Comparison Of Direct And Indirect Selection For Rainbow Trout Sea Grow-out Survival

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Introduction

Survival of farmed fish during grow-out is important economic, environmental and animal health issue. General assumption has been that traits under strong natural selection harbour little genetic variation. However, in our previous studies (Vehviläinen et al. (2008); (2009); (2010)) we have established that 1) rainbow trout survival during grow-out period has low, but significant heritability (0.08-0.17), 2) genetic correlations between survival in generation and test-station specific cohorts are not stable, 3) life-stage (egg, fingerling, grow-out) specific survival traits are best regarded as separate traits, 4) genetic correlations between grow-out survival and growth are favourable (mean r_G=0.17) 5) health traits are favourably related to grow-out survival, and 6) fingerling survival is not genetically related to growth. Breeding programs are typically started with selection on few traits such as body weight and maturity age. Survival is not usually among the first traits directly selected, but it may improve as a correlated genetic response to selection for other traits. Thus, after establishing the genetic associations of survival with other traits, the first question asked here was: <u>1) How effective is the current indirect selection of sea grow-out survival via other traits in Finnish national rainbow trout breeding program?</u> In rainbow trout farming, sea survival is economically important. However, breeding takes place in freshwater nucleus and G x E has to be taken into account. That only alive fish can be selected and the binary nature further complicate the selection of sea survival. Thus, the second question of this study was: <u>2) How much can the accuracy of sea survival be elevated by utilising information from other traits?</u>

Materials and methods

The data originates from the Finnish national rainbow trout breeding programme. The freshwater breeding nucleus is held at FGFRI Tervo station in Central Finland. The breeding population has been established in 1992 and pedigree is known until a base population in 1989 (Kause et al. (2005)).

Traits recorded. Eight traits selected in the programme (Kause et al. (2005)) were analysed. Traits were recorded after second growing season (fingerling period at freshwater + one grow-out season in either freshwater or sea). <u>Freshwater traits:</u> body weight ($Weight_2$), survival ($Survival_2$), deformed skeletal structures ($Deformation_2$), eye cataracts ($Cataract_2$), skin colour ($Skin\ colour_2$), and sex-specific maturity trait ($Female\ maturity_2$). <u>Sea traits:</u> body weight ($Weight_{2sea}$) and survival ($Survival_{2sea}$). Causative agents of deformations have not been examined in our population but deformations may be caused by high water temperature,

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diseases, deficient composition of a diet, or management (Kause et al. (2007)). The fish eye cataracts are caused by parasitic *Diplostomum* spp. eye fluke (Kuukka et al. (2010)).

Evaluation of sea survival improvement. To assess the degree to which currently used selection indices indirectly improve sea survival, correlations between sea survival EBV, current indices, and other trait EBV were calculated using data from latest year-class (birth year 2007). To assess how much selection accuracy of sea survival can be improved by utilising information from other seven traits accuracies of sea survival were calculated when it is selected directly or indirectly together with alternative trait combinations. The accuracies were calculated with SelAction program (Rutten et al. (2002)). The population parameters for SelAction were 100 male and 300 female parents, 15 male and 15 female offspring per female parent, 35 fish from each fullsib family left to nucleus and 15 + 15 sent to sea stations. The 30 offspring per females represent the next generation candidates (35 fish – 5 dying before maturation).

Estimation of genetic (co)variances and breeding values. The data used for (co)variance estimation had 200,173 individuals with observations and a total of 1,159 ancestors without observations. The fish originated from ten year-classes belonging to four generations. Each year-class consisted of 109-341 families of 48-168 sires and 79-272 dams, mated using either nested paternal or partial factorial designs. Phenotypic and genetic parameters were estimated using restricted maximum likelihood and multitrait animal linear mixed models (DMU-AI software; Madsen and Jensen (2008)). The breeding values were estimated using whole breeding programme data starting from the base population (16 year-classes, 7 generations) using MiX99 program (Lidauer and Strandén (1999)). The current selection indices are based on estimated breeding values (EBV) of growth, maturity age, external appearance, skeletal deformations, fillet colour and cataract (Kause et al. (2005)). From year-class 2001 onward the breeding program was divided into two lines: GROWTH and DELAYED MATURITY (Ritola et al. (2006)). The selection index of GROWTH-line (hereafter $\mathrm{Index}_{\mathrm{Growth}}$) is weighed mainly for rapid growth (around 50 % of index weight on growth and 10 % on maturity), and fish are used to produce both fillet and caviar. Index for DELAYED MATURITY-line ($\mathrm{Index}_{\mathrm{DelMat}}$) is designed especially for selection of late maturity (around 50 % of index weight on maturity and 10 % on growth), and fish are used for high quality fillet production.

Results and discussion

1) Indirect selection of sea survival by current indices. The correlations between sea survival EBV and indices of two selection lines differed quite dramatically (table 1). The association of sea survival EBV and $\mathrm{Index}_{\mathrm{Growth}}$ was favourable (r=0.36) suggesting that sea survival is enhanced via selection on growth traits (50 % of index weight on growth and 10 % on maturity). Indeed, the correlations between individual trait EBV revealed that positive association comes mainly via sea body weight. In contrast, the correlation between sea survival EBV and $\mathrm{Index}_{\mathrm{DelMat}}$ was unfavourable (r=-0.18) implicating that sea survival in this line is indirectly selected downwards. This is because body weights are not heavily weighed (50 % of index weight on maturity and 10 % on growth). In addition, the main unfavourable association of individual trait EBV comes via selection for late maturity (r from -0.18 to -

0.35, table 1.). Taken together, current indirect selection of sea survival is fairly effective with Index_{Growth}, but serious attention must be paid on the moderate unfavourable association of sea survival and Index_{DelMat}.

Table 1: Correlations between sea survival EBV, total indices and separate trait EBV in the two selection lines.

	GROWTH	DELAYED MATURITY
Index_{Growth}	0.36	-
Index_{DelMat}	-	-0.18
Weight_{2sea}	0.31	0.32
Cataract_{2}	0.11	0.03
Skin colour_{2}	0.01	0.08
Deformation_{2}	0.01	-0.01
Weight_{2}	-0.01	-0.07
Female maturity_{2}	-0.18	-0.35

2) Accuracy of sea survival in alternative selection indices. Direct selection only for sea survival resulted in accuracy of 0.392 (table 2a). Accuracy is substantially elevated (up to 0.479) when all traits are added into index (table 2a). This represents 22% increase, which could be achieved by adding both survival traits into current index. The most effective traits were Survival_{2} and Skin colour_{2}, which both alone elevated the accuracy by 7 % and together by 14%. Including Weight_{2}, Female maturity_{2} and Deformation_{2} provided almost no extra gain (increase in accuracy from 0.001 to 0.002.) Indirect selection (table 2b) for currently selected freshwater traits resulted in maximum accuracy of 0.244 for sea survival, which is 62 % of accuracy gained by direct selection only for sea survival. Addition of Weight_{2sea} to index raised accuracy to 0.341. This represents 87 % accuracy of direct selection for sea survival and is the maximum accuracy achieved indirectly with currently selected traits. Favourable association suggests that fast growing fish are also resistant to mortality factors. In the indirect selection, Survival_{2} was found to be very effective. If it is included to index together with all currently selected traits, the sea survival accuracy was 9 % higher (0.428) than accuracy gained by direct selection only for sea survival. Also the substantial effect of skin colour on accuracy suggests that the appearance traits can viewed as general vigour indicators. To sum up, the results of alternative indices show that clearly the best option would be to directly select for sea survival. Furthermore, the benefits gained via including other traits are substantial (22 % increase in accuracy). However, if there is no possibility to record sea survival, the next best thing would be to include freshwater survival to index as it elevates accuracy of indirect selection greatly (50 % with only freshwater traits and 25 % with all traits).

Table 2. Accuracies of alternative selection indices for improving sea survival (Survival_{2sea}).

Traits	Accuracy of index
a) Direct selection for sea survival	
Survival_{2sea}	0.392
Survival_{2sea} + Cataract_{2}	0.399

$Survival_{2sea}$ + $Weight_{2sea}$	0.402
$Survival_{2sea}$ + $Survival_{2}$	0.418
$Survival_{2sea}$ + Skin $colour_{2}$	0.420
$Survival_{2sea}$ + All other traits	0.479
b) Indirect selection for sea survival	
$Weight_{2}$	0.025
Female $maturity_{2}$	0.027
$Deformation_{2}$	0.042
$Cataract_{2}$	0.100
Skin $colour_{2}$	0.224
All currently selected freshwater traits	0.244
$Survival_{2}$	0.266
All currently selected freshwater traits + $Survival_{2}$	0.366
$Weight_{2sea}$	0.181
All currently selected freshwater traits + $Weight_{2sea}$	0.341
All currently selected freshwater traits + $Weight_{2sea}$+ $Survival_{2}$	0.428

Conclusion

The current indirect selection for sea survival is moderately effective in the GROWTH-line. In contrast, the weighing of traits in current selection index for DELAYED MATURITY-line results in unfavourable association of index and sea survival, and this line would particularly benefit from inclusion of sea survival into index. The alternative indices studied revealed that accuracy for sea survival selection can be elevated substantially (9 % in indirect and 22 % in direct selection) by having correlated traits in the index.

References

Kause, A., Ritola, O., Paananen, T. *et al.* (2005). *Aquaculture* 247 : 177-187.

Kause, A., Ritola, O., and Paananen, T. (2007). *Genet. Sel. Evol.* 39: 529-543.

Kuukka-Anttila, H., Peuhkuri, N., Kolari, I. *et al.* (2010) *Heredity* 104:20-27.

Lidauer, M. and Strandén, I. (1999). *J. Dairy Sci.* 82: 2779-2787. www.mtt.fi/BGE/Software

Madsen, P. and Jensen, J. (2008). *DMU - a package for analysing multivariate mixed models, version 6.* www.dmu.agrsci.dk

Ritola, O., Paananen, T., and Kause, A. (2006). *Proceedings of the 8th World Congress on Genetics Applied to Livestock Production*: 3.

Rutten, M.J.M., Bijma, P., Woolliams, J.A. *et al.* (2002) *J. Hered.* 93: 456-458.

Vehviläinen, H., Kause, A., Quinton, C. *et al.* (2008) *Genetics* 180: 507-516.

Vehviläinen, H., Kause, A., Quinton, C. *et al.* (2009). *The 10th international symposium on genetics in aquaculture (ISGA X)*: 39-40.

Vehviläinen, H., Kause, A., Koskinen, H. *et al.* (2010) *Genetics Research* 91: 1-11.