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RESEARCH ON QUANTITATIVE GENETICS ON SALMONIDS IN NORWAY

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ABSTRACT

Studies on quantitative genetics in aquaculture are carried out by two institutions in Norway. The main purpose of these studies is to form the basis of a strategy for genetic improvement of salmonids for fish farming. In the present report an account of the experiments is given, including aim of the studies, size of experiments, preliminary results and future objectives. All experiments are carried out on salmonids.

## INTRODUCTION

Farming of salmonids has become increasingly popular in Norway during the last 10-15 years, and in 1978 about 5000 tons were produced mostly in enclosures and net pens in the sea. The potential, however, is much greater than this, and a considerable increase in the quantities produced is expected.

Studies on quantitative variation in traits of productive importance in fish farming were started in the late 60's. Experiments were conducted on rainbow trout, Salmo gairdneri, Atlantic salmon, Salmo salar, and occasionally on sea trout, S. trutta, arctic char, Salvelinus alpinus and on crosses of all the above. Most emphasis, however, has been laid upon Atlantic salmon.

The main purpose of these studies was to form the basis of a strategy for genetic improvement of farmed salmonids. A second aim was to learn more about genetic variation of quantitative characters in fish in general, and in this respect the salmonids were to be regarded as experimental fish. Most emphasis is laid upon characters of economic value.

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.

In the present report accounts of the experimental work carried out by both institutions are given. Results of the experiments until now are published elsewhere, and the main intention of the present report is to give a situation report of the experiments on quantitative genetics related to aquaculture in Norway. The research is supported by the Norwegian government, Agricultural Research Council and Fisheries Research Council.

DEPARTMENT OF ANIMAL GENETICS AND BREEDING

Breeding experiments were started in the late 60's at the Research Station for Salmonids, Averøy and Sunndalsøra units, Department of Animal Genetics and Breeding, Agricultural University of Norway, 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. A series of papers has been published on this matter (Aulstad et al. 1972, Gjedrem and Aulstad 1974, Kanis et al. 1976, Refstie et al. 1977, Gjedrem and Gunnes 1978, Gunnes and Gjedrem 1978, Refstie and Steine 1978, Gunnes and Gjedrem 1979, Refstie 1979). These 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 a very low genetic variation in condition factor.

Inbreeding and crossbreeding experiments have shown that there is some non-additive genetic variance in some characters (Aulstad and Kittelsen 1971, Aulstad et al. 1972 and Gunnes and Gjedrem 1979). 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.

Reciprocal crosses between different salmonid species have been made. The cross between Atlantic salmon and Arctic char shows good promise for commercial culture (Refstie and Gjedrem 1975).

Several techniques, including manipulation of chromosome number, have been tried to produce sterile fish (Lincoln et al. 1974 and Refstie et al. 1977). Finally, we succeeded in producing tetraploid rainbow trout (having four sets of chromosomes instead of the normal two), by treating newly-fertilized eggs with the drug cytochalasin B. By fertilizing eggs of normal fish with sperm from tetraploids, we hope to be able to produce sterile triploids which could be grown larger than ordinary trout.

In fish farming, survival frequency is very important economically. However, recording resistance to a disease, such as vibriosis, as dead or alive, is not satisfactory for selective purposes. An investigation has therefore been started at Sunndalsøra to study the genetic variation in vibrio antibody concentration in rainbow trout.

In 1977, funds was made available to establish a salmon egg-bank. This has three objectives:

- ⊙ Production of eggs from selected salmon families and strains for commercial farming.
- ⊙ Production of eggs of distinct salmon strains from individual rivers to supplement wild populations in those rivers.
- ⊙ Preservation of salmon strains which are threatened with extinction.

Egg hatching and smolt production is carried out at Sunndalsøra, but production of brood fish for future supply of eggs is at Averøy and Svanøy (Svanøy Foundation, Fish Farm).

The members of the egg bank get annual delivery of an agreed amount of eggs of their local salmon strain. To establish a salmon strain in the egg bank, a small quantity of eggs from the river must be sent to Sunndalsøra for 3-4 years.

INSTITUTE OF MARINE RESEARCH

Fertilized salmon eggs were collected from 8 Norwegian rivers and a few fish farms each autumn from 1971 to 1975. In 1971 eggs from two Canadian and one Swedish river were also sampled. The year-classes were named according to the year of hatching. Part of the 1976 and the whole 1977 year class were based on selected parent fish from the 1972 and 1973 year-classes.

Likewise, fertilized eggs of rainbow trout were collected from commercial farms each winter from 1972. The 1975, 1976 and 1977 year-classes were based on selected parent fish from the first two year-classes.

Experiments in the fresh water stage are carried out at the research station Akvakulturstasjonen Matre, except from November 1977 to August 1978 when part of the material was kept at a provisional field station because IPN (Infectious Pancreatic Necrosis) virus was detected at Matre (see later). Experiments in the seawater phase are carried out at commercial fish farms, and, from 1978, partly at the research station Akvakulsturstasjonen Austevoll.

In autumn 1977 IPN virus was discovered among the research fish. IPN was until then not registered in Norway, and, in order to prevent further spreading of the virus. The experiments had to be discontinued. The fish were not allowed, by the veterinary authorities, to be used as brood stock for the new generations.

However, the adolescent fish were allowed to be reared to normal slaughtering age at certain fish farms. These fish were the offspring of selected parents, and thus they may give valuable data on the effect of selection so far. Thus despite the interruption, these experiments can be of value for future studies, although they cannot give practical results in form of improved brood stock.

After the detection of IPN virus, the experiments were started again with new base material, which was kept at a provisional hatchery and reading station until the research station was disinfected and kept empty for one month. In August 1978 the new material was brought to Matre.

Each year-class consists of about 40 full sib families of salmon and about 20 full sib families of rainbow trout.

In addition to IPN (which in fact has caused very little mortality), vibriosis has been a common disease and has caused heavy mortality in some year-classes. Also, accidents with the water supply or quality have occasionally reduced numbers. A series of reports on the results to date has been published (Møller et al. 1976, Nævdal et al. 1975, a,b, 1976, 1977, 1978 a,b,c). Variation in growth rate and age at first sexual maturity have been most investigated, and in both these traits large genetic variation was found. It is a general impression that the brood stock of salmonids, used in the Norwegian fish farming industry, vary widely in value. In rainbow trout, a clear connection was found between age at maturation and size. Preliminary selection experiments with rainbow trout gave promising results, but unfortunately they had to be interrupted due to the IPN virus.

Of the hybrids tested, crosses between Artic char and salmon, and possibly between salmon and brown trout, seemed promising, but the hybridization experiments had to be postponed due to a lack of capacity.

It was intended to study the variation in return rate after liberation of salmon smolt (sea ranching), starting with two year smolt of the 1976 year-class. However, due to the IPN virus, these experiments are still not under way.

REFERENCES

- Aulstad, D. and Kittelsen, A. 1971. Abnormal body curvatures of rainbow trout (Salmo gairdneri) in inbred fry. J.Fish.Res.Bd. Canada 28:1918-1920.
- Aulstad, D., Gjedrem, T. and Skjervold, H. 1972. Genetic and environmental sources of variation in length and weight of rainbow trout (Salmo gairdneri) J.Fish.Res.Bd.Canada 29:237-241.
- Gjedrem, T. and Aulstad, D. 1974. Selection experiments with salmon. I. Differences in resistance to vibrio disease of salmo parr (Salmo salar). Aquaculture 3: 51-59.
- Gjedrem, T. and Gunnes, K. 1978. Comparison of growth rate in Atlantic salmon, pink salmon, Arctic char, sea trout and rainbow trout under Norwegian farming conditions. Aquaculture 13: 135-141.
- Gunnes, K. and Gjedrem, T. 1978. Selection experiments with salmon IV. Growth of Atlantic salmon during two years in the sea. Aquaculture 15: 19-33.
- Gunnes, K. and Gjedrem, T. 1979. A genetic analysis of body weight and length in rainbow trout reared in seawater for 18 months. Aquaculture (in press).
- Gunnes, K. and Gjedrem, T. 1979. Effect of inbreeding of growth and mortality in rainbow trout. Aquaculture (in press).
- Kanis, E., Refstie, T. and Gjedrem, T. 1976. A genetic analysis of egg, alevin and fry mortality in salmon (Salmo salar), sea trout (Salmo trutta) and rainbow trout (Salmo gairdneri). Aquaculture 8:259-268.
- Lincoln, R.F., Aulstad, D. and Grammeltvedt, A. 1974. Attempted triploid induction in Atlantic salmon (salmo salar) using cold shocks. Aquaculture 4: 287-297.
- Møller, D., Nævdal, G., Holm, M. and Lerøy, R. 1976. Variation in growth rate and age at sexual maturity in rainbow trout. FAO Technical Conference in Aquaculture. Kyoto, Japan 1976. (E:61) 1-7.
- Nævdal, G., Holm, M., Møller, D. and Østhus, O.D. 1975 a. Experiments with selective breeding of Atlantic salmon. Coun.Meet. ICES 1975. (M:22):1-9.
- Nævdal, G., Holm, M., Lerøy, R. and Møller, D. 1975 b. Variation in age at sexual maturity in rainbow trout. Coun.Meet. ICES 1975. (M:23) 1-7.
- Nævdal, G., Holm, M., Møller, D. and Østhus, O.D. 1976. Variation in growth rate and age at sexual maturity in Atlantic salmon. Coun. Meet. ICES 1976. (E:40) 1-10.

- Nævdal, G., Holm, M., Lerøy, R. and Møller, D. 1978 a. Individual growth rate and age at first sexual maturity in Atlantic salmon. Fisk.Dir. Ser.HavUnders., 16: 519-529.
- Nævdal, G., Holm, M., Ingebrigtsen, O. and Møller, D. 1978 b. Variation in age at first spawning in Atlantic salmon (Salmo salar) J.Fish.Res.Bd. Can. 35: 145-147.
- Nævdal, G., Holm, M., Lerøy, R. and Møller, D. 1978 c. Individual growth rate and age at sexual maturity in rainbow trout. Coun.Meet. ICES 1978 (F:22) 1-14.
- Nævdal, G., Bjerke, Ø., Holm, M., Lerøy, R. and Møller, D. 1978 d. Growth rate and age at sexual maturity of Atlantic salmon smoltifying at one and two years of age. Coun.Meet. ICES 1978 (F:23) 1-10.
- Refstie, T. 1979. Genetic and environmental sources of variation in body weight and length of rainbow trout fingerlings. Aquaculture (in press).
- Refstie, T. and Gjedrem, T. 1975. Hybrids between salmonidae species, hatchability and growth rate in the freshwater period. Aquaculture 6: 333-342.
- Refstie, T. and Steine, T. 1978. Selection experiments with salmon. II. Genetic and environmental sources of variation in length and weight of Atlantic salmon in the fresh water phase. Aquaculture 14: 221-234.
- Refstie, T., Steine, T. and Gjedrem, T. 1977. Selection experiments with salmon. II. Proportion of Atlantic salmon smoltifying at one year old. Aquaculture 10: 231-242.
- Refstie, T., Vassvik, V. and Gjedrem, T. 1977. Induction of polyploidy in salmonids by cytochalasin B. Aquaculture 10: 65-74.