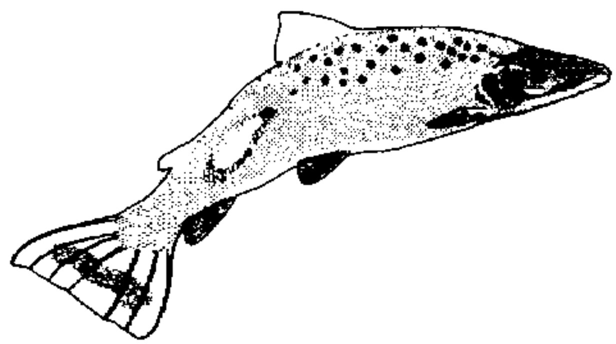
Part I:
Introduction



Introduction

Successful commercial fish farming depends on the operator's understanding of genetics and selective breeding principles. Selective breeding of fish stocks can improve growth rates and disease resistance, and prevent inbreeding or other negative genetic consequences. Stock enhancement programs can use these principles to manage resources and maintain genetic variation, while conservation programs can use the principles to evaluate and maintain genetic diversity of wild stocks.

Three aspects of selective breeding of fishes are reviewed in this volume: selective breeding to improve fish performance for aquaculture, genetic resource management for stock enhancement and conservation of natural genetic resources. The important themes that emerged during the workshop and the terminology and topics discussed throughout the proceedings are explained below.

Important Themes

Selective Breeding Improves Production Efficiency

The potential for commercial fish farmers to improve production efficiency with selective breeding is significant and may be greater in fish than in terrestrial farm animals. Using a combination of mass selection and family selection, Hershberger et al. (1990) averaged a 10.1% increase in coho salmon body weight per generation and Gjedrem (this volume) reports that genetic gains of 10-23% have been achieved in fish.

The development of successful breeding programs for aquacultured species requires commitment to a long-range permanent improvement program, industry acceptance and direct industry experience with the improved stocks. Implementation of new selection programs requires government support during the early years, followed by on-site demonstration projects under conditions familiar to farmers.

Genetic Conservation and Enhancement of Natural Stocks

Stock enhancement has been effective in some locations at augmenting existing fish populations and restoring fish populations in environments where they previously existed. Enhancement programs must consider gene conservation. Enhancement will affect the genetics of wild stocks when gene flow occurs between cultured and wild stocks.

Monitoring is essential for long-term success of stock enhancement. A stock enhancement program should include an initial inventory of the natural population's genetic resources and periodic characterization to evaluate any changes in gene frequencies following hatchery releases.

Need for Conservation of Genetic Resources

The importance of natural genetic diversity for future aquaculture production, enhancement efforts and conservation is recognized worldwide. Declines in natural fish populations, of cultured and natural species, have been documented in many countries. Overfishing and environmental degradation have been principally responsible for the declining abundances. Direct evidence of negative genetic effects of cultured fishes on natural populations is lacking; however, decisions are being made by individual countries about conserving genetic diversity of natural stocks. Which species to conserve, how to store genetic material and costs of conservation must all be considered.

Potential Breeding Benefits and Risks

There are both benefits and risks posed by developments in biotechnology. Potential benefits include the production of sterile fish for farming and commercial fisheries, and the ability to preserve reproductive cells for future use. Potential risks include negative ecological and genetic interactions between natural and genetically engineered stocks. Transgenic fish could potentially breed with wild fish and transfer transgenes into wild populations. Various countries and international organizations are presently developing guidelines on the use of genetically modified fish in aquaculture systems (Hallerman, this volume).

The genetic risk posed by stock enhancement on natural stocks varies depending on the protocols used for broodstock collection and hatchery production. Two approaches have been used to enhance fish stocks around the world: relocation of broodstock from one region to another, and collection of local broodstock to produce juveniles for release within the same region. Movement of broodstock between regions has a greater potential to affect the genetic variation of the local population than collection and production of local stocks. Use of local broodstock for production of juveniles is needed to prevent loss of adaptive genes.

Terminology

Breeding for Aquaculture Production

Few genetically improved stocks have been developed for commercial finfish aquaculture, although several methods are available to domesticate those stocks. They include mass selection, family selection, crossbreeding and new or biotechnology-based techniques.

Mass selection or individual selection is considered to be the simplest, oldest and most effective method of genetic improvement for some species. It consists of selecting individuals according to their phenotype or individual performance. Each individual, regardless of family, is compared to all others, and the best performers are selected to produce the next generation. To determine the effectiveness of mass selection, two generations (parents and their offspring) must be grown to maturity. Mass selection is not efficient for traits with low heritability. For fish, it is therefore best applied to growth rate and to some extent to selection for age and sexual maturity (Gjedrem 1985).

Family selection is based on the performance of families rather than individuals. Specific pairs of brood fish are mated and the offspring are reared separately in individual family groups (Tucker and Robinson 1990). More extensive facilities are required for family selection than for mass selection, because a relatively large number of families are raised and tested to achieve a reasonable selection intensity and reduce inbreeding (Wohlfarth and Hulata 1989). Family selection is preferred when the selected character is difficult to measure on individual fish, cannot be measured without sacrificing the fish, or has additive genetic variance with low heritability. Family selection is an efficient selection technique for the following traits: survival, age at maturation and feed conversion efficiency (Gjedrem 1985).

Cross-breeding or hybridization is a process where new combinations of alleles are created in the offspring by mating fish with different genetic backgrounds. Parents can be from different strains within the same species (intraspecific hybridization) or from different species (interspecific hybridization) (Tucker and Robinson 1990).

Often, **inbreeding** occurs in an attempt to genetically improve a fish population. Inbreeding within a large population is defined as the mating of individuals that are more closely related to each other than to randomly-mated individuals. Although inbreeding reduces genetic variation and productivity, inbreeding is sometimes used to create inbred lines that breed true for a specific character (Tave 1993). Inbreeding depression results when there is a reduction in the expected performance of the affected trait.

A number of new biotechnologies have been developed to genetically improve fish stocks, including polyploidy, gynogenesis and transgenics. **Polyploids** are individuals with more than the normal (2N) number of chromosome sets, which were induced in the fish by temperature or pressure shocks to eggs soon after fertilization. It is relatively easy to change the chromosome number in fish because fertilization is external for most fish species. Triploids (3N) are created to increase growth and produce sterile fish. Tetraploids (4N) are created to cross with diploid fish and produce triploid offspring. This eliminates the need to produce triploid fish manually (Tave 1993).

Gynogenesis is a genetic engineering procedure that pairs both sets of chromosomes from a single female parent and results in the production of all female fish. Because female fish tend to be larger than males, producing all female offspring results in production of larger fish for market.

Genetic engineering has also been used to transfer genes from one animal into another. If successful, the gene is expressed in the parental fish and transmitted to the offspring. The fish are then referred to as transgenic or genetically modified fish. Genes can be transferred between different species or different types of organisms. Genetic engineering has the potential to improve growth rates or increase disease resistance in fish.

Enhancement of Natural Stocks

Stock enhancement is the release or stocking of hatchery-reared juvenile organisms into the natural environment to supplement the existing population and thereby, expand opportunities for harvesting, rebuilding declining populations or establishing new populations (National Research Council 1992). The need for stock enhancement has principally been attributed to two factors, habitat degradation and overfishing.

Marine stock enhancement was first practiced in the United States in the late 1800s, when thousands of unmarked eggs and newly hatched larvae of several species of commercially important marine fish were released to supplement natural stocks (National Research Council 1992). Early enhancement efforts ignored the genetic effects of escape or release of hatchery-reared fish on wild populations (Pullin 1992).

More recently it has been recognized that unintentional selection can change the gene pool of natural breeding populations and potentially affect their survival and reproduction. The **gene pool** is defined as the sum total of all the genetic information within a population of interbreeding or reproducing individuals (Oldfield 1989). Thus, for enhancing natural stocks, the hatchery manager's goal is to **avoid selection** in the hatchery.

Today many enhancement programs have taken a new approach that incorporates genetic resource management together with a monitoring and evaluation program (Discussion Group Summaries and Shaklee et al., this volume). Marking systems (i.e., coded wire tags, genetic markers) are used to evaluate the impact of enhancement efforts.

Conserving Genetic Resources in a Natural Environment

Conservation is defined as the wise use of natural resources (Oldfield 1989). Conservation does not imply that every species or every form of genetic resource must be preserved in perpetuity, but that genetic resources need to be carefully managed against exploitation or habitat destruction. **Genetic resources** are the economic or societal value of the genetic materials contained within or among species (Oldfield 1989). Ecologists and evolutionary biologists generally agree that species diversity and genetic variability are necessary for the long-term maintenance of stable populations, species and complex ecosystems (Smith and Chesser 1981).

Preservation and conservation of genetic resources differ. **Preservation** is a short-term static process that involves removing a species or their reproductive parts for management or preservation to a storage facility (i.e., gene bank). Alternatively, conservation is a long-term dynamic process involving management of genetic resources under natural conditions, allowing evolution to continue (Frankel 1970, Oldfield 1989, Gall, this volume).

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