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REPORT OF THE WORKING GROUP ON GENETICS, 1982

Galway, Ireland, 30 March, 1 and 3 April 1982

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REPORT OF THE WORKING GROUP ON GENETICS

1. PARTICIPANTS

The ICES Working Group on Genetics met in Galway, Ireland, on 30 March, 1 and 3 April 1982. The meeting was arranged in connection with the International Symposium on Genetics in Aquaculture arranged at the same place from 28 March to 2 April. The following appointed members were present:

B. Chevassus, France
H. Grizel, "
A. Longwell, U.S.A.
D. Møller, Norway (chairman of Mariculture Committee)
G. Newkirk, Canada
G. Nævdal, Norway, chairman
L. Nyman, Sweden
C. Purdom, U.K.
R.L. Saunders, Canada

At the first day of the meeting (30 March) some of the participants at the Symposium (from ICES member countries) were present to be informed about the objectivities and activities of the ICES Working Group on Genetics.

Dr. H.R. Henderson, FAO, attended the first day of the Working Group meeting. He presented the report: FAO/UNEP, 1981, Conservation of the genetic resources in fish; problems and recommendations. Report of the Expert Consultation on the genetic resources of fish. Rome, 9-13 June 1980. FAO Fish. Tech. Pap., (217): 43 p.

2. TERMS OF REFERENCE AND ITEMS FOR THE MEETING

At the 1981 Statutory Meeting it was decided (C.Res. 1981/2:19) that:

> "the Working Group on Genetics should meet for three days immediately after the 1982 COST Symposium on Mariculture Genetics in Galway, Ireland, in March 1982, in order to discuss factors influencing efficient selection for growth rate such as food conversion efficiencies, social interactions, stocking densities, feed and feeding techniques and schedules."

At the Statutory Meeting there also were some discussion whether genetics of natural populations should be included in the general terms of reference for the Working Group. No decisions were made, but the Working Group decided to discuss this further at the meeting in Galway. The group also found it necessary to discuss and evaluate as far as possible any information which we found relevant and important enough to bring to the attention of the Mariculture Committee. The Symposium papers are listed, Appendix I. In the text the Symposium papers are referred to by numbers.

Based upon these considerations, the following list of items was put up:

Factors influencing efficient selection for growth rate

Other items concerning genetics in culture stocks

Broadening of the Working Group of references to include genetics of natural populations (management)

Strategy and next meeting (items, place, date, chairman etc.).

3. <u>FACTORS INFLUENCING EFFICIENT SELECTION FOR GROWTH RATE</u>

(Consideration of the Working Group and insight from Symposium papers and discussion)

Growth rate of fish and shellfish is a very important production trait in aquaculture. High variations are seen within most species used for intensive aquaculture, and the idea of genetic improvement by selecting brood stock is nearly as old as the aquaculture itself. Growth rate, however, is a complicated process influenced both by genetic and environmental factors.

Experiments especially designed to reveal the genetic variation in growth capacity of fish have been carried out by several institutions during the last ten years, and also considerable work has been done on shellfish. Gjedrem (15) reviewed this work for the Symposium, and he also listed genetic parameters concerning other productive traits. From this review it appears that there is considerable genetic variation for growth in aquaculture species. The estimates of heritability (the proportion of the phenotypic variation which is controlled by additive genetic factors), however, differ greatly among the different studies and the different species, and several of the estimates are based on rather limited material, particularly in oysters and other shellfish. Due to the high fecundity of most species used in aquaculture, it is possible to have a higher selection intensity than in less fecund species, and this may in part overcome rather low heritabilities. The importance of family selection was also stressed by Gjedrem (15) referring a.o. to Falconer (1960). Figure 1, reproduced from Falconer (1960), shows that regardless of the value of heritability, combination of individual and family selection is more effective than either of the two methods practised alone. Especially when heritability is low to moderately high, family selection is much more effective than individual selection.

The Working Group in its 1981 report discussed growth rate and concluded that experiments specially designed to study growth rate and its interaction with environmental and other factors, will be very valuable in understanding and utilizing the pronounced variation observed in this trait.

The terms of reference for the 1982 meeting further stress complications of the growth process. The different sub-items reflect much of the disagreement which evidently excist concerning growth rate, and the genetic control of this trait.

Food conversion efficiency. Conserning this item an important paper was presented at the Symposium by Kinghorn (21). He reported on an experiment especially designed to measure food conversion efficiency indirectly by measuring energy metabolism (via oxygen consumed) and the energy component of growth in rainbow trout. There were high correlations (phenotypic and genotypic) between food consumed and growth rate. Food conversion efficiency consequently showed a low coefficient of variation and very low heritability.

From these experiments it seems reasonable to conclude that at the time being, food conversion efficiency cannot be efficiently included in selection programmes on rainbow trout. Growth rate in contrast seems to be highly correlated with food consumed, and at the moment the best way of measuring it seems to be to measure growth rate directly. However, further development of systems for direct or indirect measurements of food consumed should be given high priority (recommendation 2).

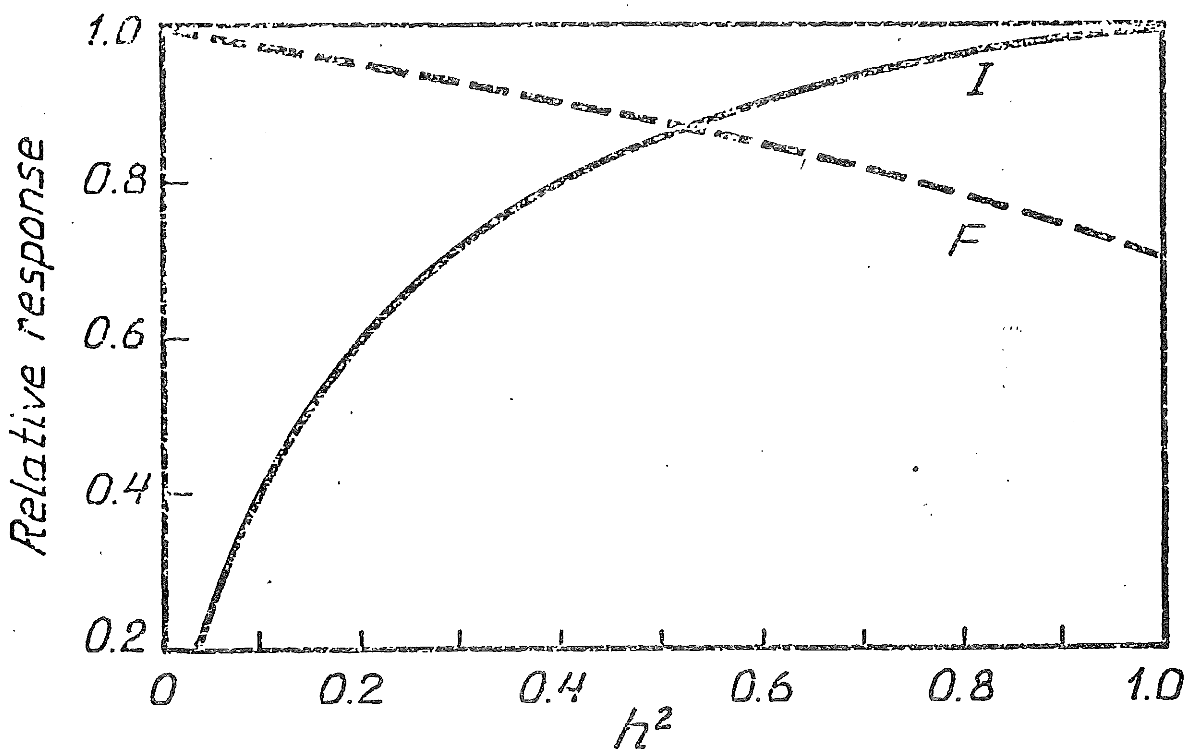

FIGURE 1. Relative merit of fullsib family (F) selection compared with individual (I) selection. Number per family is infinite and there is no variance due to common environment (Falconer, 1960).

<u>Social interaction in finfish, stocking density, feed and feeding technique and schedules.</u>

It is well known that in a group of fish some grow better than others due to the phenomen of social hierarchy. It is not entirely clear nor is there agreement as to the influence of this on selection efficiency for growth rate. Wohlfart and Moav (1969) found no indication of presence of competition (agressiveness) genetically independent of yield capacity, in experiments with carp stocks kept in separate and communal ponds.

The results presented by Busack (23) on selection for body weight in the mosquitofish, <u>Gambusia affinis</u>, are also interesting. He states: "Although a selection response was achieved, the average weight of all lines decreased over 40% during the experiment. A similar decline was observed in the proportion of male fish mature at 56 days of age. The cause of this decline in performance is unclear; a genetic competition model is presented as a possible explanation. Under this model, fish exhibiting superior performance in early generations do so because they possess genotypes for competitive advantage in genetically heterogeneous groups, but possess genotypes for poor performance in homogeneous groups. As selection proceeds, the population becomes more homogeneous; competition and performance decrease." These results may be representative also for aquaculture species.

Similarly, it is well known that stocking density influences significantly the growth rate of fish and shellfish possibly also influencing the strength of the social hierarchy in fish, although no linear relationship between growth rate and stocking densities seems to exist. Wohlfarth, Moav and Hulata (40), at the Symposium presented data that showed that the Chinese carp is dominant over the European carp in poor environment (high density, low feeding rate) while in a good environment the European is dominant, and in intermediate environments the inter racial crossbred is overdominant. Refstie and Kittelsen (1978) found a clear effect of densities on presmolt growth of salmon. They also found significant interaction (P<0.0) between strain and density for length and weight, indicating that some wild strain will be more suitable than others for high density culture.

Experience with higher vertebrates indicates that domestication often results in great increases in genetic variance. Fish at various stages of domestication, and possibly even over generations of a selection experiment, will respond differently if growth is a factor influenced by the domestication process. A reduction in the social hierarchy of fish on domestication would influence, of course, the effects of competition and stock density where they are significant factors. (One effect of domestication in higher vertebrates is the loss or breakdown of the social hierarchies of the wild species, reduced competitiveness, and dependence on man for an overabundance of food.) Doyle (38) at the Symposium presented data which showed that management procedure have strong selective effect and that genetic change may be expected to occur rapidly.

Although there are few known results and the interpretations may be questioned, it seems reasonable to take factors as density, feed and feeding techniques and schedules into consideration when ranking families or strains for growth performance in selective breeding experiments. New experiments on this topic are needed, conf. the 1981 Working Group report (recommendation no.2).

Particularly as stock density, feeding rates and schedules may influence social interaction of fish, husbandry practices ought to be detailed in the report of results of genetic experiments; that is, of course, in addition to the founding stock and size and background insofar as it is known, which should influence heritability, selection progress, and ultimate gain.

To minimize the influence of non-genetic factors selection in general should be based on size measurements taken close to the time of marketing the animals. As far as possible the use of correlated traits should be avoided. The experimental animals should be tested in the same type of environment as in which the production will take place to avoid genotype-environmental interaction. In conclusion selection for improving growth rate in fish and shellfish is recommended (recommendation no. 1) to complement good, well-established husbandry practices.

4. OTHER ITEMS CONCERNING GENETICS IN CULTURED STOCKS TAKEN UP AT THE SYMPOSIUM.

Chromosome engineering

At the Symposium several paper were presented dealing with various types of chromosome engineering. The Working Group briefly discussed such methods in its 1981 report, and continued the discussion on the 1982 meeting on basis of the Symposium papers.

Gynogenesis (parthenogenetic development of eggs after activation by genetically inert spermatozoa) has the theoretical potential of enabling one to circumvent generations of inbreeding and achieve highly inbred lines for selection and hybridization in one generation.

In fish, the technical aspects of induced gynogenesis appear to be reasonably well-worked out. This is not so for the invertebrate species, the eggs of which are usually spawned at a different stage of meiotic development than are finfish eggs.

There is no model from which fish breeders can gain insight on the relative advantages (and surely some disadvantages) of gynogenetic breeding as opposed to more conventional breeding plans. Also, relatively little is known of the performance characteristics of highly inbred fish. Without doubt, gynogenesis will be a powerful tool in developing the basic research of fish species of aquaculture importance.

Polyploidy (produced by treating newly fertilized eggs by physical or chemical treatments) seems to be easy to be obtained in several fish and shellfish species and could supply an interesting solving for the problem of sterilization. Preliminiary results concerning tetraploidy were reported but the evaluation of the viability, stability and fertility of those animals is still to be done.

Sex reversal, produced by hormonal treatment, can produce all female populations, either directly by feeding the fingerlings with the hormone or, better, indirectly by producing functional males from genetic females; those males leading to the obtention of 100 per cent females in their progenies.

Chromosome engineering will probably find significant use in commercial breeding in some conjunction or other with other methods of selection and hybridization (as when, for example, fast growth and early maturation are highly correlated, selection for the former and induced gynogenesis in selected females for induction of sterility). The main direct advantage of gynogenesis in breeding would appear to be in rapid development of highly inbred lines for hybrid production, but there are other uses as to produce fertile hybrids of otherwise sterile crosses. However, general evaluation of the methods for mariculture use seems impractical at the moment (see p.13 and recommendation no.5 c).

Genetics in shellfish cultures.

Molluscs

A general consideration on genetic research in oyster breeding was given by the Working Group in the 1981 report. At the Symposium, several papers dealing with oysters and other molluscs were presented. The following conclusions, partly also expressed in the 1981 report, were drawn from the presentation.

a. Selection for improved growth rate in oysters may be successful.
b. There is a positive correlation between heterozygosity (genetic variability) and economic traits (especially growth rate) in some shellfish.

c. Polyploid individuals showed only small differences in performance compared to normal diploids. The differences observed could be explained by heterosis due to increased heterozygosity in polyploid individuals.

Hybrid vigor was observed when crossing two species of clams (Mercenaria) (13).

Crustaceans

Crustacean aquaculture genetics was reviewed by Malecha (53). This review pointed out that the number of genetic studies in crustaceans is quite limited. Reference was made to two other current reviews which summarize most of this research to 1981. The majority of the work has been done on the biochemical genetics and color polymorphisms of Artemia. Very few papers of these publications deal with genetic variance or hybridization, and there are no published studies on selection responses.

The cytogenetics of crustaceans is reasonably well worked out. Genetic and sex determination are treated in separate chapters in the book "Biology of Crustaceans" to be published by Academic Press. Sex reversal is possible in crustaceans following surgical procedures so that physiological females are obtainable from genetic males, and vice versa, as in fish, with attendant advantages in certain breeding programs. Artificial inseminations is also possible. A keynote paper dealing with the genetics of domestication (38) described some initial experimental findings on the marine copepod Gammarus, and explored theoretical possibilities using this copepod as a model. The thesis of the presentation was an effort to understand the role of natural selection on which the aquaculturist imposes his own efforts at selection when a wild organism is bred continously from generation to generation and becomes adapted to the conditions of artificial culture.

Among the constraints on breeding of commersial crustaceans, using Macrobrachium rosenbergii as an example, the reviewer of the crustacean section of the symposium listed cumbersome life cycles, inability to make pair matings at will, and the relatively undeveloped stage of the crustacean culture industry.

U.S. work on the lobster (Homarus americanus) (Hedgecock, 24) has encompassed a range of research - isoenzymes as markers, hybridization and quantitive genetics - but mainly emphasizes the importance of gaining better control over the life cycle and improved technology for economic rearing under standardized conditions essential for good genetic analyses of quantitive traits. An expanding industry should have some interest in improved brood stocks.

The joint Japanese-Irish study (Kittaka, Chida and Mercer, 14) evaluated performance of the interspecific hybrid between the European and American lobster (H.gammarus and H.americanus) under culture conditions at Katasato University, Japan. In all larval phases studied the hybrid performed better. In terms of survival and growth to one year the hybrid performed at least as well as the better parental species.

An Italian study (Sbordoni et al, 7) was presented on biochemical genetic differences between two species of penaeid shrimp (Penaeus kerathurus and P. japonicus) fished commercially, and also employed in experimental culture systems. Estimates of genetic variability in the two species differed largely, with P. japonicus having relatively high level of genetic variation.

5. BROADENING OF THE WORKING GROUPS TERMS OF REFERENCE TO INCLUDE GENETICS OF NATURAL POPULATIONS (MANAGEMENT).

The basis of the Working Group on genetics was an ICES Study Group on Genetics. In its report (Svanøy, Norway, 1981) this group recommended that the Working Group should be established. The Study Group recommended that this group should be concerned both with genetics in aquaculture and genetics in management. By genetics in management was meant identification and delineation of natural population units and identification and conservation of genetic resources. However, when the Working Group on Genetics was established, only genetics in mariculture was included in the terms of reference. At the Consultative Committee meeting at the Statutory Meeting in autumn 1981, interest in genetics in natural populations, especially herring stocks, was expressed, but no decisions were made. The Anadromous and Catadromous Fish Committee in their 1981 report requested that the Report of the Working Group should be coded for reference to that committee.

The Working Group again discussed broadening of the terms of reference at the Galway meeting. The reasons for including genetics of natural stocks are:

a. a great member of papers appear each year on genetic variations, mostly biochemical genetic markers, within and between populations of commercial fish and shellfish. Although the results are of much significance for management, the interpretations are often difficult. General evaluation of this literature is demanding.

b. There seems to be a growing interest in identification and recognition of the significance of genetic resources. To evaluate reasons and methods for conservation of such resources refer to the report worked out by the expert group appointed by FAO (Conservation of the Genetic Resources of Fish, FAO Fisheries Technical Paper No. 217, Rome 1981).

c. Genetics of cultured and natural stocks are closely related which leads to:

   i: natural genetic variation is the basis for genetic programmes when wild organisms are used as founding stocks for aquaculture programs.

   ii: development of culture based fisheries, release of young fish for enhancement purpose as well as involuntary escapement of cultured organisms can under some circumstances influence the composition of natural gene pools.

The Working Group found again that there were sufficient reasons to include genetics of natural stocks into its general terms of reference, and a recommendation on that point (recommendation no.4) was formulated.

The Group also found that a reasonable point to start would be to make an account of ongoing work concerned with genetics in natural populations of commercially important species in the ICES member countries. A great part of the work would have to be carried out by correspondance because many of the ICES member countries are not represented in the Working Group. A second consideration would be an evaluation of the interdependence of natural and cultured populations in respect of their gene pools and genetic variation (recommendation no.5d). The effect of deliberate or natural selection in hatcheries on the fish performance in Nature, must also be considered. These are proposed as items for the next meeting along with others.

6. FURTHER PLANS OF THE WORKING GROUP AND PROPOSAL FOR A 1983 MEETING.

The Working Group discussed the next meeting and items for that meeting. In the 1981 report it was recommended to meet in Lowestoft in 1983. It was agreed to repeat this recommendation (recommendation no.5).

Several items for the next meeting were discussed (recommendation no.5 a-e). If genetics of natural populations is included in the general terms of reference of the Working Group, it seems reasonable to start with an account of ongoing research in the ICES member countries concerning genetics relevant to management and conservation of genetic resources. Likewise it seems reasonable to update the account made in 1981 concerning genetics in aquaculture. Because all member countries are not represented in the Working Group, these accounts must partly be compiled by correspondence.

Another item for discussion would be the mutual influence of natural and cultured populations. Cultured populations (especially those resulting from semiculture) may have severe impact on the genotypes of natural populations. In addition preservation of natural genetic variation is of importance for future development of cultured stocks. Probably, it is not likely that this item can be completely evaluated at the next proposed meeting. However, the Working Group considers it important to begin focusing on this matters and have a provisional discussion (recommendation no.5 d).

Evaluation of methods of chromosome engineering for aquaculture use seems important, and the Working Group considered that at least one day of the next meeting should be a workshop to sum up the ongoing research on such methods and their application in practical aquaculture. To this workshop specialists outside the Working Group and also from countries outside ICES should be invited, and reports and review articles should be published in an international journal (recommendation no.5 c).

Finally, the Working Group at its next meeting would like to consider new research methods on genetics relative to applications in aquaculture and evaluate such for the ICES committees (recommendation no.5 e).

7. RECOMMENDATIONS

1. Genetic selection for improved growth rate for fish and shellfish in aquaculture is recommended. Carefully planned selection experiments with appropriate control populations should elucidate results generation to generation.
2. New experiments and development of new methods for evaluation of genetic variations of food conversion efficiency, and influence of social interaction (stocking densities etc.) and husbandry practise on efficiency of selection experiments should be given high priority.
3. Further research on the significance of natural genetic variation (biochemical genetics etc.) for aquaculture purpose is recommended. If possible such variation should be correlated with variations in productive traits.
4. The ICES Working Group on Genetics should have genetics of natural populations included in their general terms of reference.
5. The ICES Working Group on Genetics should meet for three days in late April 1983 in Lowestoft, England, to:

   a. Update the account of activities in the field of genetics in aquaculture in the ICES member countries.
   b. Work out a similar account on activities concerning genetics in natural fish and shellfish populations.
   c. Arrange a one day workshop on practical use of chromosome engineering in aquaculture. If possible specialists outside the Working Group and the ICES member countries should be invited.
   d. Consider the mutual influence of aquaculture and management of natural populations on gene pools and genetic resources.
   e. Discuss and evaluate for the Mariculture Committee any new approaches in aquaculture genetics.

REFERENCES

(other than presented at the Symposium)

Falconer, D.S. 1960. Introduction to quantitative genetics. Oliver and Boyd, Edinburg. 365 pp.

Wohlfarth, G.W. and Moav, R. 1969. The genetic correlation of growth rate with and without competitin in carp. Verh.Internat.Verein.Limnol., 17: 702-704.

Refstie, T. and Kittelsen, A. 1976. Effect of density on growth and survival of artificially reared Atlantic salmon. Aquaculture, 8: 319-326.

Appendix I

List of papers given at the
International Symposium on Genetics in Aquaculture
University College, Galway, Ireland
March 29th to April 2nd, 1982

1. N.Ryman. Distribution of biochemical genetic variation in different salmonid species.

2. A.Ferguson, J.B.Taggart, T.Henry and W.W.Crozier. Genetic variation in the brown trout, Salmo trutta L.

3. G. Ståhl. An estimate of the amount and distribution of genetic variation in Atlantic salmon (Salmo salar) in northern europe.

4. B.J.McAndrew and K.C.Majumdar. Tilapia stock identification using electrophoretic markers.

5. L.A.Beltchenko and V.I.Glazko. Analysis of genetic structure of two populations of Carassius auratus gibelio and Carassius carassius.

6. J.M.Macaranas and L.C.Bentitez. Developmental Genetics of Lactate Dehydrogenase Isozymes in Siganus guttatus.

7. V.Sbordoni, G.Allegrucci, A.Caccone, D.Cesaroni, M.Cobolli Sbordoni, E.De Matthaeis. Genetic differentiation between Penaeus kerathurus and P.japonicus (Crustacea, Decapoda).

8. E.Zouros, D.W.Foltz, A.Mallet and G.Newkirk. Allozyme variation in oysters: to be or not to be a heterozygote.

9. L.J.Lester. Genetic analysis of Partially Controlled Breeding Systems.

10. B.Chevassus. Hybridization in fishes.

11. T.Refstie. Hybrids between salmonid species. Growth rate and survival in seawater.

12. G.Hulata and G.Wohlfarth. Progeny-testing selection of tilapia broodstocks producing all-male hybrid progenies.

13. W.Menzel. Observations on hybridization and selection in Quahog clams.

14. J. Kittaka, N. Chida and J.P. Mercer. Biological characteristics of Homarus hybrids in Aquaculture.

15. T. Gjedrem. Genetic variation in quantitative traits in fishes.

16. J.E. Thorpe, R.I.G. Morgan, C. Talbot and M.S. Miles. Inheritance of developmental rates in Atlantic salmon, Salmo salar, L.

17. B. Gjerde. Response to individual selection for age at sexual maturity in Atlantic salmon.

18. R.L. Saunders and E.B. Henderson. Genotypic-environmental interaction in the timing of sexual maturation in Atlantic salmon (Salmo salar).

19. S.M. Hurley and C.B. Schom. Genetic and environmental components of swimming Stamina in Atlantic Salmon.

20. B. Ayles and R. Baker. Genetic differences in growth and survival between strains of rainbow trout (Salmo gairdneri) stocked in aquaculture lakes in the Canadian prairies.

21. B. Kinghorn. Genetic parameters of Food Conversion Efficiency and Growth in Young Rainbow trout.

22. D. Linder, K. Nyholm and S. Sirkkomaa. Genetic and phenotypic variation in production traits in rainbow trout strain crosses in Finland.

23. K. Bondari. Response to bidirectional selection for body weight in channel catfish.

24. C.A. Busack. Four generations of selection for high 56-day body weight in the mosquitofish (Gambusia affinis)

25. D. Hedgecock. Genetics and broodstock development of the Lobster Homarus.

26. L.M. Finley & L.E. Haley. The genetics of Aggression in the Juvenils American Lobster - Homarus americanus.

27. S.R. Malecha, S. Masuno and D. Onizuka. Feasibility of Measuring the Genetic Control of Growth Pattern Variation in the Cultured Freshwater Prawn, Macrobrachium rosenbergii (de Man): Juvenile Growth.

28. L.J. Lester. Developing a Selective Breeding Program for Penaeid Shrimp Mariculture.

29. G.F. Newkirk. Selection for Growth rate in the European oyster, Ostrea edulis.

30. G.A.T. Mahon. Selection goals in oyster breeding.

31. H.L. Kincaid. Inbreeding in fish populations used for aquaculture.

32. D. Thompson. The efficiency of induced diploid gynogenesis in inbreeding.

33. T.F. Cross and J. King. Genetic effects of hatchery rearing in Atlantic salmon.

34. A. Mallet. Genetics of growth traits in the oyster, Crassostrea virginica.

35. F. Yamazaki. Sex control and manipulation in fish.

36. R.F. Lincoln and P.A. Hardiman. The production and growth of female diploid and triploid rainbow trout.

37. G.A. Huner and E.M. Donaldson. Demonstration of male heterogamety in Coho salmon: implications for the production of all-female stocks for aquaculture and resource enhancement.

38. W.E. Calhoun and W.L. Shelton. Progency sex ratios mass spawnings of sex-reversed broodstock of Tilapia nilotica.

39. R.W. Doyle. Quantitative analysis of domestication selection.

40. R.K. Koehn and S.E. Shumway. Metabolic energy demand, Genetic variation and aquaculture.

41. G.W. Wohlfarth, R. Moav and G. Hulata. A genotype-environment interaction for growth rate in the common carp, Growing un intensively manured ponos.

42. I. Balakhnin. On the role of genotype in fish resistence to invasion.

43. R.O. Smitherman, R.A. Dunham and D. Tave. Review of catfish breeding research at Auburn University.

44. R.A. Dunham and R.O. Smitherman. Response to selection and realized heritability for body weight of channel catfish, Ictalurus punctatus.

45. L. Siitonen, D. Linder, U. Lindstrøm and O. Sumari. A comparison of the growth traits of ten rainbow trout stocks; preliminary results.

46. G. Nævdal. Genetic factors in connection with age at maturation.

47. C.E. Purdom. Genetic engineering by the manipulation of chromosomes.

48. E.P. Moynihan and G.A.T. Mahon. Quantitative karyotype analysis in Bivalve molluscs.

49. J.G. Stanley, S.K. Allen and H. Hidu. Growth fertility, and heterozygosity in triploid shellfish.

50. S.K. Allen. Flow cytometry: Assaying experimental polyploid fish and shellfish.

51. M.U.Patwary and J.P.van der Meer. Improvement of Gracilaria tikvahiae, through genetic modification of thallus morphology.

52. J.P.van der Meer and M.U.Patwary. Genetic modification of Gracilaria tikvahiae. The production and evaluation of polyploids.

53. S.R.Malecha. Crustacean aquaculture genetics.