oxygen concentration increases slowly. Thus, a great deal of equipment and a large amount of power is required to prevent low DO (dissolved oxygen) 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. This invention has a patent application currently pending with the U.S. Patent and Trademark Office. Two commercial-scale PTA's were installed in an 8-acre catfish production pond and gave promising results. This new equipment will both lower energy costs and enable higher production densities.

Burrowing shrimp recruitment monitoring tool
The burrowing activities of two species of shrimp cause shellfish to sink under the mud and die in West Coast estuaries. The aquaculture industry has addressed this problem by annually treating some of their beds with a pesticide, but are searching for alternative control measures and attempting to implement an integrated pest management program. ARS researchers in Newport, Oregon, discovered that shrimp population abundance can be traced to distinct years when shrimp pelagic larvae recruit to each estuary. Their abundance after settlement can be used to forecast the need for treatment of older shrimp on aquaculture beds, since adult shrimp don't move. This accomplishment will enable researchers and producers to develop simple monitoring techniques that can be used to track recruitment and be adopted in their integrated pest management program.

Intensive production of hybrid catfish
ARS researchers at Stoneville, Mississippi, have completed four years of research on the intensive production of hybrid catfish (a cross between channel catfish females and blue catfish males). Production of hybrids has reached over 20% of the catfish produced (nearly 200 million juveniles per year, up from only a few million 5 years ago). Research has demonstrated that hybrid catfish can tolerate a slightly lower dissolved oxygen concentration than channel catfish. They also have better tolerance to common diseases affecting catfish, resulting in a greater feed intake through spring and fall when diseases are more common. Continued adoption of hybrid catfish by the industry is resulting in increased profits due to faster growth (reduced production cycle), increased survival, and improved food conversion ratios.

Development of a heat exchanger for use in a commercial catfish hatchery
At a local commercial catfish hatchery, a counter-current heat exchanger system was installed and reduced the non-renewable energy use by approximately 50%. This is equivalent to an estimated energy savings (operating cost) of $790 per day or $35,550 per season (45 days). Modifications to the original design should improve efficiency even more next hatching season.

Development of improved culture methods for fry and fingerling production
Survival of fingerling catfish in nursery ponds is highly variable and averages between 50-60% on most commercial operations. While disease is an important variable, fingerling survival is often poor in the absence of disease. Scientist from Mississippi State University conducted pond studies to evaluate hatchery practices on growth and survival of catfish fingerlings. Channel catfish fry were transferred from the hatchery to nursery ponds at different developmental stages to reflect current industry practices. Fry were stocked before being fed a commercial fry diet (before or at the time of yolk sac absorption) or 4-7 days after being fed a commercial fry diet. Stocking fry in the early developmental stages resulted in poor survival. Since nursery ponds contained adequate zooplankton populations that serve as a food source, poor survival of early stocked fry was likely related to predation by aquatic insects. To increase fingerling survival fry should not be stocked in nursery ponds until they are fully developed and readily accept commercial diets. In a second study we found that there were no differences in fish production between fry nursery ponds that are fed commercial diets and ponds that rely on natural productivity for the first six weeks. Total kg

of feed fed was significantly reduced in the delayed feed treatment, averaging 26 kg/pond less feed fed. If proper fertilization practices are implemented, large numbers of desirable zooplankton for catfish fry culture are attained, and these zooplankton are able to sustain catfish fry stocked up to 250,000/ha. Therefore, no commercial diets are required during the first 6 weeks of culture, saving over $95.55/ha in initial feed costs.

Carotenoid content in channel and hybrid catfish

One problem for the catfish industry has been wide variation of fillet color, and some fillets have an unattractive yellow color thought to be caused by carotenoids in their diet. The objective of this study was to compare the most abundant carotenoids from channel and hybrid catfish. ARS scientists from the Southern Regional Research Center in New Orleans, Louisiana, collected fresh channel and hybrid catfish fillet samples from a commercial processor in Mississippi. Samples were freeze dried and then extracted with acetone; and carotenoids were identified using liquid chromatography/mass spectrometry (LC/MS) (Silica column, APPI). Two major carotenoids, lutein and zeaxanthin, were identified in both the channel and hybrid fillets, and the average content in channel catfish was higher than that in the hybrid fillets. This study identifies the major carotenoids in hybrid catfish, and will support efforts to standardize the color of catfish fillets.

Green water improves hybrid striped bass larval culture

The availability of larval fish is critical for the successful development of aquaculture. Aggressive behavior by the fastest growing fish and the need to provide an adequate quantity of food items are constraints to larval culture of hybrid striped bass. In a study using recirculating aquaculture technology, scientists at the Stuttgart National Aquaculture Research Center, Stuttgart, Arkansas, demonstrated that introducing algae into the culture water (green water) increased larval survival by more than 20% and decreased variation in individual fish size relative to those reared without the addition of algae (clear water). Green water reduced the ability of larger fish to locate and attack smaller fish and improved the ability of fish to find and consume food items. Increased larval survival of hybrid striped bass has been shown to reduce the cost of production by 10% for each 5% increase in survival, thereby resulting in more efficient utilization of culture facilities.