SRAC
SOUTHERN REGIONAL AQUACULTURE CENTER

SRAC Publication No. 190
June 2012
Revision

Production of Hybrid Catfish

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The mating or crossing of two different species is a process called hybridization, with the offspring known as hybrids. When a hybrid has characteristics superior to both parents it is said to have hybrid vigor or positive heterosis, which, of course, is the ultimate breeding goal. Genetic enhancement programs attempt to develop hybrids that are either superior to their parent species for individual traits or whose overall performance for several traits makes them economically more profitable than their parent species.

Hybrids between the seven major species of North American catfish (ictalurids) were first researched and evaluated in 1966. Of these 42 different interspecific catfish hybrids (crosses between two distinct species), only one has characteristics that would favor commercial application compared to the prominently cultured channel catfish (*Ictalurus punctatus*). That hybrid is the channel catfish female × blue catfish (*I. furcatus*) male (denoted as the C×B hybrid). It is important to note that mating the male channel catfish with the female blue catfish does not produce a hybrid with the same superior production characteristics as the C×B hybrid.

Research on C×B hybrids has demonstrated that they are genetically improved for several commercially desirable characteristics. This improved performance for many commercial traits in a single cross is unusual, making the C×B hybrid the best example of genetic improvement ever attained in aquaculture in regard to overall performance.

The C×B hybrid is superior to channel catfish because of its

- faster growth,
- better feed conversion,
- tolerance of low oxygen,
- increased resistance to many diseases,
- tolerance of crowded growth conditions in ponds,
- uniformity in size and shape,
- higher dressout percentage and fillet yield,
- increased harvestability by seining, and
- increased vulnerability to angling.

The performance of the C×B hybrid has been confirmed on commercial catfish farms. Twenty years ago, C×B hybrid technology was not economically feasible. The gametes (sperm and eggs) are compatible, but the two species seldom mate with one another because of behavioral incompatibility, preferences in spawning environments, or other factors. However, recent advances in artificial spawning and fertilization techniques have improved fry production and made it economically feasible. Another important development has been the use of different strains of channel catfish and blue catfish to make the hybrid, which has produced genetically distinct C×B hybrids with even more superior production characteristics.

Identifying the C×B hybrid

The channel catfish has a gentle slope from the tip of the snout to the base of the dorsal fin and is spotted. It has high-set eyes; long, thick lateral barbels (whiskers); and a rounded anal fin with 24 to 26 fin rays. The blue catfish has a steep slope from the tip of the snout to the base of the dorsal fin, giving it the appearance of a "hump." It has no spots (except the Rio Grande strain); the eyes are set lower than in the channel; it has short, light colored, thin lateral barbels and a straight or squared anal fin with 30 to 36 fin rays (Fig. 1). The C×B hybrid looks much more like the blue catfish than the channel catfish. The hybrid has a steep slope from the tip of the snout to the base of the dorsal fin, so it has the "humped" appearance. It has few or no spots (unless the Rio Grande blue is used in the cross); the eyes are set low;

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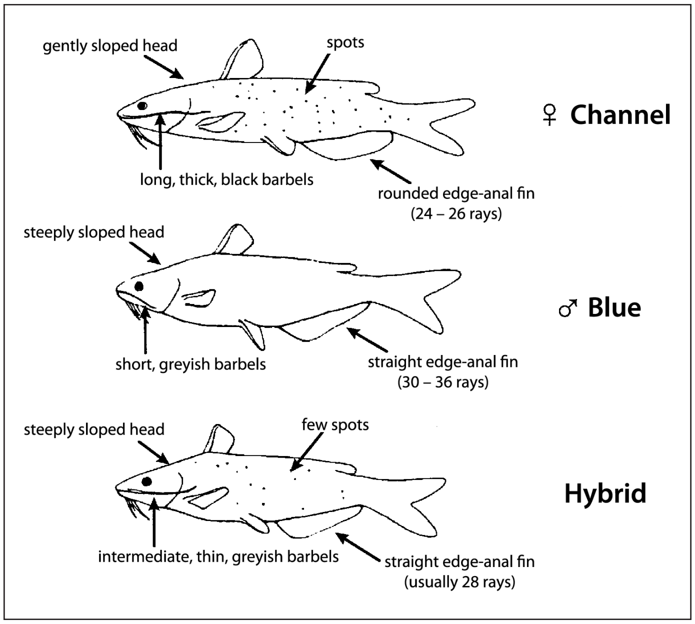

Figure 1. External characteristics of channel catfish, blue catfish, and C×B hybrid catfish.

the barbels are intermediate; and it has a straight anal fin with an intermediate number of fin rays (usually 28).

With the increasing popularity of C×B hybrids, farmers may wonder how to verify that the fingerlings they purchase are actually F_1 C×B hybrids. The morphological appearance described above is a good indicator of C×B hybrid identity, but it may not be obvious to all fish culturists. The use of DNA analysis for identification is definitive.

In the field, there is a quick, easy technique for verification. Channel catfish have a single, lobed, heart-shaped swim bladder (Fig. 2). Blue catfish have a long, narrow, bi-lobed swim bladder (two distinct chambers). The C×B hybrid also has a bi-lobed swim bladder, but the first chamber close to the head of the fish has a large, heart-shaped lobe while the second lobe is a small, attached protrusion.

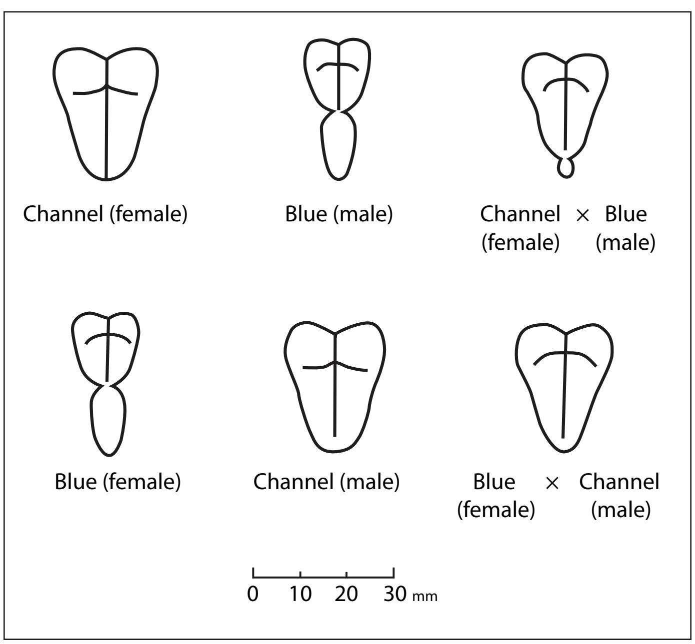

Figure 2. Swim bladders.

Production characteristics of C×B hybrids

Growth and feed conversion

In early experiments, C×B hybrids grew about 20 percent better than commonly cultured strains of channel catfish. However, recent research using selected parental strains of channel catfish and blue catfish have shown that the C×B hybrid can grow twice as fast as commercial strains of channel catfish, depending on environmental conditions. With good culture practices, an increase in growth rate of 25 percent or more is not unusual. This increased growth is due to a combination of increased food consumption and improved feed conversion efficiency.

In general, C×B hybrids grow faster than channel catfish in both single-batch and multiple-batch (mixed size populations in the pond) systems. The growth advantage of the hybrid increases when stocking density increases, although the overall risk of fish loss will obviously increase with density. Fingerling C×B hybrids out-perform channel catfish fingerlings at all densities when grown to food-size fish. If fry are stocked at low densities (less than 60,000 per acre), the C×B hybrids grow at the same rate as or slower than channel catfish fingerlings until they reach a length of approximately 6 inches; after that the C×B hybrids grow faster. When stocked at 100,000 per acre or more, C×B hybrid fingerlings generally grow 50 percent faster than channel catfish fingerlings. In general, the C×B hybrid displays its superior growth in the second year, and this growth difference is even more pronounced at densities of 7,000 to 22,000 per acre.

Experiments comparing channel catfish to C×B hybrids suggest that the hybrids grow faster because they start feeding earlier in the spring and because feed conversion in C×B hybrids averages 10 to 15 percent better than in channel catfish. On-farm feed conversion of C×B hybrids is 10 to 20 percent better than channel catfish.

Effects of parental strain

The parental strain of channel catfish and blue catfish affects the performance of the C×B hybrid for several traits. In some experiments, the C×B hybrid did not grow as fast as some strains of channel catfish or blue catfish not used to make the hybrid. When C×B hybrids are produced by crossing superior strains of channel and blue catfish, these hybrids out-perform the parental strains for growth in open ponds. Hybrids always outgrow their parent strains.

The strain of the parents also affects characteristics such as dressout percentage, body composition, seinability, angling vulnerability, and tolerance to low oxygen.

Uniformity

The uniformity of growth and body shape of hybrids is superior to that of channel catfish but not superior to blue catfish. C×B hybrid fingerlings produced at high densities (200,000 per acre) are not particularly uniform, but fingerlings produced at lower densities have very uniform growth. Research has shown that the body shape, weight and length of the C×B hybrid are more uniform than in channel catfish.

Survival and disease resistance

Many disease problems in the channel catfish industry could be reduced by culturing C×B hybrids because hybrids survive better in all growth phases. In 30 years of research at Auburn University, hybrid fingerling survival has averaged 80 to 85 percent and food-fish survival has averaged 90 percent. On-farm survival rates are similar. In contrast, the average survival of channel catfish fingerlings is 50 to 60 percent, and the survival of food-sized channel catfish is approximately 70 percent. Although the C×B hybrid is not totally resistant to disease, it is more resistant than channel catfish to columnaris (*Flexibacter columnare*), enteric septicemia of catfish (*Edwardsiella ictaluri*), aeromonas (*Aeromonas hydrophila*), Ich (*Ichthyophthirius multifilis*), and channel catfish virus. Field observations indicate that the hybrid may be more vulnerable to *E. tarda,* but they respond readily to treatment.

Carcass yield

Dressout percentage and fillet percentage are generally higher for the C×B hybrid than for channel catfish based on small-scale research and on data collected in processing plants. The hybrid has this advantage in all months of the year.

The uniform body shape of the hybrid should increase dressout percentage in processing plants using automatic processing equipment because the equipment can make more precise cuts and achieve maximum carcass yield. However, uniformity in body size could be a problem, as fish that are too uniform will not use all the processing lines simultaneously, which could reduce processing plant efficiency.

There has been some concern that automated processing machines would have to be reset to accommodate the hybrid's body shape. However, recent observations have shown that the hybrid can be processed by the same equipment used for channel catfish without any adjustments, still resulting in increased dressout and fillet yield. If processing equipment is adjusted or designed for hybrids, the advantage of the hybrid may be increased even further.

Harvestability

One of the most important traits of the C×B hybrid is its seinability. The hybrid is generally two to three times easier to catch by seining than channel catfish. This makes the hybrid better suited for all open-pond culture systems, particularly where seining of large channel catfish is problematic and ponds are seldom completely drained for harvest. Hybrids in hill ponds are also easier to trap than channel catfish and more susceptible to angling. In fact, the C×B hybrid is about twice as easy to catch by hook-and-line as the channel catfish, a trait that has important implications for fee-fishing and recreational fisheries.

Commercial observations indicate that virtually all of the hybrids in a pond can be captured in two or three seine hauls, whereas five or more seine hauls will not harvest all of the channel catfish in a pond.

Seinability is an undervalued trait. Harvest costs increase with each seining required. The efficient removal of fish maximizes the number that can be sold, alleviates the problem of leaving fish that will grow larger than the desirable processing size, improves feed conversion efficiency, and reduces losses from disease and predation.

Potential harvest problems and solutions

Traditional seines and grading socks do not work well with C×B hybrids if they do not match the size of the hybrids correctly. The hybrid has a small head and sharp spines inherited from the paternal blue catfish. When hybrids are selectively graded by traditional equipment, they tend to gill themselves in the netting, creating a handling and stress problem (for both fish and people).

This problem can be overcome in two ways. Seining the pond with a 1-inch mesh seine followed by grading with the side-panel grader developed by David Heikes at the University of Arkansas at Pine Bluff (a 1-inch mesh sock with flexible PVC grading panels on one side of the sock) eliminates the gilling problem. In the case of a single-crop system, the problem is solved by using a smaller mesh seine than normally used for channel catfish.

Production expectations

Research and commercial trials in Alabama and Mississippi have shown that C×B hybrid fry stocked in May or early June at 100,000 fry per acre can yield 7,000 to 10,000 pounds of fingerlings per acre by late October. If these fingerlings (7+ inches) are stocked in a single-crop system at 3,000 fish per acre in the spring, 5,500 pounds of marketable fish should be ready for harvest in the fall. If stocked at 5,000 fingerlings per acre, 9,000 pounds of marketable fish should be ready for harvest in the fall. This production level requires near satiation feeding and adequate aeration to sustain the fish.

Production will vary from pond to pond and farm to farm depending upon environmental conditions, inputs (such as feed and aeration), depth of the pond, and the skill of the farmer. However, it is not unreasonable to average 12,000 to 13,000 pounds per acre of C×B hybrid catfish with a stocking density of 6,000 fish per acre, and 7,500 to 9,000 pounds per acre should be easy to achieve. If split ponds or in-pond raceways are used, 20,000 pounds of C×B hybrid catfish per acre may be harvested.

Production systems

Hybrids are well suited for a variety of production systems currently used in the catfish industry. They are advantageous in traditional multi-batch or modular systems if the panel grader is used. They are almost essential for split-pond and in-pond raceway systems to work properly. They are particularly well suited for single-crop systems, which are not widespread. More research needs to be done in this area. By altering the size of the fingerlings stocked, the stocking density, and the timing of stocking, and coordinating this within a single farm or among farms, a single-crop system should be able to produce a year-round supply of C×B hybrids. This would yield even better feed conversion, production, and harvest efficiency, while providing the variety of sizes needed to efficiently use all production lines in a processing plant.

Spawning methods

There are three basic spawning techniques: open-pond spawning, pen spawning, and artificial fertilization (induced ovulation followed by hand stripping). Artificial fertilization is the most productive and consistent technique for making C×B hybrid catfish.

Most channel catfish do not become sexually mature until at least 3 years of age, and most blue catfish do not become mature until at least 5 years of age. Channel catfish females 4 to 5 years old are the most reliable for hybridization early in the spawning season. Using younger females at the end of the spawning season can extend the season if brood fish are kept in deep, cool ponds. If multiple year classes are prepared in the same pond and are underfed, the younger, smaller fish may not compete well and not become gravid.

Open-pond spawning

Open-pond spawning is not a consistent way to produce C×B hybrids. Usually, no spawns occur, but there have been rare instances when up to 33 percent of the female channel catfish spawned. In these cases it appears that the sexes were not properly identified (i.e., not only female channel catfish and male blue catfish were stocked) and fish of the same species were able to reproduce. Thus, no hybrids were actually produced. Therefore, the open-pond spawning of channel catfish with blue catfish to produce C×B hybrids cannot be recommended.

Pen spawning

Pen spawning is a more consistent way of producing C×B hybrids than open-pond spawning. Pens should be similar to those used in traditional channel catfish spawning. Spawning pens are constructed next to the bank of the pond, using treated lumber driven into the pond bottom and plastic mesh or plastic-coated wire mesh for sides. The mesh (½- to 2-inch) should allow for adequate water circulation. Most spawning pens have dimensions of 4 x 6 or 4 x 8 feet. Spawning containers must be large enough to accommodate the size of the male blue catfish.

Male blue catfish and female channel catfish are individually paired in pens when the water temperature at the depth of the spawning container is between 75 and 82 °F at sunrise. Male blue catfish should be placed in the pens a day or two before the female channel catfish. Female channel catfish should show the classic signs of readiness for spawning, including a soft, distended belly and, preferably, a genital opening that is red and swollen. Female channel catfish are injected with luteinizing hormone analog (LHRHa) at 100 µg/kg to induce ovulation and mating with blue catfish.

If mating occurs, spawns will usually be found 72 hours after the female is introduced into the pen. In rare cases, spawning has occurred up to a week after the female is introduced.

Pen spawning success has been as high as 100 percent, but the usual result is 0 to 20 percent success. Average spawning success over 14 years of continuous research at Auburn University was approximately 15 percent. Therefore, pen spawning is not considered a dependable method of producing C×B hybrid fry.

The strains of blue catfish or channel catfish used affect the success of pen spawning because some strains are more likely to hybridize with the other species. Blue catfish males of the AU-1 strain have a high hybridization rate with channel catfish females. For 2 consecutive years these males had a high spawning and hybridization rate (50 to 60 percent), but in the third year no spawning occurred. Obviously, this is an unacceptable level of risk, so pen spawning to produce C×B hybrids cannot be recommended.

Artificial spawning/fertilization

Artificial fertilization technology made C×B hybrid production possible in the catfish industry. Ten years ago, approximately 1 million C×B hybrid fry were produced. In 2011 that figure had risen to approximately 100 million. The entire industry could be converted to hybrids in 2 years if the industry demanded the change. If properly conducted, the artificial spawning of female channel catfish should be 67 to 100 percent successful. The following protocol has been the most successful in producing C×B hybrids.

Female channel catfish brood stock should be fed a commercially manufactured 36 percent protein diet 3 days a week during summer and fall. During March-May they should be stocked at no more than 1,500 pounds per acre and fed 3 to 5 days a week with a commercially manufactured 36 percent protein diet containing 500 ppm vitamin C, 6 percent animal/fish protein, and 6 to 10 percent marine fish oil. Male blue catfish should be stocked and fed in a similar fashion, but they also benefit from forage fish.

Females selected for injection should have soft, distended bellies and, preferably, red, swollen genital openings. Selected females are placed in spawning bags (the same as ¼-inch mesh laundry bags, Fig. 3) suspended in holding vats. Water flow and aeration in the vats should maintain total ammonia near 0 mg/L and dissolved oxygen above 6 mg/L. Ideal water temperature is 82 °F, but positive results can be obtained between 72 and 86 °F.

Females are induced to ovulate with LHRHa, carp pituitary extract (CPE), or channel catfish pituitary extract (CCPE). The first ovulating agent used to spawn catfish was human chorionic gonadotropin, but this hormone yields unacceptably low ovulation and fry production. The pituitary extracts are inferior to LHRHa but have the advantage of synchronizing ovulation among females better than other spawning aids. Pituitary extracts are powerful for ovulation and release of eggs, but often the eggs are of lower quality and have a lower hatch rate compared to LHRHa.

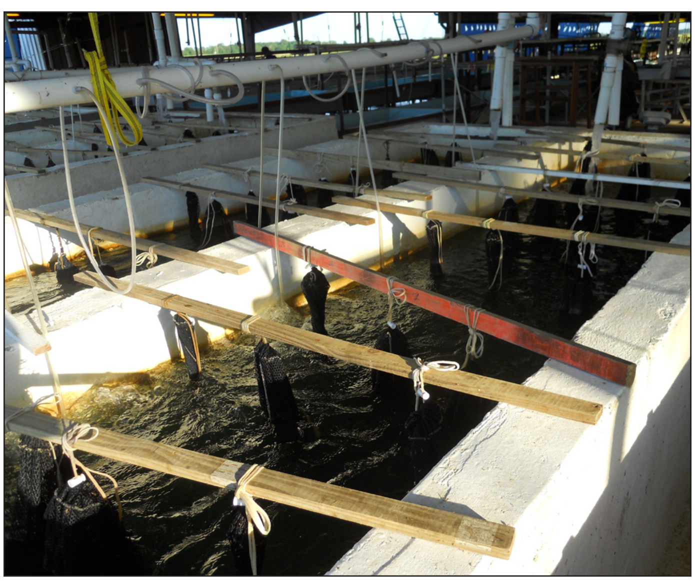

Figure 3. Spawning bags.

LHRHa can be administered as an injection or an implant, although implants produce the overall best and most consistent fry output. Implants are also advantageous late in the spawning season and require only a single administration (injection of the implant), whereas injectable LHRHa is given in two injections several hours apart for best results.

LHRHa or pituitary extract should be administered no more than 2 days after females are seined from ponds and brought to the holding vats in the hatchery. In the case of the injectables, the first injection (called the priming dose) should be made about 12 hours before the second injection or resolving dose. It is essential to weigh each female accurately in kilograms so that precise doses can be calculated.

The first injection of pituitary extract at 2 mg/kg of body weight should be administered intraperitoneally (into the body cavity under the base of one of the pelvic fins). This can be done just before placing the female in the spawning bag or the injection can be administered through the mesh of the bag. Then the female should be suspended in her bag, which is hung upon wooden dowels, boards or other appropriate rods lying across the top of the vat. The second injection is given 12 hours after the first injection, at a dose of 8 mg/kg of body weight. Thirty-six hours after the first injection, most of the female channel catfish should be ready to ovulate and be hand stripped if they have been held at 80 to 82 °F. Females will begin releasing eggs into the bags. The bags are gently lifted and examined in the water; if eggs are detected, the female is ready for hand stripping. At colder temperatures, the process of ovulation is slowed.

The same procedure is used for LHRHa injections. Early in the spawning season, the most effective dose is 30 µg/kg for the priming dose and 150 µg/kg for the resolving dose. Once the peak of the spawning season is reached, the dose should be reduced to 20 µg/kg for the priming dose and 100 µg/kg for the resolving dose. LHRHa gives better fry output than pituitary extract, but the timing of ovulation will vary more. The first ovulations usually occur 40 to 44 hours after the first injection, but some females will ovulate and produce high quality eggs up to 60 hours after the first injection. Once peak spawning is reached, the first check for eggs should be done 34 to 36 hours after injection, as the earliest ovulating fish may release eggs at this time.

Fish given implants have the most consistent and the overall best fry output for the entire spawning season, but the timing of ovulation is the most variable. This is understandable, since the eggs are at different stages of readiness in each female. Thus, forcing all females to ovulate at the same time (which happens with pituitary injections) would not allow time for all their eggs to properly mature first. The dose for the LHRHa implants is 90 µg/kg early and in the peak of the spawning season. Late in the spawning season, the best results will be obtained with a dose of 75 µg/kg. Implants are injected into the muscle (intramuscularly) about 1 inch below and slightly behind the base of the dorsal fin.

When implants are used early in the spawning season, the first fish begin ovulating about 44 hours after implantation. If the water is cold (75 to 77 °F, ovulation will be delayed to 50 to 55 hours after implantation. After the first week or two of the spawning season, some females will begin ovulating as early as 36 hours after implantation, so the first check of the bags should occur at this time. Slow ovulating females may still be giving high quality eggs as late as 72 hours after implantation, but the vast majority will have ovulated within 60 hours. If temperature cannot be controlled and the water is 73 to 75 °F, good ovulation and hatching can still be obtained, but egg release will be greatly delayed and the average time of ovulation will be 75 to 80 hours after implantation.

A few hours before stripping the females, the male blue catfish must be sacrificed and their testes removed. Males are usually euthanized and surgically opened with an incision along the anal opening to about three-fourths of the way to the head along the belly (without damaging the gut). The testes are removed by gently cutting them from the mesentery connective tissue. Try to minimize bleeding, as this will obscure the view of the testes and make removal difficult (Fig. 4). Remove only the white portion of the testes. Gently dry the testes with a paper towel until all blood and moisture have been removed. This prevents activation of the sperm when the testes are macerated to release the sperm. Finally, weigh the testes with an accurate electronic gram scale. Approximately 0.5 g is needed for each 100 mL or g of eggs. If sperm counts are made, use 65 million sperm per g of eggs. As a general rule, it takes one male to fertilize five to ten females, depending on the size and quality of the male and the number of eggs collected.

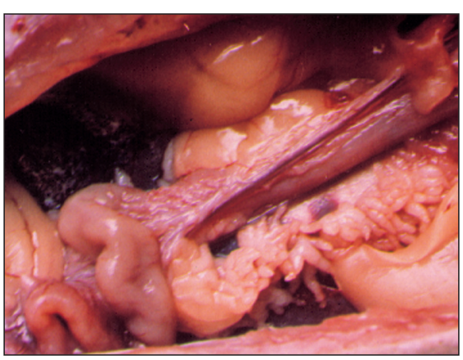

Figure 4. Testes of male blue catfish.

Place the testes in a low-speed blender with 10 mL of 0.9 percent saline per g of testes and macerate by blending for three 45-second bursts. Then filter the sperm/testes solution with a 100-micrometer mesh to remove testicular debris from the sperm solution.

When females are ovulating they are removed from the tanks and placed in an anesthetizing solution of MS-222 at a concentration of 250 mg/L. When a female is immobilized but the gills are still slowly moving, remove her from the anesthetic and quickly rinse her with clean water to remove any remaining anesthetic. Carefully towel dry the female and wrap the towel around her head and upper body. This is to remove moisture that might prematurely activate the eggs and sperm. Hold the female head up and tail down during the stripping process, with the genital opening just above a metal pie pan lightly coated with vegetable shortening. Strip the eggs into the pie pan. Feel the belly region to locate the roll (mass) of eggs in each ovary. Gently but firmly press the belly with strokes beginning at the top of one ovary (one side at a time) and ending at the genital opening (Fig. 5). When it becomes difficult to get eggs to flow out of one ovary, begin stripping the other ovary and alternately strip each ovary as needed. When no more eggs can be stripped or blood begins to come out of the genital opening, then stripping is completed and the female should be returned to a vat for recovery.

Then mix together the eggs and the sperm solution. Add oxygenated water to the egg and sperm mixture to activate fertilization, which is completed within 2 minutes after water is added to the gametes. After 2 to 5 minutes, add additional water to the pan. After a few more min-

Figure 5. Hand stripping of eggs from female channel catfish.

utes, move the eggs to a trough and allowed them to water harden for about 15 minutes. Then transfer the eggs to a traditional catfish egg hatching trough. After this point the eggs and fry are handled like channel catfish eggs.

Artificial fertilization technology is labor intensive, but efficient compared to open-pond spawning of channel catfish. By controlling temperature in the hatchery, the hatchery operator can dictate the start of the spawning season and prevent the cyclic nature of natural spawning, which has peaks as well as periods of little spawning. If brood stock are properly prepared and hybrid spawning protocol is followed, a plan can be developed that will allow the hatchery to operate at capacity continually until the hot weather at the end of the season over ripens the females and ends the season. Because artificial spawning is reliable and has guaranteed results virtually on demand, the number of brood stock and the amount of acreage devoted to brood stock can actually be decreased as compared to open-pond spawning of channel catfish.

Hormones

At the time this publication was written, there were no hormones or spawning aids approved by the Food and Drug Administration (FDA) for spawning of catfish. Please check with your Extension fisheries/aquaculture specialist for current registrations before using these hormones. To produce C×B hybrid catfish, one must participate in the program for Investigational New Animal Drugs (INADs). The United States Fish and Wildlife Service (USFWS) administers permits for LHRHa and carp pituitary extract. However, the USFWS dose for the LHRHa INAD is restricted to a total of 100 µg/kg, which is less than the most effective dose. Auburn University and Eagle Aquaculture administer a separate INAD for LHRHa injections and implants. This INAD allows injection doses of up to 180µg/kg, as needed. USFWS administers the catfish pituitary INAD.

Hybrid fertility

The strains of channel catfish female and blue catfish male used to produce first generation (F_1) C×B hybrids affects whether or not they can reproduce. Some F_1 C×B hybrids can spawn and produce large numbers of second generation (F_2) hybrids; other types of F_1 C×B hybrids have low fertility or are essentially sterile. With difficulty, F_1 C×B hybrids can be crossed with a pure strain of channels or blues to produce backcross hybrids. However, the performance of these F_2 and backcross hybrids is inferior to that of F_1 hybrids and channel catfish. Therefore, producing fry from C×B hybrid parents is not recommended. To obtain genetic improvement and hybrid vigor, channel catfish females must be mated with blue catfish males each year to produce F_1 C×B hybrids for production.

Management considerations

Genotype-environment interactions

The genotype-environment interaction is defined as the change in the value of a genotype when the environment changes. In other words, the best genetic type for one set of environmental conditions may not be the best genetic type for another set of environmental conditions; or, the advantage of the particular genotype may increase or decrease in a second environment.

Genotype-environment interactions occur for the C×B hybrid. The genetic advantage of the C×B hybrid relative to channel catfish or blue catfish increases with increasing stocking density. The hybrid is superior to channel catfish and blue catfish in earthen pond culture, large raceways, in-pond raceways, and split ponds. However, the hybrid does not grow well in small units, and channel catfish will grow faster than hybrids in aquaria, small hapas, and cages that are a cubic yard or smaller.

Conclusion

The use of the C×B hybrid is a management tool. The hybrid increases the likelihood of high production and profitability, but it is not a solution to all problems. The performance, phenotype or production (P) of an individual or population is a result of the environment (E), genotype (G), and genotype-environment interaction (GE).

$$P = G + E + GE$$

The best genetic type of catfish in the world will not perform well and reach its potential without a good environment or good farming practices. Of course, the worst genetic type of catfish will not perform well even in the hands of the best farmer. Under certain conditions, C×B hybrids may experience disease outbreaks, feed poorly, or exhibit other problems, but they are less likely to have these problems than channel catfish. Because they have many superior characteristics and are suitable for a variety of culture systems, C×B hybrids can improve farm production and profitability.

USDA

United States Department of Agriculture

National Institute of Food and Agriculture

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 2008-38500-19251 from the United States Department of Agriculture, National Institute of Food and Agriculture.