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International Council for
the Exploration of the Sea

C.M. 1980/F:21
Mariculture Committee

REPORT OF STUDY GROUP ON GENETICS

ABSTRACT

A Study Group on Genetics was established by C.Res. 1979/5:5 to propose guidelines on genetic studies in aquaculture and fisheries management. A meeting was arranged at Svanøy, Norway, June 10-13, 1980, with participants from Canada, France, Norway, Sweden and USA.
The impact of genetics on aquaculture and fisheries management was discussed based on written and verbal contributions. Recommendations reflecting the assumed impact of genetics in the mentioned fields are presented in the present report. To continue the work, establishment of an ICES Working Group on Genetics is recommended.

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INTRODUCTION

A Study Group on Genetics was established by C.Res. 1979/5:5. The purpose of the group was to propose guidelines on the following areas:

1. Genetic variability among populations.
2. Directed and experimental breeding.
3. Loss of genetic diversity.

A meeting was arranged June 10-13, 1980, at Svanøy, Norway, with the following participants:

Mr. L. Anderson, Sweden
Dr. B. Chevassus, France
Mr. K. Jørstad, Norway
Dr. H. Kincaid, USA
Dr. A.C. Longwell, USA, rapporteur
Dr. G. Newkirk, Canada
Dr. G. Nævdal, Norway, chairman
Dr. R.L. Saunders, Canada
Dr. G. Ståhl, Sweden

Dr. T. Refstie, Norway, and Prof. N.P. Wilkins, Ireland, gave written contributions to the meeting, but were not able to attend. Dr. C. Purdom, UK, Dr. W. Hershberger, USA and Dr. R. Chessner, USA, were invited but unable to attend.

The following written contributions were given:

Chevassus, B. (joint with J.M. Blanc, R. Goyomard and D. Chourrot) Genetic research applied to aquaculture in France.
Kincaid, H.L. Working Paper for ICES Study Group on Genetics.
Newkirk, G. Views on approaches to the selective breeding of oysters. A discussion paper for the ICES Genetic Study Group.
Refstie, T. Directed and experimental breeding.
Wilkins, N.P. Genetic variability in natural populations of aquatic organisms: Some comments and proposals for cooperative research.

Verbal contributions were given by Dr. Longwell (Review on genetic studies on invertebrates in USA), Dr. Nævdal (Introduction), Dr. Saunders (Genetics in sea ranching) and Dr. Ståhl (Studies on biochemical genetics of salmonids in Sweden).

The discussion was based on the written and verbal contributions. Two main areas of interest in genetics exist within fisheries biology: Genetics in aquaculture (selective breeding, hybridization, in-breeding) and genetics in management (identification of populations, population studies and conservation of genetic resources. Subgroups for each of these areas were formed for part of the discussion.

A set of recommendations in each of these areas was agreed upon. A third item discussed was the formation of an ICES Working Group on Genetics. These three areas will be dealt with separately.

1. GENETIC IN MARICULTURE

A. Present and potential importance.

Mariculture has made impressive gains during the last decade. A number of disciplines have been incorporated such as disease diagnosis and treatment, nutrition, physiology of growth and reproduction, and water recycle technology. For several reasons genetics might be expected to make a major impact on aquaculture. Yet, the contribution of this discipline has not been realized to the extent deserved. To speed the further development of mariculture the Genetic Study Group recommends the adaptation of a systems approach incorporating all disciplines, including genetics.

Several study groups have addressed this issue of genetics in aquaculture in the past and encouraged the application of genetic principles to mariculture (CHERFAS, 1969; FAO, 1972; 1976; FUJINO, 1979; US National Research Council, 1978). The various groups have addressed the subject from slightly different aspects and prepared their reports for different groups. Yet, essentially their recommendations are the same as must be made here.

This strongly suggests that implementation of recommendations is what is essential, not new recommendations.

Progress has been made towards carrying out some of the recommendations made in the past. However, available funds and resources have not been commensurate with the economic improvements genetics can make in commercial and public mariculture. There are a few cases where substantial effort has been made on the appropriate scale and an economic impact has been evident. The choice of optimally desirable salmon stocks in Norway achieved through extensive programs of stock evaluation has aided salmon farmers. The production of hybrid carp in Israel and the USSR, and the use of the Bester hybrid sturgeon in the USSR are pointed to as examples of culture successes contingent upon proper genetic manipulation of available gene resources of the particular culture group.

The following are the series of steps which would be used in moving from a wild source of animals to a domesticated, improved stock. These are the basic steps potentially applicable to any species in which it is possible to control the reproduction and culture. In any particular case the program will have to be modified to suit the biology of the species, the culture practises, and the resources available. Particular modifications and choices of alternate breeding programs are best left to the specialists culturing and studying the several aquaculture groups.

1. Undertake a survey of the available genetic resources, including all related species, stocks, strains and ecotypes. An assessment of important traits should be made to determine which sources are likely to provide individuals pre-adapted to farming. (This, of course, will be contingent on being able to utilize non-indigenous populations at least in some instances).

2. Evaluate material from various sources. Samples of individuals or populations from the most promising sources should be performance-tested under culture conditions and/or in the

environment in which they are to be grown-out. It must be emphasized that controlled comparisons be used as the data produced will provide the basis for choosing original broodstocks, a choice which will greatly influence the eventual outcome of the breeding program.

3. Implement a breeding program to enhance performance for the desired characters. The choice of a particular breeding program (methods) will depend on knowledge of the genetic basis for the traits of concern, the scale of the breeding program and its long-and short-term goals which must be clearly determined. A breeding program is seldom one solely of selection, or hybridization, or inbreeding alone. More likely, it would utilize a combination of these breeding systems, or utilize different ones at different times in the program. Breeding methods are described below.

4. Maintain genetic variability for future use. Many agricultural breeders are now looking for new sources of genetic variability in domesticated animals, and notably in staple crop plants. Hopefully, genetic variability might be maintained in mariculture species by insuring the perpetuation of natural populations, and by wise management of domesticated strains.

B. Methodology.

Two groups of methods are available for a breeding program. These methods may be used separately but are most effective when combined in an integrated program.

1. Selection.

Selection is the choice and propagation of an individual (individual selection) or a group (group selection) on the basis of its own performance relative to the criteria considered.

1.1 Individual selection.

The efficiency of individual selection can be estimated a priori by determining two parameters, i.e. variability and

heritability of the character. In aquatic organisms, the observed variability for characters of economical interest seems to be rather large. However, only a few good heritability estimates (the additive genetic variation within the total observed variability) have been obtained to date. In the case of fishes, the values seems to be low concerning growth, indicating that individual selection for this character would not be very efficient.

The selection efficiency can also be measured directly by means of experimental selection, but such experiments are rather scarce. One such experiment is underway at the Milford, Connecticut, Northeast Fisheries Center Laboratory for high and low growth rate in Long Island Sound oysters, Crassostrea virginica, (LOSEE, 1979). The simultaneous maintenance of unselected control lines is essential for a correct interpretation of longterm selection programs. Individual selection studies for growth have yielded variable results as typified by the negative results of MOAV and WOHLFART (1976) in the common carp, the promising results of NEWKIRK (working paper for the study group) on European oysters, Ostrea edulis, and also the selection progress for disease resistance in the Mid-Atlantic American oyster (HASKIN and FORD, 1979).

1.2. Group selection.

Measurement of the mean performance of animals from several groups tested in a homogenous environment provides a good estimate of the genetic values of these groups. A large range of performances was shown by several studies made on local populations of salmonids (GJEDREM, 1976; HOLM and NAEVDAL, 1978). A rather large genetic gain can thus be expected in the short term by using this method. In the long term, selection on accelerated growth rate over several generations seems to be very promising for salmonids (10% genetic gain per generation, KINCAID et al., 1977). However, use of these methods require the development of expanded rearing facilities.

2. Cross-breeding.

Cross-breeding is the choice of an individual or group based on the performance of a specific cross with other individuals or groups. There are three types of crossing:

2.1 Interspecific cross-breeding : hybridization.

Aquatic species very often show extensive possibilities for hybridization, particularly when artificial insemination is used. Such possibilities have not been very much investigated up to now. However, several hybrids with interesting traits have been obtained in fish, mainly in Acipenseridae, Cyprinidae, Salmonidae and Cichlidae. Interspecies hybrids have also been made in oysters of the Crassostrea group (MENZEL, 1973). Wide hybridization has been made in seaweeds (WEST, 1979). These hybrids offer the possibility of using new environments and, when they are biologically sterile, they permit efficient management of extensive aquaculture systems.

2.2 Intraspecific cross-breeding between divergent populations.

Such crosses may combine specific characteristics of different populations resulting from natural selection in different environments and/or from domestication with selection for different traits.

The result of MOAV et al.(1975) concerning crosses between divergent populations of common carp show a significant increase of productivity in pond culture. Crosses between wild and domestic populations of Salmonids also seem to be promising (FLICK and WEBSTER, 1976).

2.3 Cross-breeding between inbred lines.

The use of inbred lines provides a better characterisation and choice of the components to be crossed, resulting frequently in higher levels of heterosis. The gynogenesis techniques, now available for several species of fish (PURDOM, 1969; STANLEY, 1976; CHOURROUT, 1980) lead to rapid production of inbred lines, previously the main problem limiting the practical use of this method. High performance

of the crossbred lines of inbreds were recently demonstrated by KINCAID in Salmonids (working paper for the Study Group). Gynogenesis does not seem so easily induced in oysters as in fish (STILES, 1978). Experimental inbreeding is being studied in two different species of commercial oysters (STILES, 1979; LANNAN, in press).

C. Recommendations.

To expedite the successful integration of genetics into mariculture production systems and assure its continued advantageous use, the following is recommended:

1. Pilot-scale hatcheries and genetic breeding. Integration of well-planned breeding programs into production systems in pilot-scale hatcheries.
2. Training for hatchery personnel. Development and augmentation of training programs for administrative and field personnel to familiarize them with basic genetic principles so that they might properly conduct breeding programs intended to improve mariculture broodstocks and avoid genetically damaging breeding practises. Timely information on strictly national programs should be exchanged among ICES member countries.
3. Conservation and introduction of non-indigenous species as genetic resources. Recognition of the importance of conservation of natural resources of aquaculture species and preservation of the developed genetic resources of mariculture species to assure availability of particular genotypes for future needs of artificial, intensive aquaculture. At the same time the occasional need for controlled introduction of non-indigenous forms for breeding must be made clear.
4. Mission-oriented basic research. Development in mariculture species of basic studies on gynogenesis and sex control, polyploidy, cytogenetics, cryopreservation of both male and female gametes and embryos, mutation breeding and nuclear transplantation. All of these areas could lead to new advances with potential to greatly facilitate the success of traditional breeding programs. All would strengthen the currently inadequate basic data base on maricultured species.

2. GENETICS IN MANAGEMENT (also genetics of the wild resources used to found mariculture breeding program).

A detailed understanding of the reproductive relationship within the species is prerequisite for formulation of effective fishery management and conservation programs, for knowledgeable utilization of wild resources as broodstocks for artificial culture programs, and for natural enhancement. Recent investigations on distribution of biochemical genetic variation indicate that the genetic structure, i.e., of naturally occurring populations of several fish species is far more complicated than previously recognized.

The identification of intraspecific genetic resources is largely a matter of estimating the amount and the distribution of genetic variation within the species considered. Many fish species are highly variable ecologically and morphologically. A considerable portion of this phenotypic variability is non-genetic and a genetic evaluation can therefore not be exclusively based on analysis of phenotypic characteristics. Electrophoretic analysis of protein polymorphisms provides a valuable, practical tool for delineating the variability and differentiation of gene pools. Extensive use of such techniques in the planning and carrying out of fisheries management programs is foreseen. Other uses are in selection of wild stock for culture and in monitoring artificially cultured stock.

For fisheries management and conservation of genetic resources and to expedite optimal use of the wild resources in artificial breeding programs the following is recommended:

1. Identifying and mapping the resources. That the amount and pattern of genetic variation within single species over a wide geographical range of environmental conditions be identified and mapped. Data must include ecological descriptions for different populations, as well as biochemical genetic differences, and also information concerning any other biological differences between populations.
2. Conservation of the resources. That management programs be initiated for the conservation of as much genetic variability

within and between populations as possible. Decisions concerning the amount of effort that should be spent on conservation activities of single stocks should be based on a thorough description of the genetical and ecological characteristics of each particular population. Efforts should be directed towards conserving unique and genetically variable forms, as they are likely to provide material for good management of our natural resources and future use of these resources in aquaculture.

3. Harvesting natural populations. That, as genetic data accumulate, fisheries be managed with due consideration of the basic knowledge of the genetic population structure of each species. This should optimize harvesting of stocks without causing unwanted genetic changes.
4. Monitoring natural resources. That to avoid damage of differentiated populations, an ongoing monitoring system - including genetic studies - be established for each stock. Monitoring systems are necessary to evaluate the stability of different populations and possible interactions and intermixing of populations.
5. Cultured populations and stock enhancement. That any existing knowledge of population genetics of a species be considered when aquacultural organisms are used in natural enhancement programs. A monitoring system should be established for each enhanced stock to determine the success of the program in maintaining the genetic quality of the resource. Care should be taken when releasing fish into natural environment to avoid damage through mixing and dilution of genetically differentiated populations. Genetic markers should be applied to estimate the interaction between the natural and artificial populations and to evaluate the effect of stocking over time and space.
6. Underlying basic research. That the importance of further basic research on maricultured and other commercial species be recognized and supported. To augment and extend the new information biochemical genetics is developing on natural populations, new methods are needed to describe genetic variability at other levels - chromosomal, DNA and immunological. More powerful statistical methods must be developed

for better revealing genetic heterogeneity in samples of mixed populations that have differentiated genetically. To aid in the conservation of germ plasm, as well as to expedite artificial breeding in mariculture, additional research is essential on cryopreservation of the gametes and embryos of mariculture and other commercial species.

3. RECOMMENDATION THAT A WORKING GROUP BE FORMED AND OUTLINE OF PROPOSED FUNCTIONS.

Continuation of the work on genetics in aquaculture and management was througly discussed by the Study Group.

In view of the importance of making meaningful applications of genetics in fishery science - a field which developed almost independent of genetics - it is recommended that the Mariculture Committee set up a Working Group in Genetics. This should continue over a period of a few years provided it continues to perform a useful function for the Mariculture (and other ICES committees). The function of the Working Group would be to:

1. Consider in depth the genetics and directed breeding of specific maricultural species utilizing the talent of specialists working with each species.
2. Consider the likely future importance of genetic resistance to disease in mariculture systems, and the practicality of selectively breeding for disease resistance. Also the impact of genotype on nutritional requirements, and its significance in developing acceptable artificial foods and increasing the likelihood of species acceptance and efficient use of such.
3. Work on plans for monitoring the natural resources and consider matters of stock identification through use of biochemical genetic markers. Consider new evidence for any impact of hatchery stocks on genetic resources of wild stocks. Plan strategy for conservation of the genetic resources of commercial and mariculture species. Discuss advances in identifying and mapping the resources for such genetic variation.
4. Define and/or standardize the diverse terminology now employed in population genetics, and by geneticists and biologists

culturing different species groups, taking into consideration use of such terminology in stock assessment work.

5. Prepare for distribution (to interested breeders, population and other geneticists in the several member countries of ICES) an annual report detailing current genetic studies directly and indirectly relevant to mariculture and management, as well as information on planned breeding programs of substantial scale. (This report would be more technical than one prepared for non-genetic specialists).
6. Consider the desirability of organizing an international symposium on aquatic genetics and related subjects with a central focus on cultured species, and the population structures of the wild resources of the species.
7. Exchange information and cooperate with the following genetic study groups which have already requested such in anticipation of ICES activity in this area:
   FAO/UNEP Expert Consultation on the Conservation of Genetic Resources of Fish; the Genetics Panel of the World Mariculture Society; the Genetics Group of the Japanese Society of Scientific Fisheries and the COST (European Cooperation in the field of Scientific and Technical Research) project aimed at identification of genetic and environmental characters of commercially important European mollusks (N.P. Wilkins, Chairman).

The Study Group is aware that several ICES committees are involved by the items here outlined. It is our opinion, however, that such Working Group should mainly report to the Mariculture Committee, but when treating matters of special interest for management, should also report to the committee concerned (Fish or shellfish committee). Alternatively, the Working Group could be divided into two sections, one on mariculture, the other on management.

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