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International Council for the  
Exploration of the sea

C.M. 1981/F:5  
Mariculture Committee

REPORT OF THE WORKING GROUP ON GENETICS

Copenhagen, 12-14 May, 1981

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TABLE OF CONTENTS

	Page
1. PARTICIPANTS . . . . .	3
2. TERMS OF REFERENCE . . . . .	3
3. GENETICS RELATED TO MARICULTURE IN THE ICES MEMBER COUNTRIES . . . . .	4
4. GENETICS AND DIRECTED BREEDING OF SALMONIDS .	5
5. DIRECTED BREEDING AND GENETICS OF ØYSTERS . .	9
6. CYTOGENETICS MANIPULATIONS AND CRYOGENICS IN MARICULTURE CYLOGENETICS . . . . .	14
7. COOPERATION AND CONTACT WITH OTHER GROUPS CONSIDERING AQUACULTURE GENETICS AND RELATED FIELDS. . . . .	15
8. STRATEGY AND FUTURE MEETING OF THE WORKING GROUP . . . . .	16
9. RECOMMENDATIONS . . . . .	17
10. APPENDIX I	

## REPORT OF THE WORKING GROUP ON GENETICS

### 1. PARTICIPANTS

The ICES Working Group on Genetics met in Copenhagen 12-14 May 1981 with the following participants:

H. Grizel, France  
A.C. Longwell, USA  
G. Nævdal, Norway (chairman)  
Th. Neudecker, Germany, Fed.Rep.of  
C. Purdom, England  
R.L. Saunders, Canada  
N.P. Wilkins, Ireland  
J. Bailey, Canada (observer)

The following appointed members were not able to attend the meeting:

H. Ackefors, Sweden  
B. Chevassus, France  
J. Guillaume, France  
G. Newkirk, Canada  
L. Nyman, Sweden

### 2. TERMS OF REFERENCES

At the 1980 Statutory Meeting it was decided (C.Res.1980/2:2) that:

- (i) a Working Group on Genetics should be set up with the following terms of reference: to consider the genetics and selective breeding of the present mariculture species groups and future candidates for such culture, employing as far as practical those specialists actually working with the particular groups.

(ii) the Working Group should meet at the Council's Headquarters for three days, preferably during the first two weeks of May, and should report to the next meeting of the Mariculture Committee.

(iii) Dr. G. Nævdal (Norway) should be Chairman.

### 3. GENETICS RELATED TO MARICULTURE IN THE ICES MEMBER COUNTRIES

As a first approximation the Working Group intended to compile an account of the activities in genetics related to mariculture in the ICES member countries. These activities include common quantitative genetics on aquaculture species applying techniques as selection and hybridization, and also more basic though mission-oriented research and techniques of potential importance to mariculture genetics. Considerations centered about the oysters and salmonids because they have been most widely cultured for the longest. This is not meant to be taken that genetic improvement is not also important in other aquaculture groups.

Sea ranching and other types of semiculture is here included in the concept mariculture. Biochemical genetics is also included so far as it can be applied to cultured species or strains. It seems best at this stage of aquaculture genetics not to exclude considerations of freshwater fish as they provide to some extent a model for marine species.

For those countries represented in the Working Group the participants prepared working papers or presented the activities as verbal communications. For countries not represented the chairman asked the delegates about activities in their countries. At the time this report was prepared, replies had been made by all countries except three (Belgium, Poland and USSR).

The activities reported are listed in APPENDIX I.

The Working Group will stress that the ICES member countries should recognize that guarantees of adequate support for pilot-scale selection programs are essential. Genetic improvement is in most cases a long-term project, and the selection programs dictate the facility requirements, i.e. genetic programs require a minimum of time and space to be effective. A full evaluation of genetic progress is nearly impossible with only one or two selected generations (recommendation no. 1 and 2).

The Working Group also will point out that when genetic breeding programs are initiated and reported on, the sources of experimental material (stocks, strains etc.) are identified as completely as possible (recommendation no. 3).

#### 4. GENETIC AND DIRECTED BREEDING OF SALMONIDS

##### 4.1 Background

With the exception of rainbow trout and to a lesser extent, brook trout, brown trout and Atlantic salmon, the artificial propagation of salmonid species is relatively new by comparison to most domesticated species. Thus very few generations of salmonids have been exposed to the insidious selection pressure of domestication and are still similar, phenotypically, to wild populations. A feature common to all salmonid populations reared under hatchery conditions is the very large variability present for most quantitative traits examined. Quite naturally, this has led to the belief that potential for rapid gains by genetic selection is large relative to domestic animals. Significant levels of salmonid production in some ICES member countries, Denmark, U.K., Ireland, Norway, Canada and USA, can probably be improved following genetic research and its application.

##### 4.2 Selection goals and production traits

The first consideration essential to the selective breeding of salmonids is elucidation of specific selection goals. Coupled with this is the need for an evaluation of the relative

influence of genotype and environment. Improvement of husbandry practices tend to evolve largely by trails and error as the knowledge of the biology of the animal increases. In the short term substantial gains may be possible through directed research in animal husbandry. Further gain is usually possible through directed breeding applying genetic principles. Goals for selective improvement ought to be precisely defined and kept as simple as possible. The more traits selected for usually the less intense and less effective selection can be for any single one.

Growth rate. Growth rate is very plastic in fish and largely determined by the rate of which food is given or eaten. Within populations some fish grow faster than others due to hierarchy phenomena. Thus we don't know how much variations in growth rate is due to variation in food intake and what portion is attributable to variation in food conversion rate. Possibly because domestication and husbandry practice minimize or eliminate social hierarchies in farm animals, animal breeders have largely been able to ignore the question of food intake versus conversion efficiency in selecting for growth rate. Nevertheless, variation in growth rate in an given environment can easily be measured. Much data indicate that a substantial part of the variation is controlled by genetic factors, although we don't know whether these factors influence growth rate directly or via ethological or ecological factors. Experiments specially designed to study growth rate and its interaction with environmental variations and other phenomena, will be very valuable in understanding and utilizing the pronounced variations observed in growth rate. Hybridization of inbred lines (see below) is an alternate method (to selection) for genetic improvement of traits as growth, utilizing possible non-additive genetic factors controlling the trait in question.

To do this a number of inbred lines must first be bred. It should be noted that such lines could contribute much to the basic genetic understanding of the species concerned.

The importance of experiments revealing the nature of variable growth rate in fish is stressed. Additional information should help in the improvement of this trait as a part of developing strains suited for culture.

Age at maturation is important both for cage culture and sea ranching. Very clear intra- and interstrain variation exist, and although still subject to interpretative differences, additive and possibly non-additive genetic factors seem to be responsible for at least part of the observed variation. Age of maturation is also related to growth rate phenomena and they are probably interdependent trait. For evaluation and utilization of variation in this trait, methodology is of crucial importance and should be defined as closely as possible.

Alternative methods (to conventional selection, inbreeding, hybridization) for manipulating the maturation process will be valuable because selection for later age at first maturation increase the generation interval thus decrease change of rapid genetic gain in other traits (see p.8 ).

Smolting factors (early smoltification) is important in anadromous species. Smolting is very closely associated with presmolt growth rate. Growth rate either improved genetically or through better rearing conditions will give higher proportion of 1-year smolt.

Features of ranched salmon are divided into those belonging to the rearing phase and to the marine growth phase. The rearing phase in fresh water is largely comparable to the presmolt phase of farmed salmonids, and approximately the same selection goals and methods may be used. In the marine phase probably a

considerable but uncontrollable natural selection takes place as well as mortality due to marine fisheries. Thus artificial selection based on return rate may be a nonpredictable process of minor value.

Egg size and season of spawning is of importance for hatching and presmolt growth rate. Large eggs give large alevins which usually begin feeding more easily than smaller alevins and thus have lower mortality in this critical phase. However, egg size depends on size and eggs of the female. An extended spawning season may be valuable for the practical operation of hatcheries. In particular early spawning of Atlantic salmon will be a way of producing underyearling smolt.

Resistance to diseases may be obtained by selection, as there is some evidence of genetic factors controlling variation in this trait in salmonids as in other species. It is too early to evaluate the practical possibilities for genetic gain. However, the Working Group will encourage experiments designed to evaluate natural disease resistance levels in different species and strains. Hybridization of more generally desirable with more resistant strains or species could provide one generation benefit to some industries.

4.3 Hybridization of species, strains or inbred lines mainly utilize the non-additive genetic variation. Hybridization of inbred lines is being used to improve the growth rate of rainbow trout (Kincaid, 1980)<sup>1)</sup>. It is not possible to decide on hybridization contra selection as the better or least expensive method to achieve the same goals. Reciprocal recurrent selection for heterosis between inbred lines could prove a useful breeding strategy.

4.4 Control of genetic gain. Regardless of traits and methods, suitable controls must be employed. The choice of control is critical, very demanding and should be determined at the

<sup>1)</sup> Kincaid, H. 1980 Working Paper for ICES Study Group on Genetics, Svanøy, Norway, June 1980.

initiation of the selection program. Suggestions might include a random-bred control, selection in two directions, careful managements of unselected control lines, or successive sampling of natural stocks not influenced by artificial selection (recommendation no. 4). In the future, use of cryopreserved gametes and/or zygotes could do much to solve the matter of appropriate controls.

#### 5. DIRECTED BREEDING AND GENETICS OF OYSTERS

Genetic and breeding studies on oysters up to 1975 were reviewed by Longwell (1976) <sup>1)</sup>. A more recent review by Newkirk (1979) <sup>2)</sup> refers as well to much of the greater amount of work published after 1975. This review was presented by Newkirk to the 1979 ICES Genetics Study Group meeting in Norway. Some of the same work, as well as Japanese studies on oysters and other pelecypod mollusks, is reviewed by Numachi (1978) in a symposium, "Genetics and Breeding Improvement" held in Japan, the publication of which was translated to English through NOAA, U.S. Dept. of Commerce (copies currently available from U.S. Mariculture Committee member). A comprehensive bibliography on the genetics and breeding of oysters, closely related groups and highly relevant subjects was compiled specifically for and made available to Genetics Working Group members. This cites about 140 papers, including abstracts and reviews, far less than a 24-year (1948-72) general bibliography of oysters which cites 4117 references. This number of genetic papers, taken as an indicator of total effort supported in this area, is far less than any similar bibliography on salmonids would contain. Moreover, as members of vertebrates, much more

1) Longwell, A.C. 1976. Review of genetic and related studies on commercial oysters and other pelecypod mollusks. J.Fish.Res.Bd.Can., 33: 1100-1107.

2) Newkirk, G.F. 1980. Review of the genetics and potential for selective breeding of commercially important bivalves. Aquaculture 19: 209-228.

in-dept information is available on the general biology of fish than of mollusks. Most published genetic work done on oysters has been on the genus Crassostrea. There are hardly any papers on the Ostrea group which incubates its fertilized eggs and is consequently a more difficult group in which to make specific crosses than in the Crassostrea species where eggs are non-incubating.

Oysters are characterized attractively (to breeders and geneticists) by an enormous fecundity, with adult female American, C. virginia, oysters producing as many as sixty-five million eggs. They are, however, also characterized by a highly sensitive larval phase, particularly pronounced in the American oyster, and presumed less so in the Japanese oyster, C. gigas. Mortality at this stage seems to be one of two largest single contributing factors to full biologic and economic success of U.S. commercial hatcheries. Shellfish have both advantages and disadvantages relative to salmonids in the establishment of directed breeding programs.

In spite of this high larval sensitivity, and uncertainty about basic factors as the diet of adults no longer fed hatchery-produced algal foods past the juvenile stage, genetic and breeding studies seem to indicate considerable genetic variance in the American and Japanese oysters that might be exploited to commercial advantage. This is, of course, provided larval mortality can be controlled, and some reasonable measure of environmental control maintained over stocks to be bred selectively. There also appear to be genotype x environment interactions which must be particularly strong in an animal as the oyster. Possibilities of combining traits in inter-species hybridizations and possibilities of wide choices in the selection of stock from a variety of species and geographic populations are now attracting commercial interest. The American oyster, both in artificial culture and in nature, seems to respond to artificial and natural selection for at least one serious oyster disease.

On the other hand, probably because of the inherent difficulties in maintaining suitable control over the cultures in experiments and breeding programs and small sample size, results of different researchers and even of the same researcher at different times are in disagreement. Where commercial hatcheries have to compete with natural wild oyster set they have been unable to do so economically (refer to paper presented to the ICES Working Group on Genetics - "Artificial and competitive natural production of oysters and marine finfish in the U.S. as determinants of the need for or impracticality of breed improvement". (It should be noted that none of these operating hatcheries competing with natural set have maintained any consistent breeding improvement programs.))

Even so, the great commercial worth of oysters, the vagaries of natural seed production, and the fact that some industries will continue to depend entirely on artificial or imported sources of seed assure that hatchery production will be attempted or even successfully employed in numbers of situations worldwide. Given this state of affairs the application of genetic principles to the artificial propagation of oysters is advised insofar as this is at all practical at the same time a wider, stronger base of genetic and breeding information is built on which subsequent applied work and commercial breeding programs can be based. This should eventually assure in the very least a more efficient aquaculture production than if good genetic breeding practices were ignored in generation to generation artificial reproduction of oysters.

The same general guidelines given above for salmonids regarding controls, choice of selection characters based on indications of genetic variance, etc., apply to the oysters. The following are specific points pertaining to oysters:

1. Results of selection experiments and/or heritability estimates seem to indicate selection for growth rate and certain disease resistance in adults may be worthwhile

when a faster growing or resistant oyster offers commercial or culture advantage. In the U.S. loss of small hatchery-produced cultchless juveniles, when placed in nature for bottom culture, contributes seriously to failure of hatchery-produced seed. Faster-growing juveniles placed in nature at a somewhat larger size would reduce this loss.

2. Phenotypic correlations among characters of commercial importance are less well-defined with conflicting data than is the case in salmonids. Possibly, the environmental influence here is more variable and generally stronger than in fish.
3. As with salmonids, efforts are being made to evaluate the desirability of inbreeding lines for hybridization as an alternative, highly inbred lines would be of value in elucidating effects of inbreeding and also basic genetics of oysters otherwise difficult or impossible to ascertain.
4. Larval viability must have a large non-genetic maternal influence, but there is evidence that prime conditions or maturation time (as gauged partly by larval success) is under genetic influence.
5. Recognition of strain or ecotype differences in oysters is more difficult than with vertebrate fish. This is even though the American oyster, for example, has an unusually wide natural range extending from the Gulf of St. Lawrence to the Gulf of Mexico. The performance of oysters from different geographic areas in terms of culture suitability for different situations should be further explored as well as hybrids of these where indicated.
6. Especially for Ostrea edulis assessment of geographic populations seems at the moment to be most important. Adaption of wild (or "semiwild" stocks) are related to physical environmental factors and also to resistance to disease. Diseases threaten the whole oyster industry, for instance in France, and resistant strains or species will be very valuable. Identification of wild stocks

also include the application of biochemical genetics, history of former transfer of oysters between areas (COST Project 46 will prepare an atlas) and conservation of wild and possibly locally adapted stocks for future use in aquaculture (see recommendation no. 2).

7. It has not even been demonstrated that the currently most discussed species hybrid (American x Japanese oyster) can be satisfactorily produced on any meaningful scale. However, possibilities seem to exist for several hybrids of Crassostrea species of potential use in particular locales or industries. Ostrea species hybrids have yet to be even considered.
8. Over-intense reproduction can create problems of meat quality and crowding in warm climates as in the South Atlantic States of the U.S. where spatfall is continuous from May to October and three to four times as intensive as in New England or the Mid-Atlantic area. Some genetic control over fecundity could be desirable in some such situations. Also, it would be more generally valuable in any climate if it diverted energy from gonad production to overall growth and glycogen production.
9. Genetic improvement of oysters is commonly thought of in terms of hatchery production and rearing of larvae which are put in natural waters as juveniles. It can also be considered in the context of developing oysters for natural restocking or developing of new spawning beds which might then produce new generations without hatchery assistance.
10. It is expected that as husbandry improvement are made and as the oyster is domesticated, progress by selective breeding will be more reliably or easily made. In the interim, maximum use of hybrid genotypes could circumvent some of the difficulties of a strict selection program.

6. CYTOGENETIC MANIPULATIONS AND CRYOGENICS IN MARICULTURE  
CYTOGENETICS

Chromosome engineering has contributed enormously to the field of plant breeding. Because it has not been of much significance in livestock breeding is no reason to assume it has no major role in fish and invertebrate breeding. That it can and has already played a role in seaweed breeding is indicated by the work of C.K. Tseng and T.C. Fang in China.

Specific chromosome techniques are now available or are being developed which could represent alternatives to or greatly facilitate traditional breeding programs. The Working Group discussed such technique and their application, with special emphasize on use of triploids, one sex individuals and gynogenesis.

Tetraploids are made by manipulating the meiotic cell divisions by chemical treatment of the eggs. By crossing tetraploids by normal diploid, triploid fish (or oysters) are obtained. Such fish (at least the females) are likely to be sterile, may grow faster and thus attractive for intense fish farming. The males seem to develop secondary sexual characters, and may be more useful for sea ranching as they will be sexual incompetent have no uncontrolled effect on gene pools of natural stocks.

All females may be produced by feeding the young fish male steroids thus making functional males from genetic females. By crossing such males to normal females, only females are produced. Because females as a rule mature later than males, all female populations represent an improvement for the fish farming industry.

Gynogenesis is a method for producing highly inbred lines by cytogenetic manipulations in one generation. This could be especially important in combination with a breeding program calling for hybridization of inbred lines for the purpose of utilizing any heterosis (see p. 8).

## CRYOGENICS

Cryopreservation of the male gametes are now possible thus storing genetic information for subsequent generations. Research is being conducted on cryopreservation of eggs and young zygotes. Most of these cytogenetic and cryogenic techniques are not yet being used commercially, but the Working Group recommends that further such studies be conducted with the aim of making their use on commercial scale practical (recommendation no. 7).

### 7. COOPERATION AND CONTACT WITH OTHER GROUPS CONSIDERING AQUACULTURE GENETICS AND RELATED FIELDS.

The Genetics Working Group recognized that considerable work on genetics in mariculture (and more broadly aquaculture) is carried out by countries outside ICES, and that other organizations as UNEP/FAO, COST, World Mariculture Society etc. are concerned partly with the same problems as the ICES Working Group. For these reasons we stress it is important that the ICES Working Group exchange information with these other groups. We also would like to invite observers (guests) from such groups or from countries outside ICES to future Working Group meetings (recommendation no. 8).

More specific COST, Project 46, chaired by Prof. N.P. Wilkins, is arranging a Symposium in March/April 1982 in Galway, Ireland. The Working Group recognizes that the tentative program for this symposium covers a considerable part of genetics related to mariculture. We therefore recommend that the symposium be endorsed by ICES and that the ICES member countries encourage participation and contributions to the symposium (recommendation no. 9).

The attention of the Anadromous and Catadromous Fish Committee and the Working Group on the Introduction and Transfer of Marine Organisms should be drawn to the significance of single sex broods and sterile fish production technique.

8. STRATEGY AND FUTURE MEETING OF THE WORKING GROUP

Because the COST Symposium is arranged for 1982, and in view of the apparent difficulties of obtaining travel funds, we propose no meeting of the Working Group in 1982. The next meeting is proposed for May 1983. Dr. C. Purdom exposed an invitation to hold the meeting at Lowestoft, and the Working Group concurred (recommendation no. 10).

## 9. RECOMMENDATIONS

The ICES Working Group on Genetics recommends, without any priorities as these will be established by the culture in the particular countries, that:

1. The ICES member countries should recognize that guarantees of adequate support for pilot scale selection programs are essential; that facility requirements are dictated by the selection program; and that programs must have continuity to exploit and evaluate progress made over several culture generations.
2. Limited control over aspects of a species' life cycle limits genetic progress. Research into better husbandry methods should go hand in hand with breeding efforts, particularly in oysters.
3. Sources of experimental material (stock, strains etc.) should be identified as completely as possible in genetic studies.
4. Genetic research should follow strict genetic protocol so as to provide a sound basis for evaluating results, i.e. appropriate control stocks or strains.
5. The development of strains suitable for cage rearing of fish and hatchery production of oysters should be stressed.
6. The development of strains suitable for sea ranching and for restocking natural oyster beds should be stressed.
7. Research and further development on methods of cryo-preservation of gametes, cytogenetics and biochemical genetics for use in genetic programs should be encouraged.
8. The Working Group and the Council should exchange information with other genetic groups with parallel interests, and observers should be invited to future working group meetings.
9. The 1982 COST Symposium on Genetics should be endorsed by ICES and participation should be encouraged by the member countries of ICES.
10. The ICES Working Group on Genetics should meet for three days in the first half of May 1983 in Lowestoft, England.



## APPENDIX

### CURRENT AND PLANNED GENETIC STUDIES RELATED TO MARICULTURE IN ICES MEMBER COUNTRIES

1. BELGIUM

No information

2. CANADA (report compiled by Richard L. Saunders)

Aquaculture Genetics Program - Dalhousie University, Halifax,  
Nova Scotia

R.W. Doyle, L.E. Haley, and G.F. Newkirk

European oyster, Ostrea edulis

The goals of the genetics program with O. edulis are: to prevent the future accumulation of inbreeding in the stock through broodstock management and enhancement with new stocks; and to produce through selective breeding a strain of oysters adapted to the Canadian Maritime environment, hatchery propagation and intensive tray culture. Initially the primary traits of concern are growth rate and survival.

The stock being used is mainly descendants of an import to Canada in 1969 from Milford, Connecticut, U.S.A. (the Milford stock came from the Netherlands in the late 1940's). In 1979 stocks were imported from Maine,

U.S.A. and North Wales, U.K. When the second generation of these stocks are cleared from quarantine, a crossbreeding program will be used to incorporate these stocks into the main stock. At present, selection of broodstock is done on the basis of individual weight, when the year-class is close to market size. Selection for survival is at present a result of natural selection. After perfecting a technique of producing families, it is planned to use family selection to select improved overwinter survival.

Until now, lines selected for size (growth rate) have been produced by mass spawning. This species broods the larvae for half the larval period. There are nine first-generation selected lines and 16 second-generation selected lines. Unselected control lines are also maintained. The five first-generation lines that have reached market size average 23% higher than contemporaneous control lines.

American oyster, Crassostrea virginica

Experiments are continuing on genetics of the American oyster, especially on traits associated with commercial production. The investigators have been able to produce large numbers of families from matings of pairs of oysters. Crosses of oysters between populations which were known to have different growth rates produced hybrid offspring which in general showed no hybrid vigour. Second-generation crosses have now been completed to test for hybrid vigour in reproductive traits. Since genetic analysis indicated significant additive genetic variance in growth rate, selected lines are now being assessed for growth performance. Other experiments are being conducted on the genetics of shell shape and physiological traits such as filtering rates.

Atlantic salmon, Salmo salar

Dr. Newkirk has been directing a broodstock establishment program in preparation for a selective breeding program at a private hatchery. Autumn of 1980 was the first season of operation during which time families were produced from several river stocks from New Brunswick and Nova Scotia through cooperation with the Department of Fisheries and Oceans and the Salmon Genetics Program.

These stocks and others obtained in subsequent years will be performance tested in marine cage culture. The next phase is to start selecting the stock and produce a domesticated strain adapted to cage culture in local environments and improved for commercial traits.

Crustacean Ecological Genetics

Dr. Doyle's research falls into four categories: (1) Studies on a "model" organism, the amphipod Gammarus lawrencianus. This work is aimed at obtaining genetic information about the variance (heritability) and covariance of traits related to the production and yield of crustacean populations in controlled environments; (2) Theoretical/mathematical studies of the relationship between artificial selection and "natural" selection in pond culture. The concentration here is on finding selection techniques which can produce domesticated strains of indigenous species through the activities of artisanal aquaculture in developing countries; (3) Studies on the intensity and direction of "domestication selection" exerted on Macrobrachium rosenbergii populations during aquaculture operations in Thailand (in collaboration with Mr. Somsuk Singholka of the Thailand Ministry of Fisheries); (4) Model studies on the fish Poecilia reticulata are just getting underway. The objectives are similar to those described for crustaceans.

Marine Ecology Laboratory, Bedford Institute of Oceanography,  
Dartmouth, Nova Scotia - L.M. Dickie, K.R. Freeman, and  
K.E. Gartner-Kepkay

Blue mussel, Mytilus edulis

An attempt has been made to measure the relative importance of genotype in controlling production parameters. Growth and mortality rates of individuals have been measured from a variety of stocks and observed at frequent intervals for periods of about two years each, when held and grown under different conditions. It has been established that both growth and mortality rates show a significant stock-related (genetic) component in their total variation. Differences between stocks appear to be higher for mortality than for growth rates. A high fraction of total variation in mortality is stock-related.

The apparent genetic differences among stocks of blue mussels can be indexed by differences in frequency distributions of alleles at several polymorphic gene sites, although functional relations cannot be specified. To date, one set of genetic crosses has been made among different source stocks. Some of the resulting hybrids appear to show hybrid vigour but the experimental design and data are not yet sufficient to provide estimates of heritability.

The investigators plan to use new facilities enabling them to study inheritance of production parameters in mussels and possibly to extend the analogue models to other species. There will be attempts to quantify the potential for selective alteration of productivity and its relation to artificial manipulation.

Salmon Genetics Research Program, North American Salmon Research Center, St. Andrews, New Brunswick - J.K. Bailey, B.D. Glebe, R.L. Saunders, and C.B. Schom

Breeding studies with Salmo salar

The Salmon Genetics Research Program has been ongoing since 1974 with breeding studies using several wild stocks of Atlantic salmon. The major long-term objective of the SGRP is to produce and evaluate two or more selected strains of S. salar which are specifically adapted for sea ranching from the NASRC facility and are superior to available wild stocks in terms of production traits. The NASRC has a large production capability which is used to hatch and rear many sib groups for measurements of survival, growth, incidence of precocious maturity and age at smolting. Micro-tagged smolts are released in a stream flowing past the NASRC and entering the estuary 0.5 km away. Returning adults are captured in the estuary and selected individuals are used as broodstock together with adults collected from selected rivers. Several unselected strains of smolts have been released and those from one small Bay of Fundy river have given superior adult returns in comparison with those from other New Brunswick rivers. There was consistent development of bimodal length frequency distribution in 32 hatchery populations. The proportion of individuals in the upper mode was strongly correlated with age variables in the female parent whereas large mean length in the upper mode was strongly associated with early smolting male parents and late maturing female parents.

Sea cage rearing

Some of the smolts from NASRC are reared in sea cages in order to produce additional data on survival and growth and age at sexual maturity. Some of the adults produced will be used as broodstock. The SGRP is also conducting breeding in support of a developing salmon aquaculture (sea cage rearing) industry.

#### Precocious male parr

Precocious sexual maturation of male salmon parr has been studied extensively. The incidence of precocious parr varies greatly among hatchery reared strains of salmon representing various river stocks. Precocious parr have been used as sires in breeding studies. The age at maturity of the parents did not influence the number of precocious parr offspring.

Relative to the progeny of anadromous males, the use of precocious parr did not alter the proportion maturing after one sea year. Comparisons are being made between sea ranched and cage reared fish in respect to precocious vs anadromous sires.

#### Effects of low pH

Studies have been started on resistance to low environmental pH. Emphasis is being placed on family selection for resistance and the use of precocious parr will be considered as a mean of reducing generation time. Resistance to heavy metals is also being studied. Motility of salmon sperm is reduced at pH 6.5 and ceases near pH 4.0. No fertilization takes place below pH 3.5.

#### Sex reversal and delay of sexual maturation

Dietary methyltestosterone and estradiol are being used for sex reversal and for delaying maturation. MT treatment after sex differentiation can prevent development of precocious male parr. Data on age at maturity, survival and growth of sex reversed (possibly sterile) salmon which are being sea ranched and cage reared will be available in 1981. An experiment to evaluate the effectiveness of MT for delaying sexual maturity during the marine phase is in progress.

Research Section, Fisheries Branch, Stocks Assessment and Genetics Unit, Ontario Ministry of Natural Resources, Maple, Ontario - P.E. Ihssen

#### Growth of rainbow trout

This project is conducted in cooperation with G.W. Friars and Laura R. McKay of the University of Guelph. Diallel crosses are used to measure genetic components of variation for growth rate of fry and yearling trout. Genetic correlation between growth rate at different ages and at different temperatures is also determined. Growth rates of two genetic stocks are being compared.

#### Maturation of rainbow trout

Two Ontario stocks (one hatchery, one naturalized) are compared for rate of maturation. Family data are used to estimate components of variation for maturation of males and females at different ages.

#### Genetic marking of rainbow trout

For each of two stocks, several genetically marked lines (isozyme allelic markers as determined by electrophoresis) are being selectively bred. These genetically marked lines will be used to study the comparative effectiveness of eyed egg and fry plantings of these stocks and their hybrids. Also, natural reproduction (relative contribution of the stocks to subsequent generations and relative to existing naturalized stocks; inbreeding among the planted stocks and with existing naturalized stocks) will be studied using genetic markers.

#### Sanctuary lake studies

This project involves transplanting stocks that are endangered by environmental degradation to sanctuary lakes. The first transplant involves Lake Simcoe lake trout. Transplants of

whitefish and possibly brook trout are planned. The genetic aspect of this project involves comparing electrophoretic allele frequencies of the donor stock, the progeny after hatchery rearing and the survivors in the sanctuary lake. Physiological and morphological characters of the transplanted stock will be compared with those of the donor stock.

Freshwater Institute, Department of Fisheries and Oceans,  
Winnipeg, Manitoba - G.B. Ayles

#### Trout and Arctic char

Research objectives are to develop strains of rainbow trout and Arctic char more suited for commercial aquaculture. Interstrain comparisons, heritability estimates and estimates of genotype-environment interaction are being made for rainbow trout in extensive culture operations and Arctic char and rainbow trout in intensive aquaculture systems using waste heat. Genetic analysis of growth, survival and some body carcass characteristics have been completed for rainbow trout.

Nutrition and Applied Endocrinology Program, West Vancouver Laboratory, Department of Fisheries and Oceans, West Vancouver, B.C. E.M. Donaldson, G.A. Hunter, and J. Stoss

#### Production of all female stocks of Pacific salmon using hormones

All female (phenotypic) coho salmon groups have been produced and raised to maturity by direct estrogen treatment. Their ova were either 1:1 male female or 3:1 male female, indicating that the male salmon is heterogametic and the female homogametic. Experimental work is now underway to produce phenotypic male salmon which are genotypic females. Sperm from these fish are being used to fertilize normal ova and thus produce all female stocks of salmon. Species studied include coho, chinook, chum and pink salmon.

Production of sterile salmon using hormones.

Studies are being conducted on the hormonal sterilization of genotypic male + female Pacific salmon: coho; chinook; and pink.

#### Gynogenesis

Studies on gynogenesis in coho were carried out in 1980 and will be continued in 1981/82, possibly including other species of the same genus. The goals for this work are to induce monosex offspring, to produce genetically highly similar fish and to investigate their performance in production traits. An all female group of coho has been produced by gynogenesis.

#### Cryopreservation

Studies are being conducted on the cryopreservation of Pacific salmon sperm and newly fertilized eggs. One reason for this research is the interest in "banking" genetically distinct strains which are in low abundance and possibly endangered.

Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, B.C. - W.C. Clarke and B.E. Riddell

#### Assortative mating experiments with coho salmon

The purpose of this work was to obtain an estimate of heritability of growth rate in an accelerated rearing mode at the experimental fish farm (net pens at Pacific Biological Station). By June 1979, the heritability estimate for smolt growth ( $\log_{10} b$  offspring on mid-parent) was 0.48. The smolts were nosetagged in October 1980 but the tags have not yet been decoded.

#### Changes in gene frequencies resulting from domestication

Plans are being developed to document changes, if any, of gene frequencies in hatchery stocks from those of natural donor populations. Electrophoretic comparisons are being conducted among

three chum salmon stocks being reared in a Japanese chum style hatchery (Conuma hatchery in Tlupana Inlet). Comparisons are between stocks within natural and hatchery environments and between environments within stocks. This study is to continue over 3-5 years.

### 3. DENMARK

In Denmark a research project on cryopreservation of fertilized fish eggs will be initiated in spring 1981 if financial support is granted. The project is a cooperation between the Royal Veterinary and Agricultural University and the Danish Institute for Fisheries and Marine Research. The research is coordinated with activities at the Institute for Hydrobiology and Fisheries Science in Hamburg.

The experiments will be conducted on fertilized eggs of trout, herring and possibly of turbot and sole. The experiments will include investigations on the effects of different concentrations of cryoprotective agents and effects of freezing and thawing rates.

### 4. FINLAND (report by Kai Westman).

Finnish Game and Fisheries Research Institute is making studies on selective breeding of rainbow trout. The purpose of these studies is to find out differences in growth characters between different strains and hybrids and after that begin systematical breeding programme. Studies are made at Laukaa Fish Culture Research Station in cooperation on with the Institute of Animal Breeding Science at the University of Helsinki. The Research Institute has also made the first general plans for a new fish breeding station in central Finland, with approximate 400 rearing units for egg and fingerling groups. After the first year of rearing in the breeding station the fish will be reared further at commercial fish farms in fresh and brackish water. In breeding programmes, the main interest is in growth rate, food conversion, disease resistance and marketing qualities. Later also other salmonids will be included in the breeding studies.

At Laukaa Fish Culture Research Station there is also going on experiments on sex control of rainbow trout. Trout are fed with hormones in food in the beginning of start feeding. Experiments on the cryopreservation of salmonid milt are planned to begin soon. The method would be of value in breeding and sex control programmes. Cryopreservation studies of milt are going on also in the Institute of Biology in the University of Joensuu, where they have studied milt from brown trout, rainbow trout and whitefish.

Finnish Game and Fisheries Research Institute has also begun, in cooperation with the Genetic Department of the University of Helsinki, studies concerning genetic variation of the Atlantic salmon. Most part of our natural river populations has been lost, and there are only three salmon rivers left running to the Baltic Sea. The aim of the study is to analyse the amount and distribution of the genetic variation on natural populations and hatchery stocks of the salmon. The results will be used in the planning and implementation of management, breeding and conservation programmes. The work will be done by enzyme electrophoresis and the first examinations for finding polymorphic loci has already begun.

Previously, enzyme electrophoretic studies have been made with coregonids. The phylogeny and taxonomic status of the different whitefish populations living in the Baltic Sea and inland lakes has been examined at Abo Academy. The geographic variation and inheritance studies of enzymes in vendace has been studied at the University of Joensuu.

5. FRANCE (report by B. Chevassus and H. Grizel)

SALMONIDS AND OTHER FINFISH

Research work undertaken in France commenced in 1971, having taken into account three principal restraints:

- the absence of a prospective allowing for the definition in the medium term of species intended for aquaculture and their conditions of rearing;
- the absence of basic information in most of the genetic aspects on aquatic species which are susceptible to be chosen;

- lack of sufficient experimental facilities for undertaking study programs of natural populations in controlled rearing conditions.

Research work is therefore oriented towards a methodological examination of salmonids for which the rearing techniques and experimental installations were developed enough to allow for the carrying out of genetic studies.

Research work is split between five principal themes:

- interspecific hybridisation
- quantitative genetics
- mendelian genetics
- biochemical genetics
- cytogenetics

#### INTERSPECIFIC HYBRIDISATION

A first study phase both bibliographic and experimental has pointed out a certain number of hybrids in which the survival rate was compatible with large-scale rearing.

- With regard to sterility, the object is to study to what extent sterile hybrids can grow continuously to a large size, without interruptions or slackening connected with sexual maturation, and correlatively can give a better rate of survival during winter periods. Sterility seems to be limited to inter-generic hybridisation, the cross chosen being between Salvelinus fontinalis ♂ X Salmo trutta ♀, which was tested for its performance in both fresh water and seawater.

- With regard to disease resistance, the program has been based on a hybrid between Oncorhynchus kisutch ♂ X Salmo gairdneri ♀. This hybrid, although very fragile, has been produced in quantity and has been tested for resistance to VHS (viral haemorrhagic septicaemia), a virus which affects the rainbow trout but not the coho salmon. The results obtained show a marked resistance of the hybrid to viral infection, a resistance which is nevertheless feebler than that of the coho. The study of the fertility of this hybrid will allow us to determine in what way this resistance can be transmitted to rainbow trout by successive re-crossing.

## QUANTITATIVE GENETICS

Taking into account the ease of collection of information (length and weight) and the economic importance of this parameter, growth has been chosen for most studies.

### Genetics of growth

The aim of the program is to determine the genetic bases of phenotypic variation in growth in reared populations.

This variability was analysed into three components:

- inter-population variability,
- inter-group intrapopulation variability (groups of full or half-sibs),
- intra-group variability.

The results obtained lead to the conclusion that there is a pronounced interpopulation and inter-group genetic variability and show the effectiveness of such "group selection" (family selection, strains comparison).

Nevertheless, the importance of genetic factors has proved difficult to encompass in the case of intragroup variability, in so far as phenomena of inter-actions between individuals appear to play a preponderant role in the genesis of this variability.. These interactions, which in many cases increase with age, tend to limit, or even to negate the efficiency of selection as soon as the precocious growth stage is over.

The study of genotype-social factor interaction has thus become the main research axis for studies on growth genetics. The lines of approach planned or in progress are as follows:

- estimation of genetic parameters (variability, heritability) in isolated situations (individual rearing) and in competitive situations between individuals;
- evaluation of the performances of groups of known genotype maintained both separately and in intra or in interspecific competitive situations and comparison of the classifications obtained.
- influence of competition on the maintenance of fortuitous initial differences (maternal effects, age at hatching or first feeding).

### Other characters

Several other characters have been or are now the subject of genetical analysis, generally within the framework of multi-disciplinary projects or of programs carried out by French scientists working abroad.

- Resistance to mercury pollution; partly controlled by genetic factors, this resistance can be built up by selection always with the risk that selected population become dangerous to consumers and to man in particular.
- Duration of embryonic development: the study of this character has shown a particularly strong genotypic-environment interaction.
- Rearing survival: research is at a preliminary stage and has run up against theoretical and practical difficulties connected with contagion phenomenae.
- Swimming performance against a variable flow of water, a characteristic which could be valuable for estimating the stamina of individuals intended for stocking in the wild.
- Number of pyloric caecae; the aim of this study is to develop lines which have a low or high number of caecae in order to assess the role of these tissue in the nutritive process, and the consequences on growth.
- Resistance to VHS, a virus which cause heavy losses in intensive Salmo gairdneri culture.

### Analysis of the effects of inbreeding

Two techniques which have been perfected in the rainbow trout allow for the possibility of rapid production of inbred lines:

- the synchronous self-fertilisation of hermaphrodite individuals resulting from steroid hormones in the food during the phase of sexual differentiation.
- diploid gynogenesis, which permits the easiest and most rapid production of a high level of inbreeding.

The first of these lines have already been obtained and the importance of the effects on inbreeding on survival parameters, on growth and on fertility can therefore be determined.

## MENDELIAN GENETICS

### Research into visible genetic markers

Problems relating to the comparison of the performance of numerous experimental groups in different tanks have already been described.

In connection with these problems, the use of visible genetic markers offers a simple solution by allowing the use of a within tank control population, the performance of which permits a simultaneous evaluation of the effects of treatment and of residual effects between tanks.

The program now in progress is a study of a de-pigmentation characteristic of Salmo gairdneri.

### Genetic determinism of sex

The absence of differentiated sex chromosomes in most fishes obviates the possibility of sexing of animals by karyotypic techniques. The information on the genetic determination of sex can thus be based on evidence obtained from studies of the sex-ratio of certain particular crossings.

Study of sex ratio in the products of interspecific hybridisation and among the offsprings of sexually reversed individuals has led to the hypothesis of heterogametic males in certain species and females in others.

A second program intended to determine the heterogamic sex by a study of the sex ratio in self fertilised or gynogenetic lines has been started on Salmo gairdneri.

## BIOCHEMICAL GENETICS

Interest in the in situ characterisation of species and of populations has been shown in the first part. Research now directed along this path is on two themes:

### Identification of species and of interspecific hybrids

With regard to salmonids, the identification of protein markers allowing the identification of most species and the detection of possible hybrids has been realised.

### Identification of populations

The measure of the total genetic variability of a species and its distribution between and within populations is a precise method of approach to a certain number of genetic improvements (determination of methods of sampling in order to develop rearing populations, opportunity for inter-population crosses). The study of protein polymorphism in the rainbow trout has led to the determination of several enzymatic variants the frequencies of which are a characteristic of a population. The programs undertaken therefore propose a study of a certain number of reared populations isolated since several generations in order to determine the importance of inter-population variability in this species, to measure the possible reduction of genetic variability resulting from isolation and to study subsequently the relationship between genetic distance determined by these methods and the effects of heterosis which may result from a re-crossing between populations.

### CYTOGENETICS

#### Karyotypes

The karyological study of individuals can prove a precise complement to biochemical methods with regard to the identification of species, hybrids or (more rarely) of populations. Moreover, they are a preliminary to all programs of experimental cytogenetics leading to a modification of the karyotype.

The present studies are on perfecting techniques that do not require the killing of the animal. Leucocyte culture techniques have been shown to be adequate and are now used for several species of the genus Tilapia and for Salmo gairdneri.

#### Experimental cytogenetics

The use of these methods (gynogenesis by inactivation of sperm, polyploidisation of species or of hybrids) can yield original material which can be used directly in aquaculture (inbred lines, monosex populations, sterile triploids, allotetraploids).

The program now in progress on gynogenesis in rainbow trout is split into these phases:

- inactivation of sperm and haploid gynogenesis
- spontaneous or induced diploid regulation
- obtaining triploids.

## SHELLFISH

Short time aims for the genetic program on shellfish include the following points:

- 1) intraspecific variations in natural and reared populations of flat and concave oysters.
- 2) interspecific variations in different shellfish species, especially oysters.
- 3) acquisition of specific genetic characteristics (resistance to Marteiliae refringens) for a definite oyster population.

Concerning point 1 and 2, during the first trials the electrophoretic technique (polyacrylamidegel) has been improved in order to distinguish between electrophoretic patterns of muscle protein of Crassostrea angulata, C. gigas and C. commercialis. Protein polymorphisms were discovered in C. gigas and C. angulata. The frequency distributions of the phenotypes were in accordance with expected Hardy-Weinbergs distributions thus indicating a simple Mendelian genetic mechanism. Also very clear differences were observed between C. commercialis on one side and C. gigas and C. angulata on the other side. These studies will be extended to studies on serum proteins and enzymes.

Long time aims are experiments on selection and crossbreeding. These experiments are planned upon request from oyster farmers. The purposes are to improve the growth rate and meat and shell quality of the oysters, and also to search for strains which are resistant to diseases. For these reasons rearing experiments with flat and concave oysters will be conducted. The studies will be based on intraspecific variations in different strains, on the performance of the oysters in different areas of France, and on the different traits mentioned above. These observations will make it possible to draw a map of the different oyster population in the coast of France where also the principal environmental components (topography, temperature, salinity etc.) will appear.

6. GERMANY, DEMOCRATIC REPUBLIC OF - -

No activities reported.

7. GERMANY, FEDERAL REPUBLIC OF - -

(information by Th. Neudecker).

There have been no studies in the past and no studies are planned which are directly devoted to genetics in mariculture. As the level of development of mariculture in this country is low, there are no special needs for immediate genetic research, and the facilities for genetic studies are not yet available.

There are, however, some technique and skills available at research institutes that might be of importance to genetic studies, for instance cryopreservation of gametes. In oysters, Crassostrea gigas, data are being collected on the biological performance of imported stocks in German waters which may be used as guidelines for future genetic work.

Basic research on genetics is being done at some universities on aquarain fish and freshwater fish. The results of these studies are believed to be very useful and the technique may also be directly applied to future genetic studies in mariculture. Likewise, different lines of trout are kept at inland institutes which could be used for genetic studies.

8. ICELAND

No activities reported.

9. IRELAND

GENETICS OF CULTIVABLE MARINE MOLLUSCS

Prof. N.P. Wilkins, Department of Zoology, University College, Galway.

A research team at the Department of Zoology, University College, Galway, National University of Ireland, is currently undertaking a programme of research on the genetics of aquatic organisms amenable to artificial cultivation on a commercial scale. The Department has dry laboratories and computer facilities at the main campus in Galway and an extensive pilot scale hatchery and wet laboratory complex at Carna, about 50 miles away. The genetics programme, which is funded by the

Irish National Board for Science and Technology, is being carried out by a core staff of six scientists, with student and technician assistance, and in co-operation with the staff of the Carna hatchery and the staffs of other private and semistate fish and shellfish farms.

Genetic studies on mollusca are concentrated on marine species, including Bivalvia and Gastropoda, and they encompass three major project areas:

1. An analysis of the heritability of commercially important metrical traits in oysters, Ostrea edulis, and clams, Tapes decussatus, and the design and advancement of a selection programme for the genetic improvement of the European oyster.
2. An analysis of biochemical genetic variability and its adaptive, ecological and physiological significance in wild and hatchery-produced stock of various species.
3. An analysis of the karyotype and of karyotypic variability in wild and hatchery produced stocks of species of actual or potential importance in aquaculture.

Activities in these three project areas are co-ordinated and integrated as far as possible. Details of the various project areas are given on separate forms. The overall aim of the integrated programme is to provide accurate information on the genetics of cultivable species and to apply this information in the improvement of national shellfish resources and the advancement of the aquaculture industry.

#### ANALYSIS OF METRICAL CHARACTERS IN THE EUROPEAN OYSTER

##### OSTREA EDULIS

Dr. G.A.T. Mahon, Department of Zoology, University College, Galway.

The aim of the initial experiments is to rear a sufficient number of families of O. edulis, each family being of sufficient size to provide the basis for a first generation of selective breeding.

The minimum number of families can be shown to be 40. To measure the heritability of a trait like larval survival, family size should be no less than 5000; to discriminate among families

for a trait like growth rate to commercial size, family size should be not less than 700.

With the aim of finishing 40 full-sib families, 100 pairs of oysters will be obtained from researchers and commercial growers. Three suppliers will be chosen who produce oysters in widely separated areas with different environments. Each supplier will be asked to supply 40 good, vigorous oysters.

Containers of 5 liter capacity will be used to hold pairs of oysters until larvae are released. The water surface in each container will be examined morning and evening for the release of larvae. Each larval group released will be reared to settlement in a separate 50 liter plastic container. The number of larvae will initially be adjusted with a view to obtaining 8000 settled larvae per group. The number of surviving larvae per container will be counted every four days. (40 containers are envisaged).

Settled spat will be grown in the hatchery on settlement surfaces in bins to a size (perhaps 4 mm.) at which they can be put in the sea with a reasonable chance of over-wintering successfully. Spat will be regularly measured for size and scored for survival frequency. When large enough, spat will be removed from settlement surfaces, divided into subgroups, and dispatched to sites in the open sea. Each family will be represented twice at each site. The sites will be those used by the producers from whom the original parents were obtained. Each subgroup will be measured at 4 month intervals (thinning as necessary) until the oysters are of sale-able size.

Data on various growth and commercial traits will be collected throughout the whole experiment and analysed to determine heritability. Subsequent selection will be based on the performance characteristics of the different families.

#### INVESTIGATION OF SHELLFISH CHROMOSOMES

Eleanor Moynihan M.Sc., Zoology Department, University College, Galway.

The work aims to provide information on the number, karyotype

and variability of chromosomes in Irish populations (both wild and hatchery produced) of commercially important bivalve molluscs.

Chromosome preparations are made by two methods:

- 1) Squash treatment of unfertilized and newly fertilized eggs, stained with aceto-carmin or aceto-orcin.
- 2) Heat-dried spreads of cell suspensions prepared from testis, stained with Giemsa.

Preliminary results have been obtained for a number of species - flat oyster Ostrea edulis (L), the Pacific oyster, Crassostrea gigas (Thunberg), the scallop Pecten maximus (L.), and the variegated scallop Chlamys varia (L.).

Attempts to band chromosomes in these species have so far been unsuccessful.

#### BIOCHEMICAL GENETICS OF SHELLFISH

Dr. Elizabeth Gosling, Zoology Department, University College, Galway.

#### General

This work involves the measurement of genetic variability in wild populations of shellfish and in hatchery produced stock; investigation of the correlation between ecological variability and genetic variability; analysis of the effect of differing enzyme genotypes on growth and survival.

#### Specific projects

Ostrea edulis - the European oyster.

Natural populations of the native oyster are being analysed from selected commercially important sites to determine whether there are genetic differences between these populations. In addition, genetic variability is being compared between wild and hatchery produced O. edulis. It is hoped to determine whether genetic variants at specific enzyme loci can be used subsequently as

~~markers~~ to distinguish between members of different families of O. edulis reared en masse under hatchery conditions.

Crossostrea gigas - the Pacific oyster.

C. gigas in Europe are all bred from individuals either imported directly from Japan or from Japan via Canada. The extent of genetic variability at approximately 30 loci is well documented for native Japanese C. gigas. An analysis of genetic variability at these loci at present underway in hatchery produced C. gigas in Ireland will presumably illustrate the founder effect i.e. reduced genetic variability in this species produced as a result of hatchery production - the oysters in the hatchery representing only a small portion of the genetic variability present in the wild parent population.

Mytilus edulis - the edible mussel.

Analysis of genetic variability in this species has been underway since 1975 with the co-operation of personnel involved in raft culture of mussels in the Galway area. Each year samples are collected from the main June settlement of young mussels and are compared with values for recruits collected in this region since 1975. Regular sampling within single year classes of mussels suggests that the proportions of certain enzyme genotypes change as a population ages - this could be of important commercial significance. This year it is hoped to determine whether allele frequency at specific loci in settling spat is constant over the whole settlement period from May to October i.e. do individuals of some enzyme genotypes preferentially spawn early in the breeding season and those of other enzyme genotypes later on.

#### 10. NETHERLAND

No studies in genetics related to mariculture is carried out at the moment, but genetic studies on carp and other freshwater fishes are conducted by the organization Improvement Inland Fisheries, Nieuwegein.

## 11. NORWAY

Experiments on selective breeding are carried out at two institutions in Norway; The Department of Animal Genetics and Breeding, Agricultural University of Norway, Ås and the Institute of Marine Research, Directorate of Fisheries, Bergen. The practical experiments are carried out at research stations and at commercial fish farms. Mainly Atlantic salmon and rainbow trout are concerned.

Breeding experiments were started about 1970, to evaluate the potential for selective breeding in salmonids. First it was necessary to study the genetic and phenotypic parameters for the characters of largest economic value. The results have demonstrated that, for Atlantic salmon and rainbow trout, there exists a large genetic variation in growth rate and age at sexual maturation; a moderate amount of genetic variation in survival, resistance against disease, meat quality characters and digestibility of food; and possibly a low genetic variation in condition factor.

Inbreeding and crossbreeding experiments have shown that there is some non-additive genetic variance in some characters. However, it is not quite clear what emphasis should be put on crossbreeding in a future selection programme.

An extensive selection programme is carried out in Atlantic salmon and rainbow trout at Sunndalsøra, Averøy and in cooperation with several private farms. The base population of Atlantic salmon was sampled from 40 different Norwegian strains. Each year about 200 full-sib families are tested from hatching to maturation. Selection is based on individual performance and records from full- and half-sib families. The following characters are taken into consideration: Growth rate prior to maturation, survival, meat quality and age at maturation. For rainbow trout, the selection programme is similar, and about 150 families are tested each year. The progress made during the first years of selection is very promising.

Experiments on induced polyploid to obtain sterile fish are also carried out at Sunndalsøra.

At the Institute of Marine Research, Bergen, similar experiments are carried out, but due to detection of IPN virus in the material in 1977, the experiments had to be discontinued and started again with new material in 1978. Selection experiments are now under way, and

in addition to the program for intensive fish farming purpose, we hope to look for genetic variation in survival and return rate in connection with a sea ranching program.

12. POLAND

No information received.

13. PORTUGAL

No activities

14. SPAIN

No activities

15. SWEDEN (information by L. Nyman).

In 1980 Sweden organized a Steering Committee on aquaculture with the aim of coordinating and simplifying future development within the entire field of aquaculture activities in this country. The Steering Committee (chaired by Hans Ackefors) later organized seven working groups with different responsibilities. One of the groups was given instructions which are highly relevant to ICES Working Group on Genetics, viz. to consider the biological/genetical, economic and practical aspects of fish culture. Already this summer the working group will give recommendations to the Steering Committee concerning a national policy for breeding techniques hopefully compatible with both genetic and economic prerequisites. It goes without saying that we will try to follow earlier international recommendations as closely as possible. All types of fish culture will be considered, e.g. food fish production, fish raised for restocking purposes in natural and rotenonetreated lakes and also the preservation of endangered stocks. Since most mariculture activities in Sweden are centered on food fish/shellfish production we feel that few innovative recommendations will be justified, considering the fairly good availability of brood fish. However, for the salmonid species considerable changes are expected.

It should also be noted that the present activities in the field of genetic work on fish in this country are limited to a few species of salmonid fish like salmon, brown trout/sea trout and Artic char. Two groups of scientists account for the bulk of research, viz. the Department of Genetics at the University of Stockholm and the Institute of Freshwater Research at Drottningholm.

16. UNITED KINGDOM (report by C.E. Purdom)

Government research in fish cultivation is spread over three geographic areas:

England and Wales: Ministry of Agriculture, Fisheries and Food.  
MAFF. Laboratories at: Lowestoft (Husbrandry)  
Weymouth (Disease)  
Conny (Shellfish)

Scotland: Department of Agriculture and Fisheries for Scotland.  
DAFS. Laboratories at: Aberdeen (general)  
Pitlochry (Salmon)

Ireland: Department of Agriculture for Northern Ireland, DANI  
Laboratory at Colerain  
Fish farm at Movanagher

Non-government research is conducted by the White Fish Authority, Sterling University, The University of Asters, Plymouth Polytechnic and a number of other institutions with minor interest. None of their work is genetic. The principle genetic work is undertaken by MAFF with lesser involvement by DAFS and DANI.

Genetic studies in aquaculture by MAFF. The programme began in 1966 with ad hoc facilities, but a planned experimental farm was conceived in 1972 and is due to be constructed 1981-1982. Preparation for a comprehensive genetics programme with those species of fish and shellfish of relevance to the U.K. began in 1974 with progressive development up to the construction of the experimental farm. The species of interest are: rainbow trout, sea trout, cod, sole, oysters and lobsters. Of these, the only ones currently used widely for aquaculture are rainbow trout and oysters.

Rainbow trout. The long term aim is to establish a variety of strains with a wide range of spawning seasons to encompass all U.K. needs for egg supplies. Individual strains are to be evaluated for performance in a number of ways outside spawning time. Electrophoretic analysis of isozyme polymorphism and allele frequency is being conducted to establish (1) the distinctness of strains and

(2) the extent of heterozygosity and hence the degree of inbreeding.

Gynogenesis is being used to analyse recombination frequency and to accelerate the development of inbred material. Line breeding of 10 strains of rainbow trout, one strain of steelhead trout and one strain of sea trout is established, and addition to the brood stock collection will be made when facilities permit and will include Atlantic salmon, coho salmon and additional rainbow trout of summer spawning types.

F<sub>1</sub>-hybrid rainbow trout are being evaluated and reciprocal-recurrent selection trials for heterosis will be established. The correlated phenomena of inbreeding depression and heterosis will be studied. It seems likely that a F<sub>1</sub>-hybrid type production system will be the most rational procedure for fish farmers to adapt in future, in line with poultry breeding strategy.

Selection programmes are being conducted for further spread of spawning time and for egg size.

Growth rate aspects of strains are being assessed by the measurement of the growth rate of alevins during the yolk sac absorption phase.

Short term aims with rainbow trout include the control of sex ratio which has now been established for some of our strains and is in commercial use, and genetic sterility by the production of triploid fish. The production of triploid trout has been accomplished during the past year but techniques are not yet ready for commercial application.

Studies with triploids suggest that the triploid female is the most suitable type for practical use. In intensive farming, such fish are likely to be sterile and show no secondary sexual characters. Triploid males may show secondary sexual characters and may be more useful for "ranching" than triploid females because they will be reproductively incompetent but stimulated to return migrations. Non indigenous species introduction could be made safe by the use of triploid male and female fish. Safety could also be achieved by the use of female only fish (diploids) providing that males are entirely absent.

Sea trout + steelhead trout

These breeds are maintained for future sea ranching trials. Salmon are of lower priority in the east coast of England than in Scotland or Wales but ranching of trout is attractive because of the relative short migration phases which can be accommodated within the North Sea. Sea trout is "difficult", and studies on the effect of "domestication" are being conducted. Steelhead (anadromous rainbow trout) are less difficult and may represent a non-indigenous species with good economic prospects and low ecological threats. Rainbow trout do not, with rare and doubtful exceptions, breed in U.K. conditions.

Turbot. Pilot scale commercial farming excersis are now under way for this species. Short term genetic studies include the development of female only breeds (female grow more quickly than males) and the use of triploids to enhance, by sterelity, the growth of the fish.

Hybridization of turbot with brill is also studied. This hybrid of either reciprocal type, is more viable than either of the straight rossès , turbot or brill, a form of hybrid vigor which has no easy explanation. Most individuals are sterile females. A few partially fertile males occur and these could be used for the development of introgressed hybrids with more or less, turbot as opposed to brill genetic content.

Sex control of turbot is being studied. It seems possible that the heterogametic sex in flatfish is the female (as opposed to the situation in trout) but all-female (best) or all males broods ought to be feasible. Survival rates of hybrids to metamorphosis are 30-60% compared to 1-2% for turbot or brill. Short term genetic manipulation of cod and sole is feasible, i.e., sex control or gynogenesis, should either of these species be- cause of economic importance for farming.

Oysters. Two species are of promising importance, Ostrea edulis and Crassostrea gigas. The former, our native oyster, is difficult to rear, and present research is directed towards creating a reliable rearing technique. Some attention will be paid to hybridization with a related species, O. lutaria, which is an import from New Zealand which apparently has established itself

sub-littorally. Spat from O. lutaria settle quickly so it, or its hybrids, might be useful where natural settlement adjacent to laid stocks is desirable. Pacific oysters, C. gigas do not reproduce in U.K. waters. They are therefore dependent on hatchery production, but because this is relatively easy, they are the best oysters for domestication and, hence, for genetic manipulation. Several strains of C. gigas are held and their evaluation together with  $F_1$  hybrids is under study. In-breeding (family, line breeding) is being done with crossbreeding to establish the value of crossbreeding and heterosis. Between -species hybrids are also being studied (C. angulata X C. gigas) in conjunction with cross-breeds with flat oysters.

Lobsters. Trials with ~~European~~ lobsters, Homarus homarus, for complete cultivation have proved unacceptable on economic grounds. Trials are now proposed for sea ranching. Hybrids of H. homarus and H. americanus are being studied for use in "ranching" on East coast sites of England and offshore islands of Scotland.

DAFS. Genetic research is being performed on sex-ratio control in salmon. Further genetic studies are proposed but lack of an experimental site is holding these up.

DANI. Some "local" rainbow trout strains are maintained for use in neighbouring fish farms. Efforts are being made to breed "cobolt-blue" trout - a condition associated with hypothalamus malformation with some, perhaps complex, genetic background.

17. USA

(Report by Arlene Longwell)

PROPOSED AND ONGOING RESEARCH

A requirement of the U.S. Aquaculture Bill was the preparation of species plans for the various aquaculture organisms, as agreed upon by academic and government researchers and commercial interests. These plans have been formulated. Special breeding and genetic studies were implicated in the plans for all the following species: salmon, trout, oyster, the hard clam (Mercenaria), abalone, Macrobrachium, crayfish, and brine shrimp. In both trout and salmon, concern was expressed about adverse effects of released stocks on natural stocks. A need was noted for genetic counsellors for salmonid commercial interests.

One of the recommendations to come out of a recent review of the U.S. Sea Grant Program was the need to develop long-term genetics and selective breeding programs of sufficient scope to produce special strains of salmon, shrimp, Malaysian prawns, and oysters. This came from a desire to move from the "green thumb" approach of aquaculture to more sophisticated operations of modern agribusinesses. The belief was expressed that continued reliance on wild stocks will severely limit opportunities to increase yields in aquaculture systems.

The U.S. research currently being supported on aquatic species extends from the quite fundamental to efforts at developing strains of restricted use in particular locales or environments. There seems to be an appreciation of the value of inbred lines in research, and the necessity for strain evaluation of species as trout and catfish. There is a growing interest in the genetics of food conversion efficiency in fish, difficult as such studies may be, and possibilities of effective selective breeding for such.

CURRENT AND PLANNED GENETIC STUDIES RELEVANT TO MARICULTURE IN THE U.S.

Various breeding and genetic projects, encompassing rather standard selection and hybridization approaches, stock evaluation, efforts at establishment of new stock, sex control, and more fundamental

studies, are currently being supported or have recently been reported in a number of states and in a few federal laboratories. These are identified below as follows according to culture group. Because freshwater species will inevitably for some time be looked to for information of use in the breeding and genetics of marine species, relevant projects on these are included. Cryo-preservation projects are noted because of the implications of successful gamete and zygote preservation for aquaculture breeding. Information was made available from the U.S. Sea Grant Program, the National Marine Fisheries Service, the U.S. Department of the Interior, and the U.S. Department of Agriculture. More specific information on these researches, and names of investigators are obtainable from the U.S. Mariculture Committee members.

## SHELLFISH

### Oyster

Demonstration of the value of genetics in molluscan culture studies (University of Washington).

Breed the fourth generation of America oysters selected for resistance to the MSX disease caused by Minchinia nelsoni infections (Rutgers University).

On the American oyster, 2-way selection experiment for post-settling growth rate; development and study of inbred lines; geographic and inter-species hybridizations (Northeast Fisheries Center, Milford, Conn., Laboratory).

### Hard clam

Biochemical genetic and breeding structure of natural populations of hard clams (South Carolina Consortium, Virginia Institute of Marine Science, and University of Georgia).

### Abalone

Assessment of sperm-egg interactions during fertilization and hybridization of the California abalone (University of California).

## CRUSTACEANS

Assess amount of biochemical genetic variation within and between wildcaught stocks of culturable marine crustaceans; develop lobster and shrimp broodstock in which the mating system can be demonstrated with biochemical genetic markers; estimate heritability of growth in laboratory-reared family groups (U. California).

In vitro fertilization and hybridization of the Malaysian prawn (South Carolina Sea Grant Consortium).

An evaluation of the nutritional value of three selected strains in finfish culture (U. Rhode Island).

## SEAWEEEDS

Application of genetic studies to production of the seaweed, Chondrus crispus (U. Maine and U. New Hampshire).

## SALMONIDS

### Salmon

Coho salmon stock development for marine pen culture (U. Washington). Genetic interaction of Auke Creek, Alaska, hatchery pink salmon with natural spawning stocks (U. Alaska). Stock development for pen culture and natural enhancement (U. Washington and Oregon State University).

### Rainbow trout

Development of improved rainbow trout broodstock through strain hybridization; development of improved rainbow trout broodstock through hybridization of highly inbred lines; development and maintenance of a trout strain registry; thorough biochemical (electrophoretic) characterization of fish strains define relative amounts of inbreeding in tested populations, characterize the strains, and evaluate the degree of relatedness between strains. The strain characterization also includes lake trout, striped bass, Atlantic salmon, and channel catfish (U.S. Dept. Interior, Fish and Wildlife Service).

### Brook trout

Development of strains suitable for survival in waters impacted by acid precipitation; estimation of heritability of tolerance to a challenge in acid brook water; extensive field testing of two wild x New York domestic strains (Cornell U.).

An investigation of the genetic impact of stocking a wild brook trout population using electrophoretic analyses (Iowa State U.). Induced polyploidy in brook trout (U. Rhode Island).

In brook trout and lake x brook hybrids determinations of soluble protein types, their genetic bases, genetic linkage and cytogenetic relations, and pleiotropic effects; also the banding pattern of chromosomes. Use of these genetic traits in differentiating strains of trout. Study of the chromosomes of normal and sex-reversed fish with the intention of relating findings to studies of the evolution of trout genomes (Pennsylvania State U.).

### FRESHWATER FISH

#### Catfish

An evaluation of channel catfish strains from widely divergent areas (Texas A and M University).

Heritability estimates of growth in channel catfish (Mississippi State U.).

Two-way selection between and within families of channel catfish for 40-week body weight and growth uniformity; development of inbred lines in an evaluation of inbreeding depression (Georgia Coastal Plain Experiment Station).

Replicated experiments to test diets against growth rate in four strains of channel catfish (Kansas State U.).

Crossbreeding of strains and evaluation of the hybrid strains of channel catfish (Louisiana State U.).

Establishment of a northern Michigan ecotype broodstock of a warm water channel catfish with concomitant selection for disease resistance,

rapid uniform growth, and efficient food conversion (Michigan State U.).

Heritability and correlation estimates in channel catfish for head width, head depth, fork length, total weight, and dress-out weight for 30, 60, 90, 120, 150, and 480 days (Mississippi State U.).

Crossbreeding of populations of channel catfish from geographically isolated sources, testing of crossbreds among blue, channel, and white catfish (Auburn U.).

#### Tilapia

Crossbreeding between species of Tilapia to produce all-male broods; heritability estimates by half-sib analysis for length and weight in Tilapia nilotica from Africa (Auburn U.).

Evaluation of various species and monosex hybrids (U. Puerto Rico).

#### Striped bass

An evaluation of striped bass-white perch hybrids (with a determination of food preference of hybrid larvae) for use in aquaculture (U. North Carolina).

#### Yellow perch

Selection of yellow perch and other cool water species for adaptation to hatchery operations (U. Wisconsin).

Control of sexual differentiation (U. Wisconsin).

#### CRYOPRESERVATION

Of pike, trout, salmon and muskellunge sperm, eggs, and zygotes (U. Minnesota).

Of striped bass sperm (North Carolina State U.).

Of yellow perch sperm (U. Wisconsin).

#### U.S. AQUACULTURE DATA RESOURCE BANK

It has been recommended (Natl. Res. Council Rept., Role of the

U.S. Department of Agriculture in Aquaculture, 1979) that a central data resource in the National Technical Information Systems of the Science and Education Administration collect, collate, and disseminate aquaculture data, and provide aquaculturists with information. This would be on production, research, marketing, supply and price data, regulations, and consumer information. As of May 1981, this recommendation was being acted on.

18. USSR

No information.