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Survival in Fry and Juvenile Stages of Masu Salmon *Oncorhynchus masou*: Estimates of Heritabilities and Correlations

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A genetic analysis for survival in fry and juvenile stages of masu salmon was described. Data from two year-classes of masu salmon were analyzed to estimate the heritability for survival during the fresh water-rearing period. The overall survival for each year-class during 8 months of freshwater rearing were 17.8 and 11.6%, respectively. Whirling disease virus (WDV) was the main cause of death in all year-classes.

Survival data obtained for offspring of 42 sires and 60 dams of masu salmon (two year classes of data) was analyzed. Average survival rates in the observation period ranged 2-87% for 1994; 0-98% for 1995, respectively. In both year-classes, heritabilities for survival derived from the sire components of variance were low(0.13-0.18), except one. Heritabilities derived from the dam components of variance ranged 0.14-0.61, including non-additive genetic and /or common environmental effects. Correlations between survival in two long-term periods were all positive and medium to high in magnitude (0.345-0.918).

Correlations between survival in non-succeeding periods were, in general, low and insignificant. Correlation between long-term survival and growth rate was found in masu salmon. The corresponding correlation in masu salmon was not significantly different from zero. Correlations between sire survival and body weight, length and condition factor of slaughter were not significant, but varied.

Key words : Masu salmon, *Oncorhynchus masou*, Early survival, Genetic analysis, Heritability, Correlation

Introduction

Any method that may help to increase survival rates of an adromous fish is of interest to public and private hatchery programs because of the associated economic benefits. The economic value of improving early mortality may not justify the selection efforts. However, mortality at later stages can be more important economically and probably deserves more attention.

In general, low additive genetic variance is reported for the early survival traits in salmonid(Ayles, 1974; Kanis et al. , 1976; Gall and Gross, 1978; Robinson and Luempert, 1984). In salmonid farming, a substantial number of incubated eggs are lost during the early freshwater period. It is therefore of interest to know whether early survival traits are influenced by genetic effects and whether they are related genetically. It is also of interest to know their genetic correlations among important traits.

Few studies have been concerned with these

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questions. Robinson and Luempert (1984) found high positive genetic correlations between survival in early periods in brook trout, and reported low positive genetic correlation between weight at 144 days and survival. The proportion of variance in family mean mortality rate that is due to maternal effects (Vm/Vp) in hybrids is high in uneyed eggs (78±22%), and is reduced through eyed eggs (68±24%) to alevins (40±19%)(Ayles, 1974). The residual variation is largely due to additive genetic differences (the heritability of alevin mortality was 41±18%, but this appears to have been overestimated two-fold), which in this case appears to be related to resistance to blue sac disease. Kanis et al. (1976) have estimated the heritability of mortality of eyed eggs at the level of 5-11% (Atlantic salmon), 15-20% (rainbow trout) and mortality of fry at the level of 1-4% (Atlantic salmon), 6-14% (rainbow trout). In the present study, heritability of survival in early and juvenile periods, and correlations between survival in different periods and between survival and growth rate were estimated for masu salmon (*Oncorhynchus masou*).

Materials and Methods

Fish

Thirty experimental families of masu salmon were developed at Faculty of Fisheries, Hokkaido University in 1994 and 1995, respectively, to study the sources of survival such as size, conformation, and growth rate. These fish were described by Choe and Yamazaki (1998). Two systems of fertilization were used in both years. In one system, the eggs from ten females were fertilized separately with sperm from one male to make 10 half-sib families. In the other system, the eggs from each of twenty females were fertilized with sperm from twenty males to make 20 full-sib families. The fertilized eggs were incubated in a 185- ℓ tank. The incubated eggs of each family hatched in November in both 1993 and 1994. Feeding started on January 2, 1994 and December 26, 1994, respectively. In 1994, after feeding for three weeks, 270 randomly chosen fish from 27 families were kept in separate outdoor tanks (550- ℓ) for 4 months in 1994. In 1995, 250 fish from 26 families were randomly chosen and kept under the same conditions as in 1994. The number of fish from the three families with less than 270 fry ranged between 248 and 256 in 1994. In 1995, the number of fish from the four families with less than 250 fry ranged between 60 and 184.

Marking

After 4 months in the outdoor tanks, the fish in each family were marked with fin clips as described by Nielsen (1994) and with colored fluorescent elastomer tags as described by Choe and Yamazaki (1995).

Measurements

The number of fish after 3, 4 and 8 months in fresh water-rearing was used to calculate survival rates. The following traits were studied: survival (%) and body weight, total length after about 4 and 8 months of outdoor rearing.

Growth traits of fish after 3 months of outdoor rearing were not recorded, so analyses on correlation between survival and growth traits were only carried out with 4-and 8-month of outdoor rearing data in both year classes. The number of sires, dams, and individuals used in the analysis are listed in Table 1.

Recorded survival traits (Period I-III) were

Table 1. The number of sires, dams and progenies used in analysis of survival for masu salmon in both years.

Year	Sires	Dams	Progenies
1994	21	30	8100
1995	21	30	7500

defined as survival rates in those periods shown in Fig. 1. Long-term survival was calculated as the survival rate during the whole periods of period I, II and III. For each full-sib family, survival rates were calculated using the number of individuals alive at the end of each period. At the 4 and 8 months after outdoor rearing, all the fishes from each family were measured. The family means of weight and length were used as a parameter of growth.

Analysis

For the purposes of statistical analysis, dead and living fish was assigned scores of 0 and 1, respectively. The analysis of data was carried out by cording method on a within year-class basis.

The following model was used for survival:

$Y_{ij} = \mu + S_i + e_{ij}$

where Y_{ij} is the observation on the j th progeny of the i th mating; μ is the population mean; S_i is the effect of the i th mating; e_{ij} is the residuals associated with the ij th record. Heritabilities and standard errors were estimated on the observed survival trait following the methods Becker (1984) described. The observations for survival were coded as 0 (dead individuals) and 1 (living individuals). Estimates of heritability for growth rate are not presented, as only mean weight for each full- (or half-) sib family was available. Correlation between survival during the freshwater periods and the other traits studied were also estimated. These correlations should be close to the sample genetic correlations where the number of offspring per sire is large, as in the present study.

Results

Phenotypic means

Mortalities during first stage (Period I) and during second stage (Period II) accounted for more than 62, 57 % and 92, 59 % of the total mortalities for 1994 year-class and 1995 year-class, respectively.

Phenotypic means with standard deviations for the observed traits are given in Table 2. The large standard deviations indicate a considerable variation among full- (or half-) sib families within and between years for all survival traits.

Means of cumulative survival rates are shown in Fig. 2, based on daily countings of dead fish collected from outdoor rearing tanks. Mortality was high throughout the outdoor rearing period, with rapid increase during the 4-month

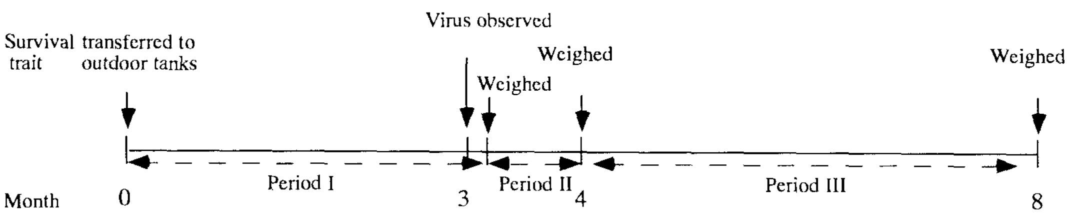

Fig. 1. Recorded survival traits.

Table 2. Phenotypic means(x)[a] and standard deviations (s.d.) within years for the observed traits for two year classes of masu salmon

Year	Period I		Period II		Period III		Period I+II		Period I+II+III	
	x	s.d.	x	s.d.	x	s.d.	x	s.d.	x	s.d.
1994	0.489	0.225	0.494	0.257	0.727	0.336	0.247	0.136	0.178	0.123
1995	0.432	0.243	0.758	0.206	0.362	0.257	0.520	0.236	0.116	0.082

[a]Means and standard deviations are calculated based on the mean values for each full-sib family; Period I=after 3 months of outdoor rering; Period II=from 3 months to 4 months of outdoor rearing; Period III=from 4 months to 8 months of outdoor rearing.

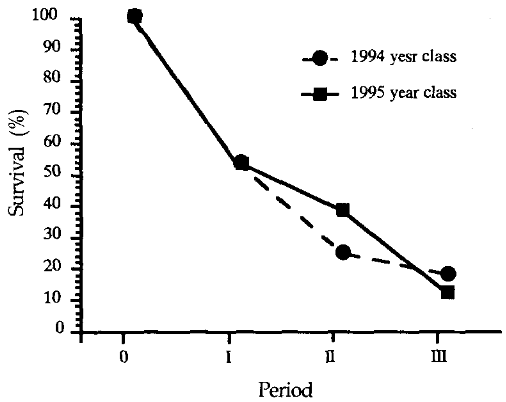

Fig. 2. Survival of masu salmon in outdoor rearing tanks for 1994 and 1995 year classes.

Table 3. Heritabilities(h^4) and standard errors(S.E.) of heritabilities for survival derived from the sire and dam components of variance calculated by coding method

Period* and year class	Sire		Dam	
	h^2	S.E.	h^2	S.E.
I + II				
1994	0.13	0.04	0.40	0.18
1995	0.54	0.13	0.61	0.25
I + II + III				
1994	0.18	0.06	0.30	0.14
1995	0.18	0.06	0.14	0.07

*Peroid I =after 3 months of outdoor rering; Period II=from 3 months to 4 months of outdoor rearing; Period III=from 4 months to 8 months of outdoor rearing.

rearing period.

Heritabilities

Heritabilities for survival within year-classes derived from the sire and dam components of variance are presented in Table 3. In this study, the heritabilities of sire in survival in masu salmon were estimated to be 0.13, 0.54 at the period I+II and 0.18, 0.18 at the period I+II+III in 1994 and 1995, respectively. The heritabilities during the period I+II for the 1994 year-class were lower than for the 1995 year-class. Differences in the estimated heritabilities between the two years may have been influenced by differences in breeding environments and genetic differences in spawners used in the experiments both years. Heritability estimates derived from the dam components of variance were substantially higher than those derived from sire components, and for all periods highest in masu salmon. In additive genetic effects, the dam component of variance also includes possible non-additive genetic effects, maternal effects and tank effects.

Correlations

Table 4 shows correlations of means between survival and growth traits. All the correlations of survival with body weight and length were extremely low. For the 1995 year-class, correlations were negative (-0.355~-0.414). Correlations

Table 4. Correlation of means for survival with total length(T.L.), body weight(B.W.), and condition factor(C.F.) during outdoor-rearing periods for two year classes of masu salmon

Periods*	1994 year class			1995 year class		
	T.L.	B.W.	C.F.	T.L.	B.W.	C.F.
Ⅰ + Ⅱ	0.058	-0.082	-0.460	-0.355	-0.414	-0.202
Ⅰ + Ⅱ + Ⅲ	-0.073	0.101	0.092	0.248	0.277	0.265

P<0.005; *Period Ⅰ =after 3 months of outdoor rering; Period Ⅱ=from 3 months to 4 months of outdoor rearing; Period Ⅲ=from 4 months to 8 months of outdoor rearing.

between means for survival in the different periods are presented in Table 5. Correlations were generally high in both year-classes. In masu salmon, the correlations between survival in two cumulated periods were positive with the range of 0.345~0.918.

Table 5. Correlation between means for survival in the outdoor-rearing periods for two year classes of masu salmon

Periods[1]	Year class	
	1994	1995
Ⅰ / Ⅱ	-0.493	-0.052
Ⅰ / Ⅲ	0.477	-0.465
Ⅱ / Ⅲ	-0.283	-0.101
Ⅰ / Ⅰ + Ⅱ	0.473	0.898*
Ⅱ / Ⅰ + Ⅱ	0.448	-0.193
Ⅲ / Ⅰ + Ⅱ	0.391	-0.433
Ⅰ / Ⅱ + Ⅲ	-0.161	-0.144
Ⅱ / Ⅱ + Ⅲ	-0.806*	0.191
Ⅲ / Ⅱ + Ⅲ	0.148	0.630*
Ⅰ / Ⅰ + Ⅱ + Ⅲ	0.533*	0.286
Ⅱ / Ⅰ + Ⅱ + Ⅲ	0.367	0.166
Ⅲ / Ⅰ + Ⅱ + Ⅲ	0.609*	0.395
Ⅰ + Ⅱ / Ⅰ + Ⅱ + Ⅲ	0.918*	0.345
Ⅱ + Ⅲ / Ⅰ + Ⅱ + Ⅲ	0.682*	0.591*

*P<0.005; [1]Period Ⅰ =after 3 months of outdoor rering; Period Ⅱ=from 3 months to 4 months of outdoor rearing; Period Ⅲ=from 4 months to 8 months of outdoor rearing.

Discussion

The results presented show significant differences between half and full-sib groups of masu salmon in survival during the outdoor rearing period. Heritabilities based on the sire components of variance for survival have been reported early in Atlantic salmon, rainbow trout and sea trout (Kanis et al., 1976) and in brook trout (Robinson and Luempert, 1984). They indicated low additive genetic variance in salmonid, as fitness traits showed low additive variance. Similar results on survival related with specific fish diseases in the freshwater phase have been reported (Gjedrem and Aulstad, 1974; McIntyre and Amend, 1978; Refstie, 1982).

In this study, information about the cause of death to individual fish was not available. It is clear that, in addition to WDV, many unknown causes may have been responsible. In spite of this, the results are interesting. The variation between sires was large, and promising response to selection can be excepted after testing under similar environmental conditions.

The heritability on survival in the freshwater-rearing period Ⅰ+ Ⅱ was high in both years, and this trait may be of great economic importance. Heritability estimates derived from the dam components of variance were generally higher than those derived from the sire components. These differences may be due to maternal effects, non-additive genetic variations and common environmental effects. However, it is difficult to use directly so far because the cause of mortality can vary between year-classes and between different periods within year-classes.

Correlations of sire components for survival with the other traits studied in the present study were generally low and, with one exception, not significantly different from zero. Correlations between sire means for survival in subsequent and overlapping periods (Ⅰ+Ⅱ/Ⅰ+Ⅱ+Ⅲ and Ⅲ/Ⅰ+Ⅱ+Ⅲ) were very high. This is to be excepted as overlapping periods contain common information.

The correlation between survival rates in periods I and II was negative and different in both year-classes. The difference may be due to the variation of mortality. An outbreak of disease at the end of period I and period Ⅰ+Ⅱ may result in a high correlation between survival during the two periods, while an outbreak at the beginning of period I and another at the end of period Ⅱ may give a low correlation. In the latter case, one explanation is that the fish are exposed to different diseases from period I. Another is that various resistance mechanisms would be triggered at different stages of development. The relatively even distribution of mortality over these periods supports the theory about varying causes of mortality for different periods and year-classes. This agrees with the variation in heritability estimates for survival between year-classes and periods.

Standal and Gjerde (1987) studied genetic variation of survival of Atlantic salmon during the sea-rearing period when hemorrhagic syndrome (Hitra disease) was the main cause of death. Heritabilities for survival calculated from the observed scale varied from 0 to 0.21.

Kanis et al. (1976) studied mortality rates during the freshwater period for Atlantic salmon, seatrout, and rainbow trout. The average heritability of the mortality rate for all species was 0.08 for eyed eggs and 0.05 for alevin stage, respectively, while estimates for fry mortality did not differ large from zero. Rye et al. (1990) analyzed on survival during the freshwater period for Atlantic salmon and rainbow trout. The heritabilities for survival of eyed eggs, alevins, fry, and fingerlings were 0.08, 0.04, 0.06. and 0.04 in Atlantic salmon and 0.08,0.08, 0.09, and 0.05 in rainbow trout, respectively. Genetic correlations between survival and growth were 0.37for Atlantic salmon and 0.23 for rainbow trout. Gjerde and Refstie (1984) reported significant differences in the average (additive) effect of strains of Atlantic salmon for survival of fry and fingerlings but not for survival of eyed eggs and alevins. Ayles (1974) reported significant additive genetic variance for survival of splake hybrid alevins.

With heritabilities obtained in the present study, selective breeding in survival traits would be effective in masu salmon culture. In general, when heritability is lower than 0.5, family selection is more efficient for fish breeding. Therefore, family selection to increase survival of masu salmon is recommended.

In general, selection should be made from measurements as close as possible to the market size of the fish. However, maintaining a large number of market size fish in a breeding program is laborious and expensive. Selection performed at an early age would greatly facilitate breeding work. In the present study, correlations among periods were generally high, and breeding effect at the early age would be expected on survival traits.

On the other hand, the results obtained in masu salmon indicated that selection for increased growth in early periods will not negatively affect survival in the same period.

In resent years estimates of genetic parameters for survival including disease are few. The increase in fish farming has, however, led to increase in the variety and incidence of disease.

Moreover, the high losses because of disease were occurred in the early stage of development. Further investigation between survival including disease and increased growth in early periods will be needed in masu salmon.

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