Taiwanese red tilapia, probably a three-way hybrid *(Oreochromis mossambicus x Oreochromis niloticus-aureus).* Red tilapias account for about 5% of the total Taiwanese cultured tilapia production, which exceeds 50,000 t/yr. Photo: Roger Pullin.

Suggestions for Developing Improved Strains of Tilapia

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The focus on tilapia species for aquaculture means that domesticated strains will be needed and should be produced as quickly as possible because the need for selectively improved strains currently exists, but the development of these strains will take considerable time. The added yield resulting from selectively-improved domestic strains will justify the time and effort involved.

As a geneticist, there are certain suggestions that I would like to offer to the aquaculturists who will be controlling this domestication process. These concern the population that serves as foundation stock, the breeding system that is employed, and the process used for selecting broodstock.

Principles

First, the progress that can be made through selection is related to the genetic variation in the foundation stock. Most cultured stocks of tilapia have poorly understood histories and may have experienced population size bottlenecks (very small numbers) or contamination from hybridization with other species. Before starting a domestication program, an effort should be made to augment the cultured stock from wild stock or from different cultured stocks of the same species. This will ensure that heritabilities and selection responses are indicative of the species and not just a single strain.

Second, the breeder should assume that tilapia will be like other fish and have some of the variance of commercial traits determined by independent gene activity (additive genetic variance) and some of the variance resulting from the effects of gene interaction and dominance effects. This assumption implies that the best domestication program contains aspects of individual selection and family selection (using the whole brood). If selection among families is to be practiced, mass spawning tanks cannot be used to produce fry. Mass selection can be practiced on the fry resulting from such spawning conditions, but tanks for single pair or one male-several female matings must be employed for interfamily selection. Stock improvement should therefore encompass taking advantage of additive genetic effects through *individual* selection, and dominance and epistatic effects (the suppression of one gene by another), as well as additive effects through *family* selection, in order to progress towards phenotypes with improved culture performance traits needed for aquaculture use.

Third, commercially valuable traits should not be selected piecemeal. A great deal of thought should go into an attempt to define the commercially valuable traits that are important for current conditions and those that will become important in the predictable future. These traits should be ranked or weighted in terms of the commercial importance of

Tagging individual tilapia broodstock at the Kibbuts Ein Hamifratz Hatchery, Israel. Here selected pure lines of *Oreochromis aureus* and *O. niloticus* are used to generate high performance hybrids.

each. Such weighting values are essential for the development of a selection index which can condense a set of multiple measurements taken from an individual into a single value which can be used to determine whether that individual should be selected for use as broodstock. Selection in the first generation of the program could be initiated on each trait independently in different populations. This would permit the estimation of the realized heritability of each trait and the level of correlated responses between pairs of traits. After this initial phase, the weightings of economic value, the trait correlations, and the heritabilities are used to construct a selection index into which the measurements are put to determine breeding value. Once the index is developed it becomes the primary basis for evaluation in the selection program. The index is computed for individuals by summing the products of their trait values and the associated weighting coefficients and can be used in family selection by inputting mean values.

There are several advantages to the use of a selection index over separate selection programs for each trait. It can reduce significantly the number of generations required for the development of well balanced domestic strains. When two commercially valuable traits are negatively correlated, a selection index permits slow progress in both according to their economic weight, but a sequential selection program permits the regression of early selected traits (loss of benefits) during selection of succeeding traits while a selection index produces simultaneous selection of all the included traits.

Applications

As an example of how this process might work, let us consider the problem of developing a strain of tilapia that would: 1) become sexually mature at a large size; 2) have a high fecundity; 3) grow rapidly to 500 grams; and 4) have a high salinity tolerance. All species of tilapia should be considered for their resemblance to the required characteristics and their ease of culture in the region. Once the species is chosen, all known sources of the species should be evaluated for these traits. The foundation population should be composed of broodstock from several sources, particularly those with different values of the target traits. In the first generation, four populations would be produced from mass spawnings (there should be replicates if space permits). After a growth period a selection process should be carried out on each population to yield a selected and an unselected group of broodstock.

In population one, broodstock would be selected on the lack of evidence of prior reproduction or gonadal maturation through periodic examination and culling. The other populations would be selected for a different trait of interest. Selected and unselected broodstock are allowed to reproduce and their offspring reared to a similar stage of maturity for scoring. Then a realized heritability is calculated for the selected trait in each population. The covariance of the selected trait and the other three is estimated by determining how much the unselected traits have changed in populations that were selected for a different trait. Thus the correlation between growth rate and salinity tolerance is determined by how the salinity tolerance changes when growth rate is selected and vice versa.

By this stage, the economic weightings of these traits should have been determined, preferably by a group of experts. For illustration, let us assume that the weightings are proportional and were assigned as 0.40 for growth rate, 0.30 for delayed maturation, 0.20 for fecundity, and 0.10 for salinity tolerance. In family selection, these weightings are multiplied with the mean value of that trait for the family and the products are summed to yield a selection index value. A selection index for individual selection should be constructed in a way which takes into account the additive genetic contribution to each trait and the correlation between traits. Introductory texts in quantitative genetics discuss how this can be done; for example, Falconer, D.S. (1981). Introduction to Quantitative Genetics, 2nd Edition, Longman, London and New York.

In subsequent generations, a large foundation population should be maintained and subjected to moderately intense mass selection in each generation. At each generation, a set of families from single pair or single male matings should be tested with the selection index and 10 to 20% of them kept and inbred for future crosses. Once a family has been selected, individual selection should be practised within it. When all of the small ponds available are filled with selected inbred families, crosses between families should be performed to determine whether there is significant heterosis (hybrid vigor) for the selected traits.

For distribution to small-scale fishfarmers, it would be preferable to develop a strain from the crossing of selected families which could be maintained by random mating. This would preclude the necessity of continuous supply of fry for each production cycle. Large production facilities which could support the maintenance of several strains of broodstock could rear inter-strain or interspecific hybrids. Use of hybrids in a production facility may be justified for additional yield if some of the important traits have large contributions from non-additive genetic effects. ●