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Considerations about dissemination of improved fish strains

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INTRODUCTION

Aquaculture production systems in developing countries are largely based on the use of unimproved species and strains. As knowledge and experience are accumulated in relation to the management, feeding and animal health issues of such production systems, the availability of genetically more productive stock becomes imperative in order to more effectively use resources. For instance, there is little point in providing ideal water conditions and optimum feed quality to fish that do not have the potential to grow faster and to be harvested on time, providing a product of the desired quality. Refinements in the production system and improvement of the stock used must progress hand in hand.

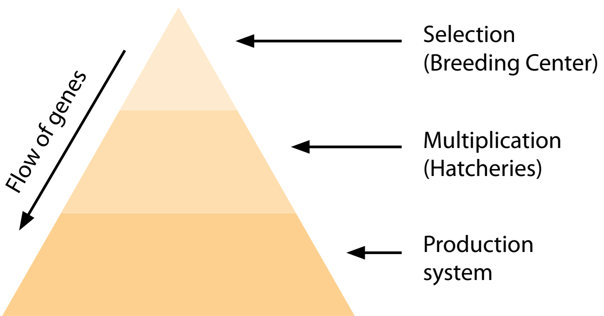
There is documented evidence about the success of selective breeding in several species (Gjedrem 2005), and there are indications that the potential benefits are very large (Ponzoni et al. 2007, 2008). However, it is quite clear that such gains will have no impact on farmers unless the progeny from improved strains reach the production system in a state that makes them capable of prospering during the grow-out period until they reach market weight. Achieving genetic change in a population will often be easier than achieving effective multiplication and dissemination of the resulting improved strain. In the former case, we simply have to control the reproduction and mating among the fish, whereas in the latter we have to influence people and the way they operate. Assuming that because we have an improved strain, hatchery managers will effectively multiply it and disseminate it, and that farmers will adopt it, is unrealistic.

In this paper we deal separately with genetic and non-genetic issues pertaining to the multiplication and dissemination of improved strains. The separation is somewhat arbitrary, and as will be evident from our discussion, there is frequent interaction between the two.

GENETIC CONSIDERATIONS

In well-structured animal industries, genetic improvement typically takes place in a very small fraction of the population. The genetic improvement achieved in that 'elite' of superior animals is multiplied and disseminated to the production systems. The flow of genes is graphically illustrated in Figure 1.

Figure 1. Flow of genes from the breeding center to the production system.



Note that throughout this paper we use the term 'fish' in a broad sense to include invertebrate as well as vertebrate aquatic animals. With their high reproductive efficiency, fish are very well placed for the development of cost-effective structures for disseminating genetic gain. The implementation of the genetic improvement program in a relatively small number of animals can be enough to service a very large population involved in production.

Unfortunately, experience shows that when a successful strain and market for such a strain develop, malpractice often proliferates, facilitated by the very high reproductive rate of fish, and stock quality deteriorates as a consequence of inbreeding and small population size. There is no simple way out of this, except through the creation of a formal structure that is not only technically sound but also regulates the process and enables the implementation of quality assurance practices. In this section of the paper, we outline the genetic considerations that should be made to ensure the delivery of high-quality seed to farmers, and we formulate recommendations to this effect.

Brood stock management in hatcheries: General situation

For many cultured fish species, hatcheries have been in operation without a corresponding genetic improvement program. The bad management of brood stock from a genetic viewpoint has led to the frequently encountered scenario of low and deteriorating performance in hatcheries. This deterioration may be attributed to the combined effect of selection in the wrong direction and to inbreeding (Eknath 1991). Efforts have been made to explain the genetic basis of the deterioration of stock performance and to prescribe methods to avoid it. However, when a genetically improved strain is available, the role of hatcheries should not be the 'management' of the stock, but rather the rapid multiplication of the latest (most improved) generation of the strain. Here we outline what may be considered to be the ideal method of disseminating an improved fish strain. We also provide guidelines for brood stock management in case the implementation of the 'ideal' method is not an option.

Ideal brood stock management policy for hatcheries

Assume that we have an improved strain of demonstrated superior performance relative to other populations of the same species currently used by farmers, and that it is undergoing a continuous program of genetic improvement. From the point of view of production of high-quality seed, the ideal is that hatcheries regularly receive brood stock from the breeding center where the genetic improvement program is being implemented, produce seed for farmers from that brood stock, and replace it when its reproductive efficiency declines or ceases. In this way, hatcheries would be multiplying and distributing to farmers seed from the latest generation of the nucleus in the breeding center, with the greatest number of generations of selection behind it. They would not be breeding with the purpose of generating their own replacement brood stock.

The required rate of replacement of brood stock would depend on the hatcheries' individual needs, and it would be related to the wear and tear of brood stock and the anticipated fry output. Because in this scheme hatcheries do not produce their own replacement brood stock, considerations about numbers are of a different nature than when they do. There are, nevertheless, some simple guidelines that can be followed.

First, the number of brood stock in the hatchery at any particular time will have to be consistent with the anticipated output of larvae or fry. This can be easily calculated from the reproductive rate for the hatchery in question. Second, steps should be taken in the hatchery to ensure that close relatives are not mated. This can be achieved by supplying, from the breeding center, brood stock in two groups, say A and B, with the condition that group A is progeny of a different set of parents than group B. If we further impose the condition that in the hatchery males from group A can only be mated with females from group B and vice versa, we eliminate any chance of mating individuals that are full sibs or half sibs. Of course, brood stock could be supplied in more than two groups if that were necessary for some reason.

The brood stock supplied to the hatcheries by the breeding center would typically consist of individuals that are surplus to the genetic improvement program, individuals resulting from special matings (in addition to those conducted in the context of the genetic improvement program) of selected parents, or redundant parents (i.e., already used in the nucleus but no longer required because a new generation is, or will soon be, available). The use of redundant parents by the hatcheries could be very valuable in rapidly disseminating the genes of the best individuals of the improved strain, thus reducing the genetic lag between the nucleus and the production sector.

A change in the perception that hatcheries have to breed their own replacements would benefit the industry as a whole. The achievement of such a change will require education of hatchery managers and the implementation of procedures for certification of hatcheries that join the scheme and are prepared to follow the necessary protocols. Note that this is the approach that was initially followed by the GIFT Foundation.

Brood stock management guidelines when replacements are bred within the hatchery

General: If an improved strain were made available to hatcheries with no conditions or restrictions on the use of the stock, their multiplication through the reproduction of a limited number of parents of undetermined relatedness to each other would inevitably result in inbreeding and impaired performance. This would have at least two undesirable consequences. First, farmers would not be able to benefit from the genetic gain achieved in the nucleus, as this would have been eroded by inbreeding depression by the time they received fry. Second, the poor performance experienced by farmers would give the improved strain a bad reputation, making its dissemination to other farmers more difficult. Given the resources and effort that have been put into the development of an improved strain, this would be a most unfortunate turn of events, hence the highly formalized scheme of multiplication by continuous stock replacement advocated and described in earlier paragraphs and the reservations expressed about the notion of hatcheries producing their own replacement stock.

Inbreeding: Inbreeding is the mating together of individuals that are related to each other through having one or more ancestors in common. The offspring of such a mating are inbred to a degree dependent on the closeness of the relationship between their parents. It is the relationship between the parents that makes the offspring inbred. Either or both of the parents may be inbred themselves, but if they are not related to each other their offspring are not inbred. The primary consequence of inbreeding is to reduce the number of individuals that are heterozygous for any one gene pair and to increase the number that are homozygous. The reduction in the number of heterozygotes and increase in the number of homozygotes can be worked out mathematically and provides a measure of the degree of inbreeding, known as the *coefficient of inbreeding*. The coefficient of inbreeding ranges from 0 percent at the start, to 100 percent when inbreeding is complete.

There are two practical consequences of inbreeding, both of which result from the reduction of heterozygotes and increase of homozygotes. The more obvious of these is the *inbreeding depression*. The animals become generally less healthy and more susceptible to disease, and their reproductive capacity is reduced due to lower reproductive efficiency and survival. This effect of inbreeding follows from the fact that most deleterious genes are recessive. In a non-inbred strain these genes are present mainly in heterozygotes where, being recessive, they do not show in the phenotype. As inbreeding proceeds, however, they appear more and more often in homozygotes, where they exert their full deleterious effect on the phenotype. The second practical consequence of inbreeding is to change the amount of genetic variability among the animals. When inbreeding results from a relatively small population size, rather than from deliberate mating of relatives in a large population, the genetic variation is diminished, thus reducing the scope for genetic gain from selection.

Avoiding inbreeding in the hatchery: guidelines. In this section, guidelines aimed at the maintenance of brood stock quality are provided, and a number of practical suggestions are made.

<u>*Effective population size*</u> The effective population size is one of the most important concepts in the management of a population. It depends upon several factors, such as total number of breeding individuals, sex ratio, mating system and variance of family size. In a random mating population, effective population size (N_e) is calculated as

$$N_e = \frac{4N_f N_m}{N_f + N_m}$$

where N_f and N_m are the number of female and male brood stock, respectively.

The effective population size is inversely related to the rate of inbreeding per generation (ΔF):

$$\Delta F = \frac{1}{2N_e}$$

We may also write the following:

$$\Delta F = \frac{1}{8N_f} + \frac{1}{8N_m}$$

Although the above equations are strictly only applicable to random mating populations, we may use them to illustrate a number of important practical consequences of population size. First, the effective population size is not the same as the census size. For instance, two populations, one consisting of 5 males and 15 females, and another consisting of 10 males and 10 females, have the same census size, but the effective population sizes are 15 and 20, respectively. Second, and following from the calculations just made, for a given census size, the effective population size is maximized when the number of females and males used is the same. Third, if we set an upper limit to the increase of inbreeding per generation, say at 1.0 percent, then we can calculate the effective population size that would be required (i.e., 50). This effective population size could be achieved by mating 25 females with 25 males, assuming that they all leave offspring, and that offspring from all pairs contribute to the next generation. Of course, this effective population size could also be achieved in other ways.

These design considerations have to be carefully applied in species such as tilapia. Fessehaye et al. (2006) found that in O. *niloticus* under mass spawning in large hapas, there was a large variance in male reproductive success, with one third of the males siring more than 70 percent of the offspring. This led to a rate of inbreeding of approximately twice that predicted from the effective population size. In practical terms, this would mean that to achieve a given rate of (low) inbreeding, one should have a population size double that indicated by theory.

It should be realized that in a closed population of finite size, inbreeding will inevitably occur. The fact that the smaller the Ne the greater the rate at which inbreeding will increase has to be kept in mind. If brood stock replacements are produced in the hatchery, the aim of the hatchery manager should be to reduce the rate of inbreeding by increasing the effective population size.

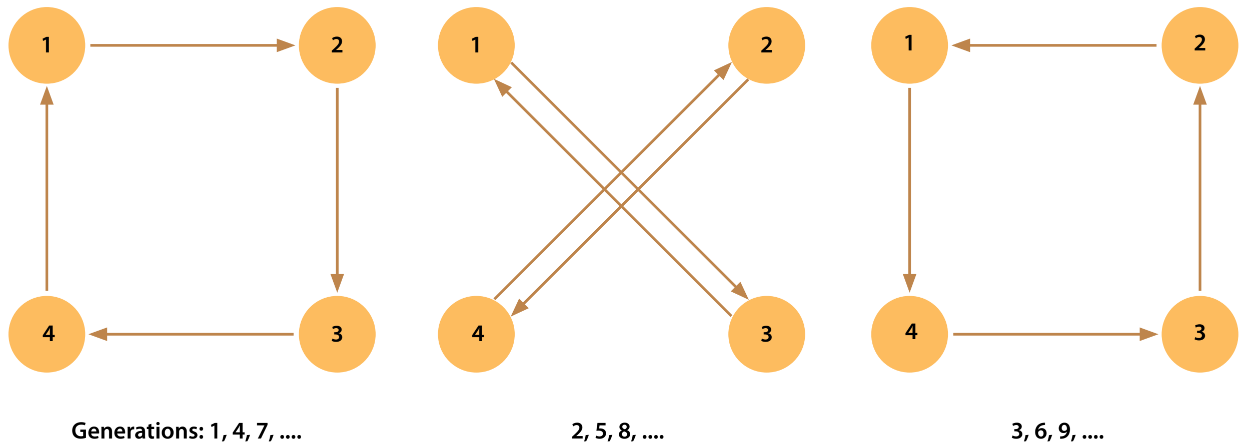
Both private and public hatchery managers will require sound advice and monitoring on this matter, as they generally have limited knowledge about genetic principles and corresponding proper brood stock management. Often, private hatcheries have limited space for brood fish, and they are understandably profit oriented. Conflicts can emerge between short-term profit gains and considerations about inbreeding. Preferably, hatcheries undertaking the maintenance of their own brood stock should have a separate unit for that purpose, apart from the one producing fish seed for sale.

Practical considerations The following is a list of practical matters to be attended to by hatcheries engaging in the production of their own brood stock replacements. Note, however, that this is no substitute for person-to-person discussions with hatchery managers and for ongoing monitoring of the operations.

- Increase the effective population size, as this reduces the rate of inbreeding. There is no fixed or ideal number of brood stock that can be universally recommended, but producing offspring from a minimum of 50 pairs of parents in each reproduction cycle is advisable. Note that to be sure that offspring from at least 50 pairs of parents are produced, more may have to be used. Repeated use of the same brood stock in a way that could result in the mating of parents to their own progeny should be avoided.
- For a given census size, maintaining a ratio of one male to one female among the brood stock will result in the lowest rate of inbreeding.
- Instead of mass breeding, stripping of fish can be adopted, as this will allow greater control of reproduction and of the contribution of parents to the next generation. Also, it may enable the avoidance of matings among close relatives.
- Hatchery managers should have detailed knowledge of their brood stock. For instance, they should maintain records on the location (e.g., pond, tank) of each stock. Keeping year or age classes separate is useful.
- Marking in some way or fin clipping can be carried out for identification of different groups of brood stock. Even in cases in which the fish cannot be individually identified, keeping different groups will enable the organization of mating in ways that delay the onset of inbreeding and that result in a more uniform rate of inbreeding in the population than random breeding. Figure 2 shows how mating could be organized with four such groups. This mating system is also known as 'cohort mating'. The groups could be year classes or could be nominated by the breeding center on the basis of parentage. The arrows indicate the transfer of males. The principle is that male progeny are mated with females of a different group from the one in which they were born. The transfer follows the pattern indicated in the diagram. Males are transferred in the directions indicated by the arrows, whereas females stay in the group where they were born. The pattern of transfer varies with the generation number. This is a relatively simple mating system, and it can result in considerably less inbreeding than random mating (Nomura and Yonezawa 1996). Of course, the scheme can work with a greater number of mating groups, and the greater the number of groups, the lower the rate of inbreeding.
- Periodic (and preferably frequent) introductions of brood stock from improved stock or from hatcheries with a reputation of having good performance should be undertaken. Crossing with the hatchery's stock will undo any inbreeding and introduce genetic variation. However, the identity of the introduced stock should not be lost, and it should be stocked separately, in readiness for further matings.
- The use of cryopreserved milt can increase the effective population size and save rearing space that would have to be assigned to male brood stock. Milt should be from improved stock or from males from another hatchery with a reputation for good performance. The use of cryopreserved milt would not only reduce the requirements for rearing space for the males, but would also facilitate transport from one place to another.

Example of cohort breeding design for tilapia A detailed protocol of the cohort breeding design developed and implemented with tilapia in a number of countries is shown in Appendix 1.

Figure 2. Cyclic mating scheme to avoid inbreeding.



NON-GENETIC CONSIDERATIONS

This section is largely based on a detailed report prepared by M. Gupta, B. Rodriguez and R. Ponzoni as part of a consultancy to the Central Institute of Freshwater Aquaculture (CIFA) of India. In collaboration with the Norwegian Institute of Aquaculture Research (AKVAFORSK), CIFA had been successful in developing a genetically improved strain of rohu, which they called *Jayanti Rohu*. Testing of the improved strain confirmed the superior growth performance of *Jayanti Rohu* relative to other stocks of rohu being used by farmers across India. CIFA then engaged in the process of designing a multiplication and dissemination program for the genetically improved rohu. The objective of a *Jayanti Rohu* multiplication and dissemination program was to make the genetically improved seed available to farmers as widely and as quickly as possible. Hence, the considerations made and experience gained in that instance are highly relevant in the context of the present paper.

General aspects

In developing a strategy for effective multiplication and distribution of the genetically improved seed, the following aspects need to be addressed:

1. the total demand for seed and the geographical distribution of the demand across the country.
2. the presence or absence of private and government hatcheries in areas where the improved seed are needed.
3. the skill level and resources of such private and government hatcheries.
4. farmers' need for additional training, education and technical support to be able to take full advantage of the improved seed.

Multiplication: Hatcheries using brood stock from a breeding nucleus produce seed for distribution to farmers.

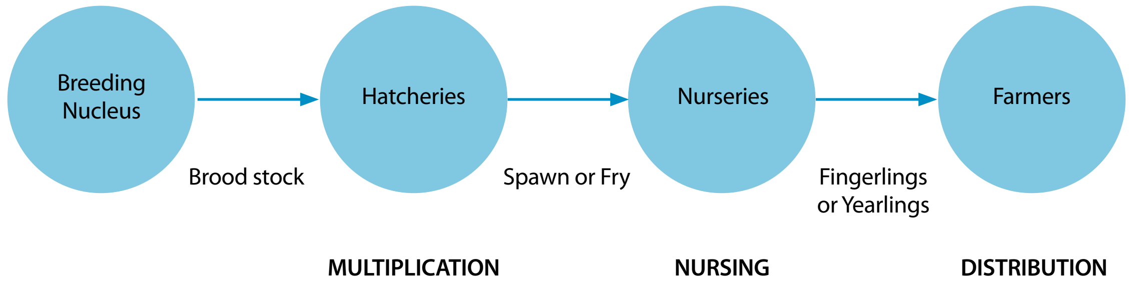
Nursing: Seed from the hatcheries are sometimes reared prior to stocking in grow-out ponds. The rearing may be conducted by the end-user farmers themselves or by nursery operators who, in turn, sell and distribute the reared seed (fry, fingerlings, yearlings) to grow-out farmers.

Distribution: This activity is conducted by the hatchery or the nursery. It includes the marketing, selling and physical delivery processes as well as auxiliary services, if any, which are part of the total market offering.

Basic elements in multiplication and dissemination

Elaborating on the simple structure presented in Figure 1, the basic elements of a multiplication and dissemination program can be described in the following way (see Figure 3):

Figure 3. Basic elements of a multiplication and dissemination program.



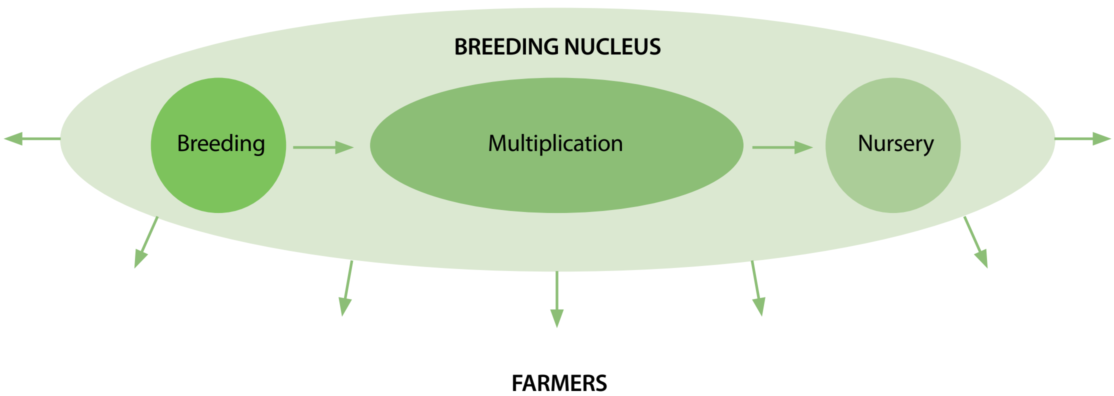
Centralized or decentralized seed production and distribution

The terms 'centralized' and 'decentralized' seed production and distribution are used in at least two different contexts, one in reference to geographical location of the source of seed, and the other in relation to the degree of control exercised over the process of multiplication and distribution.

In some countries, large hatcheries have been established in what was considered a strategic location, with the intention of supplying fry to a large number of farmers. Such arrangements usually fail to effectively deliver seed to remote areas. In contrast, decentralized seed production and distribution is that which takes place close to or within relatively easy reach of farmers. Needless to say, the latter approach is to be pursued if farmers in all corners of a country are to be serviced by improved seed. In this respect, it appears essential to establish - after a careful analysis of the industry and its needs - a plan that specifies the number of hatcheries and their geographic location to effectively service farmers.

The second issue is related to the degree of control over the distributed germplasm (Figure 4). Generally, the greater the number of multiplier units and the wider the geographical distribution of the multipliers, the greater the need to consider the issue of control. Under a fully centralized model, the institution or firm managing the nucleus would deal directly with the farmers and would be in full control of the production and distribution processes. It would exercise full control over these processes by having them undertaken either by internal departments or divisions; by subsidiary departments, divisions or companies under its control; or by other parties under service contracts. Building and maintaining such an infrastructure, however, may require significant resources and investments, and these could be beyond the possibilities of most of the institutions that develop improved strains in developing countries.

Figure 4. Fully centralized model.



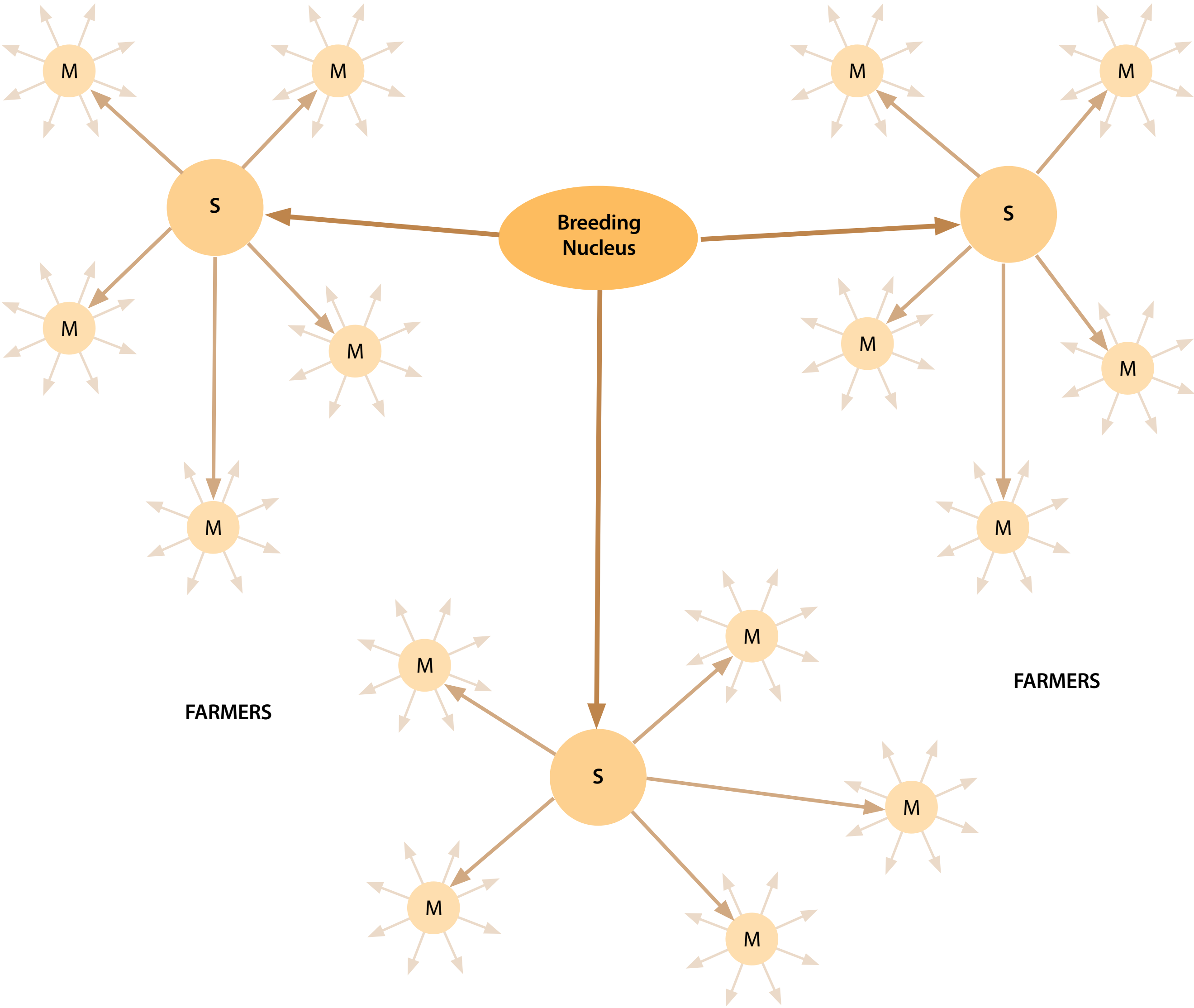
Decentralization, on the other hand, is an option that will be generally easier to implement. It will require a smaller number of resources than those necessary to build up a centralized system for multiplication and dissemination. However, by decentralizing, some of the control over the operations is foregone as a consequence of allowing other parties to be involved in the multiplication and distribution processes. These other parties can be involved as multipliers, nurseries or distributors for specific locations or areas. They will be expected, through their investments, to provide resources and take on a share of the risk.

While decentralization will require the 'owners' of the improved strain to let go of some of their control, the institute managing the nucleus and the genetic improvement program can continue exercising some degree of control over the process:

- through the manner and process used in selecting entities to participate in the multiplication and distribution program.
- through the terms and conditions of the agreements between the nucleus managers and these entities.

These aspects are discussed later in the paper.

Figure 5. Decentralized model (S = further satellite nuclei to extend the reach of the improved strain; M = multiplier units); the arrows from M indicate fry going to farmers.



Private and government multipliers

In order to meet the objective of making seed of an improved strain available as widely and as quickly as possible, both private and government hatcheries should be considered for participation in the multiplication and dissemination program. Some areas or regions may have the right conditions to attract the private sector to make investments in the hatchery business. In other areas or regions, private sector interest in operating hatcheries may be low, and the government may have to operate a hatchery or hatcheries as part of its effort to encourage farmers to engage in aquaculture and to stimulate the growth of the industry.

It would therefore make sense to utilize private hatcheries to serve as multipliers in areas or regions where the existing demand for seed is already high. High demand would be present in areas that are already producing significant volumes of the species in question, that have a critical mass of farmers engaged in aquaculture, and where privately owned hatcheries are already in operation.

Government hatcheries, on the other hand, could serve as multipliers in areas or regions that are not sufficiently served by private hatcheries. Areas that could be said to be insufficiently served include the following:

- areas where the combined capacities of all private sector hatcheries are not enough to meet the needs of farmers there.
- areas where certain segments of farmers remain un-serviced by private hatcheries due to distance, small order quantities, high transaction costs or other reasons.
- areas where the presence of only one or a few private hatcheries may potentially result in abuse of the market due to lack of competition from other hatcheries.

The decision to utilize private or government hatcheries (or both) as multipliers should be made on a region-by-region basis within each country. When government hatcheries are used, their basis for participating in the multiplication and dissemination program should be made clear. The private sector should be encouraged to eventually take over the role of multipliers. Care should be exercised so that government hatcheries are not perceived as being in direct competition with private hatcheries.

Branding

Virtually all seed in developing countries are produced and distributed as a commodity with little or no differentiation being made on the basis of strain, source or origin of the seed. No registered, identifiable strains of fish seed generally exist. The launch of a brand name for an improved strain would most probably capture the attention of farmers, at least as a novelty. The interest generated among farmers by the branded fish seed should provide opportunities to educate farmers about the benefits of selective breeding and the advantages to the farmers of choosing the improved strain over any other fish seed. These efforts should lead a significant number of farmers to try the new strain.

The value of a brand, however, goes beyond its initial novelty. Novelty wears out very quickly, especially if the product does not perform significantly better than its competition. As more and more farmers use the improved strain, the actual experiences and the testimonies and expectations resulting from these experiences will determine the impact and value of the brand.

As more and more farmers perceive the brand to be synonymous with high quality and good performance, the value of the brand will continue to grow. Of course, the efforts made to educate farmers on the features and benefits of the improved strain will also contribute to the positive perception regarding the brand. The branding of genetically improved seed and the subsequent effort to build up and manage the brand(s) are therefore important for the following reasons:

- The brand name will serve to articulate the major attributes of the product and the meaning that the brand is expected to convey to the public.
- The brand introduction will highlight the benefits of selective breeding and genetic improvement.
- Brand promotions will increase the awareness among farmers of the need to better manage genetic stocks.
- Brand success would be expected to attract private sector effort and investments to the business of genetic improvement, multiplication and/or dissemination of fish seed.
- Brand value will positively contribute to efforts (e.g., pricing, licensing arrangements, royalty fees) to establish self-sustaining mechanisms for the breeding operations.

Utilizing all legal means to effectively control the use of a brand may help realize the expected benefits from branding and brand management efforts. Successful brands are often pirated, and fish seed brands are no exception in this respect. As an example, the GIFT Foundation in the Philippines found it necessary to officially register and aggressively defend its sole right to use the 'GIFT Super Tilapia' trademark in order to accomplish the following:

- Protect farmers from breeders and hatcheries who were falsely claiming to also be producing and selling genetically improved tilapia fingerlings.
- Control the use of the GIFT trademark.
- Enhance the superior image of the GIFT trademark in the market, and differentiate it from other brands of genetically improved tilapia.
- Maximize the value of (and hence the income it could generate from) its licensing program with private hatcheries.

Choice of multiplier enterprises (hatcheries)

Once the requirements (in terms of number, location and type) for hatcheries have been established and the degree of control that the institution managing the nucleus intends to exercise over the dissemination program has been decided, the process of choosing such hatcheries can proceed.

Access by hatcheries to the improved breed can take a number of forms:

- **Open access:** No selection process is performed. All hatcheries wishing to purchase breeders are served on a 'first come, first served' basis. No agreements are required between the multiplier and the nucleus management.
- **Accreditation:** Specific criteria for accreditation are established. All applicants meeting the criteria are accredited and provided with breeders on a 'first come, first served' basis. The accredited hatcheries are monitored periodically to ensure that they continue to comply with the criteria for accredited hatcheries. Some accreditation programs have documented agreements.
- **Restricted access:** Specific criteria are established. Meeting the criteria does not automatically make the hatchery a multiplier of the program. Sole discretion to approve hatchery applications rests with the nucleus management team (e.g., the management team can disapprove the application for any reason). A legally binding agreement specifying obligations, roles, commitments and limitations is a standard feature of this option.

If the management of the nucleus decides to be selective in accrediting multipliers, candidates will be screened for the following attributes:

a. **Technical and managerial competence:** Such competence will be needed to operate the hatchery efficiently and effectively, as well as meeting the quality standards established for the improved strain. The hatchery operator and staff should also be prepared to provide farmers with technical support services to ensure that these farmers benefit from the improved seed.
b. **Adequate field facilities:** The production of good-quality fish seed is dependent on access to certain facilities (e.g., ponds, equipment, water supply). The facilities required for production should be defined.
c. **Financial capability:** Multipliers should have the financial capability to build, maintain and repair facilities; make necessary improvements; maintain appropriate levels of working capital; and hire the staff they need to operate the hatchery.

On the basis of the above desired attributes of multipliers, a list of specific criteria that will be used in selecting multipliers for the program should be drawn up by the nucleus management team. A sample list of such criteria is presented in the table below.

1. Technical Competence	• Education (specify minimum degree or equivalent being sought) • Experience (specify kind of technical and managerial experience and minimum length of experience required)
2. Facilities	• Location • Minimum land area required • Existing ponds and facilities and ability to build required ponds and facilities on the property • Adequate supply of water • Availability of electricity • Accessibility by road • Land tenure (e.g., owned, long-term lease)
3. Financial Capability	• Ability to submit financial information • Financial criteria based on submitted financial information • Positive credit reports • Positive feedback from trade references • Minimum level of working capital being made available for the business

The list of criteria against which multipliers will be selected should be communicated widely, and any questions arising about the validity of criteria should be addressed. The above sample list of selection criteria is more applicable to private sector candidates, but criteria for the choice of government hatcheries to serve as multipliers should also be drawn up.

In addition to lists of criteria, it will be necessary for the nucleus' management to establish internal procedures for the recruitment of multipliers of the improved strain. Such procedures will include the development of standard application forms and procedures, as well as standard processes for the verification (farm visits, checklists, trade and credit checks) of the information provided by the applicants.

Structuring the multiplier relationship

As earlier discussed, the management team of the nucleus can establish and maintain control over the multiplication and dissemination program through the terms and conditions of the multiplier agreement. There are different ways of structuring the relationship between the nucleus and its multipliers. The options available may include the following:

1. **Joint Ventures:** Each multiplier could be established as a joint venture between the nucleus and other entities. These entities could, as their share in each joint venture, contribute land, facilities, working capital and other resources. An agreement should be drawn up to define each party's contribution, the valuation of the contributions, the resulting share of ownership in the joint venture, the management responsibilities, the dividend policies, and any other issue deemed relevant.
2. **Licensing:** The nucleus could provide entities with commercial breeders and other know-how in exchange for an upfront fee plus royalties on the sales generated by the licensed hatchery. Licensing agreements can be limited to specific technologies, geographic areas and applications, and may include marketing and distribution responsibilities for the licensee.
3. **Contracted Production:** The nucleus could contract entities (for a fee) to produce fingerlings following specific processes (e.g., exclusive use of breeders) in order to meet specific product standards. Such contracted production assumes, however, that the nucleus or another entity (to be appointed and contracted by the nucleus) will be responsible for marketing and distribution.
4. **Various Combinations of the Above:** The nucleus may decide to configure special combinations of the above options. Combinations should address the specific conditions and needs of the particular aquaculture industry in question, as well as the needs of the breeding program and the private sector partners.

Regardless of how the relationship is structured, it will be very important for a formal multiplier agreement to be drawn up and entered into between the nucleus and its multipliers, private or government.

Multiplier agreements

The agreement is the document that describes the binding rights and obligations between the nucleus and the multipliers. The document should specify the conditions of the relationship between the nucleus and the multipliers. An agreement would include the following key provisions:

1. **Recitals**: The agreement recitals or preamble essentially set the stage for the discussion of the contractual relationship. This component contains the background information on the development and ownership of the genetically improved fish seed that the hatchery is being allowed to multiply and distribute. The preamble will also include language that describes the extent of control that the nucleus wishes to maintain (e.g., obligation of the multiplier to operate the hatchery in strict conformity with the standard operating procedures and quality control standards specified by the nucleus and agreed to by the multiplier).

2. **Grant, term and renewal**: Normally, the first section of the agreement describes the rights granted by the nucleus to the multiplier. For example, the multiplier can be granted the right to produce seed using breeders to be provided by the nucleus and to distribute and sell the seed under the brand name owned by the nucleus.

   This section of the agreement also specifies the length of time (e.g., five years) for which the multiplier will be granted the rights. The term specified by the nucleus may be influenced by a number of factors, such as market conditions, need to periodically review and change material terms of the agreement, expectations related to start-up costs, the timing required to produce new generations, and anticipated farmer demand for the seed.

   In addition to the specified term, the agreement could also indicate renewal rights, if any, granted to the multiplier and the conditions under which renewal of the term will be considered.

3. **Territory**: The agreement could define the geographic area that is being granted by the nucleus to the multiplier as well as the exclusive rights, if any, granted in conjunction with the territory.

If no territories are being specified, the agreement should say so. If the multiplier is allowed to establish a hatchery in a specific location, this must also be specified in the agreement.

4. **Obligations of the nucleus**: Some of the nucleus' obligations to the multiplier are obvious:
   - to continue the selective breeding effort
   - to produce breeders and make them available to the multiplier as needed
   - to provide multipliers with training and continuing technical support in hatchery operations and brood stock management

   Other obligations that the nucleus, depending on the dissemination model it chooses to pursue, may assume are the following:
   - brand development and national marketing activities
   - monitoring the performance of the multipliers and enforcing the provisions of the agreements

5. **Obligations of the multiplier**: The degree of control desired by the nucleus will be reflected in the multiplier obligations that are articulated in the agreement. In most cases, these obligations will reflect the efforts by the nucleus to maintain quality control and product consistency across all multipliers. Multiplier obligations may include the following:
   - Care for the breeders following the guidelines specified by the nucleus.
   - Attend the training courses provided by the nucleus.
   - Adhere to hatchery standard operating procedures established by the nucleus.
   - Deliver the reports (e.g., breeder inventory, seed production and sales) required by the nucleus.
   - Fully comply with the guidelines on the use of the brand and trademark.
   - Conduct local marketing activities.
   - Participate in national marketing activities organized by the nucleus.
   - Do not compete with the nucleus (e.g., no unauthorized brood stock to be maintained in the hatchery or to be marketed by the hatchery).

6. **Fees**: If the nucleus has specified fees to be collected from its multipliers, this section of the agreement will include the following:
   - the types of fees and what are covered by these fees
   - the amounts of the fees or the formulas used in the calculation of these fees
   - acceptable forms of payment
   - payment schedules
   - penalties or interest charges to be collected in case of payment delays

7. **Termination**: The agreement should define the events that would allow either party to terminate the agreement. Since not all events are of the same level of severity, the agreement should differentiate between events that would result in automatic termination and events that may be discussed and remedied by either party. The obligations of the multiplier upon default and notice of termination should also be specified.

Addressing farmers' needs

During the design and implementation of a multiplication and dissemination program, the focus is very often on the improved seed and the mechanisms required to make the improved seed available to farmers. Whereas such a focus is justified, it may cause the nucleus and its multipliers to lose sight of the farmers and their needs. The nucleus should take steps to ensure that farmers are able to obtain the maximum benefit offered by genetically improved seed. This will often require that the farmers are provided with adequate training, education and technical support. Although government extension programs may exist, the nucleus and its multipliers must carefully evaluate the appropriateness of the services provided to the farmers by the government agencies. They should be prepared, in the event that these services are inadequate, to do the following:

1. Work closely with the government extension agencies and personnel to improve the level of services.
2. Build the capacity of government extension services with training, education and technical support services of their own.

Cost recovery

One major decision that the nucleus will have to make is whether or not to try to recover the costs incurred for the breeding and dissemination programs. Such a decision will have an impact on the prices, fees or payments that the nucleus will collect directly or indirectly from the brood stock or the improved seed.
If the industry is at a stage where the government, as a matter of policy or development strategy, wants to encourage farmers to engage in aquaculture, providing farmers with free seed or seed at subsidized rates may have to be considered. By contrast, if the industry has already evolved and farmers in large numbers are doing well, it would be wise for the nucleus to attempt to recover as much of the costs of the breeding and dissemination program as possible by charging farmers appropriate prices for the seed. In addition, levies could be imposed on market fish to contribute to the sustainability of the industry. Developing a pricing policy to recover costs is critical for the long-term sustainability of the breeding program, which requires continuous spending, but this cost recovery may take time because most aquaculture industries in developing countries are still in an immature stage in this respect. Note that although seed, especially genetically improved seed, plays a major role in the profitability of farm operations, seed costs are generally a minor component of total farming costs.

The pricing of seed or brood stock thus plays a very important role in the dissemination program. Practices to be cautious about and maybe avoid include the following:

- Charging farmers less than the prevailing price of fingerlings charged by private hatcheries. This practice not only discourages the private sector from making investments in hatcheries but also removes the opportunity to recover investments made in selective breeding and dissemination.
- Providing private hatcheries with free or minimally priced brood stock. This practice not only limits the ability of the nucleus to recover costs but also provides the private hatchery with a subsidy from which farmers may not benefit.

Management and funding issues

The nucleus management team should recognize that the establishment and operation of a multiplication and dissemination infrastructure will require resources above and beyond resources already allocated to the selective breeding program. The infrastructure required for effective multiplication and dissemination will include the following:

- facilities for the production of commercial brood stock.
- facilities to conduct research in hatchery as well as grow-out production systems.
- multiplication facilities (hatcheries).
- distribution systems (e.g., nursery and rearing/storage facilities, conditioning and packing facilities, delivery)
- systems for the delivery of extension/technical support services.
- marketing organization.
- management infrastructure.

Whereas some of these components can, as earlier discussed, be handled or provided through partnerships and alliances with other parties, the dissemination effort should be recognized as a significant activity separate from selective breeding. As a significant activity, it will require planning, staffing and budgets. It cannot be absorbed by other resources that are already being fully utilized.

If existing resources are insufficient to cope with both the selective breeding and dissemination efforts, the nucleus should seriously consider establishing a self-sustaining program under which revenues generated by the dissemination activities will augment resources currently available. Unfortunately, in many cases, established government policy requires revenues generated by government units to be remitted in full to the national treasury. Under such a policy, no portion of the revenues generated from the seed dissemination activities may be retained and used by the nucleus.

The following are alternative means for the nucleus to address the funding issue:

1. Obtain an increase in the institution's budget to accommodate the multiplication and dissemination program's physical and management infrastructure. Such an increase can be justified on the basis of the impact that the immediate implementation of the program will have on the farmers, the industry and the country as a whole. The revenues that the dissemination program may generate for the government can serve as additional justification for the budget increase.
2. Alternatively, the nucleus may seek exemption from any policy requiring that revenues be remitted in full to the national treasury. The nucleus can seek an exemption that would allow it to retain all or a portion of the revenues generated by the dissemination program. Justification for the exemption would be the same as for alternative 1 above, plus the fact that it would avoid the need to obtain an increase in the institution's operating budget.
3. If alternatives 1 and 2 are not viable or if pursuing them will take an inordinate amount of time and effort, the nucleus should explore the possibility of establishing mechanisms that could allow it to channel funds generated by the dissemination program to cover the operating needs of the program as well as of the selective breeding effort. Possible mechanisms include the establishment of a separate legal entity (e.g., foundation, non-stock non-profit corporation, government corporation) or to organize a formal project for the self-sustaining dissemination of improved seed. These two possible courses of action are discussed in more detail below.

<u>Establishing a Separate Legal Entity</u>

Establishing a Separate Legal Entity Establishing a legally distinct entity, separate from the nucleus, would allow such an entity to have full control over the disposition of the revenues it is able to generate from the dissemination program. It may also allow the entity to do other things (e.g., own trademarks, purchase land, enter into contracts and agreements) that the nucleus as a government institution may not be able to do. There are a number of legal forms that such an entity could take: non-stock non-profit corporation, foundation, government corporation, stock corporation, and others. The issues that have to be addressed in determining the form of the legal entity are, among others, the following:

- membership or ownership (particularly if other parties will be sharing in providing the resources needed by the entity to operate).
- management structure.
- access to facilities or special arrangements needed to have access to such facilities.
- structure of the breeding and dissemination program.
- working relationship with the nucleus.

The separate legal entity would have a wide range of options in terms of the way it structures its operations and its relationships with other parties.

In the beginning, the activities of this separate entity will be very closely related to the activities of the nucleus. However, these activities should be expected to diverge from the activities of the nucleus over time given its ability to make independent management decisions.

<u>Organizing a Project</u>

Rather than establish a separate legal entity, the institution may decide to organize the breeding and dissemination programs into a project. Such a project should have the ability to maintain specific financial accounts (e.g., revenues generated by project activities will be used to fund the project). It would also be to the advantage of the institution if the breeding and dissemination activities also benefit from the implementation of project management systems. The project structure would also allow the participation of collaborators, including private sector entities.

Considerations will, among others, include the following:

- project management (e.g., appointment of a project manager, project planning and evaluation procedures).
- facilities and resources required by the project.
- involvement of private sector entities in the activities of the project.
- obtaining grants for initial funds to be used by the project to get it started.

Since a project will always be under the full control of the institution implementing it, it is likely that the operations of the project will not diverge from the operations of the institution. Options available to the project will be limited, however, due to the fact that it does not have a legal identity outside the identity of the institution.

Decision-making process

In this report we examined and discussed the major strategic issues involved in the design and implementation of a multiplication and dissemination program for an improved strain. The final structure of the dissemination program will be the result of a very large number of decisions and innumerable hours of analysis, study and consultation.

It will be important for the nucleus management team to involve others, especially other government institutions, in the decision-making process. This will allow all parties to articulate and focus on the strategic objectives of the selective breeding and dissemination program. Participation will also lead all parties to share in the ownership of the final plans for the dissemination program.

There are a number of ways (e.g., steering committees, consultative meetings, workshops) in which the nucleus can implement the decision-making process. Conducting a stakeholder workshop can be particularly effective in communicating the goals and objectives of the breeding and dissemination programs as well as in allowing key stakeholder groups to be involved in the consultation and decision-making process.

CONCLUDING REMARKS

In this section we briefly re-emphasize the major points made in the body of the report. In order to capitalize on the effort made in the development of an improved strain, its dissemination to farmers must be effective. To this end, the relative sizes of the population sectors involved in selection, multiplication and production should be examined and made consistent with an effective transfer of genetic gain to the production sector.

The implementation of a policy of continuous replacement of brood stock in the hatcheries, from regular supplies made by the breeding center, should be advocated. This will most likely require a process of accreditation of hatcheries that agree to comply with an established protocol of brood stock replacement and management. The accreditation will ensure the quality of the brood stock used in the hatchery and of the larvae or fingerlings produced. Our perception is that this will often be the preferred option to be considered in the multiplication and dissemination of an improved strain.

The notion of hatcheries engaging in the production of brood stock should be discouraged. Experience shows that this is likely to result in inbreeding and impaired performance and lead to an undermining of the improved strain's reputation. It must be recognized, nevertheless, that the practice of producing their own brood stock is entrenched in the industry. For that reason, guidelines on management to avoid inbreeding and a deterioration of performance were provided in earlier paragraphs.

A lesson to be learned from other (terrestrial) species is that the processes of multiplication and dissemination occur in a more systematic and effective manner when special resources are assigned to the task. It is our perception that at least one person (and preferably two) with background knowledge of animal breeding and of the aquaculture industry in question should be given the responsibility of implementation and of continued supervision of the hatcheries involved. Of course, the person(s) involved should be provided with the necessary operational resources to carry out the task. Relying on existing staff who have numerous other responsibilities will reduce the chances of success. The feedback provided by the person(s) involved to the breeding center on matters related to the genetic improvement program will be an extremely valuable byproduct of the activity.

Finally, the effective dissemination of improved strains should be accompanied by the application of other aquaculture technologies (e.g., providing hatcheries and farmers with technical guidelines on breeding, feeding, veterinary medicine, and other management and culture practices). Sound marketing strategies would also help facilitate the adoption of improved strains by farmers. Strategies for responsible dissemination should also be developed to minimize possible impact of the use of improved strains on natural environments and genetic biodiversity. This is a separate and complex issue that is not dealt with in the present document.

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Appendix 1
Cohort breeding program for GIFT[1]

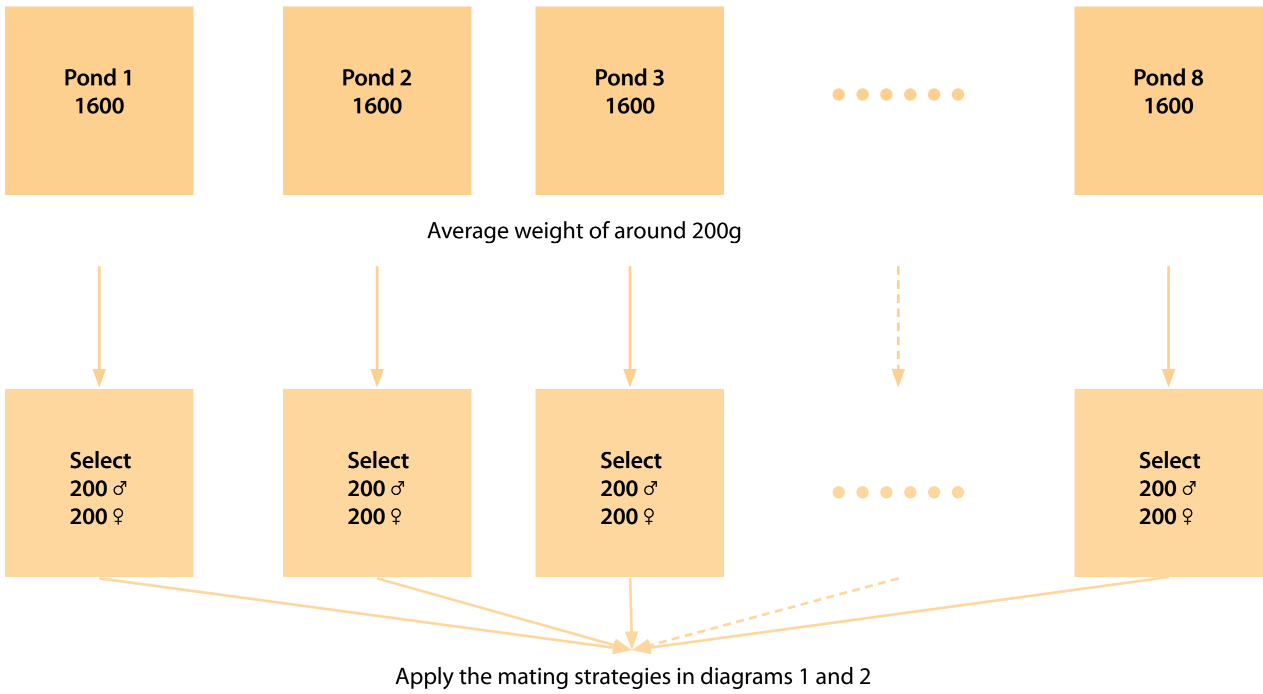
I. The first generation of selection (and every odd generation)

1. Obtain 50 families (20 to 40 individuals per family) from WorldFish.
2. Form 8 groups of unrelated families to stock in each pond (6 × 20 to 40 = 120 to 240 fish per pond or tank). There will be 8 cohorts (or ponds) in total.
3. Grow the fish to sexual maturity (~ 200 to 250 g after 4 or 5 months).
4. Perform rotational mating (Diagram 1). Males from pond-1 will be shifted to mate with females of pond-2, while males from pond-2 will go to pond-3 and so on. Note that females will stay in their respective ponds.
5. Collect 5000 to 10,000 fry per mating pond to rear until fingerlings (5000), and then choose randomly 1600 fish for grow-out in the respective ponds.
6. After producing enough progeny, take out the breeders and put in other ponds or hapas. These parents can be used to produce fingerlings for farmers.

II. The second generation of selection (and every even generation)

1. When the fish reach sexual maturity, selection and mating are conducted.
2. In each pond, select the best 200 males and 200 females in terms of size (or weight) as parents of the second generation.
3. Rotational mating scheme is conducted following Diagram 2. The males from pond-1 will move to mate with females of pond-3, while males from pond-2 will go to pond-4 and so on.
4. After producing enough progeny, take out the breeders and put in other hapas. These parents can be used to produce fingerlings for farmers.
5. The extra brood fish can be stocked in the respective ponds to transfer to other hatchery units (or breeding stations).

III. Layout of the breeding scheme



Note: After selection, the balance of 1200 fish (1600 minus 400) of each pond will go to other hatcheries or locations to produce fry for farmers.

[1] Number of cohorts, number of fish per cohort, and number of breeders selected per cohort can be adjusted to fit physical facilities and practical conditions of hatcheries.

IV. Mating scheme

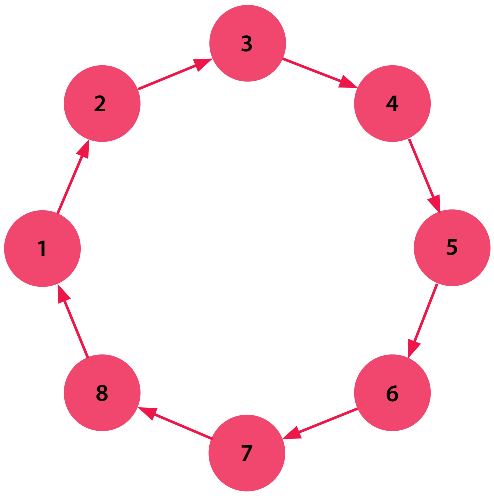


Diagram 1: Rotation of males for generations 1, 3, 5 and so on

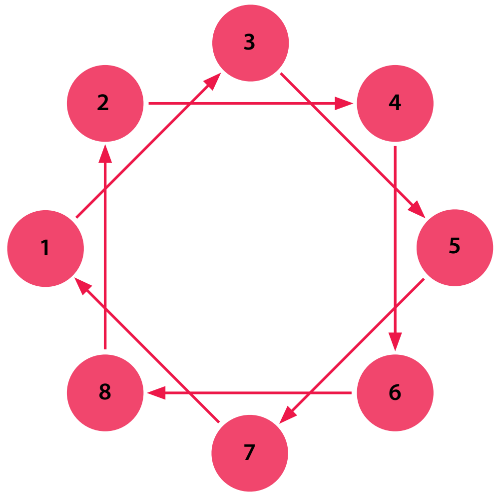


Diagram 2: Rotation of males for generations 2, 4, 6 and so on

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