Aquaculture Genetics Workshop

A.J. Lymbery

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

PROJECT NO: 98/342

TABLE OF CONTENTS

NON-TECHNICAL SUMMARY

98/342 Aquaculture genetics workshop

PRINCIPAL INVESTIGATOR: Dr A.J. Lymbery
ADDRESS: Division of Veterinary and Biomedical Sciences
Murdoch University
Murdoch WA 6150
Telephone: 08 9360 2729 Fax: 08 9310 4144
E-mail: alymbery@central.murdoch.edu.au

OBJECTIVES:

- To hold an aquaculture genetics workshop.
- To focus the Australian aquaculture industry on the importance of genetics in relation to aquaculture production.
- To identify and initiate appropriate species specific genetic improvement programs by Australian industry and government research sectors.
- To provide a scientific basis for assessing genetic risks arising from the translocation or restocking of aquaculture species.
- To identify research and development needs.

NON-TECHNICAL SUMMARY:

Aquaculture in Australia is a rapidly growing industry. More than 60 aquatic species including crustaceans, molluscs, finfish, crocodiles and microalgae are presently cultured in Australia, although less than ten species support around 80% of the total value of the industry. In 1995, a review of world aquaculture resources by the Food and Agriculture Organisation identified genetic and diversity issues as major constraints to the future development of aquaculture. There are two areas in which genetics is especially important in aquaculture development: (1) the genetic improvement of important production traits; and (2) genetic implications of the intentional movement (translocation) of organisms for aquaculture or restocking programs.

Genetic improvement

Genetic improvement of aquaculture species offers substantial opportunities for increased production efficiency, disease control, product quality and ultimately profitability for aquaculture industries. Most aquaculture industries in Australia are at an early stage of development and would benefit from the introduction of genetic improvement programs.

The first step in a genetic improvement program is to determine which traits should be improved (the breeding objective), and find measures for those traits (the selection criteria). Size at harvest is perceived by industry participants, managers and researchers as the trait that will most influence profitability for all major aquaculture species in Australia. Other traits of general importance are survival to harvest, disease resistance (especially in edible molluscs), meat yield and feed conversion efficiency. For some aquaculture species, such as trout, there are good estimates of the heritabilities and genetic correlations among these traits, and studies are beginning for a number of crustacean and mollusc species. In most cases, however, we still lack the basic information needed to define effective selection criteria for the traits we wish to improve.

Once the breeding objective and selection criteria have been determined, we need to consider the methods by which superior breeding stock will be selected. Mass selection, where breeding stock are chosen on the basis of individual performance, is most common in aquaculture species. This may lead to inbreeding, however, because individuals with superior performance will often be closely related. One method of overcoming this is by taking the performance of relatives into account when choosing breeding stock (family selection). The major research priority for genetic improvement across all aquaculture species in Australia is the development of genetic markers to enable accurate pedigree determination. This would allow the more widespread use of family data in selection decisions, without costly maintenance of separate family lines until individuals can be physically marked.

The major constraint upon the implementation of genetic improvement programs by aquaculture industries is lack of available funds and resources. Many aquaculture industries in Australia are small and immature, and uncertainties over production costs and market opportunities limit investment in long-term genetic improvement programs. Ensuring industry ownership of genetic improvement programs, and national coordination among researchers, are vital in all aquaculture industries. Government support may be necessary in the early stages of development, and the favourable benefit:cost ratio demonstrated, for example, by the Norwegian breeding program for salmonids, should encourage the targeted investment of public funds into genetic improvement programs for aquaculture species.

Genetic implications of translocation

The translocation of aquatic organisms is an issue of increasing concern. Potential genetic risks associated with translocation arise from genetic shifts in natural populations through hybridisation with translocated species or genetically different strains. In assessing the genetic risks from translocations, a fundamental distinction should be made between translocation for the purpose of aquaculture and translocation for the purpose of stock enhancement.

When translocation is for aquaculture, the question of interest is: what is the maximum level of escapes which should be permitted, beyond which there is an unacceptable probability of adverse genetic effects upon the natural population? Risk minimisation should concentrate on management solutions that minimise escape from aquaculture facilities.

When translocation is for stock enhancement, the question of interest is: what is the maximum level of genetic differences between hatchery and wild stock which should be permitted, beyond which there is an unacceptable probability of adverse genetic effects upon the natural population? Risk minimisation should concentrate on hatchery management procedures that minimise genetic differences between hatchery stock and wild stock from the proposed recipient population.

Where translocation poses a significant risk of adverse genetic changes, then a monitoring program is required, linked to a policy that prescribes management actions for the range of possible outcomes from the monitoring.

The main limitation to our ability to develop an effective risk assessment and monitoring process is lack of data on how the interaction between genetically different stocks affects the adaptation of aquatic organisms to their local environment i.e. how do we establish the probability of adverse genetic effects upon natural populations? This is an area where more research is urgently required.

INTRODUCTION

BACKGROUND

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. Australia has mirrored this global trend. Since 1985, the gross value of aquaculture production in Australia has grown from $49m to around $400m, with a current annual growth rate of about 30%.

More than 60 aquatic species, including crustaceans, molluscs, finfish, crocodiles and microalgae, are cultured in Australia, although less than ten species support around 80% of the total value of the industry. The successful culture of comparatively few species suggests Australian aquaculture remains species limited. The industry has had a chequered history and there are numerous examples where apparently suitable candidate species have failed for one reason or another.

The aquaculture industry in Australia is at an important stage of development. Continued growth requires the identification of key constraints in the core areas of marketing, capital investment, production technology, environmental sustainability, and industry management.

NEED

In 1995, a review of world aquaculture resources by the Food and Agriculture Organisation identified genetic and diversity issues as major constraints to the future development of aquaculture. There are two areas in which genetics is especially important in aquaculture development: (1) the genetic improvement of important production traits; and (2) genetic implications of the intentional movement (translocation) of organisms for aquaculture or restocking programs.

Genetic improvement The power of selective breeding in increasing productivity and efficiency has been amply demonstrated in traditional livestock species. Aquaculture species, however, have hardly benefited from modern developments in animal breeding, despite their typically high reproductive capacity and therefore high potential for genetic improvement. The key questions that need to be addressed are:

- Which traits need to be improved (what is the breeding objective)?
- What are the best measures (selection criteria) for these traits?
- What are the best selection methods for improving the traits in the breeding objective?
- What are the research priorities?
- How can we ensure that genetic improvement programs are implemented by the aquaculture industry?

Translocation The existence of population genetic structuring has long been recognized in the description of races, stocks and subpopulations of fish and other aquaculture species, and the environmental implications of such structuring have been discussed before. Important questions remain, however:

- What are the best tools for measuring population genetic structure?
- What levels of gene flow will alter the genetic constitution of local populations?
- Will this have any effects on local adaptation?
- How do we estimate long-term population viability?

OBJECTIVES

- To hold an aquaculture genetics workshop.
- To focus the Australian aquaculture industry on the importance of genetics in relation to aquaculture production.
- To identify and initiate appropriate species specific genetic improvement programs by Australian industry and government research sectors.
- To provide a scientific basis for assessing genetic risks arising from the translocation or restocking of aquaculture species.
- To identify research and development needs.

METHODS

The symposium on *Genetics in the Aquaculture Industry* was held in Perth, Western Australia, 27-29 September 1998. 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.

The symposium was divided between formal presentations, from invited Australian and international speakers, and two workshops, involving all delegates. Nine presentations outlined examples of genetic improvement programs in species of edible molluscs, crustaceans and finfish, while four presentations considered the genetic implications of translocation for the purposes of aquaculture or stock enhancement.

A workshop on genetic improvement aimed to develop practical guidelines to implement breeding programs, and to identify research and development priorities for different species in Australia. 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 worked through a series of structured questions for their species:

- What is the breeding objective?
- What are the selection criteria?
- What are the best methods of genetic improvement?
- What are the R&D priorities?
- What are the major risks in implementing genetic improvement programs?

A workshop on translocation sought to identify the scientific information required to provide an accurate assessment of genetic risks when species are deliberately moved from one area to another. Delegates were split into six groups, containing a mix of occupations, and each group was presented with a fictional, although realistic, translocation scenario. Each group then considered a number of questions relating to their scenario:

- What is the purpose of the movement?
- What are the genetic risks associated with the movement?
- What more do we need to know to assess the risks?
- What can be done to minimise the risks?

RESULTS AND DISCUSSION

The contributed papers and workshop summaries from the symposium were published in a special issue of the journal Aquaculture Research:

Lymbery, A.J., Doupé, R.G., Jenkins, G. and Thorne, T. (Editors) Genetics in the Aquaculture Industry. *Aquaculture Research* **31 (1)**. 2000.

Other publications arising from the project are:

Lymbery, A. (1999) Genetics in the aquaculture industry. *ACWA News* **24**: 9-10.

Lymbery, A.J. (1999) Genetic improvement in Australian aquaculture industries. *Proceedings of the Association for the Advancement of Animal Breeding and Genetics* **13**: 420-423.

Lymbery, A.J. (1999) Genetic improvement in Australian aquaculture. *Austasia Aquaculture* **Aug/Sept**: 48-50.

BENEFITS AND FURTHER DEVELOPMENT

The principal beneficiaries of the symposium will be aquaculture enterprises and government regulatory agencies.

Aquaculture enterprises benefit from genetic improvement programs through increased productivity, decreased feed costs, reduced losses from disease, and the development of new markets (e.g. for seedstock). For example, selection for increased growth rate in aquaculture species typically leads to genetic gains of 5-10% per year, leading to increases in farm gate value of 10-15% at current price structures (see Jones & McPhee 2000; Knibb 2000). Improvement in flesh quality traits would be expected to improve farm gate prices, while improvement in feed efficiency and disease resistance traits should decrease farm costs.

A crucial step in the further development of genetic improvement programs for aquaculture species is the development of breeding objectives that account for all significant economic inputs and outputs in aquaculture enterprises. Essentially, defining the breeding objective means asking economic questions about the biology of production and product quality. There are four useful steps in defining the breeding objective:

- Identify the production and marketing system.
- Identify the sources of returns and costs.
- Determine the biological traits influencing returns and costs.
- Derive the net economic value of each trait, i.e. the additional profit expected from a unit improvement in that trait, assuming all other traits are held constant.

Government regulatory agencies will benefit from the adoption of a consistent approach to assessing proposals for the translocation of aquatic organisms. Currently, only Queensland and Western Australia have comprehensive translocation policies that specify a generic risk assessment process. Unfortunately, even these policies do not clearly specify the types of genetic risks involved in translocation for different purposes, and the data that are needed to adequately assess those risks. The benefits of adopting a consistent, scientifically rigorous approach to assessment of translocation risks are both improved environmental management and more rapid implementation of industry development proposals.

The next step in developing a consistent approach to assessing the genetic risks from translocation is to develop a policy framework around the approaches suggested from the current project (Doupé & Lymbery 2000). This is occurring in Fisheries Western Australia with the development of a policy for the translocation of barramundi. This will form the basis of a general policy for the translocation of aquaculture species in the state.

References

Doupé, R.G. and Lymbery, A.J. (2000) Managing translocations of aquatic species. *Aquaculture Research* **31**: 151-156.

Jones, C.M., McPhee, C.P. and Ruscoe, I.M. (2000) A review of genetic improvement of growth rate in redclaw crayfish, *Cherax quadricarinatus* (von Martens) (Decapoda: Parastacidae). *Aquaculture Research* **31**: 61-67.

Knibb, W. (2000) Genetic improvement of marine fish – which method for industry. *Aquaculture Research* **31**: 11-23.

CONCLUSION

The objectives of the project were:

- To hold an aquaculture genetics workshop.
- To focus the Australian aquaculture industry on the importance of genetics in relation to aquaculture production.
- To identify and initiate appropriate species specific genetic improvement programs by Australian industry and government research sectors.
- To provide a scientific basis for assessing genetic risks arising from the translocation or restocking of aquaculture species.
- To identify research and development needs.

Objective 1: To address these issues, a symposium on *Genetics in the Aquaculture Industry* was held in Perth, Western Australia during September 1998. 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.

Objective 2: The symposium was divided between formal presentations and two workshops, involving all delegates. Invited speakers from Australia and overseas presented seminars on:

- The theory of genetic improvement programs.
- Examples of the implementation of genetic improvement programs for species of edible molluscs, crustaceans and finfish.
- Examples of the natural genetic structure of crustacean and fish species.
- The genetic implications of translocating aquatic species.

Objective 3: One workshop aimed to develop practical guidelines to implement breeding programs for the major species groups: edible molluscs, freshwater crustaceans, marine crustaceans and finfish.

Size at harvest was perceived by industry participants, managers and researchers as the trait that will most influence profitability for all species. Other traits of general importance were survival to harvest, disease resistance, meat yield and feed conversion efficiency.

The general consensus across all industries was that traditional genetic improvement programs, utilising selection on estimated breeding values, need to be implemented as soon as possible, or continued where they are already in place. The application of molecular genetic technologies was generally considered a secondary priority, except that molecular markers are needed so that animals can be identified in selection programs (see Objective 5, below).

Although most current genetic improvement programs in aquaculture use mass selection, inbreeding is widely regarded as an important problem, and the use of family data in selection decisions is considered essential for continued genetic improvement. Selection among stocks was not rated a high priority, although there was support for the development of selection lines from different stocks, to provide the potential for crossbreeding.

Objective 4: The other workshop sought to identify the scientific information required to provide an accurate assessment of the genetic risks posed by translocation for the purposes of either aquaculture production or wild stock enhancement. In assessing the genetic risks from translocations, a fundamental distinction should be made between translocation for the purpose of aquaculture and translocation for the purpose of stock enhancement.

When translocation is for aquaculture, the question of interest is: what is the maximum level of escapes which should be permitted, beyond which there is an unacceptable probability of adverse genetic effects upon the natural population? Risk minimisation should concentrate on management solutions that minimise escape from aquaculture facilities.

When translocation is for stock enhancement, the question of interest is: what is the maximum level of genetic differences between hatchery and wild stock which should be permitted, beyond which there is an unacceptable probability of adverse genetic effects upon the natural population? Risk minimisation should concentrate on hatchery management procedures that minimise genetic differences between hatchery stock and wild stock from the proposed recipient population.

Where translocation poses a significant risk of adverse genetic changes, then a monitoring program should be put in place, linked to a policy which prescribes management actions for the range of possible outcomes from the monitoring.

Objective 5: The major research priority for genetic improvement across all aquaculture species is the development of genetic markers to enable accurate pedigree determination. This would allow the more widespread use of family data in selection decisions, without costly maintenance of separate family lines until individuals can be physically marked.

The major research priority for achieving an effective risk assessment and monitoring process for translocation is to develop an understanding of how the interaction between genetically different stocks affects the genetic basis of quantitative fitness traits that adapt organisms to their local environment.

The main conclusion from the symposium was that genetic issues should be to the forefront in the early stages of development of aquaculture industries. The major constraint upon the implementation of genetic improvement programs by aquaculture industries, and the development of effective risk assessment policies by management agencies, is lack of available funds and resources to address basic gaps in our knowledge. Industry involvement and national coordination of research and development are the best ways of addressing this constraint.

APPENDIX: STAFF

Agriculture Western Australia/Murdoch University

Alan Lymbery

Aquaculture Council of Western Australia

Simon Bennison

Edith Cowan University

Rob Doupé

Fisheries Western Australia

Rod Lenanton
Yvette Lourensz
Greg Maguire
Tina Thorne

South Metropolitan College of TAFE

Greg Jenkins

The Productive Edge

Michael Elliott