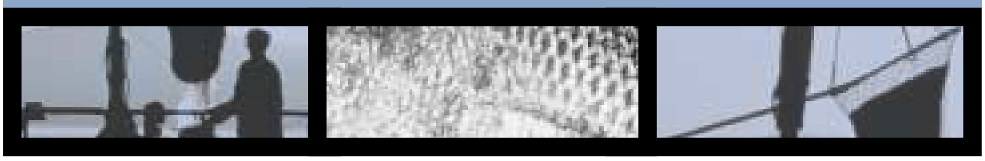
PROFITABILITY OF

SELECTED *aquaculture* SPECIES



authors

Leeann Weston, Susan Hardcastle and Luke Davies

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Australian Bureau of Agricultural and Resource Economics
GPO Box 1563 Canberra 2601

Telephone +61 2 6272 2000 Facsimile +61 2 6272 2001
Internet www.abareconomics.com

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Foreword

Since the early 1980s aquaculture in Australia has been expanding rapidly and now accounts for almost a third of fisheries production. The growth in aquaculture production has been concentrated mostly on five species that (with the exception of southern bluefin tuna) have been produced in Australia over a long period.

Reflecting the diversity of the Australian natural environment, over seventy species of fish are being cultivated or being researched. Few of these species have been cultivated for more than a decade. Consequently, there is uncertainty about the viability of farming many of these species, the impact of the assorted risks in growing and marketing these species and the implications for future industry development and government policies.

This report presents analyses of the viability of production using current technologies of six species in Australia — abalone, Murray cod, mussels, silver perch, snapper and yabbies. The principal aim is to identify the main types of risk and uncertainty that may affect the viability of farming each of these species rather than to present a most likely or average rate of return. Given the ranges in growing conditions, management expertise and other production factors across Australia, these results should not be used as a forecast for investment purposes. The information and results presented in this report are intended as a guide to future directions in the industry and for which factors of production research may have the best payoffs.

BRIAN S. FISHER
Executive Director

March 2001

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Introduction

Aquaculture in Australia has a relatively long history, beginning in the 1800s with the production of salmonids, followed rapidly by oyster culture (edible and pearl), but with little change to the structure, composition and size of the industry until the 1980s. Diversity of the Australian natural environment coupled with the development of new production techniques and technologies, and sustained growth in investment in aquaculture has since allowed the expansion of existing aquaculture industries, as well as an increase in the number of species cultured in Australia.

In less than a decade, sustained rapid growth in the production of high value species has resulted in aquaculture production increasing its share of the gross value of Australian fisheries production from 17 per cent in 1989-90 to 30 per cent in 1998-99 (ABARE 1992, 2000).

Currently, over seventy species of fish are being cultivated or researched in Australia. Of these, five species account for 93 per cent of the total value of aquaculture production and have relatively long histories (except for southern bluefin tuna) of production in Australia. On the other hand, few of the remaining species have been cultivated for ten years or more in Australia.

In this context, questions arise about the viability of farming particular fish species in Australia, the types and potential impacts of assorted risks and uncertainties about farm viability and the implications of these for future industry development based on the culture of these alternative species. Information on these issues, particularly for the smaller, fledgling aquaculture industries, may enhance policy making on the regulatory and institutional environments in which aquaculture occurs, resource allocation to and within aquaculture by government agencies and industry, and private and public investment decisions.

In 1991, ABARE published a report on the *Profitability of Selected Aquacultural Species* in response to a perceived dearth of information and analyses of the likely returns to Australian aquaculture projects (Treadwell, McKelvie and Maguire 1991). The objective in that report was to examine the relative viability of investing in selected finfish, crustaceans, crocodiles and molluscs using a range of production systems compared with investing money elsewhere in the economy. Given the growing status of aquaculture in Australia since then and the persistent uncertainty about the nature and significance of future aquaculture development, the objective in this report is to investigate the likely viability of investment in the commercial production of selected species in Australia. The species selected are abalone, Murray cod, mussels, silver perch, snapper and yabbies. These industries are currently at various stages of development in Australia and accounted for only a small percentage of aquaculture production and value in 1998-99 (ABARE 2000). An explanation of the species selection process and profiles of each species are provided in subsequent chapters.

Another objective in this report is to identify the specific types of risk and uncertainty that may affect the viability of farming each of the six species, and the significance of these in terms of the impacts they may have on farm viability.

The analysis of the six species is based on farm models constructed using production and financial data, and information on risk and uncertainty collected from fish farmers, industry participants and Commonwealth and state government researchers. The methodology adopted to undertake these analyses draws heavily on the report by Treadwell et al. (1991) and is detailed in chapter 2. Industry profiles, market outlook and the results of the analysis for the six species are presented in chapters 3–8. It should be noted that the results are intended only as a guide to the likely profitability of farming these species and are subject to the physical and financial assumptions underpinning each model. The scenarios analysed are indicative of the significance of different types of risk facing growers of each species. The results of these analyses therefore should not be taken as a forecast for particular investment options, as returns will vary according to the unique circumstances of that investment, particularly site characteristics, distance to markets, labor and management expertise.

2

Method of analysis

Species selection

Species selection for the case studies was undertaken in consultation with Commonwealth and state research agencies and industry participants using five main selection criteria. These criteria include proven technology for culture and commercial operation in Australia, availability of farm physical and financial data for Australia, coverage of freshwater and marine species, and unresolved issues affecting the potential for commercial production of these species in Australia.

The species chosen for analysis based on these criteria are abalone, Murray cod, mussels, silver perch, snapper and yabbies. Australian production of these species in recent years is given in table 1. The commercial cultivation of these fish species is spread across all Australian states (but not territories), although not all six species are produced in each state. While the culture of mussels and yabbies has been undertaken for decades in Australia, commercial aquaculture production of abalone, Murray cod, silver perch and snapper has only recently commenced in Australia.

1 Australian commercial aquaculture production – selected species a

	1988-89		1996-97		1997-98	
	t	$'000	t	$'000	t	$'000
Abalone	–	–	10	450	33	1 130
Murray cod	–	–	–	–	2	–
Mussels	660	1 322	1 266	3 244	1 271	3 435
Silver perch	–	–	115	965	162	1 438
Snapper	–	–	2	–	5	–
Yabbies	–	–	215	2 156	306	3 021
Total (including other species) **b**				433 840		504 267

a Includes processed product where processed by farmers, and excludes hatchery production. **b** Includes pearl oysters worth $189 million in 1997-98.
Sources: ABARE (1992, 2000); O'Sullivan and Roberts (1999); O'Sullivan (1998); state departments of agriculture and fisheries, and industry.

Farm model structure, data sources and assumptions

To analyse the potential returns to aquaculture, a farm model was built for each of the species selected for investigation. The models have been designed to reflect the current techniques used for farming each species. Subsequently the models were modified to incorporate anticipated productivity improvements to illustrate potential farm development. An example of such a development would be an improvement over time in the feed conversion ratio for a species. A lower feed conversion ratio implies a decrease in the volume of feed required to raise stock, translating into reduced feed costs per unit of output and potentially improving the overall viability of the operation.

The representative farm model was defined in consultation with farmers growing each species, aquaculture industry representatives and other researchers. After defining each model farm in terms of size (output produced) and technology, the parameters were chosen on the basis of information gathered from farmers, researchers and aquaculture literature. Ranges for key parameters were used in the analysis to reflect the risks arising from particular factors. These include seasonal factors, the early phase of the culture of these species in Australia, limited farmer expertise to date, uncertainty about market factors and the potential availability of alternative technologies and scales of production units to grow these species in Australia.

Costs for each farm model were determined using data supplied by farmers, researchers and suppliers of farm inputs and equipment. At this stage, farm model parameters and costs were presented to industry participants for review, and any comments were incorporated into the models for further analysis.

In trying to answer questions about the potential viability of farming these species and the likely impacts of various risks or uncertainties on viability, a number of assumptions were made in conducting the farm model analyses. Some of these assumptions were made on the basis that farmed production of the six species occurs at locations where physical characteristics differ markedly and is undertaken using an assortment of production systems and technologies. It has not been possible to capture in the farm models every feature of actual farms or the attributes of all of the locations in which they exist. Farmer choices (of species and production system) are determined largely by the environmental attributes of the location of the farm (such as climate, topography and availability of infrastructure) and whether these meet the biological requirements of the fish species under consideration. In this case it has been assumed that potential farmers select suitable sites (biophysically) for aquaculture production.

The assumptions underpinning the farm models used in this study are as follows:

- Farms are assumed to buy juvenile stock to grow out to maturity (except for yabby producers and mussel growers).
- Net returns to farms are calculated over a twenty year period, with assets liquidated at the end of the final year of operation at assumed prices.
- Only private costs and returns on a pre-tax basis are taken into account. External benefits and costs associated with farming are excluded in the calculation of farm benefit–cost ratios.
- Farm net returns are based on a number of output volume, output price and feed price assumptions.
- Farm returns and costs are expressed in constant year 2000 values. To allow for uncertainty about farm costs related to site specific characteristics, a stochastic (random) factor has been added. Through innovation and farming experience the actual costs incurred by farmers in producing fish may differ from those collated and presented in the tables. Costs may also differ depending on the location and the type of system being operated. The costs reported for each of the species farm models should be thought of as a guide for the purposes of the analysis only.
- Output prices, production volumes and input prices are assumed to be statistically independent in the analysis. This means, for example, that a high feed cost is not necessarily generated by high production and that prices of inputs are not influenced by how much is produced. In reality, however, this may not be the case. For example, for some species, output prices may be affected by volumes produced. This is anticipated to hold for species that are (relatively) new on the market with only small volumes currently being sold (such as Murray cod, silver perch, snapper and yabbies).
- Full production is possible in the first year and capital outlays are made in the first year of operation. In reality, production may gradually increase from a low level over a number of years. In that case some capital outlays may not have to be made in the first year of operation but rather as the operation expands.

- Farm sites are selected to meet the physical and biological requirements of the species to be farmed and are assumed to have ready access to water and other inputs to production.
- Site selection and management practices are assumed to be sound and consistent with aquaculture licence conditions.
- Disasters that would cause extremely low production volumes during a production cycle are allowed for through ranges of yields. An allowance for insurance is included in the administration costs for damage to equipment.
- The value of spinoff fish farm enterprises, such as tourism, is not included in the farm models.
- It is assumed that there is no borrowing and only equity is used to finance the enterprise.
- Farmers are assumed not to engage in risk management activity through, for example, forward price contracts or joint ventures with purchasers.
- A risk free interest rate of 6 per cent a year real has been used as the discount rate in the calculation of the benefit–cost ratios and payback period for each farm model. This assumption implies that the discount rate is nonstochastic (predetermined), constant over time and independent of the size of the capital investment.

An explanation of the selection criteria applied for the six aquaculture projects is included below.

Selection criteria

Investment analysis involves the use of a selection criterion by which alternatives may be compared with a benchmark or ranked against one another (Treadwell et al. 1991). The three most widely used criteria are internal rate of return, net present value and benefit–cost ratio. The advantages and limitations of using these criteria have been widely discussed in investment evaluation literature and are not revisited here. (For an overview of the strengths and limitations of each approach and the guidelines for their appropriate uses, see Department of Finance 1991, 1995). For the farm analyses presented in this report the benefit–cost ratio has been selected as the appropriate criterion by which alternative aquaculture projects may be compared. The payback period for operations has also been included to indicate how long it would take for the initial capital outlays of farms to be recouped.

The benefit–cost ratio indicates the value of expected discounted benefits relative to the value of expected discounted costs over the lifetime of a project. For a project to be viable the benefit–cost ratio must be greater than one — that is, the benefits must exceed the costs of undertaking the project. A benefit–cost ratio value below one indicates that the costs outweigh the returns from undertaking the project and that the project is not viable. When choosing between mutually exclusive projects, the project with the highest benefit–cost ratio would be selected if there were no constraints on the size of that investment.

Information about the timing of costs and returns associated with a new aquaculture venture may also be valuable to potential investors as an indication of the annual and cumulative cash flows and the payback period for the farm. The decision to invest in an aquaculture project may be influenced by the time taken to recoup the initial capital outlays and the length of this period may affect the perceived riskiness of proceeding with the project. The benefit–cost ratios (and their associated probability distributions) and the payback period for each of the six species are presented in chapters 3–8.

Investment analysis

Risk and uncertainty are inherent to agriculture and aquaculture production and influence the returns to all farming enterprises. The establishment and management of a farm business, the physical environment in which farms operate, the biological requirements of livestock and crops, including the time required to grow them to salable condition, as well as current and future market developments and institutional arrangements are all examples of typical sources of risk that primary producers face.

Awareness of the sources of risk and uncertainty and the interaction between risks and uncertainties and the farm operation may enable farmers to take actions to mitigate the potential impacts of these influences on farm returns. Farmers do this by incorporating their assessments of risk into their business planning and by making adjustments to farm management practices that are consistent with their attitudes to risk.

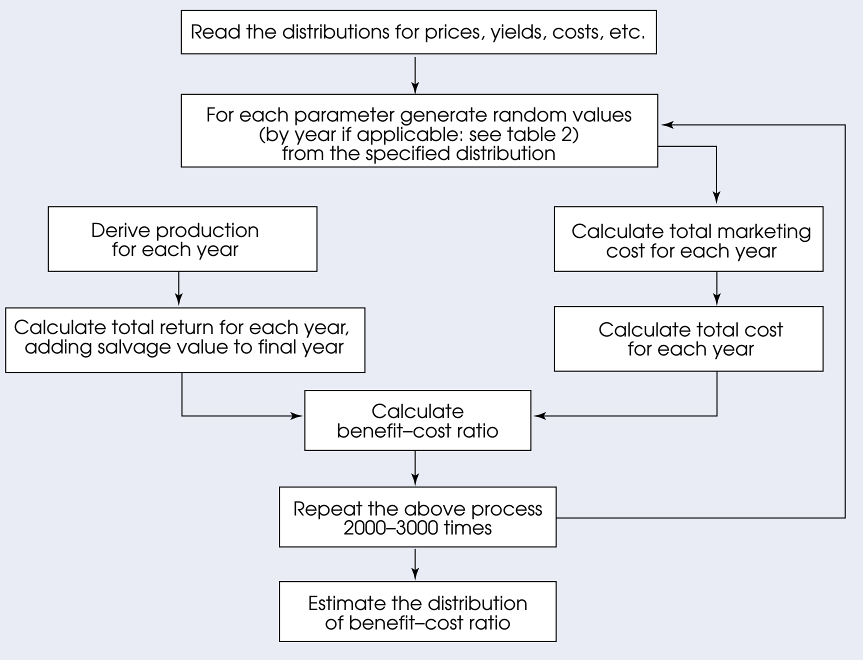
For the six species under examination, additional sources of risk and uncertainty may arise in the use of relatively new technologies or techniques of production and the maturity of the industry and markets in which production is sold. As a result there is often a high degree of uncertainty surrounding the cost structures and the performance of various species under a range of culture conditions. Under these circumstances it is inappropriate to use point estimates for parameters for which there is a range of possible values (such as prices, outputs and costs) as point estimates may be speculative and uninformative (Treadwell et al. 1991).

Alternatively, there are three standard ways of handling risk or uncertainty in investment analysis:

- using a single estimate for each parameter, adjusted for risk;
- using an upwardly adjusted discount rate; and
- using the most likely value for each parameter, together with sensitivity tests over the range of possible values for the uncertain parameters.

Most commonly the third alternative is used but the procedure becomes unwieldy when there is a broad range of values for many of the major parameters. Under these conditions interpretation of the results of the sensitivity analyses becomes difficult. An alternative to sensitivity analysis is stochastic investment analysis. In effect, the technique uses the range of

A **Stochastic investment analysis**



values for uncertain parameters to derive a range of results with their corresponding probability of occurrence (Treadwell et al. 1991). This method of analysis follows the approaches to investment analysis and gross margin analysis used and discussed by Fairley and Jacoby (1975), Anderson (1976), Brown and Hall (1982) and Treadwell and Woffenden (1984).

The procedure used for evaluating the profitability of farming aquaculture species is depicted in figure A. Basically a Monte Carlo simulation study (using @risk software) of returns and costs was used to generate a cumulative distribution function of the benefit–cost ratio. A point on this cumulative distribution indicates the chance (probability) of the benefit–cost ratio for a particular project being equal to or less than than a particular value. A benefit–cost ratio of one indicates the probability of the project being unviable (see box 1 and figure B).

The return and cost parameters listed in table 2 are subject to varying degrees of uncertainty, precluding the adoption of point estimates for the analysis and requiring the use of a range of values for each parameter. The ranges of values for the parameters listed in table 2 were determined through consultation with aquaculture researchers and Australian farmers of the six species selected.

In most cases the nature of the distribution for each parameter could not be determined so it was assumed that each parameter has a distribution based on minimum, most likely and maximum values of the parameter under consideration (a betaPERT distribution). Such a distribution is considered to be suitable for modeling the views of experts — in this case the farmers and researchers of these species — on the uncertainty about specific parameters (Vose 1996).

For each iteration of the Monte Carlo simulation a value is randomly generated for each parameter in accordance with the specified distribution. Some parameters may be chosen from a different distribution each year. The parameter values

2 Parameters in stochastic investment analyses

	Variation between simulations	Variation over time
Domestic prices		
Fresh	yes	yes
Production parameters		
Years to initial production	yes	na
Years from initial to mature production	no	na
Mature production	yes	no
Farm costs		
Annual operating costs	yes	yes

na Not applicable.

generated for each iteration are used to calculate the associated stream of costs and returns from which the benefit–cost ratio is derived (figure A). The procedure is repeated 2000–3000 times using the @risk software package to derive a set of benefit–cost ratios that are then ranked and presented graphically in the form of the cumulative probability distribution for the benefit– cost ratio (figure B and box 1). Stochastic investment analysis not only yields the 'most likely' benefit–cost ratio (which, in most cases, is *not* the 'average' benefit–cost ratio) but also indicates the effect of uncertainty by providing a range of benefit–cost ratios with their probabilities of occurrence. The uncertainty about parameter values is reflected in the probability distribution of the benefit–cost ratio. Additional sensitivity tests may still be undertaken to show the impact on the most likely benefit–cost ratio of alternative specifications of the distribution of a parameter. Such sensitivity tests have been undertaken for each species.

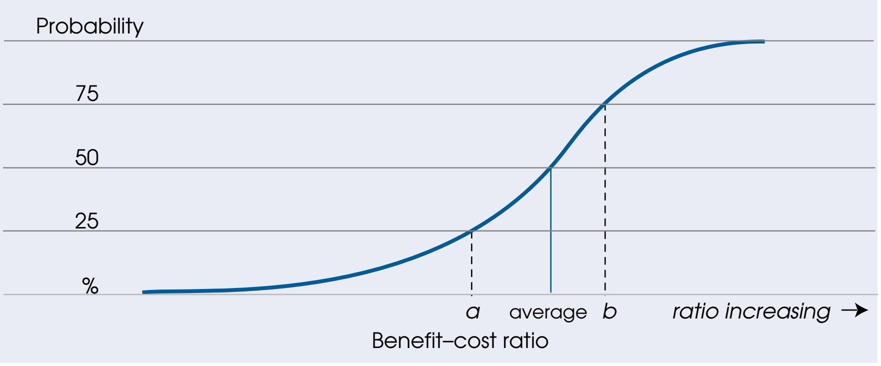
1 Cumulative probabilities of benefit–cost ratios

A cumulative probability distribution shows the probability of the benefit–cost ratio being not more than any particular level. The point at which the horizontal line associated with a 50 per cent probability meets the cumulative probability function is the mean or average benefit–cost ratio (figure B). If this average benefit–cost ratio was equal to one (as an example only) there would be a 50:50 chance of the project being viable.

If point *a* in figure B represented a benefit– cost ratio of one, there would be a 25 per cent of the project being unviable and a 75 per cent chance of it being viable.

If point *b* was a benefit– cost ratio of one, there would be a 75 per cent chance of the project being unviable and a 25 per cent chance of it being viable.

B Cumulative probability distribution of the benefit–cost ratio



The degree of uncertainty about the stochastic parameters varies significantly between the species under examination and is an important factor when considering the viability of investment in alternative projects. Mussels, for example, have been farmed and sold in Australia since the 1970s so there is an established price for them in the domestic market and data are available on historical price movements. In contrast, only a small number of price observations are available for fish that have only recently been cultured in Australia. Consequently, there is greater uncertainty about the starting and future prices for such species.

Understanding that there are differing levels of uncertainty about the range of values for parameters such as prices is important in understanding the nature of risks facing potential farmers of each species. The same argument may be applied to other parameters such as output, feed conversion ratios and feed prices. A discussion of the components of these parameters, how they have been dealt with in the farm models and how they may be interpreted is provided in box 2.

2 Management of stochastic parameters

Incorporating risk and uncertainty in models

The modeling process used in this project allows for the incorporation of information about differences in risk and uncertainty between species. Differences between species in factors such as production risk, uncertainty about substitutability with wild species and price risk can have an important impact on financial risk and the degree of confidence that can be placed on expected values of benefit–cost ratios.

Through interviews with farmers and researchers, information was gathered about not only the expected or most likely value of parameters, but also their potential range and the degree of uncertainty about them. The interviews confirmed the importance of uncertainty about particular parameters over time. For example, in the case of output prices, uncertainty may exist about the price in the first year of production when the product is new on the market. Uncertainty may also exist about output prices in subsequent years.

Information was collected about the degree of uncertainty for each parameter over time and incorporated into each farm model. Sensitivity tests were also undertaken for each species to investigate the potential impacts of risk and uncertainty about parameters anticipated to have a significant influence on farm profitability, such as input and output prices.

2 Management of stochastic parameters *continued*

Types of uncertainty

In the base case model for each species the best possible set of information for all stochastic parameters and their components was used. Broadly, this 'best set' of information aimed to cover all types of uncertainty related to the production and sale of each fish species. The stochastic parameters and their components used in the farm models are described below.

Data used in the farm models were determined through visits with farmers and researchers and from time series data from ABARE, Australian wholesale fish markets, the Australian Bureau of Statistics, the Food and Agriculture Organisation and other fisheries and aquaculture statistical sources.

Output prices

Uncertainty about output prices for the six aquaculture species analysed arises in a number of forms. For species for which farmed production is only beginning in Australia, and for which there are no close substitutes or wild products available whose prices may act as reliable proxies for the price of the farmed product, there is substantial uncertainty about output prices. The sensitivity of BCRs to prices was tested specifically in the cases of Murray cod, silver perch and snapper.

Annual variability

This type of price uncertainty is common to all types of commodity production, particularly agricultural and aquaculture production unless contracts and forward markets are used to even out price variability. This is particularly the case where production is seasonal or where wild product competes with farmed production and all producers sell at the same time or where demand is seasonal. Seasonal price variability may affect some species (such as mussels and yabbies) to a larger extent than others, although may be more predictable especially in cases where supply or demand is seasonal, such as with yabbies. As industries mature and output is available all year round, price variability may be reduced. Sensitivity tests of annual variability are preformed for mussels and yabbies.

Price trends

Expected trends, and the degree of confidence attached to these, were based on past trends from time series data and on information gathered in the field. Past price trends were estimated using price time series and price information from farmers. Informed judgment by industry, market and research sources was also used to assess expected price trends, in the light of factors such as expected production. Where a high degree of uncertainty was thought to exist for price trends for particular species, sensitivity tests were undertaken to examine the importance of this uncertainty to the expected benefit–cost ratios obtained.

2 Management of stochastic parameters *continued*

Yields

Production risks are inherent in aquaculture and relate to a number of factors including:

- the biophysical characteristics of species and the environments in which they are cultured;
- the techniques and technologies used to produce them;
- the time elapsed until output is of salable size; and
- farm and risk management.

Mortality during early learning

The models take into account the limited experience of a first time producer with the chosen production system by incorporating higher mortality rates in the first few years of production. Mortalities are assumed to be higher while the new farmer is developing production techniques and gaining knowledge about the operation of specialised farm equipment. They will also be higher until the aquaculturist has a comprehensive understanding of the biophysical requirements of the species being farmed. Farmers of each species have been assumed to gain adequate experience and knowledge in the initial years of operation to eliminate early learning mortalities. Yield variability may then be explained by the other facets of yield risk discussed below.

Examples of how early learning mortality may arise include:

- overstocking of juveniles or spat in the culture medium, such as abalone in tanks or mussels on longlines — overstocking in tanks, ponds or cages may cause deficient dissolved oxygen and toxic levels of nutrients in the water as well as stress and disease in the fish that results in mortalities. Overstocking longlines with mussel spat may result in losses if mussels are not able to attach to longlines securely or if mussels drop off lines as the weight of the lines increases with the growth of mussel biomass.
- limited experience with farming equipment or technology such as rope seeding equipment used in mussel farming, or automatic feeders and paddle wheels in silver perch ponds. In the case of mussels, losses may be incurred if ropes are unevenly seeded with mussel spat, resulting in mussels being unable to anchor themselves securely to ropes. Silver perch losses may be incurred until farmers have a good understanding of how to set automatic feeders and paddlewheels to deal with variable climatic conditions in the ponds. Changes in temperatures may require alterations to the volume or frequency of feed delivered to the ponds and the intensity of use of paddlewheels to oxygenate the ponds.

2 Management of stochastic parameters *continued*

- the attitudes of new farmers to risk and farm management, which may be reflected in farmer choices like whether to use intensive or extensive culture techniques, to employ backup systems to ensure against power failures, to conduct regular diagnostic tests of water in ponds or tanks or of how densely to locate longlines in mussel leases.

Annual variability in yields
Between years, yields can vary in response to events that may be unpredictable and beyond the control of the farmer such as climatic variability, system failures, the arrival of predators, the onset of disease, and human error. Annual variability has been accounted for in each model by assessing how often these types of event would be likely to occur and what their potential impacts on yields would be (based on information gathered in interviews with farmers and researchers of each species). This assessment is reflected in the ranges used for annual variability in each farm model.

For example, annual variability was assumed to be low in abalone production relative to that in semi-intensive silver perch production or mussel production. This is because abalone producers are assumed to employ the most intensive production system for the species — minimising losses attributable to unanticipated events that are outside farmers' control. However, because abalone take between two and four years to reach a marketable size (depending on the species produced) the impact of an unexpected event may be catastrophic depending on the timing of the event and the extent of stock losses. Significant input costs would have been incurred, new expenditures on replacement stock and other inputs would be required, and the farm may have to wait for the replacement stock to reach market size before cash flows were restored to previous levels. Clearly, this type of risk may be mitigated to some extent by investment in faster growing species of abalone such as greenlip.

Costs
Feed prices
Feed prices are assumed to trend downwards over the twenty year period examined in each farm model. This assumption is based on competition between an increasing number of feed suppliers producing larger volumes of feed, leading to lower input prices. It will also be assisted by the substitution of relatively expensive fishmeal inputs (currently a main input in commercial feeds) with alternative sources of protein such as lupins, wheat gluten products and meatmeal. The downward trend in prices is limited by the cost of feed components and the cost of research and development of new feeds, particularly specialised fish diets.

➩

2 Management of stochastic parameters *continued*

Feed costs
Like feed prices, feed costs are assumed to trend downwards over the twenty year production period for each farm. Feed costs, a product of feed prices and the volume of feed used, will decline owing to a combination of the decline in feed prices discussed above and to improvements in the *feed conversion ratios* attained by farmers. The feed conversion ratio is the weight of feed needed by a fish per unit of weight gain. Feed conversion ratios are anticipated to improve as farmers gain greater skills and expertise in delivering feed to fish and as specialised diets are developed for more farmed species. With the culture of most of the selected fish species at an early stage of development, researchers are still experimenting with nutritional requirements and diets for each species. For example, most Murray cod producers are using diets formulated for other species such as salmon, trout, barramundi and silver perch.

Prices for juveniles
Prices for juveniles are also assumed to trend downwards over time. This is because of an anticipated increase in the number of hatcheries operating and volumes produced as the demand for juveniles increases with the establishment of new aquaculture ventures and decreased reliance on natural sources of juveniles. Larger scale production of juveniles by a greater number of producers may also help reduce prices if the costs of production of juveniles are reduced.

A combination of reduced early learning mortalities (reducing the numbers of juveniles required by an operation in the early years) and forecast reductions in juvenile prices result in a downward trend in juvenile costs over the twenty year period examined. As juvenile costs represent a large proportion of operating costs for most species, sensitivity tests were undertaken to examine the impact of a fall in juvenile prices on farm viability.

3

Abalone

Abalone aquaculture began in Australia in the early 1980s in Port Lincoln in South Australia and in Tasmania through research on spawning greenlip (*Haliotis laevigata*) and blacklip (*H. rubra*) abalone (Hyde 1998). While these two states have led the development of commercial abalone aquaculture in Australia for the past decade (Hyde 1998), Victoria and Western Australia are now in the early stages of commercial abalone farming and plans have also been made for land based abalone farms in New South Wales. Three marine hatcheries are currently producing abalone in Victoria and one is in the developmental phase in Western Australia.

Expansion in hatchery production of juvenile abalone will be an important factor influencing the costs involved in growing abalone to market size and in reducing current reliance on wild abalone spat.

Of a number of species of wild abalone that grow in Australian marine water (blacklip, brownlip, greenlip, roes and tropical), only greenlip and blacklip are currently being produced commercially by farms in these four states. These species are grown to market size using a diverse range of production systems in either land or sea based facilities, with a recent trend toward the development of land based systems. The latter systems are thought to allow greater control over the growing environment and to avoid some of the potential difficulties associated with obtaining access to suitable marine sites.

Aquaculture techniques currently in use in Australia include the use of sea cages, recirculation tanks or concrete raceways, as well as experimental production through the reseeding of depleted reefs and ranching abalone on existing or constructed reefs. To minimise the cost of abalone farming, most Australian farms are still experimenting with culture methods and equipment. This is reflected in the large range of techniques and production systems currently being used in Australia.

Since the mid-1990s, increased availability and industry acceptance of specialised diets and improved tank technology have allowed farmers to grow abalone to minimum market size (70 millimetres) in three to four years compared with four to five years previously (Hyde 1998). This improvement in productivity has enabled farmers to earn income from abalone earlier and to some extent has lowered the riskiness of investment in abalone farming. Additionally, hatcheries in South Australia, Tasmania, Victoria and most recently Western Australia have produced millions of juveniles, facilitating the establishment of specialist growout operations and obviating the cost of investment in new hatcheries.

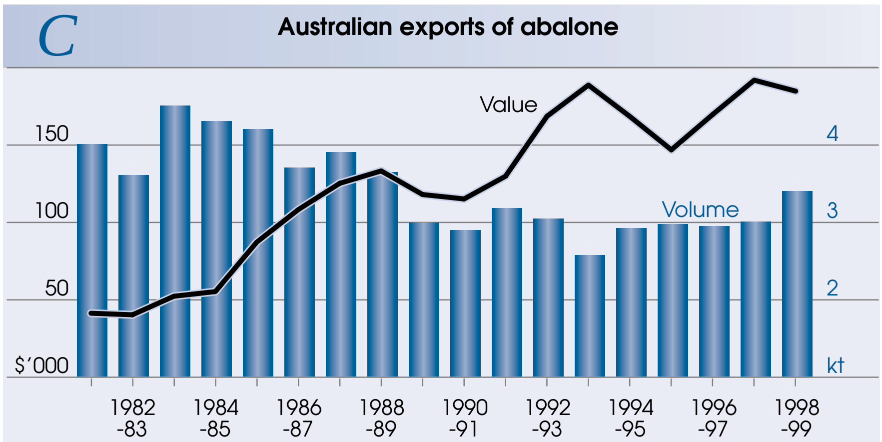
Australian states responsible for wild abalone fisheries regulate the number and size of abalone that may be taken, to protect stocks from overfishing and to maintain commercial harvesting at sustainable levels. If total allowable catches of wild abalone remain relatively stable in Australian states in future, farmed production may eventually account for the bulk of Australian abalone production in volume and value terms. The impact of larger volumes of farmed abalone on product prices will depend mainly on the substitutability of other fish for abalone and the potential for product differentiation — species, source of supplies (wild or farmed), product size and markets to which production is directed.

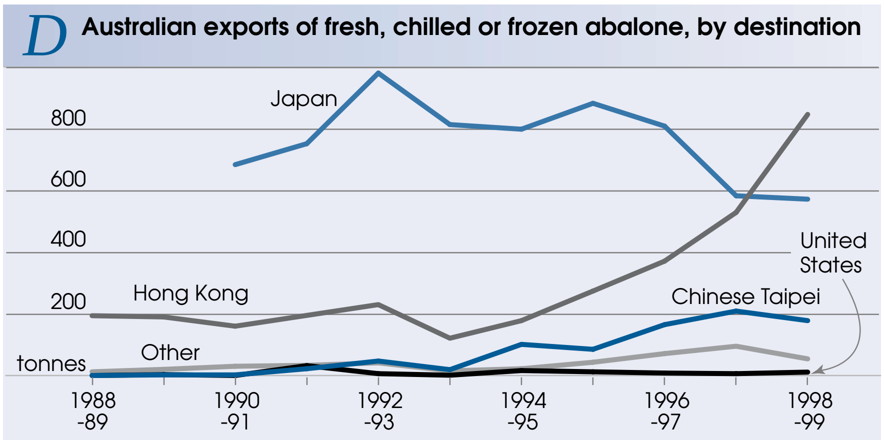
Differentiating between cultured and wild abalone may allow farmed abalone to develop its own place in export markets, particularly as sales of wild abalone from Australia are restricted by minimum harvest size limits imposed on capture (at least 120 millimetres). In contrast, farmed abalone may be sold at any size and is primarily exported as a live 'cocktail' product in the size range 50–100 millimetres per abalone. Cocktail size abalone has been able to fetch premium prices on export markets compared with wild abalone, mainly reflecting greater consistency and quality of the product. Small quantities of cocktail abalone have also been marketed domestically, obtaining prices in the range $40–45 a kilogram live, whole weight (Hyde 1998).

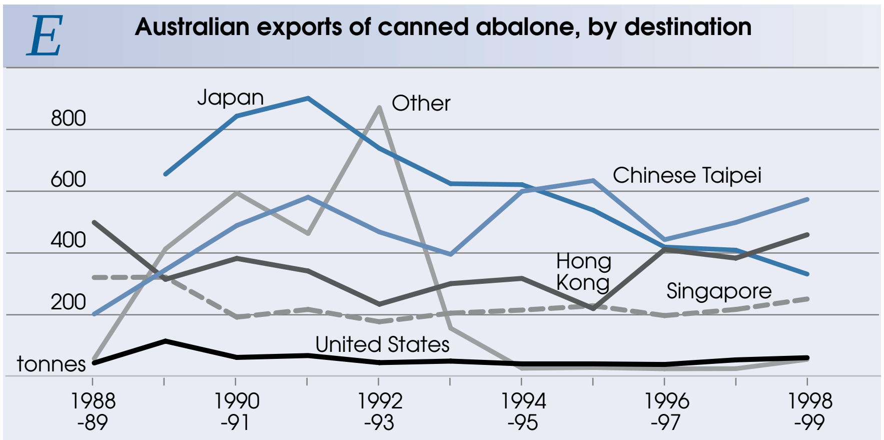
Market outlook

Domestic market

Limited global supplies of and relatively high market values for wild abalone have been the main drivers of abalone farming in Australia. Australia supplies over 40 per cent of the world's wild harvested abalone, and the two main commercial species farmed in Australia (blacklip and greenlip) have significant price margins over abalone species harvested from other countries. Historically, aquaculture efforts in Australia have concentrated on the blacklip and greenlip abalone, as they appeal to different segments of the Asian market, with small sales of abalone domestically. The Chinese favor the greenlip abalone, while the Japanese favor blacklip. Other established markets


C
Australian exports of abalone
Value
Volume
150
100
50
$'000
4
3
2
kt
1982
-83
1984
-85
1986
-87
1988
-89
1990
-91
1992
-93
1994
-95
1996
-97
1998
-99


D
Australian exports of fresh, chilled or frozen abalone, by destination
Japan
800
600
400
200
tonnes
Hong Kong
Other
United
States
Chinese Taipei
1988
-89
1990
-91
1992
-93
1994
-95
1996
-97
1998
-99


E
Australian exports of canned abalone, by destination
Japan
Other
800
600
400
200
tonnes
Chinese Taipei
Hong
Kong
Singapore
United States
1988
-89
1990
-91
1992
-93
1994
-95
1996
-97
1998
-99

for Australian abalone are Chinese Taipei, Singapore, Hong Kong and the United States.

From a farming perspective, greenlip culture may be preferable to blacklip culture because of the potentially faster growth rates achievable (20–30 millimetres a year for greenlip compared with 15–25 millimetres a year for blacklip) (Hyde 1998) and hence an earlier return on the farm investment. However, suitable biophysical conditions are required to culture both types of abalone and farm sites will determine to a large extent the type of abalone that may be viably produced.

In 1999-2000 there was no indication that abalone farmers would redirect marketing efforts toward the domestic market, especially when Australian abalone fishers and growers are the largest suppliers of abalone and hence are price makers on the world market. Instead, traditional and new export markets will continue to be the focus of abalone marketing efforts, with abalone farmers using trade links developed by commercial abalone fishers as a starting point for farmed product market development.

World market

Australian exports (by volume and value) of abalone, by product type and country, are presented in figures C, D and E. It should be noted that these figures relate predominantly to wild caught abalone but may serve as a general guide to the prices that abalone producers have received in export markets. Abalone is sold by weight in export markets, with live products usually sold by farmers directly to distributors in the major markets Hong Kong, Japan or Singapore. Abalone farmers also sell abalone to Australian processors to on-sell as either canned or fresh frozen abalone to wholesalers in Asia.

The main issue in the outlook for Australian farmed abalone is whether the current level of prices received will be sustainable in the medium to long term, especially as the volume of farmed product available from Australia increases. The historical price data for wild caught abalone reveal that there is some seasonality associated with prices and that in years in which production is high, prices are low. All other things being equal, prices for farmed abalone would be expected to be lower in the medium to long term as the volumes produced increase. Price trend declines may be averted through targeting new segments of traditional markets or by developing entirely new markets for abalone. More stringent limits on future harvests of wild stocks may also help to sustain current market prices.

Abalone farm models

Farm models for abalone were built assuming that farmers use land based tank culture that is increasingly being adopted in the abalone producing states of Australia. Sea based abalone production is undertaken commercially in Tasmania. However, land based abalone culture was selected for the analysis, with sea site selection and allocation issues considered.

Two sizes of farm are analysed — 100 and 200 tonne farms. The farm models presented are generalised models that have been constructed using information from sources that represent the diversity of land based farm production systems currently in use in Australia. It should be noted that the farm models presented are not able to replicate the full range of production and financial conditions experienced by actual operations in use around Australia; however, they serve as an approximation of these systems, both technically and financially. Hence, the results of the models should be used generally to illustrate:

- the expected viability of farming abalone given the model assumptions,
- the main sources of risk and uncertainty facing new farmers of abalone, and
- the potential impacts of these risks and uncertainties on the probability of new abalone farms being viable.

Technical assumptions

The 100 and 200 tonne farm models are assumed to be comprised of tanks for the land based growout of 20 millimetre juvenile greenlip abalone to a market size of 70 millimetres (table 3). The farm operation is modeled over

3 Key characteristics of the abalone farm models

	Unit	Most likely		Range	
		Greenlip	**Blacklip**	**Greenlip**	**Blacklip**
Size at harvest	mm live	70	70	50–100	50–100
Growout time	months	27	39	24–36	36–42
Feed conversion ratio		1.4	1.4	1.1–1.6	1.1–1.6
Survival rate	%	80	80	70–95	70–95
Total farm production	t/yr live	100	100	80–105	80–105
Farm gate price	$/kg live	45.0	45.0	32.5–65.5	32.5–65.5

a twenty year period with all capital costs outlaid in the first year and the time to initial output assumed to be three to four years from farm establishment. The initial stocking rates of abalone are relatively high because of an assumed early learning mortality rate of 20 per cent. As the farmer gains experience in operating the farm, mortalities are reduced over the twenty year period to the assumed underlying mortality rate of 10 per cent for each cohort of abalone grown to maturity. The implication of declining mortality rates is that operating costs are reduced over the twenty year period as fewer juveniles need to be purchased and fed to maturity to produce the 100 and 200 tonnes of output.

The risk of system failure is also factored into the model through an annual variability component in the output parameter. This component allows for random system failure at the farms over the twenty year period. These failures result in unanticipated animal mortalities and have large negative impacts on farm cash flows in the short term. In the long term, the probability of farm viability is reduced.

Early learning mortality attributable to lack of farmer expertise or experience with a new farm system, and annual output variability resulting from unanticipated system failures affect farms in a number of ways simultaneously:

- farm income may be severely reduced for a prolonged period depending on the incidence and extent of mortalities (which cohorts are affected, how many deaths per cohort and the overall impact on annual output) and the time until mature production reaches full capacity again;
- operating costs may be significantly increased in the year that extra mortalities occur through the purchase of replacement juvenile abalone; and
- cash flows may become negative when farms have to wait until replacement stock mature before earning income to offset operating costs, such as feed, labor and fuel costs, incurred in growing the original and the replacement abalone.

Consequently, the range and probability of the benefit–cost ratios being greater than one are reduced for both 100 and 200 tonne farms.

The assumed feed conversion ratios for the 100 and 200 tonne farms range between 1.1 and 1.6. In the initial years of operation the feed conversion ratio for both size farms is assumed to be 1.4. Over the twenty year period this is assumed to trend towards 1.1 as farmers improve their farming techniques, and research and development efforts result in improved productivity of abalone feeds (Forster 1996). Consistent with the downward trend in feed conversion ratios over twenty years, feed used and hence feed costs per farm (at unchanged feed prices) also trend downwards. Reinforcing this trend is the assumption that feed prices (in 2000 Australian dollars) trend downwards very slowly from a starting price of $3000 a tonne to $2000 a tonne over the twenty year period.

Based on historical prices for wild abalone, prices per kilogram are assumed to range from $32.5 to $65.5 in the farm models, with the most likely price assumed to be $45 and a declining trend over the twenty years of 0.5 per cent a year. The main operating costs are attributable to the purchase of juveniles, feed, labor and power. Sensitivity tests to the purchase costs of juveniles and the other main components of operating costs generally were undertaken to show their effects on farm viability. The results of the farm model runs are discussed below.

Average annual operating costs and capital costs for the abalone models are given in tables 4 and 5 respectively.

4 Average annual operating costs for the abalone farm models

	100 tonne farm (annual capacity)	**200 tonne farm** (annual capacity)
	$	$
Juveniles **a**	1 110 700	2 141 400
Feed **b**	336 500	670 900
Freight	15 000	24 000
Marketing (incl. processing and packaging)	200 000	400 000
Electricity and fuel	250 000	500 100
Labor **c**	350 000	700 100
Repairs and maintenance	35 000	70 000
Miscellaneous	7 500	15 000
Security	75 000	150 000
Administration costs (incl. site lease and licence)	100 000	150 000
Total	2 479 700	4 821 500

a 20 mm at $0.6–0.8 each. **b** $2500–3500 a tonne. **c** 10–12 people full time for the 100 tonne farm size and 15–18 people full time for the 200 tonne farm size.

5 Capital costs for the abalone farm models

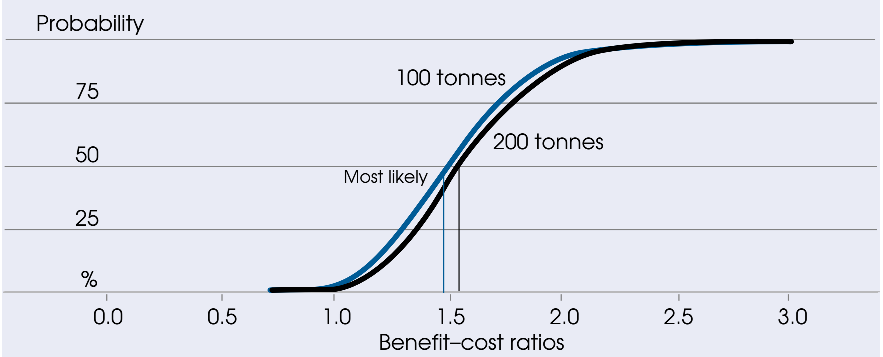
	100 tonne farm (annual capacity)	200 tonne farm (annual capacity)	Scrap value	Life
	$	$	%	yrs
Land	50 000	100 000	–	–
Buildings (incl. workshop, office, and pump shed)	200 000	200 000	50	20
Growout tanks and shade	2 100 000	4 200 000	10	20
Water delivery system	400 000	600 000	–	20
Coarse filtration system	50 000	50 000	–	10
Three phase power	15 000	15 000	100	–
Backup facilities	5 000	5 000	10	10
Compressor	15 000	15 000	–	10
Laboratory equipment	20 000	20 000	10	5
Generator	30 000	30 000	10	10
Security	30 000	50 000	–	20
Grading equipment	10 000	15 000	10	10
Office equipment	15 000	15 000	–	20
Safety equipment	2 500	5 000	10	5
Temperature regulation	15 000	15 000	–	10
Miscellaneous	30 000	30 000	–	5
Total	2 987 500	5 365 000		

Farm model results

As shown in figure F, the most likely benefit–cost ratios for both abalone models are above one and the probability of farm viability for both size farms is high given the basic set of farm model assumptions. The most likely benefit–cost ratios and payback period for both size abalone farms are presented in tables 6 and 7. There is only a 3 per cent chance that the benefit–cost ratio will be below one for the 100 tonne farm and 2 per cent for the 200 tonne farm. The probability of a viable operation increases with farm size and the estimated average benefit–cost ratio for the 100 tonne farm is 1.48 compared with 1.53 for the 200 tonne farm. This is because farm costs increase less proportionally with output.

The benefit–cost ratios for the production of blacklip abalone may be expected to be slightly lower than those for greenlip abalone because of the longer time required to grow to maturity. The payback period for blacklip abalone farms would be longer than those for greenlip abalone farms. The range of

F Benefit–cost ratio distributions: 100 and 200 tonne abalone farm models



benefit–cost ratios would be wider because of the increased risk associated with longer growout periods.

To examine the impact of changes in the stochastic parameters anticipated to have the largest impact on farm viability, sensitivity tests were undertaken by altering the values of key parameters. In the case of abalone the importance of product unit prices, juvenile, feed and labor prices to farm viability were examined. The results of these tests are presented in tables 8 and 9.

If volumes of farmed abalone increase significantly in the future it is likely that per kilogram prices of abalone would fall. Prices may also be expected to fall from the average price per unit if product demand or quality falls. Analysis was conducted of the effect of prices falling by 1 per cent a year in relation to farm costs (table 8). The results show that the expected profitability of abalone farming is sensitive to price. With relative prices falling consistently by 1 per cent a year the estimated most likely benefit–cost ratios for the 100 and 200 tonne farms, respectively, fall to 1.04 from 1.48, and to 1.08 from 1.53.

6 Benefit–cost ratios from the abalone farm models

Farm model (annual capacity)	**Most likely BCR**	**90% confidence interval**	**Probability of BCR less than 1**
			%
100 tonne farm	1.48	1.21–1.86	3
200 tonne farm	1.53	1.28–1.92	2

Abalone farming is a relatively young industry in Australia so it may be reasonably assumed that abalone growers may achieve productivity increases in future. These increases may be reflected in improved survival rates of juvenile stock and reduced labor required per production cycle. These improvements would have the effect of reducing farm operating costs. Additionally, expansion in the number and productivity of abalone hatcheries in Australia may be expected to result in lower juvenile prices.

7 Payback period for the abalone farm models

Farm model (annual capacity)	**Payback period**	**90% confidence interval**
	yrs	yrs
100 tonne farm	6	4–10
200 tonne farm	4	3–6

To test the sensitivity of farm viability to changes in the major operating costs, sensitivity tests were undertaken for the cost of juveniles, labor and feed (table 9). The results indicate that the viability of abalone farming would be markedly improved if there was a 1 per cent decrease in labor and feed costs each year, with a very low chance of either farm being unviable. Likewise, an annual 1 per cent increase in these input prices reduces the ratio of benefits to costs in each project even though investment in the farms remains viable. In this scenario the estimated most likely benefit–cost ratios fall to 1.39 and 1.45 for the 100 and 200 tonne farms respectively.

8 Impact of alternative output price trends on the abalone farm models

	Most likely BCR	**90% confidence interval**	**Probability of BCR less than 1**
			%
Standard settings			
100 tonne farm	1.48	1.21–1.86	3
200 tonne farm	1.53	1.28–1.92	2
Abalone prices reduced by 1 per cent each year			
100 tonne farm	1.04	0.78–1.61	12
200 tonne farm	1.08	0.83–1.78	10
Abalone prices increased by 1 per cent each year			
100 tonne farm	1.60	1.43–2.00	1.5
200 tonne farm	1.69	1.55–2.31	0.5

9 Impact of alternative input price trends on the abalone farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings			
100 tonne farm	1.48	1.21–1.86	3
200 tonne farm	1.53	1.28–1.92	2
Juvenile prices reduced by 1 per cent each year			
100 tonne farm	1.54	1.36–1.97	2
200 tonne farm	1.61	1.41–2.10	1
Labor and feed costs increased by 1 per cent each year			
100 tonne farm	1.39	1.17–1.74	3.5
200 tonne farm	1.45	1.20–1.86	2
Labor and feed costs reduced by 1 per cent each year			
100 tonne farm	1.85	1.29–1.93	1
200 tonne farm	1.93	1.35–2.30	0

Concluding comments

Based on the assumptions used in the analysis, the production of abalone in tanks on land has a high probability of viability for operations of both 100 and 200 tonnes annual production. In all scenarios there appears to be a low probability of the benefit–cost ratios of either project not exceeding one. Additionally, the payback periods for the two operations are six and four years respectively. In the farm models, if the scale of production is increased or the time to initial mature production can be reduced, the chance of profitable abalone production is further improved and the payback period is reduced.

The key risks involved in the production of abalone appear to be:

- the long lead times to grow abalone to marketable size and the chance of system failures occurring during this period;
- the availability and price of juvenile stock; and
- substantial fluctuations in market prices and feed and labor costs.

These risks are especially pertinent given the large capital outlays required to establish abalone farms and the time elapsed before farms generate cash flows. If disasters occur in the initial years of operation the viability of the farm is jeopardised. Investment in stock is lost through the stock losses, and stock replacement incurs additional costs. The time lag between stock replacement and income generated from the sale of mature stock increases the risk of failure of the operation and, if the operation continues, the payback period.

Juvenile, feed and labor costs account for a significant proportion of operating costs and so the viability of both size farms is sensitive to any reductions or increases in these costs. On the basis of current domestic trends and historical trends observed in agricultural and international aquaculture industries, juvenile and feed costs are likely to trend downwards over time as:

- the availability of inputs increases;
- feed research and development allows improved feed conversion ratios to be achieved in abalone farming; and
- farmers reduce mortality rates during the early learning phase of operation.

Market price for abalone is the other key factor influencing the viability of abalone farming. As demonstrated in the analysis, the viability of both size abalone farms appears to be sensitive to assumed market prices. While the volumes of abalone sold into export markets from Australia are still relatively small, the price risks associated with increasing volumes of Australian abalone being sold in markets are relatively low compared with species such as Murray cod and silver perch. This is because abalone markets are well established, based on wild supplies, and substitutes for abalone in traditional (Asian) abalone markets are limited.

Overall the probability of viable abalone production is high for the range of assumptions used in the analysis.

4

Murray cod

The Murray cod (*Maccullochella peeli*) is the largest native freshwater fish found in Australia. Its natural distribution occurs within the Murray Darling Basin ranging from south eastern Queensland to New South Wales, Victoria and South Australia. During the late 1800s and early 1900s, wild Murray cod were commercially fished in large numbers, and were widely sought by recreational anglers. As a result, the abundance of wild fish declined, which led to the introduction of regulations to limit their capture (Ingram and Larkin 2000).

The decline in abundance of Murray cod is also thought to have resulted from a general degradation of the riverine environment caused by a number of factors, including modifications to rivers for hydroelectric, flood mitigation and irrigations schemes, increased pollution from domestic, agricultural and industrial sources and competition from introduced species.

In the early 1980s, breeding techniques for Murray cod were developed and stock enhancement programs were established within New South Wales and Victoria to help increase the numbers of this fish. However, it was not until the 1990s that Murray cod was farmed commercially. The farming attributes of Murray cod include the fish's ability to adapt to artificial environments, efficient feed conversion and high stocking density tolerance.

New South Wales, Victoria and South Australia are the main states currently farming Murray cod. While there are only twenty-five farms in these three states that are producing Murray cod, there are many more farms that are licensed to produce the fish but are not currently producing (Larkin and Ingram 2000).

The majority of farmed Murray cod is produced using either intensive recirculation systems or in semi-intensive tank culture. In addition, the growout culture of Murray cod is undertaken extensively in ponds. In the past, it was originally thought that Murray cod was unsuitable for intensive culture because of its aggressive and territorial nature. As a result, Murray cod have been extensively cultured in farm dams and ponds. However, this technique results in lower yields and variable growth rates compared with intensive culture and so it is expected that future commercial production from extensive culture will be limited (Primary Industries and Resources, South Australia 1999b).

Trials in New South Wales have shown that Murray cod adapts well in intensive recirculation tank systems. The stocking of Murray cod at high densities reduces the opportunity for the fish to establish territories, so competition between the fish declines and consequently they become a schooling fish. Although Murray cod aquaculture using intensive systems is currently in its early stages, the use of intensive recirculation systems rather than extensive pond culture for Murray cod has many advantages in that the environment in which the fish are grown can be controlled so that optimal growth rates can be achieved.

Market outlook

Domestic market

The domestic market for farmed Murray cod is largely undeveloped in Australia as there are currently only twenty-five producers who sell the fish commercially. Most producers sell direct or through a distributor (Larkin and Ingram 2000).

Murray cod is sold live, chilled or gilled and gutted. To date the majority of product has been sold live. While live Murray cod prices have been used in the farm models, other product forms such as chilled, and gilled and gutted are discussed in this market section.

Live Murray cod is sold mostly to the niche gourmet/restaurant market in Melbourne and Sydney, although some product has been exported. Only small quantities have been sold on the Sydney and Melbourne fish markets. Farmed Murray cod, sold live, is mostly purchased by Asian restaurants as it is a popular fish among Chinese communities (Harding 1998).

Currently the main sizes at which Murray cod is sold are:

- plate size, 350–500 grams (10–18 months old) and
- banquet size, around 1.5 kilograms (1–2 years old) for Chinese banquets (Victorian Aquaculture Council 1999b).

Prices for farmed Murray cod on the domestic market vary according to size, grade and market. In 1998-99, average farm gate prices for Murray cod sold to restaurants ranged between $9.50 and $21.50 a kilogram for a 350 gram fish and between $10.25 and $22.50 a kilogram for a 500 gram fish. However, some producers received $25–30 a kilogram for small quantities. Average prices for Murray cod sold on the Sydney fish market were in the range $12–15 a kilogram for farmed product and $18–23 a kilogram for wild Murray cod in the same year.

As farmed Murray cod is a newly developing industry, there is uncertainty whether current prices can be sustained if production increases. Currently, Murray cod has a high market profile in Australia owing to its cultural and historical significance with indigenous people.

It is well sought after as a table fish for restaurants as it has highly regarded eating qualities such as a firm white flesh that is considered ideal for steaming. As a consequence farmed and wild Murray cod have achieved premium prices in niche markets. However, expected increases in supply are likely to place downward pressure on prices in the medium term.

The demand for farmed Murray cod will depend on the supply of other domestic freshwater fish species, imports of other finfish and the supply of wild caught Murray cod. (Murray cod is commercially fished in the Murray Darling River system; however, as from 1 September 2001 the commercial fishing of native finfish species, including Murray cod, will be banned in New South Wales.)

Murray cod producers also face competition from finfish imports. In 1998-99, Australia imported almost 98 000 tonnes of edible fish valued at $441 million. A large proportion of fish imports into Australia are low value products (ABARE 2000).

Wild Murray cod is normally sold at much larger sizes (over 1 kilogram) than farmed Murray cod (500 grams). Wild Murray cod has a different taste to the farmed fish because it has had a longer period to develop and has had a different diet. Consumers who like the muddy flavor of wild Murray cod may not like the taste of farmed Murray cod. However, an advantage of farmed Murray cod over the wild caught fish is that it can be supplied all year round. There is no catch of wild Murray cod when the season is closed for breeding purposes. In addition, supplies of wild Murray cod are expected to decline in 2001 with the ban on the commercial fishing of native finfish species in New South Wales.

Export markets

Currently, exports of Murray cod are limited because of the lack of substantial supply and the price of Murray cod relative to the prices of other farmed freshwater fish such as carp. Packaging and freight costs also reduce the competitiveness of Murray cod in world markets. In addition, Murray cod is relatively unknown and tried in overseas markets and therefore may take some time to gain market acceptance in the face of competition from more established and better known species such as farmed tilapia and Nile perch. However, in the medium term, opportunities for exports of live Murray cod to Asia are believed to exist if Murray cod was available at a competitive price. In 1999, a market taste test evaluation on Murray cod was undertaken by Austrade in Asia (box 3), receiving favorable feedback (Stoney 2000).

3 Market taste test evaluation of Murray cod

The market taste test evaluation was a preliminary market investigation to identify export opportunities for farmed Murray cod in overseas markets. Taste tests were carried out in Singapore, Chinese Taipei, Hong Kong and Japan. Participants included seafood wholesalers, importers, chefs and food journalists.

The market test found that:

- Australia is seen as a source of healthy, safe and high quality fish.
- In addition to taste, the price of fish is an important factor in determining participants' acceptance.
- Asian consumers like the firm white flesh of the Murray cod.
- A suitable marketing name is needed for the species to be exported into Asian markets.

Specific country results

Japan

Potential prospects for the fish are good, if it is marketed as a 'premium fish' to the food service/institutional sectors.

Positive aspects

- Currently there is no similar fish available in Japan. Murray cod would be best sold as a whole fish to avoid fillet substitution.
- Slime on fish and skin color are favorable characteristics to the Japanese.
- Sale potential is year round, with the highest demand in October–December.

Limitations

- High freight costs from Australia.

3 Market taste test evaluation of Murray cod *continued*

Chinese Taipei

Positive aspects

- Participants had a positive reaction to the taste, fat content, texture and size of Murray cod.
- Participants preferred Murray cod to be cooked and served as a whole fish.
- Demand for fish in Chinese Taipei increases in the 'wedding season' (October–March). Murray cod may be able to take advantage of this opportunity.

Limitations

- Strong competition from locally farmed 'cod like' species and imports.
- Distribution chain in Chinese Taipei lacks storage facilities for live fish.
- High import tariffs on fish (chilled 28–42 per cent; frozen 15–28 per cent).

Hong Kong

Participants in the market test generally viewed Murray cod as a quality fish suitable for the market all year round. It was noted that pricing is the single most important factor for successfully positioning the species in the market. Repeated market research is also important to introduce new products (species) and to find appropriate distribution channels. Choice of fish name is important.

Positive aspects

- Participants had a positive reaction to Murray cod's features — high flesh yield, no tainted flavor or smell.

Limitations

- Murray cod faces direct competition from a similar fresh water cod imported live from China and other species on the market such as grouper.

Singapore

Positive aspects

- Participants had good responses to the look, taste and texture of Murray cod.

Limitations

- The fish market in Singapore is highly competitive and extremely price sensitive (wide range of substitute fish available).
- In Singapore the live fish market is small, and therefore it is recommended that Murray cod marketers pursue the frozen food service sector.

Source: Stoney (2000).

Acquiring ‘premium’ fish status for Murray cod will require an effective marketing strategy and promotional funding. Murray cod suppliers may also need to develop consistent quality standards to meet the needs of the export market.

Murray cod farm models

The Murray cod farm models were built based on semi-intensive tank culture and intensive recirculation systems, the two main techniques used in the production of Murray cod in Australia. While Murray cod is suited to intensive farming systems, culture also occurs extensively in ponds. As discussed earlier, however, extensive culture results in variable growth rates and lower yields compared with intensive culture. As a result, it is expected that commercial production from extensive culture will be limited and therefore was not modeled in this study.

Three farm models were constructed for Murray cod — two based on semi-intensive tank culture (5 tonne and 10 tonne annual capacity) to demonstrate the effect of economies of scale in Murray cod farming, and one based on a recirculation system (30 tonne annual capacity) to demonstrate returns from a different farming practice. The key characteristics of the farm models developed for the analysis are detailed in table 10.

It is assumed that semi-intensive culture allows a Murray cod farmer to grow a 300–400 gram fish in eighteen months, while the intensive recirculation allows a farmer to grow Murray cod, within optimum temperature conditions, to a market sized 500 gram fish in ten months.

10 Key characteristics of the Murray cod farm models

		Semi-intensive		**Intensive recirculation**	
	Unit	**Most likely**	**Range**	**Most likely**	**Range**
Size at harvest	g live	350	300–400	500	450–550
Product form		live fish		live fish	
Growout time	months	18	16–20	10	8–12
Initial feed conversion ratio		1.5	1.2–2.0	1.5	1.2–2.0
Density	kg/m^3	100	60–100	100	60–100
Survival rate	%	90	0–100	90	0–100
Initial farm gate price	$/kg live	15.00	9.50–21.50	17.50	10.25–22.50

Each model is of growout operation only. Fingerlings (1 gram) are purchased from a hatchery at an initial price of 60 cents each; it is assumed that fingerlings are available consistently. Survival rates can range from 0 to 100 per cent, with an expected survival rate of 90 per cent for both systems, after higher mortalities are expected in the first few years. In each year, expected output does not change for each model as downward trends in expected mortality is compensated by lower requirements for fingerlings.

The expected starting farm gate prices are assumed to be $15 a kilogram (live, 350 grams) for the semi-intensive models and $17.50 a kilogram (500 grams) for the intensive recirculation model. However, there is a relatively high degree of uncertainty about both prices. The prices represent the average farm gate price that producers receive for selling live product to distributors. Given the small size of the market currently, any increase in output is likely to put pressure on prices. Consequently, in the model, prices were assumed to fall by 2.5 per cent a year such that after twenty years the most likely price would be close to the lower end of the current range in prices.

While it is recognised that the cost of water will vary between states and regions, in the models the operating and capital costs for water are based on prices set in Victoria in the Goulburn–Murray region. Prices are based on Victorian prices because that state is one of the main producers of farmed Murray cod in Australia.

The cost of a permanent water licence is based on a price of $800 per megalitre. It is assumed that the 5 tonne, 10 tonne and 30 tonne farms use 30 megalitres, 60 megalitres and 5 megalitres of water respectively. The 30 tonne intensive recirculation system uses less water compared with the semi-intensive systems because it recycles the majority of the water used. In addition, it is assumed that 100 per cent of the water licence will be allocated each year and that producers have to pay a fee of $300 to apply for a water licence. The cost of the water used by the producer is based on a price of $6.50 per megalitre plus an annual delivery fee of $66 to the supplier. These prices are based on the prices reported by Goulburn–Murray Water.

A major source of risk for farmed Murray cod is the uncertainty about where it will fit into the market as it has different taste characteristics to wild Murray cod which has an established name in niche markets. Therefore, it is unclear whether farmed Murray cod will receive premium prices in the market place to match those received for wild Murray cod. Also there is uncertainty about the price of Murray cod at higher production levels. To demonstrate the sensitivity of model results to changes in prices, model runs were conducted with a lower and higher farm gate price.

Labor is the largest component of operating costs for all three Murray cod model farms (table 11). For the both the 5 tonne and 10 tonne semi-intensive model farms, labor represents 23 per cent of the total operating costs. For the 30 tonne intensive recirculation model farm, labor represents 21 per cent of total operating costs.

Farming Murray cod semi-intensively and intensively requires a substantial amount of labor to feed the fish, as well as to clean, change and maintain the water in tanks. Because of the cannibalistic nature of the fish, Murray cod also has to be graded every few weeks. Developments in labor saving techniques such as automatic feeding systems may help reduce labor costs. However, manually feeding is advantageous as it allows the farmer to better monitor fish health. To demonstrate the sensitivity of model results to changes

11 Average annual operating costs for the Murray cod farm models

	Semi-intensive		Intensive recirculation
	5 tonnes (annual capacity)	**10 tonnes** (annual capacity)	**30 tonnes** (annual capacity)
	$	$	$
Fingerlings **a**	11 000	22 000	44 400
Feed	10 700	21 400	61 600
Oxygen	–	–	22 500
Rent on oxygen tank	–	–	6 000
Electricity and fuel	12 800	25 500	72 300
Labor			
– owner/manager	15 000	30 000	40 000
– permanent	–	–	35 000
Repairs and maintenance	3 000	5 000	15 000
Packaging	2 600	5 200	15 000
Marketing	5 200	10 400	12 000
Freight	3 100	6 200	18 000
Water	300	500	100
Security	–	–	8 000
Administration	1 000	2 000	10 000
Miscellaneous	1 500	3 000	5 000
Total	66 200	131 200	364 900

a At 60 cents each.

in labor costs, model runs were conducted with labor costs set 25 per cent higher. Labor costs may vary depending on the local availability of labor as well as the level of skill in the local labor force.

Electricity, fingerling and feed costs also contribute a large proportion of operating costs for all models. Semi-intensive and intensive recirculation systems require large quantities of electricity to recycle, aerate and heat the water to allow optimal growth rates to occur. As Murray cod production is still in its infancy with few hatcheries, there may be scope for fingerling prices to decline as the industry develops. To demonstrate the sensitivity of model results to changes in fingerling costs, model runs were conducted with fingerling costs reduced by a third to $0.40 each.

Capital costs for the models are listed in tables 12 and 13. It is assumed that the full cost of all capital items (including land, vehicles and connection to

12 Capital costs for the Murray cod semi-intensive farm models

	5 tonnes (annual capacity)	**10 tonnes** (annual capacity)	**Scrap value**	**Life**
	$	$	%	yrs
Water licence	24 000	48 000	100	20
Water licence application fee	300	300	0	20
Water meter and installation	1 000	1 000	0	10
Land	10 000	10 000	100	20
Road	2 000	2 000	100	20
Backup system / generator	8 000	12 000	10	10
Tanks – growout	2 000	2 800	–	20
Tanks – weaning	6 000	19 200	–	20
Power installation	1 000	1 000	–	20
Buildings	25 000	45 000	–	20
Water pumps and motors	1 900	3 800	10	10
Airblowers	4 000	8 000	10	10
PVC pipes	2 000	4 000	10	20
Boiler	7 000	9 000	10	10
Monitoring and testing kits	1 000	2 000	–	10
Vehicle	30 000	30 000	10	20
Processing and cooling room	2 000	3 500	10	20
Harvesting equipment	200	400	–	10
Office equipment	5 000	5 000	–	20
Miscellaneous equipment	1 000	2 000	–	10
Total	133 400	209 000		

power supply) and all operating costs (including labor) would be incurred when establishing and operating a stand alone Murray cod farm.

Farm model results

It should be noted that currently there is great diversity between production systems for Murray cod that the farm models presented in this study are not able to reproduce. Returns to Murray cod farming will vary considerably between growers depending on the chosen market, product form and management inputs. Therefore, the results of the models should be used to illustrate the main sources of risk and uncertainty facing potential Murray cod

13 Capital costs for the Murray cod intensive recirculation farm model

	30 tonnes (annual capacity)	**Scrap value**	**Life**
	$	%	yrs
Water licence	4 000	100	20
Water licence application fee	300	0	20
Water meter and installation	1 000	0	10
Land	20 000	100	20
Power installation	2 000	–	20
Road	2 000	100	20
Backup pumps and generator	45 000	10	10
Tanks – initial	4 000	–	20
Tanks – growout	76 000	–	20
Drum filter	25 000	10	10
Biological filter	25 000	10	10
Pumps	30 000	10	10
Fractionator	4 500	10	20
Degassing tower	10 000	10	20
Buildings	75 000	50	20
Plumbing	15 000	10	20
Ozone generator	10 000	10	20
Vehicle	30 000	10	10
Oxygen generator	10 000	10	20
Ozone / oxygen reactor	4 000	10	20
Ultraviolet	3 500	10	20
Monitoring and testing kits	20 000	–	10
Office equipment	10 000	–	20
Miscellaneous equipment	5 000	10	10
Total	431 300		

14 Benefit–cost ratios from the Murray cod farm models

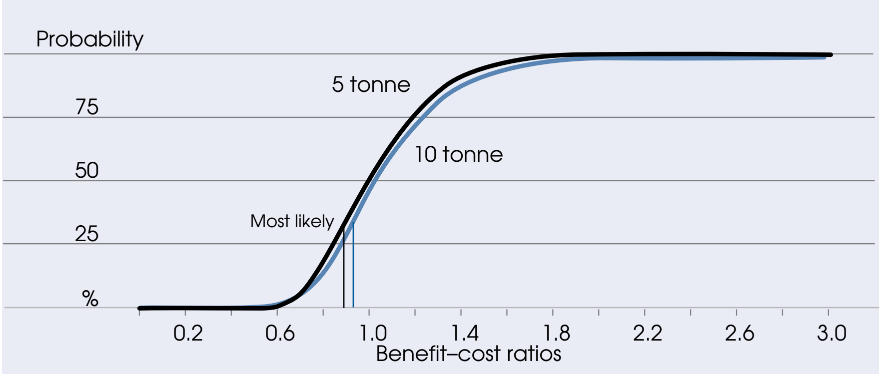
Farm model (annual capacity)	**Most likely BCR**	**90% confidence interval**	**probability of BCR less than 1**
			%
5 tonne farm	0.88	0.73–1.50	50
10 tonne farm	0.93	0.70–1.60	42
30 tonne farm	1.15	0.80–2.01	20

farmers and the potential impacts of these on the probability of new farms becoming viable.

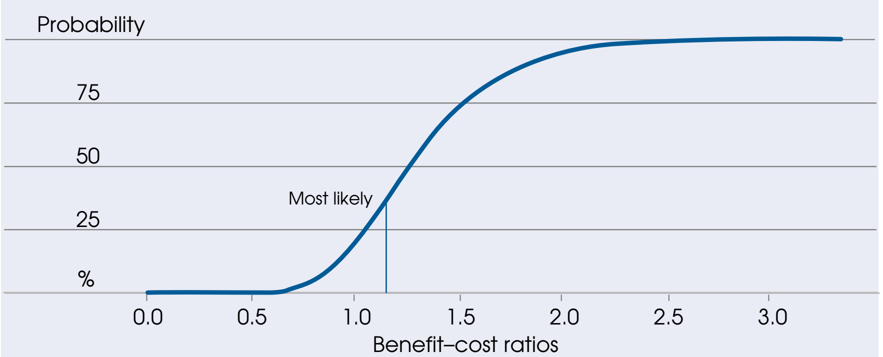
Based on current performance and technology, the results show that Murray cod enterprises based on semi-intensive tank culture producing 5 tonnes and 10 tonnes a year have most likely benefit–cost ratios that are below one, indicating that expected costs are larger than expected benefits (table 14). The results also show that there is only a 50 per cent chance that the benefit–cost ratio for the 5 tonne farm will be above one and a 58 per cent chance that the benefit–cost ratio will be above one for the 10 tonne farm (figure G).

For the 30 tonne intensive recirculation farm, based on current performance and technology, the most likely benefit–cost ratio is greater than one, indicating that expected benefits are greater than costs. However, the estimated benefit–cost ratio of 1.15 may not justify the 20 per cent chance that expected costs are greater than expected benefits and therefore investors may see this farm as only marginally viable (figure H).

G Benefit–cost ratio probability distributions: Murray cod semi-intensive models



H Benefit–cost ratio probability distribution: Murray cod intensive recirculation model



For both the 5 and 10 tonne semi-intensive farms the expected payback period exceeds the twenty year timeframe used in this analysis (table 15). For the 30 tonne intensive recirculation farm the expected payback period is three years. However, analysis of the 90 per cent confidence interval indicates that it is not 95 per cent certain that the 30 tonne farm would recover the initial cash outlay within the twenty year timeframe.

As discussed in the previous section, a major source of risk for farmed Murray cod is the uncertainty about farm gate prices. As an increase in production of Murray cod may place downward pressure on prices, a scenario was developed using the farm models to assess the impact on the viability of farming Murray cod if the farm gate price fell to $9.50 for the 350 gram fish (5 tonne and 10 tonne semi-intensive model farms) and to $10.25 for the 500 gram fish (30 tonne intensive recirculation model farm).

The results show that the viability of Murray cod farming is highly sensitive to the farm gate price and that farming Murray cod would not be viable at low prices. The most likely benefit–cost ratio is less than one for all three models when the farm gate price falls. For the 5 tonne, 10 tonne and 30 tonne farms, there is only a 2 per cent, 3 per cent and a 13 per cent chance, respectively, that the most likely benefit–cost ratio will be above one (table 16).

15 Payback period for the Murray cod farm models

Farm model (annual capacity)	Payback period	90% confidence interval
	yrs	yrs
5 tonne farm	20+	3.5–20+
10 tonne farm	20+	2.5–20+
30 tonne farm	3	1.1–20+

Reflecting the uncertainty about where farmed Murray cod will fit in the market given the different taste to wild Murray cod, a scenario was developed to assess the impact on the viability of farming Murray cod if the farm gate price increased to $21.50 for the 350 gram fish (semi-intensive model farms) and to $22.50 for the 500 gram fish (intensive recirculation model farm).

As can be seen in table 16, if consumers have a positive view of farmed Murray cod in comparison with wild Murray cod (which could result in premium prices being obtained) the expected benefit–cost ratios for all three models are greater than one. This indicates that the three farm models are expected to have benefits greater than costs. The probability of the expected benefit–cost ratio being below one for all three models is low and therefore investors may see these farms as profitable investments.

16 Benefit–cost ratios from alternative scenarios for the Murray cod farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings			
5 tonne farm	0.88	0.73–1.50	50
10 tonne farm	0.93	0.70–1.60	42
30 tonne farm	1.15	0.80–2.01	20
Low price outcome			
5 tonne farm	0.56	0.44–0.93	98
10 tonne farm	0.59	0.48–0.97	97
30 tonne farm	0.68	0.48–1.20	87
High price outcome			
5 tonne farm	1.26	1.10–2.00	4
10 tonne farm	1.33	1.07–2.13	3
30 tonne farm	1.48	1.10–2.67	3
Lower fingerling costs			
5 tonne farm	0.92	0.70–1.60	45
10 tonne farm	0.97	0.75–1.64	40
30 tonne farm	1.18	0.80–2.33	20
Higher labor costs			
5 tonne farm	0.84	0.61–1.37	70
10 tonne farm	0.89	0.70–1.60	50
30 tonne farm	1.11	0.70–2.01	22

A third scenario evaluated the effect on the viability of farming Murray cod of lowering the price of fingerlings by a third to $0.40 each. The results from the scenario show that for the 5 tonne and 10 tonne model farms, the most likely benefit–cost ratios, while slightly improved from the base model, would still be less than one. The most likely benefit–cost ratio for the 30 tonne farm was above one. However, there is a 20 per cent chance that costs will be greater than benefits (table 16).

Finally, as labor is the largest operating cost for all three Murray cod farm models, a scenario was developed to assess the effects on viability if labor costs rose by 25 per cent. The results from the scenario (table 16) show that for the 5 tonne and 10 tonne model farms, the most likely benefit–cost ratios are less than one and lower than those for the standard settings. The most likely benefit–cost ratio for the 30 tonne farm was above one but there is a 22 per cent chance that costs will be greater than benefits.

Concluding comments

At the current level of performance and technology, the results from the analysis indicate that Murray cod farming does not appear to be viable for the 5 tonne and 10 tonne semi-intensive farms and only marginally viable for the 30 tonne intensive recirculation farm. However, while the results show that expected benefits are greater than costs for the 30 tonne farm, there is a high degree of risk about these results. Therefore, given the level of associated risk, investors may be unwilling to invest in a Murray cod intensive recirculation operation of this size. However, ultimately this will depend on the investors' attitude to risk.

In all cases for the semi-intensive model farms, the farming of Murray cod is more risky for the smaller farm relative to the larger farm, indicating that economies of scale can be achieved. Savings may be made in areas such as transport, marketing and input costs as larger quantities will be bought and sold.

The results from the analysis show that returns to Murray cod farming are sensitive to the farm gate price, the cost of fingerlings and labor costs.

Referring to price, if consumers take a positive view of the taste of farmed Murray cod in comparison with wild Murray cod and premium prices can be obtained at current production levels then the results show that all three farms would be viable, with expected benefits greater than costs.

However, the results suggest that farming Murray cod semi-intensively producing 5 tonnes and 10 tonnes a year and intensively producing 30 tonnes a year may not be viable in the long run with the prospect of falling farm gate prices. As discussed, Murray cod is currently sold in small niche markets such as restaurants. However, this market is limited. Also, restaurants can be transient customers as they constantly seek new products and regularly change their menus. Therefore, unless the market for Murray cod expands, an increase in production of Murray cod is likely to place downward pressure on farm gate prices.

However, price declines may be partially offset with productivity improvements such as improvements in yields, feed conversion ratios and selective breeding, or by lower input costs such as fingerling costs. The results showed that the most likely benefit–cost ratios improved for all three models when the cost of fingerlings decreased (even though for the 5 tonne and 10 tonne farms the expected benefit–cost ratio was still below one).

While the results from the standard settings suggest that the 5 tonne and 10 tonne semi-intensive specialised Murray cod farms may not appear viable, integrating Murray cod production with agriculture or horticulture has the potential to improve returns because capital costs such as land and some machinery can be shared and the waste water from the fish operation could be used for irrigation.

5

Mussels

The Australian mussel aquaculture industry is based on the production of the blue mussel (*Mytilus edulis planulatus*), which is the only marine mussel species farmed in Australia. This species is found in the temperate waters of both the northern and southern hemispheres. The blue mussel is thought to have been introduced to Australian waters as fouling attached to the hulls of ships and subsequently established itself along the southern coasts of Australia, from Cape Hawk on the east coast to Fremantle on the west coast, including the waters around Tasmania. They also inhabit New Zealand waters (Primary Industries and Resources, South Australia 1999a).

Mussels were traditionally harvested from the wild by dredging or by divers. However, growing environmental concerns during the 1980s led to dredging being phased out and aquaculture of mussels became the main source of production.

Mussel farming is a well established industry in many parts of the world, with the most common species cultured being the blue mussel. The main producers of mussels include China, Korea, Spain, the Netherlands, Denmark, France and New Zealand. In 1997, world production of mussels was 1.1 million tonnes. China, the largest producer of mussels, produced approximately 400 000 tonnes in the same year (Beasley and Maguire 2000).

In the Pacific region, New Zealand is the largest mussel producer, exporting greenlip mussels to Australia. Imports from New Zealand, at 2473 tonnes and $8 million, in 1998-99 were roughly double Australian aquaculture production of mussels, which accounts for almost all Australian mussel production. Australian production, of 1297 tonnes in 1998-99, was made up of 679 tonnes in Western Australia, 534 tonnes in Victoria, and 84 tonnes in South Australia. While New Zealand producers are reported to have lower average costs than Australian producers, prohibition on imports of live mussels from New Zealand (AQIS, Condition C8910, AQIS website, 21 July 2000) offers a market opportunity for Australian mussel growers.

The dominant mussel farming technology used in Australia is the longline system — horizontal ropes with buoys to provide flotation, with vertical droppers attached every 1–4 metres, depending on site conditions. Longlines are used for spat collection as well as for ongrowing juvenile mussels to market size and most large farms are increasingly automating their reseeding and harvesting (New South Wales Fisheries 1999a).

Mussel spat are generally collected from wild populations because of the ready availability of wild spat. Hatching production is technically possible but is generally not necessary or commercially viable because of the relatively low value of mussels and the low cost alternative of wild spat collection. When the mussels are still small, they are reseeded, a process that involves passing droplines through a declumping machine before the spat are fed through a funnel and onto a growout rope evenly and in smaller numbers to encourage further growth. These processes, as well as harvesting, cleaning and bagging are becoming increasingly mechanised, following the New Zealand example. However, the labor requirements for mussel farming in Australia are still generally very high (New South Wales Fisheries 1999a).

Market outlook

The majority of mussels produced in Australia are currently sold domestically through local wholesale markets, at the farm gate or directly to restaurants as live product. Consumption is concentrated in capital cities and coastal centres. On the domestic mussel market, farmed mussels compete with small quantities of commercial dive mussels, as well as other seafood products. Products such as oysters, scallops, smoked salmon and prawns all compete with mussels especially as entrée courses in restaurants (Victorian Aquaculture Council 1999a).

Australian mussel producers also compete for domestic market share with New Zealand producers. Over recent years, mussel imports, largely from New Zealand, have increased considerably. In the five years from 1994-95, Australian imports of mussels increased by 15 per cent (figure I). In 1998-99, Australia imported 2500 tonnes of mussels valued at almost $8 million, the majority of which were imported from New Zealand (Australian Bureau of Statistics 2000).

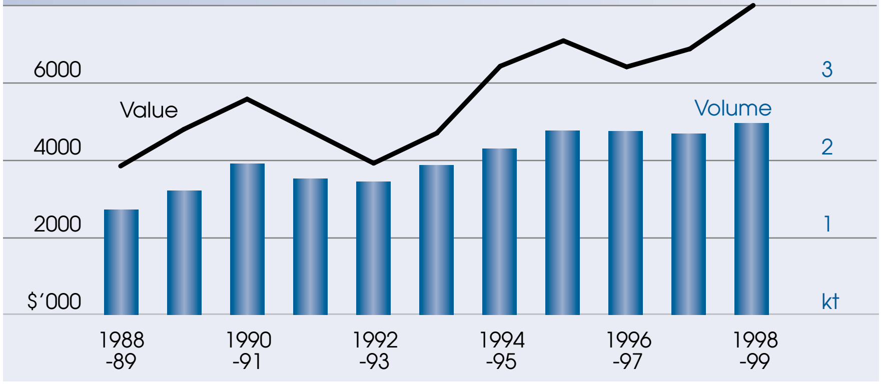
The recent increase in imports of green mussels from New Zealand is attributable mainly to lower prices per unit weight of green mussels compared with domestically produced mussels. However, prohibition of live mussel imports into Australia to prevent the potential translocation of disease and pests to Australia may have limited the extent of competition that Australian mussel producers have been exposed to from New Zealand mussel growers. This has produced a tendency toward value added product by New Zealand exporters to Australia, such as vacuum packed mussels with herbs and spices added.

An expected initial price of $2.05 a kilogram is used in the farm model to account for transport (which varies by location) and packaging costs, though market commission is not subtracted on the assumption that the bulk of producers would be able to arrange sales with wholesalers outside the market.

Some producers currently receive substantially higher prices through niche marketing. This may involve supply of graded and cleaned product direct to the public on wharves or direct to restaurants. There are reports of up to $7 a kilogram for high quality product through such means. However, such methods would result in additional costs, and it is questionable whether the price premiums would be maintained if new producers followed suit.

Expansion of Australian mussel production may have a number of impacts. With unchanged demand, prices for live mussels can be expected to fall with increasing supply. However, expansion of supply from a very small base may also increase consumer awareness, expanding demand for live mussels as an inexpensive, fresh seafood product. An industry with substantial and consistent supplies provides the opportunity for supermarkets and restaurants to offer Australian mussels as a standard product. The opportunity to replace imports on the domestic market will be constrained by continued low cost mussel imports from New Zealand. As a result there is little prospect for rising prices.

I **Australian imports of mussels**



Product forms available on the domestic market include wholeshell live, fresh, mussel meat frozen, half shell, processed (jars, canned, crumbed, marinated, vacuum packed) and bait. However, imports make up the bulk of these forms, with Australian produced mussels being sold either live or as bait.

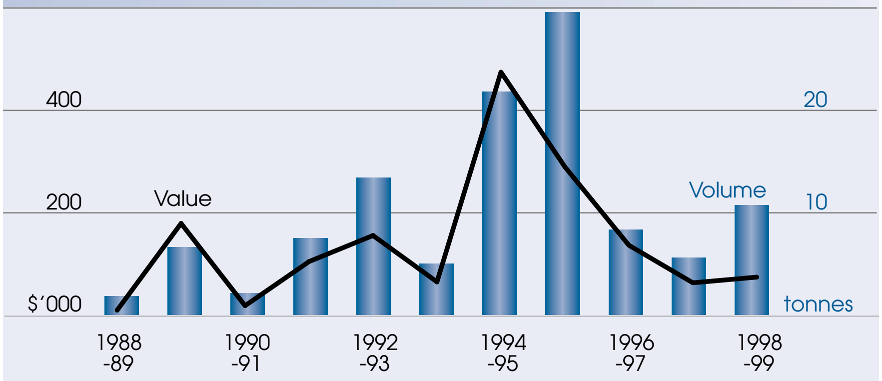
Value adding by Australian mussel producers is still generally limited to the cooperative grading and distribution of live mussels, though a limited amount of small scale processing is starting in Victoria. However, it is questionable whether inputs of Australian mussels can compete in the long run with lower priced New Zealand inputs.

The potential to export mussels from Australia seems limited. This is because, with the low prices per unit weight received for mussels worldwide, the transport costs associated with exporting live product may price Australian mussels out of the market.

While exports of mussels increased sixfold over the ten years ended 1998-99, less than 1 per cent of Australia's mussels are exported. In 1998-99, Australia exported 10.7 tonnes of mussels worth approximately A$73 200 (figure J). Australian mussels are exported as live, fresh or chilled product, frozen, and dried salted or in brine. The major export market for Australian mussels is Singapore, which accounted for 38 per cent of Australian exports of mussels in 1998-99 (Australian Bureau of Statistics 2000).

Europe is by far the largest market for mussels, but competition from European and Asian producers as well as European tariff barriers may effectively prohibit Australian producers from entering the market. North America

J Australian exports of mussels



also supports a sizable market for mussels, but production in the United States is growing to meet this demand. In addition, US sanitation standards would apply, which may add considerably to the production costs of mussels for export to that market.

Mussel farm models

Two farm models were constructed for mussels. One had a most likely output of 100 tonnes a year, while the other most often produces 200 tonnes. The two sizes can help to demonstrate the effect of economies of scale in mussel farming — when output doubles, costs tend not to. The key characteristics of the farm models are given in table 17.

The mussels are farmed using longline technology. The molluscs grow directly on lines (droplines) that hang vertically from horizontal lines (longlines) supported at or slightly below water level by buoys along their length. Moorings at either end hold the system in place. Harvest takes place in the models over a period of a number of months between 12 and 18 months from initial socking of spat onto droplines (though collection of spat takes place prior to this). The mussels at harvest are between 65 and 100 millimetres long, and weigh 25–45 grams, of which 22–40 per cent can be recovered as cooked meat.

Site location is a crucial element in the establishment of a mussel farm as characteristics of waterways can affect the profitability of a site. Bivalve leases require sufficient water flow to dilute effluent, to provide a flow of suspended food, to ensure that dissolved oxygen levels are adequate and to

17 Key characteristics of the mussel farm models

	Unit	Most likely	Range
Size at harvest	mm	na	65–100
Whole weight	g	na	25–45
Cooked meat recovery	% whole weight	29	22–40
Product form		whole, live	
Growout time	months	na	12–18
Survival rate	%	77	0–100
Total farm production (100 tonne farm)	t/yr live	100	0–130
Initial farm gate price	$/kg	2.05	1.50–2.80

Technology assumptions: 70 metre double-backbone longline per 10 tonnes planned production.
Site requirements: Clean water, deep, sheltered (with current), nutrient rich. **na** Not available.

prevent solid wastes from building up on the seabed below. Sheltered waters are also a requirement as sites with excessive wave action can be disadvantaged as the mussels are more susceptible to dropping off the ropes. Another important factor is the location of a farm in relation to other mussel farms. Farms that are located on the edge of the site are likely to have higher yields as they benefit from receiving the nutrients flows first than a farm that is in the middle of a site and surrounded by other farms that receive the nutrient flows first.

The capital costs in the model are based on the assumption of ten double-backbone longlines 70 metres long being used for the smaller farm, and twenty for the larger. However, this capital requirement depends on the characteristics of the sites. Calmer, more nutrient rich waters may allow substantially higher stocking densities, with consequent lower longline costs.

The most likely (or planned) output is 100 tonnes from the smaller farm and 200 tonnes from the larger farm, although because of substantial chances of loss each year (due to storms, pollution, etc) the mean (or expected) output is lower than this. The initial expected output is 84 per cent of planned output, though this rises first quickly to 88 per cent in the third year of output, and then slowly to 95 per cent in the twentieth year. This trend is based on assumed improvements in farmer knowledge of techniques and the particular site, as well as gradual improvements in techniques and equipment design as rigs are replaced over time. Modeled output in any particular year can range between 0 and 130 per cent of planned output.

The price in the model is assumed to be constant across the harvesting season, though in reality, this will vary depending mainly on quality (size, meat recovery) and supply in the market. The expected initial farm gate price is $2.05 a kilogram, though this can differ substantially between locations because of transport costs of heavy live product. Sites close to Sydney or Melbourne may receive much higher farm gate prices than sites in remote parts of Western Australia.

A very slight upward trend to $2.17 a kilogram in year 10 is expected. However, there is uncertainty about price movements, as discussed in the market section, because of limited current consumer awareness of live mussels, and uncertain long term trends in preferences. For instance, in year 10, there is a 25 per cent chance that the annual expected price is above $2.40 a kilogram and a 5 per cent chance that this price is above $2.85 a kilogram in the model. On the other hand, in the model there is a 25 per cent chance that annual expected price is below $1.88 a kilogram and a 5 per cent chance that this price is below $1.58 a kilogram.

Labor makes up the bulk of operating costs (approximately 85 per cent) in both sizes of operation (table 18). Labor requirements are high for the processes of socking spat onto droplines, defouling and harvesting. However, the requirements for these processes can vary between sites as well as between techniques and technologies employed. In the large New Zealand industry, for instance, there is a great deal of mechanisation of these processes. It may be that over time technology can be adapted affordably to the smaller Australian operations.

18 Average annual operating costs for the mussel farm models

	100 tonne farm	200 tonne farm
	$'000	$'000
Total labor	120.0	180.0
Licences	4.3	4.3
Repairs, maintenance	5.0	8.0
Rates	0.6	0.6
Electricity	1.0	1.2
Fuel	4.8	9.6
Other	1.2	2.2
Accountant	1.0	2.0
Insurance	3.2	4.2
Total	141.0	212.0

The total capital investment is $258 000 in the smaller farm and $402 000 or 56 per cent higher for the larger farm with double the output (table 19). Operating costs also increase by only 50 per cent in the move to the larger farm. The impact of the economies of scale shown here are an important driver of the results reported in the next section.

The largest capital cost item is in boats. While a number of combinations may be possible, particularly for larger farms, the minimum requirement is a stable platform including machinery and hydraulic lifting gear.

Another large investment is in land, assumed to be $50 000 in the small farm and $60 000 in the large farm. Of course, the cost of land

19 Capital costs for the mussel farm models

	100 tonne farm	200 tonne farm	Scrap value	Life
	$'000	$'000	%	yrs
Land	50	60	100	
Longlines	43	86	0	5
Boats	90	142	10	10
Shed	30	40	50	20
Coolroom	7.5	7.5	50	10
Vehicles	21	45	20	10
Pallet jack/ forklift	0.5	5	20	10
Workshop equipment	10	10	10	5
Computer	2	2	10	5
Other, incl. office	4	4	10	10
Total	258	402		

will vary significantly depending on the location, though reasonably easy access to boat ramps is important. Longlines, including moorings, ropes and floats are also a substantial proportion of costs and require regular replacement.

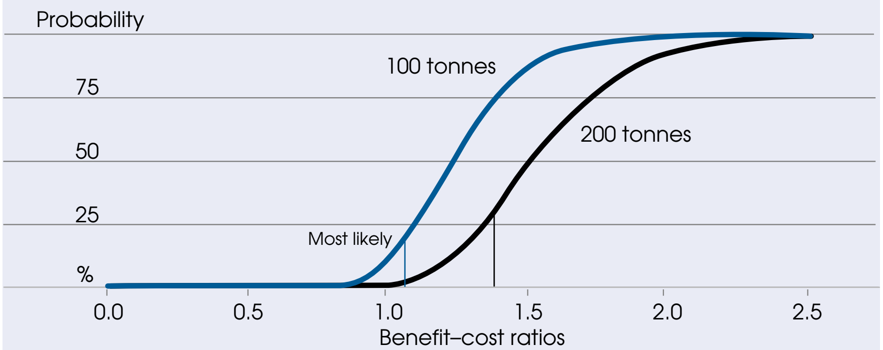
Farm model results

Results for the standard settings of the model are presented in table 20 and in figure K. The most likely benefit–cost ratio is 1.07 for the 100 tonne farm and 1.39 for the 200 tonne farm, indicating that both farms are expected to have benefits greater than costs. The larger farm also has a much smaller chance of producing benefits that are less than costs (2 per cent chance, rather than 10 per cent).

For the 100 tonne farm, the expected payback period is seventeen years, while for the 200 tonne farm the expected payback period is seven years (table 21). The 90 per cent confidence interval indicates that it cannot be assumed (with 95 per cent probability) that either farm will recover the initial cash outlay in the twenty year timeframe.

A major source of risk facing mussel farming is the uncertainty about future prices for Australian live mussels. As a consequence, scenarios were run to determine the impact of an increase and decrease of the farm gate price on farm viability. Results are shown in table 22 for a run with all prices 25 per cent higher than the standard settings, as well as a run with prices 25 per cent lower than standard settings. These results may also be a useful indicator for

K **Benefit–cost ratio distributions: 100 and 200 tonne mussel farm models**



20 Benefit–cost ratios from the mussel farm models

Farm model (annual capacity)	**Most likely BCR**	**90% confidence interval**	**Probability of BCR less than 1**
			%
100 tonne farm	1.07	0.87–1.63	10
200 tonne farm	1.39	1.07–2.06	2

potential operators who will receive different farm gate prices because of location that can influence transport costs significantly.

As may be expected, the impacts of these changes are quite significant. In the low price scenario, neither operation is an attractive investment, and it would take substantial cost savings (perhaps through a much larger operation) to allow a viable business. In the larger farm, benefits are expected to marginally exceed costs, although there is a 22 per cent chance that they will not do so. In the smaller farm, costs are expected to outweigh benefits.

On the other hand, in the high price scenario, both farms have both much higher benefit–cost ratios and almost negligible risk of loss.

Another group of scenarios that is tested is a different set of labor costs, which make up the bulk of operating costs. With higher labor costs, the smaller farm becomes clearly nonviable, with a most likely benefit–cost ratio less than one (table 23).

Because labor is a substantial component of costs, variability in labor costs can have a big impact on profitability. The scenarios of lower labor costs demonstrate the benefits of finding efficiencies in production. The small farm, which is marginal at standard settings, is clearly profitable and has relatively low risk in the scenario with 25 per cent lower labor costs. However, capital costs have not been increased in this scenario, and it may be that the capital costs necessary to produce such savings are substantial. In the larger farm, the labor savings simply increase the

21 Payback period for the mussel farm models

Farm model (annual capacity)	**Payback period**	**90% confidence interval**
	yrs	yrs
100 tonne farm	17	5.5–20+
200 tonne farm	7	3–20+

22 Impact of alternative prices on the mussel farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings ($2.05/kg initial expected)			
100 tonne farm	1.07	0.87–1.63	10
200 tonne farm	1.39	1.07–2.06	2
Low price outcome ($1.53/kg initial expected)			
100 tonne farm	0.80	0.69–1.25	69
200 tonne farm	1.04	0.85–1.59	22
High price outcome ($2.56/kg initial expected)			
100 tonne farm	1.33	1.12–2.08	1
200 tonne farm	1.73	1.40–2.60	0

most likely benefit–cost ratios, and result in negligible risk of losses under model settings.

As has been mentioned, mussel farming requires very particular sites. Not only are deep, sheltered waters required, but also currents and nutrient rich conditions are necessary. Very nutrient rich waters can result in growing times of as little as six to eight months, rather than twelve to eighteen months, although in the extreme, nutrient rich waters can cause excessive fouling and

23 Impact of alternative labor costs on the mussel farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings			
100 tonne farm	1.07	0.87–1.63	10
200 tonne farm	1.39	1.07–2.06	2
Higher labor costs (25 per cent higher than standard)			
100 tonne farm	0.91	0.80–1.48	30
200 tonne farm	1.18	1.00–1.85	5
Lower labor costs (25 per cent lower than standard)			
100 tonne farm	1.29	0.05–1.92	4
200 tonne farm	1.67	1.28–2.45	0

24 Impact of alternative yields on the mussel farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings			
100 tonne farm	1.07	0.87–1.63	10
200 tonne farm	1.39	1.07–2.06	2
Low yield (25 per cent lower than standard)			
100 tonne farm	0.80	0.68–1.25	70
200 tonne farm	1.03	0.82–1.58	25
High yield (25 per cent higher than standard)			
100 tonne farm	1.34	1.12–2.10	1
200 tonne farm	1.73	1.40–2.60	0
High yield, high labor cost (25 per cent higher yield and labor cost than standard)			
100 tonne farm	1.13	0.92–1.72	12
200 tonne farm	1.47	1.13–2.20	1

the risk of algal bloom damage. Poorer conditions, on the other hand, can result in much lower yields. Scenarios are reported in table 24 of 25 per cent higher and 25 per cent lower yields, as well as 25 per cent higher yield and labor cost.

In the low yield scenario, even the larger (more profitable) farm has benefits expected to only slightly exceed costs, with a very high chance of them not doing so. In the high yield scenario, both farms are expected to be profitable, and have very low risk of losses. This is a significant result, indicating the value of finding appropriate sites — a process that may involve testing, as well as small scale trials. However, this result should be treated with some caution, as some increases in labor (and other) costs can be expected with higher yields.

The results of the scenario that includes a 25 per cent increase in both yield and labor costs indicate that the improvement in this case would be much smaller — with the small farm still having a 12 per cent chance of losses.

Concluding comments

The results from the analysis indicate that mussel farming appears to be viable for both the 100 tonne and 200 tonne farm sizes at the current level of performance and technology. While the results show that expected benefits are greater than costs for both farm sizes, the larger farm provides a greater benefit and it takes less time for the initial cash outlay to be recovered than for the smaller farm. In addition, there exists a high degree of risk surrounding the benefit–cost ratio of the smaller farm.

As farming mussels is more risky for the smaller farm relative to the larger farm and the benefit–cost ratio is higher for the larger farm, this indicates that economies of scale can be achieved.

The results from the models show that a major source of risk facing mussel production is the uncertainty about future prices for Australian live mussels. As discussed in the market outlook section, substantial expansion in the production of mussels in Australia may have a number of impacts. With unchanged demand, prices can be expected to fall with increasing supply. The results show that neither farm size is viable when the price is 25 per cent lower than the base price assumption.

However, expansion of supply from a very small base may increase consumer awareness and therefore expand demand for live mussels as an inexpensive fresh seafood product. An industry with substantial and consistent supplies provides the opportunity for supermarkets and restaurants to offer Australian mussels as a standard product.

Operating costs are another important factor in determining the viability of mussel farming. The scenarios of lower labor costs demonstrate the benefits of finding efficiencies in production. Efficiency in farming practices therefore plays an important part in determining the profitability and minimising risk. A shift to a more capital intensive (labor saving) mode of production may be a useful direction for mussel farmers to take, although this may be difficult for small producers.

The results also emphasise the importance of sites in mussel farming. Different sites have different yields that can result in substantially different benefit–cost ratios and risk outcomes. For instance, at some sites, risk is increasing from the growing frequency of toxic algal blooms caused by decreasing coastal water quality in the vicinity of urban centres. Algal blooms cause the mussels to develop a bitter taste and therefore prevents sales.

Finally, given the large variation between sites and styles of operations, the results for mussels should not be interpreted as indicative of the risks or benefits and costs of any farm in particular. Rather, the results should be used to inform an understanding of the interactions that are important in determining risk and net benefit from mussel farming.

6

Silver perch

Silver perch (*Bidyanus bidyanus*) is an Australian native freshwater fish occurring naturally in the Murray Darling river system and in south eastern Queensland. The abundance and distribution of silver perch in the wild have decreased since the early 1980s as a result of habitat destruction and overfishing, to the point where it is has been given the conservation status of 'potentially threatened' by the Australian Society of Fish Biology (Rowland and Bryant 1995).

In 1916, silver perch was recognised as a potential candidate for aquaculture but it was not until 1965 that New South Wales Fisheries began research on this species. Commercial production of silver perch commenced in the early 1990s (New South Wales Fisheries 1999b). Silver perch has a number of characteristics that make it a suitable fish for aquaculture. These include its ability to be raised in high densities because of its noncannibalistic nature, its willingness to accept artificial foods and high survival rates (over 90 per cent) (Ivey ATP 1995).

New South Wales and Queensland are the largest producing states, producing 134 tonnes and 27.5 tonnes of silver perch respectively in 1997-98 (New South Wales Fisheries 2000; Lobegeiger 1999). Production of silver perch does occur in Victoria and South Australia but, to date, quantities have been negligible. Currently, small scale and pilot enterprises are being developed in Western Australia.

The silver perch industry is characterised by a large number of licensed operations; however, only a small minority are currently growing substantial volumes of fish and hence aggregate production has been low.

The main method for silver perch cultivation is in aerated purpose built ponds in extensive or semi-intensive farming systems. Currently some growers are experimenting with intensive recirculation tank system farming but to date results have not been conclusive. The advantage of silver perch culture is that the hatchery industry has been established for many years to supply the fingerlings for stocking into farm dams. This has meant that the supply of fingerlings has not been an impediment to the developing industry. However, in response to the decline in abundance of silver perch in the wild, a prohibition on the capture of the fish from the wild in New South Wales was introduced in 1998. As a consequence of this prohibition the availability of broodfish is limited. In the future, potential shortages of broodfish could increase the chance of inbreeding and therefore reduce the quantity and quality of fingerlings (New South Wales Fisheries 1999b).

The cost of feed is also a critical influence on the prospects for the silver perch industry. Silver perch require low protein diets, with most feeds available based on a protein content of around 35 per cent. Current feed formulations have an average of 27 per cent fish meal, which is the most expensive input. Research is currently underway to substitute the fish meal component of feeds. Food conversion ratios (FCR) for silver perch are generally in the range 1.5–2.0, often depending on the farmers' experience and husbandry practices (New South Wales Fisheries 2000).

Market outlook

Domestic market

Currently almost all of Australia's production of silver perch is consumed domestically. Markets for silver perch are divided into the premium live fish market, the fresh chilled market and the fillet market. The main product forms include:

- large whole fish for Asian 'shared plate' dining, mostly sold live, ranging from 500 to 1000 grams;
- chilled whole fish for non-Asian cuisine, mostly sold to retailers with the size of the fish ranging from 400 to1000 grams;
- chilled plate sized fish 'for one', for western or eastern cuisine, mostly sold whole, or some gilled and gutted for western restaurants, with the size of the fish ranging from 350 to 500 grams; and
- fillets, mostly for western style restaurants: 100–200 grams from fish 400–800 grams (Ruello and Associates 1999).

To date, the marketing of silver perch has been targeted mainly at the live fish trade, which accounts for approximately 75 per cent of output. Chilled whole silver perch represents 20 per cent of production and other product forms such as gilled and gutted fish or fillets represent only a small proportion of the industry's output. Sydney is the major market for silver perch, followed by Brisbane and Melbourne (Ruello and Associates 1999).

Demand for silver perch is dominated by Asian consumers (mainly Chinese) buying the fish from live tanks in restaurants and chilled fish from retail outlets. The demand for silver perch is essentially uniform throughout the year, but as with seafood generally there is noticeably increased demand for live and fresh fish during the week leading up to Christmas and New Year (western and Chinese).

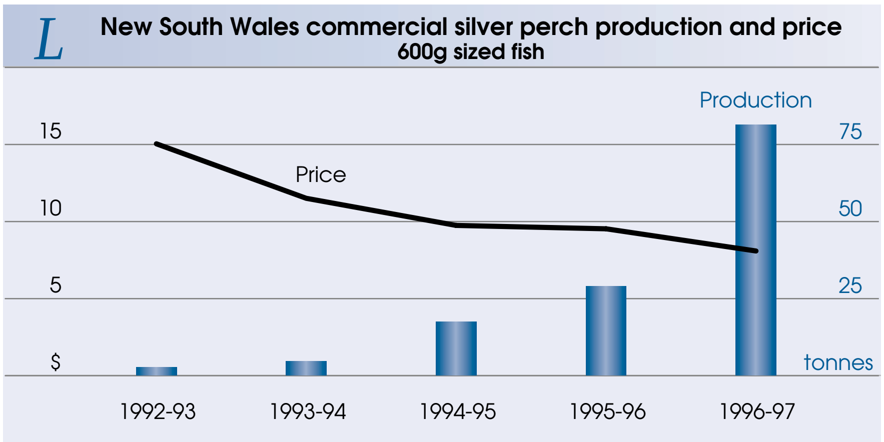
While silver perch has been well received by Asian consumers, it is not widely known in the mainstream fish/seafood market and restaurants outside of the Asian community where there is low consumer awareness of the fish. It is not as popular as other inland water species to the general community and hence only small quantities have been sold on the fresh fish markets such as in Sydney and Melbourne (Ruello and Associates 1999).

Prices for silver perch vary between markets and product form. The farm gate price of silver perch sold live to restaurants ranged from $8.50 to $9.00 a kilogram for a 500–600 gram fish; however, some producers receive up to $15 a kilogram for small quantities. Retail prices are in the range $20–45 a kilogram. Chilled product sold for an average farm gate price of $7.50 a kilogram (in the range $5–8 a kilogram) for a 500 gram silver perch and for a retail price of $11.50–12.50 a kilogram.

Although some producers are obtaining high prices for live silver perch sold in niche markets, such as to expensive restaurants, this market is limited. Also restaurants require only a small amount of product. Therefore as the production of silver perch increases it is unlikely that these prices will be sustained. In addition, such restaurants are perhaps the most transient of customers as they are constantly seeking new products and change their menus regularly.

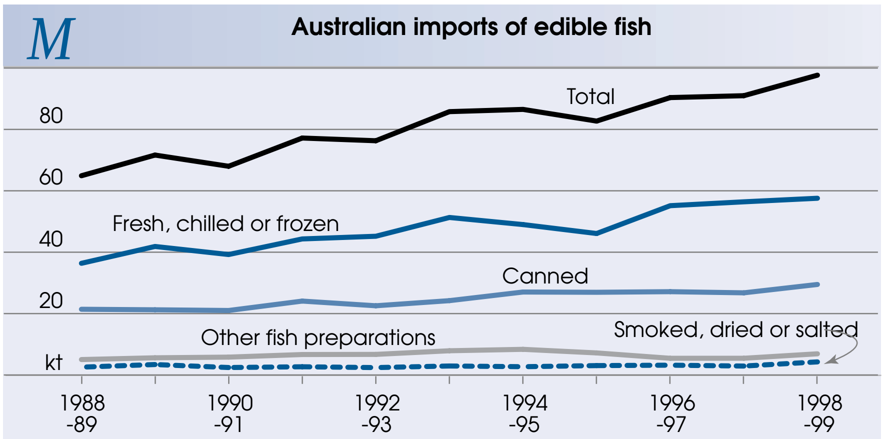
An increase in the volume of production of silver perch may place downward pressure on farm gate prices as producers compete for market share (figure L) (New South Wales Fisheries 1999b). According to some researchers, in the long run the silver perch industry could grow to produce 10 000 tonnes of fish a year (Rowland 1998). However, this could cause domestic prices to fall considerably and substantial export markets would be needed to absorb such production.

The demand for silver perch is influenced by the availability and prices of other fish. Golden perch in particular, a favorite among Asian communities, is a strong competitor in the market both in the live and chilled fish trade, as



is snapper and barramundi in the non-Asian segments of the market as well as the Asian segment. Snapper and barramundi represent the greatest competition to silver perch in the medium to long term because they both have a widely known and well regarded name and appeal across all ethnic groups in Australia. In addition, they can also be grown to sizes where fillets and even cutlets can be produced (Ruello and Associates 1999).

Silver perch producers also face competition from finfish imports. In 1998-99, Australia imported almost 98 000 tonnes of edible fish valued at $441 million. A large proportion of fish imports into Australia are low value products. Over the decade ended 1998-99, Australian imports of edible fish increased by 51 per cent, with fresh, chilled or frozen products increasing by 59 per cent (figure M) (ABARE 2000).



In addition, the industry must compete with a large and increasing supply of cultured freshwater fish, particularly in Asia where production costs are low. Farming of freshwater finfish dominates world aquaculture production, with production of carp and tilapia reaching 11 million tonnes in 1995 (FAO 1997).

Large scale marketing and promotion of silver perch has not yet been undertaken because of the limited supply of fish (Rowland 2000). The marketing of silver perch is generally undertaken by individual producers dealing either direct to restaurants, retailers and wholesalers or with live fish specialist distributors. However, more recently there have been some joint marketing initiatives by several groups of farmers working under various arrangements.

For example, a group of growers located near Gloucester in New South Wales operates as a cooperative and shares a small processing facility. The cooperative has the advantage of allowing producers to deliver both quantity and continuous supply, therefore allowing them to target larger markets. Economies of scale can also be achieved in both buying farm equipment and supplies, and marketing.

One of the issues that could hinder the future development of the silver perch industry is the variability in product quality. Silver perch has a tendency to develop a muddy flavor. This occurs as a result of fatty tissues in the flesh absorbing compounds released by the blue green algae in the culture ponds. The off flavor is removed by purging the fish in clean water for 3–21 days, depending on the extent of tainting.

The sale of unsatisfactory, earthy tasting fish by some growers who do not purge their fish can damage the trade image and reputation of silver perch established by other producers who purge their fish, therefore hindering the market potential of the fish. Currently there are no industry standards or quality assurance brands that can guarantee that the fish has been purged. Consumption is unlikely to grow if this is not rectified.

In New South Wales, the silver perch industry is in the process of developing a quality assurance program that is aimed at ensuring the food safety and taste quality of the product.

Another issue that could affect the image of silver perch is the ‘dumping of road death fish’ (from the live fish trade) or other inferior product onto the auction markets. This poor quality fish affects the image of the fish species and works to the detriment of the farmer selling good quality fish in this marketing channel (Ruello and Associates 1999).

To date the silver perch industry has been production driven and because it is a relatively unknown and untried freshwater fish, it will require trade and consumer education as well as promotion and branding to facilitate market entry and assist market growth.

Export markets

Export markets for silver perch while still relatively unexplored are currently limited by the current price of silver perch and the lack of substantial supply as well as the variability in quality. In addition, silver perch is relatively unknown and untried in overseas markets and therefore may take some time to gain market acceptance in the face of competition from lower priced and better known species such as farmed Tilapia and Nile perch.

However, one enterprise does export silver perch on a small scale and other farmers have shipped samples to countries such as Singapore, Hong Kong, China, Japan, Italy, the United Kingdom and the United States (Ruello and Associates 1999).

The industry has also sold several million fry into China, Chinese Taipei, Hong Kong and Singapore. The success in exporting fry is seen as a mixed blessing by the industry as it may give rise to a situation where Australia could be competing in world markets with silver perch produced in other countries.

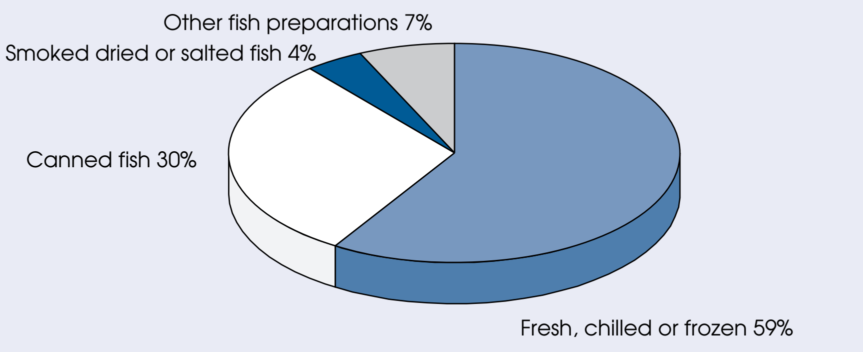
Overseas market entry and development will require investment of financial resources and time that only appears to be within the means of the larger enterprises or groups of growers.

Import replacement potential

The industry has envisaged that silver perch has the potential to replace imports (predominantly in the form of inexpensive frozen white fillets) by becoming an industry that produces high volumes of silver perch at low values (Rowland 1998).

In Australia, demand for inexpensive frozen fillets by the catering/takeaway food service sector is mainly sourced by low value imports. Finfish products

N **Australian imports of edible fish, by composition, 1998-99**



such as fresh, chilled or frozen products contributed 59 per cent to the total value of edible fish imports in 1998-99 (figure N) (ABARE 2000). In the long term it is possible that the average price of some imports into Australia could decline as aquaculture production expands worldwide and overseas producers seek alternative markets.

Frozen hake and hoki, both imported, are the main two species used in the catering/takeaway food service sector. On the wholesale market they sell for approximately $4.50 a kilogram as graded white fillets (table 25). Australia imported over 13 600 tonnes of hake in 1998-99, of which 92 per cent were frozen fillets (ABARE 2000).

25 Wholesale prices of imported fish fillets in Sydney, October 1999

Fish fillet	$/kg
Orange roughy skinless boneless	18.00
Barramundi skinless boneless	11.30
Ling skinless boneless	9.50
Leather jacket skinless boneless	8.00
Red snapper (lutjanidae) skin on	8.00
Smooth dory skinless boneless	7.50
Blue grenadier (hoki) skin on	5.60
Nile perch skinless boneless	5.50
Hake skin on	4.50
Red cod skin on	3.80

Source: Ruello and Associates (1999).

Ruello and Associates have estimated that, in the medium term, silver perch fillets with the skin on could cost $20 a kilogram and therefore it is unlikely that silver perch could replace imported frozen fillets at this price. Consequently, the farm gate price of silver perch would have to fall significantly to be able to compete with imports.

Silver perch farm models

While the silver perch industry is relatively small, the technology for silver perch production is well developed (Rowland 2000). Commercial production is based on extensive and semi-intensive pond based culture. While some enterprises use recirculating filtered water technology to grow silver perch in tanks, as discussed earlier production to date has been negligible and therefore this production system was not examined in this study.

Two farm models were constructed for silver perch. The silver perch models were built based on semi-intensive pond culture and includes the growout operation only (table 26). Farm models of 50 tonnes and 100 tonnes of silver perch have been constructed to demonstrate the effects of economies of scale on silver perch farming.

The production system involves the purchase of fingerlings at 5 grams (at 20 cents each) from which growout takes place. The length of the annual production cycle is assumed to be seventeen months to produce a 600 gram fish for which the average water temperature exceeds 20 degrees Celsius. Survival rates can range from 0 to 100 per cent, with an expected survival rate of 98 per cent, after high mortalities are expected in the first few years. In each year, expected output is 50 tonnes or 100 tonnes, with downward trends in expected mortality affecting fingerling and feed costs.

An expected starting price (farm gate) of $7.50 a kilogram is used in the models; however, there is a relatively high degree of uncertainty about the price. This price is the average farm gate price that producers receive for selling live product to distributors. Given the small, undeveloped market,

26 Key characteristics of the silver perch farm models

	Unit	Most likely	Range
Size at harvest	g live	600	600–800
Product form		whole fish sold live and chilled	
Growout time	months	17	15–18
Initial feed conversion ratio		2:1	1.5:1–2.3:1
Density	5g fingerlings/ha	20 000	
Survival rate	%	98	0–100
Yield	t/ha live	10	0–10
Initial farm gate price	$/kg live	7.5	6.2–8.8

prices are likely to fall as output increases. Consequently, in the model a price fall of 2.5 per cent a year was applied, so that by the end of twenty years the most likely price is $4.60 a kilogram live.

The farm size for the 50 tonne silver perch model farm is assumed to be 12 hectares — 5 hectares of growout ponds (ten ponds at half a hectare each), with the remaining area used for sheds, roadways and channels. The farm size for the 100 tonne silver perch model farm is assumed to be 25 hectares — 10 hectares of growout ponds (twenty ponds at half a hectare each), with the remaining area used for sheds, roadways and channels.

While it is recognised that the cost of water will vary between states and regions, in the models, operating and capital costs for water are based on prices set in New South Wales in the Murray irrigation area. Prices are based on New South Wales prices as that state is currently the largest producer of silver perch in Australia.

The cost of a permanent water licence is based on a price of $400 per megalitre. It is assumed that both farms use 40 megalitres of water per hectare

27 Average annual operating costs for the silver perch farm models

	5 hectare farm (annual capacity)	**10 hectare farm** (annual capacity)
	$	$
Fingerlings **a**	21 400	42 800
Feed	98 100	196 300
Packaging and marketing	47 500	67 000
Freight **b**	15 000	30 000
Electricity and fuel	12 600	25 200
Labor		
– owner/manager	40 000	40 000
– permanent		35 000
– casual	15 000	15 000
Licences, permits and rates	2 000	3 000
Repairs and maintenance	15 000	20 000
Administration	8 000	10 000
Water	5 000	10 000
Miscellaneous	3 000	5 000
Total	282 600	499 300

a At 20 cents each. **b** All sales are domestic, with freight costing 30 cents a kilogram.

and hence the 5 hectare farm and the 10 hectare farm would require a 200 megalitre and a 400 megalitre licence respectively. In addition, it is assumed that 100 per cent of the water licence will be allocated each year and that producers have to pay a fee of $300 to apply for a water licence. The cost of the water used by the producer is based on a price of $25 per megalitre. These prices are based on the prices reported by Murray Irrigation Limited.

Feed is the largest component of the annual operating costs for both silver perch farm models, accounting for 35 per cent for the 50 tonne farm and 39

28 Capital costs for the silver perch farm models

	5 hectare farm (annual capacity)	**10 hectare farm** (annual capacity)	**Scrap value**	**Life**
	$	$	%	yrs
Water licence	80 000	160 000	100	20
Water licence application fee	300	300	0	20
Water meter and installation	1 000	1 000	0	10
Land	50 000	100 000	100	20
Pump	2 000	4 000	10	5
Pond construction	60 000	120 000	–	20
Power on site	50 000	50 000	100	20
Power distribution – ponds	20 000	40 000	100	20
Pipelines	15 000	30 000	–	10
Antibird netting	10 000	10 000	10	3
Purging shed (powered and plumbed)	40 000	60 000	50	20
Backup generator	10 000	15 000	–	20
Pond walkways	6 000	12 000	–	20
Paddle wheels	20 000	40 000	10	5
Automatic feeders	10 000	20 000	–	3
Transport tank	1 000	2 000	10	10
Harvest net	2 000	2 000	–	3
Tanks, biofilter and aeration	20 000	25 000	10	10
Vehicles – 4WD	45 000	50 000	10	10
Water testing equipment	2 500	2 500	–	3
Laboratory equipment	2 500	2 500	–	5
Ice machine	6 000	10 000	10	10
Cool room	3 000	3 000	10	10
Processing room	5 000	5 000	–	20
Office equipment	5 000	5 000	–	20
Miscellaneous equipment	5 000	7 000	–	20
Total	471 300	776 300		

per cent for the 100 tonne farm (table 27). This is based on an initial feed price of $900 a tonne and an initial feed conversion ratio of 2:1, and on the assumption that average mortalities occur halfway through the weight gain. Packaging and marketing is the second largest annual cost, followed by labor.

Total capital investment is only 65 per cent higher for the larger farm even though output is twice the size of the smaller farm (table 28). It is assumed that the full cost of all capital items (including land, vehicles and connection to power supply) and all operating costs (including labor) would be incurred when establishing and operating a silver perch enterprise. This is based on establishing the full scale of the operation immediately whereas in practice there may be advantages in gradual expansion as experience with fish production is gained.

The profitability of silver perch farms is sensitive to changes in price and the cost of feed. To demonstrate the sensitivity of model results to changes in price and the price of feed and to the advantages of sharing capital with an existing agricultural operation, model runs were conducted with these variables changed from the standard settings.

Returns to silver perch farming will vary considerably between growers depending on the chosen market, product form and availability of a number of fundamental requirements including land, water, climate and management inputs. Therefore the results from the models are used to illustrate the main sources of risk and uncertainty facing potential producers and the potential impacts of these on the profitability of new farms being viable.

Farm model results

The results show that a silver perch enterprise producing 50 tonnes a year based on current performance and technology has a most likely benefit–cost ratio of one, indicating that expected benefits are equal to expected costs (table 29). However, the results also show that there is a 20 per cent chance that the benefit–cost ratio will be below one and that there is only a 5 per cent chance that the ratio would be above 1.75. Investors may not see this sized farm as viable as the most likely benefit–cost ratio of one may not justify the 20 per cent chance that costs could exceed benefits.

For the 100 tonne size farm, the results show that production based on current performance and technology the most likely benefit–cost ratio is greater than one indicating that benefits are greater than costs. However, results show

29 Benefit–cost ratios from the silver perch farm models

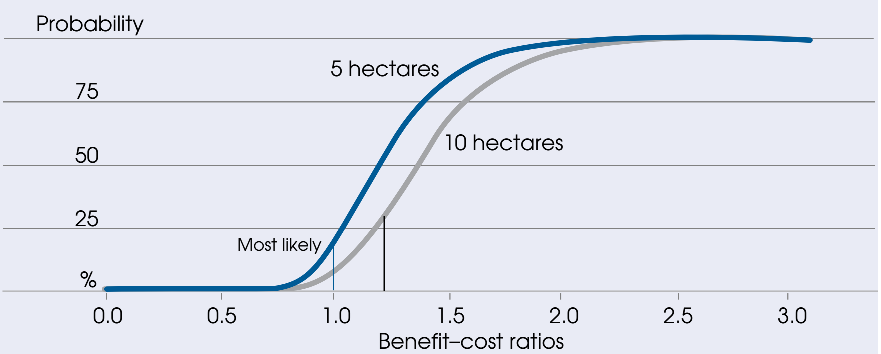
Farm model (annual capacity)	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
5 hectare farm	1.00	0.84–1.75	20
10 hectare farm	1.21	1.00–2.00	9

that there is a 9 per cent chance that the most likely benefit–cost ratio will be below one and that there is only a 5 per cent chance that the ratio would be above two. The models therefore indicate that economies of scale can be achieved in silver perch farming (figure O).

The expected payback period for the 50 tonne farm is twelve years, while for the 100 tonne farm the expected payback period is two years. Analysis of the 90 per cent confidence interval indicates that it is not 95 per cent certain that either farm will recover the initial cash outlay (table 30).

A major source of risk for silver perch farming is the uncertainty about the farm gate price, as discussed in the market outlook section. As an increase in production of silver perch may place downward pressure on prices, a scenario was developed using the farm models to assess the impact on the viability of farming silver perch if the farm gate price fell to $6 a kilogram. The results show that viability of silver perch farming is sensitive to the farm gate price of silver perch. For both farm models the most likely benefit–cost

O Benefit–cost ratio probability distributions: 5 and 10 hectare silver perch farm models



30 Payback period for the silver perch farm models

Farm model (annual capacity)	Payback period	90% confidence interval
	yrs	yrs
5 hectare farm	12	2.5–20+
10 hectare farm	2	1.0–20+

ratio is less than one and would be unviable if the farm gate price was $6 a kilogram (table 31). For the farm producing 50 tonnes of silver perch a year the sensitivity analysis shows that there is only a 45 per cent chance that the most likely benefit–cost ratio will be above one and for the 100 tonne size farm there is a 65 per cent chance that the ratio will be above one.

A second scenario evaluated the effect of a productivity improvement on the viability of farming silver perch by lowering the price of feed for silver perch by a third to $600 a tonne. Currently, research is underway to substitute the fish meal component of feeds for silver perch with locally available agricultural proteins such as lupins, wheat gluten products and meatmeal. This research could assist in lowering feed costs through the replacement of the costly fishmeal component of commercial feeds.

The results from the scenario show that a silver perch enterprise producing either 50 or 100 tonnes a year based on current performance has a most likely benefit–cost ratio greater than one (table 31). However, there is a 15 per cent

31 Benefit–cost ratios from alternative scenarios for the silver perch farm models

Farm model (annual capacity)	Most likely BCR	90% confidence interval	probability of BCR less than 1
			%
Standard settings			
5 hectare farm	1.00	0.84–1.75	20
10 hectare farm	1.21	1.00–2.00	9
Lower price outcome ($6/kg)			
5 hectare farm	0.85	0.70–1.40	55
10 hectare farm	0.97	0.80–1.60	35
Lower feed costs outcome ($600/t)			
5 hectare farm	1.16	0.90–1.90	15
10 hectare farm	1.34	1.00–2.20	5
Sharing capital outcome			
5 hectare farm	1.11	0.90–1.80	17
10 hectare farm	1.25	0.99–2.13	8

chance that the ratio will be below one for the 50 tonne farm and a 5 per cent chance that it will be below one for the 100 tonne farm.

Finally, a third scenario was undertaken to show the impact of sharing existing capital with another farming enterprise. The standard settings for silver perch take into consideration each of the capital, operating and fixed costs that are typically incurred in establishing and operating a silver perch growout enterprise that does not have access to any existing infrastructure or complementary farming activities. Under these circumstances, the total cost of production is likely to be higher than could be achieved if the operation was integrated with complementary farming activities.

Given that the capacity of an individual farm to incorporate an integrated silver perch growout operation is highly variable, the potential advantages to integration in terms of reduced costs of production can only be addressed in the broadest sense. Capital items including land, vehicles and office equipment such as computers are likely to be available to an aquaculture activity on most properties and therefore have been excluded in the capital costs.

The results from this scenario show that a silver perch enterprise producing 50 or 100 tonnes a year based on current performance and technology has a most likely benefit–cost ratio that is greater than one (table 31). However, the sensitivity analysis shows that for the 50 tonne farm there is a 17 per cent chance that the most likely benefit–cost ratio will be below one and for the 100 tonne farm an 8 per cent chance.

Concluding comments

At the current level of performance and technology, the results from the analysis indicate that silver perch farming does not appear to be viable for the 50 tonne farm and appears to be only marginally viable for the 100 tonne farm. While the results show that expected benefits are equal to costs for the 50 tonne farm and expected benefits are greater than costs for the 100 tonne farm, there is a high degree of risk surrounding these results. Therefore, given the level of associated risk, many investors may be unwilling to invest in a silver perch operation of these two sizes. However, ultimately this will depend on the investors' attitude to risk and the circumstances and associated costs for the particular farm.

In all cases, the farming of silver perch is more risky for the smaller farm relative to the larger farm, indicating that economies of scale can be achieved.

The results from the models show that returns to silver perch production are sensitive to the price of silver perch, feed costs and the amount of capital that is shared with another farming enterprise. The results suggest that silver perch farming may not be viable in the long term, with the prospect of falling farm gate prices as production increases. For both farm sizes the most likely benefit–cost ratio is less than one, indicating that costs are greater than benefits.

However, price declines may be partially offset by productivity improvements such as improvements in yields, feed conversion ratios and selective breeding, or by lower input costs such as feed. The results indicate that when feed costs were reduced by a third, returns to silver perch farming are markedly improved as both farm sizes have a most likely benefit–cost ratio that is greater than one, with only a relatively small risk that the farms would be unprofitable. Savings could be made in areas such as transport, marketing and fingerling costs as larger quantities are bought and sold.

While the results suggest that a small specialised silver perch operation may not appear viable, it may be possible for small operations to be viable when integrated with agriculture or horticulture. Integrating a silver perch operation with an existing agricultural enterprise has the potential to improve returns as capital costs such as land and machinery can be shared.

Although not discussed in the results, polyculture also has the potential to improve returns. Polyculture involves farming more than one species in the same enclosure and can help improve profitability as it allows more than one crop to be harvested (Fowler 1999). Research is currently being undertaken for the culture of silver perch with yabbies (Pacific Seafood Management Consulting Group 1995).

7

Snapper

The Australian snapper farming industry was developed initially using production techniques employed for red sea bream in the Mediterranean and Japan. The majority of research into snapper aquaculture has been conducted in Japan, where the species has been grown experimentally since the early 1900s and successfully farmed commercially since 1965. In Australia, research has been undertaken to refine production techniques for the local environment (Primary Industries and Resources, South Australia 1999c).

Experimentation with snapper farming in Australia has taken place in South Australia, Western Australia and New South Wales, with New South Wales and South Australia appearing most likely to develop substantial snapper farming industries. South Australian operators, however, are now trialing yellowtail kingfish, as a fast growing alternative, despite somewhat lower prices. The ability to switch species may indeed be an advantage of sea cage farming, as it reduces the risk of failure from poor market acceptance of a particular species over the medium term. Alternatively, risk from short term price fluctuations of individual species can be reduced by farming a number of species concurrently.

Aquaculture production data for snapper have not been available because of the small number of operators, although it is likely to be small in comparison with total snapper production of 3617 tonnes, valued at $16.4 million in 1998-99. Almost three-quarters of this quantity (2589 tonnes) was produced in Western Australia (ABARE 2000).

Snapper farming in Australia is done in sea cages similar to those used in the salmon and tuna farming industries. A cage usually consists of a net suspended from a circular floating ring, moored at a number of points. Sometimes a second net is used to exclude predators, which can potentially produce substantial losses. Modern sea cages are capable of withstanding substantial swell and benefit from deep water with good current flow to maintain oxygen and water clarity. As a result, cages may be several kilometres from shore facilities, although it can also be important for sea cages to be readily accessible from shore facilities to avoid higher costs from increased fuel and time.

An important concern for snapper growout operators is the availability of affordable healthy fingerlings over the life of their investment (Kable 1996). In the absence of an established industry (with a number of competitive hatcheries) or government hatchery, this may require farmers to establish their own hatchery, which may need to be large scale to be viable. In the modeling of this report, it is assumed that growout operators have access to a consistent supply of affordable fingerlings.

Market outlook

Wild snapper is a popular fish in the Australian market, with beach prices in New South Wales averaging $8.43 a kilogram in 1998-99. This is substantially above the average in South Australia and Western Australia, which have a greater supply of snapper and a smaller human population. The eastern states absorb substantial imports not only from these other Australian states, but also from New Zealand, which supplied 1377 tonnes to Australia in 1999, at an average price of A$5.34 a kilogram (New Zealand Seafood Industry Council 2000).

Farmed snapper has a number of potential market advantages over wild snapper. An important factor is consistency of supply. While wild harvest may fluctuate heavily, aquaculture harvests can be planned in advance. This allows wholesalers and retailers to offer snapper as a constant product form at predictable prices. This may be an advantage for restaurants that use standardised menus, as well as for supermarkets that depend on the development of customer familiarity with standard products.

The ability to plan harvests also offers potential opportunities to time supply to meet periods of high price. These high price periods may follow seasonal patterns. Alternatively, high prices may result from supply conditions. Wild harvests may be poor at particular times of year, resulting in price rises. However, such price rises would be limited by the willingness of consumers to switch to other fish species when there is a lack of snapper available. Species that may be considered competitors are blue-eye, mulloway, kingfish, black bream and yellow bream, as well as other aquaculture products such as barramundi.

However, farmed snapper has a different appearance to wild snapper, which creates a degree of uncertainty about how the product will be accepted by traditional purchasers in the medium term. Farmed snapper is a slightly different shape and has darker skin than wild snapper.

It is not clear at this stage whether the positive or the potential negative characteristics will be most significant when the market becomes familiar with farmed snapper. An expected starting price of $8.63 a kilogram is used in the model, with a relatively high degree of uncertainty around that price. This price is the average price on the Sydney fish market (less 60 cents a kilogram for transport), in 2000 dollars, between 1995 and 1999 of small whole snapper that had been prepared in an ice slurry. Market commission is not subtracted from the price because it is anticipated that the consistency of supply will allow farmers to bypass the market and sell direct to wholesalers with little additional work.

Snapper farm models

Two farm models were constructed for snapper. One was of a 100 tonne farm, the other was a 200 tonne farm, to demonstrate the effect of economies of scale in snapper farming. Table 32 shows the key characteristics of the farm models. Plate size (0.5 kilogram) fish are produced over a period of sixteen months, chilled in an ice slurry, and sold for an expected price of $8.63 a kilogram. Unlike in the other case studies, the assumed price remains at this level throughout the twenty year period. Survival rates range from 0 to 100 per cent, with an expected survival rate of 85 per cent, after higher mortalities expected in the first few years. In each year, expected output is 100 tonnes or 200 tonnes, with downward trends in expected mortality affecting fingerling and feed costs.

Each model is of a growout only operation that uses sea cage technology. Fingerlings are assumed to be purchased from a hatchery at an initial price of 70 cents each, although the results would be unchanged if the operation had a hatchery with average costs of 70 cents per fingerling. It is assumed

32 Key characteristics of the snapper farm models

	Unit	Expected	Range
Size at harvest	kg whole	0.5	na
Product form		ice slurry, whole	
Growout time	months	16	14–18
Initial feed conversion ratio		1.5:1	1.2–2.0
Survival rate	%	85	0–100
Total farm production	t/yr live	100	0–118
Initial farm gate price	$/kg	8.63	5.15–11.85

33 Annual operating costs for the snapper farm models

	100 tonne farm	200 tonne farm
	$'000	$'000
Fingerlings	154	307
Feed	135	271
Electricity and fuel	24	30
Labor	324	416
Repairs and maintenance	10	15
Administration	8	11
Miscellaneous	5	7
Total	660	1 057

that fingerlings are available consistently throughout the year, though often this may not be the case. As with other cost items, the cost of fingerlings is allowed to vary in the simulations owing to uncertainty.

As can be seen in table 33, with the assumed fingerling prices and survival of 85 per cent, fingerling costs are 23 per cent of total operating costs for the 100 tonne farm, and 29 per cent for the 200 tonne farm.

The largest operating cost component in both models is labor. Sea cage farming tends to require substantial labor to feed fish, as well as to clean, change and maintain nets. It is generally also necessary to employ security staff to patrol cage areas at night. Developments in automatic feeding systems may offer some labor savings, though it can be helpful to feed manually to better monitor fish health. To demonstrate the sensitivity of model results to changes in labor costs, model runs were conducted with labor costs 25 per cent higher. Labor costs may vary depending on the local availability of appropriate labor, as well as practicalities such as the distance between cages and shore facilities.

The other big cost component is feed, though in the case of snapper, feed is only 20 per cent of operating costs for the 100 tonne farm and 26 per cent for the 200 tonne farm. This is based on a feed price of $1000 a tonne, which should be available for farms of this scale, and an initial feed conversion ratio of 1.5:1, and on the assumption that, on average, mortalities occur halfway through weight gain.

Total capital investment is $669 000 in the smaller farm and nearly $1.04 million in the larger farm (table 34). Although capital investment is 56 per cent higher on the larger farms, output on those farms is double that of the smaller farms. The largest item is the sea cages (including nets, mooring, etc), which makes up 36 per cent of total capital costs in the smaller farm and 46 per cent in the larger farm. The next largest investment is in boats that are needed to feed, as well as to allow diving and lifting during harvest and net changes.

34 Capital costs for the snapper farm models

	100 tonne	200 tonne	Scrap value	Life
	$'000	$'000	%	yrs
Cages	240	480	10	7
Land	100	120	100	na
Boats	130	180	10	10
Shed	18	20	50	20
Office	5	8	50	20
Toilet	10	10	50	20
Processing facilities	30	50	50	10
Vehicles	20	30	10	10
Net washer	20	20	10	5
Feed cannon	5	10	10	10
Scientific equipment	5	7	0	5
Tools	5	7	0	5
Harvest equipment	4	5	0	5
Forklift	5	7	10	10
Transfer tanks	2	2	10	10
Fish counter	7	7	10	10
Grader	45	55	10	10
Tractor	13	15	10	10
Office equipment	5	6	10	5
Total	669	1 039		

Land for shore facilities (for processing, net repairs, maintenance and office) is the other big cost, although this will vary depending on location. Because it is necessary to travel regularly between the cages and the shore facilities, often with equipment, it can be worth investing in land close to shore.

Farm model results

The most likely benefit–cost ratio is 1.09 for the 100 tonne farm and 1.37 for the 200 tonne farm, indicating that both farms are expected to have benefits greater than costs (table 35 and figure P). However, there is a substantial difference between the two ratios, with the larger operation providing a much greater expected benefit to investors than the smaller. The larger farm also has a much smaller chance of producing benefits that are less than costs (2.5 per cent chance, rather than 15 per cent). Indeed, many investors may see the smaller farm as only marginally viable. The most likely benefit–cost ratio of 1.09 may not justify the 15 per cent chance that costs are greater than benefits.

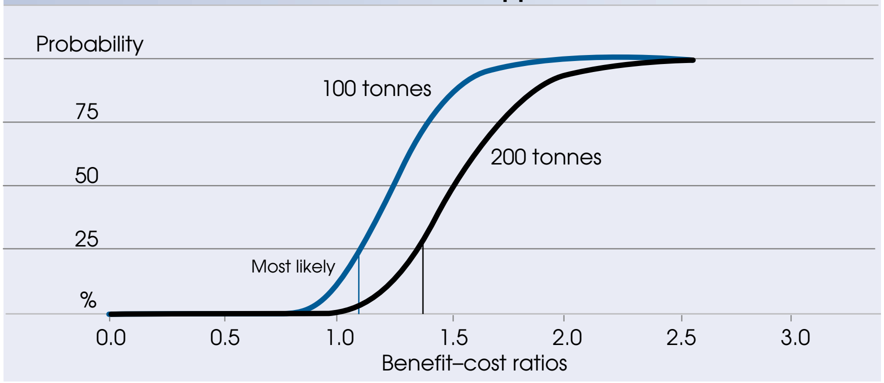
35 Benefit–cost ratios from the snapper farm models

Farm model (annual capacity)	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
100 tonne farm	1.09	0.91–1.63	15
200 tonne farm	1.37	1.10–2.00	2.5

Another way of getting an indication of risk levels is to look at the payback period for investments. The measure used here is an economic rather than accounting measure, in that future costs and benefits are discounted by the risk free interest rate, to allow for the income that financial capital can earn without risk elsewhere in the economy. For the 100 tonne farm the expected payback period is twelve years, while for the 200 tonne farm it is expected to be five years. By looking at the 90 per cent confidence interval, it is unclear whether either farm will recover the initial cash outlay in twenty years (table 36).

A major source of risk is the uncertainty about where farmed snapper will fit into the market when buyers become familiar with its characteristics. Will it earn a premium over wild snapper because of its supply consistency, small size and freshness, or will it be shunned because of its unfamiliar dark color? These questions may be resolved over the next couple of years as the first producers test and educate the market. If so, future entrants to the industry (or expanded current players) may be much more certain about their

P Benefit–cost ratio probability distributions: 100 and 200 tonne snapper farm models



investments than current investors. Scenarios have been run with more certainty around the initial price — at a low price, and at a high price — to account for this increase in information over the next couple of years.

36 Payback period for the snapper farm models

Farm model (annual capacity)	Payback period	90% confidence interval
	yrs	yrs
100 tonne farm	12	4–20+
200 tonne farm	5	2.5–20+

If consumers take a poor view of snapper, and an expected price of $5.50 a kilogram appears quite certain, the most likely benefit–cost ratio would be substantially less than one for both farms, with quite a small chance of it being greater than one (table 37). On the other hand, if purchasers accept the different color (perhaps because restaurants value highly the consistency and long shelf life), and an expected price of $11.50 a kilogram becomes more realistic, then both sizes of operation are expected to have very good benefit–cost ratios, and negligible chances of ratios of less than one.

Another group of scenarios that is tested are higher and lower labor costs, which make up the bulk of operating costs. With higher labor costs, the smaller farm becomes nonviable, with a most likely benefit–cost ratio less than one (table 38). The lesson for potential farmers is that if their viability is somewhat borderline, a blowout in even a single cost factor can result in

37 Impact of alternative prices on the snapper farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings			
100 tonne farm	1.09	0.91–1.63	15
200 tonne farm	1.37	1.10–2.00	2.5
Low price outcome ($5.50/kg expected)			
100 tonne farm	0.69	0.69–0.92	97
200 tonne farm	0.87	0.82–1.20	55
High price outcome ($11.50/kg expected)			
100 tonne farm	1.46	1.32–1.95	0
200 tonne farm	1.82	1.65–2.45	0

38 Impact of alternative labor costs on the snapper farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings			
100 tonne farm	1.09	0.91–1.63	15
200 tonne farm	1.37	1.10–2.00	2.5
High labor costs (25 per cent higher than standard)			
100 tonne farm	0.99	0.83–1.45	30
200 tonne farm	1.26	1.02–1.83	4
Low labor costs (25 per cent lower than standard)			
100 tonne farm	1.23	0.98–1.80	6
200 tonne farm	1.51	1.18–2.15	1.5

business failure, particularly if that factor is a substantial input, such as labor in snapper farming.

On the other hand, the still strong benefit–cost ratio of the 200 tonne farm under higher labor costs shows that making use of fundamental effects such as economies of scale, to create a buffer between the most likely benefit–cost ratio and business failure, allows farms to deal with situations such as higher labor costs in a particular location.

Concluding comments

The results of the analysis indicate that snapper farming at the current level of performance and technology is viable, as expected benefits are greater than costs for both farm sizes. As snapper farming is more risky for the smaller farm relative to the larger farm and the benefit–cost ratio is higher for the larger farm, this indicates that economies of scale can be achieved.

However, the potential for industry expansion is likely to be limited, as a major source of risk facing snapper farming is the uncertainty about where farmed snapper will fit into the market. The results show that the profitability of snapper farming is sensitive to farm gate prices and if consumers take a poor view of farmed snapper and as a result the price falls then snapper farming is not viable for either farm size.

The scenarios of lower labor costs demonstrate the importance, in terms of benefits flowing to businesses, of finding efficiencies in production. For marginal businesses, such efficiencies may be vital for viability, while for others, they may simply reduce risk and increase net benefits. Labor costs may be reduced a number of ways — often because of particular site specific circumstances. For instance, in a particular case, it may be possible to locate land and sea facilities within close proximity. However, some cost savings may depend on the reliability of new technology such as automatic feeding systems.

8

Yabbies

Yabbies (*Cherax albidus* and *C. destructor*) are native to the central and eastern regions of Australia, with the majority of yabbies found in these regions being *C. destructor.* In Western Australia the species of yabby found is *C. albidus*. The species was originally introduced in 1932 from western Victoria to farm dams around the Narembeen area of Western Australia.

The development of an inland Australian aquaculture industry for freshwater crayfish began in the late 1960s with experimental culture of yabbies. Most commercial yabby production in Australia comes from extensive farming and trappings in farmers' dams, although increasingly yabbies are produced semi-intensively in purpose built ponds on farms. The use of farm dams originally built to water stock has allowed a rapid expansion of the industry because of the relatively low entry cost (McCormack 1994).

Yabbies are currently farmed in Western Australia, New South Wales, South Australia and Victoria. The structure of the industry in 1995-96 was as follows:

- Farmers in Western Australia produce the largest volumes of yabbies and operate the most mature yabby industry in Australia. Commercial harvesting of yabbies commenced in the 1980s, and by 1995-96, there were 43 yabby farms. Most yabby farming is still undertaken using extensive culture systems. A number of farms are undertaking yabby culture as a means of supplementing farm income when commodity prices for other outputs produced on farm such as wheat or sheep are relatively low.
- In New South Wales there are 116 permits for yabby farming, with 37 farms operating commercially.
- In South Australia there are around 400 registered crayfish farmers, 68 of whom were commercial yabby farmers.
- In Victoria, 72 culture permits have been issued for growing yabbies and 51 culture permits for growing yabbies in conjunction with fish farming. More recently, licences have been issued to farmers wishing to specialise in commercial semi-intensive yabby aquaculture.

Production of yabbies from farm dams has grown rapidly — from a total of 1.5 tonnes in 1987 to about 300 tonnes in 1994. Semi-intensive pond production of yabbies has grown more slowly, with production increasing to around 50 tonnes in 1995-96. For many farmers, the major limitation to increased yabby production is the amount of water available. Yabby farming sites must have soils containing sufficient clay to minimise seepage and adequate rainfall or water supplies to fill dams or ponds as well as replace water lost through evaporation and seepage.

Yabbies spawn readily so there is usually no need to purchase juveniles, with most farms producing more stock than required. In the eastern states of Australia, careful monitoring of ponds may be required to prevent native wild yabbies from inhabiting and breeding in farm ponds and competing with farm yabbies for food and shelter.

Prolific breeding can become a major problem in yabby farming if overpopulation of yabby dams or ponds occurs, resulting in stunted growth and smaller individual yabbies. To some extent yabbies can be protected through the strategic placement of yabby hides (mesh shelters) that may house yabbies of various sizes in ponds. These hides are also relatively easy to remove from ponds for yabby grading or harvesting (Mosig 1995).

To prevent dams/ponds becoming overcrowded farmers may:

- grade yabbies, although the risk of mortalities is increased through handling, and
- in the near future, stock ponds with hybrid yabby broodstock that produce only male offspring (McCormack 1994).

Grading allows yabby numbers and health to be monitored as well as enabling the farmer to maintain similarly sized stock in each pond to minimise stock losses through overcrowding. Mortalities caused by handling may also be reduced through the use of recently developed yabby grading equipment. This equipment is used in the pond and minimises the time that yabbies are handled and are out of the water (McCormack 1994).

Stocking dams solely with hybrid male yabbies enables farmers to more accurately record the progress of stock in ponds and the yields available per pond as stocks are not augmented naturally and regularly through breeding in ponds.

The use of a system of purpose built ponds for more intensive farming of yabbies has a number of advantages over widely spread and isolated farm dams. Most of these advantages relate to more efficient management of ponds that is reflected in average yields of up to five times those in traditional extensively managed farm dams. Pond stocking rates vary from five yabbies per square metre for extensive farming to ten yabbies per square metre for semi-intensive farming.

Yabbies will consume any food readily available within the pond system such as plant or animal material. However, for the commercial production of yabbies, farmers may use specialised yabby diets (commercial crayfish pellets) or grain based diets (such as lupins) supplemented by the natural food available in the growout ponds. Food conversion ratios for yabbies have been generally estimated at 4–5:1, implying that for 1 gram of growth a yabby would need 4–5 grams of pellets.

The use of aerators in semi-intensive ponds may allow larger volumes of crayfish pellets to be fed to yabbies while ensuring dissolved oxygen levels are maintained at safe levels in ponds (aerators may also be used to maintain water quality for stock).

Market outlook

Domestic market

Presently, yabbies are marketed at sizes ranging from 30 grams to 100 grams and are mainly sold live. Grading is based on weight, meat recovery and condition of the yabby, with these characteristics reflected in the farm gate and market prices paid. Prices also vary with seasonal availability and market destination — domestic or export. Higher prices are paid for yabbies that are purged, graded and packed by the farmer, as well as for larger yabbies, reflecting greater demand for larger sized yabbies. Generally, farm gate prices vary from $6 for smaller 30–40 gram yabbies to $15–20 for 80–100 gram yabbies.

The domestic market for yabbies is still relatively undeveloped. Most production is sold live to restaurants directly or through wholesale markets on a seasonal basis. To date, the Western Australian market for yabbies is the most developed in Australia and is generally characterised by a significant degree of coordination between growers, processors and marketers of yabbies.

Historically, the harvest and sale of wild yabbies may have constrained the development of the yabby farming industry in the eastern states. Wild yabbies are not necessarily distinguishable from farmed yabbies and therefore may compete heavily with farmed product.

Any person with a licence to harvest and sell yabbies may market wild product in competition with farmed product without incurring the capital and operating costs associated with farming. While the returns associated with the sale of wild yabbies are highly variable and uncertain compared with semi-intensive yabby farming, income may be earned with relatively little effort, at a relatively low cost and with a lower risk of large losses when poor production years occur. Generally, the availability of wild yabbies in these states has resulted in greater seasonal variability (and uncertainty) in yabby prices (reflecting greater seasonal variability in total yabby supply).

Since Treadwell et al. (1991) studied the viability of farming yabbies, the yabby industry and market have grown. However, volumes are still small enough for any large increase in volumes to have a significant downward effect on prices. This negative price effect may be magnified if there were more intense competition from substitutes such as other crustaceans and niche or gourmet food products generally.

World market

Western Europe, east Asia and north America are the main export markets for Australian yabbies. Demand in these markets has been encouraged with the supply from Australia of a high quality yabby of larger size than the crayfish produced by overseas competitors, freedom from major diseases and the ability to land live yabbies reliably in major international markets (Treadwell et al. 1991). Demand for freshwater crayfish in these markets is forecast to increase, particularly with lower domestic supplies caused by crayfish diseases. These diseases have severely reduced numbers in many native populations of freshwater crayfish. Australia’s freshwater crayfish are still disease free.

Australian processors are focusing on establishing a reputation in export markets for being reliable suppliers of consistent high quality yabbies. The existence of size economies requires facilities and expertise for the production, processing and marketing of large volumes of yabbies to major markets.

Yabby farm models

While the bulk of Australian yabby production takes place extensively in farm dams and mainly for the purpose of supplementing farm income, there has been a recent shift to more semi-intensive culture of yabbies, particularly in Western Australia. This development is likely to continue as improvements are made to yabby genetics, farm equipment and feeds that enable farmers to:

- prevent undesirable breeding in ponds by stocking ponds with hybrid males only,
- grade and harvest yabbies with minimal mortalities, and
- increase yields through improvements in feed conversion ratios and growout of hybrid male stock.

Reflecting these changes the models constructed are for a 20 hectare semi-intensive farm and a 20 hectare integrated farm. The integrated facilities are those where farmers engage in another agricultural activity and have adapted their farm to include the production of yabbies. Existing farm infrastructure and capital such as dams, vehicles and sheds are adapted to accommodate the production of yabbies as well as other farm outputs (for example, wheat or sheep production). When examining the viability of investment in integrated yabby production, only the impact of sharing some farm capital on the returns to yabby farming is investigated. That is, the viability of the operation as a whole, including the returns from the production of other agricultural outputs, is not analysed. Further, and generally, it is assumed that the farm is vertically integrated — the operator grows, harvests, purges and markets the yabbies.

The characteristics of the two farm types analysed are summarised in table 39. Annual operating costs and capital costs for the yabby models are summarised in tables 40–42. The yabbies produced in these systems are fed and graded throughout the year and are sold at

39 Key characteristics of the yabby farm models

	Unit	Most likely range
Area of growout ponds	ha	20
Pond size	ha	0.2
Number of ponds	no.	100
Size at harvest	g	50–100
Farm yield	t/ha	1–2
Total farm production	tonnes	20–40
Product form		live
Growout time	months	9–12
Feed conversion ratio		4–5:1
Trend mortality rate	%	15–20
Farm gate price	$/kg live	6–15

40 Average annual operating costs for the yabby farm models	50 grams	100 grams
	$	$
Feed	27 290	53 984
Freight	30 030	50 050
Marketing	40 040	70 070
Electricity and fuel	14 824	14 531
Labor	44 472	43 593
Repairs and maintenance	9 883	9 687
Miscellaneous	4 447	4 359
Administration costs	4 941	4 844
Total	175 926	251 118

either 50 grams or 100 grams. Yabby hides are used in the ponds to minimise mortalities through predation by birds, rats or larger yabbies. It is assumed that farmers do not need to purchase juveniles beyond the first year when mature broodstock may be kept for breeding purposes in subsequent years.

The greatest risks associated with yabby farming are associated with annual variability in farm output that results from climatic and pond conditions and uncertainty about future price trends. The more intensive the production system, the lower the risk from factors external to the system. Yields are more variable in the early years of production as a result of early learning mortalities. These are eliminated once the farmer has fully developed the necessary skills for yabby farming and has fully tested and fool proofed the production system employed.

Product prices are anticipated to trend downwards as the volumes of yabbies produced and sold domestically increase further. Therefore, in the model a price decline of 0.5 per cent a year was applied, such that the most likely price for 100 grams of live yabbies declines from $14.50 to $13.10 a kilogram.

Establishment costs (table 41 and 42) are assumed to be lower for the integrated farm than for the stand alone yabby farm, although some costs are accrued in the adaptation of farm infrastructure. The largest proportion of costs for both types of operation are attributable to the labor, marketing and feeding (crayfish pellets) of yabbies (table 40).

Farm model results

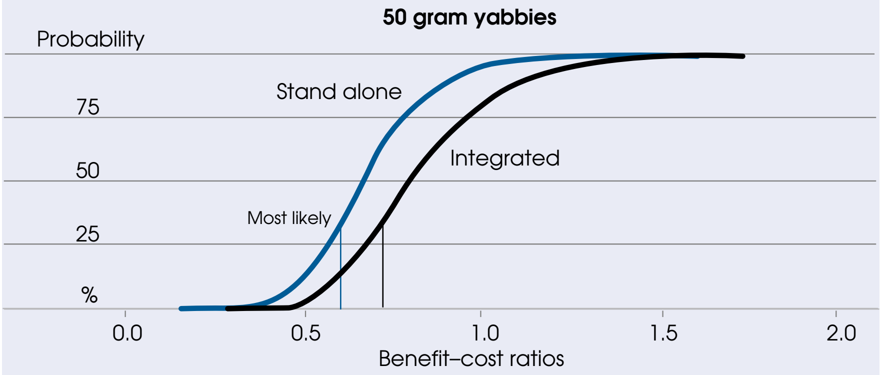
The analysis of both farms indicates that selling yabbies at 50 grams is not viable, with a significant probability that the benefit–cost ratios will be below one (figure Q). For the stand alone operation the most likely benefit–cost ratio is 0.6, while sharing some farm costs with other agricultural outputs in the integrated operation raises the ratio marginally to 0.72. However, there is still around a 90 per cent chance that both operations will not be viable (table 43).

In contrast, if farmers delay harvesting until later in the year when yabbies of 80–100 grams may be harvested, investment in both types of farm may be justified with most likely benefit–cost ratios of 1.4 and 1.55 respectively for the semi-intensive and integrated operations (figure R). The probability that investment in both farms will be viable is also somewhat improved given the standard set of farm model assumptions. While there is still a 12 per cent

41 Capital costs for the yabby farm models – semi-intensive farm

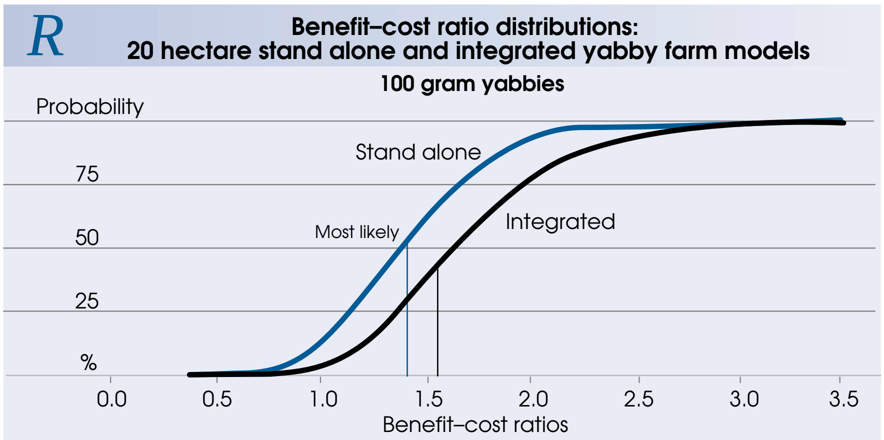
	20 hectare farm	Scrap value	Life
	$	%	yrs
Land	100 000	100	20
Perimeter fence	16 000	5	20
Office and storage shed	30 000	50	20
Electricity connection	20 000	100	20
Generator	10 000	10	10
Water storage dam	40 000	–	20
Ponds, channels, gates, screens	250 000	–	20
Biofilter and plumbing	1 500	–	10
Pumps and motors	30 000	10	5
Piping	80 000	–	10
Netting and shelter	70 000	–	5
Aerators	25 000	–	5
Truck / utility	20 000	10	10
Tractor	15 000	10	10
Motorcycle	7 000	10	5
Bucket	1 000	10	10
Blade	1 000	–	10
Feed blower	1 000	–	5
Water testing equipment	2 000	–	5
Grading equipment	1 000	–	10
Harvesting equipment	20 000	–	5
Holding tanks and shelter	10 000	10	10
Coolroom / freezer	10 000	10	10
Processing room	20 000	–	20
Processing equipment	7 000	–	5
Office equipment	5 000	10	5
Miscellaneous	5 000	10	5
Broodstock	12 000	–	–
Total	809 500		

Q



42 Capital costs for the yabby farm models – integrated farm

	20 hectare farm	Scrap value	Life
	$	%	yrs
Office and storage shed	30 000	50	20
Electricity connection	5 000	100	20
Generator	10 000	10	10
Ponds, channels, gates, screens	30 000	–	20
Biofilter and plumbing	1 500	–	10
Pumps and motors	30 000	10	5
Piping	40 000	–	10
Netting and shelter	70 000	–	5
Aerators	25 000	–	5
Bucket	1 000	10	10
Blade	1 000	–	10
Feed blower	1 000	–	5
Water testing equipment	2 000	–	5
Grading equipment	1 000	–	10
Harvesting equipment	20 000	–	5
Holding tanks and shelter	10 000	10	10
Coolroom / freezer	10 000	10	10
Processing room	20 000	–	20
Processing equipment	7 000	–	5
Miscellaneous	5 000	10	5
Broodstock	12 000	–	–
Total	331 500		



chance that the benefit–cost ratio will be below one for the stand alone farm there is only a 5 per cent chance of investment in the integrated farm being unviable (table 43).

The payback period for each operation is another means of examining the riskiness of investment in yabby production. In table 44 the number of years until each operation recovers the initial cash outlay is presented. Clearly, yabby farming is relatively risky compared with other types of investment, with the expected payback period for the stand alone farm being ten years. Compared with the semi-intensive operation, investment in the integrated farm is less risky. However, the expected payback period for the integrated farm is still eight years. Semi-intensive farming of yabbies is still a relatively young industry in Australia, so it may be reasonable to assume that yabby farmers may attain productivity increases in future. These increases may be

43 Benefit–cost ratios from the yabby farm models

Farm model	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
20 hectare semi-intensive farm			
50 grams	0.60	0.79	96
100 grams	1.40	1.76	12
20 hectare integrated farm			
50 grams	0.72	1.10	88
100 grams	1.55	1.98	5

44 Payback period for the yabby farm models

Farm model	Payback period	90% confidence interval
	yrs	yrs
20 hectare semi-intensive farm		
50 grams	not applicable	not applicable
100 grams	10	8–12
20 hectare integrated farm		
50 grams	not applicable	not applicable
100 grams	8	7–11

45 Impact of input price trends on the yabby farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings			
20 hectare semi-intensive farm			
50 grams	0.60	0.79	96
100 grams	1.40	1.76	12
20 hectare integrated farm			
50 grams	0.72	1.10	88
100 grams	1.55	1.98	5
Trends in labor, feed and marketing costs increase 1 per cent each year			
20 hectare semi-intensive farm			
50 grams	0.50	0.71	99
100 grams	1.20	1.66	15
20 hectare integrated farm			
50 grams	0.57	0.90	93
100 grams	1.40	1.85	8
Trends in labor, feed and marketing costs decrease 1 per cent each year			
20 hectare semi-intensive farm			
50 grams	0.80	1.10	89
100 grams	2.00	2.20	9
20 hectare integrated farm			
50 grams	0.96	1.40	82
100 grams	2.40	2.20	3

reflected in improved survival rates of juvenile stock, higher feed conversion ratios and yields and reduced labor required per production cycle. These improvements would result in reductions in farm operating costs. The impacts of these changes on farm viability have been examined by simulating increases and decreases of 1 per cent a year to the major operating costs (feed, labor and marketing costs) (table 45).

For the operations producing 50 gram yabbies, the results indicate for the semi-intensive and integrated farms that the most likely benefit–cost ratios are less than one when operating costs are increased or decreased by 1 per cent. However, this is not the case for farms producing 100 gram sized yabbies. The results show that when operating costs are increased by 1 per cent for the semi-intensive and the integrated farms producing 100 gram yabbies, the most likely benefit–cost ratios are greater than one (1.2 and 1.4 respectively) indicating that expected benefits are greater than expected costs. Clearly, the ratios for both farms are higher when operating costs are reduced by 1 per cent. In that case, the most likely benefit–cost ratios for the semi-intensive and integrated operations are 2.0 and 2.4 respectively, with small probabilities of the ratios being less than one (9 per cent and 3 per cent respectively).

46 Impact of a decline in output prices on the yabby farm models

	Most likely BCR	90% confidence interval	Probability of BCR less than 1
			%
Standard settings			
20 hectare semi-intensive farm			
50 grams	0.60	0.79	96
100 grams	1.40	1.76	12
20 hectare integrated farm			
50 grams	0.72	1.10	88
100 grams	1.55	1.98	5
Yabby price trend reduced by 1% each year			
20 hectare semi-intensive farm			
50 grams	0.50	0.63	98
100 grams	1.22	1.50	14
20 hectare integrated farm			
50 grams	0.61	1.00	90
100 grams	1.40	1.81	7

As discussed earlier, if volumes of farmed yabbies increase significantly it is likely that prices for yabbies would fall. Prices may also be expected to be lower if product demand or quality falls. Analysis was conducted to examine the effect of prices falling by 1 per cent a year.

As with other aquaculture species, the results show that the expected profitability of yabby farming is sensitive to prices. With prices falling consistently by 1 per cent a year, the most likely benefit–cost ratios remain less than one for both farms producing 50 gram yabbies, and fall to 1.22 and 1.40 for the stand alone and integrated farms producing 100 gram yabbies respectively. For both farms the probability of the ratio being less than one is higher (table 46).

Concluding comments

At the current level of performance and technology, the results indicate that yabby production can be viable if producers are able to produce larger yabbies (100 grams). The riskiness of the investment may be further reduced if the farmer is able to use existing farm infrastructure and equipment to produce yabbies.

Because yabby farming is at an early stage in Australia, current technology is likely to be improved and adapted to Australian conditions. In particular, operators are likely to search for labor saving techniques in production to lower operating costs. Such developments could improve the prospects of yabby farming in Australia.

The major risks associated with yabby production are associated with the maintenance of the biophysical conditions required to minimise yabby mortalities and maximise yabby yields as well as the uncertainty surrounding price trends as the volume of production in Australia increases. Farm gate prices may fall in response to increased supplies. The extent of such a price fall is extremely difficult to gauge given the relatively undeveloped state of the yabby market. These two risks will be crucial to the potential of the industry, because they could alter returns considerably.

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