DEVELOPMENT OF INDIGENOUS SPECIES

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1. DEVELOPMENT OF INDIGENOUS SPECIES

When we endeavour to bring a species into culture we are taking the first steps on the road to domestication. Domestication can be defined as the condition wherein the breeding care and feeding of an animal are more or less controlled by man. When we look at aquatic organisms it can be seen that very few of the enormous number cultured world wide would fall into this class. This is because of the relatively recent emergence of aquaculture world wide. There are only a few 'established' domesticated species and these include the European and Chinese carps (*Cyprinus carpio*), the ornamental carps (*Carassius auratus*), and the Rainbow trout (*Salmo gairdneri*). These fish have now been cultured for long enough for different strains to have arisen. The majority of the other species in culture can still be regarded as being essentially 'wild' in their genetic makeup. This has the disadvantage in that the characteristics of these species are not truly understood, but hopefully they still contain the enormous amount of genetic variation or potential for improvement exhibited in natural populations. Domesticated land animals have undergone centuries of genetic improvement either applied consciously or subsconsciously and in some cases developed over hundreds of years into forms hardly recognisable from their natural progenitors. Today with the improved understanding of the underlying genetic mechanisms it should be possible to accelerate the general improvement and by simple manipulations obtain rapid improvements in particular areas. Genetic improvement cannot proceed on its own; it must go hand in hand with improvements in husbandry practice. The further genetically developed strains depart from the natural forms, the more closely the artificial culture environment needs to be controlled so that natural selection does not operate against the proposed improvement. This is because genetic improvement often strips away the natural defence mechanisms which allow a species to survive in the wild, thereby allowing more energy to be concentrated in improved traits.

2. BIOLOGICAL DESCRIPTION

When an organism is found to have potential for aquaculture one of the first objectives should be a total biological survey of the species, and should try to cover the organism's complete life cycle. Much information will probably be available in the statistical records of the fishery and from local knowledge of the fishes' population structure. Important information such as the organism's environmental tolerances and optimal habitat can be gained from the fishes' natural habitat preferences. Analysis of commercial catches can give evidence of food preferences (gut contents) throughout the year and examination of gonads can also determine the age of maturity of the different sexes and appropriate time of natural spawning. Spawning behaviours and information on the type of eggs and mode of development of the young organisms is essential for successful development of artificial spawning.

In many cases with some more established culture species, much of the organism's biology has remained unknown and geneticists are having to go back to wild populations to study many of the above factors before genetic improvements can be undertaken.

Once a biological profile has been obtained it should be much easier to establish a suitable culture regime from the outset. The initial introduction into culture is often made using wild caught fingerlings, juveniles or adults. It will be the job of aquaculturists to optimise culture conditions. This will require some form of experimental design which will allow the use of different stocking densities, feeding regimes, or other parameters which may affect the organism's production. Often a good measure of the success of a husbandry practice is a direct comparison with the natural observed growth rate.

Spawning of the new species is usually the first major difficulty encountered in the development of a new species. Many tropical and marine species have not progressed past the wild capture stage because of this very problem. Spawning in many fish often requires a number of triggers to initiate maturation and eventual ovulation. These are often not present in the new culture environment. Known triggers include day length, increased/decreased temperatures, salinity, changes in water level, turbidity and floating debris. It may be possible to devise methods for reproducing one of these or the correct sequence of a number of these in hatchery practices. Often gonad maturation can be obtained but the final ovulation is not possible because of the lack of the required stimuli (flowing water, mating behaviour). This can often be overcome by inducing spawning with injections of pituitaries from mature fish species such as carp.

After successful spawning, larval survival often becomes the major constraint. In general the smaller the egg the more difficult it is to successfully rear the organism, because of the requirements for the correct sized food organism. The techniques involved in rearing fry from many marine species usually require expensive hatchery and live food rearing facilities. However, as the number of successfully reared species increases so the technology will become more available. A major breakthrough is likely to involve the use of suitable artificial diets in a micro encapsulated or micro bound state which can be made to suit the particular nutritional requirements of each species and so greatly reduce the expense and complexity of existing fry rearing hatcheries.

Serious genetic improvement cannot really occur until the organism has been successfully reared completely through its full life cycle and routine husbandry practices developed. At this stage it should be possible for the aquaculturist to state the problems exhibited by the species and give explicit objectives for improvements in the culture performance under existing conditions.

Two quite different approaches may be made towards genetic improvement. First is the conventional approach of selection, in which traits are progressively altered through the generations. The second is more direct, and involves the use of manipulation which often immediately generates the desired response. It is because the latter category offers an immediate improvement at the lowest cost in terms of effort that I will deal with these first. They include strain evaluation, hybridization, cross breeding, sex control, polyploid production, special breeding and genetic engineering.

3. STRAIN EVALUATION

As I have already mentioned, very few fish species have been cultured for long enough for individual strains to be recognised. The exceptions are the rainbow trout and carp. When different strains of either of these species are compared under standardised conditions often quite clear differences in performance are observed. In this case the strain with the characteristics closest to your local requirements can be chosen. Natural populations of many organisms are often split into many sub-populations inside the species range. When the different characteristics of individuals from these populations are compared under the same conditions, large differences in performances and other commercially important attributes can often be observed. This type of comparative performance study will allow the choice of strains with much higher threshold values for a given trait. It may take many years of genetic selection on a randomly chosen strain to reach the threshold value of an existing natural population.

4. INTERSPECIFIC HYBRIDIZATION

Fish and many other aquatic animals hybridize readily and large numbers of different hybrids have been reported. There have been many attempts to produce superior fish for aquaculture and in many cases these have been a failure. In general, interspecific hybrids are intermediate in performance between the parental species. However, the recombination of important traits from the 2 parents into a single individual often gives the hybrid a commercial advantage over either parent in the culture situation. Examples of such successes are: The hybrid between the Beluga (great Russian sturgeon) *Huso huso* and the diminutive starlet (*Acipenser stellatus.*) The hybrid is intermediate in growth, but can tolerate a freshwater environment and so avoid esturinal pollution; a major problem for the andromonous Beluga.

The hybrid between *O. niloticus* × *O. aureus* not only gives a skewed sex ratio (80% male) but gives a fish which is intermediate in growth but has increased cold and saline tolerance, important for the marginal culture conditions in Israel.

5. CROSS BREEDING

This is different to hybridisation in that it involves breeding from unrelated animals or plants from the same species. It is normally practised on inbred lines; 2 inbred lines being crossed to produce an F1 hybrid, individuals of which are usually highly uniform because they inherit uniform genes from each parent. The F1 hybrid also shows improved performance over its parents. In fish, the crosses between domesticated strains or geographic races have almost always shown the crossbreed to be intermediate in performance to the parents.

At present no deliberate inbreeding has been attempted on fish species to produce uniform inbred lines. However, unintentional inbreeding caused by low numbers of broodstock and poor hatchery management is the main threat to many existing hatchery populations. The rate of inbreeding (close relatives mating) often causes loss of viability and performance greater than the rate at which genetic improvement can improve a stock. Inbreeding can cause increased mortality, increased food conversion ratios, increased deformities, decrease in disease resistance and reduced fecundity, all of which can seriously degrade the commercial status of hatchery populations.

6. SEX CONTROL

Sex control is often the most successful way of improving the performance of many cultured species, because both sexes are not always equally useful, or because of problems with excessive reproduction.

In tilapia the male is the fastest growing sex and monosex populations also overcome the major problem of overpopulation of ponds by reproduction. In many species the female is the preferred sex, particularly in salmonids.

Fish show nearly every possible sex determination mechanism known from environmentally determined sex through hermaphrodism multigenetic systems, to sex chromosomes. It is still not known which genes are involved in sex-determination, but it is often possible to manipulate the sex of the fish by the administration of hormones at the appropriate time during development. This technique may be used directly to produce monosex populations directly as in 'tilapia' or to produce monosex lines by breeding sex reversed individuals.

7. POLYPLOIDY

Polyploids are organisms with more than the usual set of chromosomes. Triploids have 3 sets and tetraploids 4, (higher levels are rarely encountered in animals). The method of producing such polyploids involves interfering with the normal maturation of the female chromosome set of the egg. Triploids are formed by the suppression of the second meiotic division in females and tetrapolids by the first meiotic division of the fertilised egg. (see diagram).

The use of polyploids was first proposed for the possible farming of marine flatfish, since in such fish the development of gonads can be a serious waste of energy in a culture regime. The onset of maturation in many fish is also accompanied by a decrease in growth rate and often serious loss of condition. The theory behind the production of triploid fish is that they are theoretically sterile. In general the females are usually, however males still produce testes but the sperm are usually inviable. Triploids have been produced in a number of different species and the use of all female triploid rainbow trout has revolutionised the rainbow trout industry in the U.K.

The technique for inducing tetraploidy is similar to that for triploidy (see diagram). In theory, tetraploids can be produced by timing the shock to coincide with the first mitotic division of the egg. So far, results of experiments have been inconclusive. Theoretically if tetraploids could be produced and grown to maturity they would be of great importance in the production of triploids by crossing tetraploids with normal diploid individuals.

8. SPECIAL BREEDING (Gynogenesis)

Gynogenesis is the activation of an egg by a genetically inert spermatozoan and the resultant haploid constitution can be made diploid by the

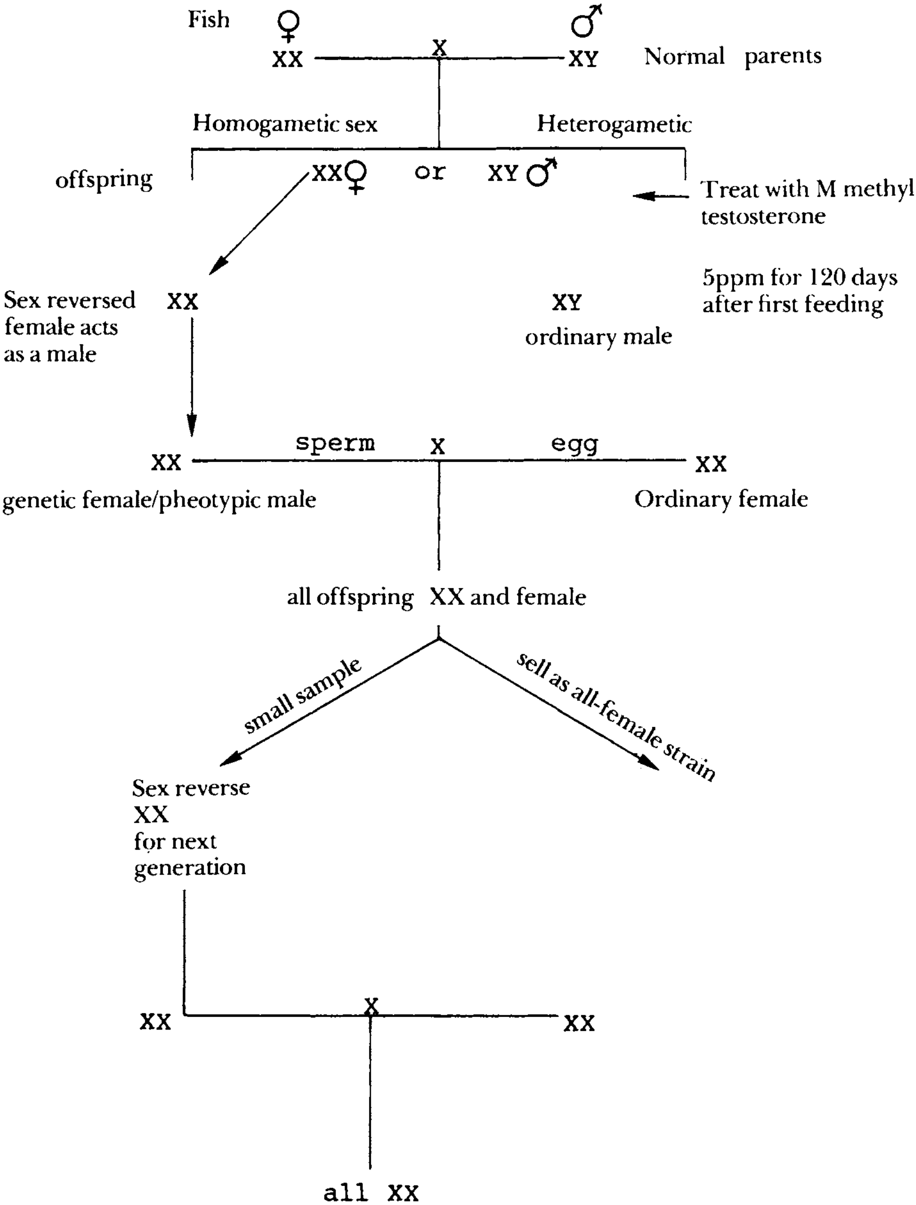

Diagram of the procedure for the production of all-female lines of rainbow trout.

application of shock treatment as in induced polyploidy. The advantage of this technique is that it is a rapid method of producing isogenic lines, one generation of gynogenesis being equivalent to 8 or more generations of full sib mating. This technique gives geneticists a rapid means of fixing strains with particular culture characteristics, and has important implications for studying the genetic mechanisms underlying traits such as sex determination in fishes.

9. GENETIC ENGINEERING

This is a new and potentially important area for the genetic improvement of aquatic organisms. The essence of the technique is the identification of individual genes controlling some important trait. These genes can be isolated from one organism and can be inserted into another, thereby conferring the ability to produce the new material. Several genes have been isolated and have been successfully transferred to bacteria for the production of materials such as insulin. Genes have been transferred into higher organisms such as mice but the problems is to get the genes to operate in a regulated fashion within the cell.

10. SELECTION

This is the classical view of what genetic improvement entails. The evidence is that possibly every characteristic of fish can be modified by selection, but the question is how much effort will be required and what will be the possible benefits? Genetic selection requires that there is a clear objective, usually growth rate. Growth rate has long been an obsession with fish farmers. Despite this interest, little real progress has been made in selection programmes. Growth in fishes is very plastic and the level of additive genetic variation is often quite low.

Reports given in the literature show improvements of between 0 - 33% per generation but on average 3-5% improvement/generation. It can be seen that with such a low response, particularly in long generation time, organism improvement is likely to be a long term aim. It is also important to run control experiments to determine the magnitude of improvement over and above an unselected population as this should help to separate out improvements caused by husbandry effects.

The majority of the techniques outlined in this paper are dealt with in a variety of published papers and books. Useful reference sources are:-

REFERENCES

Kirpichnikov, V.S. 1981. Genetic bases of fish selection. Springer-Verlag, New York, U.S.A. 410p

Wilkins, N.P. and E.M. Gosling (Eds.). 1983. Genetics in Aquaculture. Proceedings of an International Symposium held in University College, Galway. Elsevier Science Publishers BV.

Fishelshin, L. (ed.). 1983. Proceedings of the international symposium on tilapia in aquaculture. May 8-13. Israel.