BREEDING PLAN FOR NILE TILAPIA *(Oreochromis niloticus)* IN INDONESIA: INDIVIDUAL SELECTION

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FOREWORD

The International Network on Genetics in Aquaculture (INGA) was established in 1993 with the objective to contribute through collaborative research, to the domestication and sustainable performance of tropical finfish species farmed in developing countries and to strengthen national capabilities for genetic enhancement through exchange of germplasm, methodologies and through training and interactive forums.

To realize this objective, the network has been assisting the member countries in developing regional research programs and plans for national breeding programs. INGA fielded a mission to Indonesia in November 1996, consisting of the INGA Research Coordinator Dr. Modadugu V Gupta and Drs. Trygve Gjedrem and Hans Magnus Gjoen of Institute of Aquaculture Research (AKVAFORSK), As, Norway, to assist national scientists in prioritizing aquaculture species for genetic improvement and develop plans for selective breeding of the prioritized species.

Tilapia (*Oreochromis niloticus* and *O. mossambicus*) contributes about 64,000 tons per year to aquaculture production (fresh and brackishwater) or about 13% of the finfish production from aquaculture. Initial trials undertaken by the Indonesian institutions indicated better performance of GIFT strain of Nile tilapia as against the local strains and hence the government is interested in developing a breeding program for the species.

This report details plans for selective breeding of GIFT strain Nile tilapia in Indonesia using individual selection and has been prepared by Drs. Trygve Gjedrem and Hans Magnus Gjoen of AKVAFORSK and Drs. Atmadja Hardjamulia, Ir. Sudarto, Ani Widiaty, Rudi Gustiano, Anang Hari Kristanto, Lies Emmawati and Wartono Hadie of the Research Institute for Freshwater Fisheries (RIFF), Sukamandi, Indonesia.

INGA acknowledges the support provided by the Indonesian Network of Fish Genetics Research and Development (INFIGRAD) to the mission and in preparing these plans.

We hope that this document will be useful to researchers in Indonesia for implementing the plans developed and informative to others involved in selective breeding in other countries.

Modadugu V Gupta
INGA Research Coordinator

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INTRODUCTION

Total aquaculture production in Indonesia in 1994 was 493 000 tons of finfish, 169 000 tons of crustacea, mainly shrimp and 115 000 tons of seaweed with an estimated value of 2 075 million US $. In 1994 the production of Nile tilapia was 17 600 tons and for Mozambique tilapia it was 46 800 .

The area of Fresh waters, which consist of lakes, dams, rivers, swamps and other water basins, is estimated to be 14 mill. ha. Potential areas for fish culture is estimated to 338,121 ha. with a production potential of 8-900 000 tons each year. (Source: Directorate General of Fisheries, Indonesia.)

Nile tilapia (*Oreochromis niloticus*) in Indonesia is cultured both in earthen ponds and in cages. It is assumed that production in cage culture will grow fastest in the years to come. The market for Nile tilapia is considered to be increasing. Nile tilapia from Thailand (Chitralada strain) was introduced in Indonesia in 1990, while GIFT strain was introduced from Philippines in 1994.

The strategic plan of AARD (Agency for Agricultural Research and Development) for 1995 - 2005 gives high priority to improvement of genetic potential of fish, livestock, crop and micro-organisms (AARD, 1994). In accordance with this, the Indonesian Network of Fish Genetics Research and Development (INFIGRAD) in co-operation with the International Network on Genetics in Aquaculture (INGA) has taken the initiative to establish a breeding program for Nile tilapia in Indonesia. In this program, INFIGRAD will have its role as research co-ordinator, and the members may contribute in the research and development under the responsibility of RIFF.

The effect of a breeding program depends very much on how it is organised to get the obtained improvement transferred rapidly to the farmers. AIAT (Assessment Institute for Agricultural Technology) and FADC (Freshwater Aquaculture Development Centre) are given a central role in this dissemination of the improved fish. It is important that INFIGRAD co-ordinate this process.

In this proposal, the Research Institute of Freshwater Fisheries (RIFF) serve as the breeding centre where mating, testing and selection takes place. After the first generations, as RIFF develops and improves the

breeding program, mating, testing and selection will become more and more standard routine work. This activity will also take up much of the research capacity of RIFF. At that stage, INFIGRAD may assist in reorganising the breeding program in order to reduce the routine breeding work at RIFF and in developing other breeding centres.

The *generation interval* (see Appendix), will depend on the time needed to reach sexual maturation. Today this is 9-12 months for the strains that are in common use in Indonesia, but it is not known what it will be with the GIFT-fish, which has an improved growth rate compared to the strains used today.

BREEDING GOAL

The most important economic traits for production of Nile tilapia in Indonesia are:

- Growth rate
- Delayed sexual maturation
- Disease resistance
- Dressing percentage

Growth rate should be recorded at the marketed size, about 0.3 kg, which is usually obtained at half year of age.

As discussed under the next paragraph, Selection Method, individual selection is the method of choice for Nile tilapia in Indonesia. Thus, growth rate is the only trait that can be efficiently selected for. Late sexual maturation, dressing percentage and disease resistance may, however, be included later if desired, but family tagging must then be used in the breeding program.

Preliminary results from the GIFT project in the Philippines, may indicate that delayed sexual maturation has a negative genetic correlation to growth rate. This should be carefully monitored in the present breeding program, and at a later stage it should be decided if the breeding program should be expanded to a family selection program in order to efficiently improve this trait.

Before disease resistance could be included in the breeding goal, there is need for investigations and development of methods for testing, e.g. challenge tests. Even though disease resistance is not included as specific and recorded traits, a natural individual selection will take place in the breeding population. Genetic gain in this trait may therefore still be expected in the proposed breeding plan for Nile tilapia.

Dressing percentage has, in several investigations in fish, shown to be genetically positive correlated to growth rate, and is thus expected to improve as a correlated response to selection on growth rate.

SELECTION METHOD

Results from the Genetically Improved Farmed Tilapia (GIFT) project in the Philippines have shown large genetic variation and large response to selection for growth rate. This genetic variation may, however, also be utilised easily by individual selection, i.e. without the necessity of tagging. The breeding program should then be designed to control and restrict accumulation of inbreeding and thus avoid loss of genetic variation and inbreeding depression. This is done by securing a large effective population size. In the proposed breeding plan, a large effective population size is achieved by using many breeders in each generation, and a restricted number of progeny per pair to be available for selection at the end of the grow-out test. The variation in the number of progeny between pairs is kept as low as possible by separate rearing of the family groups through the early life phases, when the mortality is high. A fixed number of progeny per pair may then be counted and communally stocked for grow-out testing. Assuming the heritability to be 0.2 for growth rate, the design of this breeding program is expected to result in a rate of inbreeding of less than 1% per generation, which will be sufficient to maintain the genetic variation and thus ensure a sustainable genetic progress.

Individual selection is chosen rather than a combined individual and family selection because of research and test capacity reasons. Furthermore, as cage culture becomes more and more important in freshwater aquaculture, early sexual maturation becomes less of a problem in this farming system.

As mentioned before, a future broadening of the breeding goal by delayed sexual maturation, improved disease resistance and increased dressing percentage, will require tagging or branding for pedigree recording and family selection. This may be done as a continuation of the proposed breeding program, since loss of genetic variation and accumulation of inbreeding will be kept under control and the breeding population may serve as a future base population for a program that employ family selection.

BASE POPULATION

Through the International Centre for Living Aquatic Resources Management (ICLARM) and INGA, RIFF has established contacts with the GIFT project in the Philippines. A request for transfer of a broad sampling of families of the latest generation from the GIFT project to RIFF (Sukamandi) has been forwarded. This should represent all the families in the GIFT project and each family should be represented with at least 5 fish (about 1000 in total). The fish may be family tagged to avoid fullsib

mating, but this is strictly not necessary. The imported GIFT fish will then form the base population for a breeding program for Nile tilapia in Indonesia.

MATING SYSTEM

Natural mating, i.e. mouth brooding, should be practised by placing the broodstock in breeding hapas (1x1x1 m^3). Before mating, the breeders will be conditioned, which means they are given better space and feed, to improve and increase rate of sexual maturation. One male will then be stocked with 2 females in each of the breeding hapas (Fig. 1). A total of 75 breeding hapas should be installed in one pond. All hapas should be inspected once every week for swim-up fry. Swim-up fry will be collected separately from each hapa and transferred at a standardised stocking density (300 fry) to 1x1x1 m rearing hapas, one hapa for each fullsib group. The date of collection of swim up fry should be recorded. The spent females shall be removed from the breeding hapas. Breeding should continue until 100 fullsib groups are produced. After 3-4 weeks in the rearing hapas, the fry of families collected in the 1st week will be transferred at a reduced number (200) to an earthen pond. The fry from families collected the 2nd an 3rd week will likewise be transferred to a 2nd and 3rd pond.

When the fish reach about 10 g (after *ca* 1.5 months), fish in each pond should be transferred to 3 cages in RIFF's floating net cage unit. The fish will be reared in the cages for 3-4 months until they reach an average size of 250-300 g which is considered to be the market size. Assuming 50 % survival from the time of transfer to the ponds to the end of the grow-out period, it is expected that on an average 100 fish from each family will be present at time of selection.

SELECTION OF BROODSTOCK

At the time of selection, there will be about 3 300 fish in each cage, averaging 250-300 g. To allow some mortality from time of selection of broodstock until mating, in total 150 males and 300 females should be selected and transferred to Sukamandi. In addition, the second heaviest fish should be selected for purpose of dissemination and should be transported to the organization that will perform the dissemination (see Fig. 2 and also next section).

Since the fish in the 3 cages on average are considered to have the same genetic value, equal number of males (50) and females (100) should be selected from each cage. Likewise, fish to be used for dissemination should also be equally selected from each of the 3 cages.

In order to find the fish with the highest body weight, it is not necessary to record body weight of all fish. A grading system could for example save one third of the heaviest fish as possible broodstock. These fish should then be weighed and the heaviest ones from each cage should be selected as described above. Mating should be performed between males from one cage and females from another cage in order to decrease the risk of inbreeding depression.

DISSEMINATION OF IMPROVED SEED TO THE FISH FARMERS

In order to maximise the benefit from the breeding program, the genetic improvement should reach the fish-farmers without delay. From RIFF there are mainly three routs for dissemination, namely trough AIAT, FADC and directly to private hatcheries. For this purpose, only improved broodstock should be used.

Because of the relatively low fecundity of Nile tilapia, dissemination of improved seed will have to be based on distribution of improved broodstock to hatchery operators (Figure 2). After production of fullsib families for the breeding population have been completed, the selected parents should be used for mass production of seed for hatchery operators. The progeny of the selected parents will, when reaching sexual maturation, be top genetic quality broodstock, followed by the progeny of the discarded breeders from the best one third of the population (see above).

It is very important that the collaborating breeding centres are informed and educated in how to use the new broodstock. The new breed should not be used as broodstock in the same manner as the old pure strains inasmuch as offspring of the selected broodstock should not be re-entered into breeding. It is also important that the hatchery managers and multipliers understand that it is of significance to use top quality seed from the breeding system.

CONTROL TO ESTIMATE GENETIC GAIN

Establishing a procedure for control of genetic gain in a breeding program is not required to obtain response to selection. Including a routine for genetic control will, however, make it possible to check if the assumptions that are made are valid, or if the program needs adjustments for other reasons.

At the same time as the largest breeders are selected, 20 sexually mature males with average male body weight and 20 sexually mature females with average female body weight should be selected (The average should be determined from a sample of at least 200 fish). These breeders will be used to produce a control group. Their progeny may be used to estimate genetic gain from each generation of

selection. After the progeny of single pair matings of selected and average broodstock has been nursed in separate hapas, 30 larvae from each hapa containing progeny of selected breeders and 150 larvae from each hapa containing progeny of a pair of average breeders should be counted from the hapas as shown in Figure 3. The 3 000 (30 x 100) progeny of the selected breeders should then be pooled and randomly divided in 3 equally sized groups of 1 000 larvae for stocking in 3 nursery hapas (replicates) as shown in Figure 3. The same procedure should be repeated with the 3000 (20 x 150) progeny of the average breeders. The 6 nursery hapas should then be placed together in the same pond and given the same treatment .

At fry size, about 330 fry from each nursery hapa should be transferred to separate rearing hapas and reared until fingerling size. The fry should be reared in the hapas until they have grown to a size when they may be fin clipped to separate the two groups from each other (e. g. by clipping the pectoral fin on one side on progeny of selected breeders and the other side on progeny of average breeders). Both groups should be fin clipped to eliminate any effect of this on growth rate. About 100 fin clipped fingerlings from each hapa (i. e. 300 randomly sampled progeny of selected breeders and 300 randomly sampled progeny of average breeders) should then be communally stocked in a grow-out pond until the market size. The fish should be stocked at a low density and under proper feeding and management conditions to ensure good growth performance. The difference in mean body weight between the two groups will then represent the response to the previous round of selection. The procedure may be repeated in each generation.

In addition to this control group, a sample of the GIFT fish in the Philippines should be brought to Indonesia for example every 5th generation. This will give interesting estimates of how individual selection is doing compared to a combined individual and family selection which is applied in the tilapia breeding program in the Philippines.

EXPECTED BENEFIT FROM A BREEDING PROGRAM

When additive genetic variation is present in a trait, there will always be response to selection if efficient selection methods are applied. In the literature there are several estimates of response to selection in growth rate in large scale breeding experiments and breeding programs. The following estimates should be mentioned (given as genetic gain in percentage per generation of selection): For coho (Pacific) salmon, 10.1; for rainbow trout, 13; for Atlantic salmon, 10.6-14.2; for channel catfish, 12-20; and for Nile tilapia, 17 %. An average figure of these estimates are 15 % genetic gain per generation for growth rate. This means that it should be possible to double the growth rate in less than 7 generations. This is a larger genetic gain than usually obtained in farm animals, and it is achieved because fish and shellfish

have larger genetic variation in growth rate and have higher fecundity; consequently, it is possible to apply a much higher selection intensity.

The benefits of genetic improvement in growth rate are reduction in both fixed costs and production costs, the latter due to lower energy requirement for maintenance for the entire life span. Often also a correlated response can be observed as an improved feed conversion rate.

In the Norwegian breeding program, which today supply genetically improved eggs of Atlantic salmon and rainbow trout to more than 70 % of the fish farming industry, has a cost/benefit ratio of 1/15. Similar estimates are also found from breeding programs in farm animals. This ratio will depend largely on the total production output that benefit from the genetic improvement. In view of the large production of Nile tilapia in Indonesia, an even better ratio may be expected for the proposed breeding program.

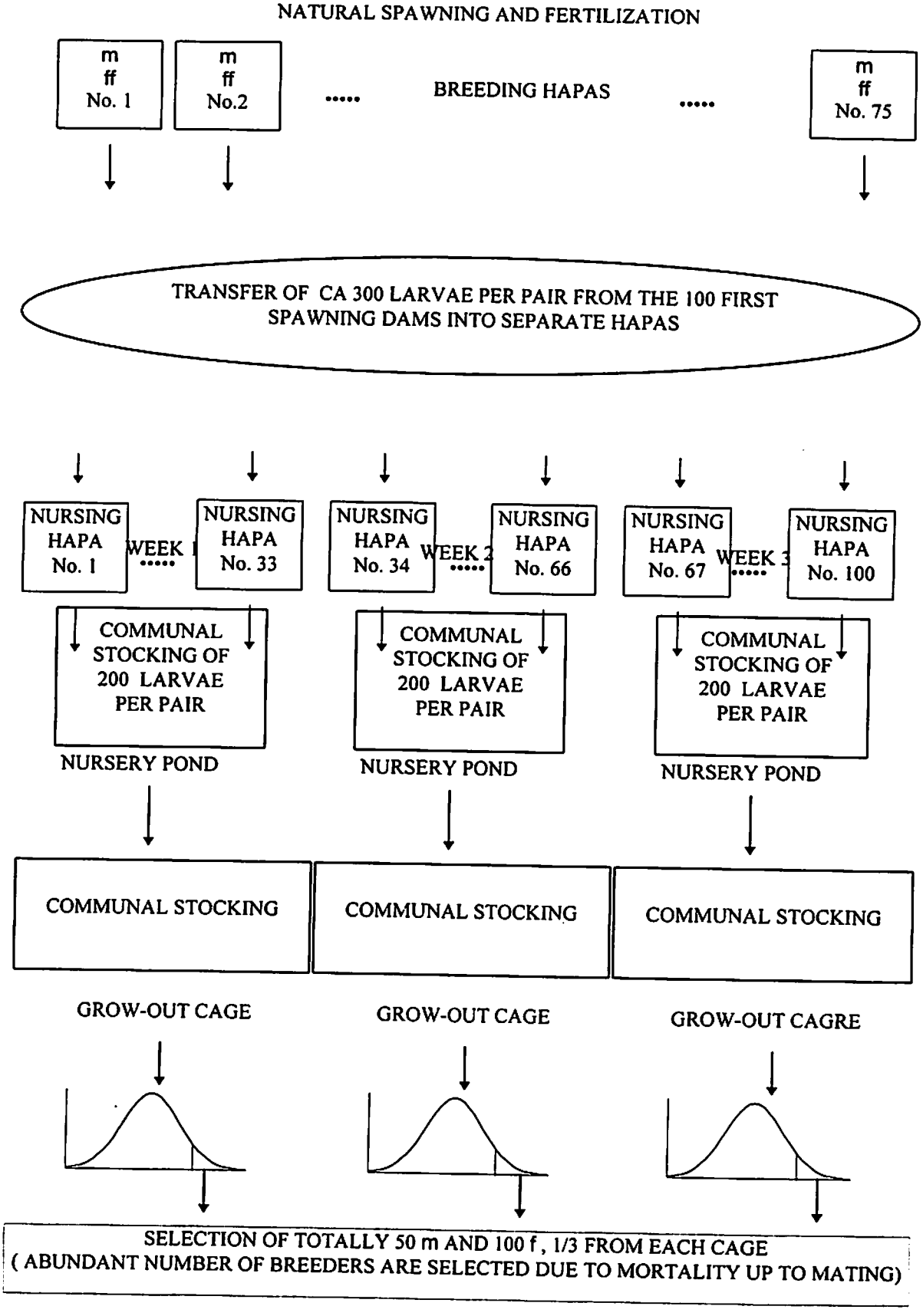

FIGURE 1. MATING OF THE PARENT BROODSTOCK AND REARING OF PROGENY UNTIL NEXT ROUND OF SELECTION

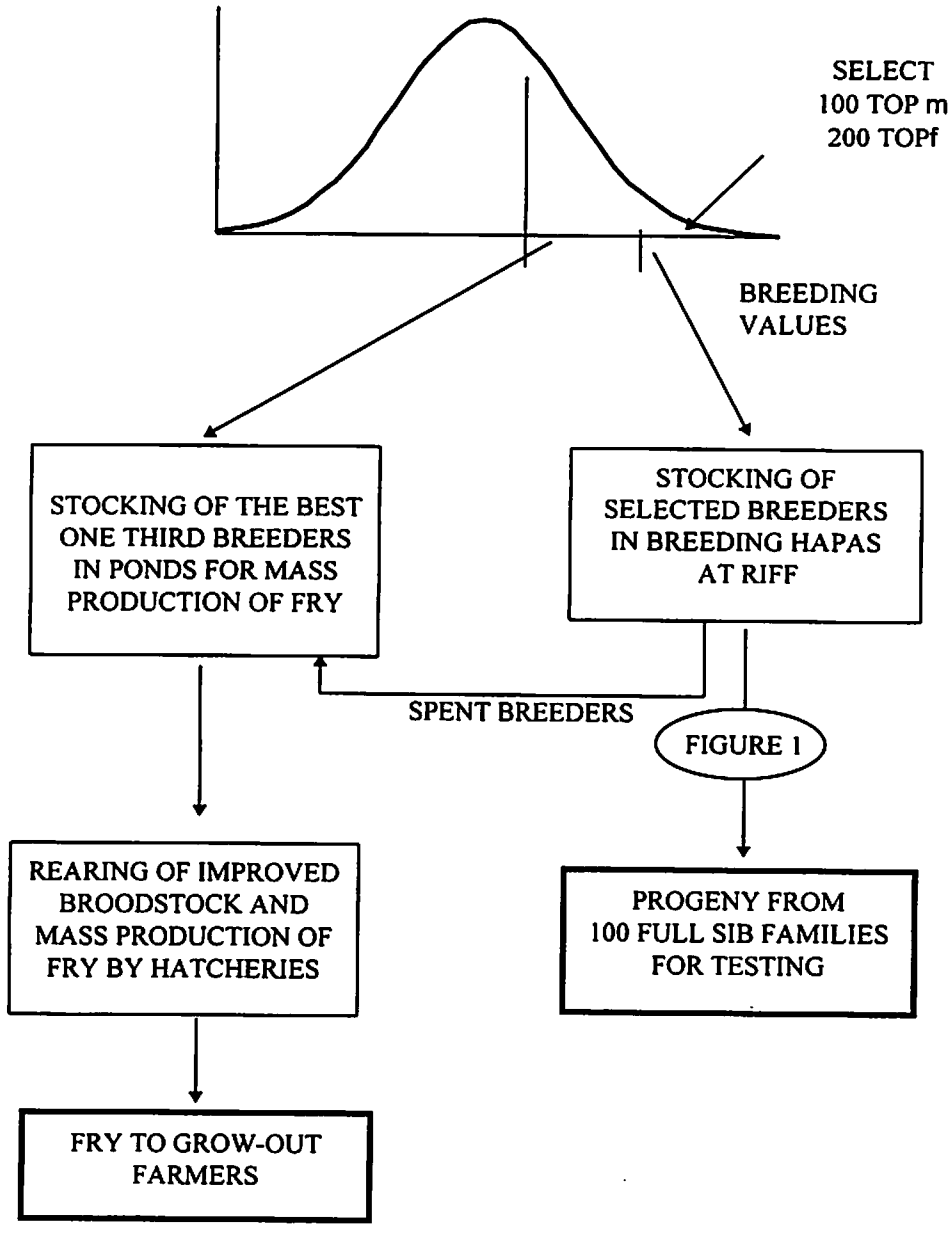

FIGURE 2. SELECTION OF BREEDERS AND DISSEMINATION OF GENETICALLY IMPROVED TILAPIA TO FARMERS

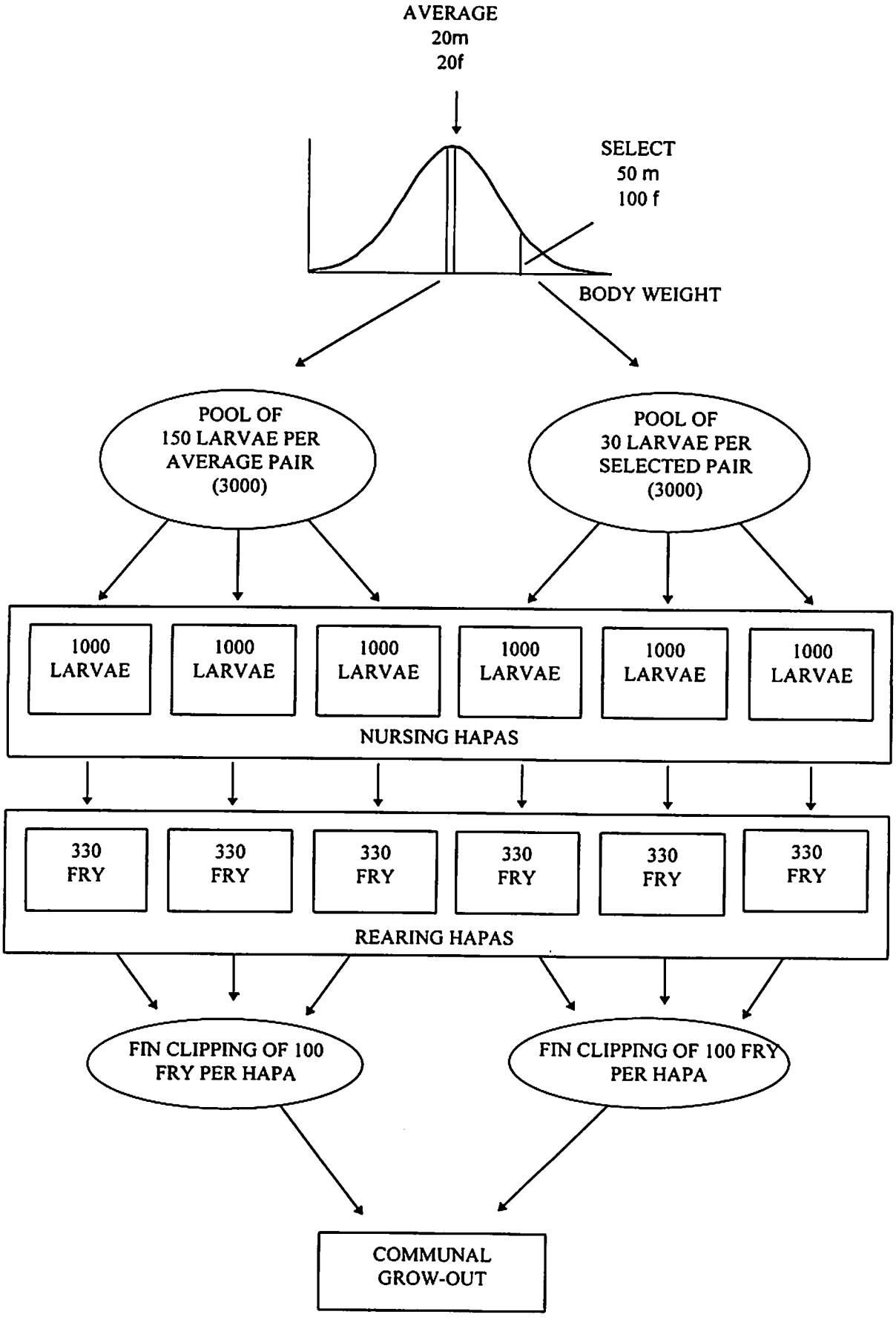

FIGURE 3. CONTROL OF GENETIC GAIN. COMPARISON OF PROGENY OF SELECTED BREEDERS WITH PROGENY OF AVERAGE BREEDERS

Appendix

Some definitions of common expressions from quantitative genetics and selective breeding plans:

Base population: The initial random-mating population that form the base for the selection experiment or selection program. It is customary to assume that the inbreeding coefficient is zero in the base population, and this is therefore the reference for estimation of inbreeding in later generations. This requirement may not always be met, but all efforts should be made to establish a base population of unrelated individuals.

Family selection: Selection based on information from fullsibs and/or halfsibs to estimate the breeding value (may also include information from other relatives). The selection is among families and not within family since no information is available to distinguish between family members (it can, however, be combined with other information in a multiple-trait index which enables us to select the best overall breeding candidate within family). The method requires that information of relatives are recorded, which means that fullsib groups must be reared separately until the fish have reached a size for which a marking system can be applied.

Fullsibs: Offspring from the same sire and dam, i.e. same pair of parents.

Dam: Female parent.

Generation interval: The average age of the parents at the birth of their selected offspring.

Halfsibs: Offspring from one sire (i.e. paternal halfsibs) or one dam (i.e. maternal halfsibs). This means that within a halfsib family some of the fish may also be fullsibs, e.g. when one sire is mated to two dams.

Heritability expresses the extent to which phenotypes, i.e. the observed value of that trait, are determined by the genes transmitted from the parents. It is given by the ratio: (additive genetic variance) / (phenotypic variance)

Hierarchical mating structure: A mating structure where for instance one male is mated with two females. Simulation studies have shown that this structure gives maximised genetic gain.

Inbreeding means the mating together of individuals that are related to each other by ancestry. This is unfavourable for two reasons: 1) it leads to inbreeding depression (low performance) in many traits, especially fitness traits (e.g. survival and fertility), and 2) it leads to decreased genetic variation.

Index selection: Selection based on a combination of sources of information to estimate the breeding value, from the individual itself, and from relatives, especially fullsib or halfsib-information. The method requires that genetic relationship among the individuals must be recorded, which means that fullsib groups must be reared separately until the fish have reached a size for which a marking system can be applied.

Individual selection: Selection based on the performance of the individual itself only, to be distinguished from *Family* and *Index selection*. The method do not require a marking system, but the number of offspring from each family that are allowed to contribute their genes to the next generation must be restricted in order to control *inbreeding*.

Sire: Male parent.