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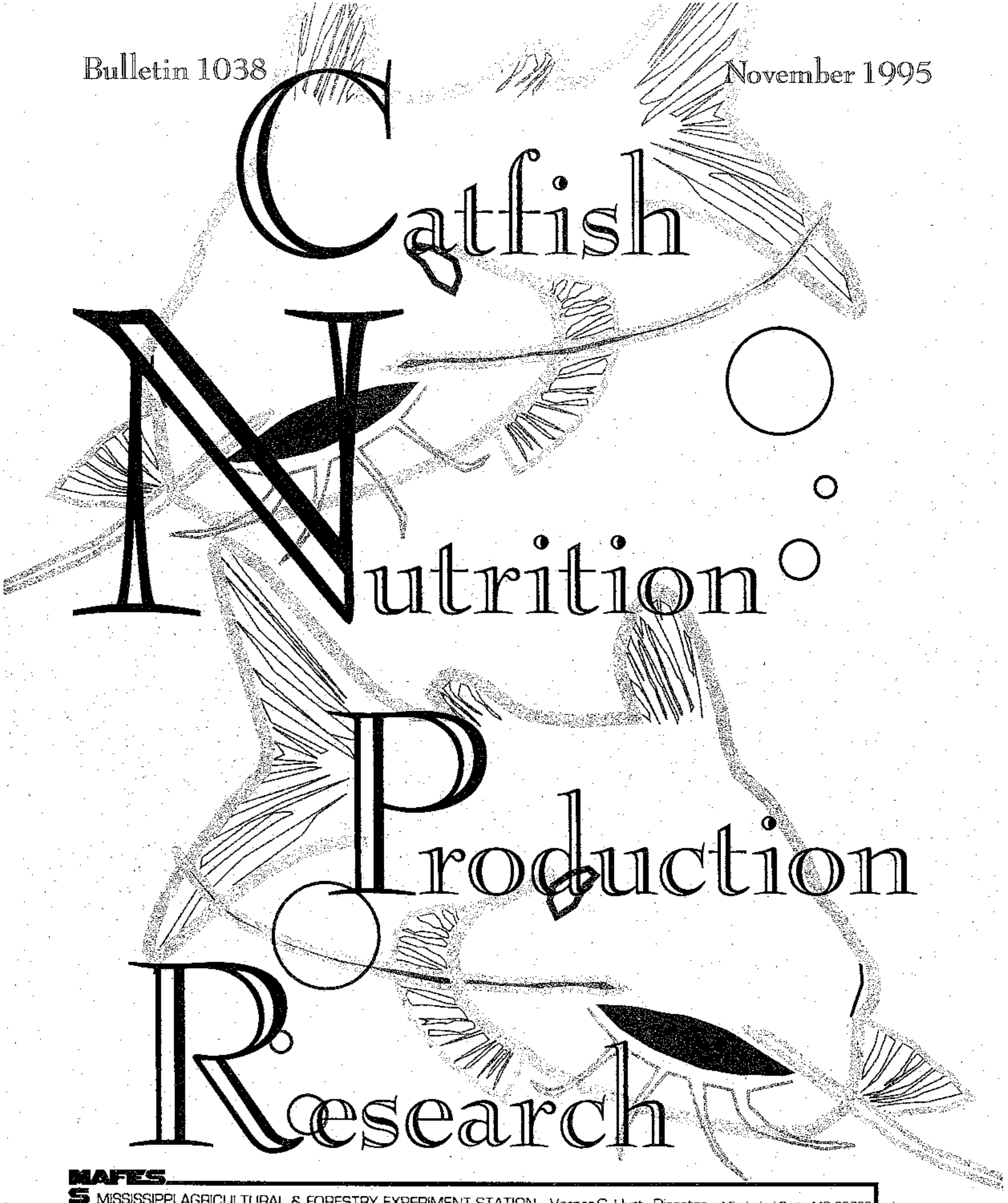

Catfish Nutrition Production Research

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Preface

To be useful to the catfish producer, catfish nutrition production research must be conducted in a manner that closely reflects commercial culture practices but yet be controlled to the point that valid conclusions can be drawn. This may not seem like a difficult task, but it is often an exasperating process because of the complexity of catfish production practices. This report summarizes, hopefully in a practical and usable manner, practices used to conduct catfish nutrition production research. It also points to some of the pitfalls. The material is based on experience of the authors and that drawn from other researchers. The material herein is not intended to be a "how to" manual on catfish research, but rather a guide that may offer insight into some of the problems one may experience in production research.

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Introduction

E. W. Shell stated in his enlightening book, *Fish Farming Research*, that "while the design, execution, and evaluation of research in agriculture are relatively well understood, experimentation in aquaculture is not." These words written more than 20 years ago still hold true in many respects. Certainly progress has been made. But research with catfish has become more complicated because of production practices that have been implemented over the last decade or so. Stocking and feeding rates are three to five times what they were 10 to 20 years ago, all sizes of fish are present in the pond throughout the year, and ponds are rarely drained.

These factors are problematic because production practices impact how aquacultural experiments are designed and conducted. If aquacultural production research is to have credibility with the clientele it is intended to serve, it must be conducted in a manner that closely reflects commercial culture practices. Yet it also must be controlled to the point that proper experimental design techniques, based on sound scientific principles, can be used and proper statistical methods can be applied so that valid conclusions can be drawn. This may not seem like a difficult task, but it is often an exasperating process.

Consider that in catfish production research, one is working with an animal for 6 to 12 months or more without actually being able to observe the animal (except in a cursory fashion). Additionally, the animal is raised in an environment that is a universal solvent. Further, consider that to this environment one is obligated to continually add organic and inorganic material (feed) that, either through release of byproducts of digestion and assimilation to the environment or through breakdown of uneaten feed, increases the level of potentially toxic nitrogenous compounds and leads to the uncontrolled growth of various plants that may be undesirable. Also, one has to contend with wide fluctuation in dissolved oxygen concentrations during each 24-hour period. Some ponds may require the use of emergency aeration to keep fish alive during episodes of low dissolved oxygen while other ponds of fish on the same experimental treatment may require no aeration.

The bottom line is that no two ponds respond the same. That is, fish production in adjacent ponds with similar soil and water types receiving identical nutrient inputs and treated alike in all other aspects may differ greatly.

Aside from all of the confounding factors that make practical experimentation with catfish difficult, this type of research is expensive. A considerable capital outlay is needed initially for facilities, and a continued source of funding is required to maintain facilities, purchase seed stock, feed, and equipment needed to handle large numbers of fish and to pay salaries and wages.

Regardless of the difficulties associated with conducting production research with catfish, such research is essential to the continued growth of the catfish industry. It is the only way to answer many of the problems that plague the industry. This bulletin is intended to provide insight into how we conduct nutrition production experiments with catfish. It will cover various aspects of experimental design, data evaluation, and problems associated with such research.

Experimental Design

Defining the Problem

A major consideration in designing a production trial is to define what the problem is and what question must be asked to solve the problem experimentally. Is the problem amenable to solution under conditions simulating commercial catfish culture? For example, one should not attempt to precisely quantify the requirement for a micronutrient by feeding small increments of the nutrient to fish in ponds. Pond systems are generally not sensitive enough to detect small differences in nutrient concentrations unless an extraordinary number of replicates are used. However, it is feasible to evaluate the effect of certain nutrients as supplements to practical feeds (e.g., amino acid or vitamin supplementation) or to evaluate differences in dietary protein or energy levels, or to evaluate feeding practices.

Once the problem is defined and it is established that a solution is feasible through production research, the experiment must be designed so that any inferences drawn from the data are sound and are appropriate for use in commercial catfish culture. Misinformation provided to a catfish farmer could be economically disastrous.

Statistical Considerations

Statistics is an important tool in designing and evaluating scientific research; however, statistics should not be an end unto itself upon which all decisions are made. J.R. Campbell and J.F. Lasley sum up the role of statistics fairly well in their book, *The Science of Animals that Serve Humanity*, in which they make the following statements: "No amount of statistical manipulation will overcome a poorly designed experiment. Statistics are no substitute for good judgement." Further, they quote E. Bidwell Wilson, who proclaimed "the statistical method, like other methods, is not a substitute for, but a humble aid to, the formation of a scientific judgement."

Statistical analysis should be a part of an equation, which also includes experience and potential economic impact. For example, a 50 percent protein feed might provide for maximum growth response, but this result must be considered in conjunction with feed cost and possible negative effects on environmental quality. If additional analyses involving these other factors could be done in the same experiment, a more informed decision could be made weighing as many factors as possible.

Controls

Control treatments are essential to the experimental process. A control can be used as a reference for comparison with other treatments. A control also serves to check that the experimental system is working properly. Use of a proper control is particularly important in nutrition production research, because decisions that may have great economic impact on the catfish industry are made by comparing experimental treatments to some standard (control) that has been proven to be effective in commercial catfish culture.

For example, in studies involving dietary protein concentrations, a diet containing 32 percent protein and 3.0 kcal digestible energy per gram of diet is typically used as a control diet. This diet is used as a control because it has been the standard feed in the commercial catfish industry for many years. All other treatments, either higher or lower in protein, can be compared to this diet.

The control described here is considered to be a positive control (replete in all nutrients) because fish performance should be maximal. A negative control might also be used during an experiment.

For example, in a study on the use of supplemental lysine in catfish diets, a diet that is deficient in lysine (negative control) should result in fish weight loss as compared to fish fed the positive control. The negative control would serve as a reference point to determine the effectiveness of supplemental lysine.

Experimental Error

All experiments contain variation, part of which is inherent in the measurements taken and material used and part of which is due to the manner in which the experiment is conducted. Inherent variability may be associated with an animal's genetic makeup, its nutritional history, or variation in the size, location, or to other attributes of ponds. Variation within an experiment is associated with the lack of uniformity in how the experiment was conducted.

Experimental error is a measure of the variation among experimental units (ponds or cages suspended in a pond) treated alike. Care must be used in the manner in which an experiment is conducted and every effort must be employed to limit the impact of inherent variability to reduce the magnitude of experimental error.

Replication

When each experimental treatment is assigned to more than one experimental unit (such as a pond or cage suspended within a pond) the experiment is said to be replicated. Replication serves several purposes, but replication is primarily used to provide an estimation of experimental error. Estimation of experimental error is essential to determine if differences between treatments that are observed can be attributed to chance or not. Thus, unless an experiment is replicated, it is not possible to determine if treatment effects are truly different or in all likelihood due to random variation.

The number of replicates needed for an experiment is affected by several factors, including the precision desired, the experimental design, and the inherent variation of a particular type of study. The smaller the difference between treatments to be detected, the more replicates required. It should be noted that replication does not reduce error caused by poorly designed experiments. Experimental error derived from similar production studies conducted previously can be used to estimate the number of replicates needed. For a completely randomized design an estimate of the number of replicates needed for comparison of two treatments is

$$r \geq 2(Z_{\alpha/2}+Z_{\beta})^2(\sigma/\delta)^2$$

where

r = number of replicates needed to detect desired differences,

α = level of significance to be used in actual experiments and is the probability that you determine there is a treatment difference where there is not,

β = probability that you determine there is not a treatment difference when there is,

Z = normal probability value (from table),

σ = square root of true variance σ^2, and

δ = difference to be detected.

An example of how this formula can be used follows. Coefficients of variation (CV) for weight gain of catfish in our pond studies have ranged from 7.6 to 11.5% with an average of approximately 10%. The CV for pond studies with catfish has been reported to be as high as 20%. Assuming that the average weight gain for pond studies Y is one pound per fish, then

$$s = CV(Y)/100 = 0.10$$

where s is square root of variance (s^2). Assuming both α and β are 0.05 and the difference to be tested is 10% of the mean, then

$$r = 2(1.96+1.645)^2(0.1/0.1)^2 = 26.$$

This means at least 26 ponds would have to be used for each treatment to detect significant differences under the conditions described above. If the difference to be tested is 20% of the mean, then $r = 6.5$ or 7; for 25% of the mean, $r = 4.2$ or 4; and for 30% of the mean, $r = 2.9$ or 3.

Type of Design

There are several designs that can be used for pond studies to test various hypotheses. The most commonly used is completely randomized design (CRD). Treatments are assigned to each experimental unit at random. This design is useful when the experimental units (ponds) are relatively homogenous in terms of location, physical characteristics (e.g.

surface area, depth, shape, orientation, etc.), and water source. As an example, assume an experiment is to be conducted using 20 ponds that are similar in all known conditions and that four dietary treatments are to be used. Each of the four treatments would be assigned randomly to five ponds.

However, if ponds are at different locations or different in any obvious physical characteristics that could affect results of the study, a randomized complete block design (RCB) may be more appropriate. Each treatment is assigned randomly within each block so that each block contains all treatments. This design considers variation among blocks; therefore, experimental error can be reduced and the precision of the experiment can be increased. Blocking can be by location or by growing season if other conditions are similar. As an example, suppose eight old ponds and eight newly constructed ponds are to be used in an experiment in which four treatments are to be evaluated. To account for possible variability between old and new ponds, each experimental treatment should be assigned randomly to two old ponds and two new ponds. Old and new ponds are blocks.

Factorial experiments are often used in catfish production research. This type of experiment allows for the joint effects of two or more factors on the response to be assessed. For example, suppose one wishes to test two levels of dietary protein (one factor) and three levels of dietary energy (a second factor). This can be done using a 2 X 3 factorial treatment. The number of factors tested is primarily limited by available resources. Statistical analyses designed specifically for factorial experiments must be used.

Experimental Unit and Sampling Unit

In pond studies, the experimental unit is the individual pond. Cages suspended in a pond can also be considered as experimental units. A sample is usually a fraction of the experimental unit, but may be the entire experimental unit. For example, weight gain of fish in each pond (which is usually determined as the total fish weight minus initial fish weight divided by total number of fish) is a sample as well as the whole experimental unit.

Subsampling (nested sampling) can increase precision of the experiment, but subsamples must be analyzed correctly. Analysis of variance based on several values of a measured variable in a single pond per treatment does not allow for a true measure of experimental error that treatment differences can be compared with. However, taking the average of observations on subsampled units as one value for the specific experimental unit is a valid approach for assessing treatment effects.

For example, if hematocrit is determined for 20 fish from each replicate pond, the average hematocrit for all 20 fish represents a single value for that pond. If this is repeated for five ponds, one would have five values for estimation of experimental error not 100 (the number of individual fish sampled).

Probability Level

In a statistical test for differences in means, the probability level, α, is the chance a type I error will occur; that is, the chance of rejecting a true null hypothesis (determining treatment differences when treatment differences do not exist). Traditionally, α values of 0.05 and 0.01 have generally been used. In pond studies where experimental error is relatively high and expense dictates that replication be held to a minimum, an α value of 0.10 is acceptable. The larger the α value, the greater the risk of a type I error. The smaller the α value, the greater the risk that another error (type II error or β) will occur. Type II error is acceptance of a false null hypothesis (there are true differences but statistical analysis shows no significant differences).

Randomization

Randomization is important to ensure that an estimate of experimental error and differences among treatments are valid and not biased. Randomness assures that every treatment has an equal chance of being assigned to any experimental unit. When sampling fish for any analysis, randomness eliminates bias in sample selection. However, if an individual fish appears to be sick compared to the majority of the population, it may be excluded from the sample.

Standard Deviation and Standard Error

In scientific papers, reporting variability of a sample is somewhat confusing. Some researchers use mean ± standard deviation (SD), while others report mean ± standard error (SE). Standard deviation, which is the square root of variance, is an estimate of the variability in a population. SE is an estimate of the variability of an estimate of a parameter, in this case a sample mean. Standard deviation is generally used to express the variability of individual values of a sample from a population. For example, a sample of fish collected from a pond or lake for weight and length distribution can be expressed as mean ± SD. When differences among treatment means are compared, SE should be used instead of SD because the interest is not in individual sample values, but rather in the mean.

Unless there is evidence that variances are heterogeneous, pooled standard error should be reported [SE = square root of (s^2/n), where s^2 is an estimate of variability among experimental units treated alike, and n is the number of replicates for the mean], because SE of each treatment mean is different and only pooled SE is useful in comparing mean differences. Roughly, if a mean difference exceeds two times that of the pooled SE, the difference is significant at $P = 0.05$. In addition, other statistical information, such as variance and CV, can be derived from the pooled SE.

Multiple Comparison and Regression

Multiple comparison procedures, such as Duncan's new multiple range procedure and Tukey's procedure, are statistical procedures used to test differences among treatment means. Any possible combination of means can be tested.

Regression analysis can also be used to evaluate data from treatments with quantitative levels. Regression involves describing how one variable is related to another variable.

Ponds

Pond Type

Since commercially cultured catfish are raised in earthen ponds, practical research studies should be conducted in similar type ponds. Moreover, certain types of research may be site-specific and, thus, should be conducted in ponds with water and soil characteristics similar to those at the commercial sites where the information will be used. For example, research conducted on effects of feeding on water quality in hill ponds in Alabama may not apply to ponds in the Mississippi Delta and vice versa. Ponds should have a ground water source for filling and maintaining water level and they should be equipped with an aerator for emergency aeration.

Pond Size

No one pond size is the "best" size to use for research with catfish. Pond size should be such that the data generated can be applied in commercial catfish culture. Fish production derived from studies in small ponds should not be extrapolated directly to commercial culture, because catfish production in small ponds is typically higher than that achieved in large ponds.

For example, in 0.1-acre earthen ponds at our research station, we routinely produce 1,000 to 1,200 pounds of catfish per pond (10,000-12,000 lb/acre) over one growing season (April to October). This is considerably higher than the 5,000 to 7,000 pounds per acre we typically produce in 4-acre research ponds or that is achieved in 10- to 20-acre ponds used in commercial catfish culture. Differences in production caused by pond size can most likely be attributed to the fact that small ponds can be managed more effectively than large ones.

Although the absolute production data may not translate to commercial production, relative feed comparisons taken from studies in small ponds will hold for commercial production. For example, studies comparing 32 percent versus 28 percent protein feeds conducted with catfish in small ponds give the same relative results when scaled up to commercial size ponds. On the other hand, if one desires to evaluate the effect of feed distribution (feeding along one levee vs feeding on two levees or around the entire pond) on fish production within a pond, large ponds will be required. Ponds for these type of studies should be no smaller than 1 acre in size and ponds of 4 to 10 acres would be desirable.

Although the type of research to be conducted largely dictates the size of pond that should be used, other factors should be considered. Research conducted in large ponds (1 acre and larger) provides production data that are more representative of production in commercial fish ponds, but research conducted in large ponds is expensive. Large numbers of fish must be stocked and feed and labor costs are increased. In addition, there is considerable cost in building and maintaining large ponds. Costs (exclusive of indirect cost) of a feeding trial conducted in 15 one-acre ponds at our station this year were as follows: fingerlings, $10,000; feed, $31,500; labor, $18,000; and analytical procedures, $15,000. The total cost was $74,500 or about $5,000 per pond. The study, if conducted in 0.1-acre ponds, would have resulted in about one-third this cost.

Pond Number

There can be a large variation in the environment among ponds stocked and managed similarly since water quality, water temperature, and natural productivity of ponds vary greatly. No two ponds are exactly alike. Thus, there is considerable variation in fish production among ponds treated alike. To conduct an experiment properly, one must account for this variation in experimental units treated alike; that is, an estimate of experimental error is needed.

Replicates are required to determine experimental error. The number needed can be calculated with an equation like the one given in the section on experimental design. In reality, the number of replicates for production trials is driven by resources available. Thus, three to five ponds are generally used for each treatment.

Management

Stocking

The number of fish that should be stocked for production research has been subject to debate between fish researchers and catfish producers — at least it has been in the Mississippi Delta. Almost all the production research trials with catfish have been conducted at stocking densities lower than those used in commercial catfish culture. Stocking densities in experimental ponds should be representative of those used in commercial culture, but not so dense that they mask treatment effects because of variables (such as poor water quality) introduced by excessive stocking densities.

One confounding factor is that stocking rates vary greatly among catfish producers and typically range from 5,000 to 10,000 or more fish per acre. There appears to be no one "best" stocking rate. We suggest that no catfish feeding study of economic importance should be stocked with fewer than 5,000 fish per acre and most should be stocked at higher rates. We stock almost all of our production research projects at 10,000 fish per acre. However, at this stocking rate, it is difficult to grow the fish to a harvestable size in the normal April to October growth period unless a large fingerling is stocked (7- to 8-inch fish weighing 100-130 lb/1,000 fish). A compromise stocking rate that appears to work rather well is 7,500 fish per acre. At this stocking rate, fish of 6 inches in length (60 lb/1,000 fish) should be stocked for a study in which the fish will be grown to harvestable size in the typical 150- to 200-day growing period.

In some studies, it is desirable to stock different sizes of fish in the same pond. For example, in studies where feed is restricted, fish size may be an important factor. The larger more aggressive fish may consume the greater part of the feed and as a result smaller fish may be undernourished. In a study of this type, if a single size of fish were used the effects of feed restriction may lead to a different conclusion than when several sizes of fish are present. One scenario is to use equal numbers of 60 lb/1,000, 250 lb/1,000, and 500 lb/1,000 fish to mimic commercial catfish culture. This approach makes harvest and data handling more of a problem, but in some instances, such an approach provides more realistic data.

Feeding

Catfish are generally fed for rapid gain, which means they should be fed to satiation — that is, what they will freely consume within a reasonable time. Satiation feeding is particularly important in nutrition studies where it is essential that the diet effect be fully expressed. Feeding at a restricted rate may mask treatment effects. Also, since fish generally exhibit a hierarchical feeding order, if feed is restricted, the more aggressive fish may consume all the feed they want while less aggressive fish may be underfed. Satiation feeding is also beneficial in cases where the number of fish in experimental ponds become unequal because of mortalities; all fish still have the opportunity to consume as much feed as desired.

For most of the growing season, it is relatively easy to satiate fish because the fish biomass is rather low. However, late in the season, when standing crops may reach 10,000 or more pounds of fish per acre, it is difficult to feed to satiation without adversely affecting water quality. Thus, the amount of feed fed should be restricted to about 100 to 120 pounds per acre per day. It appears that generally the biota of catfish ponds can effectively "metabolize" a nutrient load in this range. If this rate is exceeded on occasion it is not a problem. We have fed up to 150 to 200 pounds per acre per day for several days without detrimental effect; however, in reality, one would rarely reach this level of feeding in an experiment unless the stocking rate is exceptionally high.

For most experiments, a single daily feeding (7 days a week) is generally recommended. Feeding twice a day may be desirable in that it may allow some of the smaller less aggressive fish to feed more nearly to satiation, but because of the logistics involved, most catfish producers do not feed twice a day. If fry or small fingerlings are being used in an experiment or if feeding frequency is a variable, multiple daily feedings are necessary.

Study Duration

The experimental period should generally correspond to a typical growing season. Because of dramatic changes in water temperature and water quality during a growing season, an experiment conducted during only one segment of the growing season may not provide results that are truly reflective of fish reared for an entire growing season. In feeding studies with catfish in the southeastern United States, fish are generally stocked in March-April and harvested in October-November. In certain studies, it may be desirable to include the winter months in the experimental period. For example, if one is evaluating response to a particular nutrient, the effects of overwintering may be important. This is particularly true in early spring when the water begins to warm (increasing the growth of infectious bacteria) at a time that the immune response may be less than optimal. Also, fish are in commercial ponds throughout the winter. Thus, the effects of overwintering are important economic considerations.

Harvest

Most production studies with catfish use a single-crop, clean-harvest approach in which fingerlings are stocked in the spring and all fish are harvested in the fall. However, we conduct long-term studies that may cover a 3- to 5-year period during which a topping and understocking program is followed. Harvestable size fish are removed once or twice during the year and the ponds are understocked with fingerlings in early spring each year. This type of approach closely reflects practices in commercial catfish culture, but it is expensive, ties up ponds for several years, and makes it difficult to maintain accurate inventory records.

Harvesting fish in a timely manner is problematic in production research because of the amount of time actually needed to remove fish from the ponds and for collection of samples. Even a study with relatively few ponds takes a considerable amount of time to harvest. In large studies, it may take weeks or even months to complete a harvest. This is a concern because some fish will be in the ponds much longer than others. This is a confounding factor that is difficult to overcome. When faced with this situation, we often estimate the amount of feed needed to maintain fish body weight (neither gain nor lose weight) and feed that amount to fish until they can be harvested. Obviously, this is a highly subjective practice and is not as statistically sound as one would like. However, it is often the best that can be done.

When possible, it would be more appropriate to harvest one pond of fish from each treatment each day and treat that as a block. Blocking would help eliminate effects of possible differences between fish on the same treatment harvested at different times. In practice, it is often impossible to physically harvest a pond from each treatment each day; thus, blocking by day would not be possible. Perhaps one could block over a period of 2 or 3 days without a major problem, but blocking over a longer period of time may not be feasible.

Water Quality

Water quality in production research should be managed as is typical of management on a commercial catfish farm, unless experimental protocol is such that more frequent measurements are necessary or parameters other than those typically monitored are needed. Dissolved oxygen should be monitored during morning, late afternoon, and several times during the night. Emergency aeration should be used as needed. As a rule of thumb, we employ emergency aeration in production research trials when the concentration of dissolved oxygen drops to 3 to 4 mg/L. Ammonia and nitrite levels should be measured on a predetermined schedule; weekly or biweekly intervals are usually sufficient.

Evaluating Fish Response

There are several methods used to evaluate the response of fish to experimental treatments. These include fish weight, fish length, feed conversion ratio (FCR), feed consumption, body composition, or a combination of these. All are useful and all have their limitations. Since weight is fairly simple and inexpensive to determine and can be expressed in a number of ways including standing crop, net production, percentage gain, daily gain, or as part of a growth curve, it is often the choice to evaluate treatment effects.

Standing crop is the total weight of fish in a pond at any given point during the experiment. However, unless standing crop is used to establish a growth curve, the standing crop at the end of the experiment is the most useful. Establishment of a growth curve provides information on the time a particular treatment begins to exert an significant effect on production. Since standing crop data do not reveal anything about the changes in biomass, they may not be as important to the researcher as to the catfish producer.

Net production (standing crop at end of the experiment minus initial fish weight at stocking) is more useful than standing crop since it provides yield data. Thus, net production provides information on changes in the biomass during the experimental period.

In experiments where there are unequal numbers of fish among experimental ponds at the end of a trial (which is generally the case in catfish production trials), response may be best expressed on an average gain per fish. Of course, this assumes that it is possible to enumerate the fish. In ponds larger than 0.1 acre, it is almost impossible to accurately account for dead fish and/or to count each fish at the end of the experiment.

Percentage gain or relative growth rate indicate how much the fish has increased in size in relation to its initial weight. Weight gain data are often expressed in this manner by researchers in feeding trials conducted in the laboratory where gain is measured over a short period. Percentage gain is useful when initial weights are unequal. Percentage gain is not of much interest to catfish producers.

Average daily gain, which is commonly used to express growth of livestock during feeding trials, is generally not a useful method for expressing fish weight gain. Daily gain is related to fish size, that is, large fish gain more weight per day than small fish. Thus, for comparison, the data must be collected under standardized conditions with regard to fish size, length of feeding trial, environmental conditions, etc. There are no set standards for conducting catfish feeding trials. Another disadvantage of daily gain is that growth of a population of fish in a pond is generally curvilinear and the value is constantly changing. Daily gain is useful in expressing gain of individual animals in which growth is linear.

Regardless of how it is expressed, weight as an indicator of fish growth is incomplete. Weight gain does not provide insight into the composition of that gain. Gain might be in the form of fat instead of the desired protein. Composition of gain is important when evaluating nutritional treatments, because composition of gain may affect dressed yield. Dressed yield may not be important as such to catfish producers since they are paid on round weight. However, dressed yield is important to the catfish processor. There appears to be a negative correlation between percentage fat in the visceral cavity and dressed yield in catfish (though this is not always the case). In general, it is desirable to provide a diet that results in a high-protein, low-fat carcass. Thus, in nutritional experiments it is important to conduct slaughter procedures to determine dressed yield, percentage visceral fat, and proximate composition of edible tissue. Methods for determining these parameters are discussed in various animal nutrition textbooks.

Fish length can also be easily taken. Although length is generally not useful to the catfish producer, it can be useful to the researcher since it provides an indication of fish size at a specific stage of the growth cycle. It is impractical to measure all fish in a production trial, but a sample of individual fish can be weighed and measured to provide information on the size distribution of fish in a pond.

The FCR is useful in evaluating feed utilization and is correlated to gain. Best gainers are generally the best converters. The FCR is certainly an important factor and one that is commonly discussed by catfish producers. Typical FCR's in catfish production experiments (1.4-1.8) are almost always lower than those typically reported for commercial catfish (1.8-2.5). This would be expected because most research ponds are much smaller than commercial ponds and therefore are easier to manage. Experimental feeds that provide for the lowest FCR are generally superior feeds. However, feeding is a highly subjective practice and it is easy to over- or underfeed. Either situation will skew the FCR. FCR can be artificially inflated by feeding to excess to ensure that fish are satiated. These factors have to be taken into account when using FCR to evaluate treatment response.

Feed consumption is an important factor in evaluating treatment response. Feed consumption can be expressed in a number of ways. For example, weight of feed consumed per fish or as a percentage of fish body weight are useful measurements to the researcher, but may not be as meaningful to the catfish producer. Catfish producers often speak of feed consumption in terms of the amount of feed fed per acre per day. The major problem associated with feed consumption data is that the measurement is dependent on the skill and judgement of the person feeding the fish. Uneaten feed (resulting from overfeeding) artificially inflates feed consumption. Underfeeding may provide a more accurate estimate of what was actually consumed, but underfeeding does not allow the diet effect to be fully expressed.

Catfish Production Trial Problems

Generally, conducting production trials with catfish under the best of conditions is imprecise because problems inherent to such studies as well as to other problems that arise during the trial. The primary problem inherent to catfish production trials is that variation among ponds tends to be large. This, coupled with other problems that occur, often makes it difficult to draw meaningful inferences from production data. Researchers may often feel that they have little control over the experiment even though their experimental design was sound. Numerous problems can occur in catfish production, but problems that are of most concern to the researcher are diseased fish and mortality, reproduction, wild fish, environmental changes, and aquatic weeds.

Diseased Fish and Mortality

Diseased fish and mortality (regardless if caused by disease or other factors) are major concerns in conducting catfish production trials. Bacterial diseases are the most common infectious disease problem encountered. There are two obvious problems when experimental fish become diseased. One is that they feed poorly, if at all. Additionally, disease often results in large numbers of dead fish. There are no easy solutions as to what should be done. The question to treat or not to treat is largely a subjective call. Once the causative agent is identified and treatment is decided on, only approved substances should be used.

Another question is: Should all ponds of fish be treated? In research, a rule of thumb is to treat all experimental units as much alike as possible. This is technically true in the treatment of diseased fish, but there may be other considerations in production-scale research.

For example, assume that we are conducting an experiment using 24 one-acre ponds and that the fish in two of the ponds are infected with a bacterial disease. Further assume that the recommended treatment is to give an antibiotic feed. The question is: Should the nondiseased fish be fed the medicated feed along with the diseased fish or should only the two ponds of diseased fish receive the medicated feed? Technically one should treat all fish alike; however, in large experiments, cost of medicated feeds may prohibit treating all but just the sick fish.

Also, one must consider the effect of treatment on the overall experiment. Depending on the experiment, the use of an antibiotic feed or other chemical treatment may impact the data. For example, the composition of the medicated feed may differ from the experimental feed. It would be more appropriate to add the medication to the experimental feed, but this is not always possible. There is no single correct answer. Each situation must be decided on what is feasible and what will have the least negative impact on the study.

Mortality due to infectious diseases or other causes such as depletion of dissolved oxygen will occur, but hopefully the number of dead fish will be minimal. As mortality increases in a particular replicate the usefulness of that replicate is diminished. There is no magic formula to evaluate the effect the loss of fish has on a particular experiment. As a rule of thumb, we generally do not use data from a replicate where mortality is 20 percent or higher.

Accounting for dead fish is difficult, particularly in large ponds when the fish are relatively small. If a fish surfaces, it can usually be accounted for, unless birds or other predators remove the fish before it can be enumerated. In large ponds, the estimate may be crude because it is difficult or impossible to pick up all dead fish. In small ponds (0.1-0.25 acre), a more accurate account of dead fish can be made because it is easier to find the fish and the ponds are usually drained and all fish accounted for at the end of an experiment.

The time that mortalities occur during an experiment impacts the effect of mortality on experimental treatment. If the fish are lost early during the experiment, little biomass is lost and the effect is different than if the fish were lost after they have reached a half a pound or so. Small fingerlings lost early in a study often go undetected. In practice, dead fish (if found) are generally replaced during the first 2 weeks after stocking. The rationale for this is that the stress associated with stocking caused the mortalities; thus, they would be unrelated to treatment effects.

Feeding to satiation increases the chances that all fish in the experiment are being adequately fed regardless of numbers of fish in the pond. This will minimize the adverse effects of mortalities in the experiment. However, varying fish densities within experimental ponds caused by mortalities generally has an effect on experimental results.

Reproduction

Fish from wild spawns are a confounding factor. Reproduction should be minimized because it adds an uncontrollable factor that varies from replication to replication. Reproduction of catfish in feeding trials is generally not a problem when fingerlings are stocked and grown to a harvestable size during a single growing season. It can become a problem if mature fish are stocked or if an experiment is conducted for a number of years and the fish mature.

We have experienced problems with reproduction of stocked fish several times over the years. There is little that can be done to prevent wild spawns when mature fish are used. Also, it is difficult to estimate the impact of newly hatched fish on experimental results. In general, one can get a crude estimate of first-year fingerlings at harvest because of their smaller size. It is practically impossible to physically separate fingerlings from food fish in large experiments. The overall effect of reproduction of stocked fish on feed conversion and growth of other fish is generally relatively small since the biomass of fingerlings is small compared to biomass of harvestable size fish.

Wild Fish

The presence of wild fish in experimental ponds is not desirable. They increase fish numbers and biomass, compete for feed, and may transmit diseases. Prior to stocking of an experiment, wild fish should be eradicated either by draining the pond and allowing it to dry or by using a fish toxicant. Wild fish are generally not a problem in catfish production trials, but can be troublesome in trials that are conducted for several years using a topping, understocking type of program.

Although difficult, if wild fish are introduced into an experimental pond, an attempt to measure their impact on a particular replicate should be made by estimating the biomass of wild fish. If an estimate cannot be made, that particular replicate may be lost.

Environmental Changes

Changes in the environment may occur that are independent of experimental treatment. Algae blooms, water temperature, dissolved oxygen, ammonia, nitrites, water seepage rates, etc. vary among ponds. Some of these factors can be managed effectively. For example, maintaining high levels of chloride by adding salt (NaCl) will help prevent problems with nitrite. Dissolved oxygen can be maintained by using mechanical aeration. However, those factors that cannot be controlled will impact fish in each replicate in often unpredictable ways.

Sufficient replication will help to minimize the effect of environmental variables on the overall experiment. A method such as analysis of covariance may help to account for some of the added variation seen through environmental variables.

Aquatic Weeds

Infestations of experimental ponds with aquatic weeds can have deleterious effects on an experiment. Weeds may affect phytoplankton production, feeding behavior, and water quality, and make fish harvest difficult. Thus, aquatic weeds should be controlled. In small ponds aquatic macrophytes can be removed manually. Manual removal of aquatic weeds is labor intensive and is often ineffective because regrowth often occurs. Chemical treatment or a combination of manual removal and chemical treatment of aquatic weeds appear to be the most effective solutions. Chemical treatment is about the only choice in large ponds. If chemicals are used, care must be taken to minimize any negative effects.

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