Fishery genetics: An emerging discipline

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Fishery genetics has grown rapidly in the last one and a half decades accumulating so much of knowledge and information of applied interest that it can be assigned the status of a discipline.

GENETICS has now acquired an important status in fishery science. There is growing interest on the subject as revealed by multifold increase in the number of research papers on cytogenetics, molecular, quantitative and biochemical genetics[1], suggesting the utility of applications of genetic principles and methods for improving the fish breeding programme, for documenting genetic diversity in natural populations[2] and developing proper management programmes to conserve genetic diversity[3]. In the present article the developments, scope and importance of the subject are discussed.

Fishery genetics – a definition

It is tempting to provide a comprehensive definition to this growing discipline. Since the subject concerns the applied aspects of fish culture and natural fishery, it appears more appropriate calling the subject 'fishery genetics' rather than 'fish genetics'.

Fishery genetics may be defined as the application of genetic principles and methods for increasing aquaculture productivity by genetically modifying fish stocks and for the management of fish populations to obtain maximum sustainable yield without affecting the genetic diversity.

Factors leading to the growth of the subject

The interest in fishery genetics grew primarily for two reasons. It was gradually realized that the anthropogenic factors such as over-exploitation of natural fishery from open waters, modification of aquatic environment by pollution load, development programmes like damming of rivers, etc. have led to a decline of wild populations and these have genetic and evolutionary consequences[4]. Also, the necessity was felt for improving aquaculture productivity by genetic improvement of fish stocks primarily to meet the increasing demand on fish proteins. The implications of each of these factors are discussed below briefly.

Over-exploitation and habitat modification

Effect on production trait

Evidence shows that traits such as growth rate and age of maturity of brood fish and feed conversion efficiency are heritable and cultured populations of fish respond to selection for these characters[5]. It is now recognized that harvesting can exert an evolutionary selection pressure that may bring about genetical changes[6]. For example, most fishing gear selects a certain size of fish. Big hooks cannot catch small fish and wide meshes allow small individuals to wriggle through. There is a considerable variation in growth rates in fish of the same age group. Thus, it is expected that the fishing gear selects out fast growers in an age class. If growth rate is partly determined by the genetic factors, it is likely that prolonged inadvertent selection against fast growth will lead to selection of slow growers. Experiments with tilapia (*Oreochromis mossambica*) showed that harvesting has a negative selection pressure[7]. The other traits which harvesting can affect are the ability to escape net, body proportions, number of eggs per unit weight, etc.

Effective population size

Excessive mortality due to over-harvest or habitat modification and impairment of reproductive ability because of pollution load[8] reduces the effective population size. Effective population size means the number of reproductively active individuals in a population. If the population size gets small, it results in inbreeding and genetic drift.

Effects of stock introduction and unwanted hybridization

The term 'introduction', in this context, means transfer of fish by man into waters outside of their native ranges. In other words, any intentional or accidental release of fish by human activity into the natural waters is considered introduction[9]. Introduction has ecological and genetic effects. The ecological effects of introduction include processes or mechanisms such as competition, predation and habitat alteration. The genetic effects of introduction leads to alteration of gene pools of indigenous species. The alteration may be direct as in the case of introgression (gene flow) or indirect such as reduction of effective population size, making natural population vulnerable to the effects of genetic drift. Intra-specific or inter-stock crossing leads to reduction of

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genetic variability between the populations (a homogenization effect)[10]. Therefore, there has been a growing interest in identifying F1 and F2 hybrid in nature and distinguishing them and also to document genetic introgression due to back-crossing of the F1 hybrid with parental species. Therefore, a number of research papers appeared, which dealt with introgressive hybridization primarily using isozymes as the tool[11] supplemented by mitochondrial DNA analysis. A few researchers used nuclear DNA RFLP[12].

Aquaculture

Genetic studies in aquaculture have witnessed two different approaches; firstly, to reveal the genetic impacts of using small and closed populations in commercial hatchery; secondly, to improve the genetic potential of fish stock by selective breeding, chromosomal engineering, gene manipulation, sex and fertility control. The first aspect primarily aims at reducing/avoiding the improper breeding practices, while the second aspect is to develop superior strains of fish.

In the early eighties, many research papers appeared which recorded low quality of fish seed produced due to improper breeding practices[13]. Around the same time the feasibility of quick methods, such as chromosome[14] and gene[15] manipulation to improve the genetic performance of fish came to limelight. Chromosome manipulation (by thermal, pressure and chemical shock) in fish was an interesting development. Because, unlike other vertebrates, fishes can tolerate change in ploidy level, and thus bypass long-term selective breeding programme, while trying to obtain superior variety.

Scope of applied genetic research in fishery science

At present there lies ample scope for applied genetic research in fishery science. Major areas needing proper research input for the conservation and productivity improvement of this renewable resource are as follows:

Stock identification

Identification and documentation of intra-specific genetic polymorphism occurring in different populations occupying different ecological zones within a species is of enormous practical significance. A number of research papers on this aspect are already available primarily from USA and other developed countries. However, this is a very virgin field in India and many other developing nations, where most of the fish biodiversity exist. This study is useful in selective breeding programme in hatchery, devising policy on the rehabilitation and conservation of a declining stock, biodiversity documentation, study of phylogeography and systematics and proper utilization of cryopreserved gametes[16].

Stock/species introduction

Introduction is an useful approach to augment fish production by supplementing natural recruitment. However, introduction of exotic species/non-native stock for this purpose has been a matter of genetic concern. Many papers published recently pointed out that inter-stock crossing could lead to stock admixture and reduction of genetic biodiversity[17,18], which in turn would affect the future breeding programme.

Dowling *et al.*[19] pointed out that introgressive hybridization was an evolutionary factor which could bring about genetic variability. On the contrary, many researchers viewed that introgression would cause genetic contamination[2] and decline of populations by bringing about the rearrangement in co-adapted gene complexes[20].

However, many relevant questions still remain; i) How much gene flow between or within the species is permissible? ii) Is the reduced population size after genetic interaction of inter-specific hybrid due to rearrangement of co-adapted genes or due to reduced fecundity (that is partial sterility) of the later generation hybrids? iii) How much threat does 'introduction' – as a factor, pose to the intra- and inter-specific genetic diversity? Further studies on measuring of gene flow among the populations and between the species would be of great importance.

Stock improvement

The remarkable developments in aquaculture are primarily due to availability of fish seed by artificial breeding and improved management practices such as supplementary feeding, use of clean water, eradication of pests and weeds, etc. Now that the technology of production and rearing has largely been mastered for many species of culturable fishes, it is reasonable to look for genetic techniques to increase aquaculture productivity. Genetic modification of the organism to increase the growth rate has been the primary goal of stock improvement programme to improve the aquaculture productivity. Enormous research efforts have already been put into this. The technical approaches have been selective breeding and hybridization, chromosome and gene manipulation, fertility and sex control. The practical benefit of genetic improvement programmes have already been manifested in Norweigian salmon industry, where accumulated selective breeding for 15 years showed improved productivity. Some scientists have applied integrated approach (use of more than one technique) to develop better strains. For example, joint application of endocrine and cytogenetic approach to obtain monosex fish[21] and production of tetraploid fish by chromosome manipulation and hybridizing it with the related diploid species to obtain triploid individuals with better characteristics.

In spite of methodological developments and so much of experience that is being recorded in the literature, quite a lot is yet to be done to fulfil the genetic goal set by the aquaculture industry for developing superior strains of fishes.

Monitoring genetic change

Breeding of a small-sized population, in nature or in hatchery, leads to loss of intra-populational variability because of selection (intentional or unintenational), genetic drift and inbreeding. Reduction of genetic variability can be monitored in terms of reductions of heterozygosity by analysing the frequency of polymorphic loci or average number of alleles per locus. This would be useful in maintaining effective population size.

Indian scenario in fishery genetics research and education

In India, some research efforts were made on chromosome engineering[22], transgenic fish production[23], sex control by endocrine and cytogenetic manipulation[21,24], cryopreservation of gametes[25], genetic stock identification[26] and hybrid identification[27]. However, a lot more research efforts on fishery genetics are needed to generate knowledge, process and products of applied interest in aquaculture and capture fishery management.

Fishery genetics has not found its proper place in fishery education in the country. Fishery is taught as a special paper in M Sc Zoology courses in several Universities and there are about a dozen fishery colleges affiliated to agricultural/veterinary universities, offering courses on B FSc and M FSc. A preliminary survey revealed that fishery genetics is either not included in the syllabus or if some preliminary topics are included, they are not dealt with seriously. Although Indian Council of Agricultural Research has set up the National Bureau of Fish Genetic Resources in Lucknow more than a decade ago, there is a general apathy towards fishery genetics among the academicians and policy makers associated with fishery education and research.

Concluding remarks

Annual world landings of aquatic resources have increased more than four-fold; from 21.9 million tonnes per year between 1952 and 99.5 million tonnes in 1989 (ref. 28). The larger share of this production came from the capture fishery sector, which has been over-exploited, leading to decline of fish biodiversity. An analysis revealed that 20% (1800 species) of the world's freshwater species are severely threated[28]. On the other hand, aquaculture provides greater scope for increasing fish production and productivity. Thus, fishery genetics as a growing discipline will have an important role to play in future for conservation and management of natural fishery and increasing the aquaculture productivity.

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