DEVELOPMENT AND EARLY RESULTS OF THE TASMANIAN ATLANTIC SALMON BREEDING PROGRAM

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SUMMARY

Atlantic salmon (*Salmo salar*) farming commenced in Tasmania in 1984, and after 20 years of a general 'no selection' breeding practice to maintain genetic diversity, a family based selective breeding program for the industry commenced in 2004. The commencement of a selection program was delayed due to concerns that the closed population had insufficient genetic variation to warrant a program. The results of DNA marker analyses and now four years of family production and assessment show the Tasmanian population has sufficient genetic variation to make good commercial gains from selective breeding. The Salmon Enterprises of Tasmania (SALTAS) selective breeding program is unique in that it is fully dependent on DNA genotyping for pedigree assignment, and does not use the traditional practice of maintaining multiple family tanks for the nursery phase. In addition, the program differs from other salmonid programs in having resistance to an external gill parasite as the priority breeding objective. The high impact of treating this marine parasite on production costs is a further distinction of the local industry, as well as a very high dependence on all-female commercial production. The latter influences the rate of transfer of genetic gains into commercial returns. The program reached a milestone in 2008 with the production of the first selected families, and in 2009 the first commercial productions were achieved.

INTRODUCTION

History. The first six generations of the Tasmanian Atlantic salmon population were produced with the aim of maintaining genetic diversity or, in other words, preventing possible inbreeding effects. Some selection on 'appearance' and avoidance of outliers was practised. This cautious approach reflected anecdotal information and the understanding of the genetic history of the population. Tasmanian Atlantic salmon originate from the east coast of Canada; imported first to Gaden, NSW in 1965 to 1967, and from there to Tasmania in 1984 to 1986 to start Australia's leading aquaculture industry.

Improving production traits in the population through selection was first considered in the mid-1990s, however, concerns over lack of sufficient genetic diversity due to purported low effective breeding numbers in the early years of domestication in NSW resulted in a continued cautious approach to establishing a selective breeding program.

Genetic diversity in the population and estimates of the historic effective population sizes was examined in multiple year-classes using microsatellite DNA markers (Innes and Elliott 2006). Variation in the local population was compared to that observed in archived scale samples from the ancestral Canadian population. These analyses suggested that, based on microsatellite analyses, sufficient genetic diversity remained in the local population to warrant the establishment of a family based selective breeding program.

Program design. Breeding objectives were relative clear from the outset. These were improving growth (time to harvest weight), increasing disease resistance, reducing incidence of early maturation, and maintaining carcass quality traits (flesh colour and fat). The program design was less obvious and needed to consider the relative size, structure and maturity of the local industry, biosecurity restrictions on moving between marine and freshwater, lack of opportunity for introducing new genetic stock, and the resources available for the initiation and on-going management of a selective breeding program (or programs).

Traditionally in aquaculture, family based selective breeding programs have been designed around the use of family tanks for the hatchery and nursery phases. Thus each family is maintained in an individual growout unit until animals reach a suitable size for family or individual tagging, after which families can be mixed in a common growout unit. The capital outlay for a new or refurbished hatchery/nursery, with a minimum capacity of 100 family units each with controlled environment system, plus on-going management was beyond the available budget. Therefore a selective breeding program was designed on the basis of mixed family growout at all stages following hatching, and using DNA genotyping to provide the required pedigree information.

The selective breeding program (SBP) was commenced in 2004 by the leading commercial hatchery SALTAS on behalf of the Tasmanian industry. SALTAS is a cooperative venture, providing smolt to its industry shareholders based on their equity, with a current annual production of ca. 3.7 million smolt, which is ca. 40% of total smolt production for the Tasmanian industry. CSIRO through the Food Futures Flagship is partnering in the initial five years of research and development for the SBP.

The program revolves around a three-year production cycle (Figure 1), with three cycles in operation at any time. The operational plan involves freshwater spawning and nursery, with tagging and DNA fingerprinting at 12 months of age, followed by a cohort split into freshwater for growout and broodstock conditioning, and marine commercial growout and harvesting. Approximately 6,000 individuals are tagged and genotyped in each year class, with equal numbers in the marine and freshwater cohorts.

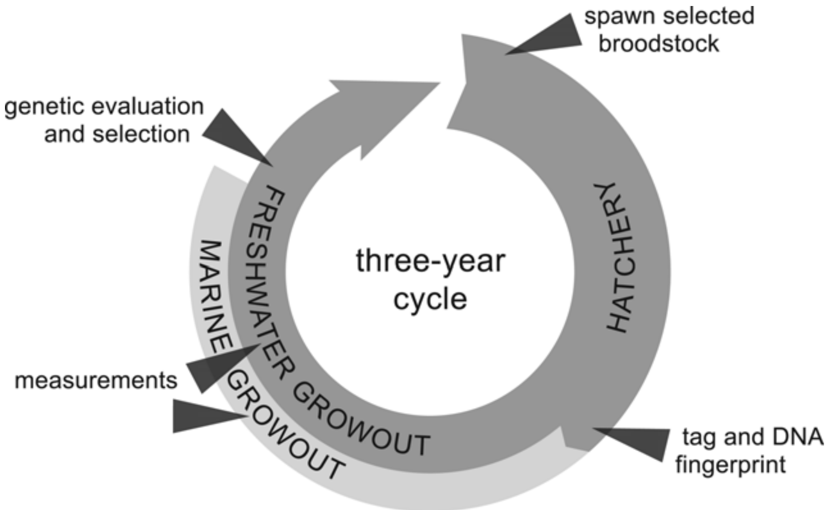

Figure 1. SBP year-class production cycle, showing cohort split at 14 months of age into the marine commercial growout and freshwater potential broodstock cohorts.

RESULTS AND DISCUSSION

Genetic variation. Five SBP year-classes (YC, 2004 to 2008) have been produced. In the first year, 2004, 70 full-sib families were produced and DNA pedigree (through Landcatch Natural

Selection, Scotland) successfully assigned 96% of a random sample of 4350 individuals to a family, with family representation at 22 to 117 individuals. Since then the SBP mating design has involved each broodstock mated twice, and the production of 180 families. Pedigree assignment success has improved, with 99% of 9341 individuals in the 2007YC being successfully assigned.

Moderate genetic variation for multiple traits has been measured across all year classes (Table 1). Consistent patterns of genetic variation have been observed across year classes and a comparison of the performance of repeated spawners (approximately 20 parents per year class) suggests good repeatability of genetic predictions across year classes. The results from the quantitative genetic analysis validated the early microsatellite DNA results that suggested sufficient genetic variation existed within this closed population to justify the development and running of a family selective breeding program.

Table 1. Heritabilities of selection traits in a combined analysis across year classes

Trait	Heritability (± se)
AGD resistance (gill score at first infection)	0.14 ± 0.03
AGD resistance (gill score at infections 2 to 5)	0.30 ± 0.04
Gutted weight (marine)	0.41 ± 0.04
Total weight (freshwater)	0.38 ± 0.04
Incidence early maturation (marine)	0.22 ± 0.03
Incidence early maturation (freshwater)	0.12 ± 0.02
Flesh colour (astaxanthin content)	0.44 ± 0.07
Flesh fat content (total fat content)	0.47 ± 0.05

Marine and freshwater correlation. Biosecurity issues necessitate that individuals that go into marine commercial growout do not return to the freshwater hatchery. Therefore freshwater broodstock selection is based on commercial performance of relatives. Reasonable genetic correlations ($r_g = 0.70 \pm 0.05$) have been observed between same age freshwater and marine growth measures based on total weight.

Disease resistance. A major marine production cost for the Tasmanian industry, and one not experienced to the same degree in other Atlantic salmon producing countries, is treatment and lost productivity due to amoebic gill disease (AGD). The disease can be managed with freshwater bathing but this is costly in terms of both labour and equipment. The estimated cost of AGD to the industry (valued in 2006/07 at $281m) is in excess of $25m a year. A key research question was therefore whether there was genetic variation in resistance to this external gill parasite.

Results from four years' data show that AGD resistance is a quantitative trait, with moderate genetic variation at all infections (an individual fish may have between 6 to 12 infections and subsequent freshwater treatments during a marine growout). However, there is low genetic correlation between the first and subsequent infections ($r_g = 0.29 \pm 0.11$) which suggests first and subsequent infections are different genetic traits. As a consequence, the selection index includes first infection and all subsequent infections as separate traits with a lower weighting on the first infection. Selection is for reduced gill symptoms and it is assumed that this will slow the rate of infection, increase the time between treatments, and therefore reduce the number of treatments required.

Commercial production. The Tasmanian commercial harvest is predominantly (ca. 95%) based on all-female production. This is due to a high incidence of early maturation in males in their first summer at sea, prior to harvest size, which results in poor growth, increased management costs and lower survival. Although there is genetic potential to reduce the incidence of early maturation through genetic selection, the focus for the breeding program is on growth and disease resistance because all-female production offers a workable solution to this problem.

All-female production requires the making of sex-reversed females or neo-males. Therefore, infusing genetic gains from the selective breeding program into commercial production requires an additional step with a multiplier population to create the neo-males.

CONCLUSIONS

Development of a commercial selective breeding program in an aquaculture industry requires patience as many competing factors influence its progress. These include the structure, business plans and maturity of the industry, as well as the species' biology and commercial production systems. A selective breeding program has been successfully developed for Australia's major aquaculture industry, and moderate genetic gains in commercial production traits for Atlantic salmon are predicted. The program is unique in three major areas - being totally dependent on DNA genotyping for pedigree assignment, the highest selection weighting is on resistance for an external gill parasite, and delivering commercial benefit requires multiplying into an all-female production system. Despite concerns over the importation events of Atlantic salmon into Tasmania, this closed population has been shown to have good genetic variation and predicted genetic gains in key production traits from the SALTAS selective breeding program.

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