GENETIC IMPROVEMENT IN AUSTRALIAN AQUACULTURE INDUSTRIES

A. J. Lymbery

New Industries Program, Agriculture Western Australia, PO Box 1231, Bunbury, WA 6231

SUMMARY

Most aquaculture industries in Australia are at an early stage of development and would benefit from the introduction of genetic improvement programs. Size at harvest is perceived by industry participants, managers and researchers as the trait that will most influence profitability. Although genetic improvement programs in aquaculture typically use mass selection, inbreeding is widely regarded as an important problem, and the use of family data in selection decisions is a priority. The major constraint upon the implementation of genetic improvement programs by aquaculture industries is lack of available funds and resources. Industry ownership and national coordination of research and development is seen as the best way of addressing this constraint. The major research priority is the development of genetic markers to enable accurate pedigree determination.
Keywords: Aquaculture, genetic improvement, breeding objective, selection

INTRODUCTION

Aquaculture has been the world's fastest growing food production system for the past decade, with an average compound growth rate of 9.6 % per year since 1984, compared with a growth of 3.1 % for terrestrial livestock meat production and 1.6 % for capture fisheries production over the same period (Tacon 1998). This spectacular growth has been fueled by a steadily increasing demand for seafood and a leveling of production from wild fisheries throughout the world. Since 1984, aquaculture's contribution to total seafood production has increased from 11.5 % to 23 % by weight (Tacon 1998). Aquaculture is seen by many as offering the greatest potential of any primary production system to meet the future food demands of a growing world population.

A major constraint to the ability of aquaculture to fill the gap between supply from wild fisheries and demand from world population growth, is the relatively poor production efficiency of aquaculture species (FAO 1995). Most aquaculture production is carried out using wild stock recently captured from natural environments. Aquaculture species have hardly benefited from modern developments in animal breeding, despite their typically high reproductive capacity and therefore high potential for genetic improvement. A recent workshop in Perth, Western Australia, brought researchers and industry representatives together to consider the current state and future potential for genetic improvement programs in the Australian aquaculture industry. This paper reports the main findings from the workshop.

METHODOLOGY

Sixty one delegates attended the workshop. By occupation, 17 were from the commercial aquaculture industry, 16 held fisheries management positions and 28 were aquaculture researchers. Four taxonomic groups were considered in the workshop: edible molluscs, freshwater crustaceans, marine crustaceans and finfish. Delegates were split into four groups, depending on their major commercial or research interest, and each group identified for their species: the breeding objective; the selection criteria; the best methods of genetic improvement; the major risks in implementing genetic improvement programs; and the R&D priorities.

BREEDING OBJECTIVES AND SELECTION CRITERIA

The relative immaturity of most aquaculture industries in Australia means that market signals are unreliable and it is often difficult to accurately detail the major sources of income and expense in commercial operations. As a consequence, although groups identified biological traits influencing returns and costs, they did not attempt to derive economic values for each trait. Table 1 shows the traits considered to be important components of the breeding objective by each group. These are general trends only; within each group the breeding objective usually differed for different species.

Table 1. Biological traits included in the breeding objective for different aquaculture species groups. 1 = high priority (all species); 2 = low priority (some species only), 0 = not a priority

Trait	Priority in:			
	Molluscs	Freshwater crustaceans	Marine crustaceans	Finfish
Size at harvest	1	1	1	1
Meat yield at market	1	2	2	0
Size uniformity	2	2	0	0
Feed efficiency	2	0	1	2
Survival to harvest	2	2	2	2
Survival to (live) market	0	0	2	0
Disease resistance	2	0	2	0
Temperature tolerance	2	0	0	0
Reproductive output	0	0	2	0
Taste	0	0	2	2
Flesh colour	0	2	2	0
Shell shape	2	0	0	0
Claw size	0	2	0	0
Peelability	0	2	0	0

All groups considered size at harvest to be the major determinant of profitability. For most species, the recommended selection criterion for this trait was body weight or body size at harvest. Earlier predictors of harvest size were considered desirable, but information on genetic correlations among growth traits is often lacking for aquaculture species (Shultz 1986). Other traits of general importance were survival, meat yield and feed efficiency. Disease resistance, as a separate trait to survival, was considered very important in Sydney rock oysters, but not in other species. Specific quality traits (eg. colour, claw size, shell shape) were considered important for some species, although it was recognized that there was little information with which to quantify economic values. Also lacking were many of the genetic parameter estimates that would allow effective selection criteria to be defined for these second-tier traits in the breeding objective.

SELECTION METHODS

Each group considered the relative importance of different strategies for genetic improvement of the traits identified in the breeding objective (Table 2). The general consensus across all industries was that traditional genetic improvement programs, utilizing selection on estimated breeding values, need to be implemented as soon as possible, or continued where they are already in place. Mass selection programs are common in aquaculture species, because of difficulties with individual identification. The emphasis on developing family selection programs reflects concerns about inbreeding in many species with high reproductive potential (Engström *et al.* 1996). The application of molecular genetic technologies was considered a secondary priority (except that molecular markers are needed for pedigree determination, see below), although it was emphasised by the mollusc and marine crustacean groups that QTL information would assist selection for traits such as disease resistance. Chromosome manipulations and transgenesis were considered important for the protection of intellectual property in improved strains, rather than priorities for the genetic improvement of production traits.

Table 2 Relative importance of different strategies for genetic improvement in aquaculture species, as ranked by groups at the workshop. Ranking refers to the number of groups (out of 4) who considered the strategy to be a priority

Strategy	Ranking
Family selection within stocks	4
Mass selection within stocks	3
Crossbreeding	3
Selection among stocks	2
Marker assisted selection	2
Transgenesis	2
Chromosome manipulation	2
Sex ratio control	1

INDUSTRY CONSTRAINTS

There were two major areas of concern, which were consistently identified over groups. The first relates to lack of funds and resources to implement genetic improvement programs. Uncertainty over production costs and market opportunities in many aquaculture industries constrains investment in long-term genetic improvement programs. This is exacerbated by the large range of aquaculture species that can potentially be farmed. There is an unresolved tension between the need to begin genetic improvement programs at an early stage of industry development, and the commercial reality that traits can often be improved and problems eliminated more cheaply in the short term through changes in management (Shultz 1986). One method of breaking this nexus is to begin genetic improvement programs with government support, but with a clear direction to transfer the program to industry as soon as commercial benefits can be demonstrated. The obvious weakness of this strategy is that the number of publicly funded genetic improvement programs is limited, and some method of choosing candidate species ("picking winners") must be found.

The second major area of concern relates to the hazards, real and perceived, of translocating aquaculture species. Translocation is the assisted movement of an organism beyond its accepted distribution. Disease risks arise principally from the introduction of exotic pathogens into natural water bodies. These risks can be reduced through disease certification, treatment of transport medium and quarantine procedures. Genetic risks arise when organisms are moved from one locality to another within their natural range, and donor and recipient populations differ genetically in traits which affect fitness. The risks can be reduced by minimizing escapes of translocated stock through licensing provisions, inspections and monitoring procedures.

R&D PRIORITIES

Encouraging industry ownership of genetic improvement programs from an early stage, and ensuring that the infrastructure requirements and strategic directions of R&D effort are coordinated nationally were regarded as priority issues by all groups. This is essentially a strategy for minimizing the risks identified in the previous section, of a lack of investment funds and a dilution of R&D effort. The principal research requirement, identified by three of the four groups, was the establishment of genetic markers to allow individual identification and pedigree verification of group reared progeny. This would permit the more widespread use of family data in selection decisions, without costly maintenance of separate family lines until individuals can be physically marked. The only other research priorities identified by more than one group were the assessment of wild genetic resources, determining the genetic basis of disease resistance and improving hatchery production.

The estimation of net economic values and genetic parameters, and the comparison of predicted and observed gains from selection received surprisingly low priorities, given the perceived lack of information with which to develop selection criteria for breeding objectives in aquaculture species. The R&D rankings may reflect the early developmental stage of many aquaculture industries, and a perceived need to develop basic infrastructure and selection technologies before the details of genetic improvement programs can be effectively addressed.

ACKNOWLEDGEMENTS

The workshop was undertaken as part of a conference sponsored by the Fisheries Research and Development Corporation and the Aquaculture Development Council of Western Australia.

REFERENCES

Engström, G., McMillan, I., McKay, L. and Quinton, M. (1996) *J. Anim. Breed. Genet.* **113:** 559

FAO (1995) "Review of the State of World Fishery Resources: Aquaculture". Food and Agriculture Organization of the United Nations, Fisheries Circular No. 886, Rome

Schultz, F.T. (1986) *Aquaculture* **57:** 65

Tacon, A.G.J. (1998) *Feedstuffs* August: 12