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History of Catfish Breeding and its Application in the United States: Lessons to Be Learned?

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Abstract

The history of selective breeding in the US catfish industry is reviewed. The failures and successes of technology and germplasm transfer for catfish genetic enhancement are discussed.

Dr. Homer Swingle and Ellis Prather of Auburn University unknowingly initiated the first ictalurid genetics and breeding program and evaluation in the 1950s and 1960s. They evaluated and compared different species of catfish such as blue catfish (*Ictalurus furcatus*), channel catfish (*I. punctatus*), flathead catfish (*Pylodictus olivaris*), white catfish (*Ameiurus catus*), and brown bullhead (*A. nebulosus*) for their suitability as aquaculture species. In reality, these were genetic comparisons, and channel catfish was identified as the genotype (species) best suited for aquaculture (Dunham and Smitherman, 1984). The catfish industry now produces over 300,000 tons of catfish per year. Between 100 and 200 commercial, government, and university hatcheries/broodstock populations exist (Dunham and Smitherman, 1984; USDA, 2003; Steeby and Wagner, 2006) and over four million head of broodstock are needed to produce fry for the industry. The industry is complex and diversified

with a variety of small, medium, and large farms. Some small farms may supplement their income by devoting a hectare or two to catfish, a typical farm may have 50-200 ha under water and the largest farm once had 4,000 ha of ponds.

The first directed breeding and genetic enhancement was conducted by the United States Fish and Wildlife Service (USFWS) in the early 1960s led by Harry Dupree, John Giudice, and O.L. Green (Giudice, 1966; Dupree and Green, 1969; Dupree et al., 1969). The research focused on interspecific hybridization and the seven major ictalurid species were hybridized in almost all possible combinations. The federal government abandoned the program in the late 1960s. There was no plan for commercialization or technology transfer. However, there was an important output, the identification of the channel catfish female x blue catfish male hybrid catfish as a heterotic and outstanding catfish genotype.

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In 1969, R. Oneal Smitherman of Auburn University, with the assistance of Israeli fish geneticists Giora Wohlfarth and Rom Moav, initiated a selective breeding program. It is important to have dedicated caretakers watching over a breeding program who appreciate its importance. While Smitherman was temporarily stationed overseas, the initial broodstock collection of several strains was destroyed, and had to be reestablished upon his return. The initial genetic enhancement programs examined were strain selection, intraspecific crossbreeding, mass selection, and interspecific hybridization (Yant et al., 1975; Green et al., 1979; Dunham and Smitherman, 1983ab). In the early and mid-1970s, the University of Georgia and Mississippi State University (MSU) initiated catfish genetics and breeding programs led by Hussein El-Ibiary and later Kaine Bondari and Roland Reagan, respectively (Reagan et al., 1976; El-Ibiary and Joyce, 1978; Bondari, 1986), followed by Rex Dunham joining Smitherman at Auburn University. At this point in time, all breeding programs were led by universities.

By the early 1980s significant genetic improvement of catfish had been accomplished and farmers were anxious for access to the improved research lines. Auburn University conducted the first release of three selected lines in 1984-1985. Farmers were offered improved young broodstock or fingerlings above market price. Fish were released to 69 farms in six states and availability met demand. A couple of years later MSU also made a release of a selected line to the industry.

In the mid 1980s, several key events occurred. Long-term dedication of administrators and scientists is necessary for the success of genetic enhancement programs. A dean at the University of Georgia closed the catfish breeding program and bulldozed the facilities, transforming it into a cow pasture. The germplasm was absorbed by Auburn University (Bondari and Dunham, 1987). The MSU program was terminated at their main campus as the principal investigator neared retirement. However, the federal government

re-entered catfish breeding with USFWS conducting a one-generation family selection led by Harold Kincaid, before again dropping catfish breeding. USDA-ARS established the Catfish Genetic Research Unit in Stoneville, Mississippi, first led by Gary Carmichael, followed by William Wolters, and now led by Geoff Waldbeiser and Brian Bosworth (Tomasso and Carmichael, 1991; Wolters et al., 1996; Li et al., 2001; Waldbieser et al., 2001). Politically, the state of Mississippi was strongly affiliated with this effort, and this state accounts for almost 70% of catfish production in the US. Also in the 1980s, Purdue University, Louisiana State University (William Wolters), and Auburn University evaluated triploid application in catfish, but all dropped this genetic enhancement program because of lack of genetic improvement and commercial feasibility (Wolters et al., 1982; Lilyestrom et al., 1999). The University of Memphis (Bill Simco and Ken Davis) and the USDA (Cheryl Goludie) evaluated monosex production, but abandoned efforts when they were unable to spawn YY females (Goudie et al., 1995; Davis et al., 1995).

The initial releases by Auburn University and MSU were a mixture of success and failure. Perhaps because of the small investment, many farmers, especially small ones, did not take good care of the fish. In some cases, they provided too much care and the fish grew to huge sizes, too large for spawning cans. A common problem for both the Auburn University and the MSU releases was low spawning rates of the select lines in the commercial environment. Many farmers were frustrated and abandoned the use of these fish. Those who had the patience to stay with the fish for a couple of generations were able to spawn the fish as the fish seemed to require a generation to adjust to commercial conditions. Positive impact occurred and, now, 20 years later, a portion of the farms still use these broodstocks with good results (USDA, 2003). In some cases, these fish were bred into existing stocks to top cross and improve the existing stocks.

In the late 1980s and early 1990s, Auburn University made two additional releases. One

was an additional selected channel catfish and the other a line of channel catfish and blue catfish that had high pen spawning rates to produce the channel female x blue male hybrid. The strategy was different this time to encourage farmers to take better care of the investment. The release was limited to a few farmers and they had to execute a royalty agreement with the university. However, interest was relatively low because of two factors. The spawning problems with the fish from the first releases may have dampened interest, and catfish farming was highly profitable at that time, decreasing the urgency to improve farm operations. The release of the select lines had little impact as two of three farms obtaining the lines decreased operations and the third had spawning and disease problems with the fish. This may have been aggravated by administrators who were slow to approve the release and limited holding space, resulting in the fish being held in suboptimal conditions for a long period of time prior to release. The fish for hybridization had small impact as only three small farms were interested in the fish and two of those never tried to use the fish after buying them. Some impact was achieved as the third small farm successfully used the fish and filled a small market niche.

Since the 1990s, selective breeding research has made a larger impact by commercial farms taking the results and applying them to their own broodstock rather than through release of improved germplasm from research institutions (USDA, 2003; Steeby and Wagner, 2006). GoldKist developed the first breeding farm in the catfish industry in Inverness, Mississippi. The manager Roger Yant (who was the first to study the channel x blue hybrid at commercial densities while a student at Auburn) followed the selection programs developed at Auburn University for catfish. Improved selected lines were developed. In an effort to protect this proprietary germplasm, only males of one line and females of another line were sold as broodstock to customers. On-farm research results were similar to those at Auburn in regards to genetic gain. In general, because the fish were well prepared, farmers were pleased

with the performance of these fish. Another selling point was high spawning rates relative to the rest of the industry. Based on artificial spawning technology developed at Auburn University, GoldKist began making channel x blue hybrid catfish every year, becoming the first farm to produce significant numbers of hybrids annually. GoldKist lines are now used by 25-30% of the industry (USDA, 2003). Later, GoldKist decided to drop catfish to focus all resources on their chicken operations and sold the farm to one of their customers, Harvest Select. Harvest Select kept the scientific staff and management and continued the genetic improvement program. However, the strategy changed and the farm consumed all its fingerlings for their own production. Recently, the management changed and the genetic improvement program has been placed on hold.

Shortly after GoldKist, the Alabama Farmers Cooperative became the second breeding farm in the industry based upon Auburn research. Their strategy was different and they initiated a selection and crossbreeding program with the aim of providing fingerlings for production rather than broodstock. After one generation of development, they merged with SouthFresh LLC, becoming SouthFresh Fingerlings and the management changed. Further genetic enhancement efforts have ceased and the majority of the fingerlings produced are consumed by cooperative members and shareholders before sales to outside customers.

About 2000, the USDA in cooperation with MSU had developed an improved channel catfish line via strain selection and family selection (Li et al., 2001). These fish were well-publicized and industry interest in the improved fish was high. The state of Mississippi has a crop certification program to protect the producers of improved germplasm and their customers. The line has been analyzed, and a unique microsatellite profile identified allowing genetic marking of these fish to verify paper trails regarding their authenticity (MSU, 2006). The fish were released to several farmers in the industry. These fish have had a significant impact in the industry and

account for 25-30% of the broodstock (USDA, 2003). However, problems have been associated with this release of germplasm. Some spawning problems have been encountered although apparently not as severe as for previous releases. Additionally, survival and disease resistance problems have been prevalent causing many farmers to be disenchanted despite rapid growth rates, and several farmers are abandoning use of this fish. However, some farmers are very pleased with this line's early sexual maturity. Once again, reports are starting to emerge that farmers who had the persistence to continue with these fish into a second generation are finding improved spawning and disease resistance.

Some farmers have applied genetic principals on their own farms (Steeby and Wagner, 2006). Several strains of channel catfish appear to have arisen on some farms, perhaps through domestication selection, and seem well suited for their particular farm environment. Some farmers have employed their own crossbreeding programs to enhance performance or to avoid inbreeding. One farm selected for early spawning, and apparently made progress. Fish of this line spawn earlier and at colder temperatures than other fish in the industry. In fact, each year, none of the farmers in Mississippi attempt to distribute their spawning cans or spawn fish until this farm has collected its first spawns. Currently, at least 67% of the catfish hatcheries use some type of genetically improved catfish rather than "pond run brood fish" (Steeby and Wagner, 2006).

Auburn University conducted the latest release of blue catfish and channel catfish lines to produce hybrids and improved hybrids. A new strategy is being tested. Technology transfer of all types has often been problematic at Auburn, falling short of major impact. A company has been formed, the majority of which is owned by the managers and investors and the minority of which is owned by the university; it is run by outside business managers. The company evaluates and chooses the technologies that it feels have the most promise and develop umbrella businesses to commercialize the technology.

This has been done for Auburn germplasm and hybrid technology. Eagle Aquaculture has been formed, and it specifically markets channel x blue hybrid catfish fingerlings. The hope is that with the increased investment and management there will be motivation to make the technology, in this case interspecific hybridization, succeed. The use of the hybrid is gradually increasing and about 2% of the industry's production is from hybrids, with a possible increase to as much as 10% in 2007. Growers and processors alike have been pleased with the performance of the hybrids. There are some problems to overcome as this fish has a different body shape than the channel catfish, necessitating adjustments in harvesting and grading.

Molecular genetics will hopefully be the next genetic enhancement on the horizon. Auburn University (Rex Dunham) began research and development on transgenic catfish in 1985 (Dunham et al., 1987; Dunham et al., 2002) and genomics research (John Liu) in 1994 (Ju et al., 2002). The USDA (Geoff Waldbeiser) is also active in the genomics area (Waldbieser et al., 2003). Auburn and the USDA continue to be the only two research institutions with major commitments to catfish genetic enhancement via traditional selective breeding, biotechnology, and molecular genetics. At least another generation of work will be needed before molecular genetic enhancement via transgenesis or marker-assisted selection can be applied and impact the catfish industry.

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