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INDIVIDUAL GROWTH RATE AND AGE AT SEXUAL MATURITY IN RAINBOW TROUT

By

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ABSTRACT

Growth rate and possible connection between growth rate and age at sexual maturity were studied on individually tagged rainbow trout from different sib groups. Great variation in growth rate and age at first sexual maturity were found among different sib groups. Significant correlations were found between size (length) of the individual fish on group mean measured at different time during the sea phase. The mean lengths within groups of fish maturing during their third year of life were significantly higher than for fish still immature in the autumn preceding spawning as well as half a year before and even one year before spawning.

Effect of sex on size of the fish was not clear, but in some groups the males were on average greater than the females. Fish maturing during their second year of life (mostly males) showed nearly the same mean size as immature fish before the spawning season. They grew considerably less during the spawning season (and showed somewhat increased mortality rate) but during next summer they matured again and showed greater relative growth rate than the other fish.

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INTRODUCTION

In two previous reports (Nævdal et. al. 1975, Møller et. al. 1976) tentative results from experiments with selective breeding of rainbow trout, Salmo gairdneri, have been dealt with. The first year class of these experiments hatched in 1972. Since then new material has been collected each year, and gradually more emphasis has been laid upon selected parent fish from the first two year classes.

The first year classes were used to study the variability in traits of economical importance for fish farming, especially growth rate and age at first sexual maturity. The influence of genetic factors on these traits were estimated from full sib and half sib correlations.

Part of the material of the first and second year class were individually tagged. In the present report the data of the individually tagged fish are used to study correlations between growth rates at different ages and the possible connection between growth rate and age at first sexual maturity.

MATERIAL AND METHODS

Egg and milt material for the present experiments were obtained from a commercial Norwegian fish farm in the winters of 1972 and 1973. In 1973 milt from three males from another fish farm was also included.

The experiments were based on sib groups. Normally the egg portion of each female was divided into two equal parts and fertilized with milt from two different males. Each male was normally used for two females. For various reasons, this 2 x 2 pattern of combinations was only partly followed in 1973.

The eggs were hatched at the hatchery at the field research station in Matredal (Akvakulturstasjonen Matre). From start of feeding to an age of 16 months (1972 year class) or 8 months (1973 year class) the fish were kept in 1,7 m^3 cylindrical tanks. Afterwards they were kept in floating cages in brackish waters near the station until they were transferred to full strength sea water. The 1972 yearclass went to a shore enclosure at the fish farm Eros Laks, Bjordal, when the fish were about 18 months, and the 1973 yearclass to floating cages at another fish farm, Risnefisk, Brekke, when the fish were about 14 months old.

During its first year, each group was kept in a separate tank. From about six months of age they were marked with combinations of fin clipping (adipose fin or pelvic fins). In November 1973 about 100 fish of each of eight sib groups of the 1972 year class were individually tagged with different types of Floy Tags (FT 4 Spagetti Tag, FT 4 Lock-on, FT 6 Dart Tag and FD 67C, all from Floy Tag and Mfg., Inc. 4616 Union Bay, Pl.N.E. Seattle, Washington 98105, USA). In April 1975 125 fish from each sib group of the 1973 year class were tagged with FT 4 Lock-on tags.

Due to fouling with mussels and algae, tag losses were heavy after about 6 months, especially the FT 6 Dart Tag gave few data. The results of the tagging experiments and comparisons of the different types of tag are dealt with in a separate report (Nævdal, Holm and Knutsson, 1977).

The length of 100-200 fish of each sib group was recorded in spring and autumn each year. Individual weights were recorded at slaughtering for the 1972 year class and at 24 and 30 months for the 1973 year class. Stage of maturity of the fish was recorded in the autumn and spring the second year, and in the autumn the third year of life. At 30 months of age, most of the fish were slaughtered, while 20-30 individuals of each group were kept alive for producing the F_2-generation.

In the present report data mainly for the individually tagged fish are dealt with. Standard methods of calculating means, correlation coefficients etc. and also of analysis of variance were used.

RESULTS

Growth rate at different ages

Marked differences between sib groups in mean growth rate and age at first sexual maturity were observed. These differences were dealt with in the previous reports (Nævdal et. al. 1975, Møller et. al. 1976). Tentative estimates of heritability factors also gave rather high values.

To compare the growth rate at different ages, correlation and regression factors between mean length for each group at the different measurements were calculated. The results are presented in Table 1 and 2. (Fish maturing during their second year of life were not used in these calculations because maturation greatly affects the growth rate).

Table 1. Correlation coefficients (above diagonal) and coefficient of regression (below diagonal) of mean length of rainbow trout hatched 1972 and measured at five different ages.

Age (in months)	6	12	18	24	30
6	-	0.81	0.67	0.48	0.06
12	1.47	-	0.40	0.25	-0.18
18	1.60	0.55	-	0.79	0.63
24	0.47	0.22	0.50	-	0.74
30	0.16	-0.26	0.61	1.14	-

Table 2. Correlation coefficients (above diagonal) and coefficient of regression (below diagonal) of mean length of rainbow trout hatched 1973 and measured at five different ages.

Age (in months)	6	12	18	24	30
6	-	0.90	0.64	0.73	0.49
12	1.22	-	0.65	0.73	0.59
18	0.66	0.51	-	0.95	0.83
24	0.75	0.64	1.26	-	0.92
30	0.67	0.61	1.10	0.86	-

Correlations were high for observations taken within 6 or 12 months, but rather low for those taken at broader time intervals, especially in the 1973 year class.

To analyse correlation between individual size at different age, the size of the individually tagged fish at the different measurements was compared, Table 3. The coefficients are in the same order of magnitude for individuals as for the sib group means, and for time intervals up to 12 months the correlations are rather high.

Table 3. Correlation coefficients (above diagonal) and coefficient of regression (below diagonal) of lengths and weights of rainbow trout at different ages.

Year class and age	1972			1973			
	length			length		weight	
	18	26	30	24	30	24	30
1972 length 18	-	0.67	0.58	-	-	-	-
" 26	0.77	-	0.86	-	-	-	-
" 30	0.81	1.01	-	-	-	-	-
1973 length 24	-	-	-	-	0.87	-	-
" 30	-	-	-	1.02	-	-	-
1973 weight 24	-	-	-	-	-	-	0.82
" 30	-	-	-	-	-	1.56	-

Relationship of age at first sexual maturity with growth rate.

The fish of each year class were separated according to sib group, sex and age of maturation (maturing in their third year or later), and lengths and weights were subjected to an analysis of variance to see if any of these factors influenced the size at one and a half, two, and two and a half year of age. Early maturing fish (i.e. fish, mostly males, maturing during their second year of life) were omitted from the present analysis because they were rather few in most groups, and because most fish were tagged after the maturation of these males. They are, however, dealt with in a later chapter (p. 6).

The results for the 1972 year class are shown in Tables 4-7.

Table 4. Analysis of variance of rainbow trout two and a half year old.

Source of variation	d.f.	Mean squares	probability
Between sex	1	150.50	$p > 0.2$
Within sex	233		
Between age of maturation	2	229.65	$0.001 < P < 0.01$
Within age of maturation	231		
Between sibgroups	28	40.18	$p < 0.001$
Within sibgroups	203	19.03	
Total	234		

Table 5. Analysis of variance of weight of rainbow trout two and a half year old.

Source of variation	d.f.	Mean squares	probability
Between sex	1	15.15	$p > 0.2$
Within sex	233		
Between age of maturation	2	6.77	$0.001 < P < 0.01$
Within age of maturation	231		
Between sibgroups	28	1.00	$p < 0.001$
Within sibgroups	203	0.31	
Total	234		

Tables 4 and 5 show that whether the fish are maturing or not influence the size in the autumn when the fish are two and a half year old. Maturing fish of both sexes has a somewhat greater mean size than fish that are still immature, and the variations between sib groups are also evident from the original data. No effect of sex could be seen, even when eliminating the variation caused by the two other sources.

Likewise, Tables 6 and 7 show that the effect of group and of age at maturation may be seen both in the spring half a year before maturation and in the autumn one year before maturation. The effect of sibgroups has been found to be clear at all ages (Møller et. al. 1976), and from the present data it is evident that the late maturing fishes, that is those maturing at an age of three and a half or later, show a lower mean growth rate than their early maturing sibs.

Table 6. Analysis of variance of length of rainbow trout two years old.

Source of variation	d.f.	Mean squares	probability
Between sex	1	53.56	$p > 0.2$
Within sex	206		
Between age of maturation	2	96.50	$p \sim 0.05$
Within age of maturation	204		
Between sibgroups	28	30.51	$p < 0.001$
Within sibgroups	176	4.72	
Total	207		

Table 7. Analysis of variance of length of rainbow trout one and a half years old.

Source of variation	d.f.	Mean squares	probability
Between sex	1	4.74	$p > 0.2$
Within sex	166		
Between age of maturation	2	260.27	$p < 0.001$
Within age of maturation	164		
Between sibgroups	27	17.34	$0.01 < P < 0.05$
Within sibgroups	137	8.59	
Total	167		

Corresponding results of the 1973 year class are shown in Tables 8-11. A significant effect both of sib groups and age of maturation could be seen on lengths and weights at slaughtering when the fish were 2½ years old (Tables 8 and 9) and these effects were also evident the preceeding spring (Tables 10 and 11). Also in this year class late maturing fishes showed a lower mean growth rate than their earlier maturing sibs.

Table 8. Analysis of variance of length of rainbow trout two and a half year old.

Source of variation	d.f.	Mean squares	probability
Between sex	1	210.04	$p > 0.2$
Within sex	1288		
Between age of maturation	2	1662.20	$p < 0.001$
Within age of maturation	1286		
Between sibgroups	58	75.86	$p < 0.001$
Within sibgroups	1228	14.80	
Total	1289		

Table 9. Analysis of variance of weight of rainbow trout two and a half year old.

Source of variation	d.f.	Mean squares	probability
Between sex	1	15683.02	$p > 0.2$
Within sex	1288		
Between age of maturation	2	378485.64	$p < 0.001$
Within age of maturation	1286		
Between sibgroups	58	9138.26	$p < 0.001$
Within sibgroups	1228	1297.31	
Total	1289		

Table 10. Analysis of variance of length of rainbow trout two years old.

Source of variation	d.f.	Mean squares	probability
Between sex	1	~0	p > 0.2
Within sex	1285		
Between age of maturation	2	898.0	p < 0.001
Within age of maturation	1283		
Between sibgroups	58	76.14	p < 0.001
Within sibgroups	1225	5.13	
Total	1286		

Table 11. Analysis of variance of weight of rainbow trout two years old.

Source of variation	d.f.	Mean squares	probability
Between sex	1	53 408.59	p > 0.2
Within sex	1284		
Between age of maturation	2	5150 068.05	p < 0.001
Within age of maturation	1282		
Between sibgroups	58	414 705.33	p < 0.001
Within sibgroups	1222	34 518.65	
Total	1285		

Effect of sex could not be seen when analysing the material this way, but when eliminating the effect of sibgroups and age of maturation, a significant effect of sex was found. In the total material the mean sizes of the males were a bit greater than of females, but this sexual dimorphism was more evident within some groups than in others.

Growth rate and survival of the earliest maturing fishes.

In the previous reports (Nævdal et. al. 1975, Møller et. al. 1976) is mentioned that a very clear difference between sibgroups were found concerning proportions of fish maturing in their second year of life (nearly exclusively males). The individual taggings were made when the first maturing fish already were near spawning (1972 year class) or spent (1973 year class). These early maturing fish were eliminated from the material when making the analysis of correlations and variance in the former chapters.

However, especially in the 1973 year class the growth and survival of these early maturing males could be observed from November 1974, when they could be classified as maturing, until slaughtering one year later. Of the 1972 year class only few early maturing fish were tagged and they are omitted here.

Of the early maturing males, all but three surviving fishes were maturing again the next year. The proportions of mature fish in the groups were approximately the same in April -75 as in November -74, indicating that no higher mortality had occurred among mature than among immature fish during the winter. Mature (spent) fish tagged in April -75 showed about 8 per cent lower survival rate until October the same year. This observation is to some extent in contrast to the experience of fish farmers who claim that mature fish show markedly increased mortality during winter and spring.

Observations on growth rate of the early maturing males compared to later maturing fishes are summarized in Table 12. Prior to the spawning season (November 1974) when maturing fish barely could be recognized by visual inspection of live fish, the total means of maturing and immature fish were nearly the same. In April the next year after the spawning season, mature fish were considerably smaller than immature fish, and also at slaughtering next autumn (October 1975) the early maturing fish (now mostly rematuring) were still smaller than fish yet immature or maturing for the first time. But the difference was smaller than in April, and converting the figures to specific growth rate (Weatherly 1972), the rematuring fishes showed the higher specific growth rate during summer, but lower both in the winter period and the total period from November to next October.

DISCUSSION

Koto (1975) found that the mean body length of maturing fish was larger than that of immature fish before the spawning season, while the immature fish grew faster and reached a higher mean length after the spawning season. He also found higher percentage of early maturing males in groups reared with a larger amount of food, but the percentage of mature fishes also seemed to be affected by genetic factors.

In the present investigation it is evident that the percentages of mature fish both in their second and third year of life are affected by genetic factors. This will be more closely dealt with in later reports when similar results from other year classes also will be dealt with. Concerning maturation in their third year of life, the analysis of variance have shown that the mean size of maturing fish is greater than of immature fish, and this difference may be traced back half a year and even one year before onset of maturation.

Difference in growth rate between males and females is more obscure, and seems to be more pronounced in some sib groups than in others. Differences in growth rate between sibgroups are significant, implying that genetic factors are of importance for differences in growth rate. These observations too will be more closely dealt with in later reports.

As observed by Koto (1975) the growth rate of early maturing fish was greatly retarded during the spawning season compared to immature fish. However, after the spawning season, the spent fish showed a higher specific growth rate than the others, and the length difference at slaughtering was less than half a year before. But the early maturing males did not reach the size of the later maturing fish, and thus they are less valuable for fish farming in spite of their rather high growth rate after the spawning season. Thus it seems clear that rainbow trout used for fish farming in Norway is of varying value both concerning their ability of growth and their age at first maturation, implying that selective breeding may give genetic gain which will be of practical interest.

The present data indicated that males maturing in their second year of life, were of the same mean size before onset of maturation as those maturing later. However, maturation was recognized on live fish in November, and at that time the growth rate of maturing fishes could already have been retarded. The present data therefore give no information about whether early maturing fish have a higher mean growth rate during their first year of life, as claimed a.o. by Hallingstad (1978).

Correlations for individual growth rate were found to be significant for measurements up to one year apart (observations of broader time intervals are lacking). High correlation factors were found between measurements taken half a year apart, and thus selection for individual growth rate may be made after at least one sea year.

As far as could be compared, correlations of mean size of sibgroups measured at different ages, were in the same order of magnitude as correlations of individual growth rate. Correlations between the earliest measurements and measurements during the sea period were generally low for the 1972 year class, but somewhat higher for the 1973 year class. As a conclusion it may be said that mean size of the sibgroups after half a year in the sea (18 months of age) may be used as measurement of the groups ability of growth, but size after one year in the sea (24 months of age) or size at slaughtering (30 months of age) should be preferred for selecting fast growing groups.

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Table 12. Growth rate of males maturing at an age of one and a half year compared to later maturing fishes. Number in paranthesis.

$\bar{l}$ = mean length

$$r = \text{(growth rate)} = \frac{\ln \bar{l}_{t2} - \ln \bar{l}_{t1}}{t_2 - t_1}$$

November 74, t_1		April 75, t_2				October 75, t_3					
maturing	immature	mature		immature		rematuring			immature		
$\bar{l}$	$\bar{l}$	$\bar{l}$	$r(t_2-t_1)$	$\bar{l}$	$r(t_2-t_1)$	$\bar{l}$	$r(t_3-t_2)$	$r(t_3-t_1)$	$\bar{l}$	$r(t_3-t_2)$	$r(t_3-t_1)$
34.39 (76)	34.41 (1588)	35.96 (135)	0,89	41.05 (1858)	3,52	48,1 (86)	4.84	3,05	51,62 (1290)	3,81	3,68

t_2-t_1 = 5 months, t_3-t_2 = 6 months, t_3-t_1 = 11 months.