Priorities and Principles for Investment in Aquaculture Research by NSW Department of Primary Industries

Trevor S Gibson
Director, Production Research
NSW Department of Primary Industries, EMAI, Menangle

Geoff L Allan
Research Leader, Aquaculture
NSW Department of Primary Industries, Port Stephens

Geoff File
Director, Research Operations
NSW Department of Primary Industries, Orange

John D Mullen
Research Leader, Economic Evaluation and Coordination
NSW Department of Primary Industries, Orange, NSW

Helen Scott-Orr
Director, Health Sciences, Science Alliances and Evaluation
NSW Department of Primary Industries, Orange

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Abstract: This review examined the characteristics of the main aquaculture industries in NSW with respect to current impediments to growth, market development and future opportunities. Within this context, it examined the nature, funding and impacts of the NSW Department of Primary Industries' current and proposed investments in aquaculture R&D and industry development, as well as its alignment with DPI and industry priorities.

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Author's Contact Details:

Trevor Gibson, NSW Department of Primary Industries, PMB 8, Camden, NSW 2570
Telephone: 02 4640 6308 Facsimile: 02 4640 6395
Email: trevor.gibson@dpi.nsw.gov.au

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Australian Aquaculture Industries – An Overview

Aquaculture is the fastest growing livestock industry in the world. Key factors contributing to this growth include increased human population and income, increased demand for seafood in affluent communities related to health attributes and decreasing wild fish stocks globally. Advances in technology, changing tastes and preferences and changing relative prices have also impacted on the growth of this industry.

Asian countries in particular have responded to this global demand with massive increases in low cost aquaculture production. Exports of their products to Australia have provided major competition for local producers in recent years. Consequently, there must be doubts that Australian investment in some sectors of aquaculture competing in the same markets as imported seafoods will be profitable, threatening the continued growth of the industry.

Australian aquaculture growth has been slower than that in Asia and is concentrated in Tasmania (salmon), South Australia (tuna) and Queensland (prawns and barramundi). In NSW, aquaculture growth has been much less than in other States, and while still significant, it is from a very small base for most species. NSW has also had the additional pressures of increasing coastal urbanisation and recreational use which have placed limits on the growth of some forms of aquaculture.

There is uncertainty about why aquaculture growth in Australia has been slower than earlier predictions indicated. Insufficient or inappropriate capital investment, regulatory restrictions, a general lack of knowledge and skills and a small and highly competitive domestic market have all contributed.

Rationale for Government Involvement in the NSW Aquaculture Industry

While Governments can do little to reverse these general economic and resource limiting issues there are areas in which governments can promote the growth of aquaculture.

Growth in many sectors of NSW aquaculture has been limited by:

- Lack of profitable technologies adapted to NSW conditions and extended to NSW producers.
- The ‘infant’ nature of some aquaculture industries preventing economies of scale being realised for the growout sector and the associated fingerling, feed and processing sectors.
- Lack of understanding about aquaculture by regulators and the community leading to protracted approvals.
- Land use conflicts.
- Competition from imported, low cost seafood

The aquaculture industry in NSW consists of a number of small sectors, many with growth potential. Not surprisingly there is no single recipe for government involvement in these sectors because of the diversity of production, environmental, and regulatory issues they confront. However further R&D and extension programs may ameliorate slow growth by developing and extending new technologies that significantly lower the cost of producing aquaculture products and NSW DPI, through its R&D activities partly funded by industry, has already made significant contributions to the actual and potential growth of these sectors**.**

Nevertheless, at a time when public funds available for R&D in primary industries are declining, it is sensible to review the rationale for government involvement in aquaculture not only through R&D but more generally. In the course of this review, several potential grounds for increasing or limiting government involvement were identified and gave rise to the following recommendations:

Recommendations

1. Continuation of Government assistance to 'infant aquaculture industries' should be regularly reviewed against criteria such as research success, increased industry funding and the continued growth of the sectors involved

2. Beneficiaries of DPI aquaculture R&D should share in the costs of R&D in a more proportionate manner:

    a. Industry and recreational fishers should contribute, on average, more than half the costs of R&D where they are the principal beneficiaries.
    b. Public funds should be used to leverage industry investment in R&D that delivers both industry and public benefits.
    c. Public funds should be used to undertake research delivering benefits to community that would otherwise not be undertaken by industry.

3. Government should continue research into the biology of vulnerable native species such as silver perch and eastern freshwater cod to provide a basis for the protection of these species through regulation and restocking, and into the preservation of environmental assets from pest species (banded grunter in the Clarence) and exploitive fishing (abalone reefs).

4. In developing a Recovery Plan for threatened fisheries species the NSW DPI Division of Agriculture and Fisheries should identify the source of funds for research into the conservation of vulnerable species (eg silver perch, eastern cod) and other environmental issues associated with threatened species (such as the restoration of coastal reefs by restocking with abalone)

5. Government owned specialised hatcheries used in the production of spat or fingerlings of different aquaculture species for commercial, conservation and recreational fish restocking should be run in a manner likely to encourage the growth of a commercial hatchery sector by pricing in a competitively neutral way and by the transfer of technology to the sector.

6. The NSW Government should maintain an aquaculture health research and diagnostic capacity through training DPI laboratory and field veterinary staff to enhance DPI's capacity to respond to catastrophic disease and pest occurrences threatening commercial aquaculture, native species and food safety

7. NSW DPI should increase its capacity in aquaculture industry development and extension to support aquaculture industry growth and the adoption of new technologies.

8. The approval process for commercial aquaculture developments should be continued to be coordinated on a state wide basis by the State Aquaculture Steering Committee.

Oysters

The state's largest aquaculture industry, Sydney rock oysters (SRO) is under threat from interstate competition based on faster growing Pacific oysters, coastal urbanisation, estuarine pollution and disease epidemics (particularly the catastrophic QX disease which has devastated SRO production in those estuaries it has infected).

NSW DPI's oyster breeding research has provided the industry with a capacity to respond to QX disease and to become more competitive through selection programs that have led to increased oyster growth rates. This research has also provided the industry with some capacity to diversify into other species such as flat and Pacific oysters. However the industry will continue to decline unless it undergoes considerable restructuring, improves its marketing strategies, and undertakes practice change from traditional stick culture to hatchery based seed culture.

Pearl oysters on the other hand could develop into a significant industry now that a large development in Port Stephens has been approved.

Recommendations

9. Any commercial production from the NSW DPI oyster hatchery should be fully self-funded (through sale of spat) by July 1, 2008. A Business plan should be developed to help guide this and be based on the NSW DPI Diagnostic and Analytical Laboratories charging model.

10. NSW DPI should continue to invest in oyster R&D with the following provisos:
    a. That funding for the routine selection for commercial traits should move to being progressively industry based through FRDC, direct industry investment and an additional levy on the sale of spat
    b. That NSW DPI will need to retain a credible capacity to maintain a breeding program to protect the SRO industry from serious endemic and exotic diseases
    c. That NSW DPI investment into oyster research be further reviewed in 2010 to ensure industry are contributing at least 50% of the costs

11. NSW DPI should seek industry support for a cost-benefit analysis of practice change from the traditional stick culture to single-seed technology, a change necessary if farmers are to use disease resistant, faster growing oysters.

12. NSW DPI should investigate methods of assisting the oyster industry restructure from a stick culture based industry to single seed technology.

13. NSW DPI should explore ways to better facilitate industry change through improved extension services and industry consultation.

14. Future DPI research into pearl oyster species should be on a commercial basis wherever the research is in the nature of an exclusive service to particular firms.

Abalone

The NSW abalone fishery has been in decline for thirty years and despite the introduction of a quota system in 1989 the abalone population has still not stabilised. Annual catch peaked at about 1,200 tonnes in 1971/1972 and has declined to only 130 tonnes in 2005.

There are land based abalone farms in WA and Victoria and hatcheries in these states but none yet in NSW due to regulatory difficulties of gaining development approval (one venture has been seeking approval for more than five years).

In response to threats to the longevity of the abalone fishery identified above, the former NSW Fisheries undertook a program of research based at leased facilities at Tomaree into the feasibility of using hatchery- produced seed to restock depleted abalone populations. This controlled breeding technology provided a number of important flow-on benefits to the abalone aquaculture industry in southern Australia. In parallel has been a program of research into how best to ‘seed’ reefs with hatchery produced ‘buttons’.

Related to the loss of the fishery is the environmental degradation of the fishery. Many formerly productive areas of reef, typified by dense stands of seaweed and associated complex communities of fish and invertebrates including abalone, have undergone a transition to “barrens”. The seeding technology developed by NSW DPI may prove a practical means of ameliorating this degradation.

At present, in the absence of public and industry funding, all research and extension programs in NSW DPI related to abalone have ceased and the extent to which technologies developed in past research are adopted by industry is most uncertain. An MoU recently completed with the Department of Ageing, Disability and Home Care ensures continued access rights to the Tomaree facility for use in any future research opportunities.

Recommendations

15. Abalone research at the Tomaree hatchery and aquaculture facility should remain suspended, at least until the results of the large experiment to field test abalone enhancement is completed in 2008. Given the likely requests from abalone shareholders for new research if the results are positive, it is recommended that if future research is required then NSW DPI should pursue both public and industry funds for future R&D as a component of abalone enhancement and NSW coastal reef management

16. In order to increase the sustainable catch of abalone in NSW, DPI should consider the policy requirements associated with approvals for abalone stock enhancement including ranching of abalone on existing or artificial reefs and for land based abalone farming.

17. Reef management in NSW should be reviewed by the Division of Agriculture and Fisheries and a whole of reef management strategy should be developed with particular emphasis on abalone, urchins and lobster. DPI may need to seek public funding to maintain a research capacity in this area.

Marine Finfish

Large-scale aquaculture of marine finfish in Australia is currently limited to production of Southern bluefin tuna (South Australia), Atlantic salmon (Tasmania) and barramundi (predominantly Queensland, New South Wales and Northern Territory). Sea-cage production of yellowtail kingfish and mulloway has increased in South Australia.

In general, due to reductions in wild catch and the preference among Australians for marine fish, there is a potentially large market for cultured marine fish in NSW. Provided sufficient venture capital can be attracted and with favourable water temperatures and access to the Sydney markets, the long term expectation is that marine finfish aquaculture production in NSW has the potential to increase to between 2,000-5,000 tonnes per annum within 10 years although strong competition from imports will have some bearing on this.

However at present the NSW marine fish industry remains small and employs few people directly. Production in NSW has stalled with one off-shore seacage operator going into receivership. While commercial interest in reinvesting in seacage culture in NSW has been low, a second seacage operation in Botany Bay has been leased for small scale mulloway and kingfish production. Recent interest by South Australian producers is encouraging. While existing approved sea-cage sites could produce 2,000 to 5,000 tonnes per annum, there are only a limited number of suitable sites for offshore sea-cage culture in NSW, and obtaining approvals for farming activities will be difficult while the current approval process remains.

One of the main reasons why commercial marine fish aquaculture has struggled in NSW has been the failure of the hatchery sector to produce reliable supplies of fingerlings at competitive prices. It is not currently possible for NSW sea-cage grow-out farms to purchase snapper, kingfish or mulloway fingerlings from interstate (SA) hatcheries because of real or perceived concerns with genetic pollution and disease transfer

NSW DPI has a potential role in using its hatcheries to overcome these ‘infant industry’ problems by providing a secure source of fingerlings to the grow-out sector and simultaneously encouraging the growth of a commercial hatchery sector. Without a reliable supply of fingerlings, new investment in marine finfish aquaculture in sea-cages is unlikely. The model employed in Tasmania for Atlantic salmon and in Queensland for barramundi, where government helped secure fingerling supplies and progressively handed this business to industry, warrants consideration in NSW. Joint venture operations with the industry may also warrant consideration.

Aquaculture of marine fish species in inland saline groundwater is a developing industry with potential for large-scale production. Sixty five thousand ML of saline water is pumped annually in the Murray Darling Basin into evaporation ponds and opportunities exist to use this resource for grow-out of marine species and to offset the costs of the subsurface drainage schemes. Identification of suitable species and development of production methods are still in a research phase at NSW DPI's Inland Saline Aquaculture Research Centre near Wakool.

Large-scale stocking of marine fish species into estuaries and ocean environments in NSW is not currently government policy due to the lack of knowledge of potential impacts of stocking. However, several NSW DPI research projects to determine the feasibility and to model the impacts of stocking juvenile mulloway have demonstrated excellent potential for stocking into estuaries to enhance recreational fisheries.

Recommendations

18. Research and Development in marine fish aquaculture for aquaculture, stock enhancement and inland saline should continue while current contractual commitments exist.

19. New research into marine fish would require levels of industry funding to average greater than 50%

20. NSW DPI should supply fingerlings on a commercial basis to the marine finfish sector to overcome a significant impediment to the growth of the sector. To encourage the development of a private hatchery sector, DPI would need to price fingerlings at a competitively neutral rate and make its technologies and breeding stock available to private hatcheries as they emerged. DPI should exit from this business when private hatcheries have the capacity to supply the market.

21. Investment by NSW DPI in finfish aquaculture should be again reviewed in 2010 (when current R&D commitments are winding down), against the profitability of the hatchery, the growth in external R&D funding and the growth in the industry (expected to be in the order of 500 tonnes per year for sea-cage production and 150 tonnes from inland saline aquaculture).

22. Production of fingerlings for restocking rivers and oceans should be fully funded by the beneficiaries (recreational and commercial fishers) through license fees and/or government agencies responsible for protecting biodiversity.

23. Industry-funded feed research of benefit to NSW aquaculture farmers, feed manufacturers and the agricultural feed ingredient sector (providing it is largely industry funded) should be continued.

24. There is an urgent need for a coastal and offshore zoning policy, and for a commitment by government to marine aquaculture within appropriately zoned areas.

Inland Finfish

Silver perch has long been recognised as having great potential for aquaculture. It is also a popular fish because of its edible and sporting qualities. Over the last 30 years, there has been a significant decline in distribution and abundance, and it is now a threatened species with the conservation status of “vulnerable”.

Research at the Grafton Aquaculture Centre (GAC) to develop techniques for grow-out to market size has provided a technical basis for development of the silver perch industry. It is now the 3rd largest and most valuable aquaculture industry (behind oysters and prawns), as well as being the largest freshwater industry in NSW

There is an increasing interest in silver perch amongst irrigation farmers, and the integration of aquaculture and agriculture has the potential to lead to a significant expansion of the industry over the next five to ten years. This is dependant upon future water supply outcomes for irrigation areas in NSW.

Approximately half the annual production of silver perch is sold into the live fish markets to predominantly Asian consumers in Sydney, Melbourne, Brisbane and Canberra. Although this is a limited, niche market, it has continued to grow steadily over the last ten years and will continue to do so.

If production costs could be lowered, silver perch could compete with and replace imports. It is one of the few, if not the only species in Australia with this potential. However, unless production costs are lowered through cheaper fingerlings, accelerated growth rates, improved survival rates, reduced feed costs or a combination of the above, this potential won’t be realised.

Current research work at GAC is aimed at reducing production costs through the use of genetics and breeding to gain significant improvements in growth, production, and disease resistance in farmed silver perch. New technology to produce silver perch in cages is being investigated as a potential new business opportunity for farmers with access to irrigation water (e.g. cotton farmers).

A barrier to industry growth is the restriction on collection of brood stock from the wild because of the low abundance of silver perch and its listing as “vulnerable” under the Threatened Species legislation. Government (NSW DPI) needs to play a role in ensuring that industry has access to genetically heterogenous wild stocks

GAC also undertakes activities associated with the conservation and fisheries projects on the ecology and conservation of the endangered eastern freshwater cod and the distribution and biology of the pest species, banded grunter. For these programs it is likely that the community, rather than industry, captures most of the benefits

As almost all farmers who have entered or are likely to enter this industry are agricultural farmers without any skill base with fish culture, any R&D must be strongly supported by an extension service to facilitate improvements in on-farm practices and the up-take of new technology

At present it is likely that the industry is too small to fully support a credible research program. From this review of the industry it seems probable that a key constraint to the growth of the industry is the high cost of producing silver perch which will make it difficult to gain market share in the processed fish sector against imported products

Recommendations

25. NSW DPI Asset Branch should assume management of the facility operating costs for the Grafton Aquaculture Centre, in recognition that it is a multifunctional DPI facility

26. The genetic improvement program for commercial production of silver perch should be continued and be transferred to industry by 2009.

27. Adoption of results from the silver perch genetic improvement program should be facilitated through the sale of "improved fingerlings" (F1 hybrids from restocking program) to industry on a commercial basis until other commercial hatcheries have access to wild fish populations.

28. Silver perch stockings for conservation purposes should be continued as required by the NSW DPI Threatened Species Unit, subject to the availability of conservation funding.

29. Silver perch R&D should be reviewed in mid 2010 when outcomes of current genetic research are known. If there is no new significant industry or commercial funding available (at least 50% of total R&D investment), significant progress has not been made with lowering production costs and the industry has shown little growth then silver perch R&D at GAC should be terminated (note that the Division of Agriculture & Fisheries and wild fish conservation R&D would need to fully fund any continued conservation operations at GAC).

1. Introduction

The aquaculture industry is recognised as being the fastest growing primary industry for food globally, growing at an average compound rate of 8.7% annually. The greatest proportion of this growth has been in Asia, and particularly China, with 71% of global production (Tacon 2004). In Australia, aquaculture production trebled to a value of $732 million in the decade to 2003/04 (ABARE 2005), primarily in finfish (bluefin tuna and Atlantic salmon), oysters and prawns, representing 34% of the gross value of fisheries production (ABARE 2005). Over the same period, aquaculture production in NSW showed a more modest increase from $31.5 million to $51.1million. The bulk ($37.9million) of the industry in NSW is in Sydney rock oyster (SRO) culture.

Drivers for growth of the aquaculture industry worldwide and in Australia are persuasive. Consumer demand for fish products is rising because of population increases and increased affluence, particularly in Asia. Recognition of the contribution of fish to a healthy diet is also adding to demand. However, the yield from wild catch fisheries is decreasing and the sustainability of natural fish stocks worldwide is in question. Aquaculture production will be required to meet a substantial proportion of the projected gap in future demand and supply. This is particularly relevant for Australia, which in 2003/2004 imported 75% (by weight) of its seafood. However predictions for industry expansion in Australia to help reduce the gap between demand and supply at a local (Australian) level need to account for the availability of cheap seafood imports from Asia and elsewhere which continue to dampen the economic viability of aquaculture production in this country.

Australian aquaculture industries grew rapidly prior to 2000 (12.3% annually – Piper 2005) but growth has not continued at this rate since then according to the latest ABARE data available (ABARE 2005). The vision set by industry in 1999 at the National Aquaculture Conference in Melbourne of at least $2.5 billion in annual sales by 2010 has been replaced by a more conservative estimate of $1 billion (National Aquaculture Council 2004).

More recent predictions in NSW were that aquaculture industries would be valued at $100 million by 2010 (NSW DSRD/NSW DPI 2004). In NSW the value of the industry in total increased by 19.5% from 2000/2001 to a value of $51.1 million in 2003/2004 (ABARE 2005) and, from 1996/1997, has increased by 42% to 2003/2004. This has occurred in a period in which the then NSW Fisheries and industry funding bodies have invested a total of $9.67 million in R&D, primarily in fish feed technologies, hatchery technologies for finfish and molluscs, and breeding programs for growth rate and disease resistance.

1.1 Objectives of this Review

Our objective was to review the direction of future research activities by DPI in selected aquaculture sectors with a view to making judgments about:

- Their economic, environmental and social impacts;
- The beneficiaries of these research activities
- Whether proposed activities are appropriate for a publicly funded research provider;
- Whether they are consistent with the needs of industry
- Whether the mix of industry and public funding is appropriate.

This review is part of an ongoing process of specific evaluations of significant investments by NSW DPI in R&D. Detailed reports on each of these evaluations can be found in the Economics Research Report series available on the DPI web at:
http://www.agric.nsw.gov.au/reader/10550.

1.2 Context of the Review

There is uncertainty about why growth in aquaculture in Australia has been slower than anticipated. However given the competitiveness of Asian industries, there must be doubts that Australian investment in some sectors of aquaculture competing in the same markets as imported seafoods will be profitable and hence about the potential for growth in these sectors. At least in NSW, increasing coastal urbanisation and recreational use also place limits on the growth of some forms of aquaculture. Governments can do little to reverse these issues.

However, there are areas in which governments can promote the growth of aquaculture in Australia. Growth in many sectors has been limited by slow and complex regulatory processes for approval of new aquaculture developments. In some cases, the 'infant' nature of some aquaculture enterprises places constraints on growth. The small size of industries means that economies both 'on-farm' and in associated feed and processing sectors cannot be realised. In some cases, fingerling enterprises have not developed to support growout industries. Further public R&D and extension programs may ameliorate slow growth by developing and extending new technologies that significantly lower the cost of producing aquaculture products.

The aquaculture industry in NSW consists of a number of small sectors, many with growth potential. Not surprisingly there is no single recipe for government involvement in these sectors because of the diversity of production, environmental, and regulatory issues they confront. NSW DPI, through R&D activities, has made a significant contribution to the actual and potential growth of these sectors.

Nevertheless, at a time when public funds available for R&D in primary industries are declining, it is sensible to review the rationale for government involvement in aquaculture not only through R&D but more generally. In the course of this review, several potential grounds for government involvement were identified including:

- The need to maintain a research capacity to respond to catastrophic disease outbreaks, such as QX disease in oysters, threatening commercial aquaculture, native species and food safety.

- Research into the life cycle of vulnerable native species such as silver perch and eastern freshwater cod to provide a basis for the protection of these species through regulation and restocking and of pest species such as the banded grunter for the protection of environmental assets such as coastal reefs in the case of abalone.

- Research into breeding and feeding technologies allowing the operation of hatcheries to provide a reliable supply of fingerlings, said to be a constraint to the development of commercial aquaculture and to meeting the demands from the recreational fishing sector for restocking. The hatcheries should be run in a competitively neutral manner both as a means of recovering costs and encouraging the growth of a commercial hatchery sector. Such assistance to these 'infant industries' should be regularly reviewed against criteria such as research success, increased industry funding and the continued growth of the sectors.

- Where possible CRF resources should be used as in-kind contributions to industry funded projects which are likely to have both industry and public good outcomes.

- The beneficiaries of new production technologies developed by DPI will be producers, processors and consumers in these sectors and hence R&D directed towards commercial aquaculture or recreational fishing should be funded by these two groups to an increasing degree (at least 50 percent is the current goal for DPI).

- There has been a recognised need over recent years to simplify the approval process for commercial developments in most sectors of the aquaculture industry.

- Because of the high costs of public health, governments may find it efficient to invest in research that reduces the price of fish to encourage the community to increase the consumption of seafood, and of omega 3 fatty acids, because of the clearly demonstrated human health benefits.

Aquaculture R&D is also unusual in that there are few research providers and there is a strong argument that if NSW DPI does not support research into species of relevance to NSW, then the research will not take place. For example there is currently no other centre in Australia with the capability to conduct breed improvement research with SROs, the nutrition research conducted at the Port Stephens Fisheries Centre, the research on hatchery production for marine species of interest in NSW, or to develop technology for silver perch. Although most state governments, CSIRO and Universities have some aquaculture research capacity, the small size of the industry, the diversity of species and production systems being used, and the limited funding available have forced a collaborative approach and very little duplication of research effort. The consequence of this is that if NSW DPI terminated research on a particular aquaculture species/topic, it is very unlikely that it will be picked up by another research provider.

1.3 Conduct of Review

The members of the review team were Dr Trevor Gibson, Director, Production Research, Ms Helen Scott-Orr, Director, Health Sciences, Science Alliances and Evaluation, Mr Geoff File, Director, Research Operations, Dr Geoff Allan, Research Leader, Aquaculture and Dr John Mullen, Research Leader, Economics Coordination and Evaluation.

This review examined the characteristics of the main aquaculture industries in NSW with respect to current impediments to growth, market development and future opportunities. Within this context, it examined the nature, funding and impacts of DPI’s current and proposed investments in aquaculture R&D and industry development, as well as its alignment with DPI and industry priorities.

The approach taken with the review was to seek information on the aquaculture industries and on current DPI R&D programs in aquaculture from DPI aquaculture scientists. These enterprise and R&D situation statements were complemented by an industry perspective through personal contact with industry members and stakeholders in selected aquaculture industries. Industry stakeholders were asked to give an industry perspective on the potential for industry growth and future directions, major impediments to industry growth, R&D priorities and value of DPI R&D programs to the industry. Consultations and workshops took place during 2005.

Industry stakeholders raised several important issues in DPI aquaculture R&D and management, and identified some key barriers to industry development. These were taken into consideration by the review team in drafting the report.

Review findings were workshopped with DPI aquaculture scientists prior to report finalisation.

2. The Economic Framework Underpinning this Review

Aquaculture R&D, as for R&D in agriculture more generally, is often seen as having public goods characteristics. These characteristics mean that there is little incentive for the private sector to supply the good or service to the extent demanded by the community. In other words there is *market failure* and a potential reason for governments to provide the service. The debate about the nature of R&D undertaken by DPI is made difficult because these terms and concepts are often used quite loosely. They are defined (as economists use them) below:

Non-rivalry: Use by one person of a service such as information does not diminish its availability to others

Non-excludability: Difficult to exclude 'free riders' who do not pay for the service they use.

These two characteristics define the populations of those who benefit from research. Where research outcomes are rival and excludable, they can be captured privately. Where research outcomes are non-rival and excludable they can be classed as industry goods. The outcomes of research of a pubic good nature are both non-rival and non-excludable.

Private good: An example of private good research is where DPI conducted research to develop, say, a new higher yielding variety of watermelon which remained the exclusive property of a single farmer. Nearly all the benefits from this research would be captured by the farmer and hence the research should be funded by the farmer. The public good component is limited to the new knowledge about breeding that the researchers might be able to apply elsewhere. NSW DPI undertakes a limited amount of such research but only on a consultancy or contract basis with full cost recovery and where specialist resources are not required elsewhere. Perhaps DPI research into pearl oysters in association with Port Stephens Pearls is the closest example of private good research in aquaculture.

Industry good: An example of industry good research is say wheat breeding, where DPI develops higher yielding varieties of wheat which it makes widely available to farmers. Prior to plant variety rights it was expensive to limit the variety only to those farmers who might be willing to pay for its development. The benefits from this research were previously non-rival and non-excludable to all wheat farmers. The beneficiaries of the research are not just farmers but also the processors and consumers of wheat, some of whom are not residents of Australia. Note that wheat breeding does not become a public good just because consumers and processors benefit. Again the public good component of this research is limited to spillovers to others in the community who have no market relationship with the wheat industry and takes the form of say new knowledge about breeding technologies or better environmental and human health outcomes from new varieties.

Most of the research done by NSW DPI has an industry good component. However in recent decades institutional mechanisms have been developed that mitigate the non-excludability characteristic of industry goods. Plant variety rights for example mean that DPI can now recover some of the costs of breeding new varieties through royalties. Much industry good research is funded by the Research and Development Corporations who rely on the Federal government to levy their members to provide funds for research. These mechanisms preserve and exploit the non-rival nature of research in that the new information is still available to all in the industry. Until these mechanisms were developed it was commonplace for State

Departments to both conduct and finance this type of research because it would not otherwise have been undertaken. The great majority of aquaculture R&D in DPI falls in this category. R&D into breeding and feeding technologies for commercial and recreational purposes are good examples.

Public Goods: Public goods have the characteristics of non-rivalry and non-excludability and are enjoyed by the community whether or not they use the associated agricultural product. Most people accept that research into the environmental consequences of agriculture has a large public good component because the benefits flow to the broader community, both present and future generations. There would be inadequate investment in research of this type without government funding because the benefits cannot be captured by industry funders. An alternative approach to environmental concerns is regulation but this is difficult when so much of the degradation is of a non-point source nature. An important rationale for government funding of agricultural research which has a mix of public and industry benefits (goods) is that if farmers have available to them technologies that are profitable as well as being environmentally friendly then more wide-scale adoption of these technologies is likely. Research into understanding the life cycle of vulnerable species such as silver perch and eastern freshwater cod and into the management of reef communities are good examples of this type of R&D.

Evaluating the impact of R&D in aquaculture

Research activities in aquaculture deliver a range of economic, environmental and social outcomes – 'triple bottom line' outcomes – which may all have public and private good components. A key step in evaluation is to identify who benefits from R&D. Usually while innovation may occur at the 'farm' level, the efficiency gains are shared between farmers, processors and consumers (some of whom are non-residents of Australia).

A second key step in evaluating the impact of R&D in aquaculture is to identify not only the expected impact on an industry of the investment, the '*with technology*' scenario, but just as importantly, how the industry would continue to develop without the investment by NSW DPI, the '*without technology*' scenario. Rarely is the 'without technology' scenario a no-change scenario because there are usually other sources of similar technologies leading to ongoing productivity growth. The need to identify appropriate 'with' and 'without' scenarios applies equally strongly to environmental and social impacts as to economic impacts. In assessing the 'with' and 'without' technology scenarios, key outputs from research and extension activities and communication strategies used are described to give credence to claims about the contribution of NSW DPI and to assumptions about the rate and extent of adoption of the technology.

Economic outcomes of R&D arise from reduced production costs and/or improved product quality. Economists have long experience in valuing economic outcomes although applications in aquaculture in Australia are limited. It is important to recognize that the measures of economic performance already capture some environmental and social impacts. Measures of farm or industry profit reflect the impact of changed environmental conditions on yields and input costs but not off-farm impacts. Similarly, the measure of profit change is often a measure of change in industry profit, not just farm profit, which is shared between not only farmers/fishers, but also with inputs suppliers, processors and consumers, some of whom live in rural communities.

However some social and environmental ‘spillover’ impacts on the community are not reflected in industry measures of economic performance. Some important dimensions of social impacts are how the benefits of technology are shared between different types of producers and the contribution of new technology to the social capital of communities. In general we have not attempted in these evaluations to examine the distribution of total industry benefits from new technology between these different industry sectors.

In addition to the impact on rural communities through economic activity, the numbers of people living and working on farms and their skills or human capital are important to the strength of community service and cultural organizations, referred to collectively as social capital. The social capital of communities is likely to be related to their size which at least in the past has likely been linked with the prosperity of agriculture. Hence there is concern about the impact of new technology or changes in natural resource policy on the size of rural communities and their social capital.

In general the impact of technology in agriculture has seen a steady transfer of resources, particularly jobs, to other often non-rural sectors of the economy. This is the story to date of economic development in developed countries. Australian aquaculture operates in an open market dependent on world prices and hence unless its productivity growth from new technologies matches that of its competitors, it will become uncompetitive on world markets and the rate of transfer of resources out of Australian aquaculture is likely to be faster than otherwise.

Stayner and Reeve (1990) noted that there has been a ‘decoupling’ of agriculture and the economic activity of rural communities such that the prosperity of agriculture is less important to the prosperity of rural communities than formerly although the impact on communities is not uniform. Little is known quantitatively about these types of relationships between rural communities and the agricultural sector. It is unclear what ‘indicators of social capital’ we should be monitoring and what the empirical relationship is between a new farm technology and these ‘indicators’ (valuing environmental impacts faces similar problems).

3. Aquaculture Industries – An Overview

3.1 Aquaculture in Australia

With a value of $732 million in 2003/2004 (ABARE 2005), aquaculture industries represents one third of the value of total Australian commercial fisheries production and directly employs 5,000 people. Although some 50 species are produced commercially, 87% of the gross value of production (based on 2003-2004 data) is from a limited number of species - Southern bluefin tuna ($242.0 million), pearl oyster ($150.0 million), Atlantic salmon ($115.6 million), edible oysters ($71.8 million) and prawns ($55.9 million) (ABARE 2005).

The early expansion in Australian aquaculture during the 1990s was primarily from a combination of investment in new industries (southern bluefin tuna, barrumundi, silver perch, abalone, mulloway and yellowtail kingfish), and in existing industries (pearling, edible oysters, prawns and salmonids). Since 2000, neither industry production nor value has increased (ABARE 2005). One or two species dominate production in each State, edible oysters in NSW, trout in Victoria, prawns and barramundi in Queensland, pearl oysters in Western Australia, tuna and edible oysters in South Australia, and salmon and edible oysters in Tasmania. Table 3.1 shows the value by State for the aquaculture industries with a value of $10 million or more in 2003-2004.

Table 3.1: Australian Aquaculture Value of Production in 2003-2004.

	NSW $'000	Vic $'000	Qld $'000	WA $'000	SA $'000	Tas $'000	NT $'000	Aust $'000
Salmon						115,656		115,662
Trout		11,008						12,890
Tuna					242,000			242,000
Barramundi			10,000					13,383
Prawn			51,500					55,922
Edible Oysters	37,921				21,152	11,998		71,822
Pearl Oysters				150,000				150,000
Other							28,000	42,326
Total	49,648	21,440	65,550	156,842	277,756	132,575	28,000	731,811

Note: Production value of $10 million or above shown
Source: ABARE (2005)

More than 60% of production by value is exported, and some species (southern bluefin tuna, kumara prawns and abalone) are produced almost exclusively for export to Asia. The remaining dominant industries market mostly within Australia, with domestic annual seafood consumption trebling in the past 30 years to levels similar to the global average of 15.8 kg/head.

Love reviewed some of the impediments to the growth of aquaculture in Australia (ABARE 2003). The mix of institutional, physical/commercial, and structural impediments identified included:

- A multiplicity of regulatory requirements leading to concern about the appropriate balance between environmental protection and the growth of an aquaculture industry;

- Physical impediments, such as a lack of suitable sites, and commercial impediments, such as high rates of importation of seafood, were identified acknowledging the limited role for government to manage these beyond the provision of information and the conduct of research;

- The lack of industry vision and organisation with respect to promotion and marketing was seen as a structural impediment.

These impediments and others including poor market development and access, fragmented industry structures and poor species choice for investment (Productivity Commission 2004), have impacted on industry growth and investment. However, significant recent investment in some aquaculture sectors is apparent (ABARE 2003). These include sea cage yellowtail kingfish, barramundi and land based abalone, with continued rapid growth in these areas, albeit from small base levels in terms of production and value. Of the dominant aquaculture sectors, the production values of only bluefin tuna and salmon increased significantly from 1998/1999 to 2000/2001, but these have not increased since then (National Aquaculture Council 2004).

3.2 Aquaculture in NSW

Oysters

The dominant aquaculture industry in NSW is the Sydney rock oyster (SRO) industry, with a value of $35.9 million in 2003/2004 out of a total of $51.1 million for the industry as a whole. Table 3.2 gives estimates of the production and value of aquaculture production for that year for each of the major aquaculture industries in NSW.

Most SRO production is shared between ten NSW estuaries, with production increasing marginally since 2000/2001. In 2003/2004 the greatest share of production was from Wallis Lake (30%) followed by the Clyde River, Hawkesbury River and Port Stephens, each with 10-11% share of production. Cultivation method is primarily by tray culture.

The SRO industry is now at a crucial point of its development. Its greatest challenge is QX disease, as evident from the recent outbreak in the Hawkesbury River. This disease has the potential to destroy the industry in all NSW estuaries.

Industry leaders increasingly recognise that to minimise the impacts of QX disease and its spread to other estuaries, it must restructure to adopt single seed technology using genetically improved QX resistant Sydney rock oysters from structured breeding programs. The industry-based Select Oyster Company (SOCo) is now heavily involved in the supply of resistant spat to industry in collaboration with DPI. Adoption of the technology may also improve competitiveness of the industry with the Pacific oyster industry in Tasmania and South Australia. NSW DPI has been involved with the industry in developing a hatchery sector as part of its breeding program (see Section 6).

Table 3.2 Aquaculture production in NSW 2003/2004

Industry	Production (tonne)	Total Value (million $)
Crustaceans		
Black tiger prawns	363.4	4.43
Other[1]		0.35
Freshwater Fish		
Barramundi	101.2	1.13
Rainbow trout	169.7	1.55
Silver perch	232.1	2.28
Other[2]		0.49
Marine Fish		
Mulloway	3.5	0.03
Other		<0.01
Hatchery		2.04
Molluscs		
Sydney rock oysters	8 million doz	35.9
Other[3]	0.5 million doz	1.9

[1] Primarily yabbies [2] Primarily Murray cod [3] Primarily Pacific oysters

Notes:

1. individual statistics were combined for "other" categories
2. Source: NSW DPI (2005) Aquaculture Production Report 2003/2004
3. Hatchery production value primarily as fingerlings or juveniles for Murray cod, aquarium species, golden perch, silver perch and yabbies.

Pacific oysters are a minor industry in NSW, valued at under $2 million and production limited to 12 producers in Port Stephens. The QX resistance of the oyster will ensure that production will increase, at least in the short to intermediate future because it offers an alternative to the culture of Sydney rock oysters.

Production technologies have been developed for other oyster species such as flat oysters and pearl oysters but the commercial production of these species in NSW is not significant. For example, the flat oyster industry is valued at about $100,000 per year and targets a niche restaurant market in Sydney, Melbourne and Canberra. Commercialisation and industry development of pearl oysters has been impeded by regulatory barriers based upon environmental concerns by local communities. However, a recent ruling by the Land and Environment Court to overturn the decision to reject a large pearl farming proposal in Port Stephens should impact positively on the sector's development in NSW.

Finfish

With a total production value of $5.5 million, fresh and saltwater finfish represented 10.8% of total NSW aquaculture production by value in 2003/2004 (Table 3.2) and less than 1% of Australia's aquaculture fish production by value. Most of this is in native freshwater fish culture, mainly silver perch, rainbow trout and barramundi. The industry is in its infancy and early commercial interest in off-shore cage culture for growout of the marine fish snapper and mulloway has not yet been rewarded by the development of a viable industry. This is largely because of difficulties with a reliable source of fingerlings, regulatory issues and business failure not associated with the technology (e.g. undercapitalisation, poor staff recruitment, etc) (see Section 8). A limited number of land-based hatcheries remain, as does one medium scale cage fish farm and several smaller pond-based farms with a capacity to growout a relatively small amount of marine species, primarily for local markets.

One of the potential aquaculture industry development opportunities being examined by NSW DPI is the culture of marine species in inland NSW using saline groundwater. It is too early for commercial production but trials of approximately 0.5 tonnes of trout and 100 kg of prawns were produced from the NSW DPI/Murray Irrigation Ltd research facility near Wakool in south western NSW.

Freshwater fish production is based upon land-based pond culture with farms distributed from Grafton in northern NSW to Howlong in the south. The industry primarily supplies chilled or live fish to Asian markets in the eastern Australian capitals. For silver perch, early forecasts of a good growth potential for the industry attracted investment in the early 1990s and production increased from 2.6 tonnes in 1992/1993 to 300 tonnes in 2002/2003 valued at $3 million. Since then, production has decreased to 232 tonnes in 2003/2004, though silver perch culture remains the third biggest aquaculture industry in NSW behind SROs and prawns. Details are given in Section 9.

Future growth of the industry will depend on improved efficiencies through genetic and husbandry improvement, delivery of culture technologies to industry, market development, and increased incentives for investment. NSW DPI has several R&D programs supporting the finfish aquaculture industry, including nutrition and feed formulations, hatchery technologies and fish husbandry.

Prawns

The NSW prawn aquaculture industry in NSW is concentrated on the Clarence and Richmond Rivers. There are five prawn hatcheries with permits in NSW but only one has regular production. The black tiger or jumbo tiger prawn (*Penaeus monodon*) is the dominant species grown, with production of this species increasing from 170 tonnes in 1989/1990 to 363 tonnes in 2003/2004 (Table 3.3). This is down from a maximum of 462 tonnes in 1998/1999 and production has been static since 1997/1998. The prawn industry in NSW is valued at $4.4 million, second to Sydney rock oysters.

Table 3.3 Production and value of aquaculture prawns in NSW 1989/1990-2003/2004.

Year	Production (tonnes)	Value ($'000)
1989/90	170	1,827
1990/91	186	1,999
1991/92	183	1,775
1992/93	276	3,239
1993/94	265	3,235
1994/95	248	3,742
1995/96	271	4,820
1996/97	209	3,460
1997/98	362	5,526
1998/99	462	6,835
1999/2000	403	6,068
2000/01	294	4,933
2001/02	346	5,440
2002/03	409	6,178
2003/04	363	4,431

The other species that has been cultured in significant quantities in NSW is the Japanese tiger or Kuruma prawn (*Penaeus japonicus*). In NSW, *P. japonicus* was cultured exclusively for live export to Japan where it fetched a very high market price, sometimes up $150/kg. The depressed Japanese economy was the primary factor in reduced production of this species after 1997/1998.

The prawn aquaculture industry is constrained at present by market issues and low prices for farmed "vannamei" prawns (*Litopenaeus vannamei*) imported frozen from China, Thailand and Vietnam. The "vannamei" prawns are typically sold at a smaller size than tiger prawns and while prices for smaller tiger prawns has been affected, prices are relatively firm for larger prawns as a fresh product.

Industry growth is also constrained by available sites. Approval in 2004 for a large prawn farm on Micalo Island in northern NSW may significantly increase production. The farm has the potential to produce several hundred tonnes of prawns.

Hatcheries

Commercial fish hatchery production was valued at $2 million in 2003/2004, providing fingerlings, fry and juveniles of a number of marine and freshwater finfish, molluscs and crustaceans for growout by other industry sectors. In 2004, 26 hatcheries were distributed throughout NSW. One key role for hatcheries is for stock enhancement programs. On a commercial basis, this has been restricted to Australian bass for restocking inland river systems and there is potential for the development of a hatchery industry to restock marine fish such as mulloway. NSW DPI has been active in developing hatchery technologies for several aquaculture species, including snapper, mulloway, silver perch and oysters, and although not operating on a commercial basis, produces Australian bass and abalone for stock enhancement programs.

Conservation Issues

Several conservation issues are associated with aquaculture industries in NSW. Two vulnerable species, silver perch and eastern freshwater cod have been the subject of research by scientists in DPI. In addition, research into breeding and restocking abalone has implications for the management of reefs degraded in part by the overfishing of abalone.

Resources Available for Aquaculture in NSW

The land and water resources available in NSW offer a mix of opportunity and impediment to the development of aquaculture industries. Marine and coastal developments face limited suitable locations for off-shore cages and in-bay or in-estuary infrastructure because of high coastal populations and coastal urban developments. These generate competing and at times conflicting demands for public water resources and result in strict regulatory controls over aquaculture development in these areas. They also mean that coastal land required for processing infrastructure is expensive and difficult to secure.

However, the availability of inland resources in NSW does offer opportunities for aquaculture development. Significant volumes of saline groundwater in south western NSW that are pumped to surface ponds for evaporation are suitable for the culture of marine species, now under investigation by NSW DPI (see Section 8). Large irrigation water storage dams in north western NSW also offer suitable conditions for the culture of inland fish species such as silver perch and this is also under investigation by NSW DPI as part of the Cotton Catchment Communities CRC (see Section 9).

The NSW DPI aquaculture research facilities at Port Stephens and Grafton at present supply material from oyster and finfish breeding programs to industry on a commercial basis. They also provide some species of finfish to restocking programs. These facilities will play a significant role in future aquaculture industry development by maintenance of superior breeding lines and high volume commercial supply of fingerlings and spat to industry on a cost competitive basis until a viable industry hatchery sector emerges. These are discussed more fully in Sections 6 to 9.

Marketing – Imports and Exports

At a national level, seafood imports are valued at over $1.1 billion (ABARE 2005), 63% of which are frozen or canned fish, prawns or pearls. The deficit in seafood supply in Australia was 280,000 tonnes in 2000 and is predicted to increase to almost 500,000 tonnes by 2020, based on a modest projected increase in consumption from 11.33 kg/person/annum to 14.7 kg/person/annum (FRDC 2004). This estimate assumes a continued decrease in wild catch and a significant (94%) increase in aquaculture production during this period.

NSW now imports over 75% of its seafood and a key driver for the development of a robust aquaculture industry is to reduce this reliance on imported product through stock enhancement and improved production efficiencies. Exports of species derived from aquaculture is limited to a small proportion of the Sydney rock oyster production (<2%).

Imports are from both international and interstate suppliers. The NSW aquaculture industries under present structures are faced with low cost imports of whole fish and fillets, prawns and Pacific oysters (which compete with Sydney rock oysters), produced under lower cost structures (for example in Asia for finfish and prawns). The low cost of these imports places a price ceiling on the NSW-grown product, although product imported from overseas is usually frozen and competes in a different market.

The NSW aquaculture industry has not had an effective and integrated marketing program. At a national level, an FRDC marketing review in 1992 which concluded that the seafood industry in Australia did not have the marketing ability of other food sectors has produced little improvement to date (FRDC 2004). An exception was export promotion of wild caught prawns. In NSW there is limited evidence of a strong marketing culture in NSW aquaculture industries aimed to increase consumer awareness and influence purchasing decisions by an increasingly sophisticated market.

However, an encouraging exception is the completion and launch of a silver perch marketing project in June 2005, funded through the Silver Perch Growers Association and the NSW Department of State and Regional Development. The marketing plan includes analyses of factors the industry needs to address for market development, and examines new market growth opportunities, marketing strategies and funding options. The project has delivered a quality assurance document, promotional material and a new brand name “SILVAS” and is discussed in Section 9.

Current initiatives also include the development of promotion strategies and brand development for the entire Australian seafood industry (capture and culture) as part of the Aquaculture Industry Action Agenda commissioned by DAFF and National Aquaculture Council, and in collaboration with the Australian Seafood Industry Council (www.australian-aquacultureportal.com). The project is planned for implementation within the next twelve months. At a State level, the Sydney rock oyster industry released an Oyster Industry Strategy in 2005, which has a marketing element and “Oysters in the House” in 2006 and 2007 has promoted the industry to consumers.

Regulatory Issues

NSW DPI is responsible for the promotion of a viable and environmentally sustainable aquaculture industry. An aquaculture permit issued under the *Fisheries Management Act 1994* is required to authorise commercial aquaculture. An aquaculture permit is an integrated approval under the *Environmental Planning and Assessment Act 1979* that links Council and other government agencies requirements in one approval process.

Clearly, regulation of aquaculture development is necessary to manage species and site selection and to manage operational criteria for sustainable development. Aquaculture often involves the use of public waters in areas with several competing uses. It is a relatively new food production industry and little is know about it in some sectors. In the past there have been examples of inappropriate aquaculture developments in Australia and unsustainable farming practices overseas which have flavoured the perception of aquaculture in NSW.

While in NSW a number of development approval applications have experienced protracted delays, other approvals have not had similar difficulties. The NSW planning and approval process is comprehensive and complex. Problems can arise because proponents have underestimated its requirements particularly those related to environmental assessment and community/stakeholder consultation. This is particularly true of aquaculture developments in coastal areas where there have been land-use conflicts and a negative perception towards aquaculture and perceived impacts.

At a national level, the need for development of nationally consistent environmental regulation for aquaculture development (Productivity Commission 2004) has been progressed through endorsement in 2005 by the Primary Industries Ministerial Council (PISC) of the Best Practice Framework of Regulatory Arrangements for Aquaculture in Australia. The framework seeks to integrate planning and approval processes across the three tiers of Government. The complexity of the regulatory environment for aquaculture had earlier been identified as the main institutional impediment to investment in Australian aquaculture (ABARE 2003).

NSW has progressed in simplifying the approval process for aquaculture development by, integrating the approval processes and providing more guidance for approving agencies and local councils. This has been through the activities and recommendations of the multi-agency Aquaculture Steering Committee, with an on-going review of administrative processes under the *Fisheries Management Act, 1994*. Regulatory reforms including the introduction of the Integrated Assessment Approval Process, the aquaculture-specific State Environmental Planning Policy 62 (SEPP 62), the development of several Sustainable Aquaculture Strategies, development reforms for coastal developments under the *Environmental Planning and Assessment Act, 1979*, and standardised Local Environmental Plan templates.

4. Research and Extension Activities in Aquaculture

4.1 R&D Funding in Australia

An important source of funding for aquaculture research is the Fisheries Research and Development Corporation (FRDC). In some respects the FRDC operates along similar lines to other RDCs in that fishers and aquaculture operators pay levies or R&D fees to a maximum amount of 0.25 percent of the gross value of production and the Commonwealth matches this industry contribution. However there are some differences. The Commonwealth makes an additional grant of 0.5 percent of the gross value of fisheries production without matching industry funds in recognition of the public good component of fisheries research.

Fisheries and aquaculture research is primarily carried out by state departments and CSIRO. In total the states undertake more research than CSIRO. Recent innovations have been the establishment of the Aquaculture CRC (Cooperative Research Centre) from 1994 to 2000 and the Aquafin CRC from 2002 to 2008. NSW DPI has been a partner in both CRCs.

The Department is also a key participant in the new Seafood CRC, which will commence in mid 2007 and contribute over $135 million over seven years, with development of new aquaculture industries a key priority. This CRC will enhance the value and production of Australian seafood through a comprehensive program involving increased production from aquaculture, improved quality, handling and supply chain management of seafood and an increase in the capacity of the seafood sector to benefit from innovative research. The NSW component of the CRC involves aquaculture of oysters, marine fish and freshwater fish through production in coastal areas (oysters and sea cage marine fish) and in inland areas (inland saline and use of irrigation water for aquaculture). It offers significant external funding for aquaculture research in NSW.

According to the National Aquaculture Council, total public expenditure on aquaculture R&D from 1998/1999 to 2002/2003 was $106.46 million, with expenditure in individual years ranging from $14.08 million in 1998/1999 to a maximum of $29.48 in 2001/2002 (National Aquaculture Council 2004). Table 4.1 shows investment by individual R&D providers and funding bodies.

For 2003/2004, this national investment represented 3.5% of the value of production (research intensity) for the industry in that year of $731.8 million (ABARE 2005).

The largest single government-based investor group in Australian aquaculture R&D during this period has been FRDC/CRC, which has invested 18.6% of the total R&D funding over the five year period. Of the R&D providers CSIRO invested 11.0%, PIRSA/SARDI 9.8% and NSW Fisheries (now NSW DPI) 6.1% of the total investment. The NSW DPI share of investment peaked in 2000/2001 at 11%.

Table 4.1 Aquaculture R&D investment by Government agencies 1998/1999 to 2002/2003 (National Aquaculture Council 2004)[1]

	1998/99 $million	1999/2000 $million	2000/2001 $million	2001/2002 $million	2002/2003 $million
FRDC/CRC	2.46	3.92	4.87	5.18	3.43
NSW Fisheries	0.63	0.27	1.04	3.40	1.14
DPI Vic	0.34	0.41	0.19	0.15	0.09
DPI&F Qld	1.15	2.23	1.62	2.12	2.37
WA Fisheries	1.00	0.99	1.24	1.41	1.51
PIRSA & SARDI	1.98	1.28	1.21	2.82	3.10
TAFI & DPI Tas	0.63	0.58	0.47	1.21	0.47
BI&RD NT	-	-	0.24	0.24	0.39
CSIRO	2.22	1.64	1.95	2.44	3.52
AIMS[2]	0.94	1.10	1.31	1.23	1.50
RIRDC	0.13	0.09	0.04	0.46	0.26
Non Gov't	2.61	4.09	6.16	8.81	8.17
Total investment	14.08	16.60	20.35	29.48	25.95

[1]Contributions from different agencies may have been calculated using different methods
[2]Australian Institute of Marine Science

4.2 R&D Funding in NSW

Aquaculture R&D in DPI is funded primarily through government and industry co-investment through levy collections distributed by the Fisheries Research and Development Corporation (FRDC).

The Recreational Fishing Trust was established under the Fisheries Management Act 1994 to enhance recreational fishing in NSW, and is funded through licence fees from recreational fishers. Funds are allocated to projects such as stock enhancement programs, habitat protection, surveys and funding of Fisheries Officers. The Trust currently funds DPI scientists in stock enhancement programs for several inland fish species. S&R scientists are specifically involved in a program for Australian bass enhancement.

Other significant external funding bodies supporting R&D programs in NSW DPI aquaculture include the Aquafin CRC, the Australian Centre for International Agricultural Research

(ACIAR) and direct investment by industry. The Aquafin CRC and FRDC have co-invested in S&R research in fish nutrition, feed technologies and hatchery technologies for marine fish, with current projects due to terminate in 2008. ACIAR is supporting a project in India and Wakool on saline aquaculture on inland salt affected areas. Funds from the Australian Aquaculture Council and private industry also support inland saline aquaculture research at Wakool. ACIAR also funds NSW DPI to help develop their aquaculture projects, mainly in Southeast Asia. An estimated $14 million will also be invested in NSW aquaculture research and industry development through the new Seafood CRC over the next seven years.

In the five years from 2000/2001 to 2004/2005, external funding bodies have invested a total of $5.53 million in NSW DPI aquaculture R&D, peaking in 2004/2005 at $1.22 million. Investment in 2005/2006 based on existing contracts is $1.10 million. The investment in R&D areas within NSW DPI is discussed below in more detail.

4.3 NSW DPI Investment in Aquaculture R&D

Since its formation in July 2004, the Science and Research Division of NSW DPI has emphasised the strategy for R&D investment in primary industry areas aligned with the National Research Priorities, and with NSW Government and industry priorities, that attract industry co-investment, are likely to deliver a return on investment to the industry and to NSW, and that have a high likelihood of success (NSW DPI 2004)

Table 4.2 summarises the investment by DPI and external funding bodies to maintain DPI's research program in aquaculture for 2002/2003 to 2004/2005 and compares this investment with other DPI programs in Fisheries and in other primary industry sectors. These figures include salary costs for staff funded through Consolidated Revenue but do not include the overhead costs of running and maintaining nursery and pond infrastructure. During this period, industry contributions to R&D in aquaculture sectors as a percentage of total investment ranged from 46% to 50%, though there were large variations between individual sectors. These levels of external support are consistent with those for DPI R&D in the agriculture sector. A notable exception is freshwater finfish R&D, which had limited external funding during this period. This changed in 2005/2006 with funding through the Cotton CRC and FRDC funds and will be further enhanced from 2007/2008 with the commencement of the Seafood CRC. It should be noted that earlier research with silver perch was strongly supported through direct investment from industry as well as FRDC and the Aquaculture CRC. The total investment over the period was $7.9 million, with an industry share of 46%.

The level of industry co-investment in DPI aquaculture R&D (over all programs) in 2005/2006 represented 47% of the total. DPI investment from Consolidated Revenue in aquaculture R&D in 2005/2006 was $1.3 million, a level that has been maintained for 2006/2007, down from a peak of $1.62 million in 2003/2004.

The research intensity over all R&D areas for the period from 2001/2002 to 2004/2005 was about 5%, again with great variation amongst individual areas. Importantly, the research intensity for the dominant industry sector, oysters, was less than 2% in the years for which data are given. The high research intensities for marine and freshwater finfish result from the small GVPs of these industry sectors in NSW and from R&D investment in programs such as feed technologies, that benefit the finfish aquaculture sector nationally (with spillover to feed manufacturers and ingredient suppliers), hatchery technologies and fingerling production for restocking programs.

Table 4.2: Funding Sources for S&R Aquaculture R&D 2001/2002-2004/2005

Enterprise	GVP	CR Funding[1]	Industry Funding	Total Funding	Industry share of funding
	$million	$million	$million	$million	%
SR oysters					
2002/03	34.7	0.336	0.026	0.362	7
2003/04	37.9	0.397	0.268	0.665	40
2004/05		0.465	0.225	0.689	33
Flat oysters					
2002/03	<0.2	0.021	0.033	0.054	61
2003/04	<0.2	0.026	0.027	0.053	52
2004/05	<0.2	0.028	0	0.028	0
Pearl oysters					
2002/03	<0.2	0.013	0.120	0.133	90
2003/04	<0.3	0.015	0.149	0.164	91
2004/05	<1.0	0.018	0.041	0.059	70
Abalone[2]					
2002/03	0	0.034	0.200	0.234	85
2003/04	0	0.048	0.200	0.248	81
2004/05	0	0.057	0.262	0.319	82
Marine finfish					
2002/03	1.24	0.310	0.464	0.771	60
2003/04	1.07	0.338	0.441	0.779	57
2004/05		0.312	0.350	0.662	53
Inland finfish (freshwater)					
2002/03	5.16	0.386	0.064	0.450	14
2003/04	5.00	0.416	0.026	0.442	6
2004/05		0.329	0.037	0.366	
Inland saline					
2002/03	n/a	0.049	0.287	0.336	85
2003/04	n/a	0.257	0	0.257	0
2004/05	n/a	0.077	0.237	0.334	71
Aquaculture Admin[3]					
2002/03		0.090	0.06	0.150	40
2003/04		0.125	0.06	0.185	32
2004/05		0.121	0.07	0.186	35
Total Aquaculture[4]					
2002/03	50.7	1.238	1.251	2.489	50
2003/04	51.1	1.621	1.172	2.793	42
2004/05		1.407	1.218	2.625	46
Total Wild Fisheries					
2002/03	102.3	0.622	1.689	2.311	73
2003/04	88.23	0.824	1.307	2.131	61
2004/05	83.12	0.713	1.307	2.020	64
Aquatic Ecosystems					
2004/05		0.527	1.168	1.695	69
Agriculture	8,359[5]	26.2	21	47.2	45

[1]CR funds include salaries and on-costs, and operating costs but not DPI overheads; [2]Primarily for restocking rather than aquaculture; [3]Includes ACIAR contract; Animal Care & Ethics Committee (for all fisheries), Oyster Research Advisory Committee, etc; [4]Includes prawns & crustaceans; [5]average of previous five years.

4.4 DPI Research and Extension Activities in Aquaculture

DPI Science & Research Division currently conducts aquaculture R&D from three research centres: the Port Stephens Fisheries Centre (PSFC), the Grafton Aquaculture Centre (GAC) and the Inland Saline Aquaculture Research Centre (ISARC) at Wakool (in an arrangement with Murray Irrigation Limited who own the facilities). Although DPI has established a hatchery and nursery for abalone R&D at Tomaree in an arrangement with the Department of Health, this research has now been discontinued. PSFC has oyster and marine fish hatchery and nursery facilities as well as extensive experimental facilities. GAC has freshwater hatchery, nursery and growout facilities as well as extensive experimental facilities while ISARC has pond and tank-based experimental facilities. Other DPI hatcheries at Narrandera, Jindabyne and Ebor do not conduct research and are primarily for fish restocking programs. They are not included in this review. Aquaculture research at Cronulla was discontinued when the technician in charge of the aquaria facilities took a voluntary redundancy.

A feature of the activities at PSFC and GAC is that the hatcheries are also used for conservation and restocking programs. For example, the Grafton Hatchery plays an important role in providing fingerlings for fish stocking programs. Current funding structures mean that it is difficult to appropriately apportion costs to the different programs and this should be addressed.

Table 4.3 lists the current aquaculture R&D programs, their location and staff details for 2005/2006.

Compared to 2003/2004, staff numbers have decreased by 3.7 FTEs, including two CR funded positions.

Current aquaculture R&D in NSW DPI can be summarised into four broad themes:

- Large scale hatchery and breeding technologies for oysters to improve growth and disease resistance and to remove technical constraints to commercial hatchery production (Port Stephens Fisheries Research Centre).
- Technologies and systems for finfish breeding and farming. R&D areas include silver perch culture and breeding (Grafton Aquaculture Centre), improved hatchery technologies for snapper, mulloway and yellowtail kingfish, and Australian bass breeding for restocking programs (Port Stephens Fisheries Research Centre).
- Fish feed technologies, feeding strategies and fish nutrition (Port Stephens Fisheries Research Centre). One focus of this R&D is to identify suitable alternatives to fishmeal in diet formulations.
- Technologies for inland saline aquaculture based on saline groundwater. This program examines the potential for new aquaculture industries for marine species for inland NSW (Wakool Saline Aquaculture Research Centre with research direction and supervision from PSFC).

These themes are expanded in Sections 6 to 9 of this report. NSW Fisheries traditionally has not maintained a strong extension network, with only one externally-funded specialist extension officer for the whole of NSW. Researchers have taken on this role and have developed their own programs to promote the adoption of research results by industry.

Table 4.3: DPI Science & Research Aquaculture Unit Staff Details 2005/2006

R&D Program	Location	Staff Details		
		Name	**Position and grade**	**CR/Ext**
Hatchery and breeding technologies for oysters and molluscs FTEs CR: 5.1 External: 2.1	Port Stephens Fisheries Centre	Lynne Foulkes Steven O'Connor Dr Wayne O'Connor Dr John Nell Ben Perkins Dr Mike Dove Ben Finn Norm Lawler** Dr Geoff Allan	Fisheries Technician Fisheries Technician Senior Research Scientist Principle Research Scientist Fisheries Technician Scientist Fisheries Technician Fisheries Technician Research Leader	CR CR CR CR CR Ext Ext Ext CR
Freshwater finfish aquaculture FTEs CR: 2.1 External: 1	Grafton Aquaculture Centre	Dr Stuart Rowland Charlie Misfud Mark Nixon Dr Geoff Allan	Senior Research Scientist Fisheries Technician 4 Fisheries Technician Research Leader	CR CR Ext CR
Marine finfish breeding and farming (including Aquafin CRC) FTEs CR: 2.6 External: 3	Port Stephens Fisheries Centre	Luke Cheviot Dr Stewart Fielder Paul Beevers vacant Debra Ballagh** Ben Doolan** Luke Vandenberg** Kirsty Webb** Dr Geoff Allan	Fisheries Technician Research Scientist Fisheries Technician Fisheries technician Fisheries Technician Fisheries Technician Fisheries Technician Fisheries Technician Research Leader	CR CR CR Ext Ext Ext Ext Ext CR
Inland saline aquaculture FTEs CR: 0.7 External: 1.6	Saline Aquaculture Research Centre, Wakool	Dr Stewart Fielder Grant Webster Dr Geoff Allan Diana Brettschnider	Research Scientist?? Fisheries technician Research Leader Fisheries Technician	CR Ext CR Ext
Feed evaluation and development for prawn and finfish aquaculture FTEs CR: 1.1 External: 1.1	Port Stephens Fisheries Centre	Ian Russell Dr Mark Booth Dr Geoff Allan Ben Doolan** Igor Perozzi**	Fisheries Technician 1 Scientific Officer Research Leader Fisheries Technician Fisheries Technician	CR Ext CR Ext Ext
Coordination and management FTEs CR: 2.4 External: 0	Port Stephens Fisheries Centre	Dr Geoff Allan Helena Heasman Jo Pickles	Research Leader Administrative Assistant Fisheries Management Officer	CR CR CR
Total FTE = 22.8 (CR 14; Ext 8.8) **Part-time casual				

There is an ongoing need for the Department to improve communication with the NSW aquaculture industry and other stakeholders. A biennial Aquaculture Update newsletter is now produced to inform stakeholders on a range of management and research topics. The NSW DPI Aquaculture website has been remodelled to improve information access. Oyster farming field days have been re-introduced and the consultative committees (Aquaculture Research Advisory Committee, Peak Oyster Advisory Group and the Landbased Aquaculture Consultative Group) are meeting regularly.

From a scientific viewpoint, the NSW DPI Aquaculture Unit has an excellent standing in the scientific community and all CR-funded researchers are in the Research Scientist classification. The Unit has achieved a number of important research outcomes and an impressive publication record, showing that the research is of a high scientific standard and has made significant contributions to scientific knowledge. Unit members, with members of DPI's Aquaculture Management Branch, were primarily responsible for the organisation and running of the Australasian Aquaculture Conference held in Sydney in 2004. They have held executive positions (including President) in the World Aquaculture Society, routinely advise FRDC on the national FRDC R&D plans and are integral to key program direction and management of ACIAR aquaculture programs and the Aquafin CRC.

The key R&D outcomes for the Unit are listed below and are expanded in Sections 6 to 9 of this report. The Unit's scientific publications since 2002 are listed in Attachment 2.

Key achievements:

- Breeding lines developed with improved growth rates and disease resistance for Sydney rock oysters.
- Oyster and abalone hatchery technologies have been developed and a capability has been developed to supply hatchery-bred spat to industry (oysters) or juveniles for restocking (abalone)
- Superior breeding lines of silver perch available to industry for growout
- Husbandry, production technologies and species-specific diet formulations developed for silver perch and extended to industry
- Health management strategy for silver perch developed
- Hatchery and growout technologies for marine fish aquaculture developed, particularly snapper and mulloway
- Technologies developed for the use of inland saline groundwater for aquaculture of marine species
- Diet formulations have been developed for marine finfish based on non-fishmeal components

5. Aquatic Animal Health Issues – Opportunities for NSW DPI

- There is currently some diagnostic expertise within the NSW DPI Regional Veterinary Laboratory system (especially Wollongbar and Menangle) and staff are keen to add aquatic animals to the range of species covered. There is a need for Diagnostic & Analytical Laboratories (DAL) staff to further develop diagnostic skills to support research investigations in aquatic animals. Turnaround times for test results have improved since DAL took over the service, but the imposition of the Department's cost recovery policies has reduced the flow of diagnostic specimens.

- Outcomes of diagnostic investigations are often communicated to non-veterinary clients who will likely need assistance in understanding the findings and implementing new recommendations. There is a need for thorough understanding of the industry and management practices in place before recommendations can be made. The recently appointed Veterinary Officer, Aquatic Animal Health has a key role in communicating with industry, as well as in aquatic animal biosecurity preparedness and response.

- Research capability exists within the Animal Health Science staff at EMAI in key areas such as virology, parasitology and microbiology, but major engagement tends to follow aquatic animal health emergencies and/or availability of funding.

- In the recent past, the major aquatic animal health efforts of NSW DPI have been in response to new and emerging diseases. Pilchard mortalities, Perkinsus, Bonania, QX disease, Iridovirus and Nodavirus, White Spot in Prawns are a few examples of newly recognised diseases/syndromes. There is a need for research expertise to be developed and resourced to further investigate these and the new problems emerging in the future.

- There are opportunities to develop a closer alliance with the University of Sydney veterinary campus at Camden, to provide an integrated research and teaching facility in aquatic animal health, which could play a significant part in the new Seafood CRC.

- Staff in the Food Science Unit at EMAI and Wollongbar are working on antibiotic resistance and would be well placed to progress R&D on this issue if required (eg Levings *et al*. 2006). The recent linkage of antibiotic resistant Salmonella outbreaks in children with ornamental fish tanks indicates the possibilities in aquaculture. There may be requirements to monitor this situation and, if problems are found, develop appropriate quality assurance and surveillance protocols which could eventually have trade implications. This would need consultation with the NSW Food Authority and with AQIS.

- It is important the DPI diagnostic and research services involving aquatic animal health are closely integrated. This is currently being developed through DAL and Animal Health Science staff at EMAI. Input from the Veterinary Officer, Aquatic Animal Health and strong links to the Aquaculture Unit at Port Stephens will further promote this integration.

6. Oysters

6.1 Edible Oysters

6.1.1 Industry Background

The dominant edible oyster industry in NSW is the Sydney rock oyster (SRO) *Saccostrea glomerata*, one of the oldest aquaculture industries in Australia and the most valuable aquaculture industry in NSW. It is an integral part of coastal communities in NSW and produces a uniquely Australian food product.

The total NSW and southern Queensland SRO production for 2003/2004 was almost 8 million dozen with a farm gate value of $35.9 million (Table 6.1). Production has been fairly stable at this level since 1989/1990.

Table 6.1: Production and Value of Production for Oysters in NSW in 2003/04

	Production Million dozen	**Value of Production** $m
Sydney rock oysters	8	35.9
Pacific oysters	0.4	1.8
Flat oysters	0.1	0.1

The oyster industry in New South Wales continues to restructure, with the number of producers falling from 474 in 1994/1995 to 281 in 2003/2004. This fall in numbers has been attributed to leaseholders with little or no production leaving the industry in response to factors such as increasing fees and charges related to increasing regulation, QX (Queensland Unknown) disease, and environmental factors such as silting up of estuaries. Seventy five percent of production is from twenty five percent of producers. The SRO industry in NSW directly employed 590 fulltime and 410 part-time people in 2002/2003, more than any other form of aquaculture in NSW.

The SRO industry is a long established industry but one under threat in NSW through the spread of QX disease but also because the industry seems to be less efficient than other oyster industries in NSW and other States. Pacific oyster farmers in Tasmania and South Australia regularly undercut prices set by NSW producers.

Over the past three years limited farm production of “Angasi” or flat oysters (*Ostrea angasi*) has emerged as an adjunct to SRO production along the south coast of NSW and provides opportunity for a limited number of SRO farmers to diversify their production systems. A program by the former NSW Fisheries from 1997 to 2004 provided hatchery-produced seed for trial farming and assisted industry to establish field nurseries and for a limited number of growers, training to conduct successful trial hatchery rearing and settlement of flat oyster larvae.

Of the total of 14 SRO farmers with permit endorsements to also farm flat oysters, two growers on the NSW south coast have accounted for 50% of production in the past three years. Production has been limited by mutual agreement between the participating farmers to 100,000-120,000 oysters valued at about $100,000 annually, and sales have been largely to the gourmet seafood restaurants in the Eastern Australian capital cities. The limited production has ensured good market quality and current farm gate prices of $10 per dozen, which compares favourably with plate grade SROs of $4 to $6 per dozen.

Competition with Pacific oysters from other states

Pacific oysters are one of the world's most widely farmed edible oyster species. Originating in Asia, stocks of Pacific oysters were imported by the CSIRO in the 1940s and 1950s and were used to establish the Tasmanian and South Australian oyster Industries.

In the last ten years Pacific oysters from South Australia and Tasmania have made significant inroads into the NSW SRO market. Currently SROs have only about 60% of the market (and at times as little as 50%). Several reasons have been advanced to explain the success of other States in capturing a share of the NSW market.

One reason advanced is that SROs have required up to four years to reach market size compared with one to two years to produce similar sized Pacific oysters. One response by NSW growers has been to harvest earlier, moving away from their traditional 4-year-old plate sized product (100 dozen/ bag) to the smaller three-year-old bottled oyster product (130 dozen/bag).

The SRO industry in NSW was hampered until recently because two industry organisations have not been able to agree on industry financed promotion, marketing and research programs. In particular the industry has not been able to counter marketing programs for Pacific oysters by the South Australian and Tasmanian growers with a program for SROs promoting what many regard as their superior quality and keeping ability. The two NSW industry organisations merged during 2006 within the NSW Farmers Association to now present a united representative body for the industry. Promotional activities such as the annual "Oysters in the House" are now in place.

There is a view within the wholesaler and processor sectors that unless there is a significant turnaround in SRO quality, size, uniformity, marketing effort and price competitiveness, the industry it will rapidly decline to a boutique-priced minor market.

An alternative for a limited number of NSW producers is to compete by growing Pacific and other types of oysters, such as flat oysters. Pacific oysters have been reported in NSW since 1970. A deliberate introduction of Pacific oysters from Tasmania into Port Stephens in 1984/1985 led to significant problems with overcatch (the settling of spat of any species on oysters of any species) on SROs and significant increased costs of managing and harvesting oysters. Although Pacific oysters were declared a "noxious fish" under the Fisheries Act, attempts to control their numbers on commercial leases in Port Stephens failed and in 1991, farmers in Port Stephens were permitted to cultivate the oyster. In 2004, the approval to farm triploid (sterile) Pacific oysters was given to farmers in the Georges River and was extended to include the Hawkesbury River in 2005. Pacific oyster production is largely confined to approximately 12 producers in Port Stephens. NSW DPI presently conducts no research into Pacific oysters.

Pacific oyster growers in South Australia and Tasmania have well developed cooperatives, have a strict quality assurance program leading to consistent size, relatively uniform prices and their products are marketed under a single brand. Both States have invested in successful television marketing programs.

Other Marketing Issues

SROs in Australia are produced for the half-shell domestic market. Exports are still relatively small and account for <2% of the value of oysters produced. The industry is keen to expand markets through export and the establishment and adoption of the NSW Shellfish Program may facilitate the development of new export markets in Asia. However, a DPI Agsell review in 2004 found that competition with the lower priced Pacific oysters in the Asian markets would be difficult requiring emphasis on the eating and keeping qualities of SROs.

For flat oysters, there is scope for both increased production and expanded domestic and overseas marketing. Latent capacity for farming based on available production leases suggests a scope for at least a ten fold increase in production, requiring up to four million spat (ex hatchery). This is well within supply levels provided to industry by NSW Fisheries over recent years. Likewise industry has the capacity to supply advanced spat ready for on-farming on leases because of increases in field-based upweller nurseries in NSW over the past year to meet a rapidly accelerating industry demand for genetically improved strains of Sydney rock oyster spat.

There is also an option for expansion of flat oyster production in the longer term through wider industry substitution of SRO production in about 40 producing estuaries and the development of suspended culture in deep bays such as Jervis and Twofold Bays and in sheltered offshore areas (an option not available for SRO farming). Development of high priced export marketing is also possible, particularly to New Zealand, Hong Kong and Western Europe to supplement poor local flat oyster output commonly due to chronic outbreaks of the disease *Bonamia*.

These options offer potential for growth of flat oyster production as a diversification option on some SRO leases on the south coast, particularly as the two oyster species are governed by the same regulations and management policies, and require similar production systems. Flat oysters also yield higher net returns with reduced production risks and resistance to QX disease. Consequently, flat oysters and SROs directly compete for nursery capacity and flat oyster expansion would be at the cost of available hatcheries for the production of genetically improved SRO spat. This, and a lower shelf life for flat oysters with possible impacts on the development of a live export market, could be impediments to future industry expansion.

Disease Issues

The SRO industry faces three major disease threats – QX disease, winter mortality and mudworm.

Even though it remains the cornerstone of the Australian oyster industry, SRO production has declined by 43% since the 1970s to current production levels of eight million dozen. This decline in production has resulted, at least in part, from QX disease caused by a protozoan parasite, *Marteilia sydneyi*. QX disease first affected the oyster industries of southern Queensland and northern NSW in the 1970s, where it decreased production by up to 56%. More recently, QX disease devastated oyster farming on the Georges River, the most productive growing area in Australia, with a consequent 94% decrease in production. Similarly, QX disease outbreak in 2004 caused widespread and severe SRO mortality and terminated all oyster farming activity in the Hawkesbury River within 12 months, except for small experimental trials of triploid Pacific oysters and selectively bred QX disease-resistant SROs. The Hawkesbury River was the third largest oyster producing estuary in NSW by production value in 2003/2004, with around 400 hectares of oyster lease farmed by 23 permit holders.

In addition to the five growing areas already affected by QX disease, the parasite has now been detected in at least seven other estuaries, which are now under threat of QX disease outbreaks. This includes detection in Wallis Lake, which produces one third of SROs in NSW. With improved PCR-based detection methods now available, future identification of the parasite in other growing areas cannot be discounted. The economic impact of QX disease on SROs is catastrophic and its spread is a great risk to the future of the industry.

Concerned about the welfare implications of recent QX disease outbreaks, the government in NSW has recently provided assistance to those affected by ceasing to collect industry levies and making disease resistant spats available to producers. These may be appropriate temporary means of government assistance to an industry suffering a major disease outbreak.

The impact of winter mortality disease is not as catastrophic as QX disease although farmers in southern estuaries still maintain it is their most serious disease problem. Winter mortality disease is caused by a protozoan parasite, *Mikrocytos roughleyi*, which affects SROs mainly in the southern part of their range. Oysters in the area between Port Stephens and the Victorian border are particularly susceptible with up to 80% mortality, particularly of larger oysters. In severe outbreaks all sizes may be affected. The severity of the kill varies between years, estuaries and even between adjacent leases within an estuary and appears to increase with dry autumns (high salinities), early winters and low temperatures. Management options include moving oysters upstream to areas of lower salinity before the end of autumn and increasing the growing height of the oysters so they are exposed to air for longer periods. Another strategy is to sell oysters before the onset of the disease.

As described below, breeding for disease resistance in SROs has been a major focus of research activity by NSW DPI.

For flat oysters, a microscopic parasite, thought to be *Bonamia*, was detected in an average of 26% of wild oysters from all five southern NSW sites. However there have been no significant losses in pilot commercial farms over the past eight years and the disease is unlikely to be a great impediment to expanded production. Several other parasites and microbial disease agents were also detected at varying levels. These included a possible viral infection in up to 10% of sampled oysters.

Expansion of flat oyster farming to warmer areas of the north coast is likely to be prevented by a disease very similar to QX disease in Sydney rock oysters that was encountered in the Clarence River pilot farming operations in 2001/2002. The widespread occurrence of the disease in wild and (probably) farmed stocks in NSW will pose some challenges to developing live export markets especially into New Zealand and Western Europe.

The Need for Industry Restructure

The main implication of the QX disease outbreak is that the SRO industry must radically restructure from the traditional stick culture to hatchery-based seed culture of faster growing, disease resistant oysters based on NSW DPI technologies and breeding program (see Section 6.2). Such a restructuring may also provide opportunities for new industry sectors to establish including hatchery and nursery enterprises and diversification to flat and Pacific oyster growing.

However this restructuring will be expensive and, if forced on the industry by further QX disease outbreaks, it is likely to be the catalyst for increasing numbers of growers to exit the industry.

The move to single-seed production has a number of advantages and disadvantages:

On the negative side:

- New infrastructure is required and some existing materials need to be removed from leases
- All production will need trays or cages with varying mesh size as the oysters grow
- Single-seed sourced from hatcheries can be relatively expensive (single-seed can be also sourced from the wild [i.e. scrape offs] at lower cost).

On the positive side:

- Single-seed technology is needed for future benefits of breeding programs and triploidy to be delivered to oyster farmers
- QX disease resistant oysters, only available as single-seed from hatcheries, may be the only way for the SRO industry to survive if QX disease spreads to other estuaries
- Faster growing, selected oysters are capable of reaching market size one year earlier than wild oysters. Triploidy can reduce the time to market by at least a further three months
- Oysters grown from single-seed are more even in shape and are easier to open
- A major shift to single-seed based production could create new business opportunities for hatchery production of high growth rate, disease resistant seed stock and nurseries where seed are taken from 2mm to >5mm when they can be on-grown using existing farm infrastructure

These opportunities should be taken into account in any business analysis.

Regulatory Environment

NSW DPI in accordance with the provisions of the Fisheries Management Act, 1994, manages oyster farming in New South Wales. A Class A Aquaculture Permit is required to cultivate oysters in NSW and application can be made through the NSW DPI Aquaculture Administration Section. Annual fees and charges apply. Oyster leases (rights to sites in estuaries) can be purchased from oyster farmers or NSW DPI.

The NSW Oyster Industry Sustainable Aquaculture Strategy (OISAS) covers all oyster growing estuaries in NSW. It was developed as a whole of government approach to secure the long term future of this industry. It identifies Priority Oyster Aquaculture Areas for oyster farming in estuaries and incorporates the agreed water quality needs of the oyster industry in formal environmental planning legislation.

In the case of OISAS, oyster aquaculture that is consistent with the best management practice standards may be undertaken without development consent in Priority Oyster Aquaculture Areas. Oyster aquaculture outside these areas may only be undertaken with development consent. OISAS details best practice guidelines for farmers and also lists guidelines for others in the catchment to protect oyster harvest areas.

In addition to license fees, oyster growers pay levies to fund R&D and to fund a shellfish quality assurance program (NSW Shellfish Program), which involves extensive water and oyster meat quality testing. A Treasury Review into cost sharing arrangements for the Shellfish Program has been completed which has indicated a greater government financial commitment to the program. Industry lobbied the State Government to pay a share of the cost of the program because, in its view, it is general users of the estuaries including State owned utilities and local government, rather than the oyster industry that are responsible for the pollution.

No current research is being conducted by NSW DPI into food safety issues associated with oysters.

6.1.2 Past Research Achievements

There have been four broad areas of SRO research activity by NSW DPI:

- Breeding for resistance to QX disease and winter mortality disease;
- Breeding for faster growth;
- Evaluating benefits of triploidy:
- Overcoming constraints to large-scale commercial hatchery production.

For an overview of all current SRO research projects see Appendix 1.

SRO Breeding Program

In 1990, NSW Fisheries commenced a mass selection program to breed faster growing SROs in Port Stephens and in the Georges River. In 1994, QX disease was detected in the Georges River and by the end of the decade farming had effectively ceased within the estuary. SROs cannot be grown for more than 6 or 8 months in Georges and Hawkesbury Rivers, unless they are QX disease resistant.

The incidence of QX disease in the Georges River altered the breeding program, with the commencement of a selection program to breed for the survivors. NSW DPI now holds lines of oysters that are capable of reaching plate size (50g) one year faster than wild-caught oysters, and are resistant to QX disease.

The development of improved breeding lines of SROs offers significant benefits for industry. Fast growth lines give farmers the chance to reduce growing times by one year, reducing cost. Economic assessments of the benefits of fast growth have been completed (Catt 1998), but should be re-examined. QX disease resistant oysters are now being cultured in the Georges River, where SRO culture had ceased due to the disease. Selection for QX disease resistance in Georges River has reduced mortality from 80% for controls to 20% for the most improved breeding lines after one season of disease exposure. These resistant oysters are also being trialled in the current QX disease outbreak in the Hawkesbury River.

The SRO breeding program is currently under independent review by the University of New England to confirm its scientific direction and methods. NSW DPI is contributing to the review and will adopt recommendations as appropriate.

Development of a Hatchery Sector

Over the past 20 years the former NSW Fisheries has played a key role in developing a technology and capability to grow oyster spats in a hatchery rather than wild environment. The research component of developing this technology has been partly funded by industry culminating in the current FRDC program "Overcoming constraints to commercial scale hatchery production of Sydney rock oysters" (see Appendix 1). In the first instance this has expedited the breeding research related to disease resistance and growth rates.

In addition NSW Fisheries has developed a strong capability to supply hatchery-bred spat to the commercial growers, assisted by the development of technology for land–based "field nurseries". These nurseries use estuarine water to grow hatchery-supplied spats to approximately 5mm before their transfer to leases for growout. Techniques for reliable spat production and extension of technology for running field nurseries to oyster farmers have enabled the sale of over 25 million selected-line seed to industry in the past two years. A minimum order for 10 million spat is currently required before a hatchery will consider a production run. For a stand alone hatchery to be viable, orders of 40-50 million are likely to be required.

Techniques are also available to produce triploid (fast growing) SROs. These techniques are based on the application of extremely toxic chemicals. Alternative techniques have been successful with other species and should be evaluated with SROs.

The supply of spat to the Pacific oyster industry is less reliable. Diploid ("normal") Pacific oysters are readily available from Tasmania, but triploid Pacific oysters are only available irregularly from one hatchery. In addition, survival of triploid Pacific oysters spat from Tasmania has been variable in nurseries in NSW (Port Stephens). Techniques should be investigated to ensure supply to local growers to allow for expansion of Pacific oyster production.

Flat Oysters

Prior to 1997 flat oysters appeared to offer scope for diversification for NSW oyster farmers into an alternative native species with potentially superior farming and marketing characteristics. However four major barriers emerged:

1. a reliable source of hatchery produced seed due to the non availability of wild seed
2. uncertain suitability for farming on existing oyster farm leases using equipment and practices developed specifically for SROs.
3. potential major threat by the disease *Bonamia* that has decimated most flat oyster fisheries globally
4. Potential genetic risks to wild stocks of flat oysters posed by farming with hatchery produced seed

Experience gained during the three initial years (1997 to 1999) of trial farming and marketing of flat oysters on the south coast was reviewed in industry workshops hosted by NSW Fisheries in 2000 and 2001. Results showed that when flat oysters are grown on existing intertidal "rack and tray" oyster farming systems, market size is achieved in half the period required for SROs, particularly with suspended culture on deeper sub-tidal leases. Flat oysters also proved more tolerant of reduced salinities and more resistant to bio-fouling and mudworm infestation than anticipated. While sublethal infection of *Bonamia* is universally common in wild stocks through south coast estuaries, there seems to be little impact on production.

These factors and the current high prices received suggest that the economics of flat oyster culture appear attractive.

Research has also found little or no genetic reason to limit movement of spat, for culture between estuaries in NSW or to source breeding stock from particular areas to meet local spat requirements. As long as the genetic diversity of broodstock used in hatchery production is high, risks for wild flat oyster stocks will be minimal.

A comprehensive report on the project was published and widely distributed in 2004 (Heasman, *et al.* 2004). The major benefits of this R&D work is that results will free up the expansion of flat oyster farming in NSW that otherwise would have been restricted by perceived risks of spreading diseases and of genetic degradation of wild stocks within the state.

6.1.3 Funding of Research

Sydney Rock Oysters

The SRO industry pays a research levy that was recently increased from $22.00/ha to $28.00/ha to maintain its value at 0.25% of the average gross value of production (GVP) (because although there has been a decrease in the area under oyster cultivation in NSW, productivity has increased). A submission for a further $3.00/ha increase in the research levy is now under consideration. The Oyster Research Advisory Committee[1] advises the Minister on how the funds raised from the oyster research levy should be spent. By far the majority of funds raised are paid to the Fisheries Research and Development Corporation (FRDC) which funds most industry funded fisheries research in Australia. Since 1993, the FRDC estimate that it has invested $4.30 in SRO research for every dollar raised in NSW from levies on oysters.

In addition to FRDC, SRO research is also conducted by Universities through internal and Australian Research Council (ARC) funding. NSW DPI is currently an "industry partner" in two ARC linkage grants. The first of these is a project to investigate the involvement of the defensive enzyme, phenoloxidase, in QX disease resistance with Dr David Raftos from Macquarie University. The second projects aims to determine the genetic stock structure of SROs and to attempt to estimate genetic variability between estuaries and within estuaries in NSW (and elsewhere). This project will develop microsatellite markers for SROs and

[1] The Oyster Research Advisory Committee (ORAC) was replaced in 2006 by the Aquaculture Research Advisory Committee (ARAC). ARAC provides advice to the Minister on the expenditure of research levies generated from both lease-based and land-based aquaculture industries in NSW

involves collaboration with Assoc. Professor Peter Mather from Queensland University of Technology.

Details of expenditure on R&D in oysters from 2002/2003 to 2003/2004 are given in Table 4.2 (Chapter 4 of this report). In recent years DPI has been spending almost $700,000 per year on SRO research with about 40% of this being funded by industry. In 2005/2006 the proportion from external sources for oysters will exceed 60% of total expenditure and FRDC has approved funding to support research to assist the oyster breeding program from 2006/2007. Future funding until 2014 for oyster research to benefit the NSW industry has also now been secured by its inclusion in the Seafood CRC to commence in July 2007

Flat Oysters

The Angasi farmer group has co-invested in past NSW DPI research on flat oysters through the purchase of spat. Research collaborators have included the Queensland University of Technology, Diggles (ex- NIWA; New Zealand, National Institute of Water and Atmospheric Research), CSIRO-AAHL (Commonwealth Scientific and Industrial Research Organisation – Aquatic Animal Health Laboratories) and the Federal Government (RAP; Regional Assistance Program).

Although there is an industry levy on oyster production, industry endorsement by ARAC of flat oyster research for funding through FRDC is unlikely. However, there are other regional development funding sources such as RAP available to individual farmers or non incorporated farmer groups such as the NSW flat oyster farming group. NSW DPI had been investing approximately $55,000 per annum in flat oyster research with 60 percent industry co-funding, but research has now ceased.

6.1.4 Future Directions and Opportunities for Research and Extension.

Sydney Rock Oyster Breeding Program

A strategic plan for R&D developed by the industry for 2003 to 2007 (Appendix 3) identified key areas of research as ecological sustainability; impact of diseases, pollution and pests; quality assurance; hatchery and farm technology; and industry economics and marketing. After the QX disease outbreaks in the Hawkesbury River in 2004 and 2005, a QX disease workshop was hosted in July 2005 by NSW DPI and funded by FRDC to examine research, management and industry priorities for tactical and strategic actions to address QX disease. Key short-term tactical priorities that emerged from the workshop included surveillance, determining infection windows for QX disease in key estuaries in different years, improving diagnostic capacity, improving the ability of oyster farmers to access triploid Pacific oysters (as a QX disease resistant alternative crop) and demonstrating the commercial effectiveness of QX disease resistant SRO produced through the NSW DPI selective breeding program. A government/industry plan to deal with any future QX disease outbreaks in new estuaries was also identified as a critical tactical priority.

Key longer-term strategic priorities included continuation of the NSW DPI breeding program (including improving security of selected lines), understanding the mechanism of QX disease infection and determining possible environmental triggers, and understanding and hopefully closing the life-cycle for QX disease (at present transmission of QX disease from infected to non-infected oysters cannot be accomplished in the laboratory leading to the hypothesis that an intermediate or alternative host is involved).

A number of priority actions related but not specific to QX disease were also identified. These included increasing the reliability of hatchery production of oyster spat (including improved technology for triploidy induction), facilitation of a restructure within the industry away from stick culture and the reliance on tar as an anti-fouling treatment towards large-scale production based on the use of hatchery produced single seed, and improved technology transfer, training and communication.

In addition to QX disease research there is a need for research into winter mortality disease, including selection of resistant stocks, accurate documentation of the extent of winter mortality impacts and delineation of the disease from the impacts of toxic algal blooms and other incidental mortalities.

The high cost to maintain breeding lines and the potential for the expansion of the number of lines to include either pair matings and/or the selection of winter mortality resistant stocks, calls for alternative techniques for the protection and maintenance of genetic material. Techniques for the cryopreservation of sperm are available for Pacific oysters and should be evaluated for SROs. Closely allied with breeding for disease resistance is breeding for faster growth rates. In fact faster growth rates mean less exposure to disease. An FRDC-funded project for three years from 2006/2007 will continue to support the breeding program (approximately $200,000 per annum).The extension to the program was recommended by the QX workshop in 2005.

Hatchery Technologies

An FRDC project was funded in 2005 to assist industry adopt hatchery technology and to help industry assume more ownership of (and responsibility for funding) the breeding program. The applicant was the Select Oyster Company (SOCo), a new company established by industry to manage its uptake of oyster hatchery technology. This project includes a review of genetic management of the oyster breeding program by UNE and the development of a business plan for ongoing funding and management of the program. NSW DPI is involved in this project to provide advice on the current breeding program and on oyster research and hatchery operations and costs. NSW DPI receives a modest return of $34,000 per annum for two years for operating and salary expenses associated with provision of this advice.

The minimum CR resources required for oyster research comprise two research staff and three technical assistants (including hatchery staff). Physical resources include three NSW DPI owned and maintained oyster leases in Georges River and two oyster punts, use of an oyster/boat shed in Port Stephens, funding for travel and the continued operation of the mollusc hatchery at PSFC.

It is in the best interests of industry that a commercial hatchery be developed to supply NSW farmers with SRO and triploid Pacific oysters. A hatchery in Harvey Bay, Queensland, has successfully produced SROs and protocols are in place to import triploid Pacific oysters from Tasmanian hatcheries. However, unreliability in supply is a major risk and will reduce or slow industry uptake of hatchery technology. An opportunity exists for NSW DPI to use the mollusc hatchery at PSFC to supply SRO spat to industry on a commercial basis (Appendix 2). Care should be taken not to impede commercial development of a SRO hatchery capacity (particularly in NSW) by ensuring competitive neutrality. In other models, government has successfully invested in industry development by temporarily securing supply of seed stock in Tasmania (salmon), Queensland and Northern Territory (barramundi). This option could be a significant source of funding for future oyster research in NSW DPI.

Resources Required

In summary, the following resources are needed to undertake this program of research for SROs (Table 6.2).

Table 6.2: Resources required for oyster research to 2009

	CR Funds	Industry Funds*	Total Funds	Share funded by CR
	$	$	$	%
2005/06	470,000	269,000	739,000	63
2006/07	470,000	460,000	930,000	50
2007/08	470,000	388,000	858,000	55
2008/2009	420,000	396,000	816,000	51

*Includes, FRDC funding for QX/breeding research line (2006 – 2009), Seafood CRC funding (2007- $150,000) and Breeding line production (2007- $50,000).

The need for these funds may be reduced if it proves possible that the new breeding program could be run with 0.2 FTE of a Scientist's time (rather than the 1.0 FTE assumed in the budget above). In addition, should the application to FRDC be successful for the breeding program, CR operating costs of up to $50,000 could be reduced.

Flat Oysters

There is no currently funded research into flat oysters, the disease and genetics project having been completed. If funding opportunities were available, priority research topics include:

- Technologies to extend the shelf life of harvested oysters.
- Deep water culture techniques for expanded production (for example in Twofold and Jervis Bays).
- Promotion and market research.

NSW DPI is the sole source of hatchery technology and supply of flat oyster spats, and thus would play be a critical in any further industry development. There are nevertheless alternative research providers (eg Seafood Services in Queensland and shortly M P Heasman and Associates in NSW) in relation to development of extended shelf life and other improved post harvest technologies.

6.1.5 Potential Value of the SRO Breeding Program to NSW

'With DPI Research'

We have not attempted a thorough financial assessment of the potential value of the proposed SRO breeding program and an industry switch to tray based production. However three scenarios presented below give an indication of potential benefits that might flow from such changes in the industry.

- Historical data shows that estuaries where production has been decimated by QX disease comprise about 20% of total state production. If production was returned in these estuaries based on QX disease resistant stock this would be valued at approximately $3 million per annum (based on return to ~50% of production value for the Hawkesbury River and an increase in production of ~$1.5 million in the northern estuaries now affected by QX disease).

- If non-QX disease estuaries become affected, past experience shows that production will fall to less than 10% within five years and perhaps sooner. The value of this for Wallis Lake alone would be about $10 million per annum (based on value of this estuary in 2003/2004 of $10.1 million.)

- The selective breeding program also confers faster growth that takes one third off the time to market. This represents significant value to the NSW oyster industry and increases the industry's competitiveness with other oyster industries.

Projections based on results to date of this program of research indicate that 90% of spat bred by NSW DPI will have increased resistance to QX disease (80% resistance compared to 20% for non-selected stock, if oysters are exposed to QX disease for one season only) and will reach market size one year earlier than non-selected stock.

By 2010 we expect that 60-75% of the Sydney rock oyster industry will be using spat bred by NSW DPI. Should this occur, the breeding program will largely be self-funded and NSW DPI share of IP may also generate revenue from royalties.

'Without DPI Research'

Without this program of DPI research, productivity gains from disease resistance and faster growth rates in the NSW oyster industry will not occur. Further catastrophic losses to QX disease would be inevitable and, with few available alternatives for culture, more growers would be expected to leave the industry. There will be no impetus for the industry to restructure and progressive failures of businesses are likely, though there would remain an opportunity for a limited number of growers to change to triploid Pacific oysters or flat oysters.

There are large negative environmental impacts and direct costs to the NSW Government associated with QX disease infection in an estuary. For example, the NSW Government recently announced packages worth in excess of $3 million for the Hawkesbury River SRO industry, $2.7 million of which is allocated to clean up derelict leases. This will no doubt be seen by industry as a precedent should another estuary fall to QX disease. The cost to the NSW Government to clean up derelict leases in the Georges River (leases abandoned after QX disease) and in Port Stephens (where many leases were abandoned after Pacific oysters were introduced and overcatch and other problems associated with the Pacific oysters put many farmers out of business) were in excess of $4.4 million.

While the SRO industry may not completely disappear, those who value it are likely to have to pay higher prices for this 'icon' product and the consequent reduced accessibility for some sections of the community to this product may be regarded as a social cost. NSW DPI is the only research provider capable of running the breeding program.

6.1.6 Beneficiaries of Research

The outcomes from past R&D in both SROs and flat oysters have been technologies in various areas of oyster production that have the potential to increase the profitability of commercial production once adopted. The objective of SRO breeding research was originally faster growth but most recently, the focus has been on QX disease resistance. The oyster industry – producers, processors and consumers - are clearly important potential beneficiaries of the technologies developed by R&D. Few oysters are exported and hence most of these industry benefits remain in Australia.

In small coastal towns the oyster industry is an important part of the local economy and of the social fabric of the community. It adds to regional employment and turnover in local businesses, although many of these benefits would be included in any economic analysis of new technology in the industry. There may be some additional regional tourism impacts.

Importantly, the presence of a viable oyster industry within an estuary provides the community with an important assurance of estuary water quality. All oysters sold must comply with a rigorous quality assurance program that precludes oysters being marketed when water quality (including microbiological measurements) is compromised. Oysters and more importantly oyster farmers serve as "sentinels" informing the community whenever water quality is compromised

6.1.7 Rationale for Government Investment

In our view the beneficiaries of NSW DPI's oyster research are largely the oyster industries in NSW and southern Queensland. As a consequence it is reasonable to expect that industry fund most of this R&D. Already the industry makes a substantial contribution for SRO research through levies to FRDC and other R&D fund providers, and this trend should continue. In 2004/2005, 33% of the R&D by NSW DPI in SROs was externally funded with this expected to rise to over 50% by 2006/2007.

The flat oyster industry is an 'infant' industry and would normally require government support to progress. However, as most of the growers who wish to diversify are SRO farmers, they already have much of the required infrastructure and skills in general oyster farming.

It is difficult to justify using public funds to support a potentially commercial activity based on the oyster hatchery at PSFC. Once the technology is established it should be transferred to commercial interests as industry capacity develops. One option would be to sell spat from the hatchery and sell the technology developed by NSW DPI to commercial interests. However NSW DPI should also retain a share of ownership of the oyster breeding program because of its past investment. A continuing involvement in the breeding program, largely run and funded by industry, gives NSW DPI an ongoing capacity to respond to future crises. The production from the hatchery should be placed on a commercial basis. This should include production of SROs, Pacific oysters, flat oysters and pearl oysters produced for use by commercial farmers (as opposed to use for research purposes only). The hatchery should be operating in a competitively neutral way with the expectation that a private sector capacity develops.

A plan for a levy on production from selected lines of oysters is attached as Appendix 2, in which the NSW DPI hatchery maintains the breeding program and recovers costs by the sale of spat to industry partners for commercial production and sale to farmers.

While every effort should be made to increase industry funding, research into SROs, like other research, delivers a mix of public and industry outcomes, which may warrant a continuing level of government, support. This investment assists in attracting continuing co-investment by industry and ensures NSW DPI's continued influence on R&D priorities. Perhaps the strongest argument is that the NSW community expects NSW DPI to have a capacity to respond to major food safety and disease outbreaks such as QX disease. Such a capacity relies on an active R&D program and maintenance/enhancement of scientific expertise. These concerns have been discussed earlier in this report.

In addition the oyster industry is an important part of the social and economic fabric of several NSW coastal communities. Given the key challenges faced by the oyster industry today, the decline of this industry is a real threat in NSW. Support for R&D may be seen as one part of an overall adjustment package for the industry, which may in fact reduce the need for other adjustment measures.

6.2 Pearl Oysters

6.2.1 Industry Background

In 1994, the former NSW Fisheries began negotiations with a company seeking to develop an akoya pearl industry in NSW. In 1997 a call for expressions of interest in pearl farming was made and in 1998 Australia Radiata Pty Ltd was selected to assist in this research. The research program focused upon three specific outcomes: understanding the biology of pearl oysters, *Pinctada imbricata*, in NSW; developing hatchery production techniques for spat and ensuring minimal environmental impacts occurred. The overall success of the program led Australian Radiata to lodge applications and an EIS with Planning NSW to commence commercial pearl production in Port Stephens. This farm would have employed 75-80 people directly, farming 2.2 million oysters worth around $12 million annually at the farm gate on 32 hectares in Port Stephens, making this one farm the second biggest aquaculture industry in NSW.

Following submission of the pearl farm EIS, Planning NSW called for a Commission of Inquiry. The Commissioner's findings recommended that the farm be allowed to proceed with minor modifications. This application was subsequently refused by the Minister for Planning. Port Stephens Pearls (PSP, formerly Australian Radiata) then submitted a second amended application for a significantly smaller farm. This application was also subsequently refused in 2004. PSP referred the matter to the Land and Environment Court and the decision to refuse their application was overturned. Conditions under which they can operate are currently being determined but it is clear that PSP will commence commercial pearl farming operations in Port Stephens.

Since the second refusal of the PSP application, two farms have been established on intertidal Sydney rock oyster leases in Port Stephens and one in Broken Bay. A third farm has a permit to culture *P. imbricata*. However, much of the IP developed rests with PSP, which is also a significant provider of Japanese technology and experience. New farmers, such as Broken Bay Pearls have attempted to contract overseas expertise

To date only experimental batches of pearls have been produced and have only been cultured in significant numbers in Port Stephens. The value of these harvests has varied according to quantity, but has not exceeded $500,000 per annum.

Marketing Issues

Port Stephens Pearls and Broken Bay pearls are the only farmers of any significance at this time. The remaining farms should be considered experimental. Regardless, by world standards, at their projected peaks in production, both farms will be small operations and it is possible that their entire production could be absorbed by local markets.

Strong demand exists for quality akoya pearls. Independent industry experts have evaluated pearls produced in Port Stephens as being of the highest quality.

Regulatory Environment

The growth of the industry will be governed by the availability of suitable lease areas. Previous estimates have indicated that there may only be approximately 200 – 300 ha of suitable, deep-water lease area in NSW. This area was thought to be capable of supporting a $50 million industry.

The protracted approval process delayed establishment of one large pearl oyster business. Land use conflicts, negative perception about potential impacts of aquaculture on the environment and marine mammals all contributed to lengthy delays in this business receiving approval to operate.

Disease Issues

There are no known diseases for *P. imbricata* in NSW and in culture, where predation is low, survival of spat in excess of 90% per annum is expected.

Environmental Issues

P. imbricata is native to NSW and occurs throughout the state. The environmental impacts of mollusc farming of this nature are generally accepted to be low. However the potential impacts of pearl farming have been monitored by various groups (NSW Fisheries, Newcastle University and private consultants). Monitoring studies have included studies of sediment nutrients, sediment composition, benthic fauna and adjacent benthic flora and have found no evidence of impact.

6.2.2 Past Research Achievements

Previous research has demonstrated:

- The techniques necessary for hatchery production and grow-out of pearl oyster;
- NSW can produce pearls of the highest quality (Mikimoto Co) and those pearls have achieved premium prices.
- No significant environmental impacts have been detected, indeed studies of the farm in Port Stephens have suggested that pearl farming be used as a cost effective means of environmental remediation of coastal environments.

- Adequate cost effective technology for large-scale hatchery production of pearl oysters has been developed by NSW Fisheries over the past seven years and NSW DPI has the capacity to meet industry requirements for at least the short to medium term (3-5 years). Due to disease in stocks in Japan and elsewhere, the progeny of these programs are not available to Australian industry and hence at present any growth in the industry is reliant on NSW DPI.

6.2.3 Funding of Research

To date, all akoya oyster research has been industry funded, however funding for pearl research in the short to medium term is limited and research has halted. Several large south sea pearl companies are watching developments in NSW with interest and a view to potential investment. The decision by the Land and Environment Court to overturn the Minister's rejection of the PSP development application is likely to have important positive ramifications for the future of pearl oyster farming and other types of coastal based aquaculture in NSW.

6.2.4 Future Directions for Research

NSW Fisheries developed the technology for large-scale reliable production of pearl oyster spat. There are currently no commercial bivalve hatcheries in NSW and thus access to commercial supply of spat is limited and dependent on NSW DPI support. While growth of the industry was limited by regulatory issues, funds were not available to continue a program of production research. NSW DPI will need to continue a limited advisory service to those interested in the industry.

The only ongoing pearl research is in conjunction with Newcastle University and concerns ecological aspects of pearl farm operation. It is likely that PSP will contract NSW DPI to conduct further pearl oyster R&D and fund hatchery production of pearl oyster spat.

If an industry is established, the greatest initial demand for research support will come in the form of selective breeding programs. The akoya oyster industry will be entirely hatchery based and already is dependent on the selection and production of two distinct stock lines. The characteristics required for these lines are clearly defined and provide significant scope for genetic improvement.

6.2.5 Potential Value of the Pearl Oyster Breeding Program to NSW

With scenario

Provided projected production is achieved, pearls are likely to become the second largest aquaculture industry in NSW within three years. With the expansion of PSP and inclusion of new companies, to occupy 200 of estimated 400 ha of suitable lease area, the pearl industry may eclipse the Sydney rock oyster industry as NSW largest aquaculture industry. In doing so it would occupy less than 10% of the space currently leased to oysters, would offer similar levels of employment and have significantly less environmental impact.

Pearls offer significant tourism opportunities. Broome, WA, demonstrates the tourism attraction of a pearl industry and overseas, in excess of two million Japanese each year visit Mikimoto Pearls, pearl museum and demonstration centre.

Without scenario

Without DPI support in the provision of suitable oyster spat, it will be very difficult to establish a pearl culture industry. Further, there is no existing pool of akoya pearl culture expertise in Australia, and it is essential that the Department continues to provide advice to prospective farmers.

6.2.6 Beneficiaries of Research

The outcomes from past R&D have been technologies in various areas of oyster production that have made commercial production of pearls possible and demonstrated profitability. The pearl oyster industry – producers, processors and consumers - are clearly important beneficiaries of the technologies developed by R&D. Some of the consumers of pearls are likely to be non-residents of Australia and will share in the benefits of this technology.

The greatest beneficiaries will be the pearl companies. The community will benefit though significantly increased employment. Pearl oysters are a labour intensive. The industry standard is one farm employee for each 80,000-100,000 oysters. PSP estimated a requirement for 75-80 people to operate its proposed farm in Port Stephens. Industry averages suggest that for each on-farm employee a further three to five positions are created. Pearl oyster farming is at the upper end of this additional employment estimate as they have been associated with strong tourist interest, as demonstrated in Broome, Western Australia.

While the pearl oyster industry may add to regional employment and turnover in local businesses, many of these benefits would be included in any economic analysis of the industry. Some environmental benefits will ensue. Recent research by Newcastle University has demonstrated the bioremediation capacity of bivalves and pearls in particular, and the extensive monitoring of estuarine health, imperative to pearl culture, will assist in maintaining estuarine water quality. There will be some regional tourism benefits but national gains in this regard may be small.

6.2.7 Rationale for Government Involvement

Clearly most of the benefits of pearl oyster R&D flow to the industry. In fact NSW DPI rarely conducts such R&D that is as close to private good research as has been the case with pearl oysters. As a consequence it is reasonable to expect that industry fund most of this R&D and this has been the situation to date. As noted the research program has come to a halt but DPI continues to provide a limited advisory service and has produced spat on a cost recovery basis. Future R&D for PSP will be on a full cost recovery basis.

NSW DPI has developed an expertise in hatchery techniques and pearl oyster production that it has been able to use to help others enter the industry, even if only in limited ways at this stage. Research designed to monitor and overcome environmental ‘spillover’ impacts of pearl oyster production would seem to be a legitimate role for NSW DPI if a viable industry was likely to develop.

6.3 Recommendations

- Any commercial production from the NSW DPI oyster hatchery should be fully self-funded (through sale of spat) by July 1, 2008. A Business plan should be developed to help guide this and be based on the NSW DPI Diagnostic and Analytical Laboratories charging model

- NSW DPI should continue to invest in oyster R&D with the following provisos:
    - That funding for the routine selection for commercial traits should move to being progressively industry based through FRDC, direct industry investment and an additional levy on the sale of spat
    - That NSW DPI will need to retain a credible capacity to maintain a breeding program to protect the SRO industry from serious endemic and exotic diseases
    - That NSW DPI investment into oyster research be further reviewed in five years to ensure industry are contributing at least 50% of the costs

- NSW DPI should seek industry support for a cost-benefit analysis of practice change from the traditional stick culture to single-seed technology, a change necessary if farmers are to use disease resistant, faster growing oysters.

- NSW DPI should investigate methods of assisting the oyster industry restructure from a stick culture based industry to single seed technology.

- NSW DPI should explore ways to better facilitate industry change through improved extension services and industry consultation

- Future DPI research into pearl oyster species should be on a commercial basis wherever the research is in the nature of an exclusive service to particular firms.

6.4 Appendices

Appendix 1: NSW Oyster R&D project summary

1. *Sydney rock oysters: overcoming constraints to commercial scale hatchery and nursery production*

   This is a three-year Fisheries Research and Development Corporation (FRDC) funded program managed by NSW DPI. Work commenced in July 2003 and should be completed by December 2006. The total cost of the program is $2,166,484.

   The work on the program has greatly increased the reliability of hatchery production of Sydney rock oysters. As a result 10 million spat are now produced and sold to industry annually.

2. *Sydney rock oyster breeding program*

   The work on the Sydney rock oyster-breeding program is ongoing and funded by NSW DPI at the cost of $200,000 pa. Although it has been proposed that the Select Oyster Company Pty Ltd (SOCo) gets more involved in the management of the program, there is currently no proposal to seek a financial contribution from SOCo.

3. *QX disease resistance in Sydney rock oysters*

   This is three year Australian Research Council funded project managed by Dr David Raftos, Macquarie University. Work commenced in January 2004 and should be completed by December 2006.

   This program investigates the possible link between phenoloxidase and QX disease resistance in oysters. The total cost of the program is $209,000.

4. *Industry management and commercialisation plan for the Sydney rock oyster breeding program*

   This is a 2.5-year FRDC funded project managed by SOCo. Work commenced in July 2005 and should be completed by December 2007. The total cost of the project is $453,000.

   The aim of the program it to review and determine the future direction of the breeding program.

Appendix 2: Spat Levy Proposal

Aim

For the Sydney rock oyster *Saccostrea glomerata* breeding program to become fully funded. The following option is proposed: Full cost-recovery through a levy on the sale of spat produced from improved breeding lines when 80 million (i.e. 60% of all Sydney rock oysters farmed in NSW) is derived from genetically improved broodstock.

Intellectual Property

NSW DPI 70%, FRDC 20% and NSW oyster industry 10%, based on cash and in-kind contributions up to July 2005 (Table 1), currently own the background Intellectual Property (IP). Foreground IP will change as industry progressively assumes a greater share of program operating costs. The share of foreground IP should be recalculated each year on the basis of cumulative contributions from each party and ratified by all parties.

Current Status – April 2005

Georges River

Three different (5th generation disease resistance or 7th generation Georges River) breeding lines (set in February 2005). These breeding lines are expected to reach market size (50 g) 10 months earlier than controls and suffer only half the mortality of disease. They are held at:

- Line 1 – Lime Kiln Bar – QX disease and fast growth
- Line 2 – Woolooware Bay – winter mortality, QX disease and fast growth
- Line 3 – Quibray Bay – winter mortality and fast growth

They were therefore designated as fifth generation disease-resistant breeding lines. It should be noted that the lines in Georges River are not spread across the three sites but all trays and oysters of each line are held in one specific site.

Port Stephens

Four parallel 6th generation (11 months earlier to market) breeding lines (set in February 2003) spread over three sites in Port Stephens. The sites used vary from time to time depending on lease availability, overcatch, vandalism, theft etc.

Oyster Production

Average annual production of Sydney rock oysters from 1994/95 – 2001/2002 was around 100 million oysters. A 30% loss through mortality and handling over the life of a crop of oysters should be expected. Thus the total spat requirement for the NSW Sydney rock oyster industry is around 130 million. The program is to be self-funding when 60% of all Sydney rock oysters farmed in NSW is derived from improved broodstock, i.e. at an annual sale of 80 million spat.

Annual cost of breeding program

Scientific Officer – Grade 3 Year 3	
($75,441 + 22% on-cost @ 20% of time)	18,556
Fisheries Technician – Grade 2 Year 3	
(Salary $50,019 + 22% on-cost @ 100% of time)	61,538
Consulting geneticist	15,000
Operating cost	35,000
Hatchery production and hatchery staff cost	40,000
DNA analysis	6,000
Total annual cost	176,094

Cost Recovery: Calculation of broodstock levy on sale of spat

Annual cost of program of approximately $170,000/projected annual spat sale of 80 million spat is approximately 0.22 cent/spat. NSW DPI, FRDC and Oyster Research and Advisory Committee (ARAC) should review this levy biannually on the following basis:

- Program cost.
- Consumer price index (CPI).
- Numbers of spat produced from genetically improved oysters for oyster breeding program to become self-funding (this is proposed to be 80 million).

Phasing in of levy over 4 years

Hatchery production season	Cents/spat
2005/06	0.055
2006/07	0.110
2007/08	0.165
2008/09	0.220

Management and distribution of funds received by levy

Funds would be collected by Select Oyster Company Pty Ltd (SOCo) and transferred to NSW DPI for the maintenance of the breeding program. NSW DPI would ensure that it would hold sufficient numbers of the most advanced breeding lines for use by SOCo in the commercial production and sale of spat to farmers. SOCo would pay the levy by the 31 May of each year. Spat produced by NSW DPI for the maintenance of the breeding program and scientific experiments would be exempt from this levy.

Table A2.1. Funding sources for Sydney rock oyster breeding program (January1990 – June 2005).

Funding sources	1990-1996 $	1997-2000 *FRDC 96/357* $	2000- 2005 $	1990-2005 $
FRDC	0	332 308	0	332 308
NSW Fisheries	120 000	80 000	900 000	1 100 000
Subtotal Cash	120 000	412 308	900 000	1 432 308
In-kind				
NSW Fisheries	1 200 000	798 000	900 000	2 898 000
Oyster Industry – Value of lease space	54 000	51 400	90 000	195 400
Subtotal In-kind	1 254 000	849 400	990 000	3 093 400
Grand Total	**1 374 000**	**1 261 708**	**1 890 000**	**4 525 708**

Appendix 3: The 2003 – 2007 Oyster Industry R&D Strategic Plan

Programs

1. Ecological sustainability
   a. To develop a model to calculate "optimal" oyster stocking densities within part or all of an estuary.
   b. To investigate the potential that sewerage, storm water and agricultural runoff may lead to an accumulation of viruses and bacteria within oysters and/or the environment that will cause human health issues.
   c. To identify estuaries or areas within are affected by acid releases (acid sulfate soils) that either directly or indirectly impact on the productivity of oysters.
   d. To identify estuaries or areas within which are affected by water quality issues either directly or indirectly which impact on productivity of oysters through modification of the estuary environment, eg nutrient run off, chemical run off, sediment, etc.
   e. To obtain a greater understanding of the relationship between the occurrence of a disease (QX disease, winter mortality, etc) and the environment of an estuary and work towards the capability to model/predict the severity of an outbreak.

2. Diseases, pollution and pests (impacts on industry)
   a. To develop QX disease resistant stock through genetic selection.
   b. To obtain a greater understanding of the occurrence of QX disease within NSW.
   c. To develop monitoring and/or management tools that will provide the capability to better manage QX disease infections.
   d. To develop winter mortality resistant oysters through genetic selection.
   e. To obtain a greater understanding of the occurrence of winter mortality within NSW.
   f. To develop monitoring and/or management tools that will provide the capability to better manage winter mortality infections.
   g. To identify any correlation between stocking density, growing method, salinity or temperature on winter mortality infection.
   h. To develop and disseminate specific management regimes to minimise the impacts of mud worms.
   i. To develop and disseminate specific management regimes to minimise the impacts of flat worms.

3. Quality Assurance.
   a. To develop a unified whole of Government waterway classification model with clearly defined assessment criteria.
   b. To investigate and/or develop oyster depuration techniques that will ensure a safe food product is delivered to the consumer.
   c. To identify better planning and management regimes to prevent or respond to human health threats.
   d. To develop simple testing procedures for the presence of marine biotoxins.
   e. To develop an assessment process for relaying oysters which considers the disease status of each waterway.

f. To develop a code of practice and associated training program for the handling of oysters from harvest to the point of final sale.
g. To develop and identification system which allows product to be traced throughout its dealings from gate to the point of final sale.
h. To establish equivalence comparison of the internationally accepted bacteriological mean probable number (MPN) with the proposed direct plate method (DPN).

4. Hatchery and farm technology
    a. To develop techniques to maximise larval survival within a hatchery.
    b. To develop to maximise juvenile survival within a hatchery.
    c. To evaluate the disease resistance and growth rate of NSW Sydney rock oysters with New Zealand and Western Australian rock oysters/
    d. To investigate the integration of alternative species into the normal farming management regimes to enhance and diversify production from a lease.
    e. To develop through selective breeding an oyster which reaches market size (40 – 60 g) by at least one season earlier.
    f. To evaluate and/or develop commercially viable products for the protection from over catch, fouling, and borer with the aim to replace tar.
    g. To evaluate the economic effectiveness of relocating oysters to achieve faster growth rates.
    h. To evaluate and/or develop alternative commercially viable products to replace timber where applicable.
    i. To develop effective wash protection devices.
    j. To develop more effective/efficient oyster spat collectors.

5. Industry economics and marketing
    a. To develop an economic model analysis that recognises the various production and management regimes for the NSW oyster industry.
    b. To evaluate the structural processes within the oyster industry.
    c. To evaluate and develop and effective marketing strategy which will assist industry and provide a platform for increasing investment opportunities and consumer confidence in the industry.
    d. To develop a standardised marketing process and grading criteria of product.
    e. To develop a proactive marketing strategy for the promotion of product to local, interstate and international consumers.
    f. To identify and implement processes for adding value to oysters and by-products.
    g. To develop a marketing strategy that is linked to a quality assurance program to enable greater access to interstate and international markets.

7. Abalone

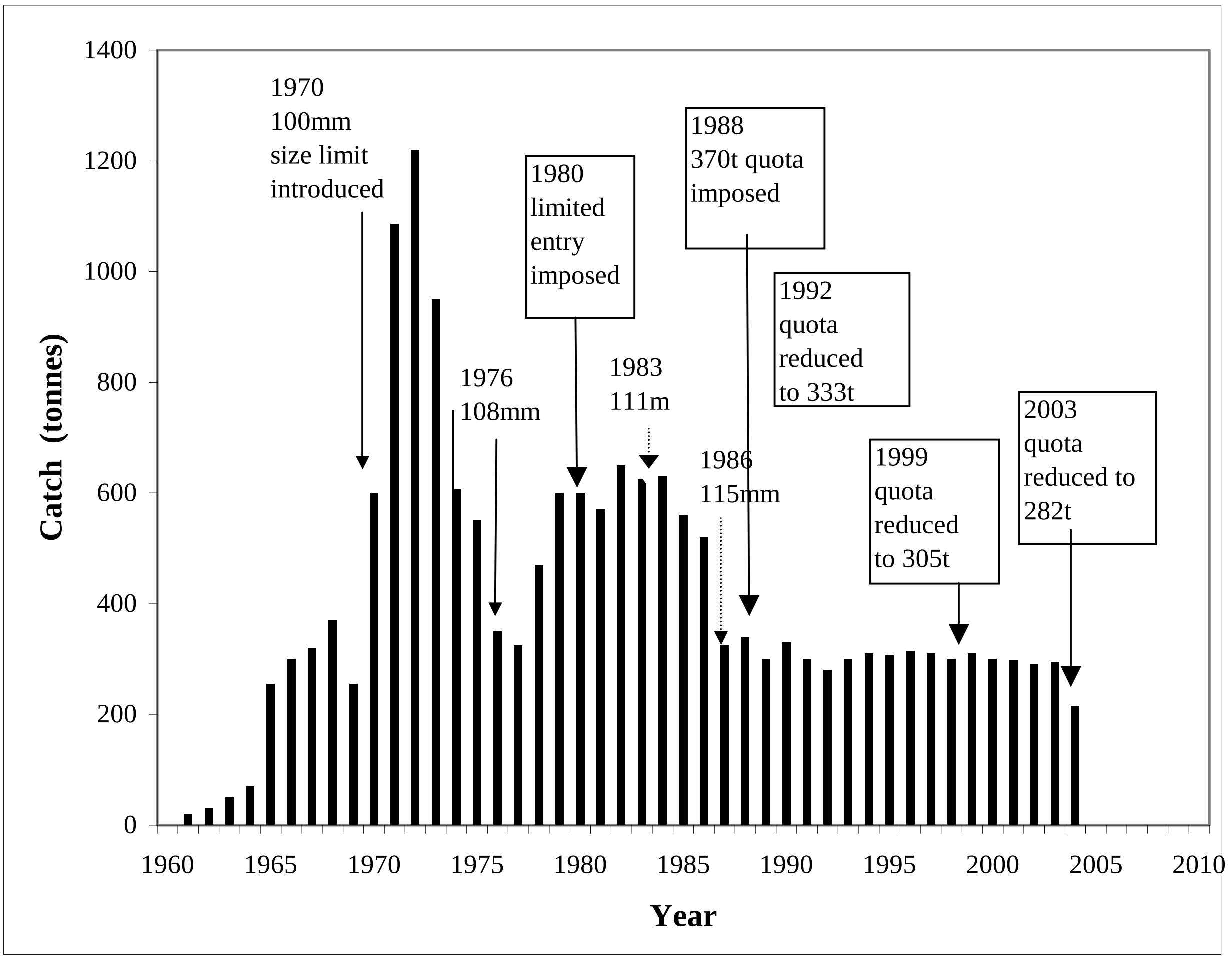
7.1 Industry Background

The NSW abalone fishery is based entirely on the black lip abalone and is confined to the southern half of the state. Annual catch (Fig.7.1) of this large sea snail peaked at about 1,200 tonnes in 1971/72, and remained above 600 tonnes through to the early 1980's. Since then the total allowable catch (TAC) has been steadily reduced. It was 330 tonnes in 1996, 305 tonnes in 2000, 281 tonnes in 2003, 218 tonnes in 2004 and 130 tonnes in 2005.

The landed value of the fishery over the past decade has been $10- 15 million per annum while processed export value has been $20 – 30 million over the same period. Recreational fishers and illicit (poaching) are each thought to account for up to a further 100 tonnes per annum valued at $6-10million (landed value).

There are 37 licensed catch quotas employing about 70 full time fishers and their assistants. The processing export sector is thought to support a further 50 – 70 jobs in southern NSW.

Figure 7.1: Trends in Production from the NSW Abalone Fishery



Marketing Issues

Close to 100% of all fishery and farm-produced abalone in Australia is exported to high priced markets mainly in Asia. Australia accounts for almost 50% of global abalone fisheries production and most competing fisheries are in chronic decline. High beach prices in the range of $25 to $60/kg whole-weight are therefore likely to persist. As Japan is the dominant market for black-lip abalone, fluctuations in the Japanese economy are the major determinant of price within the above range.

Farm Profitability.

Abalone R&D in NSW DPI has been directed towards hatchery techniques and the 'seeding' of wild stock. By way of background, information is provided from an ABARE (2001) study in which the profitability of farmed abalone is reviewed using a farm model designed to be representative of land based tank culture of blacklip and greenlip abalone. There are land based abalone farms in WA and Victoria and hatcheries in these states but none in NSW as yet because of difficulties of gaining development approval. ABARE developed models for farms producing 100 and 200 tonnes of abalone. The key assumptions were:

		Greenlip	Blacklip
Size at harvest	mm live	70	70
Growout time	months	27	39
Feed conversion ratio		1.4	1.4
Survival rate	%	80	80
Total farm production	t/an live	100	100
Farm gate price	$/kg live	45	45
Feed price - initial	$/tonne	3000	3000

Abalone are grown out in tanks from 20mm to 70mm. The capital investment in farms of 100 and 200 tonnes were assumed to be about $2.5m and $4.8m. Some of the key variable costs were as follows:

	100-tonne farm	200-tonne farm
Juveniles – 20mm @ $0.7	1,110,700	2,141,400
Feed	336,500	670,900
Marketing	200,000	400,000
Labour	350,000	700,100
Total	2,479,700	4,821,500

Hence the variable costs of production amounted to about $2.48 and $2.41 per kg. The budgets are based on greenlip abalone.

The expected benefit cost ratios for the 100- and 200-tonne farms were 1.48 and 1.53 and there was a very low probability that the benefit cost ratio would be less than 1.0. The benefit cost ratios for blacklip abalone are likely to be lower because of the longer growout time required.

Disease Issues

Global warming/climate change results in a southward extension of warm water influences on coastal reefs in NSW and could result in a southern extension of the disease *Perkinsus* that reduced some stocks north from Jervis Bay by as much as 90% in 2000/2002. The most effective (possibly only) way of combating such a development is selective breeding and seeding of more high temperature *Perkinsus* resistant blacklip stock in affected areas.

Decline of the NSW Abalone Fishery

There are two components of the decline in the NSW Abalone fishery. One concern is that overfishing threatens the sustainability of the fishery. As described in more detail below fishing has had to be regulated to protect the fishery. Despite a continuing reduction in the allowable catch, the size of the fishery is yet to stabilise.

The second issue is the environmental degradation of the fishery. A common claim of abalone fishers in relation to the decline of the NSW abalone fishery over the past 30 years is that many formerly productive areas of reef, typified by dense stands of seaweed and associated complex communities of fish and invertebrates including abalone, have undergone a transition to "barrens". These bare rock areas typically carry high densities of the common black (or purple) sea urchin. Such claims are supported by documented research findings that densities of abalone and black urchins are negatively associated and that continuous grazing pressure exerted by dense aggregations of urchins can indeed degrade diverse reefs into "barrens" that constitute 40 to 50% of near-shore reef areas in the southern half of NSW. The estimated biomass of black urchins is in the order of 50,000 tonnes, between one and two orders of magnitude greater than that of abalone. Moreover it is probable that the biomass of abalone is also far exceeded by that of other common grazing gastropods that while competing with abalone for food and space sustain negligible fishing pressure.

While the extent of barrens habitat in NSW appears to offer scope for enhancing abalone stocks, natural recolonisation is probably limited by the combination of competitive exclusion by urchins and other gastropods, and by very restricted dispersal of abalone from their parents. Research has shown that culling urchins from urchin dominated reefs in Southern NSW results in rapid recovery of abalone densities within three to four years. The recovery process also includes a dramatic increase in the coverage of seaweed and the biodiversity of plant and animal assemblages. Nevertheless, urchin culling is very labour-intensive, its effects are limited to small localised areas and it has a dubious public image. Accordingly, the task of culling urchins from up to 50% of coastal reefs commercially fished for abalone in NSW (around 2,500ha) is daunting. The release of seed, produced from wild abalone in a hatchery, potentially provides a significantly more powerful technique to rapidly enhance depleted populations of abalone over a large scale. The potential for this is currently being assessed by scientists from Sydney University (collaborators in the NSW DPI/FRDC-funded abalone enhancement project). This research will conclude in 2009.

Regulatory Issues

A succession of fishery management initiatives (Fig. 7.1) has been implemented. These began in 1973 with a restriction on fishing licenses to 37, limiting of catch by quota allocation and introduction of size limitations. Regional fishing closures were also imposed between Port Stephens and Jervis Bay following a major depletion of stocks by the disease *Perkinsus* between 2000 and 2002. A total allowable catch of 370 tonnes was first introduced in 1989. Subsequently it has been progressively reduced to 333 tonnes in 1996, to 305 tonnes in 2000 and down to its current level of 281 tonnes in 2003.

The abalone commercial fishery is a share management fishery operating through the *Fisheries Management Act* 1994 (the Act) and the *Fisheries Management (Abalone Share Management Plan) Regulation* 2000. At the commencement of the Management Plan there were 37 holders of 100 equal shares that are transactable and transferable. Abalone shareholders were also endorsed in the sea urchin and turban shell restricted fishery. The urchin/turban endorsement has since been dissociated. Shares in this fishery are now separately transferable and the fisheries are under the control of a separate Management Advisory Committee.

The main features of the current share management scheme are that:

- Most of the core management functions of the fishery, such as quota allocation, fee setting and collection, research, and monitoring and reporting, reside with the NSW Government - with management decisions resting ultimately with the Minister and then implemented through NSW DPI.
- In the case of the total allowable catch (TAC) a TAC Committee appointed by the Minister makes an annual determination after consideration of scientific, environmental, social and economic factors and following consultation with the industry and other stakeholders.
- The industry's role in the governance and management of the fishery principally entails compliance with regulations and record keeping in relation to quota allocation, size limits etc.

The industry also has an advisory/review role. This is formalised through participation in the Abalone Management Advisory Committee (ABMAC), the membership of which also includes conservation, indigenous and recreational fishing interests. ABMAC provides a forum for discussion of issues relating to the fishery and for recommendations to be made to the Minister. In addition to ABMAC, there are opportunities for the industry representatives, either individually or through industry associations, to make representations to the TAC Committee, NSW DPI or the Minister.

Further information about the management of the abalone fishery can be found in two reports available on the DPI website:

1. *The NSW Abalone Share Management Plan*
2. *"Future Governance of the NSW Abalone Fishery : Alternative Arrangements" - prepared by Marsden Jacob &Associates in March 2004 commissioned by NSW Fisheries and the Abalone Development Company*

Relationships between the former NSW Fisheries and industry members of the ABMAC have been strained over recent years. A significant consequence has been lack of industry cohesion in supplementing funding of R&D critical to the long-term development and implementation of large-scale cost effective enhancement of the fishery. It could also be argued that comprehensive fisheries stock assessment and management initiatives implemented over the past 25 years do not appear to have stemmed an apparent long-term decline of the fishery as described above (Fig. 7.1).

Another significant regulatory issue relates to development approvals in sensitive areas where there is a high level of public scrutiny. For example a proposal for a land based abalone farm at Pindimar, Port Stephens was recently rejected after a more than seven year approval process. New approval mechanisms (Major Projects SEPP) for significant developments in sensitive areas may address this constraint.

Appropriate policy and legislation to enable future enhancement of the fishery through supplementary seeding with hatchery produced seed is currently lacking and will probably involve long term integrated management of reef floral and faunal communities (ie reef ecosystems) rather than management of component reef species such as black lip abalone.

7.2 Past Research Achievements

In response to the threats to the longevity of the abalone fishery identified above, the former NSW Fisheries undertook a program of research into the feasibility of using hatchery-produced seed to restock depleted abalone populations. Mass hatchery production and release of seed abalone provides a potentially powerful means of rapidly enhancing depleted abalone sub-populations over large areas. Seeding also addresses other factors limiting recruitment and consequentially sustainable yields. Such factors include the combined effects of commercial, recreational and illegal fishing pressure, and diseases such as *Perkinsus* that has devastated stocks north from Jervis Bay to Port Stephens over recent years. Other recruitment limiting factors are pollution and competitive exclusion especially of settlement stage larvae and small juvenile abalone by a diverse array of large common reef surface grazers additional to urchins. These include other common sea snails and urchins**.**

A cost effective technology for large-scale hatchery and nursery rearing technology has been developed by NSW Fisheries over the past six years. This controlled breeding technology is in turn providing a number of important flow-on benefits to the abalone aquaculture industry in southern Australia. Most importantly, it is assisting an industry wide selective breeding program through facilitated synchronisation of spawning that in turn enables pair crossing and identification of specific genes for faster growth.

Another important benefit for the abalone farmers has been development of technology that will enable new nursery production systems with greatly improved space efficiency and much lower initial capital costs. Uptake of this technology is expected in the next generation of land based farms that will also need to incorporate controlled reproductive conditioning systems and an additional intermediate nursery system for weaning and on-growing of post-larvae from 1-3 mm. Controlled year-round conditioning and spawning has also enabled initiation of research to produce and evaluate triploid abalone that offer prospects of both faster growth, superior flesh yields and near or total reproductive sterility, all of which could be of major benefit to fisheries enhancement and farming of this species.

In parallel has been a program of research into how best to ‘seed’ reefs with hatchery produced ‘buttons’. While advances have been made in the development of seeding capsules, cost effective seeding protocols are yet to be demonstrated and environment environmental impacts of large-scale seeding and enhancement operations, especially impacts on the genetics of wild stocks and on reef communities, are yet to be evaluated.

7.3 Funding of Research

NSW DPI has been involved in abalone research since 1999 in collaboration with the Universities of Sydney and New England and with coinvestment from FRDC, through the Indigenous Fishing Strategy and other programs. The share of external fund investment has exceeded 80% from 2002/2003 to 2004/2005 (Table 4.2 in Chapter 4) and with the cessation of the current funding, DPI R&D has been dramatically reduced.

7.4 Future Directions and Opportunities for Research and Extension

At present all research and extension programs in NSW DPI related to abalone have ceased and hence the extent to which technologies developed in past research are adopted by industry is most uncertain. Adoption of improved nursery technology by the abalone farming industry is being promoted by practical training programs being run in conjunction with several colleges of TAFE in NSW and by a practical user manual for intensified nursery production of *H. rubra*, published in June 2005.

There are no commercial hatcheries and nurseries in NSW (also see comments on current proposed development of an abalone hatchery and farm at “Pindimar”). There is however considerable interest by interests in the southern states and overseas in commercial adoption of low cost seed production and deployment techniques developed in NSW.

There are two areas of research that are likely to be significant components of any future research program:

- A large-scale seeding experiment in collaboration with the University of Sydney and Queensland University of Technology to gauge the general efficacy of low density dispersed seeding and of long term impacts on the genetics and reef ecology of depleted populations of abalone at Port Stephens, NSW

- Further evaluation of the impacts of other gastropod grazers on the magnitude and sustainability of abalone catches in NSW and a broader ecosystem based approach by the NSW Government to managing the state’s coastal reefs.

With scenario

The following scenario indicates the direction that research and the industry might take were industry funding to become available in the future.

To what extent sustainable catches of abalone in NSW and elsewhere can be raised using hatchery-produced seed can only be answered by continuing long term and large scale pilot seeding operations in each State. Preliminary cost and benefit exercises suggest that cost effective seeding can be achieved if survival rates of released six- month-old juveniles through to legal size three to five years later are raised to levels of 25% or greater than corresponding rates for wild abalone. This represents a yield rate of about one legal abalone per 100 released seed.

Historical catch data (Fig 7.1) suggest that sustainable catches in NSW may have a potential to be increased to levels as high as 500 to 600 tonnes per annum representing an increase in value up to $10 – 15 million. By raising sustainable catches outside NSW by a factor of 10%, the gross value of the annual commercial catch across southern Australia would rise by approximately $20 million.

There are two broad approaches to implementing this technology for rejuvenating the abalone fishery. First, widespread fisheries enhancement using hatchery produced seed abalone could supplement natural recruitment. As seeded stock attained legal size they would be treated the same as wild catch and thereby used to increase the annual TAC (total allowable catch quota) which would be evenly allocated across the licence holders. An important outcome from this approach with public benefits may be the environmental rejuvenation of some of the 'barrens' areas off the NSW Coast.

Second, the concept of 'ranching" of abalone on artificial reef is gaining momentum in the other southern states in that it offers major potential cost of production and risk reduction advantages over shore-based farming, while avoiding the environmental, property rights and disease/predation issues associated with ranching on existing natural reef areas. This momentum has been fuelled by the relatively recent imposition of enabling policy and legislation, and the identification and allocation of "suitable" medium to long term offshore leases. e.g. Victoria (Port Phillip Bay and Western Port Bay) Tasmania (Bass Strait Islands), South Australia (Port Lincoln) Western Australia (Albany). Increasingly, developments of this type are subject to comprehensive regional planning, feasibility studies and environmental impact assessments, that include public consultation processes culminating in calls for expressions of interest from commercial proponents.

There is potential scope for substantial additional production of abalone and high value urchins on a scale of several hundred tonnes per annum in NSW through the construction and seeding of artificial reefs in conjunction with provision of formulated diets. However NSW has no such enabling policy, legislation or even 'strategies' of this type. There is to be likely strong opposition from both NSW abalone TAC quota holders and environmental interests to such developments.

Without scenario

In the absence of fisheries enhancement using hatchery seed (including breeding lines selected for resistance to the disease *Perkinsus*) and in the absence of other management initiatives to combat the dominance of NSW coastal reefs by the black sea urchin, it would seem likely that catches will at best remain within the range of 200- 300 tonnes per annum. At worst a continued decline in annual sustainable catches may occur as a continued north to south "fish down" of stocks possibly exacerbated by a progression of the disease *Perkinsus* into much more productive southern coastal reefs .

Local seed production and continued refinement of abalone seeding technology financed by industry is entirely feasible and desirable even in the short term and is supported in- principal by industry. However there are two major constraints. The first is that a small group within the industry appears interested in pursuing control/ownership of enhancement technologies and initiatives. This could have potentially serious social and legal implications if not addressed. The second is an absence of enabling policy, legislation and strategic planning to encompass reef ecosystem management (as opposed to the current *ad hoc* separate management of individual but highly interactive sympatric reef species such as abalone, urchins, turban shells, rock lobsters etc). Considering the public interest component to the long term sustainability of coastal reefs, it is hard to see the industry being left to independently undertake this task even if they are prepared to outsource and fund R&D to address these issues.

7.5 Beneficiaries of Research

The outcome from past R&D has been to develop technologies that will allow populations of abalone along the NSW coast to be rejuvenated in a potentially cost effective manner. There are potential economic and environmental benefits from this technology. The commercial abalone industry – producers, processors and consumers - are clearly likely to be important beneficiaries of the technologies developed by R&D. Most of the consumers of abalone are non-residents of Australia and will share in the benefits of this technology (industry levies are a mechanism by which they also share in funding the research even if the levies are imposed on fishers.) However because of quota restrictions on catch, it is most likely that most benefits will be captured by quota holders.

Other beneficiaries are the processing and export sector, most of whom reside in regional areas of the south coast especially south of Ulladulla, and recreational divers who account for catches of up to 100 tonnes per annum. While the abalone may add to regional employment and turnover in local businesses, many of these benefits would be included in any economic analysis of the industry, as noted above.

There is also scope for allocation of some additional TAC generated by fisheries enhancement to south coast aboriginal communities. Many of these communities have expressed great interest in the prospect of involvement in commercial fishing over the past decade as demonstrated by considerable funding of abalone hatchery R&D and training programs by indigenous linked sources. Some have also expressed interest in fisheries compliance roles in relation to the sustainable management of abalone stocks, and a wider role as custodians of coastal reefs.

There is a significant, major public good benefit in this research if it leads to reduction in the area of “barrens” and an increase in abalone populations. Recreational divers are required to purchase a recreational fishing licence if they collect abalone in NSW (bag limit 10) but the public (including future generations) also benefit from environmental outcomes. Should the area of “barrens” be reduced through enhancement of abalone, it will be critical to ensure numbers do not decline again to allow re-establishment of “barrens”. This will require regulation and education.

7.6 Rationale for Government Involvement

Because of the large potential benefits flowing to the abalone industry, it is reasonable to expect that industry fund most of this R&D.

However because of the significant environmental benefits there may remain a role for some continued funding of this research by NSW DPI or by the FRDC. However the focus of this research should be on reef management rather than the productivity of abalone populations.

7.7 Recommendations

- Abalone research at the Tomaree hatchery and aquaculture facility should remain suspended, at least until the results of the large experiment to field test abalone enhancement is completed in 2008. Given the likely requests from abalone shareholders for new research if the results are positive, it is recommended that if future research is required then NSW DPI should pursue both public and industry funds for future R&D as a component of abalone enhancement and NSW coastal reef management

- In order to increase the sustainable catch of abalone in NSW, DPI should consider the policy requirements associated with approvals for abalone stock enhancement including ranching of abalone on existing or artificial reefs and for land based abalone farming.

- Reef management in NSW should be reviewed by the Division of Agriculture and Fisheries and a whole of reef management strategy should be developed with particular emphasis on abalone, urchins and lobster. DPI may need to seek public funding to maintain a research capacity in this area.

8. Marine Finfish

8.1 Industry Background

Research and development by NSW Fisheries initiated temperate marine fish farming in Australia. Prior to 1990 no farming of temperate marine fish was conducted. However, after NSW Fisheries held a marine finfish farming workshop in 1996, aquaculture of snapper and mulloway in NSW and SA commenced.

Large-scale aquaculture of marine finfish in Australia is currently limited to production of Southern bluefin tuna *Thunness maccoyii* (South Australia), Atlantic salmon *Salmo salar* (Tasmania) and barramundi *Lates calcarifer* (predominantly Queensland, New South Wales and Northern Territory). Sea-cage production of yellowtail kingfish *Seriola lalandii* and mulloway *Argyrosomus japonicus* has increased in South Australia, where these species are now farmed in preference to Australian snapper *Pagrus auratus*. The aquaculture potential of as many as 20 other marine finfish have or are currently being evaluated in Australia to offer diversity within the tuna and salmon industries in Australia, or to provide species for similar industries in new areas. Some of these species support significant aquaculture industries in other countries. Examples include the sea-cage grow-out in Japan of Yellowtail (Japanese amberjack) *Seriola quinqueradiata* (>200,000 tonnes per annum) and red sea bream *Pagrus major* (>70,000 tonnes per annum) and the farming of gilthead seabream *Sparus aurata* in the Mediterranean (>70,000 tonnes per annum). These industries have been successful because they have developed a series of integrated technologies that encompass brood-stock management, larval rearing (hatchery), nursery and grow-out phases through either industry or government based research. In most cases, the basic nutritional requirements of these species are also well understood.

Australian consumers continue to increase their intake of seafood with average per capita consumption climbing to almost 15 kg in 2000. Australian and world trends indicate that consumption will continue to increase as consumers become more aware of the health benefits of consuming fish and seafood and the cost of other protein sources become more expensive. To date, Australia imports the majority of its seafood for human consumption. Therefore, establishment of viable, large-scale finfish industries in Australia (NSW) has the potential to redress this balance, creating wealth and employment opportunities.

In NSW, marine fish production is an infant industry and is divided into three sectors - aquaculture, stock enhancement and inland saline aquaculture.

Aquaculture

Commercial farming of marine fish for consumption is developing and is based on seacage and pond grow-out of snapper and mulloway. The aquaculture of other marine finfish in NSW waters will most likely be limited to other temperate water species such as yellowtail kingfish, bream (*Acanthopagrus butcheri* or *A. australis*) or sand whiting *Sillago ciliata*, although interest in culturing the common dolphinfish (mahimahi) *Coryphaena hippurus* and cobia (black kingfish) *Rachycentron canadum* has been expressed. The prevailing sea temperatures are considered unsuitable for the culture of either tropical or cold-water species. Small numbers of other estuarine species including silver bream, *Acanthopagrus australis*, black bream, *Acanthopagrus butcheri*, sand whiting, *Sillago ciliata* and eels, *Anguilla australis* and *A. reinhardtii* have been produced intermittently for research and commercial evaluation.

Intensive freshwater production of barramundi, *Lates calcarifer* (a euryhaline species) is also developing, but is conducted in freshwater recirculating aquaculture systems. Hatchery production of barramundi fingerlings is not permitted in NSW, due to the potential for introduction of an exotic fish virus from broodfish, and fingerlings are purchased from certified, interstate hatcheries.

Stock enhancement

Large-scale stocking of marine fish species into estuaries and ocean environments in NSW is not currently government policy due to the lack of knowledge of potential impacts of stocking. However, several NSW DPI (as NSW Fisheries) research projects alone and jointly with University of NSW to determine the feasibility of stock enhancement and to model the impacts of stocking juvenile mulloway have demonstrated excellent potential for estuary stock enhancement to enhance recreational fisheries. New projects have been funded by the NSW Recreational Fishing Trust to continue evaluation of mulloway stock enhancement (discussed below). It is anticipated that, given the success of the mulloway stockings and the political influence that recreational fishers command in NSW, marine stocking will be commonplace in the near future. Clearly, a viable, large-scale marine fish hatchery industry will be necessary to supply fingerlings when the demand arises.

In contrast, considerable numbers of Australian bass, *Macquaria novemaculeata* fingerlings are produced by NSW permit holders (Table 8.1) and NSW DPI Fisheries (~300,000 per annum) for stock enhancement of freshwater recreational fisheries east of the Great Dividing Range. Australian bass are catadromous and live mostly in freshwater but must spawn in seawater. Consequently, bass fingerlings are produced in marine fish hatcheries. Australian bass is a highly sought after sport fish and is the only native freshwater eastern drainage species which is produced for stock enhancement. Production of fingerlings is listed in Table 8.2.

Inland Saline Aquaculture

Aquaculture of marine fish species in inland saline groundwater is a developing industry with potential for large-scale production. Inland salinity is a major environmental problem in Australia and NSW. Pumping of saline groundwater from subsurface drainage schemes and disposal in evaporation ponds is the only engineering solution to this problem. Approximately 65,000 ML of saline water is pumped annually in the Murray Darling Basin and apart from salt production is unused.

Opportunities exist to use this resource for growout of marine species offsetting the costs of the subsurface drainage schemes. Identification of suitable species and development of production methods are still in a research phase. This research is being led by NSW DPI (Fisheries) with most funding from the Australian Centre for International Agricultural Research (ACIAR) at the Inland Saline Aquaculture Research Centre near Wakool (ISARC). ISARC was built by Murray Irrigation Limited (MIL), which remains the key industry collaborator (MIL has invested over $700,000 in inland saline research with NSW DPI). Fish species evaluated to date include snapper, mulloway, trout and silver perch. A semi-commercial crop of rainbow trout was produced in 2004 by NSW DPI (Fisheries). The Principal Investigator (Research Leader, Aquaculture) coordinates inland saline aquaculture R&D and commercialisation on a national basis, funded in a National Aquaculture Council project by DAFF and FRDC.

One commercial Australian bass and mulloway hatchery and growout (~10 tonnes per annum) farm using saline groundwater at East Maitland was recently wound down to focus on seacage-based aquaculture of mulloway and snapper in Botany Bay.

Production of Fish and Fingerlings

The value of marine finfish aquaculture in NSW has grown from about $140,000 in 1999 to $1.25m in 2004 (Table 8.1). By far the largest sector in the industry is barrumundi but, apart from 2004, there has been steady growth in the snapper sector and more recently in the mulloway sector. In 2003 the value of production in these two sectors was about $340,000.

Table 8.1: Marine finfish production (kg) in NSW, value and number of permit holders

	Production year					
	1999	2000	2001	2002	2003	2004
Production						
Snapper	441	885	13352	24185	15010	22
Mulloway	114	980		9275	25684	3543
Silver bream					242	240
Sand whiting					67	
Australian bass			50		506	
Barramundi	11196	16883	65353	54881	85234	101207
Eels (Anguilla spp.)	2338	2410	3975	9275	13991	7653
Value $AUSD						
Snapper	4115	9298	137501	219633	135000	176
Mulloway	1280	11280		4500	204087	32153
Silver bream					1724	3600
Sand whiting					429	
Australian bass			1000		3950	
Barramundi	112071	188606	586086	588723	905129	1127555
Eels	19264	17485	42480	117441	152285	83396
Total	**136,730**	**226,669**	**767,067**	**930,297**	**1,402,604**	**1,246,880**
Number of producers[1]						
Snapper	1/10	?/13	?/11	?/13	?/13	?/14
Mulloway	1/14	?/19	?/7	?/25	?/23	?/24
Silver bream					?/9	?/14
Sand whiting					?/14	
Australian bass			?/40		?/44	
Barramundi	3/3	?/5	?/6	?/7	?/9	7/11
Eels	3/12	?/21	?/22	6/26	?/28	

[1] producers per year (?=<6) / total number permit holders: Data from DPI NSW Fisheries production report series.

Fingerlings are produced for stock enhancement (bass and some mulloway) and aquaculture (Table 8.2). Bass production is trending upwards as more angler associations require fish for stocking. Mulloway for stock enhancement has been experimental but there is a new demand for increased research and an increased demand for routine stock enhancement is likely. Fingerlings for aquaculture (snapper and mulloway) increased to a peak in 2003. Small numbers of bream and whiting are produced on an irregular basis for stocking into aquaculture ponds.

Table 8.2: Marine hatchery (fingerling) production, value and number of permit holders.

	Production year					
	1999	2000	2001	2002	2003	2004
Fingerlings produced[1]						
Snapper	90500	49200	40259	1500		
Snapper (NSW DPI)	*na*	*na*	*na*	*40000*	*na*	*na*
Mulloway	100	300	6036	120600	22000	50740
Mulloway (NSW DPI)			*52000*	*235000*	*96000*	*na*
Silver bream		2000	2000	700	67300	9550
Sand whiting			2000	700		
Australian bass	10000	80700	167500	212000	206300	454350
A. bass (NSW DPI)	*275000*	*300000*	*250000*	*100000*	*235000*	*205000*
Value $AUSD						
Snapper	63350	48450	40259	1150		
Mulloway	100	300	5680	104645	16125	31340
Silver bream		1500	1500	830	61175	9550
Sand whiting			1500	770		
Australian bass	1500	50000	68700	98025	84400	169270
Number of producers[2]						
Snapper	2/3	?/5	?/4	?/4		
Mulloway	1/5	?/7	?/7	?/7	?/9	?/8
Silver bream		?/4	?	?	?/5	?/5
Sand whiting			?	?		
Australian bass	1/16	3/15	5/14	?/17	5/18	5/17

1 Fingerlings produced by commercial hatcheries except where indicated (*DPI NSW PSFC*)
2 producers per year (?=<6) / total number permit holders: Data from DPI NSW Fisheries production report series.

Agricultural ingredients for use in aquaculture diets

The market in Australia for aquaculture feeds is around 50,000 tonnes per annum and while growing rapidly is totally dwarfed by the 12 million tonnes per annum global market, most of which is consumed in Asia and made from imported ingredients. Availability and cost of suitable ingredients is the major constraint for the aquaculture feed manufacturing sector. Quite apart from aquaculture development in NSW and Australia, R&D into Australian and NSW agricultural feed ingredients (including value-added products such as protein concentrates from grains and low-ash meat meals) for use in the global aquaculture feed industry will provide new markets for the NSW agriculture feed ingredient sector.

An important focus of aquaculture feed R&D has been on developing diets for aquaculture species which rely less heavily on fish-based ingredients (often imported) as a source of protein.

Industry Structure

Aquaculture

The NSW industry remains small and employs few people directly. Marine fish production in NSW had stalled, but is now increasing. Previously it was based predominantly on the sea-cage production of snapper and mulloway at two locations with combined production peaking in 2000/2001. An off-shore operation in Port Stephens (permit for 500 tonnes per annum) was recently liquidated and bought by a venture capital company which has only conducted small scale on-farm pilot trials with mulloway, with little present contribution to annual production. However, this site has the potential to produce up to 2,000 tonnes per year (providing farm expansion is approved) and the surrounding area with experienced operators has an additional capacity for large scale sea-cage operations.

The Botany Bay site is now leased to an existing mulloway hatchery and growout farm operator from East Maitland (the operator is part of a partnership with NSW DPI and Ridley Pty Ltd under the Aquafin CRC). This farm has been increasing production and has recently commenced trials with yellowtail kingfish.

The transfer of technology developed by the former NSW Fisheries to NSW marine aquaculture facilities in the form of mature, G1 (hatchery-reared) broodstock and phototherm regimes, reduced their commercial hatchery start-up time by three to five years. In addition, NSW Fisheries supplied large numbers of snapper and mulloway fingerlings to commence growout operations prior to commercial hatchery production.

While commercial interest in reinvesting in sea cage culture in NSW has been low, recent interest by the Stehr Group of companies in South Australia (Port Lincoln) is encouraging. The Stehr Group own and operate the largest marine fish hatchery in Australia and a sea cage farm for tuna, yellowtail kingfish and mulloway.

Further marine fish farming activities in NSW may also occur through a new initiative by the Wollongong Aboriginal Aquaculture Corporation (WAAC). The WAAC has developed a proposal to undertake aquaculture at Bass Point (hatchery), Port Kembla (nursery) and offshore (growout) at the Five Islands using submerged cage technology. A feasibility study and a business plan have been completed and Environmental Impact Statements are being prepared. No doubt this new venture will require and/or seek the support and expertise of NSW DPI as it develops.

If the Port Stephens and Botany Bay operations reach their potential production capacity (2,150 tonnes per annum), marine fish farming in NSW will be the second largest aquaculture industry in NSW behind SROs and would be equivalent to the national barramundi industry. Several factors give the NSW seacage sites advantages over mulloway and kingfish farming in South Australia. Firstly, the water temperatures in NSW are higher year round than SA and therefore growth is greater and winter stress (diseases) is less likely to be problematic in NSW. Secondly, the NSW sites are located near Sydney, the largest seafood market in Australia, and Australia's major international airport.

Both growout ventures are supported by two land-based, marine finfish hatchery operators in NSW, located at East Maitland and Yamba. The East Maitland farm (using saline groundwater) also has a small capacity (up to 10 tonnes per annum) for grow-out of marine species. This farm has been wound down as the operator is leasing a cage farm in Botany Bay and directing his efforts into production of mulloway and yellowtail kingfish from that facility. Several small-scale farms are also located on the NSW north coast for growout of mulloway, snapper and bream as well as fishout (paying customers) of these species.

Stock Enhancement

Production of Australian bass fingerlings for stocking into farm dams and freshwater impoundments has increased as the number of capable hatcheries has increased. Individual hatcheries have the capacity to produce in excess of 100,000 fish per annum but production is largely based on orders. The main market for bass fingerlings is through the Recreational Fishing Trust introduced in 1998.

Of the 17 hatcheries currently holding permits to produce Australian bass fingerlings, only five are active (Table 8.2). Production of Australian bass fingerlings by industry increased almost six-fold in the last five years from 80,700 fish in 2000 to 454,300 fish in 2004.

NSW DPI at PSFC has a significant role in production of approximately 300,000 Australian bass fingerlings per year for stocking into NSW impoundments. Production is supported by funding from the Freshwater Recreational Fishing Trust. Demand for NSW DPI produced fingerlings is increasing and in 2004, Victorian Fisheries entered into a commercial contract for NSW DPI PSFC to produce bass from Victorian broodstock because of lack of capacity in Victorian hatcheries.

NSW DPI at PSFC has also had a significant role in the evaluation of the feasibility of marine stock enhancement with mulloway. In addition to producing and stocking more than 100,000 mulloway into Botany Bay and Smiths Lake, facilities and expertise were used to conduct research to develop cheap, effective and safe methods to tag (identify) stocked mulloway. The Saltwater Recreational Fishing Trust has recently granted funds to UNSW for continued evaluation of stocking mulloway in three northern Rivers. The PSFC hatchery will be ideally placed to fill orders for mulloway fingerlings due to the large number of mature broodstock and expertise in fingerling production. Of major importance to the stock enhancement program is consideration of impact of stocking on wild population genetics. The origin and number of parent fish contributing to stocked fish needs to be well understood. PSFC is the only hatchery in NSW with large numbers of broodstock mulloway from a range of parent stock (and likely to remain so) and is collaborating with QUT to determine suitable broodstock management for stocking of mulloway and snapper.

Inland Saline Aquaculture

Only one commercial facility (East Maitland) uses saline groundwater for aquaculture in NSW. However, potential development at Wakool for example, will attract large-scale activities. Conservative estimates based on available saline groundwater and land for ponds and raceways suggest that more than 300 tonnes per annum of rainbow trout as well as other marine fish could be produced. Murray Irrigation Limited commissioned an analysis of the business opportunity for production of trout using the Wakool saline groundwater interception and evaporation scheme and the results indicated an attractive return on investment for a large farm (eg 300 tonnes per annum). NSW DPI, in partnership with commercial operators, will lead a project within the Seafood CRC to commercialise inland saline aquaculture in conjunction with saline groundwater interception and evaporation schemes.

Impediments to growth and Policy/regulatory Issues

Aquaculture

Although permits for two seacage sites in NSW have been approved (currently for 650 tonnes per annum) which at full capacity, could produce 2,000 to 5,000 tonnes per annum, sites for additional seacage farms within NSW estuaries will be difficult to secure. There are suitable sites for offshore seacage culture in NSW, especially for submerged cage culture. However, there is an urgent need for a coastal and offshore zoning policy and for a commitment by government to marine aquaculture within appropriately zoned areas if the marine finfish aquaculture industry is to develop.

In addition, there are concerns by government and the community about environmental impacts of marine fish aquaculture which include degradation of waterways following discharge of nutrients from aquaculture farms; degradation of ocean floors; entrapment of marine mammals and birds; visual pollution; and noise pollution from farm operators. These issues will benefit from ongoing R&D by NSW DPI. For example, one of the most obvious potential impacts of fish farming is caused by increased nutrient loading in waterways from feeding fish. Research to improve feeding methods and feeds to reduce solid waste and soluble nutrient discharge is essential to improve production and sustainability.

Inland Saline Aquaculture

For inland saline developments such as at Wakool (and most other subsurface drainage schemes) aquaculture activities will be captured within operating saline groundwater disposal basins. Approvals for development will be easier to obtain as the environmental impact will essentially be nil. All waste-water is contained in the saline groundwater disposal system.

Infant industry

To a large extent development of the marine fish culture industry has been faced with a "chicken and egg" situation. For development, a growout industry and a fingerling supply industry are necessarily interdependent. One of the main reasons why commercial marine fish aquaculture has struggled in NSW has been the failure of the hatchery sector to produce reliable supplies of fingerlings at competitive prices.

It is not currently possible for NSW seacage growout farms to purchase snapper, kingfish or mulloway fingerlings from interstate (SA) hatcheries because of real or perceived concerns with genetic pollution and disease transfer. It is current policy to stock seacages with fingerlings produced from broodstock lines, which were collected in the surrounding environment. Transfer of fingerlings from SA to NSW for growout in inland saline groundwater facilities is likely to be possible due to the low risk of escape and relative biosecurity of the inland locations.

NSW DPI has a potential role in using its hatcheries to initially provide a secure source of fingerlings to the growout sector and to simultaneously encourage the growth of a commercial sector. NSW DPI would need to operate its hatchery in a competitively neutral manner and provide the growing commercial sector with access to its breeding stock and production technology. Without this, new investment in marine finfish aquaculture in seacages is unlikely. The model employed in Tasmania for Atlantic salmon and in Queensland for barramundi, where government helped secure fingerling supplies and progressively handed this business to industry, warrants consideration in NSW.

A focus of NSW DPI R&D has been on improving production of fingerlings at low cost. The results for snapper have successfully been translocated to industry. Similar R&D for mulloway and kingfish is underway at NSW DPI. The benefits of this research will directly affect both aquaculture of marine fish and stock enhancement. Existing and new marine fish hatcheries will have the opportunity to compete for contracts to supply fingerlings for aquaculture in seacages and inland saline groundwater, and for stock enhancement.

The weakness of 'infant industry' arguments is that 'infants' often fail to grow. However the potential for development of marine fish farming is good now that the CRC project between NSW DPI and the operators of the Botany Bay facility is established. Within two years production capacity of mulloway will reach 40 tonnes per annum (NSW wild catch is approximately 60 tonnes per annum). Further production will rely on expansion of seacage facilities. If suitable proponents can be identified for operation of the Port Stephens site and supply of fingerlings can be secured (possibly through a supply contract with NSW DPI), then production capacity of 500 tonnes per annum could be achieved within 3-5 years. This needs to recognise the difficulties of forecasting production trends when there are only two producers. Further production expansion would rely on commensurate development of commercial hatcheries.

Production of Australian bass fingerlings clearly demonstrates the industry capacity to respond to new markets. Since the introduction of the dollar-for-dollar stocking scheme in 1998 funded by the Recreational Fishing Trust, bass fingerling production by industry has increased from 10,000 fish per annum in 1999 to 450,000 fish per annum in 2004 (Table 8.2). Similar markets for stock enhancement are likely for marine fish, especially mulloway, based on the success of recent and current NSW DPI projects in Botany Bay. The Saltwater Recreational Trust has approved a new $600,000 research project to evaluate mulloway stock enhancement in northern rivers of NSW and Botany Bay. If successful, marine stock enhancement is likely to become policy in NSW as recreational anglers are a highly organized political group. Any stocking program will require the operation of a large, reliable hatchery industry.

The cost of feeds for marine species will also limit growth of a marine finfish industry. Feed cost can represent as much as 60% of on-farm expenses. Because the industry is small, purchasing power is limited and farmers often pay premiums for the purchase of small volumes of feed. In addition, commercial feed companies rely largely on the use of imported fishmeal and fish oil to produce marine fish aquafeeds. Feed cost and feed ingredients have been significant themes in finfish R&D by NSW DPI over recent years (see below)

Market

In general, due to reductions in wild catch and the preference among Australians for marine fish, there is a potentially large market for cultured marine fish in NSW. There is also demand for Australian marine fish including mulloway and kingfish in USA and Japan. However there is also strong competition from imports particularly in those market segments requiring a volume of processed fish products

8.2 Past Research Achievements

Marine fish research by NSW Fisheries has focused on development of techniques for hatchery production of Australian bass, snapper and mulloway, sand and trumpeter whiting and growout and feeds technology for snapper and mulloway. NSW Fisheries scientists were the first in Australia (snapper) and in the world (bass, mulloway and whiting) to rear these species and to evaluate the performance of snapper and mulloway in seacages at Botany Bay. Production techniques have subsequently been adopted by government and private hatcheries and farms in NSW, SA, WA, Vic and Qld.

Fingerling Technology

The development of a reliable technology to grow fingerlings in hatcheries has had significant on-farm impact. Mature snapper and mulloway were sold to two hatcheries saving three and six year's start-up phase, respectively, for reliable breeding programs (wild broodstock are unpredictable in spawning high quality eggs). The broodstock management techniques were implemented successfully at both hatcheries. Mature G2 mulloway are held at PSFC for future supply to private hatcheries. In addition, broodstock management including that of genetic population structure will be vital for future stock enhancement programs. NSW DPI has the capacity for this.

Growout technology

The feasibility of farming snapper and mulloway was evaluated in seacages at Botany Bay. These achievements have significant on-farm impact. Prior to the research, no temperate marine fish farming occurred in Australia. Technology was transferred to commercial snapper and mulloway seacage farms in NSW, SA and Qld.

Feeds technology

Formulated feeds specific for snapper have been developed and digestibility coefficients have been determined for a range of agricultural feed ingredients. These achievements have significant on-farm impact. Diet formulations specific for snapper are now available from commercial feed mills. Feed mills have information regarding the suitability of ingredients for snapper pellets and can formulate the cheapest and/or environmentally friendly diets for farmers according to raw ingredient market price and availability. Importantly, nutrition research conducted by NSW DPI Fisheries has determined that different blends of rendered Australian animal meals and certain oilseeds can replace significant quantities of fishmeal (all but 16%) in the diets of this species, potentially reducing feed costs and reliance on imports.

The feed research conducted and led by NSW DPI in the past (with silver perch and lately snapper) has played a large role in increasing market opportunities for Australian agricultural ingredients for use in aquaculture diets. This is particularly notable for lupins. The use of this ingredient in aquaculture diets was largely unheard of 10 years ago but now tens of thousands of tonnes are exported for use in aquaculture diets each year. Similarly, research with terrestrial animal meals has greatly increased the confidence in the use of these ingredients in aquaculture diets.

Other achievements include using dietary amendments to achieve desired skin colour in farmed snapper to ensure higher market prices.

Stock enhancement

The feasibility and impacts of stocking juvenile mulloway into estuaries have been evaluated in Smiths Lake, Swan Lake and Botany Bay, NSW. The Recreational Fishing Trust is financially supporting more research to determine impacts of estuarine stocking. The positive results will likely lead to large-scale estuarine stocking. This will stimulate commercial marine fish hatchery development.

Inland Saline Aquaculture

NSW DPI was the first to identify potassium deficiency in inland saline groundwater in NSW and how to cheaply overcome the problem for growth and survival of marine fish, snapper and mulloway. Elements of the inland saline water research project include:

- Bioassays and long-term pilot commercial-scale growout trials completed or in progress for snapper, rainbow trout, silver perch and mulloway.
- Identified potential for incorporation of aquaculture in saline groundwater interception and evaporation schemes (these schemes currently remove 65,000 ML of saline water per annum and there several more large schemes either in construction of planned).
- National inland saline aquaculture research being coordinated (with the National Aquaculture Council) to assist early commercial adoption of this technology.
- Negotiations with an Australian/Chinese consortium and several of Australia's largest trout growers are underway to develop commercial aquaculture at the Wakool-Tullakool Subsurface Drainage Scheme.

8.3 Funding of Research

A summary of research expenditure is provided in Table 4.2 in Chapter 4 of this report. Total marine fish aquaculture research has decreased from $779,000 in 2003/2004 to $662,000 in 2004/2005 with the percentage of external funds ranging from 53% in 2004/2005 to 60% in 2002/2003.

In addition, inland saline research is co-funded by Murray Irrigation Limited (MIL). MIL has made cash investments in excess of $700,000 since 2001/2002 and committed $1.14 million in-kind over three years from 2004/2005. The CR component was $310,000, $338,000 and $312,000 for 2002/2003, 2003/2004 and 2004/2005, respectively.

The successful funding of the Seafood CRC in late 2006 has secured external funding for seven years support for inland saline aquaculture (commercialisation of trout production) and feeds technology R&D from July 2007.

8.4 Future Directions for Research

Industry Development

A significant impediment to the growth of the marine finfish industry in NSW has been the lack of a robust industry hatchery sector to provide a reliable supply of low cost, high quality fingerlings. Hatchery sector development itself has been impeded by an irregular demand for fingerlings. NSW DPI now has the capacity and the technology to provide this service on a commercial basis to a growout finfish sector. This capacity also allows NSW DPI to respond to restocking demands (e.g. for Australian bass and mulloway).

Allied with this development of a commercial hatchery for finfish, NSW DPI has a program of research aimed largely at reducing the cost of fingerlings and developing cost-effective feeds for finfish that have a lower proportion of fish protein sources.

Future opportunities for external funding are outlined in the Table 8.3 and include:

- hatchery research – joint project with University of Wollongong to determine hybridisation of yellow-fin and black bream (Recreational Fishing Trust, RFT); development of techniques for control of nodavirus infection in temperate marine fish hatcheries (RFT)

- Stock enhancement – production of Australian bass fingerlings for NSW stocking (RFT); production of Australian bass fingerlings for Victorian Fisheries; production of mulloway for stocking to northern rivers research project (RFT, UNSW)

- Commercial production of snapper, mulloway and kingfish fingerlings for sale to NSW and Queensland growout farms

- Diet development – annual contracts and research project to evaluate and commercialise new diets and Australian feed ingredients for aquaculture diets (Ridley Agriproducts, GRDC, Grain CRC, Meat & Livestock Association)

- Inland saline aquaculture – extension of current project for two years (ACIAR, MIL)

Table 8.3: Current and prospective funds for marine fish R&D

	CR Funds*	**Secure Industry Funds**	**Prospective Industry Funds**	**Total Funds**	**Share funded by Industry**
	$,000	**$,000**	**$,000**	**$,000**	**%**
2005/06	307	719		1,026	70
2006/07	315	669	168	1,152	73
2007/08	323	389	498	1,210	73
2008/09	331		770	1,102	70
2009/10	340		811	1,151	70

*CR funds include salaries, operating, travel and computer lease fees (adjusted annually for 3% cpi).

With contractual commitments to the Aquafin CRC until 2008, the annual request for CR funding will be similar in real terms to the 2005/2006 request of $307,000. Past this time, DPI research investment should be dependant on significant new industry investment in marine finfish aquaculture (including seacage farming or inland saline aquaculture) and availability of significant industry funding for research. Hence for the next few years the finfish R&D programme will have access to resources of about $700,000 and as noted above there is a reasonable expectation that the marine aquaculture industry might be 500 tonnes per year from the two existing sites.

‘With DPI’ Scenario

Aquaculture

Provided sufficient venture capital can be attracted, the long term expectation is that marine finfish aquaculture production in NSW has the potential to increase to between 2,000-5,000 tonnes per annum within 10 years. At $10/kg farm-gate, this would give an industry value of $20-50 million per annum. If total research expenditure remained at approximately $700,000 per annum, this would give a research intensity of 3.5–1.4%. An industry of this size would generate research levies (0.5% including the matching grant) of $0.1-$0.25 million. The industry has to grow even further in later years to fully support the existing R&D program.

Future research will focus on improving production (quality of fish, cost of production) of mulloway and kingfish. Fingerling production research will focus on determining (1) optimal physical parameters for larval rearing including salinity, temperature and photoperiod (2) optimal, cost-effective commercial weaning diets, (3) optimal feeding strategies and interactions with parameters including photoperiod. For feed technology, new cost-effective, environmentally-friendly diet formulations will be developed. A range of Australian agricultural ingredients will be evaluated to provide digestibility coefficients for mulloway and kingfish and bioenergetic models will be developed to predict optimal nutrient requirements and diet feeding strategies for a range of different sized animals.

The funding for this research is secured from the CRC for Sustainable Finfish Production/FRDC to conduct the project “Feed Technology for Temperate Fish Species”. This project will finish in 2007/2008 and will continue as part of the Seafood CRC. The main anticipated outcome of the project is a production package for cost-effective culture of mulloway and kingfish. Optimal rearing parameters and feeding strategies for juvenile fish and feeds for growout of market-size fish will be developed.

Inland Saline Aquaculture

Inland saline aquaculture has the capacity to produce in existing sub surface drainage schemes in the order of 2,000 tonnes per annum of marine fish (based on volume of available groundwater to fill 325 ha of ponds at 2 m depth and production of 5 tonnes per ha per annum). More subsurface drainage schemes are likely to be developed in future to combat rising salinity. Therefore there is scope for further production. If current proposals to commercialise this R&D eventuate in the Seafood CRC, the value of inland saline production in NSW should exceed $1 million by 2010.

Future research will focus on evaluation of cheap, effective control of temperature in ponds for culture of mulloway and prawns. Floating, solar covers have been constructed and an experiment is in progress at ISARC to determine the performance of mulloway over a 12 month period.

Funding for the research is provided by ACIAR to conduct the project “Developing aquaculture in degraded inland areas in India and Australia”. This project will finish in 2007/2008. The main outcome of this research will be a production package for mulloway and prawns in inland saline groundwater. In addition, technology for controlling temperature in ponds will be developed which will have application in pond aquaculture situations including silver perch, Murray cod and prawns.

Feed research

Future aquaculture feed research in the Seafood CRC will focus on use of NSW agricultural ingredients, particularly the protein fractions of grains (e.g. wheat, oilseeds and legumes) and animal meals (e.g. low ash meat and bone meals, poultry products, etc).

'Without DPI' Scenario

Without NSW DPI investment, this sector will not develop beyond a small cottage industry based in coastal ponds (<10-20 tonnes per annum). One of the main reasons for this is that it is very expensive to import technology from outside NSW. One of the original selection criteria for R&D into snapper and mulloway was their similarity to Japanese red sea bream and the American red drum, respectively. Both of these species have large, established farming industries and it was anticipated that transfer of technology would enhance technology in NSW. This was not the case due to species differences, including differing hatchery abiotic parameters for spawning and larval rearing of snapper compared with red sea bream and the inability to reliably spawn wild caught mulloway. Improvements in mulloway hatchery production did not occur until G1 broodstock had been reared in the NSW DPI hatchery after six years.

A similar situation exists for the continued development of production technology for mulloway and kingfish. This must be done by experienced researchers in NSW DPI with facilities to conduct replicated experiments. Commercial hatcheries and farms do not have the replicated facilities necessary to do the research rigorously and effectively and often farm operators are not trained in experimental methodology.

Similarly, the essential research to develop cost-effective feeds containing much lower proportions of fish protein cannot be done by infant industries. The process of determining digestibility coefficients of ingredients, ability for carnivorous fish to digest and utilise carbohydrates, evaluation of experiment diets etc. must be by experienced researchers with dedicated facilities.

Without DPI feed research, it is unlikely that marketing opportunities for NSW agricultural feed ingredients for use in aquaculture diets will be realised.

Ongoing R&D by NSW DPI into saline aquaculture is essential to ensure that sound bioeconomic data are generated for new stakeholders and also for ongoing improvement of economically viable aquaculture.

8.5 Beneficiaries of Research

The marine finfish industry – producers, processors and consumers - are clearly important beneficiaries of the technologies developed by R&D. Very little finfish is exported and hence most of these industry benefits remain in Australia.

A new developing marine finfish industry will add to regional employment and economic development in regional areas. This is very important in rural, inland NSW where inland saline aquaculture has potential. Other community benefits include increased availability of seafood and attendant improved health benefits for consumers in NSW (accompanied by reduced public health costs).

Additional beneficiaries of the hatchery production sector are recreational fishers, who should and do contribute significantly to the cost of restocking marine and terrestrial environments.

Beneficiaries of feed research include the NSW agricultural feed ingredient sector.

To the extent that marine finfish aquaculture is an infant industry then the community as a whole benefits from the more rapid growth of this sector aided by DPI research and extension activities.

8.6 Rationale for Government Involvement

The strongest argument for NSW DPI to continue to support finfish aquaculture is that it may be able to help remove some of the impediments to the growth of this ‘infant’ industry. An important impediment to growth is the lack of a hatchery sector able to supply low cost high quality fingerlings reliably throughout the year. Fingerlings cannot be imported from States such as South Australia, so investment in growout farms is risky when the local hatchery sector is small.

NSW DPI has developed hatchery technologies for snapper and mulloway and has hatcheries of sufficient capacity to meet the immediate demand for fingerling by the two farms currently licensed to produce up to 500 tonnes per annum of fish.

A recommendation of this review is that DPI supply fingerlings on a commercial basis to the marine finish sector. To encourage the development of a private hatchery sector, DPI would need to price fingerlings at a competitively neutral rate and make its technologies and breeding stock available to private hatcheries as they emerged. The hatchery could also meet the demand from the Recreational Fishing Trust for fingerlings for restocking of marine environments again on a full cost recovery basis.

Impediments to the growth of a marine finfish sector include immature hatchery technologies for several promising finfish species and inadequate knowledge about feeding technologies in hatcheries and fish farms with implications for both production and environmental outcomes. The finfish research team has put forward a programme of research to address these technology gaps that is being funded by the CRC and the FRDC to the extent of just over half the total cost of the programme. Research programmes need to be closely related to hatchery development to be able to capture any economies from these joint activities.

The growth of a marine finfish industry will bring employment and economic growth to some regional communities, and help reduce the demands on wild catch and imports for finfish. However it is inefficient to use public funds to support the finfish industry if it fails to grow from current levels. With this in mind one of our recommendations is that investments by NSW DPI in finfish aquaculture be again reviewed in 2010 when current R&D commitments are winding down, against the growth in the industry, the profitability of the hatchery and the growth in external R&D funding. As noted above the expectation is that by 2010 farm production of finfish in NSW will be in the order of 500 tonnes per year from the two existing farms and that by 2015 production could be as high as 5,000 tonnes.

8.7 Recommendations

- Research and Development in marine fish aquaculture for aquaculture, stock enhancement and inland saline should continue while current contractual commitments exist.

- New research into marine fish would require levels of industry funding to average greater than 50%

- NSW DPI should supply fingerlings on a commercial basis to the marine finfish sector to overcome a significant impediment to the growth of the sector. To encourage the development of a private hatchery sector, DPI would need to price fingerlings at a competitively neutral rate and make its technologies and breeding stock available to private hatcheries as they emerged. DPI should exit from this business when private hatcheries have the capacity to supply the market.

- Investment by NSW DPI in finfish aquaculture should be again reviewed in 2010 (when current R&D commitments are winding down), against the profitability of the hatchery, the growth in external R&D funding and the growth in the industry (expected to be in the order of 500 tonnes per year for sea-cage production and 150 tonnes from inland saline aquaculture).

- Production of fingerlings for restocking rivers and oceans should be fully funded by the beneficiaries (recreational and commercial fishers) through license fees and/or government agencies responsible for protecting biodiversity.

- Industry-funded feed research of benefit to NSW aquaculture farmers, feed manufacturers and the agricultural feed ingredient sector (providing it is largely industry funded) should be continued.

- There is an urgent need for a coastal and offshore zoning policy, and for a commitment by government to marine aquaculture within appropriately zoned areas.

9. Inland Finfish

9.1 Industry Background

The silver perch (*Bidyanus bidyanus*) is an Australian native, warmwater fish that is endemic to the Murray-Darling River System. It is a popular fish because of its edible and sporting qualities. Over the last 30 years, there has been a significant decline in distribution and abundance, and it is now a threatened species with the conservation status of "vulnerable". There is a prohibition on its capture from rivers and creeks in the system, and hatchery operators are no longer allowed to collect broodfish from the wild without a specific permit from the Threatened Species Unit, DPI.

Silver perch has long been recognised as having great potential for aquaculture. For example, in 1967 the scientist John Lake wrote "Silver perch show the best possibilities to date for fish farming in Australia". Hatchery techniques were developed for silver perch at the Inland Fisheries Research Station, Narrandera (now the Narrandera Fisheries Centre) during the late 1970s and early 1980s to produce fingerlings for stock enhancement. In the summer of 1982/83, commercial hatcheries in NSW, Queensland and Victoria commenced producing and selling fingerlings. Research to develop techniques for grow-out to market size commenced at the Grafton Aquaculture Centre (GAC) in 1990, and has provided a technical basis for development of the silver perch industry. NSW Fisheries has disseminated technology for silver perch farming, including through dedicated extension officers. It is now the third largest and most valuable aquaculture industry (behind oysters and prawns), as well as being the largest freshwater industry in NSW.

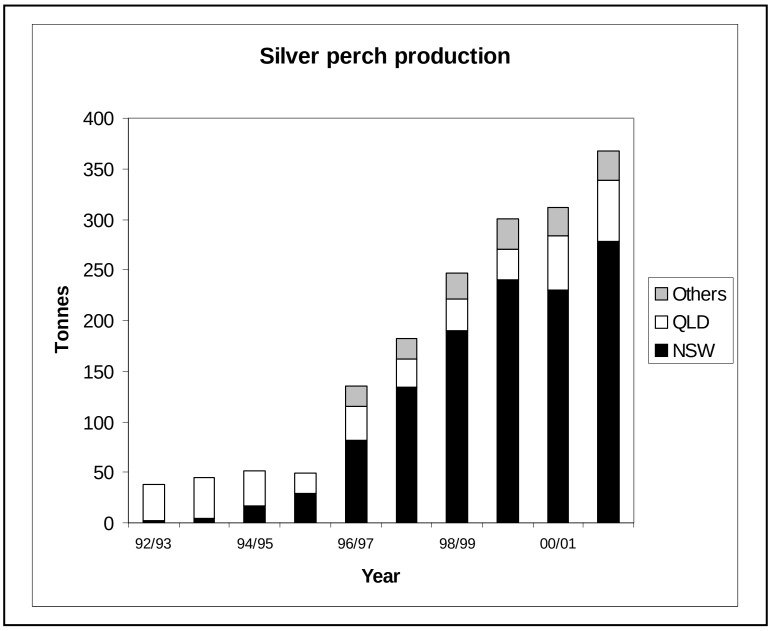
The commercial industry commenced in NSW in the mid 1990s. In 2002/03, there were 139 permits for silver perch aquaculture, 48 farms submitted production returns, production was 302 tonnes and average price received was $9.33/kg giving this industry a farm gate value of $2.8 million. Production in the Australian silver perch industry is presented in Figure 9.1 below.

The construction of several large farms in Queensland, the expansion of established farms in NSW, increasing efficiencies on some farms, the continuing good prices (>$9/kg) and growing market demand suggest that the industry should continue to expand. There is also increasing interest in silver perch amongst irrigation farmers, and the integration of aquaculture and agriculture could lead to a significant expansion of the industry over the next five to ten years.

Marketing Issues

Approximately half the annual production of silver perch is sold into the live fish markets to predominantly Asian consumers in Sydney, Melbourne, Brisbane and Canberra. Although this is a limited, niche market, it has grown steadily over the last 10 years and will continue to do so. No product is currently exported. Around 70% of all fish consumed in Australia is imported, most in processed forms, with much of this product reaching the consumer for less than $10.00/kg. Consequently, there is a very large market potential (many thousand of tonnes) for processed fish (gilled and gutted, fillets, cutlets etc.) at around $5 - 6/kg (whole fish, farm gate). If production costs can be lowered, silver perch could compete with and replace imports. It is one of the few, if not the only species in Australia with this potential. However, unless production costs are lowered, through cheaper fingerlings, accelerated growth rates, improved survival rates, reduced feed costs or a combination of the above, this potential will not be realised in the short-term and increases in production across the industry will probably cause the less efficient farmers to exit the industry as prices and profits decline.

Figure 9.1: Silver Perch Production in Australia



A study by CSIRO found that silver perch had the third highest levels of omega oils in over 200 species of wild and farmed Australian marine and freshwater seafood. These oils are of significant benefit to human health and this feature should be used a key promotional tool. There is an increasing demand in western countries for seafood, particularly fish because of its health benefits. The development of an industry producing a "healthy, native" product under strict environmental and quality assurance conditions provides a significant benefit to society.

Until recently, there has been limited quality control in the industry and little promotion of silver perch in the market place. A marketing project was commissioned for the Silver Perch Growers Association (SPGA) and funded by the Department of State and Regional Development (and others) to identify needs and directions for the industry. In June 2005, the SPGA launched the marketing report, a QA program, a new brand name "SILVAS", pamphlets, posters, and labels for fish boxes. The QA program is linked to NSW Food Authority requirements. This recent exercise demonstrates the growing professionalism of the SPGA and increasing efforts to promote and market silver perch.

In the live-fish Asian markets, the chief competitors to silver perch are fish such as barramundi, eels and some wild-caught marine species such as coral trout. The relatively low aquaculture production of Murray cod, golden perch and jade perch means these native fish are not significant competitors at the moment, and there is no longer a commercial fishery for

Murray cod and golden perch. As already noted, finfish imports are strong competitors in the fresh fish market.

Disease Issues

Little is known about fish diseases generally and the science of aquaculture health management is in its infancy. Animal health issues have already constrained the silver perch industry and will continue to be a barrier to development until on-farm health management improves. From about 1998, there have been large losses on some farms due to the problematic diseases winter saprolegniosis and white spot, and health management has been a high priority of industry over the last five years. The project "Development of a Health Management Strategy for the Silver Perch Aquaculture Industry", which was partly funded by FRDC, was completed in December 2005. This project identified key diseases, developed treatment regimes using approved therapeutics, and provided a basis for a generic health management plan and a disease diagnostic manual. Implementation should lead to improved health management on farms and across the industry; however, adoption of the technology and improved practices are dependent on an effective extension service. The Veterinary Officer, Aquatic Animal Health position should help fulfil this role.

Regulatory Environment

There is a sound policy within NSW DPI for approving silver perch farms. One key element is a permit condition of "no return of effluent water to natural waterways". This has removed approval of silver perch farms from the Department of Environment and Conservation legislation hence reducing the number of agencies involved in the approval process.

A barrier to industry growth is the restriction on collection of broodstock from the wild because of the low abundance of silver perch and its listing as "vulnerable" under the Threatened Species legislation. Government (NSW DPI) needs to play a role in ensuring that industry has access to genetically heterogenous wild stocks. Access to wild fish will maintain genetic variation in breeding programs, enable the production of F_1 hybrids with heterosis (a finding from the current genetics research at Grafton) and ensure industry growth is not restricted by genetically inferior fish (eg due to low genetic variation and inbreeding). Silver perch can be domesticated, and the proposed genetics research should provide industry with improved broodfish and a long-term breeding program, reducing reliance on wild fish.

This issue is also being addressed through consultation with industry and discussions between the aquaculture and threatened species sections of NSW DPI. Currently, a Species Impact Statement (SIS) is required before a licence to harm threatened species can be issued. There has not yet been an SIS for silver perch broodfish collection.

Another regulatory issue is the purchase and/or presence of undesirable fish in consignments from hatcheries in Queensland. In the past, some silver perch farms in NSW are known to have stocked hybrids between silver perch and Welch's grunter, contrary to their permit conditions. The noxious fish, banded grunter, has also been found in batches of silver perch from Queensland hatcheries. Implementation of the Fisheries Management Strategy (FMS) for Fish Stocking, adoption of the Hatchery Quality Assurance Program, development of a Hatchery Accreditation Scheme in NSW, communication with industry and co-operation between the states, particularly NSW and Qld should reduce or eliminate this problem.

9.2 Grafton Aquaculture Centre (GAC)

All silver perch aquaculture research, with the exception some nutrition research, has been carried out at NSW DPI's aquaculture research facility at Grafton. GAC was established in the mid 1980s, and since then additional ponds and buildings have been constructed. It is a multi-functional freshwater facility for applied research into the conservation and aquaculture of native fish.

GAC currently consists of 19 earthen ponds (0.1-0.3 ha surface area), two reservoirs (8.5 and 9ML capacity), an effluent/settlement dam (43ML), salt evaporative ponds, a hatchery/office/laboratory complex, a large workshop/storage shed and associated equipment such as pumps, aerators, a tractor and other vehicles. The main water supply is the Clarence River, and all effluent water is stored, settled and either re-used for fish culture or used for irrigation on the research station. The value of the infrastructure is around $1.5 million.

Conservation and pest species research

Conservation of the endangered eastern freshwater cod (*Maccullochella ikei*) commenced at GAC in 1985. Hatchery techniques were developed and 30,000 fingerlings stocked into parts of the Clarence and Richmond river systems where the species had become extinct. This was the first major fish conservation project in Australia, and its success has helped save this native fish from extinction. There is a current research project into the ecology of the eastern freshwater cod to provide information for management and conservation. This is a collaborative post graduate project with Southern Cross University which was completed in December 2006. In addition, there is a research project into the distribution and biology of banded grunter (*Amniataba percoides*), an introduced pest species which is a serious potential threat to the eastern freshwater cod and other native fishes in the Clarence River System.

Aquaculture research

Since 1990, research at GAC into the intensive aquaculture of silver perch has provided a technical basis for industry development throughout Australia. Past research has included production techniques in ponds, cages and tanks, fish husbandry, water quality, diseases, management of broodfish and breeding, rearing of larvae, off-flavour, nutrition, feeding and evaluation of genetic strains. Current research is discussed below.

Hatchery production

A hatchery program at GAC produces around 500,000 silver perch fingerlings a year, although production capacity is significantly higher. Fingerlings (up to ~ 100,000 a year) have been used for aquaculture research at GAC and at the Port Stephens Fisheries Centre, and the remainder are stocked into impoundments in the western drainage for conservation and stock enhancement, as part of the state-wide stocking program.

Extension

An extension service is provided by GAC staff to transfer technology to industry and to handle public enquiries. Currently there is one dedicated aquaculture extension officer, but other research staff members with extension expertise also provide information to the public and the aquaculture industry. Enquires ranging from advice about fish or plants in farm dams through to detailed technical issues about water quality and disease are handled daily. The extension officer regularly provides on-farm extension, including advice on site selection, farm design and operation, and disease diagnosis. Workshops at GAC and field days, as well as fishing clinics for children have been part of the extension program. GAC is a model fish farm and practicing and prospective farmers visit the facility.

Fisheries management

Dr Stuart Rowland, Scientist-in-Charge GAC, also plays a role in the management of freshwater fisheries and threatened species. Besides regularly providing advice to managers in NSW DPI, he is a member of the Fisheries Scientific Committee, a small specialist committee that advises the Minister on threatened species issues in NSW. Dr Rowland is also on the Murray Cod Reference Group which advises the Murray-Darling Basin Commission on Murray cod. Dr Rowland prepared Australia's first Hatchery Quality Assurance Program.

Future conservation and freshwater fisheries R&D

There are currently discussions being held about two future projects that could be based at GAC: (i) monitoring of freshwater fish in the Clarence River System (possible funding – North Coast Water, Country Energy, CMA, Recreational Fishing Trust); (ii) hatchery production and stocking of eastern freshwater cod (Recreational Fishing Trust).

GAC and the Narrandera Fisheries Centre (NFC)

Most of the current functions of GAC could not be performed at NFC, other fisheries centres, agricultural centres or commercial hatcheries in NSW for the following reasons.

- GAC is a large, specialised pond-based facility.
- Relocation would require substantial capital investment if any of the fish culture work was to continue.
- There are current and future funded commitments for aquaculture and conservation research at GAC.
- The infrastructure at NFC is fully committed for the state-wide stocking program for Murray cod, golden perch and silver perch, as well as conservation programs on threatened species including trout cod and purple-spotted gudgeon, and some ecological research.
- The temperature regime at Narrandera is sub-optimal for silver perch culture (growing season with temperatures >18°C for only five months in southern NSW, against seven months or more in northern NSW and southern Qld). This industry is centred in northern NSW (two thirds of production) and while there are good farms in southern NSW, the future growth is almost certain to be in northern NSW, including in association with large irrigation farms. One of the key future needs of industry is a selective breeding program. This should be managed from a facility within the optimal climatic regime for the species.

- Work on eastern freshwater cod and banded grunter could not be done at sites other than GAC, certainly not at sites west of the Great Dividing Range.
- Hatchery production of threatened species cannot be done at commercial hatcheries because of the strict conditions associated with broodfish collection and management, and the complex and costly requirement of threatened species breeding programs.

9.3 Past Research Achievements

NSW DPI (as NSW Fisheries) has been investing in research into silver perch culture for about 30 years. However, initial research was into hatchery production for stock enhancement, and R&D into the production of market-size (~500 g) silver perch for consumers did not commence until 1990. The commercial industry did not start until the mid-1990s, and so the industry is relatively new and still in its "infancy". Expenditure and industry support in more recent years is detailed below. Aquaculture research achievements include:

1. Selection of a species well suited to intensive aquaculture.
2. Development of techniques for hatchery production.
3. Development of husbandry and production techniques for market-size fish in earthen ponds.
4. Development and commercialisation of practical, least-cost diets, containing low levels of fish meal and Australian agricultural products.
5. Development of a feeding strategy based on restricted rations.
6. Domestication of broodfish.
7. Evaluation of performances of a domesticated and two wild genetic strains.
8. Identification of new culture techniques and strategies: (i) over-wintering fingerlings in re-circulating aquaculture systems; (ii) cage culture.
9. Commencement of a genetic improvement program.
10. Development of a health management strategy for the industry and publication of a Disease Diagnostic Manual for disease identification and treatment.
11. Extension of technology through personal contact, provision of advice verbally and in publications, conferences, workshops, and most importantly farm visits.
12. Formulation of an industry-specific policy that facilitates the development of an environmentally-sound industry.

Extension

In the 15-year period from 1990 to 2005, there were dedicated aquaculture extension officers for only eight years. At other times, the transfer of technology for silver perch aquaculture was handled by scientific staff, in particular Dr Stuart Rowland. There is currently one temporary, CR-funded aquaculture extension officer in NSW, based at GAC on 12-month tenure. He is responsible for extension to all non-oyster aquaculture industries across NSW, and also provides limited advice to silver perch farmers in Queensland, Victoria and Western Australia. One possibility is to train current agricultural extension officers (there are approximately 300 of these) to assist with disseminating aquaculture technology and assisting industry development.

Economics

An economic model (Excel based) was developed in conjunction with QDPI and is available to farmers and potential investors. There have also been several general articles written, including a business plan for a pond-based system [published in Silver Perch Culture (1995)].

A comprehensive review of the market issues and on-farm financial performance in the silver perch industry can be found in the ABARE (2001). ABARE developed models representative of silver perch production for farms of five and ten hectares. Some key production parameters were:

Size at harvest	600 g live
Growout time	17 months
Feed conversion ratio	2:1
Density	5g fingerlings per ha
Survival Rate	98%
Yield	10t/ha
Farmgate Price	$7.5/kg live

Some of the key variable costs on a 5 hectare farm were:

Feed	$98,100
Fingerlings	$21,000
Packaging and marketing	$47,500
Own labour	$40,000
Water (40Ml)	$5,000
Total Variable Costs	$282,600

The variable costs per kg were $5.64. For the ten hectare farm, total variable costs were $499,300 giving $4.99 per kg.

The total capital costs for each farm were $471,300 and $776,300 respectively.
The benefit cost ratio for this most likely scenario for the five hectare farm was 1.0 with a 20 percent chance that a benefit cost ratio of less than one would eventuate. The benefit cost ratio for the larger farm was 1.21. The discount rate used was 6%.

If feed costs are reduced by one third from $900/tonne to $600/tonne the benefit cost ratio for the five hectare farm increased to 1.16

This budget is somewhat dated. However it is forward looking in using a price of $7.50 per kg and production costs of around $5 per kg. These are the parameters expected of a larger industry. It will be a challenge to attract new investment to this industry when the profit margin may be this small. Cotton growers may find some economies in lower water costs, reduced capital costs associated with developing ponds and infrastructure, and a possible six-month production strategy of growing large fingerlings (~ 50 g) to market-size during the irrigation season.. This budget could be updated as a component of a future extension program to encourage industry growth.

9.4 Funding of Research

In the decade prior to 2002/2003, GAC was well funded by industry and FRDC for research on issues including hatchery technologies, fish husbandry, diseases and nutrition, broodfish management and breeding. Since then funding has been more limited to support a silver perch health management project, and this is reflected by the relatively low share of external funding shown in Table 4.2 (Section 4 of this report).

Current funding sources include the Cotton Communities CRC, with $265,000 contributed over three years on the culture of silver perch in cotton farm water storage dams. An application has also been submitted to FRDC for research on silver perch genetics for funding from 2005/2006 (total of $471,000), identified as high priority by the NSW Fisheries Research Advisory Board. GAC is also involved in the Seafood CRC and will receive additional funding over seven years.

9.5 Future Directions for Research and Extension

For the next few years, expenditure at the GAC on silver perch aquaculture and the conservation and other fisheries projects is likely to range between $430,000 and $630,000 (Table 9.1). The CRF component of this is $362,000 comprising:

Salaries - $255,000 (Dr Stuart Rowland, Charlie Mifsud, Mark Nixon)
Operating infrastructure maintenance - $55,000
Operating discretionary - $52,000

Table 9.1: Estimated Expenditure at the GAC, 2005/06 to 2008/09

	CR Funds $	Industry Funds $	Total Funds $	Share funded by CR %
2005/06	362,000	65,000	427,000	84.7
2006/07	362,000	248,500	610,500	59.3
2007/08	362,000	267,700	629,700	57.5
2008/2009	362,000	163,700	525,700	68.9

The share of CRF funding to support the GAC, ranging from 58 to 85 percent is high relative to other areas of aquaculture R&D. However about 40 percent of the CRF funding will be used to undertake activities associated with the conservation and fisheries projects on the ecology and conservation of the endangered eastern freshwater cod (*Maccullochella ikei*) and the distribution and biology of the pest species banded grunter (*Amniataba percoides*). These projects which are based at GAC and supervised by Dr Rowland, will provide essential data and information for the future management and conservation of the cod, and the management and possible eradication of banded grunter.

Dr Rowland plays an important role in the management of freshwater fisheries, including threatened species. For example, he recently prepared Australia's first Hatchery Quality Assurance Program. Besides regularly providing advice to managers in NSW DPI, he is a member of the Fisheries Scientific Committee, a small specialist committee that advises the Minister on threatened species issues. He is also a member of the Murray Cod Reference Group which advises the Murray-Darling Basin Commission on Murray cod.

Industry funds with some in-kind CRF contribution will be used for silver perch aquaculture research. The broad aim of this research program is to reduce the cost of silver perch production. Continuing R&D is needed to reduce costs associated with fingerling production, feed and feeding, and to increase survival rates, growth rates, production rates and disease resistance. These improvements can be achieved through improved health management, genetic improvement, advanced production of fingerlings, use of alternative rearing systems and improved farm management.

This program of research will be undertaken in the following industry-funded projects.

1. Evaluation of the Potential for Aquaculture on Cotton Farms

This project is being funded by the Cotton Catchment Communities CRC to the extent of $265,000 to December 2008 with possible follow-up. Water for irrigation is a substantial and recurring cost to cotton farmers, and freshwater aquaculture can provide an opportunity to add value to this water. The Cotton CRC will evaluate the potential of aquaculture on cotton farms in a collaborative project between NSW DPI, QDPI and the University of New England. Objectives of the NSW component of the project are to: (i) identify existing cotton farming infrastructure with potential for aquaculture; (ii) determine optimal culture conditions by evaluating the performance of silver perch in cages at different stocking densities, sizes and shape of cages, and artificial diets in controlled experiments; (iii) evaluate the feasibility and economics of silver perch culture using on-farm trials; (iv) provide technical support to cotton farmers.

If fish farming can be integrated with cotton growing, it will increase the efficiency of water use in cotton farming. The involvement of the cotton industry could enable silver perch to expand significantly and realise its potential of becoming one of Australia's largest fisheries.

The Seafood CRC-funded R&D activities will complement and build upon the results of the Cotton CRC investment and will develop pilot-scale production.

2. New technology – cage culture, re-circulating aquaculture systems (RAS) (on-going, linked to 1. above and 3. below).

Preliminary research at GAC has identified two new forms of technology that have the potential to significantly reduce losses in winter, increase growth and production, improve fish husbandry and feeding efficiency, and improve overall efficiencies on silver perch farms. These are: (i) over-wintering fingerlings in temperature controlled re-circulating aquaculture systems; (ii) cage culture within ponds. To date, there has been little uptake of these technologies because of their recent development, and they will be further investigated and validated in the two new projects.

As for (2) above, the Seafood-CRC funded research will complement and build upon the Cotton CRC results in new culture technologies.

3. Increased productivity of silver perch farming through genetic improvement and new production strategies (FRDC application; 2006 – 2009).

This project was submitted to FRDC for 2006/07-2008/09 funding, but was unsuccessful. It has been pursued in a more limited way using existing resources through the Cotton CRC project.

The objective of the project is to use genetics and breeding to gain significant improvements in growth, production, and disease resistance in farmed silver perch. Most improvements (~70%) in performance of farmed, domesticated animals have been from improved genetics.

Previous production and nutrition research with silver perch has used progeny of wild fish. Initial research at GAC has found heterosis (~18%) in F_1 hybrids between Murray and Cataract strains. Selected and non-selected lines of Murray and Cataract have been established at GAC, and a new project in collaboration with CSIRO (Animal Genetics) has been proposed and an application submitted to the FRDC through the NSW FRAB. The objectives of the research are: (i) compare the performance of progeny of the selected and unselected lines and determine heritability for growth, disease resistance and reproductive traits; (ii) compare performance and cost of production under new and old strategies; (iii) develop a long-term breeding strategy(ies) for the commercial industry. The industry claims it is able and willing to run a selective breeding program on-farm following this project.

The R&D in all these projects needs to be strongly supported by an extension service (personal contact by extension officer(s), on-farm visits, field days, workshops, seminars, publications, etc.) to facilitate improvements in on-farm practices and the up-take of new technology. Almost all farmers who have entered or are likely to enter this industry are agricultural farmers without any skill base with fish culture. The industry has highly valued the limited extension service that NSW DPI has provided in the past and has been very critical of the Department and the Government when this service has come under threat. Although silver perch farming has been adopted, uptake of technology and use of Good Aquaculture Practices have been limited to relatively few farms (of the total licensed or producing fish), restricting significant development in the industry.

A Silver Perch Taskforce helped guide government policy formulation and industry development in the early 1990s. These issues as well as R&D priorities and directions are now managed through several forums: at a State level through the Aquaculture Research and Advisory Committee (ARAC), the Land based Aquaculture Consultative Committee, the Seafood Industry Advisory Council and the Department of State and Regional Development, and at a national level through the national Aquaculture Council.

Resources for extension were not identified in the budget above.

With scenario

The research projects as described above focus upon the key areas that are required to facilitate significant on-farm improvements and development of the industry. Following the current and proposed R&D program, predicted fish performance and production under commercial conditions by the year 2010 are: (i) survival rates of >80%; (ii) production periods (from 0.5 g fingerlings) for 500 – 600g fish of 12 – 15 months; (iii) average pond production rates of around 7.5 tonnes/ha/annum; (iv) adoption of cage culture and production rates of 50 kg/m^3 or higher; (v) production costs of <$5.00/kg; (vi) overall production of 1,000 tonnes.

A combination of faster growth through genetic improvement, and a reduction of production periods from the current 18 – 24 months on most farms in NSW to 12 – 15 months using new technology and strategies, would reduce overall costs by at least $3.00/kg, bringing the cost of production to or below the critical $5.00/kg (whole fish, farm gate; including depreciation) opening the door to the large, processed fish component of the seafood industry. If the above broad targets can be achieved, expansion of the industry beyond 1,000 tonnes a year is likely. An industry of 1,000 tonnes would generate a product value of around $5.0 million. This level of development will lead to economies of scale associated with feed costs, equipment supplies and service industries.

However, because silver perch are only sold on the domestic market it is quite likely that increased production could only be sold at lower prices than at present, hence the importance of reducing production costs. Note that a reduction in price does not diminish total industry benefits. It does mean that Australian consumers share in the benefits of the lower cost technology.

Without scenario

Some silver perch farmers do not use Good Aquaculture Practices, some farms are relatively inefficient and there is not an identifiable industry leader. Over the next five to ten years, most farmers will not have the skills or experience to improve practices and reduce costs without significant R&D and extension support by NSW DPI. There is no silver perch research outside NSW DPI and only a limited industry outside NSW, and so it is unlikely any technology can be imported from interstate. Without R&D support, performance and production parameters will not meet those given in the "With Scenario", and the industry is likely to stagnate at around 500 tonnes annually, or even possibly decline if there are significant problems (e.g. diseases, no enforcement of QA, poor genetic management and inbreeding). At present, the small number of producing farms and the limited profitability of most farms restrict the ability of the industry to contribute to costs of research and extension. A lack of R&D, extension and disease diagnostic support is highly likely to discourage further investment either by current participants in the silver perch industry, by new investors or by funding agencies.

9.6 Beneficiaries of Research

Conservation of Threatened Species

Much of the research at GAC is focused on threatened species. Silver perch is "vulnerable" and eastern freshwater cod is "endangered". The projects on silver perch will: (i) increase knowledge about the biology of the species; (ii) reduce reliance on wild fish for breeding programs; (iii) provide a basis for future conservation stocking programs in rivers. With eastern freshwater cod, the research will: (i) increase our knowledge about aspects of its life history and ecology (age, growth, reproduction, diet, movements, migration etc.); (ii) provide essential information for management and conservation, including recommendations to other authorities regarding water management and land use.

Silver Perch Aquaculture

The outcomes from past R&D have been to develop technologies in various areas of silver perch production that initially enabled the establishment of an industry, and then lowered feeding and production costs. The silver perch industry – producers, wholesalers, retailers, and consumers, as well as some service industries (feedmills, equipment suppliers, tradesmen, local rural suppliers etc.), are clearly important beneficiaries of the technologies developed by R&D. No silver perch is exported and hence most of these industry benefits remain in Australia. As the industry grows and the domestic price falls, the gains will be shared by producers successful in lowering production costs and consumers of silver perch.

Some regard the silver perch industry as an 'infant' industry implying that a more mature industry would see a more efficient allocation of resources. At a regional level this is likely to mean a transfer of resources (jobs) towards the production and processing of silver perch and the feed sector from less efficient uses. Hence there may be public benefits if NSW DPI's investment in R&D results in a more rapid rate of industry adjustment.

9.7 Rationale for Government Involvement

A strong argument can be made for continued CRF support for R&D activities at the GAC associated with the conservation of threatened species.

The chief beneficiary of silver perch aquaculture R&D is likely to be the silver perch industry and hence this industry should be expected to provide the largest share of R&D funds especially as the industry grows.

At present it is likely that the industry is too small to fully support a credible research program. From this review of the industry it seems probable that a key constraint to the growth of the industry is the high cost of producing silver perch which will make it difficult to gain market share in the processed fish sector against imported products. Researchers are confident that through the use of genetics in breeding it is possible to reduce production costs to about $5 per kg providing an incentive for investment and industry growth.

Against this background a case can be made for NSW DPI to continue to provide a high level of in-kind support (greater than 50%) to industry funded projects while there is a prospect that R&D may ease the production costs constraint to industry growth. The nature of R&D support provided by DPI to the silver perch industry should be reviewed against the success of research in reducing production costs, against growth in industry funding and against industry growth in 2010.

The importance of a credible extension program to the growth of the industry has already been noted. The resources for this program must come from the Agriculture and Fisheries Division and/or from industry sources.

9.8 Recommendations

- NSW DPI Asset Branch should assume management of the facility operating costs for the Grafton Aquaculture Centre, in recognition that it is a multifunctional DPI facility

- The genetic improvement program for commercial production of silver perch should be continued and be transferred to industry by 2009.

- Adoption of results from the silver perch genetic improvement program should be facilitated through the sale of "improved fingerlings" (F1 hybrids from restocking program) to industry on a commercial basis until other commercial hatcheries have access to wild fish populations.

- Silver perch stockings for conservation purposes should be continued as required by the NSW DPI Threatened Species Unit, subject to the availability of conservation funding.

- Silver perch R&D should be reviewed in mid 2010 when outcomes of current research are known. If there is no new significant industry or commercial funding available (at least 50% of total R&D investment), significant progress has not been made with lowering production costs and the industry has shown little growth then silver perch R&D at GAC should be terminated at the completion of the Seafood CRC (note that the Division of Agriculture & Fisheries and wild fish conservation R&D would need to fully fund any continued conservation operations at GAC).

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