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VARIATION IN GROWTH RATE AND AGE AT FIRST MATURATION IN RAINBOW TROUT

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ABSTRACT

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The present report is an account of the main results of a series of experiments on selective breeding of rainbow trout. The experiments started in 1972, but were discontinued in 1979 because IPN virus was detected in the material.

Growth rate and age at first sexual maturity were the main factors studied. Full sib and half sib correlations as well as parent/offspring correlations were applied. The results were not always conclusive because the different year classes gave somewhat different results. However, sib correlations indicated control by additive genetic factors for at least part of the variation in growth rate. This was also confirmed by the parent/offspring results.

Both additive and non-additive genetic factors were indicated as controlling the variation in age at first maturation. No effect of the age of first maturation of the individual parent fish could be found among the offspring, but there was a clear effect of the mean maturation age of the parent sib group on the maturation age of the offspring group.

INTRODUCTION

Farming of rainbow trout, *Salmo gairdneri,* has had growing interest in Norway during the last 25 years. Contrary to the West European fish farmers producing «pansize» rainbow trout, the Norwegians produce «salmon-like» rainbow trout, i.e. fish of individual weights of more than 1.5, often up to 3 or 4 kg.

The Norwegian-farmed rainbow trout originally came from Denmark. For several generations now, mass selection for high growth rate and high age at first maturation has been carried out by the fish farmers, but due to lack of unselected material for control, the effect of this selection is unknown.

Sexual maturity at early age or at small size is a serious drawback for production of large rainbow trout because maturation retards the growth rate of the fish and often causes increased mortality. For farming of rainbow trout, significant improvements would be higher mean growth rate and higher mean age at first maturation. The present investigations were planned to study the genetic part of the variations in the mentioned traits and use the results to produce an improved brood stock for fish farming.

The experiments started with collection of eggs in winter 1972 parallel to similar experiments on Atlantic salmon (NÆVDAL *et al.* 1978 a, b). Most emphasis was laid on salmon, and consequently the number of experiments each year concerned with rainbow trout was limited to about 20 sib groups.

In autumn 1977 virus of *Infectous pancreatic necrocis* (IPN) was discovered among the material. IPN is not common in Norway, and to prevent spreading of the virus, the experiments were discountinued. However, the adolescent fish at that moment (second generation experimental fish) were allowed to be raised to food fish size at selected fish farms to study the effect of selection, but they were not allowed to be further used as brood stock because IPN virus is easily transferred by the eggs.

This report gives an account of observed variations and evidence for genetic control of growth rate and age of maturation. Part of the results are presented in earlier reports (MØLLER *et al.* 1976, NÆVDAL *et al.* 1975, 1979).

MATERIALS AND METHODS

Egg and milt material was for the experiments mainly obtained from a Norwegian fish farm, Eros Laks, Bjordal, each winter from 1973 to 1975. In 1973 milt from three males from another fish farm, Bolstad Fiskeanlegg, Holdhus, was included, and in 1974 twelve groups of eyed eggs were obtained from the research station Forsøksstasjon for laksefisk, Sunndalsøra, where selective breeding of salmonids is carried out under the auspices of the Agricultural University of Norway. The year classes reared in 1975, 1976 and 1977 were based on selected parent fish from the year classes hatched in 1972 and 1973.

The present experiments are based on sib groups. In the four first year classes both paternal and maternal half sib groups were formed, usually by dividing the egg portion of each female into two equal parts and fertilizing them with milt from two different males. The last two year classes consisted of only paternal half sib groups, formed by using one male for three females.

The eggs were hatched at the hatchery at the research station Akvakulturstasjonen Matre. Except for the first year class, the fish were transferred to floating cages in brackish water when they were about eight months old. When they were 12–14 months old, the fish were transferred to full strength sea water in net pens or sea enclosures at a commercial fish farm. The 1972 year class was not transferred to brackish water until the fish were about 14 months old and to full strength sea water when they were about 20 months old.

At the egg stage and during their first months of life, each group was kept in separate trays or tanks. When the fish were 5–6 months old; they were marked by fin clipping, and several groups were kept together in the same tank. Part of the fish of the 1972 and all of the 1973 year class were individually tagged with Floy Tags (FT4 Spagetti Tag, FT4 Lock-on, FT6 Dart tag or FD67 C Anchor Tags, all from Floy Tag and Mfg., Inc., 4616 Union Bay Pl. N.E., Seattle, Washington 98105, U.S.A.). The technical results of the tagging experiments are dealt with in a separate report (NÆVDAL, HOLM and KNUTSSON 1977). The 1975 and later year classes were marked by cold branding (REFSTIE and AULSTAD 1975).

Some of the sib groups died out during the egg and fry stage. The main causes were partly accidental, i.e. problems with the water supply, and partly an outbreak of vibriosis. Unfortunately, these accidents extinguished groups from several 2 × 2 sets, thus making the material unfit for calculation of male × female interaction.

The total length of 100 or 200 fish was recorded every six months for the first two year classes, later at 12, 24 and about 30 months of age. Weights were recorded at slaughtering for all year classes and at 24 months of age for the 1973 year class. Sexual maturity was recorded during the second and third years of life.

At about 30 months of age, the main part of each group was slaughtered. Of the first three year classes 20–30 fish of each group were selected for brood stock, and the three last year classes were based on these selected fish from the first two year classes. When it was known that the fish could be carriers of IPN virus, the veterinary authorities forbade any further use of them for stock, but adolescent fish were allowed to be raised to normal food fish size at selected fish farms, and data could be collected as before.

RESULTS

VARIATION IN GROWTH RATE

Observations from sib correlations

Marked differences in mean growth rate were observed between sib groups in all year classes. This variation is illustrated in Fig. 1 where mean lengths at each half year of the 1973 year class are shown separately for each sib group. The other year classes showed similar variations. Correlations between length of the individual fish as well as of group means measured at different times are dealt with in an earlier report (NÆVDAL *et al.* 1979). Close connection between growth rate at different age both for individuals and for group means were found except when correlating growth rate during the first months to subsequent growth rate in the sea.

Evidently a significant correlation existed between growth rate and age at maturation as the mean length of fish maturing during their third year were on an average significantly larger than the fish still immature, and on the individually tagged fish this lower mean length could be found even one year before maturation (NÆVDAL *et al.* 1979). Effect of sex on growth rate was insignificant in most groups and in the total material, but in some groups the males were on average bigger than the females.

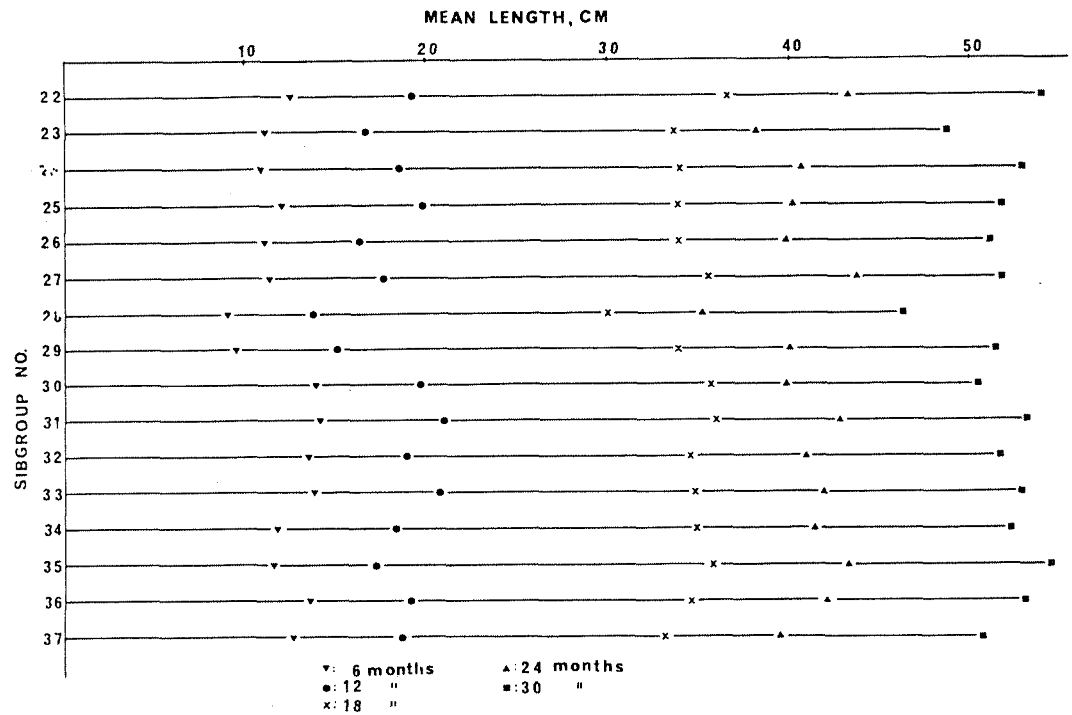

Fig. 1 Mean lengths of sib groups of rainbow trout hatched in 1973.

Calculations on heritability factors were based on half sib and full sib correlations. The results, however, were not very conclusive. The estimated factors varied from zero to about 0.5 and were occasionally even higher, depending on year class and age. On average, estimated factors from 0.2–0.3 were obtained. There was no indication of higher factors based on full sib correlations than on half sib correlations. Non-additive genetic factors contribute more to full sib correlations than to half sib correlations, and thus the present results give no indications of non-additive genetic factors controlling growth rate variations in rainbow trout. In the present study relatively few sib groups were represented in each year class, and thus the confidence limits of the calculated heritability factors were rather wide. Thus sample variations could account for part of the rather inconclusive results.

The estimates of the heritability factors and range of the group of the same year class based on weight and on length were not identical. Also, estimates of heritability factors based on individual condition factors,

$$k = \frac{100 \text{ w (g)},}{1^3 \text{ (cm)}}$$

gave values which were significantly greater than zero. Thus, body shape, which may represent both varying fat content and real height/length differences, seems to be affected by additive genetic factors.

Observation of parent/offspring correlation

The last three year classes were formed from selected parent fish from the first two year classes. Based on evidence from parent/offspring correlations, heritability factors in the same range as when based on sib correlations were obtained, with one exception, because in the 1975 year class no correlations between the size of father and offspring were found. Thus there seems to be favourable indication of control by additive genetic factors on growth rate variations in rainbow trout, and the effect of the selection was clear. Fish of inbred groups showed nearly the same mean growth rate as their non-inbred half sibs, while there was indication of somewhat reduced survival of inbred groups during their first year of life.

VARIATION IN AGE AT FIRST MATURITY

Observations from sib correlations

Preliminary results concerning age at first maturation of rainbow trout have been presented in earlier reports (Nævdal *et al.* 1975, 1979).

In all year classes considerable variation between sib groups was found in the proportion of fish maturing during their second and third years. This is exemplified in Fig. 2 where the results of the 1973 year class are shown. The

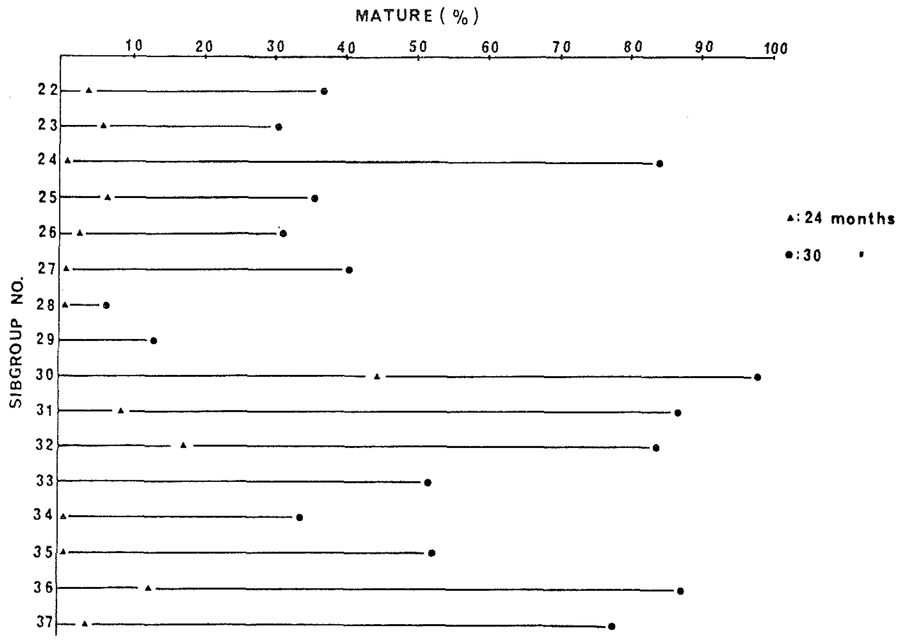

Fig. 2. Proportions of mature rainbow trout during second and third years of life of sib groups hatched in 1973.

other year classes showed similar variations, but usually with lower proportions of fish maturing during their second year. Fish maturing during their second year were, with few exceptions, males.

Heritability factors for proportions of mature fish were calculated from half sib and full sib correlations, (proportions were converted to $\sin^{-1}\sqrt{\text{proportion}}$). Concerning maturation during their second year, most estimates based on half sibs were low (0–0.15) while estimates based on full sibs varied considerably, but were usually high, (0.4–0.5 or even higher). This indicate, that non-additive genetic factors are more important than additive factors for early maturation of rainbow trout, although additive factors may also have some influence.

However, corresponding estimates for proportions of fish maturing during their third year gave higher estimates of heritability factors (mostly in the range 0.2–0.4) based on half sib coorrelations, while based on full sib correlations the estimates were also in the same range, giving no indication of control by non-additive genetic factors.

Part of the parent fish of the last three year classes matured for the first time during their third year and part of them during their fourth year. These two parent categories gave no clear difference in age of maturation of the offspring. However, significant positive correlations were found between proportions of mature fish in the sib groups of the parents and the offspring groups. This concerns both maturation during their second and their third years. These results correspond to the results of the sib correlations as far as maturation during their third year is concerned, but indicate higher values of heritability concerning maturation during their second year.

DISCUSSION

Genetics of rainbow trout have been dealt with by several authors. LEWIS (1944) altered both age of maturation, egg numbers and growth rate of fingerlings during two generations of mass selection of female rainbow trout. SAVOST'YANOVA (1972) and DONALDSON (1959) also reported on alteration of mean age of first maturity by selective breeding. KINCAID *et al.* (1977) reported on high gain in fingerling weight after three generation of selection. AULSTAD *et al.* (1972) reported heritability estimates from 0.01 to 0.29, and likewise CHEVASSUS (1976) found heritability estimates of from 0.045 to 0.375 in growth rate (weight and length) of rainbow trout and a very clear interstrain component of variation.

These examples, together with the results of the present study, show clearly that considerable genetic variations exist in rainbow trout, and although the estimates of heritability factors vary considerably, genetic improvement by selection seems possible, at least concerning growth rate. This is also confirmed by the results of the selection experiments of the present study, where clear effect of growth (size) of the parent fish at 2½ years of age was found in mean size of the offspring groups.

Concerning age at maturation, family selection gave clear results because positive correlations were found between mean maturity age of the parent sib group and the offspring. The effect of the maturity age (2½ or 3½ years) of the individual parent fish and the offspring was not clear in the present material.

Late maturing fish (3½ years or more) showed lower mean growth rate than earlier maturing fish of the same sib group. However, late maturing fish were also found among the fastest growing individuals of the sib groups, and thus the negative correlation between growth rate and age of maturity may be of minor importance for selective breeding.

The estimates of heritability factors are not very conclusive, but in most of the year classes and at most ages rather high factors were indicated in the present study, as well as in other studies reported. However, the high numbers of offspring in fish make it possible to have genetic gain even if the heritability is rather low.

As a conclusion it seems reasonably possible to produce a fast growing, late maturing «salmon-like» rainbow trout for fish farming. Unfortunately, the material of the present study could not be used for further selection experiments because it was infected by IPN virus, and thus could not give any practical results for fish farming. However, similar studies have been started again with new material for the purpose of obtained a rainbow trout better adapted to Norwegian fish farming than the brood stock used today.

The present study gives only little indication of unwanted effects of inbreeding, and no clear indication of such effects is found in the litterature. However, until it is proven that there are no bad effects, inbreeding should be paid attention to and probably avoided in schemes for selective breeding of rainbow trout and in practical fish farming as well.

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