Integrated Agri-Aquaculture Systems

A Resource Handbook for Australian Industry Development.

A report for the Rural Industries Research and Development Corporation

Edited by

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February 2003

RIRDC Publication No
RIRDC Project No. MFR-2A

ISBN 0 642 58580 6)
ISSN 1440-6845

Integrated Agri-Aquaculture Systems – A Resource Handbook
Publication No. 03/012
Project No. MFR-2A

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In submitting this report the research has agreed to RIRDC publishing this material in its edited form.

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Published in February 2003
Printed on environmentally friendly paper by Canprint

Foreword

The practice of integrating aquaculture and agriculture, also referred to as Integrated Agri-Aquaculture Systems (IAAS), is a relatively recent development in Australia. Indeed, until now much of the interest in IAAS in Australia has been centred on various RIRDC R&D projects investigating different bio-technical, economic and environmental aspects of IAAS applications. The broad rationale for IAAS application in Australia is based on the need to achieve more economically viable and environmentally sustainable primary industries, and specifically to enhance farm productivity and water use efficiency through multiple water use for integrated production of both terrestrial and aquatic crops.

IAAS practices were established long ago in many Asian countries for subsistence purposes, but are increasingly being developed for more commercial, income generating purposes in both Asia and developed "Western" countries. In Israel, very efficient, agro-industrial scale, IAAS farming, incorporating various aquaculture and irrigated horticulture operations, is now well established in what is otherwise a relatively arid production landscape, not unlike much of Australia. It is such commercially viable, large-scale IAAS ventures that are seen to have most relevance to Australian industry. The concept of IAAS in Australia is now entering a critical industry development phase as farmers endeavour to practically apply R&D outcomes and their own specific IAAS innovations at farm level. Accordingly, RIRDC has recognised the need for the preparation of relevant industry extension tools, such as this Handbook.

This Handbook, prepared by the Marine and Freshwater Resources Institute, Department of Natural Resources and Environment, Victoria, covers a number of relevant topics in relation to IAAS industry development in Australia. The Handbook includes chapters on: IAAS principles and concepts; international experiences; Australian resources, species, systems and case studies; marketing; economics; legislative issues; and business planning. In practice, it is intended as a preliminary guide to Australian industry, particularly as a starting point for both existing farmers and new entrants considering commercial IAAS opportunities. It is also intended to be the first step in implementing the national R&D Plan for Integrated Agri-Aquaculture (1999-2004) in Australia, released by RIRDC in 2000.

This project was predominantly funded from RIRDC Core Funds, which in turn are provided by the Federal Government, although a significant contribution was also made from Fisheries Victoria (Department of Natural Resources and Environment, Victoria). Valuable in-kind support was also provided from various other state fisheries (including aquaculture) agencies and industry (agriculture and aquaculture) practitioners from around Australia, and several international research institutions.

This report, a new addition to RIRDC's diverse range of over 700 research publications, forms part of our Resilient Agricultural Systems R&D program. This program aims to foster the development of agri-industry systems that have sufficient diversity, integration, flexibility and robustness to be resilient enough to respond opportunistically to continued change. Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/reports/Index.htm
- purchases at www.rirdc.gov.au/eshop

Simon Hearn
Managing Director
Rural Industries Research and Development Corporation

Acknowledgements

The editors would like to thank the many people who have been involved in the compilation of this Handbook. Our inter-state colleagues have provided valuable time and in-kind support to give the Handbook a National perspective. Our thanks are extended to: Dr Adrian Collins, Peter Peterson and Max Wingfield (QDPI); Tara Ingerson (PIRSA), Ian Lyall and Stephen Boyd (NSW) and Dan Machin and Peter Lacey (WA).

The farmers who participated in the case studies in Chapter 6 are gratefully acknowledged for their input of time and valuable information on their experiences.

Thanks are also extended to Ms Fern Hames who assisted with the editing of this manuscript. The assistance of Mr Stuart Vallis and Mrs Maureen May in finalising the document is also gratefully acknowledged.

Abbreviations

IAAS Integrated Agri-Aquaculture Systems
RAS Recirculating Aquaculture Systems

Contents

Chapter One

Introduction to Integrated Agri-Aquaculture Systems in Australia

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Background

Integrated agri-aquaculture systems (IAAS) are those which link aquaculture to conventional farming systems. The development of such systems has been driven by different needs in different parts of the world, including a desire to improve food security on small, subsistence family farms; or to minimise pollution and use valuable resources (such as water) more efficiently and effectively.

From an Australian perspective, the advantages of integrated agri-aquaculture systems over conventional farming systems include:

- Increases in farm productivity and profitability without any net increase in water consumption;
- Farm diversification into higher value crops, including aquatic species;
- Re-use of otherwise wasted on-farm resources (capture and re-use of nutrients, saline water *etc*);
- Reduction of net environmental impacts of semi-intensive farming practices;
- Net economic benefits by offsetting existing farm capital and operating expenses.

The multiple use of farm water resources for aquaculture can result in many environmental benefits. As aquaculture predominantly does not consume water, rather “borrows” it for “temporary” use, this practice can be integrated into a farming system before the water is used for its primary purpose, such as irrigating crops or pastures. In this way, nutrients are also added in organic form to the water before irrigation, which may subsequently reduce the need for additional inorganic fertiliser application. The multiple use of water in itself will mean that the farm is more efficient in terms of the value of production per unit of water used, and more environmentally sustainable.

Additional benefits are provided to the farming community in that the day to day operational requirements of IAAS are not gender, or age specific, thus allowing broad participation by the workforce - including most family members for smaller farming operations. Water authorities are also able to achieve benefits through higher value, more efficient use of land and water resources, including waste resources such as saline groundwater. This results in increased revenue without increased consumption, further offsetting existing management and maintenance costs. Apart from other chapters of this Handbook, further reading on the general principles and practices of integrated aquaculture is provided by Little and Muir (1987) and Mathias *et al.* (1998).

Australian Agriculture, Aquaculture and IAAS

Agricultural production in Australia is a highly significant industry and land use for agriculture represents 59% of total land area (Aus stats www.abs.gov.au). The gross value of agricultural production was around $29 billion in 1998/99, with 56% from crops and livestock and their products accounting for the remainder.

By comparison, aquaculture is a relatively small industry in Australia but it is growing rapidly in all states and territories. The best known aquaculture enterprises are generally the large-scale commercial operations such as the farming of salmon in Tasmania, southern blue-fin tuna in South Australia, prawns and barramundi in Queensland, pearls in Western Australia, trout in Victoria and various shellfish species throughout most states. The total Australian aquaculture production of approximately 32,000 tonnes was worth in excess of AUD$613 million in 1998/99 (O'Sullivan and Dobson 2000). There are still many potential aquaculture opportunities to be exploited by small to medium-scale ventures. A variety of marketable species may be grown in systems which make use of resources and infrastructure typically available on existing Australian farms.

Farms which have a reliable supply (seasonal and/or year-round) of good quality water may, through integration of aquaculture practices (IAAS), realise an opportunity to diversify on-farm activities and to improve productivity through producing high-value (market-focused) products. Such diversification will enable farmers to get increased value for money out of valuable water resources. This integration of aquaculture and agriculture has been happening on an *ad hoc*, largely informal basis in Australia for many years as farmers have sought new and innovative ways to diversify and consolidate their various agri-business enterprises.

Various aspects and applications of integrated aquaculture have been investigated on an R&D and commercial basis in Australia to date, including:

- use of irrigation and nutrient rich wastewater, first for aquaculture production and secondly for conventional irrigation use on land-based crops and pasture;
- concurrent/simultaneous use of water for aquaculture and crops;
- aquaculture use of water subsequently used for hydroponics, the combination of which is also referred to as “aquaponics”;
- aquaculture use of shallow saline groundwater, increasingly associated with irrigation areas, which is pumped and stored for evaporation or other forms of disposal.

Various models of integrated aquaculture systems have been developed and/or considered for application within Australia, based on the multiple use of:

- surface and artesian irrigation waters (flowing and stored);
- saline groundwaters (flowing and stored);
- industrial, domestic and agricultural wastewaters;
- public water storages (*e.g.* lakes, reservoirs *etc*).

Although all of these models have potential for IAAS, the most significant opportunity for use of this technology is thought to be associated with the highly developed irrigation networks within Australia. With this in mind IAAS, for Australian application, has been specifically defined as:
“…Integration of aquaculture and irrigated farming systems to optimise the economic and environmentally sustainable use of existing energy, resources and infrastructure…” (Gooley and Gavine *In press*).

The irrigated agriculture sector in Australia accounts for almost a third of total farm exports and is worth approximately AUD$7.25 billion annually. There is existing irrigation infrastructure in every state, with more than 2 million ha of irrigated land in total utilising an estimated 15,500GL of water per year, or more than 70% of national water demand (Crabb 1997, Thomas 1999, *Austats* – www.abs.gov.au). There is over 20,000 km of water supply channels, and myriad, relatively small, on-farm water storages. Additionally, associated with irrigated farming are extensive saline groundwater resources, estimated at about 2,875 GL across Australia.

It is apparent that water is under-utilised in Australian irrigated farming systems as a result of routine single-use only, typically with a net loss of nutrients (and therefore energy) to the environment (Gooley 2000). Longer-term projections comparing industry growth trends with regional water availability clearly suggest that present water use patterns within the irrigated farming sector are not sustainable (Thomas 1999). IAAS can offer a more sustainable future for irrigated farms.

The use of the IAAS approach was first formally recognised as a potential agribusiness sector in Australia in 1998, with the establishment of a comprehensive, five year Research and Development plan by the Rural Industries Research and Development Corporation (RIRDC) (Gooley 2000). The purpose of the R&D Plan was primarily to identify and prioritise relevant industry R&D needs, and to facilitate a coordinated, more structured and orderly approach to industry development.

The stated vision of the RIRDC R&D plan is:
"A diverse and innovative Australian primary industries sector which integrates aquaculture practices into farming systems which are both profitable and ecologically sustainable".

This integration of aquaculture into existing farming systems is now a rapidly developing new agri-business sector in Australia. It is for this reason that the Rural Industries Research and Development Corporation (RIRDC) has produced this Handbook. Specifically, this Handbook is intended to give more detailed information on the theoretical background, relevant system and species options and associated case studies, market needs, legislative requirements, cost-benefits and associated risks, and the broader planning issues to be considered before investment in IAAS development. The Handbook also follows the publication of other RIRDC funded IAAS initiatives, including a report summarising various bio-technical, environmental and economic outcomes of recent pilot IAAS trials (Gooley *et al.* 2001), and the release of the national, five year R&D strategy for IAAS in Australia (Gooley 2000). A detailed summary of recent IAAS activities in Australia is also provided by Kumar (2000), and some specific experimental scale examples are described for the Murray Darling Basin in south-eastern Australia by Ingram *et al.* (2000).

IAAS Future Prospects in Australia

Cultural and institutional change will be required by government and industry alike for the full merit of IAAS to be realised. Government policy and associated legislative and regulatory constraints presently exist, but are manageable and can be modified, changed or adapted where required. Risks associated with environmental impacts are also manageable but should be addressed in the context of Best Practice Environmental Management Guidelines. The development of tradeable emissions policy, as part of an economic market designed to recover full costs of water use externalities (*e.g.* eutrophication, salinisation) will be very beneficial to industry development. Future recognition of the market value of nutrient and salinity credits resulting from application of Best Practice technologies such as IAAS, will also stimulate development.

Marketability of inland aquaculture produce will need to be developed and improved both within domestic and offshore markets; the latter particularly in SE Asia. It is likely however that the initial stages of IAAS development, particularly during the pilot focus farm stage, will see an emphasis on domestic, niche markets, probably within specific regional areas. Species selection, system design and scale of operation will be a critical determinant of the final market strategy. Economic viability will also be largely determined by the scale and design of the IAAS operation, including the extent to which economies of scale and critical mass can be achieved through the establishment of local cooperatives or networks which are able to share harvesting, post-harvest handling and marketing resources.

The broader viability of the farm enterprise, recognising that by definition the IAAS operation will need to occur concurrently with one or more other irrigated farm enterprises, will also ultimately impact on the viability of the IAAS development. The primary strategy to ensure equitable and sustainable inputs from the different farm components is to approach the whole enterprise on a holistic, “Whole-of-Farm” planning basis. Comprehensive, PC-based financial planning tools will also need to be utilised as part of the overall IAAS business planning strategy, both at a farm specific level and the broader regional/sectoral level. These issues have been recently summarised by Gooley and Gavine (*In press*) and are dealt with in much more detail in chapters of this Handbook.

In conclusion, new IAAS investors in Australia are encouraged to investigate all aspects of their proposed development before committing themselves either financially or practically. All pertinent issues need to be thoroughly evaluated using all available management tools and documented information. Furthermore, extension services and other like-minded practitioners within the agriculture and aquaculture sectors in Australia need to be effectively engaged to ensure that all available technical expertise and working models are accessed at the earliest possible stage of industry development. To this end, this Handbook is also likely to be very informative, and it is hoped that it will prove to be a valuable resource and useful guide to all IAAS stakeholders over the next few years during the early developmental stages of the industry in Australia.

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Chapter Two

Philosophy, Principles and Concepts of Integrated Agri-Aquaculture Systems

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Introduction

Integrated Agri-Aquaculture Systems (IAAS) originally evolved in China as a means of increasing food production on small-scale farms with a limited resource base. In these systems, on-farm wastes and by-products were recycled in relatively closed nutrient cycles. More recently, such integrated systems have evolved from subsistence level to agro-industrial scale, both in China and other parts of the world, notably Israel. Conversely, conventional terrestrial farming systems (such as those used in developed "western" countries) have become increasingly dependent on external sources of nutrients (inorganic fertilisers and stockfeeds) and nutrient cycles have become increasingly open. This has resulted in various adverse environmental impacts. The growing interest in the relevance of the Asian experience with IAAS to western agriculture, including Australia, is due to the desire to minimise pollution and eutrophication, as well as to optimise use of valuable natural resources such as nutrients and, increasingly, water.

This paper outlines the philosophy, principles and concepts behind IAAS to provide a rationale for their introduction into a developed country such as Australia. The underlying premise is that practical application of a few relatively simple scientific fundamentals within an appropriate (IAAS) systems framework can lead to the achievement of both site specific and catchment-scale, economic and environmental benefits. The integration of aquaculture into farming systems is therefore consistent with the key imperatives of Ecologically Sustainable Development (ESDSC 1992).

Philosophical perspective

The need to develop environmentally friendly and sustainable farming systems was demonstrated most vividly during the successful mission to first place a man on the moon. Photographs relayed back from outer space led to the concept of the Earth as a relatively self-contained "spaceship". In this context, a spaceship is effectively considered as a self-contained, circular system in which there is a need to completely conserve and recycle both nutrients and water. Similarly, on "spaceship earth" there is a need to combine economics and science to promote the concepts of the economy as a circular or closed resource flow system, and the environment as having ecological limits comprising finite stocks or resources and natural assimilative capacities (or sinks) for wastes. We must cease to behave as though we live in a "cowboy economy" with unlimited sources of resources and sinks to be exploited, and learn to treat the planet earth as a "spaceship" (Turner *et al.* 1993).

Another example of the need for western society to live within environmental limits was provided by the attempt by a small group of scientists to live within *Biosphere II*, a glittering 3.2 acre (1.3 ha) glass and metal dome in Arizona, USA. When the attempt to replicate an ecosystem ended after two years, the engineered environment was dying. *Biosphere II* had failed to generate breathable air, drinking water and adequate food for just eight people, and the scientists survived only because fresh air had been pumped in. Yet "Biosphere I"; planet Earth, performs these tasks and currently supports over 6 billion people (Lovins *et al.* 1999).

The second example is used by Lovins *et al.* (1999) to introduce the concept of "natural capitalism". Modern industry only considers the exploitable resources of the earth's ecosystems and not ecosystem services, such as assimilative capacities, because the latter do not appear on the business balance sheet. Such "externalities", as they are referred to in conventional economics, are an amazing omission because industry and human activity systems depend on an increasingly degraded environment. The principle behind the new concept of natural capitalism is that if the "natural capital" of ecosystem services were properly valued there would be dramatic increases in both the productivity and profitability of natural resources.

The meaning of systems within IAAS context

The term "systems" is used in so many different (and usually imprecise) ways that it has become almost meaningless. However, more precise definition of the term within an IAAS context is a worthwhile exercise because it is such a powerful concept. It is not surprising that the actual word itself is used loosely and in various ways because it is derived from the Greek word *systema*, which means to bring together or combine that which are common events. According to Webster's Dictionary, a system is "a complex unity formed of many often diverse parts subject to a common plan or serving a common purpose; a set of units combined to form an integrated whole". Key words in this definition are "…parts, working together, for a plan or purpose…". The precise meaning of a system is thus an interdependent group of parts working together in a unified whole for a purpose.

In practical terms a system can be a philosophy or concept, a physical system such as an inanimate machine, an ecosystem or agro-ecosystem, such as an IAAS, or a research method (see below). Key features of such systems are people and their needs, problem solving and multi-disciplinarity. In contemporary society, people's needs are assumed to include making money through agribusiness enterprise, but also include a requirement for environmental sustainability.

Three Usages of Systems

1. A Concept
- The philosophy or concept of holism, *i.e.* the study of the whole system and not the parts independently.

2. A Physical System
- A machine;
- The hierarchy of aquaculture in systems from gene and organism, to culture system or farm, through community, region and nation to the world.

3. A Method
- Solving problems;
- Identifying opportunities.

The systems approach was developed independently by people from several disciplines, towards the end of the nineteenth and the first part of the twentieth century, in response to growing appreciation of the limitations of conventional science. Science is reductionist in both knowledge (divided into a large number of academic disciplines because of the huge and ever expanding knowledge base) and experimental method (can handle only a few variables at once because of the limitations of statistics). It has accelerated the contribution of technology, including aquaculture, to human welfare but has been less successful with respect to solving problems concerning environmental and social aspects of development. Furthermore, as human activities are having an increasingly wider and greater environmental impact, there is merit in considering integration on even larger scales than farms, such as resource systems. The two most commonly discussed forms of integrated resources management are integrated coastal zone management and integrated watershed (catchment) management.

It is now apparent that a holistic and multi-disciplinary systems approach, complementary to that of conventional science, is required to solve major developmental problems facing the region today. In aquaculture we are dealing with "soft" systems involving people (as well as fish) rather than "hard" inanimate systems such as machines. Accordingly, we need to be concerned with both equitable and environmentally friendly development of integrated agri-aquaculture in Australia, through the adoption of a systems approach.

Integrated farming defined

Integration is another common term used in a variety of ways meaning "..to make whole, to complete by addition of parts, and to combine parts in a whole". The most common technical usage of the term within an IAAS context is a narrow definition of on-farm integration in which crop, livestock and/or fish enterprises or subsystems on a farm are linked through waste or by-product recycling, and improved utilisation of space (Edwards 1998).

However, for Australian purposes it is more useful to use a broader definition of integrated farming (IAAS) in order to link (mostly irrigated) agriculture with intensive, pellet-fed aquaculture, as well as with other human activities, and also on-farm and external resources. Thus, aquaculture may be conceptually as well as practically linked through IAAS with water resources, industry and sanitation in irrigation systems, agro-industry and wastewater, respectively. Examples of actual and experimental IAAS in Asia and Australia are given in Table 2.1 with an indication of their current status and potential. Further details of the Asian, Israeli and Australian IAAS experience are provided in other chapters of this Handbook, and specifically for Australia in Kumar (2000), Gooley (2000), Gooley *et al.* (2001a), Gooley *et al.* (2001b), Gooley and Gavine (*In press*), and Ingram *et al.* (2000).

Traditional and modern farming systems

Historically, farming systems probably evolved from traditional, crop dominated systems (*Settled Agriculture Phase I*), through mixed farming (*Settled Agriculture Phase II*), in which the importance of livestock was enhanced through their integration with crops, to industrial agriculture (*Settled Agriculture Phase III*), characterised by monoculture of either crops, livestock or fish (Edwards *et al.* 1988). Settled Agriculture Phase I occurred (and still occurs) in pre-industrial societies, usually with dense human populations, with limited integration of crops, livestock and fish, and with most land under food crops for subsistence needs. In these circumstances, livestock are kept mainly as draught animals for ploughing and feed on natural vegetation and crop residues, although there are also usually scavenging or penned pigs and poultry. Most of Western Europe was in this phase until about 1850 when mixed farming developed. However, many areas in developing countries remain in Settled Agriculture Phase I except for those suitable for green revolution agriculture, which has characteristics of Settled Agriculture Phase III. Traditional Chinese IAAS, in which carps are raised in ponds manured and fed with grass, fall into Settled Agriculture Phase I as these farms are still crop dominated.

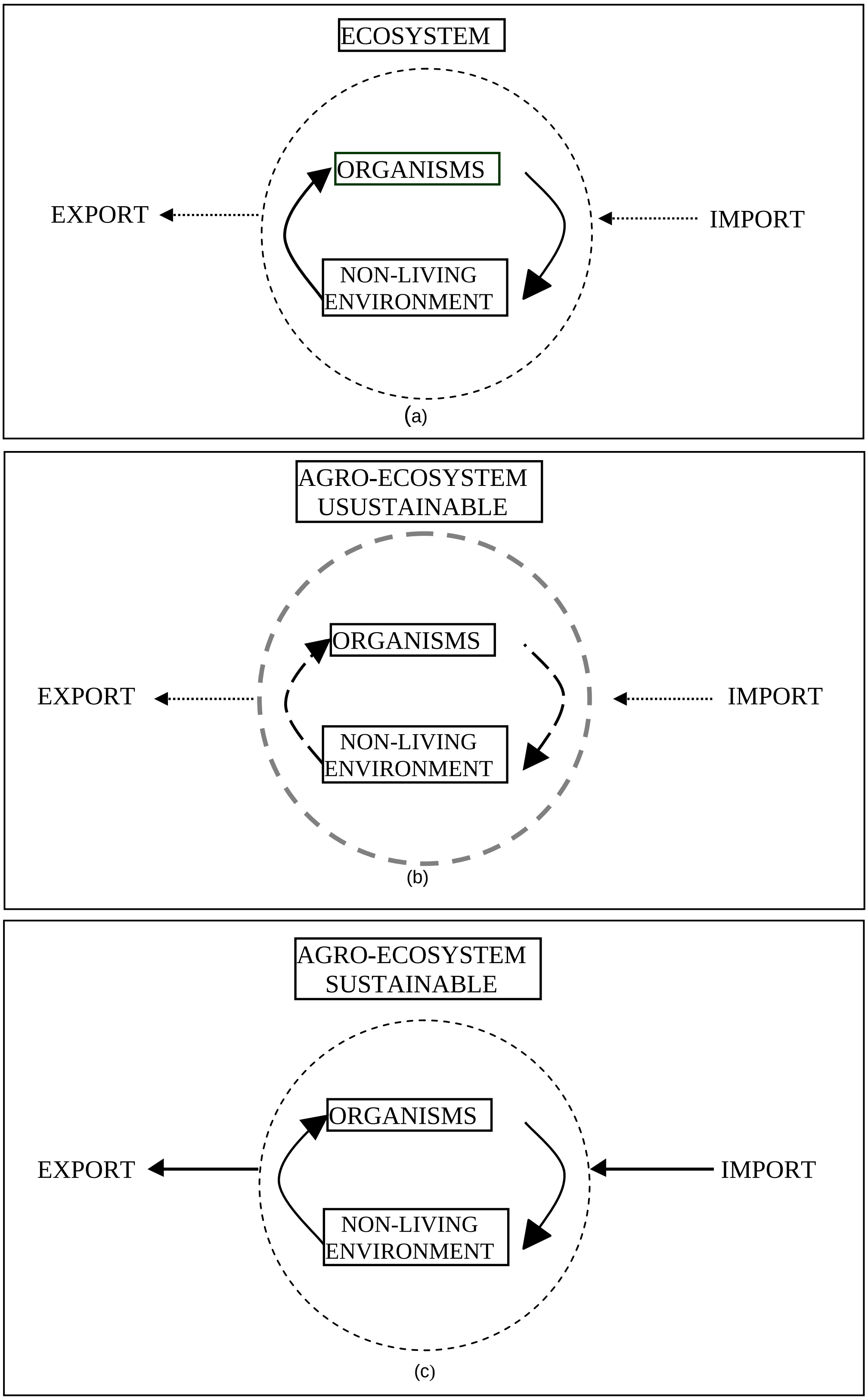

Figure 2.1. **Import of nutrients, export of produce, internal recycling and "leakiness" (directly proportional to size of spaces in circular boundary) of (a) natural ecosystem, (b) unsustainable agro-ecosystem and (c) sustainable agro-ecosystem.**

Settled Agriculture Phase II (mixed or integrated crop/livestock farming) dominated agriculture in Western Europe and North America until only a few decades ago. It was characterised by: crops farmed to feed livestock; grass cultivated as pasture, either permanently or in rotation; root crops; and livestock manure and crop rotation with nitrogen-fixing legumes to fertilise the soil. Livestock products were a more important source of income for farmers than crops.

Modern farming systems in Australia and other western countries are dominated by Settled Agriculture Phase III; industrial monoculture, in which farming technology depends on agro-industrial inputs such as improved seedstock varieties, chemical fertilisers, pesticides, herbicides, mechanisation, feed concentrates and formulated feed, and pharmaceutical chemicals. This Phase also predominates in green revolution areas of developing countries. Not surprisingly therefore, modern farming technology has effectively eliminated integrated farming in many areas because of this dependence on such industrial inputs. As H.T. Odum wrote “industrial man no longer eats potatoes made from solar energy; now he eats potatoes partly made of oil”(Odum 1971b). Since agro-industrial monoculture often causes considerable adverse environmental impact, the case is made here for a return to integrated farming systems i.e. IAAS.

Table 2.1. Examples of actual and experimental IAAS in Asia and Australia with prevalence scored (-, +, ++, +++). E = experimental.

IAAS	Asia		Australia	
	Current	**Potential**	**Current**	**Potential**
Rice / fish	+	++	E / +	++
Pond / fish				
- Crops				
- Livestock	++	+++	E / +	+++
- nightsoil	++	+++	E / +	+++
	+	+	-	-
Intensive livestock	++	+++	E / +	+
Intensive aquaculture				
- pond fish	E	+	E / +	++
- cage fish	E	+	+	++
- tank fish	E	+	+	++
- vegetables	E	+	+	++
- seaweed / molluscs	+ / E	+	E / +	++
Fisheries				
- plants	+	+	-	E
- trash fish	+	+	E /+	++
Water resources				
- irrigation	+	++	+	+++
Industry				
- crop processing	+	++		+
- slaughter house	+	++	E / +	+
- food manufacture	+	++	E / +	+
- breweries/distilleries	+	++	-	E / +
- power stations	+	++	+	+
Sanitation				
- sewage	+	+	E /+	+

A major problem with modern farming based on such agro-ecosystems is that they are too “leaky”, and therefore unsustainable. More specifically, large amounts of nutrients imported into the system are not all exported in produce; significant amounts pollute both the internal and external environment. It is suggested that the introduction of IAAS may reduce the overall need for total nutrient inputs by retaining a larger amount for internal recycling between different enterprises or subsystems, leading to increased profitability and less adverse environmental impact; in short a more sustainable agro-ecosystem (Figure 2.1).

Natural, cultural and controlled eutrophication

The pollution of water with nutrients is referred to in technical terms as eutrophication. The word literally means "becoming well fed", as enrichment with nutrients does lead to an increase in biological productivity. This is particularly so in terms of the development of large standing crops, or "blooms", of phytoplankton. Such blooms are considered to be a nuisance in western countries as they increase treatment costs for potable supplies and can decompose, leading to unpleasant odours and occasional mass mortality of fish. Some algal species produce toxins which may kill livestock and cause gastro–enteritis in humans. Overall, eutrophication causes a reduction in the amenity value of waters. At first sight it seems ironic that increased productivity of a water body would not be viewed as beneficial to fish, but in temperate latitudes eutrophication is often associated with declines in more commercially valuable trout (salmonids) and whitefish (coregonids). These species in turn are gradually replaced by perch and carps of lower market value (Colman and Edwards 1987).

Eutrophication is part of the natural succession of a water body in geological time due to weathering and nutrient building, but as it is considerably accelerated by human activity, the term artificial or cultural eutrophication has been coined. The major causes of today's problems of eutrophication are the introduction of a water-borne or sewerage system for domestic and industrial effluent, the increasing use of inorganic fertilisers in agriculture, the development of intensive livestock rearing in feedlots, and urbanisation in general. Borgstrom (1978) referred to these processes as "the breach in the flow of mineral nutrients" because of the disruption of the cycle of nutrients between human activities and the soil, which in turn has led to a one way flow of nutrients to receiving water bodies. Although the conventional view is unfortunately reflected in the philosophy "the solution to pollution is dilution" (Odum 1971a), continuation of this practice is neither environmentally sustainable nor sound economics. The guiding principle should be that there is no such thing as waste, and that wastes should simply be regarded as resources "out of place" (Taiganides 1979).

Ryther (1971) outlined a concept of "controlled eutrophication" to essentially recycle nutrients to reduce the adverse effects of pollution. However, controlled eutrophication forms the basis for many IAAS in Asia, indicating considerable dichotomy in both philosophy and practice concerning nutrient enrichment of water bodies in the East and West. Although traditional culture systems involving the integrated polyculture of carps, and more recently tilapias, are widespread in many countries of Asia, there are constraints to capitalising on traditional IAAS systems in developed countries such as Australia. For example, there may be social taboos against using manures for aquaculture, or the native fauna does not contain fish which can filter plankton as efficiently as the Chinese and Indian major carps and tilapias.

Furthermore, these fish require high water temperatures for optimal performance, and would therefore be constrained by temperate climates in the cooler, more southerly latitudes of Australia, particularly during winter. Indeed it is in these areas, particularly within the temperate regions of the Murray-Darling basin, where much of Australia's irrigated agricultural production occurs.

Sustainable production systems

A conceptual framework facilitates our appreciation of the need for a multidisciplinary systems approach to IAAS. Assessment of the potential application of the range of possible types of IAAS outlined in Table 2.1 requires consideration of three interrelated aspects of production, socio-economics and the environment (Figure 2.2); also more broadly elucidated in Australian natural resource management terms as the "triple bottom line".

Production technology includes the species to be considered for culture, the culture facilities and husbandry needed for the various stages of production (hatchery or seed production, nursery to produce fingerlings for stocking, and grow-out to produce the final product, usually for human consumption). Although more than 200 species are currently farmed globally in aquaculture, fewer are available in Australia for environmental reasons. Husbandry may involve various methods of stock management (monoculture or polyculture; single or multiple stocking and harvesting strategies), use of different feeds (natural, supplementary or complete feed), management of substrate and water quality, and disease prevention and therapy.

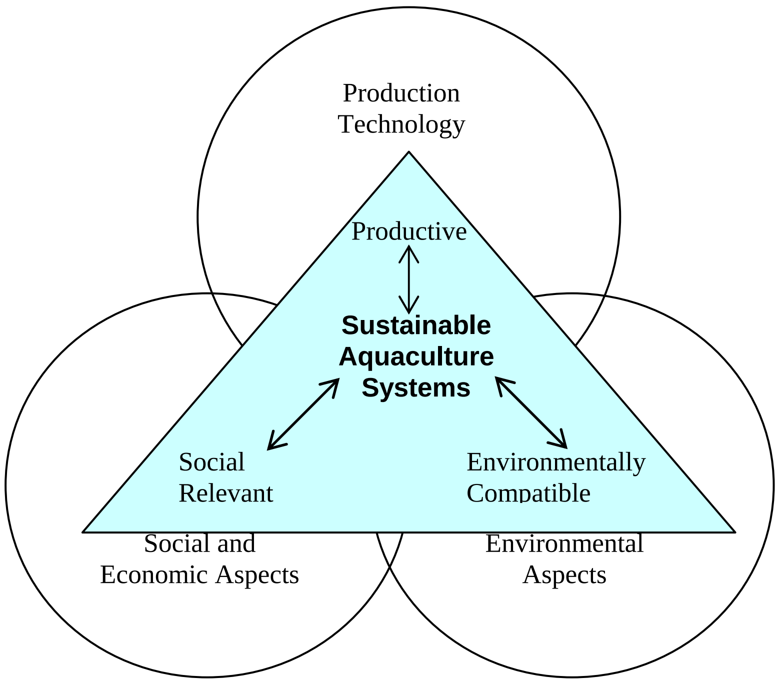

Figure 2.2. A system approach including production technology, social and economic aspects, and the environment, to promote sustainable aquaculture systems.

Social and economic factors influencing IAAS need to be considered at the macro-level (international, national and regional or state) and micro-level (rural farming community, farm and farm household). Macro-level issues include world trade, national development policy and goals, social aspects such as cultural attitudes to recycling, and input supply and marketing. Micro-level issues mainly concern the alternative use of resources *e.g.* whether IAAS are an appropriate use of resources and whether they can be linked synergistically with other farm and non-farm activities. The environment covers natural resources such as land, water, biological diversity and nutrients. There is a two-way interaction between the external environment and any aquaculture system and influences may be either positive or negative. A positive feature of IAAS is that they have the potential to exert a positive effect on the environment by utilising effluents or by-products from other adjacent or distant human activities.

Conclusion

The broad application of IAAS philosophies, principles and concepts, as outlined in this paper, could provide a tangible means of facilitating the development of sustainable, agro-industrial scale farming systems in Australia. It can assist the irrigated agribusiness sector in successfully achieving the critical elements of the "triple bottom line" in this country.

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Chapter Three

Integration of Agri-Aquaculture Systems – The Israeli Experience

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Introduction

Israel is located in a semi-arid zone, with distinct wet winter and dry summer seasons, and a low average annual precipitation of 500 mm concentrated in the 4-5 winter months. Israel has no major rivers or underground freshwater sources. The only large inland water body is the Lake of Galilee, which mainly supplies freshwater for human consumption. Moreover, in the central-north areas of Israel, where the majority of the precipitation is concentrated, the hilly and mountainous land cannot naturally hold water. In spite of the obvious climatic constraints and overall shortage of water, both agriculture and aquaculture are highly developed in Israel and considered to be world-class.

To deal with these impediments, reservoirs were constructed to store rainwater during the wet season. Israeli crop agriculture is now largely intensive and dependent on irrigation from these reservoirs during the dry summer. Recently, it has become common to use irrigation reservoirs for fish culture, in integrated farming systems. These integrated agriculture-aquaculture systems use the water twice; firstly within an aquaculture production system and subsequently to supply irrigated agriculture systems. This tradition, now a few decades old, was a significant step in the intensification of inland fish culture in Israel (Hepher 1985, Sarig 1988).

Regional Variations

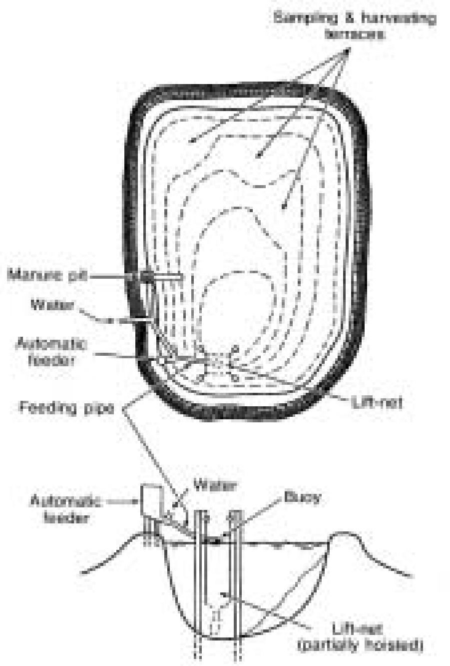
Climatically, Israel can be divided into two regions, *viz*:
1. The central-north of the country with relatively high annual precipitation (>800 mm).
2. Southern arid/semi-arid areas with very low annual precipitation (<100 mm) (the Negev desert and the Arava valley).

The two areas differ in their sources of water, the usage of it, and the type of integrated aquaculture systems employed. In the central-north region, irrigation reservoirs storing winter rainfall also operate as large, semi-intensive fish ponds. In the southern, more arid region, water is pumped year-round from geothermal bores, and used for super-intensive aquaculture in a very highly integrated water management system, from the bore to the end user. The systems developed in each region are detailed below.

Central – north regions

Dual-purpose reservoirs are used for irrigation and fish culture. Fish are reared in the reservoirs over the irrigation period of spring to autumn. Fish harvesting is carried out in autumn, when the reservoirs are nearly empty and awaiting refill over winter. Reservoirs begin to fill during autumn with a combination of spring (ground) water and early winter rains. When the water column reaches a height of 1m (normally around December) the reservoir can be stocked with fingerlings. These fish reach market size within a year. The reservoir continues to fill until January, or early spring, depending on its geographical location and holding capacity. In late spring or early summer, the stored reservoir waters are pumped for crop irrigation, and the water level in the reservoir drops gradually while the fish are being grown. By September/October, when only 1-2m of water is left; the farmers start to thin-out the fish population and prepare for final draining of the reservoir and harvesting of the remaining fish. In the 1960s, the first reservoirs were constructed in the Harod valley to serve the needs of the kibbutz (communal) settlements in that region, solely for irrigation. Five reservoirs were constructed, with a total surface area of 90 ha. These rather shallow reservoirs collected and stored brackish spring (ground) water, flowing year round, for use during the dry summer. The reservoirs were subsequently deepened to increase their storage capacity of winter rains. The farmers of these communal settlements then decided to use them for fish culture, in addition to their original purpose. In a few years it became apparent that rearing fish in such reservoirs was profitable, though professional and technological know-how was lacking.

This secondary use of water for fish culture, by introducing aquaculture into irrigation reservoirs, improved the efficiency of water usage and reduced the cost of water needed for fish culture in conventional earthen ponds. However, the main drawback was harvesting the fish from these reservoirs, since the engineers planning their construction did not consider such activities in their initial design. This led to dramatic technological developments during the late 1970's, when many new reservoirs were constructed, specifically planned for dual-purpose use *i.e.* they were equipped with a range of solutions for efficient harvesting of the fish (Figure 3.1). This development, in turn, changed the emphasis on water usage in this region.



Technical details

Reservoirs:
- Capacity 500,000 – 1,000,000 m^3 ;
- Surface area 8 - 20 ha;
- Depth 5 – 14 m.

Harvesting methods:
- Outlet pipe connects to small pond;
- Concrete harvesting box, also fed by outlet pipe but fitted with screens;
- Fish sorted from box into separate holding ponds.

Other tools:
- Lift nets;
- Automatic feeders; floating feeders connected by hose to bulk storage silos on the reservoir shore;
- Floating water pumps (see Zoran and Milstein 1998 and Milstein *et al.* 2000) to combat thermal stratification in deep (>5m) reservoirs in summer, and subsequent water quality problems.

Figure 3.1. Schematic drawing (aerial view at top, and cross section at bottom) of a dual-purpose reservoir for fish culture and crop irrigation (from Hepher 1985).

In the newly constructed reservoirs, fish culture became the primary activity and crop irrigation a "by-product". Most fish farms in Israel now operate such reservoirs, which have proved to be an efficient and profitable tool for fish culture.

In Israel, both in conventional earthen fish ponds and in reservoirs, freshwater fish are typically cultured in a polyculture system, stocked with different species of fish (Hepher 1985). Most reservoirs are stocked with 80% common carp and tilapia (at various combinations) and 20% accompanying species, such as grey mullet, grass carp, red drum and the silver carp x bighead carp hybrid. Only about 30% of reservoirs are used for monoculture of either carp or tilapia alone. The main advantages of the monoculture system relate to easier harvesting operations and storage of recovered fish.

Juvenile fish to be stocked into reservoirs are initially nursed to a certain size in conventional, shallow earthen fish ponds. None of the target species can grow from a 1g juvenile (at first stocking) to market size from spring to autumn, which is the usual operational period of a reservoir. Thus, the farm must have additional rearing ponds in order to efficiently operate a reservoir for fish culture. These ponds will also be used at harvest time to hold fish until they are marketed (all through the year), since a farm cannot market the whole harvest of a reservoir at once. Thus, the ponds are operated all year round; rearing juvenile fish in the spring and summer, and holding fish for market or for stocking the reservoirs (in the following spring) during the winter. The stored fish are fed maintenance ration during winter, and this is added to pond expenses.

Economic evaluation of reservoirs vs. conventional earthen fish ponds

Detailed examples of production figures for dual-purpose reservoirs are presented in Hepher (1985) and Sarig (1988). Production inputs and associated capital depreciation costs per unit weight of fish output in such reservoirs compare favourably with those in conventional earthen fish ponds (Table 3.1).

Table 3.1. Production inputs and associated capital depreciation costs of producing 1000 kg of fish in ponds and reservoirs in Israel.

Data	Dual-purpose reservoirs	Earthen ponds	Comments
Water	-	50,000 m^3/ha	Reservoir water price is charged to irrigated field crop
Feed	1,300 kg	2,200 kg	Ponds are used for holding fish during winter, so more feed is required overall
Labour	5 days	6 days	
Seed	4,000/ha	5,000/ha	
Energy	5,000 kW	6,000 kW	
Depreciation	2,000 NIS*	2,500 NIS*	

* 1 NIS = ~ AUD$0.48

To compare water use specifically, production of 1kg of tilapia requires:
- 7.4m^3 of water in conventional earthen ponds,
- 4.6m^3 in intensive concrete ponds,
- 4.0m^3 when cultured in reservoirs, and
- 1.4m^3 in an industrial, indoor, super-intensive culture system.

Production costs of the major species are rather similar for the two culture systems, with those in dual-purpose reservoirs being slightly lower, *viz.*

Reservoirs:
8 NIS/kg of carp
11 NIS/kg of tilapia

Conventional earthen ponds:
9 NIS/kg of carp
12 NIS/kg of tilapia

Most of this difference is due to the different feed conversion ratios attained in the two culture systems. Current market prices (to the farmer) are 13-14 NIS/kg for carp, 12-13 NIS/kg for tilapia, 5.7 NIS/kg for silver carp (and its hybrid) and 17-20 NIS/kg for mullet and red drum. A detailed breakdown of production costs of fish in dual-purpose reservoirs is presented in Table 3.2.

Table 3.2. Itemised costs of producing 1 kg of fish in dual-purpose reservoirs. Price and cost figures in NIS/kg (1 NIS = ~ AUD$0.48).

Item	Unit	Quantity	Unit price	Cost
Water	m^3	3.5	0.1	0.35
Feed	Kg	2	1.2	2.40
Fingerlings (50 g)	#	3.02	0.65	1.96
Energy (pumping, aeration)	Kwh	5	0.3	1.50
Maintenance, machinery		1	0.3	0.30
Marketing		1	0.8	0.80
Labour, management	days/tonne	3	300.0	0.90
Financing	%	5		0.41
Depreciation		1	1.44	1.44
TOTAL				10.06

South (arid) region

The term 'desert aquaculture' means the aquaculture production of fish and aquatic animals in arid areas. It sounds paradoxical given the obvious lack of suitable surface waters for such a purpose in these areas. However, during the last two decades the commercial 'desert aquaculture' industry sector in Israel has been booming, largely as a result of being able to productively utilise the vast ground water resource in the southern arid region. This development is also a result of the constant freshwater shortage in the central-north region of Israel during recent years, which in turn has limited further development of aquaculture in that region.

'Desert aquaculture' in Israel offers many specific advantages such as:

- Large quantities of brackish ground water that can only partially be used for agriculture;
- Warm ambient climate;
- Geothermal bores that, with greenhouse use, maintain high temperatures in the winter;
- Dry climate that allows water-cooling in the summer;
- Cheap land;
- Geographic isolation – natural quarantine;
- Minimal ecological risks;
- Year-round production.

These advantages have attracted large investments during recent years into a diversity of fish species, including striped bass, barramundi, carp, *Tilapia* spp., redclaw and ornamental fish species.

Aquaculture in geothermal water

Southern arid aquaculture started in 1979 with the discovery of locally available geothermal water (at 60°C), near Moshav Faran (a community settlement) in the Arava valley. The idea of using hot ground water for super-intensive aquaculture to achieve maximum growth throughout the year has subsequently been developed commercially. Combined heating of greenhouse-covered microalgae (*Spirulina* or *Dunalliela* spp.) and fish ponds has also been successfully trialed.

For both economic (cost of 1 m^3 of water in Israel is about AUD$0.5) and ecological reasons, the design of integrated aquaculture projects with agriculture areas as end-users is a necessity in arid areas. Contrary to the central-north areas of Israel, integrated aquaculture in the southern, more arid areas is super-intensive, with very tight water budgets. Water loss is minimal, predominantly due only to evaporation. Even when there is no need for heating during the summer, most of the fish farms have water exchange of at least 10% per day. A small fish farm of 2000m^3 will therefore use about 200m^3 water per day, which in turn will irrigate about 4 ha of crops in the desert summer. In winter, when a large amount of water is needed to supply the heat energy to the fish ponds in the aquaculture system, there is a need to find a solution for all the output water or effluent (Figure 3.2).

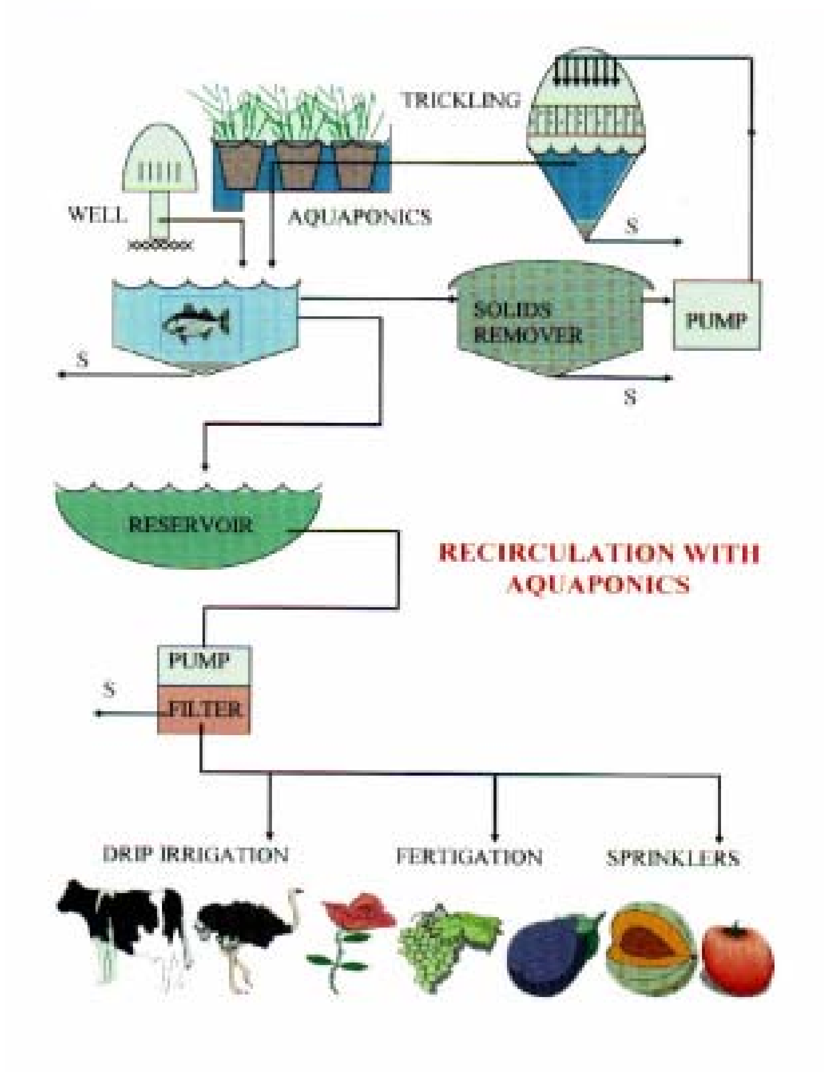


Figure 3.2. Schematic description of 'desert aquaculture'.

There are two options for transferring heat energy to the fish ponds in these production systems, *viz.:* (1) Closed system using heat exchangers and (2) Direct supply of water to the fish pond.

When using a closed system, the geothermal water is used for heating the fish pond *via* a heat exchanger, and the quality of the effluent used for irrigation is identical to the bore water. When a direct supply of geothermal water to the fish pond is used for heating, the water is also used for flushing the organic matter from the pond and to contribute overall to the water quality of the pond. Accordingly, the outlet water is loaded with suspended solids, micro-organisms, algae and plankton due to the high nutrient loading on the intensive rearing system.

When the end-user of the effluent is drip irrigation, the water needs to be filtered or otherwise treated prior to being distributed under pressure through the dripping system. Usually, a small operation reservoir (0.1-1 ha surface area) is attached to the fish farm for this purpose. This reservoir, with water treatment facilities attached, is used to provide a buffer between the agriculture project (*e.g.* greenhouse or open field) and the aquaculture system. Fish are also reared in this reservoir but at relatively low biomass. The water treatment facilities typically include high-pressure pumps, a chlorine injection system (or other form of disinfection) and an automatic filtration system. Secondary filtration is undertaken at each irrigation head to ensure good water quality for final reticulation and to prevent drippers from clogging with particulate waste matter.

Salinity of the bore water is crucial for any agricultural crop, with 0-5 ppt salinity being an acceptable concentration in most cases in Israel. Most of the geothermal water that is available in Israel is considered too salty (8-12 ppt), especially if increased salinity occurs due to evaporation in fish ponds. At these higher salinities, rearing sensitive crops is not feasible, although other crops such as watermelons, alfalfa and tomatoes are highly successful. 'Desert sweet tomatoes,' a brand name for a very sweet tomato species developed in Israel and produced in saline groundwater, is extremely successful in the local and European markets. Higher salinities have also been successfully used in production of olives and date palms in an integrated agri-aquaculture system.

Out of five model, pilot-scale farms established during the 1980-90's, two were expanded to a full commercial scale of 200-400 tonnes/year of aquaculture production. These farms were built from modular units of eight, $300m^3$ capacity ponds (Figures 3.3, 3.4 and 3.5). The ponds are connected to a water treatment unit that includes a settlement pond (100-$200m^3$ capacity) and which uses floating 'activated particles' for nitrification (conversion of harmful ammonia waste to less harmful nitrites and nitrates).

Aquaponics – integration of aquaculture and hydroponics

Different methods of 'aquaponics' have been developed and tested in Israel over many years on various pilot-scale, desert aquaculture farms (Figure 3.2). 'Fill and flush' is one of the common methods used in which aquatic plants are housed in buckets or containers filled with lava gravel (0.4-1cm) substrate. The containers (with 0.5 cm holes) are placed in a shallow, plant pond bed (1m x 10-15m). Inlet water, from the sedimentation basin/settlement pond or biofiltration unit fills the plant pond bed to the top of the gravel. The water is then drained, by siphoning or automatic valve, to a small reservoir at the edge of the pond bed system. From this reservoir the water is then pumped back to the fish ponds. During the summer months, additional water is required (up to 8-10 m^3/0.1 ha/day); a by-pass pipe is then used to prevent flushing of the bio-system.

Figure 3.3. Greenhouse with supporting reservoir

Figure 3.4. Greenhouse with super-intensive ponds

Figure 3.5. Harvesting of a pond and paddle-wheel aeration

Efficient integration of hydroponics and fish ponds allows a hydroponics to fish pond land-usage (area) ratio of about 1:1. Water quality monitoring is essential and addition of potassium, ferum and calcium carbonate is recommended. In recent aquaponics field experiments, crop production from this type of system was double that of conventional (field produced) crops. Furthermore, this was achieved with no addition of pesticides or insecticides, possibly making the crops more marketable as ‘organic’ or ‘environmentally safe’. Aquaponics crops tested included leafy plants and herbs such as basil, mint, chives, salvia, rosemary and lettuce. Many other field crops such as honey melons, watermelons, cucumbers, tomatoes, peppers and fruit trees were also successfully trialled.

Conclusions and Future Directions

During the last few years, Israeli restrictions on the use of water for agriculture and aquaculture, largely aggravated by prevailing drought conditions, have focused attention on the development of the integrated agri-aquaculture sector. More productive use of saline ground water, in desert areas, is increasingly important. Accordingly, Israel is currently investing in the development of salt tolerant crops that are suitable as the end water users after first use by aquaculture. Integrated aquaculture systems with these crops, including water efficient pond/reservoir and recirculating/greenhouse systems, are being further developed and improved. Other priority issues for industry in Israel are the evaluation of new aquaculture species that can suit these systems and which have local and/or export market potential.

At first glance it could be said that there are more differences than similarities between integrated agri-aquaculture in Israel and Australia, due largely to their considerable geographic separation and many physical dissimilarities. For example, the area of Western Australia alone is about 2.5 million km^2, compared about 20,000 km^2 for the whole of Israel. However, there are many common features, with proportionately large areas of both Australia and Israel classified as arid zone desert, much of which is underlain by substantial saline groundwater resources.

Indeed, during recent years, many parts of Australia have struggled with increased salinity in agricultural areas and, as a result of saline groundwater, vast areas are no longer available for agriculture. In Israel, a possible solution to this problem is diversifying into aquaculture and using the saline water. Moreover, even in areas without a salinity problem, many Australian irrigation farmers are looking for alternative sources of income which again, based on the Israeli experience, could be based on the multiple water-use integration of agriculture and aquaculture production systems.

In Australia, such integration within the commercial agribusiness sector is still very much in the early developmental stages. On the other hand, integrated systems are well established in Israel and the ‘desert aquaculture’ sector in the southern arid zone regions has been booming during recent years. It is therefore suggested that both Australia and Israel could benefit considerably through the establishment of collaborative links at different levels for the purposes of undertaking both R&D projects and commercial/industry joint ventures.

Opportunities for Cooperation between Australia and Israel

Due to the similarities in prevailing climate, water resource constraints and other broad agribusiness parameters in Israel and Australia, it is suggested that many integrated agri-aquaculture systems and methods developed in Israel can be readily adapted and applied in many areas of Australia. Moreover, several endemic Australian species such as barramundi and redclaw are now commercially reared in Israel in these systems. Instead of ‘re-inventing the wheel’, both countries need to initiate a process of information and technology exchange that will be mutually beneficial for industry sectors at both ends. Cooperation between Australia and Israel could be in the form of trade missions and research/industry exchange visits, business joint ventures and collaborative R&D projects, preferably underwritten through bi-lateral funding support from an industry/government consortium involving both countries.

Currently, there are already a few collaborative aquaculture R&D projects between the two countries which incorporate some aspects of agri-aquaculture integration, including:

- The Kinerret (Lake of Galili) project which involves the University of Western Australia/Centre for Water Research (UWACWR), and the Israel Oceanographic and Limnological Research Institute; funded by the Israeli Agriculture Ministry.

- Aquaculture Waste Model project involving collaboration between Fisheries Western Australia (Mariculture Research & Advisory Group), Centre for Water Research (UWA), and The National Center for Mariculture (NCM) in Eilat, Israel.

- Project investigating use of sea lettuce *Ulva* sp. to strip nutrients from fish farm effluent, involving collaboration between Fremantle Maritime Centre, Challenger TAFE (Western Australia) and NCM, Israel.

There are several areas that may have further potential as collaborative R&D and technology exchange/transfer projects between the two countries. These include:

- **Freshwater crayfish (yabby, marron and redclaw) (*Cherax* spp.) aquaculture.** Substantial expertise exists within Australia for these species, particularly in relation to extensive pond production methods. Alternatively, Israel is experienced in the high-density tank culture of redclaw. Indeed, a number of Kibbutzim and private farms in the Arava Valley and the Negev Desert regions in Israel are presently rearing redclaw (originally from Queensland), and other Australian crayfish species are also thought to have potential.

- **Silver perch (*Bidyanus bidyanus*)** – The Institute for Desert Research, Ben-Gurion University of the Negev is currently working with this fish species. The main area of research is development and evaluation of rearing methods and appropriate grow-out diets. Silver perch has also recently attracted a substantial amount of R&D and industry development in Australia.

- **Freshwater prawns (*Macrobrachium rosenbergii*)** – The Volcani Institute (Agriculture Ministry) in Israel has worked on developing intensive rearing methods for this species for 20 years. There is also an interest in the north of WA, especially within aboriginal communities, to culture this species commercially.

- **Barramundi (*Lates calcarifer*)** – In recent years the Israeli Agriculture Ministry has started to develop barramundi culture for local production. The original seedstock were imported from Australia where the industry has now been established for several years. 'ARDAG' (a mariculture company own by a number of kibbutzim) subsequently started to produce juveniles that were distributed to a number of kibbutzim in the Arava Valley and the Negev desert. Australia has extensive existing knowledge on barramundi larvae and grow-out culture technology, as well as a good understanding of the nutrition requirements for this species. On the other hand, the rearing methods in Israel are focused on water-restricted recirculation systems operating at very high densities that integrate agriculture crop production (*e.g.* olives).

- **Marine prawns (*e.g. Penaeus* spp.)** – both Australia and Israel have strong interest in developing this aquaculture sector, which is now a global industry. Environmental conditions are similar in certain areas of both countries, although different species are reared. Current Israeli initiatives are developing prawn culture in a brackish water, integrated agri-aquaculture system using a combination of relatively small culture ponds together with a large 'biofilter' reservoir/ irrigation storage.

- **Inland saline aquaculture** – due to environmental restrictions on developing cage culture in coastal areas, both countries are interested in developing cage culture using ponded inland saline groundwater from the vast natural resources that are available. To do this will require strict control over effluent discharge, which will be achieved by integration of culture ponds within agricultural systems which restrict nutrient output through re-use by other organisms such as algae and bivalves *i.e.* agri-aquaculture pond systems that will have reciprocal/dual use of the water and effluent.

Finally, effective and efficient engagement between Australian and Israel, for the development of the respective agri-aquaculture sectors in each country, would be facilitated by the establishment of a specific bilateral national body. This body would have responsibility to promote the development of the industry and R&D collaboration between the two countries and to further pursue many of the specific opportunities outlined above. In this way, the future long term viability and sustainability of agri-aquaculture industry sectors in both countries would be considerably enhanced.

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Chapter Four

Integrated Agri-Aquaculture Systems - The Asian Experience

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Introduction

Through its traditions and historical record, Asia is commonly considered to be the home of integrated aquaculture, conjuring up an image of small-scale farmers growing fish as an integral part of their agricultural systems. However, there is actually a wide variation in the occurrence and importance of aquaculture throughout the region, and many local differences in the levels of integration employed. Huet's (1972) generalisations on the Far East 'where all farmers are fish farmers and *vice versa*' was based on peri-urban areas around Bangkok and West Java (Edwards *et al*. 1996). These authors estimated that far fewer than 10% of small-scale farms in the region culture fish and of those that do, most produce less than their resource base would allow.

Although aquaculture has spread rapidly in some parts of Asia, this has been a recent development. Though traditional, its importance even in northern Vietnam and southern China was probably limited and localised; until recently, farmed production was a fraction of that from capture fisheries. The statistics suggest that the spectacular 50 fold growth in freshwater fish production in China occurred only after the founding of the People's Republic in 1949 (FAO 1999), spurred on by the ability to induce spawning in riverine carps, by population growth and the later development of a market economy. Although such figures are increasingly viewed sceptically (*e.g.* Watson and Pauly 2001) there is no doubt that aquaculture has developed fast, and in many cases official figures are probably underestimates, given the level of home consumption and local trading. Most operators producing seed in northern Vietnam and NW Bangladesh, where aquaculture is traditional, began only in the last two decades (AIT/RIA1 2000, AIT/DOF 2001).

Nonetheless, many people in Asia, including the world's largest group of very poor people, are highly dependent on aquatic animals. Fish provides at least 40% of dietary animal protein in nine Asian countries, and contributes significantly to digestible energy, essential fatty acids and micronutrients. However, there is great variability in how the people of Asia obtain their fish and how future generations might meet their needs. From simple enhanced fisheries to intensive/industrial systems, aquaculture in Asia has grown more rapidly than any other food sector, spreading away from traditional locations in densely populated river valleys and deltas to a variety of agro-ecological zones. Key factors in this growth have been the availability of seed and knowledge. These have spread, initially through international and public agencies, but increasingly through private or informal sectors. Within this range of practice, integration occurs very widely, though the degree of interconnection between aquatic and other systems varies.

The scope for Integrated Agri- Aquaculture Systems

The potential for IAAS in Asia is often linked to wider options for developing water supplies for fish production. Common property water bodies are still very important, and their structure and management can sometimes be developed to increase availability of fish at low cost. This may simply be a matter of filling a vacant ecological niche, *e.g.* introducing tilapia into man-made tanks in Sri Lanka. Such fisheries can be intensified, and highly productive, through stocking hatchery-produced juveniles, but this approach often fails because of the costs and difficulties of management. Community water bodies can also be privatised through pen or cage-based culture. External factors can be important, but producers can adapt. Thus although some commune-based stocked fisheries in northern Vietnam collapsed following economic changes in the early 1990's, hatcheries supplying seed found ready markets among rice farmers adopting pond-based integrated aquaculture.

The uptake of IAAS is as much linked to changes in the rural economy as to technical factors. Declines in natural fish resources are usually related to increased population pressure and its impacts, particularly through irrigation and more intensive rice production. Aquaculture has grown significantly: in some areas of Vietnam, more than 30% of households now produce fish (AIT/RIA 1 2000). Liberalising markets, especially those that help diversify rice production, and infrastructure development, are particularly important. The creation of borrow-pits for fill used in road and house building, also helps stimulate pond construction and in turn, fish culture.

Typically aquaculture first supplements the wild catch before sometimes later replacing it. In many parts of Asia, farmed fish can be harvested outside the monsoonal wet season in which wild stocks are plentiful. Consumers and traders begin to prefer the availability and size consistency of cultured fish, even if indigenous wild fish command higher prices. In Lao PDR indigenous species remain more popular than cultured fish (Sverdrup-Jensen *et al.* 1992) but some, especially tilapias and local species such as *Puntius gonionotus*, are widely accepted and demand has grown strongly. Wild swamp fish are usually sold live and so harvest and marketing of fish from ricefields has evolved separately from commonly stocked aquaculture species (*e.g.* in NE Thailand). However, as competition has grown with production, premiums for live cultured fish have also appeared. Control over the timing of harvest also tends to stimulate interest in processing and adding value locally.

In Cambodia and southern Vietnam small farmers may continue to catch small indigenous ricefield fish for daily consumption and invest in cultured fish as a cash crop. In contrast, export of valuable riverine fish to Thailand may stimulate fish culture for home consumption in Lao PDR. In NE Thailand, Prapertchob (1989) showed major differences in the importance of fish and other aquatic animals through the seasons and between different sectors of the community. Rural people were more dependent on seasonal supply and urban people were more likely to consume cultured fish, much produced in IAAS. In NW Bangladesh, small silver carp became the preferred fish of the poor because of their low price and ready availability.

Current conditions for development

The opportunity for IAAS in the region depends on a range of factors. Seasonal effects, especially temperature and water availability, may affect production, *e.g.* low temperatures reduce fish growth rate and the capacity of ponds to utilise waste. Lack of water may constrain culture duration and reduce flexibility of marketing. Links between fish culture and other components of smallholder rural farms can be weak and this has often undermined attempts to promote IAAS. A shortage of resources, especially nutrients, may be an issue. However, the strategic use of on and off farm inputs for aquaculture has succeeded in raising on-farm income to attractive levels in NE Thailand and Bangladesh. Increased opportunities to migrate for wage labour, can both limit the ability of households to engage in IAAS and local demand for fish, as rural communities shrink and fragment. Although wealthier households were often the first to try aquaculture in the community, it appears that poorer households with access to land have adopted it and may manage their systems more efficiently (Barman *et al.* 2001, Turongruang and Demaine 2001).

Peri-urban IAAS are common as the easy availability of by-products and wastes in urban areas can make it cost-effective to recycle through pond fish culture. Demand for high value species and the increasing use of complete feeds have also stimulated specialised monoculture. Better road access and infrastructure widens the peri-urban zone, with a broader variety of products, means of integration, and employment based on transport and trading of wastes and by-products between specialised producers of livestock and fish. Livestock processing wastes have become increasingly important to farmers raising higher value fish such as *Clarias* catfish. In southern Vietnam and central Thailand access to slaughterhouse waste is critical to profit margins of catfish farmers, despite the ready availability of complete feeds. The steady decline in prices for livestock and cultured fish in much of Asia has also constrained specialised intensive aquaculture to displace IAAS.

Status and development of IAAS

Historically the use of water bodies in Asia has been multipurpose and loosely, 'integrated'. People have relied on both community and household water resources for irrigation, bathing, and livestock production, as well as a source of fish. A number of themes for integration can be identified, related to the use of land and water resources, and to systems linked with specific types of agricultural practice and/or types of nutrient materials. Four main categories of products - (1) direct human consumption, (2) indirect consumption, (3) juveniles and (4) ornamental – can also be distinguished. The latter two are the highest valued, and the use of IAAS may be undermined by greater returns from more specialised, non-integrated approaches. However in China and Vietnam both human and livestock wastes are commonly the major input for advanced fingerling production of carps and tilapias. The culture of intermediate organisms such as fly larvae (Nuov *et al.* 1995) or duckweed (Edwards 2001) on wastes, that are then used as livestock or fish feeds, is also practiced. In contrast to (3) and (4) these are relatively low value and exploiting such strategies normally occurs if direct waste-fed fish production is unacceptable or impractical.

Land use

Some level of spatial integration normally occurs where pond construction changes land form; typically from flat deltaic land to a 'ditch-dike' arrangement in which deeper areas (ponds) are surrounded by raised dry-land areas (dikes). The utilisation of higher dike areas for dry-land crops is often prioritised in areas where seasonal flooding occurs. The complexity and intensity of these systems increases where pressure of land is greatest, such as in the suburban VAC systems in northern Vietnam. These require high labour inputs, especially for short-term vegetable crops, and a shift to longer term, less labour intensive crops such as sugar cane or bananas has become common (Setboonsarng 2001). Irrigation is facilitated by the proximity of water, and systems throughout the region vary from crop to fish dominant. The dominance of fish or horticulture can be assessed to some extent through the ratio of land to water area, the characteristics of production (Figure 4.1) and the impact of seasonality of water availability.

Rice-based systems

The integration of fish in ricefields has attracted a good deal of attention, partly because flooded rice production is a dominant form of land use. Rural people still widely depend on these for meeting their day-to-day aquatic food needs, but many factors threaten this. Increased populations result in greater fishing effort and also a tendency towards intensification of rice production. Generally this results in more controlled water use, greater use of agrochemicals and a decline in the production of fish and other animals. Productivity of aquatic animals is also connected with the quality and extent of refuge available.

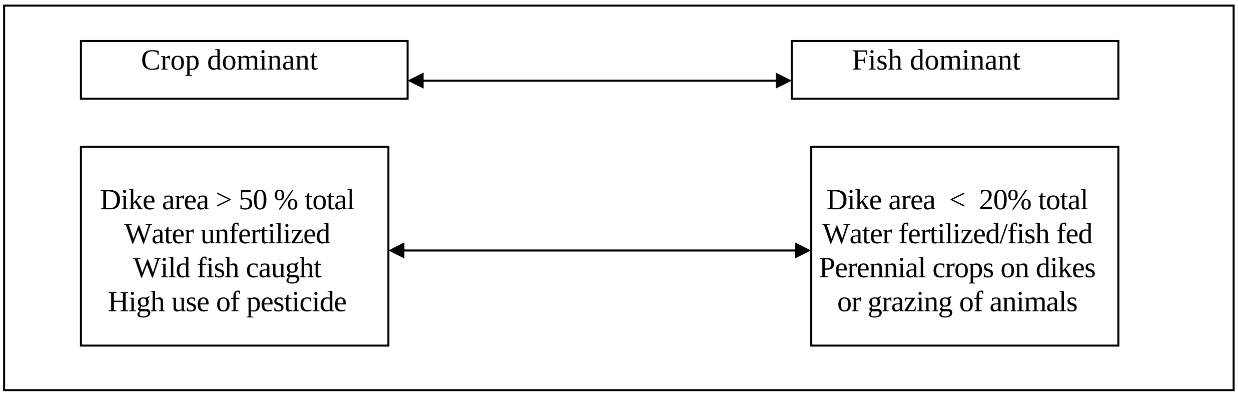

Figure 4.1. Schema showing the continuum of land and water use in IAAS in Asia and impacts on characteristics of dike and water use.

Sustaining established and introduced aquatic animals within complexes of shallow ricefields and deeper areas has great potential. Fish production is also very valuable as part of integrated pest management (Little and Edwards 1997).

Two strategies are common to increase rice-fish production; stocking a higher percentage of ricefields or maintaining/enhancing natural biodiversity. Stocking of ricefields has been heavily promoted in some parts of Asia but has either been inappropriate to farmers' needs or too resource intensive, especially in terms of use of water or labour. Where stocking has become established it has usually been cash orientated, usually for seed production. This is well established for common carp in West Java, and is spreading in Bangladesh as demand for large carp and tilapia fingerlings grows.

Rice-fish culture is best developed, and has greatest potential, where irrigated rice production and well-developed aquaculture can be combined. Its longest history is probably in Indonesia and China, but it has also had positive impacts in countries such as Bangladesh and Vietnam. A key commercial niche has been in producing large juveniles for stocking in cages and ponds. The short duration required, and the relatively high value of fingerlings, has made this an important means of sustaining overall returns from ricefields. The extra investment required, in terms of physical changes in the rice field and its water use, is also more conducive to modern rice techniques. The most important species is probably common carp, although nursing of Nile tilapia with irrigated spring rice has shown promise in both northern Vietnam and Bangladesh (Barman 2000). Juvenile silver barb and various larger riverine carps have also performed well in this type of nursery environment.

Water use

Aquaculture has usually been promoted in areas where water supplies ensure year-round production. However, it has also been attractive where availability of water is seasonal. In contrast, many irrigated areas lack aquaculture development, often as there may be no traditional interest in freshwater fish. Culturing fish to supplement seasonal or year-round scarcity can however be attractive to supplement household food security, enhance social assets or even to provide seasonal cash income. Research in India and Sri Lanka has shown that productivity can be high and the cost and risk of production low (Murray *et al.* 2001). The many small seasonal water bodies in Asia, situated in small watersheds and used for livestock watering, act as nutrient traps and have high productivity. Seasonal draw-down allows predators to be removed, and permits harvest without requiring special gear. Timely stocking of large juveniles is critical, and may require access to perennial water for breeding and nursing. This has been a key constraint in parts of Sri Lanka and southern India. In semi-arid parts of Karnataka, long and poorly developed supply chains for highly perishable juveniles have been a problem. Such areas lack the knowledge common in traditional fry trading networks in areas such as eastern India and Bangladesh (Lewis 1997).

Open agricultural wells have been found to have potential for integration with *Clarias* catfish culture in Karnataka, India (Murray 2000). Water storage in on-farm reservoirs (OFRs) has also been promoted to reduce impacts of erratic household water supply in several parts of the region. Such water bodies have become a focus for rural diversification in NE Thailand. In the Philippines, Bhuiyan and Zeigler (1994) reported that a majority of operators stock and benefit from fish. However, Fujisika *et al.* (1994) found that conflicts with rice production emerged if OFR's were managed for aquaculture.

Various approaches have been taken to privatise the use of community water bodies, through cage and pen culture. In Indonesia, lake-based cage culture has been supported by agro-industry and reached industrial proportions (Munzir and Heidhues 2001). Limited development of pond aquaculture, and demand for common carp and tilapia that grow well in cages stimulated rapid growth, in some cases exceeding environmental carrying capacity. In Thailand, intensive production of tilapia in cages has been heavily promoted by feed companies and adopted over the last three years and domestic demand appears still to be growing. Profit margins will probably come under pressure as pond operators adapt their management to compete.

In Bangladesh, smaller scale cage culture has been promoted successfully without using complete feeds. The Non Government Organisation (NGO) CARE focused on poorer households with little access to conventional pond aquaculture, using cage culture in rivers, large perennial water bodies and smaller seasonal ponds. Grass carp and tilapias produced well and risk was also reduced by growing larger, more valuable juveniles for sale to pond operators. In Sri Lanka, cages are currently being trialed for fattening tilapias caught by fishers in the same water body, using simple home-made feeds from local ingredients (Pollock *et al. In press*). More valuable larger fish are then available to maintain incomes of both producers and traders during the closed season. Clearly there is a range of contexts in which cage culture can be successful in Asia. Access to water bodies is critical, as is the level of development of conventional pond-based aquaculture that can stimulate demand for, or compete with, cage culture.

Livestock-based systems

The wastes produced by free-ranging livestock are critical for maintaining the productivity of small water bodies in many parts of Asia. Grazing at the height of the dry season often becomes spatially concentrated around remaining surface water, ensuring that nutrients are deposited close to, or within, the water body prior to the onset of rains. The subsequent yield of tilapias and carps is therefore likely to reflect the stocking density of animals within the watershed. Productivity of both livestock and fish might be improved in several ways. Livestock mortalities have been linked to toxic cyanobacteria (blue-green algae) blooms occurring in eutrophic surface water bodies. The construction of shallow wells in the vicinity of seasonal water bodies from which water can be drawn for human and livestock use reduces such risk. Productivity of both livestock and fish can be improved by using livestock feed supplements. Partial confinement and more efficient waste collection and utilisation in the water body, especially of urine, enhance output further. Zero grazing, with cut and carry of feeds and immediate disposal of waste in ponds, further improves productivity, but often requires greater capital and management costs (Little and Edwards 1999).

Livestock manure was relatively unimportant in traditional aquaculture; the dependence on grass carp in integrated aquaculture in southern China reflects the lack of such nutrient inputs. However, collectivization gave rise to more complex systems using more livestock waste. Since market reforms, integrated systems appear to have become more simple and as elsewhere in developing Asia, urbanization, greater purchasing power, and the rise of agro-industry has led to a surge in demand for livestock products. In parallel, there has been a shift from low-input carp-based polyculture towards tilapia and catfish, which tend to be more productive and profitable when integrated with modern feedlot livestock systems (Hassan *et al.* 1996). Nile tilapia, often in polyculture with carps, *Clarias* and *Pangasius* catfish dominate waste-fed systems. These species are found more frequently in peri-urban areas where the opportunity cost of land is higher. Competition for, or cost of, livestock waste disposal, availability of water and the presence of livestock feed industry are also factors.

Where fish is relatively expensive, or competition for livestock manure is high, linkages between livestock and fish culture are weaker. Under such conditions, fish production may depend more on other feeds and fertilisers. Thus in Andra Pradesh production of large Indian major carps (>1 kg/fish) is large-scale and feed-driven (Nandessha *et al.* 1996). A recent study of carp culture in Asia (Michielsen *et al. in press*) suggested that specialised carp culture must be more efficient than more interdependent complex systems to compete. In Central Luzon State, Philippines, there is relatively little livestock-waste based tilapia culture, seemingly because the high opportunity cost of land and water (Molnar *et al.*1996), and more intensive feed-based pond and cage-based production give higher returns. In both cases, prices of fish are well above those in areas where carps and tilapias are raised mainly on livestock waste. In NE Thailand the lack of small-scale, feedlot, livestock production has led to aquaculture based on inorganic fertiliser and supplementary feed. An analysis of the value of the available low-grade ruminant manure concluded that it was better used as a soil conditioner. However, subsequent research has indicated the value of collecting or channelling highly nitrogenous urine of ruminants into fish production systems (Little and Edwards 1999).

Livestock waste may not always be reused directly, especially if lack of space precludes the use of semi-intensive ponds. Processing of pig manure into live feeds for fish reduces pond area required by a factor of 10 and has been used commercially (Nuov *et al.*1995). Growth in demand for livestock products has spurred the use both of production waste and byproducts from slaughter and processing. Export of boneless chicken meat from Thailand is closely linked to high-density production of a *Clarias* hybrid for domestic consumption. Some 10% of the live weight of broiler chickens, mainly thigh bones, head and viscera, is minced with added ingredients. Wet weight food conversions of around 4:1 make the feed competitive with high quality commercial floating pellet (Little *et al*. 1994). The catfish's high tolerance to poor water quality makes the use of unprocessed feeds possible but, increasingly, water quality is maintained by recycling waste water through semi-intensive carp/tilapia ponds nearby (Figure 4.2). Year-round supply of byproducts matches the suitability for raising hybrid catfish and demand from consumers. Removal and trading of livestock wastes by entrepreneurs, both from production units and slaughterhouses, has also evolved as concentrations of wastes exceed the local capacity to utilise them, and as transport infrastructure improves.

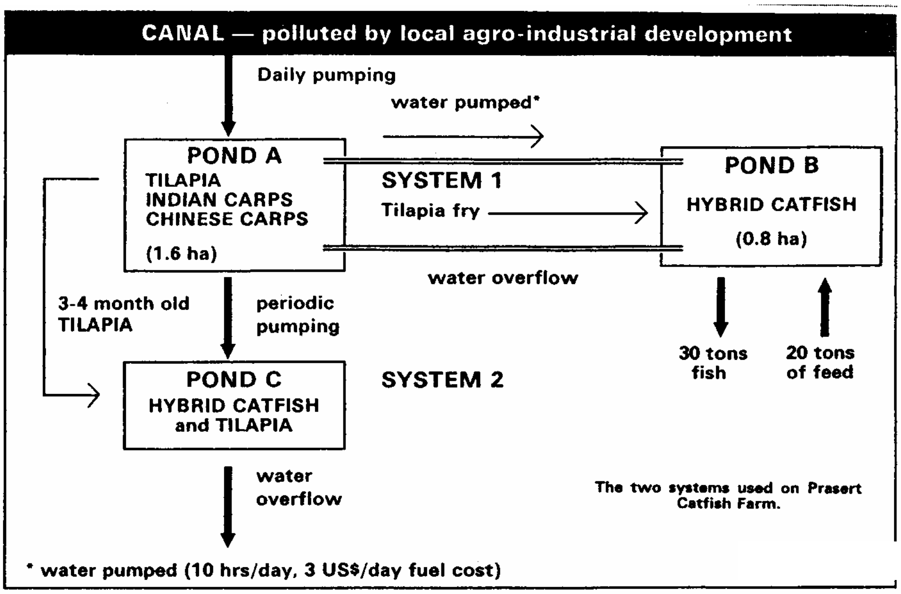

Figure 4.2. Water recycling on an inland aquaculture farm in Thailand.

Human waste-based systems

Linkages between human waste and fish production in Asia are complex. Many urban and rural areas lack formal sanitation and exposure of both natural and cultured stocks of fish to human waste is common. Where conventional sanitation is not affordable, the case for wastewater aquaculture may seem clear - producing low cost fish while safeguarding public health – but a host of institutional and social constraints may occur. A variety of formal and informal models exist throughout Asia, varying from cage production of fish in wastewater canals in Indonesia, overhung latrine-ponds in Vietnam, Cambodia and Indonesia, and large-scale sewage-fed systems in India (Ghosh 1990) and Vietnam (Pham and Vo 1990). Major threats to larger scale sewage systems are contamination with non-organic pollutants and, commonly sited on the edge of major cities, their position as desirable real estate (Bunting 2001). In both the east Calcutta wetlands in West Bengal and the Tran Tri outside Hanoi, Vietnam, major quantities of fish are being produced, large amounts of waste are being treated and any holistic risk assessment of public health is highly positive (Edwards 2001). In Calcutta, poorly maintained feeder canals restricting access to sewage constrain greater production, though year-round temperatures permit uninterrupted output and supply to local markets, usually as live fish. This is part of a complex peri-urban system in which a large proportion of the city's fresh fish and vegetables are produced. Rural aquaculture based on fresh nightsoil or overhung latrines certainly carries higher human health risk, but attempts to ban it in Vietnam, in the absence of alternatives either for hygienic waste disposal or fishpond inputs, have been largely ineffective. Rural areas remain nutrient-limiting and such systems require simple up-grading to safeguard human health.

A practical way to safeguard human health is to 'lengthen the food chain' so that resource recovery is separated in time and place from ultimate users (Edwards 1990), *e.g.* by using excreta to produce an intermediate food for other fish or livestock. Thus informal production of duckweed on urban wastewater (as in Taiwan) before feeding to grass carp or ducks, could also be used in societies where direct excreta reuse has been unacceptable. Duckweeds produced on wastewater for carps and waste-fed, free-breeding tilapias used for indigenous carnivorous fish are in use both informally and within more formalised systems throughout the Region. Although many perceive excreta-fed integration as a stop-gap, the use of aquatic macrophytes in tertiary wastewater treatment is becoming standard in developed countries. Another strategy is to utilise excreta for producing juvenile stock. In northern Vietnam, nightsoil is highly valued as a carp nursery pond input (Prax *et al.* 2001), and in the south, cost effective production of tilapia juveniles is dependent on access to sewage from Ho Chi Minh City (Dalsgard 1996). Producing live feeds for carnivorous fish, both food fish and ornamentals, is an increasingly important niche market despite the growth in complete balanced diets by feed manufacturers. Although efficiency of waste use is reduced compared to raising omnivorous and herbivorous species in waste-fed systems for direct human consumption, such systems may be more sustainable in modernising economies.

Development issues

Human and agricultural ecology are major factors affecting the potential for aquaculture, and water quality and availability is another key element. Flood and drought can both reduce agricultural productivity and increase risks; in some cases constraining opportunities for integration, in others providing a stimulus. In rural areas, water resource development is a key feature of community and household initiatives to reduce vulnerability. A role for fish production in such multi-purpose systems cannot be taken for granted, and typically requires local and participatory development, if user conflicts are not to arise. Poor availability of fish seed has also constrained the use of such resources. Incorporating fish production in watershed development in semi-arid areas may be constrained by social/cultural factors or weak institutions. In Sri Lanka high fish productivity has been demonstrated in seasonal tanks, but recent research has shown that tanks are valued for irrigation and bathing more highly than for fish (Murray *et al.* 2000). Complex rules and norms may also govern access and control over fish in such systems. In southern India, government attempts to improve fish production of seasonal tanks appear to have led to fish becoming a commodity, and local control of the resource being weakened.

Environmental factors

There is little likelihood of adverse environmental impacts from integrated systems. Most small-scale farms are nutrient poor and pond sediments act as nutrient sinks for feed and fertiliser inputs. Under such conditions any improvement in nutrient use efficiency is generally a benefit locally and reduces the requirement for external inputs. Concern has also been raised over the use and possible escape of exotic species and genetically modified organisms (GMOs) in aquaculture, and their impact on biodiversity (Pullin 1993). Much rural aquaculture has been based on exotic carps and tilapias, but indigenous species are increasingly being assessed for use. Culture ponds may also help sustain local biodiversity through their role as refuges for a range of indigenous aquatic animals.

The production of fish within IAAS may also reduce pressure on wild stocks currently exploited for direct human food or feed ingredients. If cultured freshwater fish are available, fresh and cheap, they can also substitute for marine fish. In Thailand small deep fried tilapias are now a more common sight on street food stalls than the once ubiquitous, short-bodied Indo-Pacific mackerel. Moreover if fish culture remains a core feature of integrated systems, and production costs and market prices remain low, the expected increasing use of fishmeal and other feeds in aquaculture (Naylor *et al.* 1998) is less likely.

Economic issues

In many parts of Asia, rural households seek to diversify livelihoods through aquaculture by choice, rather than necessity (Ellis 2000). As with other innovations, better off, more entrepreneurial people appear to adopt earlier and gain more benefits. Many aim to add value to wastes or byproducts, especially in peri-urban areas with access to markets. Poorer people with little land may benefit as service providers, trading inputs or products, and as consumers, as both urban and rural poor purchase fish from IAAS. Increasingly integration occurs between farms, and efficiency of resource use also needs to be assessed regionally, as integrated resource flows occur within complex networks rather than as simple linear linkages. This becomes more apparent as infrastructure improves and as people and products can move more cost effectively.

Although there is a trend for specialised, commercial aquaculture, part-time farming is also becoming more important. Some IAAS have high labour requirements, but many have only short-term demands, *e.g.* for pond maintenance and fish harvest, which can be contracted out. Investment in a pond within the farm, or modifying ricefields for raising fish and ensuring water availability for associated horticulture can increase economic resilience. Households with rice land have been targeted in Bangladesh, but even very poor people may operate homestead ponds (Barman *et al.* 2001). Migration off-farm, both short and longer term, is an important feature of rural livelihoods, and IAAS may be more compatible than alternative options as it can allow intensification within smaller land holdings. However, a major constraint to adoption of rice-fish culture to the better off in Bangladesh was linked to the opportunity cost of off-farm labour (Gupta *et al*. 2001).

Adoption of aquaculture within small Asian farms may lead to other benefits such as encouraging intensification and entrepreneurism. Gupta *et al.* (2001) reported that farmers adopting rice-fish culture tended to use more inputs and obtain higher yields. This type of IAAS has been seen as a step toward diversification and risk reduction in farming systems generally in NE Thailand and northern Vietnam. However, limiting fish production to the use of on-farm inputs alone, or limited amounts of off-farm nutrients may not meet the needs of farming households. In NE Thailand better off households sought to increase fish yields and farm incomes by using higher levels of inorganic fertilisers (Pant *et al.* 2001). Farmers may also perceive fish culture in a similar vein to livestock, *i.e.* less as a source of regular income and more as a form of savings. Grass carp raised in cages in northern Vietnam were seen as a flexible asset in this way with members of the households investing labour to cut and collect grass as an investment (Little *et al.* 2000).

Future Developments

A key issue for the future of IAAS is the impact of the region's growing urbanisation and global linkages. It might be assumed that intensive and specialised production, following western trends, will supplant or replace it. Yet evidence exists to the contrary. In particular, the rise in intensive livestock production is making production and processing wastes available at low opportunity cost. The success of commercial integrated systems in many peri-urban zones demonstrates their advantages in using these wastes, and also bringing broader benefits to environments, to the larger economy and in producing cheap fish for the poorer people increasingly drawn to these areas.

A number of issues will bear on the future use and development of integrated systems in Asia. Improved efficiency of nutrient use is a major challenge, as systems typically collect and trap nutrients that can be ill-afforded in rural areas, while in peri-urban areas the goal may be to process excess nutrients as efficiently as possible. Better strategies for stocking fish, for part-cropping and for developing flexible polyculture and monoculture options are all likely to become important. Where integrated systems provide fertile but risky or unappealing growing conditions, increased ‘finishing’ for high value markets in intensive systems is also likely.

The future role of new strains in IAAS is unclear as most improved stocks have been selected within more intensive culture environments. Preferences of farmers and consumers also need to be considered. Thus, although the exotic African catfish *Clarias garipienus* was accepted by farmers for its fast growth and high tolerance of intensive conditions, often in IAAS, its hybrid with local species has often been more acceptable to consumers, resulting in widespread adoption in SE Asia. The selectively improved strain of Nile tilapia (GIFT) has also shown promise under a range of culture conditions (Eknath *et al.* 1993). However, trials have indicated that in some locations where Nile tilapia culture was well established, local adaptation and improvement had probably occurred with strains introduced decades before (Dan and Little 2000). With a diverse range of systems and environments, this is likely to continue.

Lessons to be learned from the Asian Experience

A number of parallels may be drawn between the examples of integrated aquaculture in Asia presented here, and the Australian situation:

- Vulnerability to climate/ecological conditions is a common feature of both regions, although with different issues and consequences. In both cases, though subject to other kinds of risk, integration can offer an important overall risk-reduction strategy, and options can be developed to meet the particular mix of conditions.
- Integrated systems are still being developed in both regions. As we have sought to explain, the traditional context of integration, where it ever existed in Asia, is subject to significant change in response to changing demographic, market and resource conditions. Similar drivers may be recognised in Australia.
- The increasingly international context affects both regions, offering wider market opportunities and competitive pressure in encouraging new approaches for efficiency and diversification. Constraints may also bear in some cases in the form of greater specialisation and intensification.
- There is a similar need to develop rural economies and to diversify farm income, and in association with this, to provide a mix of on-farm and off-farm linkages.
- The importance of seed and knowledge can be widely recognised, where farmers have other assets and skills, and need these key inputs to enable them to diversify. Other inputs such as external nutrients, feeds and disease management resources are also important. Access to these, and their quality, whether from public sector or private sources, is a key issue.

- Market and commercial forces are very clear-cut in both regions, with relatively open and unprotected markets, increasingly stringent levels of consumer demand, and very cost and price competitive environments. The need for integrated aquaculture producers to meet these demands will be essential in future options.
- The role of part crops and market niches is important in both regions, and as producers become more capable and confident in exploring these options, so will the opportunities for IAAS improve and expand.

There are also some essential differences:

- Culture and traditions are obviously different, but rapid change in Asia has stimulated a more 'western' approach to markets and management. A mix may be found however, between very traditional methods and the increasingly well developed scientific and management capability which is more common in Australia.
- Consumption patterns and preferences are also generally different, but again subject to major changes in population and tastes in both regions. However, there is at present a wider variety of potentially marketable produce from Asian systems.
- Population pressure in Asia is significantly greater than in Australia, with both positive and negative impacts. Rising population has stimulated demand and has at the same time kept down labour costs in spite of increased industrialisation. It has also increased pressure on key resources, reducing their access and/or increasing costs in real terms.
- Constraints in some areas – *e.g.* in relation to human wastes, are generally less in many parts of Asia, and regulation is not as widely or specifically enforced. However internationalisation and commercial and consumer pressures are changing this steadily.
- Species options are generally far wider in Asia, and the versatility, robustness and market acceptability of carps and tilapias is a particular advantage for integrated farms in the region.

Conclusions

Rapid and far-reaching changes may make comparisons between a traditional concept of integrated aquaculture in Asia and current developments in Australia less relevant, and should help to support the view that changes in both regions are the result of similar processes. In both areas, the dynamics for intensification and for integration exist, and can be expected to lead to viable and effective aquaculture approaches in each. Internationally, both regions share competitive pressures, and their success in addressing these will be critical in the future development of the sector. At the specific level, a better appreciation of the options, the local household and financial benefits, together with the broader systems-linked economic benefits, will be important for investors and policy makers in both regions.

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Chapter Five

Resources, Systems and Species for Australian Integrated Agri-Aquaculture Systems

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Introduction

The commercial development of the Integrated Agri-Aquaculture Systems (IAAS) sector in Australia is dependent on the ready identification of suitable species and production systems that will complement the naturally diverse resource base and climatic conditions of the country. Given the extensive range of bio-geographic and climatic zones, and associated soil types, water supplies, aquatic species distribution and existing agricultural farming systems, there is also a large range of potential IAAS combinations of resources, species and systems. The final choice for any one farmer investing in IAAS, however, will also have to take into account economic realities and legislative/regulatory constraints, as well as the ambient climate and natural resource base of their existing farm sites.

The ability of farmers to have ready access to a comprehensive database of detailed and reliable information during the pre-feasibility and business planning stages of their proposed IAAS enterprise, is critical to ensuring that production systems and target species are prudently selected and appropriately matched. In turn, the optimal utilisation of available resources and the accommodation of ambient climatic conditions will enable risk to be effectively managed in order to achieve the long term economic viability and environmental sustainability of the integrated farm business in question.

This chapter aims to give an overview of the resource base in Australia for IAAS development, and to provide details of where further information can be found at federal, state and/or catchment levels. Federal, regional and state sources of information are summarised in Appendix I of this Handbook. This chapter also provides a summary of key species and preliminary guidelines for systems options suitable for IAAS development in Australia, as a starting point for farmers. It is recognised however that in the longer term, further new species and system designs will be incorporated into the IAAS sector in Australia, as farmers continue to develop, innovate and improvise in response to continually changing market, environmental, legislative and economic circumstances.

Australian Resource Base for IAAS

Landforms and soils

The Australian landscape is strikingly distinctive with a variety of landforms ranging from extensive plains and plateaux (interior lowlands) behind narrow coastal uplands in the east (eastern uplands), to great expanses of sandy and stony desert and low tablelands in the arid centre (western plateau) and the west (www.auslig.gov.au). The inter-related factors of geology, topography and soil type essentially describe the physical resources of the landscape and information on these may be important in assessing the ease with which aquaculture may be integrated, particularly if ponds have to be excavated or new water supplies have to be accessed.

The custodian of national physical landform information is Geoscience Australia which incorporates both AGSO (geological information) and AUSLIG (topographic mapping). This organisation has comprehensive databases and maps covering the whole continent. Geological information may be important to locate and quantify groundwater resources and assess the ease with which they can be developed. It may also provide information on the suitability of the land for pond excavation. The proximity of thermal groundwater resources or areas with high mineral resources may provide useful data which will either restrict aquaculture development or be beneficial to the proposed development.

Topographic information describes the physcial features of the landscape in terms of land slope (including how steep the land is between high and low points) and land elevation (Egna and Boyd 1997). These maps often contain information on surface water resources, including areas susceptible to waterlogging and flooding. Topographic maps will provide information on the suitability of land for pond construction, which can be used to minimise construction costs and maximise the use of gravity in pond filling and draining. Ideally, the land should be relatively flat or slope gently (NSW Government 2001). Most states have adopted restrictions on aquaculture development in areas which are susceptible to flooding. For example in Victoria, aquaculture development is not allowed in areas below the 1:100 year flood level. Topography can also be important if pond discharge is to be used on site for irrigation. Table 5.1 shows that some forms of irrigation have different landform requirements (NSW Government 2001).

Table 5.1: Landform requirements for irrigation systems (NSW Government 2001).

Physical Features	**Limitation**			**Restrictive Features**
	Slight	**Moderate**	**Severe**	
Slope required for irrigation systems:				
• Surface or underground	< 1%	1-3%	>3%	Excessive runoff and erosion risk
• Sprinkler	<6%	6-12%	>12%	
• Trickle/ microspray	<10%	10-20%	>20%	
Flooding	None or rare	Occasional	Frequent	
Landform characteristics	Crests, convex slopes and plains	Concave slopes and footslopes	Drainage lines and incised channels	Erosion and seasonal waterlogging risk

Soil characteristics are extremely important in the construction of aquaculture ponds. Those most commonly used for ponds are clay, silty clay and clay loams whereas those to avoid are sandy or gravelly soils, marl and gypsum containing soils and areas where limestone or shale come close to the surface (Egna and Boyd, 1997). Marl and gypsum are highly soluble materials that often result in water quality problems and limestone and shale areas are susceptible to fracture, which can result in leakage from the pond holes (Egna and Boyd 1997).

Acid sulfate soils are a problem in coastal areas of Australia where soils can contain high levels of iron pyrite (see Hey *et al*,1999 for review). The soils occur naturally, but do not become acidic until exposed to air. Problems with acid sulfate soils have emerged in recent years due to land draining for agricultural and urban development. In addition to producing acid, heavy metal problems are also associated with runoff from these soils as the acidic water leaches metals (notably aluminium) from the soil matrix. It has been estimated that in Queensland alone there are 2.3 million ha of acid sulfate soils, with NSW having around 600,000 ha (Powell and Ahern 1999). Aquaculture development in areas with acid sulfate soils may be problematic as both low pH and aluminium are toxic to aquatic species.

The presence of sodic or saline soils may also influence aquaculture decisions. Other soil-related factors which must be considered include soil contamination, possibly from previous land uses. Residues of agricultural chemicals such as herbicides or pesticides could be harmful to the stocked fish.

Finally, the suitability of the soil for crops and trees should be considered if it is planned to irrigate with aquaculture effluent. Factors such as fertility, permeability and slope should be taken into account in the context of the method of irrigation and the type of crop (NSW Government 2001). Factors affecting the quantity of effluent that can be irrigated (*e.g.* soil salinity, soil sodicity, cation exchange capacity and soil nutrients) should be established when designing an irrigation system.

It is highly recommended that soil samples are submitted for analysis prior to designing an integrated aquaculture system. Details of state agency laboratories offering analytical services and advice are given in Appendix I of this Handbook.

Climate and rainfall

Australia is a large and climatically diverse country with the northern third of the country in the tropics and warm or hot all year, whilst the rest of the country lies south of the tropics and has warm summers and mild or cool winters. Large areas of central Australia are arid desert, whilst the coastal fringes enjoy temperate, continental or sub-tropical climates. The long-term annual rainfall in Australia is 469 mm/yr, but this is extremely variable both seasonally and geographically (Figure 5.1). Rainfall, or the lack of it, is the single most important factor determining land use and rural production in Australia. Information on rainfall at a local level can be obtained from the Bureau of Meteorology with details of the nearest weather station. Important meteorological information that should be reviewed as part of the planning process includes: range and mean of monthly air temperature; rainfall; evaporation; sunshine; wind speed and direction (Pillay 1990). Figure 5.2 shows the climatic zones of Australia based on the Koppen classification scheme, which is based on both temperature and rainfall, as indicated by the native vegetation. This classification is useful for delineating climatic zones for agricultural purposes and is similarly useful for integrated aquaculture.

Other climate-related factors that should be taken into account in the design and construction phase are prevailing wind direction and the frequency, intensity and timing of storms.

Water supply

A reliable supply of good quality water is essential for aquaculture and can come from surface water or ground water resources. Factors which should be considered in evaluating the suitability of a water supply (NSW Government 2001) include:

- Seasonal changes in quantity and quality;
- Access to water - allocation permits;
- Cost of purchasing water as well as supplying it to the site;
- Pumping costs – the use of gravity flow should be maximised.

Surface water resources

On average, only 12% of Australian rainfall reaches the rivers as runoff, ranging from <2% in arid areas to >20% in tropical monsoonal climates (Water Resources Assessment 2000). The remaining 88% of rainfall is accounted for by evaporation, vegetation uptake, and water held in storages (lakes, wetlands and aquifers). The effectiveness of the rainfall is greatly reduced by marked alternation of wet and dry seasons, unreliability from year to year, high temperatures and high potential evaporation.

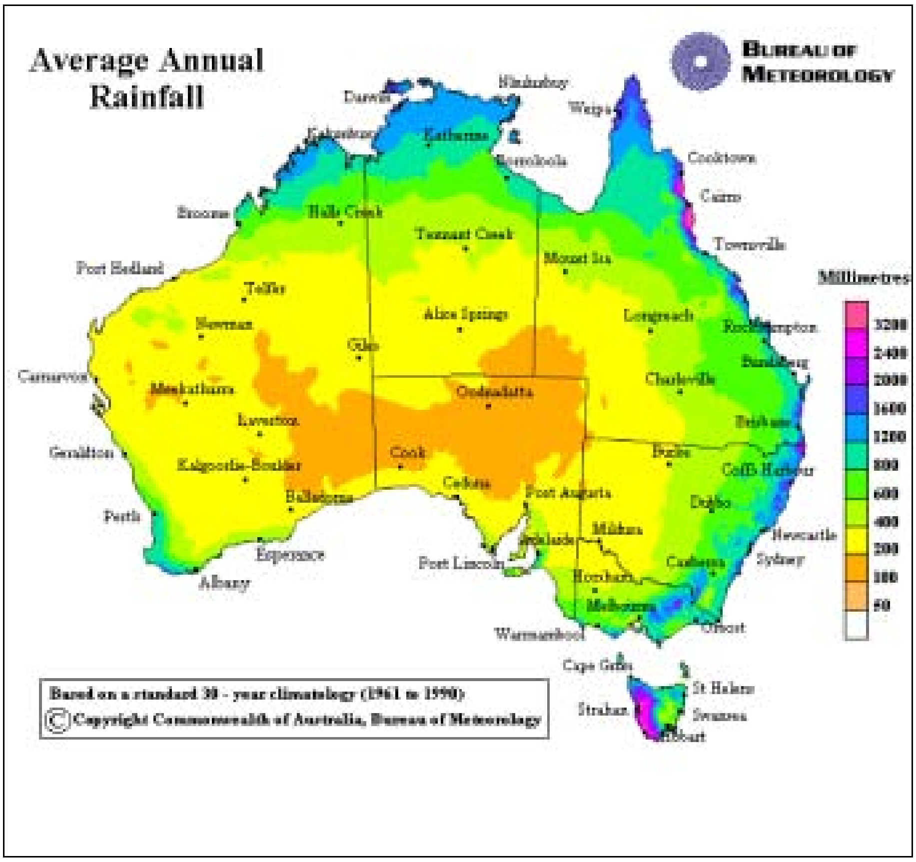

Figure 5.1: Long-term average rainfall in Australia.

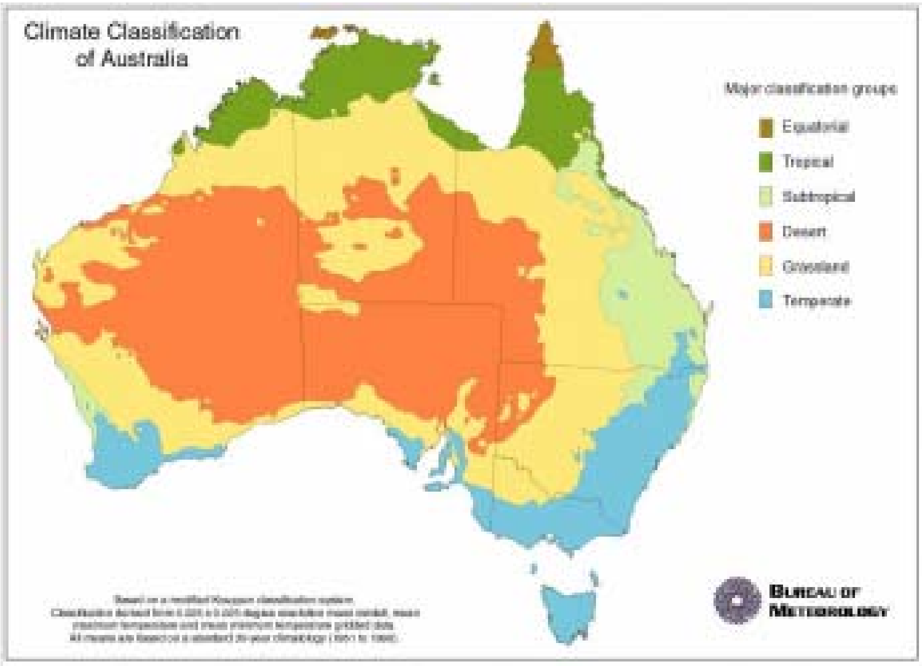

Figure 5.2: Climate classification of Australia.

The relative scarcity of water resources in Australia has led to extensive programs to regulate supplies through the construction of water storage dams and reservoirs, and there are currently 447 large reservoirs with a storage capacity of around 79,000GL (Water Resources Assessment 2000). In addition, there are several million farm dams estimated to store around 9% of the total water stored.

The volume of water diverted from rivers is estimated to be 18,147 GL, equivalent to 4.7% of total runoff. The proportion of runoff diverted is relatively low as permanent rivers and streams flow in only a small part of the continent. Approximately 73% of the 24,000 GL of water used in Australia is supplied by rivers, 21 % by aquifers and the remaining 9% by harvest of overland flows. Figure 5.3 shows that many of the surface water resources in Australia are currently fully or over allocated which will make gaining access to public water increasingly difficult in the future.

Surface water resources that may be used for aquaculture include (adapted from Egna and Boyd 1997): (1) Farm dams; (2) Unregulated rivers and streams; (3) Irrigation supplies; (4) Lakes and public storages and (5) Town water.

(1) Farms dams.
Relying on rainfall runoff alone to supply aquaculture in Australia is a risky approach due to the inherent variability of rainfall in the country. In areas of high rainfall (such as the tropical north) it may be viable to rely on rain to fill ponds, however, some form of on-farm storage of water, or alternative source of water would be prudent in case of drought. As previously described, there are several million farm dams throughout Australia which may be directly used for free range or cage culture, albeit with some modifications. Alternatively, farm dams can be used to indirectly supply water to tank or pond systems.

(2) Rivers and streams.
If using water from rivers and streams, the flow must be adequate to meet the operational requirements of the chosen aquaculture system. Long-term flow data should be used to assess the reliability of flow as well as the demands of competing water users. Hydrological information is collected and analysed by state government departments (see Appendix I of this Handbook for the relevant agency). Streams and rivers that dry out for periods during the year will not be able to provide enough water to compensate for evaporation and seepage losses. The flooding risk should also be assessed as inundation of the farm could result in stock loss. The stream bank should be well vegetated to reduce soil erosion and thus minimise turbidity in the water column (Pillay 1990). Finally, the stream should have a light silt load, especially during periods of flooding.

(3) Irrigation supplies.
Irrigated agricultural areas have been identified as the most likely to benefit from the advantages presented by IAAS (Gooley and Gavine *In press*) as there is a reliable supply of a known quantity of water for a known time period which makes planning an aquaculture venture easier. Figure 5.4 shows the major irrigated areas in Australia. Development of irrigation infrastructure has significantly improved farm productivity (ANRA 2000). Approximately 75% of Australia’s water is used in irrigated agriculture (17,935 GL) with New South Wales (48%), Victoria (25%) and Queensland (16%) accounting for 90% of all irrigation across Australia. The irrigated agriculture sector in Australia accounts for almost a third of total farm exports and is worth approximately AUD $7.25 billion annually. Total area of irrigated crops and pastures in Australia is around 2.3 million ha (ABS 2000), representing 0.4% of the total agricultural land area. Most of the irrigation water (57%) is used on pasture, livestock, grains and other agriculture. However, other significant water users are cotton (12%), sugar (8%) and rice (11%) industries (ABS 2000).

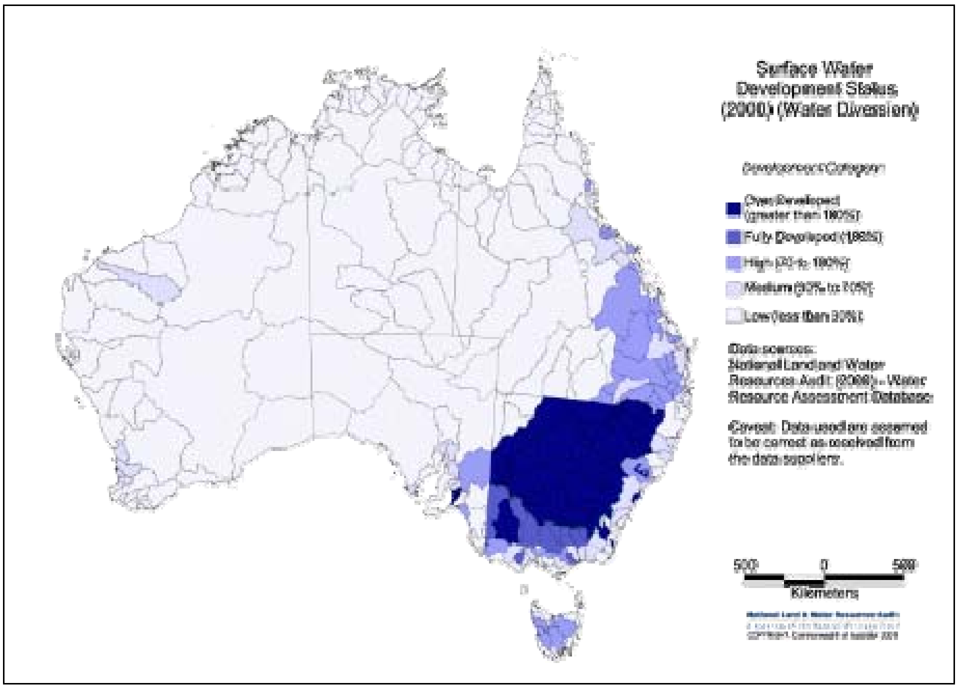

Figure 5.3: Development status of surface waters in Australia.

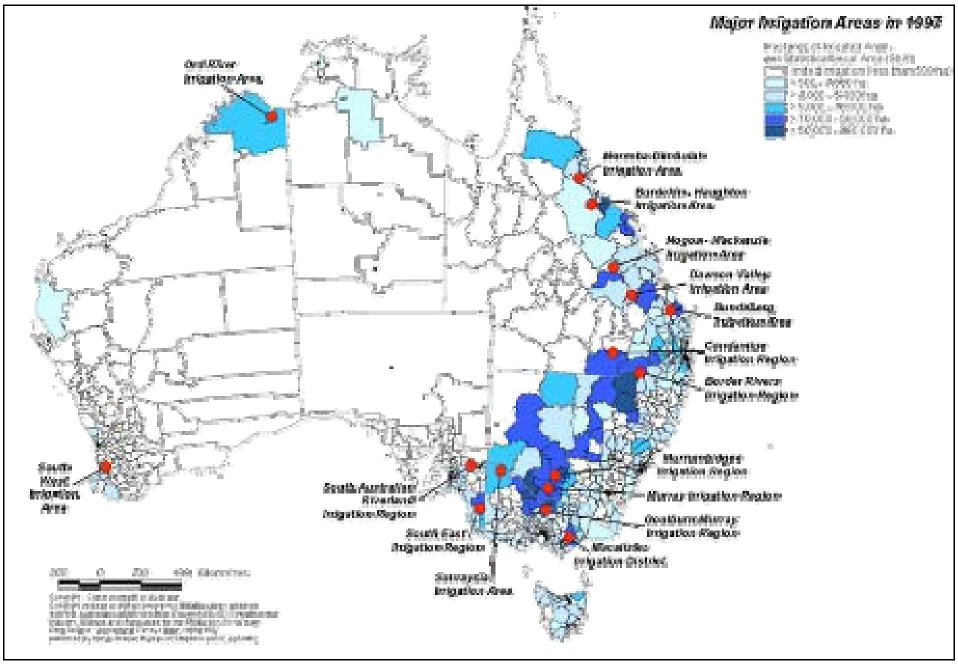

Figure 5.4: Major irrigation areas in Australia 1997.

The Murray-Darling Basin (MDB) dominates irrigated agriculture in Australia, with a total area of irrigated crops and pastures of 1.47 million ha; 71% of the Australian total (Figure 5.5). The basin extends from Queensland in the north to South Australia in the south-west and covers 1,061,469 km^2, or 14% of the total land area (www.mdbc.gov.au). Around 70% of all water used for irrigation in Australia is used within the Murray-Darling Basin, which accounts for 41% of the nation's gross value of agricultural production.

Access to irrigation waters is controlled by an allocation system and the local irrigation authority should be contacted about gaining access to the resource.

(4) Lakes.
Lakes and public water storages can be used for *in situ* cage culture or water can be pumped ashore for land-based ponds or tanks. This option will incur pumping costs which may not be financially viable. The water levels of lakes and public water storages tend to vary quite markedly in Australia and some may dry out completely during droughts. Long-term variations in lake levels should be investigated prior to development as the siting of pumping or cage infrastructure will be influenced by this. Access to lakes and storages is regulated by various regional and/or state authorities. In Australia, aquaculture usage of these waters has so far been extremely limited.

(5) Town water.
Reticulated domestic water supplies may be used for operators located near urban centres. Some degree of pre-treatment may be required as potable waters are often treated with chlorine and other chemicals. Town water is an expensive option for use in ponds, however, it may be more viable in recirculating systems where less water is used. Processing facilities often require water to be treated to potable drinking water standards.

Groundwater Resources

Australia has 25,780GL of groundwater suitable for potable, stock and domestic use and irrigated agriculture that can be extracted sustainably each year, of which around 20 % is used. Australia has one of the world's largest aquifer systems: the Great Artesian Basin is an estimated 1.7 million km^2 and stores 8,700,000GL (Water Resources Assessment 2000). Each year the Great Artesian Basin supplies 570 GL of water for a variety of uses: mainly grazing and mining. Figure 5.6 shows that many of Australia's groundwater resources are fully or over-allocated, which means that in many areas new abstraction licences will not be granted. The main types of groundwater resources are (Egna and Boyd 1997):

1. Artesian wells
Artesian wells are dug into aquifers and hydraulic pressure forces the water up and out, eliminating the need for pumping. This water source is usually suitable for both pond and tank aquaculture, although there is often a need for some degree of pre-treatment (*e.g.* aeration and settlement). It has a fairly constant water temperature and is usually free of pollutants (see Water Quality below).

2. Water table
If the water table is high enough, ponds can be designed to fill naturally, eliminating water abstraction and pumping costs. However, there is no subsequent control over water levels in the pond and the pond cannot be drained for harvest and maintenance. Problems will also occur where high water tables are salinised, which is often the case in irrigation areas.

3. Well water
Well water is usually abstracted from deep aquifers and a well must be dug so that the water can be pumped to the surface. If there is no existing well, this can be an expensive exercise depending on the depth of well to be dug and the underlying geology of the area. Deeper aquifers can also be geothermal, with the increased water temperature being used for aquaculture of warm water species in cooler climates.

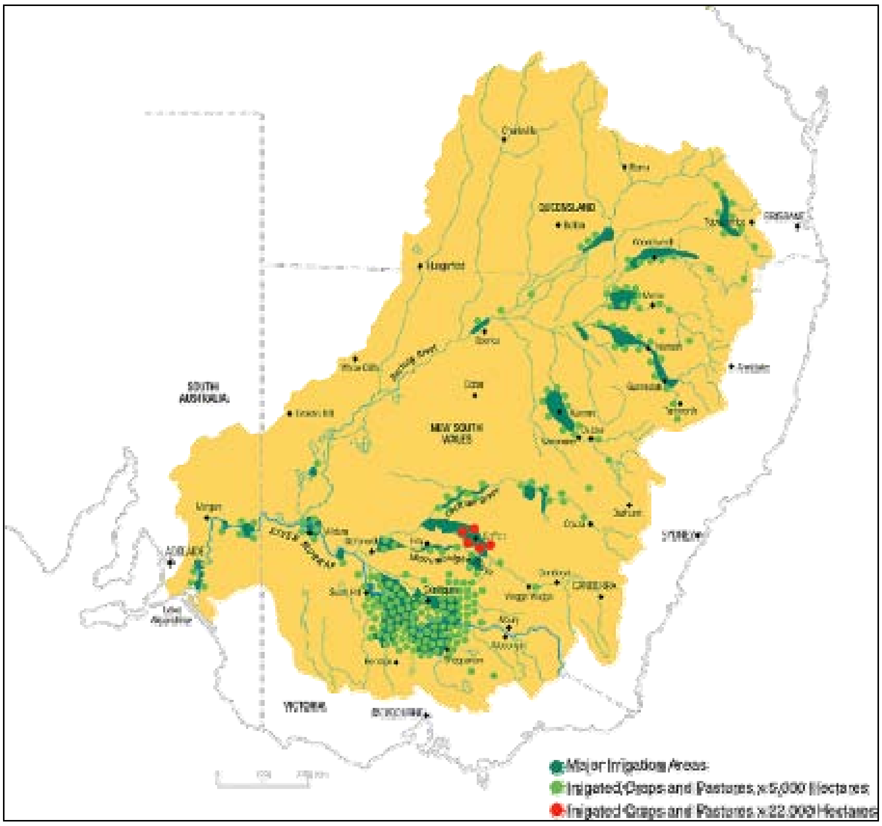

Figure 5.5: Murray-Darling Basin Irrigation Area (www.mdbc.gov.au).

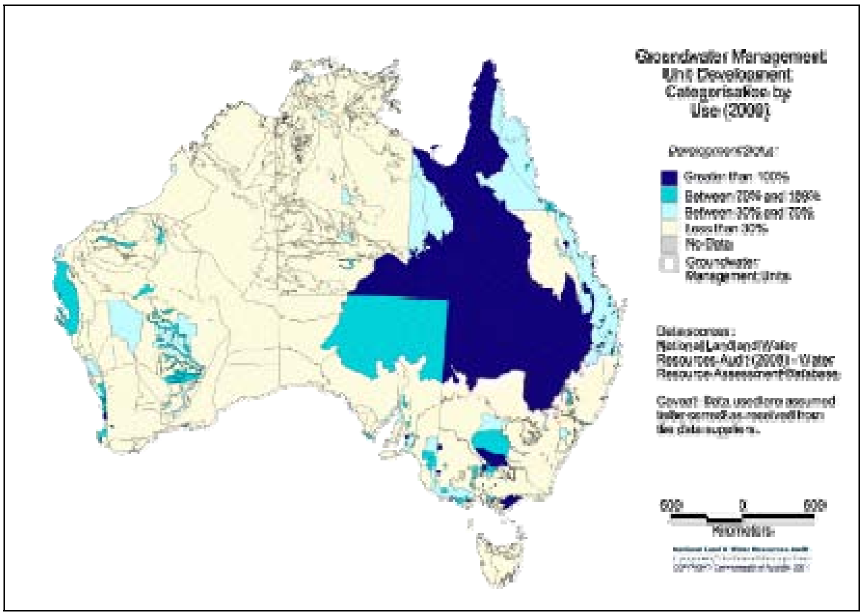

Figure 5.6: Allocation of groundwater resources.

Water management and allocation mechanisms

As previously described there are many potential sources of water that can be used for aquaculture, provided a licence to access the water can be obtained from the relevant authority. The primary responsibility for the management of water lies with the State Government (see Chapter 7 for details and Appendix I of this Handbook for the lead agencies in your state). The Commonwealth is responsible for the Territories as well as interstate bodies such as the Murray-Darling Basin Commission. Within each state there are many other organisations with a role in water management and allocation.

Recognising that water is a finite resource, the States and Territories have developed water allocation systems where security and reliability are assigned to entitlement. Trading is provided so water can be moved to high value uses and the choices of individuals are maximised. The role of economic instruments in improving the sustainability of irrigated agriculture will be discussed fully in Chapter 10. Figure 5.3 shows that the MDB has already reached its maximum sustainable water diversion limit and in 1997 a "Cap" was introduced to stop further diversion of water resources in the Basin. Any water for additional development can be obtained by improving water use and supply efficiency or by purchasing water from existing users through water trading. For advice on the availability of water entitlements contact the relevant water or irrigation authority, local stock or station agents, or consult commercial brokerages (*e.g.* www.waterexchange.com).

Water quality

Aquaculture requires good water quality and the water source should be checked that it is free from:

- Organic, agricultural and/ or industrial pollution;
- Suspended particles;
- Pathogens and other undesirable aquatic organisms.

Stickney (1979), Shepherd and Bromage (1988), Piper *et al.* (1982) and Boyd (1990) provide useful summaries of water quality requirements for various forms of aquaculture. For Australian species, various texts provide more specific water quality data (*e.g.* Rowland and Bryant (1995) and Ingram 2000). Farmers are encouraged to seek advice from their state-base extension officers to access the most relevant information.

Water quality standards for the production of aquatic organisms for human consumption have been set by ANZECC Water Quality Guidelines (Appendix II). If the supply does not meet the criteria, some form of pre-treatment may be required. Information on water quality in major rivers, streams and groundwaters can be obtained from state Environmental Protection Agencies as well as regional/ local government Water Authorities, Catchment Management Authorities and Irrigation Authorities. These organisations can also provide information on potential sources of pollution.

Important parameters in determining the suitability of a water supply in terms of water quality are:

1. **Temperature.** Data should be collected on seasonal variations in water temperature from the water supply. This information is critical to the choice of species for aquaculture. Groundwater tends to have more constant temperature than surface waters. If the water supply is from a lake or large dam, then thermal stratification of the water column may mean that water from the bottom will be cold and lack oxygen.
2. **Dissolved oxygen.** Dissolved oxygen is an important parameter for the culture of aquatic organisms, but different species have different requirements. Dissolved oxygen can be low in surface waters with a high organic load, or during the night in waters with high algal biomass. Groundwaters tend to have low dissolved oxygen levels and may need aeration prior to use in aquaculture.
3. **Salinity.** The "saltiness" of a water supply is important in selecting aquaculture species as most have specific tolerance ranges for salinity. If a water supply is brackish or saline, then extra measures may have to be taken to protect adjacent surface and groundwater resources from seepage or discharge from the aquaculture operation (*e.g.* lining of ponds; storage and evaporation of effluent water).

4. **pH.** pH is a measure of the acidity or alkalinity of a water source. Generally, a pH of between 6.5 and 9.0 is suitable for aquaculture, however, some species have more specific tolerance ranges. For example, crayfish grown in waters of pH below 7.0 tend to have soft shells. Waters with higher buffering capacities (as indicated by alkalinity levels > 20mg/l and usually associated with alkaline pH), facilitates higher productivity in aquaculture ponds reliant on "green water" techniques. Lime application to ponds can substantially increase alkalinity if required.
5. **Calcium.** Some aquatic species have specific requirements for calcium as it is required for bone formation in fish and exoskeleton formation in crustaceans (Boyd 1990). Calcium concentrations should be sufficient to meet this requirement.
6. **Turbidity.** Some turbidity is desirable in fish ponds, particularly that caused by plankton. It reduces bottom water temperatures and provides protection from birds as well as providing additional productivity to the pond ecosystem. Turbidity caused by clay particles, however, can be harmful to fish (Boyd 1990).
7. **Metals.** Heavy metals usually occur in water supplies due to pollution. They can also occur naturally in certain geological areas with mineral deposits. Iron deposits in groundwater are relatively common and need to be precipitated prior to use in aquaculture. Surface and groundwaters in regions with acid sulfate soils also tend to have high metal concentrations. Heavy metals can be extremely toxic to fish and crustaceans (see Appendix II for acceptable levels).
8. **Pesticides/ herbicides.** Surface water sources are generally vulnerable to pollution from agricultural sources such as pesticides and herbicides. These can be extremely toxic to fish.
9. **Other contaminants.** Other problem contaminants (*e.g.* bacteria and pathogens) that can impact on water use for aquaculture may occur in different water supplies. Hydrogen sulfide build up in groundwaters can be toxic to fish and needs to be removed through oxidation prior to use.

A full analysis of potential water supplies is advised as part of any feasibility study on IAAS.

Other issues relevant to IAAS development

Ecology and biodiversity

Potential impacts of the proposed IAAS development on terrestrial ecology, aquatic ecology, predators, threatened species and conservation sites should be evaluated as part of the site selection process (NSW Government 2001).

1. **Terrestrial ecology.** Existing land use is an important factor in evaluating sites for aquaculture integration. Sites should be selected to minimise the need to clear native vegetation. In some circumstances, a permit may be required to remove native vegetation.
2. **Aquatic ecology.** Impacts on aquatic ecology may occur if the species stocked is non-endemic to the catchment, especially if the selected location is susceptible to flooding.
3. **Predators.** Potential conflict may exist between the aquaculture operation and birds and water rats in the vicinity. Predator nets may have to be erected to protect the stocked fish.
4. **Threatened species.** The development should not encroach on the habitat of threatened species.
5. **Conservation sites.** Aquaculture development may not be permitted in areas which are protected by International, Federal or State legislation (*e.g.* RAMSAR wetlands, National Parks, World Heritage sites).

Native Title and Heritage

Aquaculture proposals relating to Crown lands subject to a State or Commonwealth Native Title Claim cannot be processed until the claim is resolved. If there are any built or non-built items on the site that could have heritage significance then the proposed project should not affect the significance of these items. Heritage issues can concern both aboriginal and non-aboriginal sites.

More details are provided on the legislative implications of these issues in Chapter 7. In general, however, it is expected that most IAAS developments will occur in association with private land and water as part of existing farming operations. Accordingly, the majority of these "other issues" are not likely to cause any major constraints.

Aquaculture Production System Options for IAAS

There are four broad options for production systems applicable to IAAS, namely: farm dams; pond culture; tank culture (including Recirculating Aquaculture Systems); and cage-based culture. Production system design for any one integrated farming model is likely to fit into one of the following three categories:

- Extensive systems: characterised by ambient conditions, low stocking density and generally using existing infrastructure with little or no modification (*e.g.* farm dams) or management intervention (*e.g.* no supplementary feeding).
- Semi-intensive systems: usually occurs in modified/constructed ponds, cages or tanks under ambient conditions with moderate stocking densities requiring management of water exchange, water quality and feeding regimes.
- Intensive systems: high stocking density, high levels of capital investment (*e.g.* tank-based recirculating systems) and reliant on complete control of water quality and feeding regimes under largely controlled environmental conditions.

1. Farm Dams

Farm dams or water storage ponds are amongst the easiest and cheapest aquaculture system to establish and run, however, there are limits to the number and density at which fish or crustaceans can be stocked. The use of existing farm dams for aquaculture is a low-cost option for those interested in growing stock for recreational purposes, private consumption or to supplement the farm income. In general, culture in farm dams is "extensive" and species are stocked at densities not much higher than those found in nature. In extensive aquaculture, the culture species is left to grow on its own and rely on natural food sources. Sometimes small amounts of feed can be given to improve growth. Water requirements for this form of aquaculture are minimal as little or no water exchange is required for the stocked animals. Without additional infrastructure, product quality and productivity cannot be readily controlled and system outputs are variable.

A common form of aquaculture in farm dams is freshwater crayfish (including yabbies, marron and redclaw). In most states there are restrictions on the species that can be stocked in farm dams, but in general, fish and crayfish which are native to the catchment area can be stocked in dams. Some introduced fish such as trout may also be acceptable, whereas some species (such as carp and redfin) are regarded as noxious and it may be illegal to stock them in dams. More information on the regulations that apply in your state can be obtained from your state fisheries agency (Appendix I of this Handbook).

Appropriate stocking densities depend on the size of the dam, the species stocked and the geographical location of the dam. For a 1 ha dam in Victoria, the recommended stocking rates for juvenile fish (0.5-1g in weight; 35-50mm length) are as follows (Fish in Farm Dams; www.nre.vic.gov.au):

- Australian bass, catfish, golden perch and silver perch: 250 fish/ha;
- Murray cod: 200 fish per ha;
- Trout: 375 per ha.

The recommended stocking densities vary from state to state. Freshwater crayfish are prolific breeders and once stocked will rapidly colonise the dam and must be harvested regularly to ensure that the dam is not over-populated.

The productivity of farm dams can be improved by increasing water exchange, which allows more fish to be stocked. However, for more intensive production of fish, custom-built ponds (see Pond Culture) are recommended as they are easier to harvest and maintain. Cage culture in farm dams offers another opportunity to increase stocking and production of aquatic species and also allows for polyculture with crayfish which occupy the substrate (*e.g.* Whisson 2000).

2. Pond Culture

Pond aquaculture is the use of purpose-built, earthen ponds for aquaculture with water supply and drainage infrastructure usually incorporated. Ponds are the most widely used structure for commercial aquaculture production in Australia and are generally static (*i.e.* no regular water exchange) and managed as semi-intensive systems. Intensive pond systems with high stocking and feed rates are also common but water must be exchanged regularly in these systems (*e.g.* rainbow trout farming).

Site selection for pond culture is of critical importance in establishing an aquaculture venture and factors to consider prior to pond construction are detailed in Table 5.2 (after Ogburn *et al* 1995).

Table 5.2 Major factors in site selection of pond-based aquaculture systems (adapted from Ogburn *et al.* 1995)

Factor	Item	Issues	Recommended	Notes
Water supply	Semi-intensive	Abundant, good quality supply necessary	> 10x culture volume if in storage	Droughts Evaporation
	Intensive	Year-round	40 ML/ha/yr (non-salmonid)	
Water Quality	Alkalinity	Buffering effects	50-150 mg/l for freshwaters	
	PH	Suitability	6-9	Economics of treating
	Turbidity	High silt content		
	Iron	Toxic effects	<1 mg/l	Often in bore water
	Salinity	Suitable for species selected		
Pollution	Upstream Adjacent Endemic	BOD Blue-greens Pesticides	< 10 mg/l	Seasonal changes Other users
Soil	Water holding Dike properties Non-dispersive	Physical Chemical No rocks	Contact soil scientist Clay-loam Silty/sandy clay	Pesticides pH 6-8 Fe < 200 mg/l
Topography	Pond design Reticulation Management	Slope Flooding Run-off	0.5-2m over 100 m 1/100 years Avoid	Cost Drainage Pond preparation
Climate	Temperature	Growing season	Depends on species	Seasonal variations
	Rainfall Wind	Flood/evaporation Management		
Effluent	Zero discharge Holding dam Recycle Irrigation	Capacity Bio-filter Irrigation/ hydroponics	Area for irrigation	

An abundant supply of good quality water, free from pollutants, is essential for pond aquaculture and if possible, the water should be gravity fed to save costs. Ideally, ponds should be constructed in relatively impermeable soils to minimise water losses, however, less permeable sandy or gravelly soil may require liners to be used to reduce seepage. Liners may be made of PVC HDPE and/or geotextile material, but ponds may also be lined with impermeable clay such as bentonite. Pond lining is essential if saline water is to be used in inland areas to prevent seepage onto surrounding land or into the water table.

For growing native fish, ponds should also have relatively well-structured soils with high organic content to support pond ecosystems. Ponds preferably should be designed so they can be drained completely to facilitate harvesting and disease control.

Intensive trout ponds tend to be flow-through (continual water exchange) due to the high stocking densities (>30 kg/m^2) and a requirement for good water quality. Semi-intensive silver perch ponds, however, tend to be static culture ponds with limited water exchange and lower stocking densities (around 4,000 fish/ha). The stocked fish feed on both natural feeds and artificial diets during their growth (Rowland and Bryant, 1995).

Ponds can vary greatly in size and depth, depending on site characteristics, but are generally 0.1-2.0 ha in area, 0.5-2.0 m deep and may have a sloping bottom from 0.5 m to 1.5-2.0m deep, draining to a harvesting sump (Ogburn *et al.* 1995). Such ponds may be filled and drained at the sump.

In Australia, ponds are mostly used in the commercial production/growout of native freshwater fish (primarily silver perch, but also Murray cod), freshwater salmonids, freshwater crayfish. In brackish water ponds, prawns as well as some fish species (*e.g.* Australian bass) are commonly cultured. Ponds are also commonly used for brood stock holding and conditioning and fry production. Juvenile production of several native fish species including silver perch, Murray cod, golden perch) also occurs in ponds. More detailed information on the requirements for pond culture can be obtained from your state fisheries agency (Appendix I of this Handbook).

3. Tank-based culture

Custom built tanks are used for aquaculture where the soil is unsuitable for pond construction, the land lies in a floodplain or the operator wishes to enclose the culture area in a shed or greenhouse for convenience and/or to partly control the environment. Tanks generally allow higher stocking densities of fish to be held as there is a continual flow of water through each tank and feeding regimes can be tightly controlled. Tank systems can either be flow-through or water can be recirculated to some degree using water treatment. A more intensive farming approach can be applied in recirculating systems than in open systems such as ponds, cages or flow through systems. Recirculating aquaculture systems use less water than conventional tank systems, but are more expensive to build and operate.

Recirculation Aquaculture Systems

Recirculating Aquaculture Systems (RAS) are systems which re-use water with mechanical and biological treatment between each use. A recirculating system generally occupies relatively little area, requires less water than conventional aquaculture and provides a customised and constant environment for the culture species.

The level of control provided by RAS can provide a basis for improved risk management. The trade off, however, is the increased dependence on technology and associated expense and expertise to manage it. RAS are relatively expensive to purchase and operate and for this reason it is usually only economically viable to farm high value species in these systems. These systems represent relatively new technology with a wide variation in system design, quality and cost available.

A RAS is a known as a “closed system”, although 5-20% of water is replaced each day, consisting of culture tanks, filtration and water treatment components. The culture species is grown in tanks and the water is exchanged continuously to guarantee optimum growing conditions. Water is pumped from the tanks through biological and mechanical filtration systems and then returned to the tanks. A good general knowledge of the principles of water chemistry and a good biological knowledge of the species being cultivated, including an understanding of disease prevention, identification and treatment, is essential in recirculation system management (*e.g.* see Shepherd and Bromage 1988).

Production tanks vary in size and shape, however round plastic or fibreglass tanks between 1,000 and 15,000 litres in capacity are most commonly used (Recirculation Systems Factsheet; www.pir.sa.gov.au). Quarantine tanks, isolated from the main production system, are useful in minimising disease transfer risk, particularly when new stock arrives and can also ensure that any medication used on stock does not interfere with biological filtration.

Recirculation systems usually facilitate stocking at very high densities. Oxygen can be added to the system mechanically or *via* liquid oxygen and/or an oxygen generator to maintain required oxygen levels of above 60% saturation or around 5 mg/l. A biofilter is used to convert metabolic wastes (*e.g.* ammonia and nitrites) to relatively harmless nitrates. Mechanical filtration is necessary to remove solids such as faeces, uneaten feeds and biofilter floc.

Temperature requirements vary with different culture species and it is vital to maintain temperature within the optimal range for growth for the particular species to be cultured. Fish grow more rapidly, achieve optimal food conversion ratios and are less stressed and less prone to disease within this range. Heat exchangers, electric submersion heaters/coolers, or air injection can be used to achieve the right temperature.

The loading capacity of recirculating production systems depends on flow rate, oxygen availability, filter and heat exchange unit efficiency and the particular requirements of the culture species. These requirements vary between species. For example, under optimum conditions eels can be grown at stocking densities of >300 kg/m^3 whereas Murray cod can be grown at >100 kg/m^3 and silver perch and barramundi at <100 kg/m^3. The higher the density that a species can be cultured without negatively impacting growth rates or fish health, the more commercially viable recirculating systems tend to be. Another important factor in the viability of recirculation systems is the market price per unit of product. Factsheets on recirculating aquaculture systems can be obtained from your state fisheries and aquaculture agencies. A comprehensive summary of issues and features associated the commercial RAS application is provided by O'Sullivan (2001 a, b).

4. Cage culture.

Cage culture is an aquaculture production system where fish are held in floating net pens and is a widely used practice in commercial aquaculture overseas. In Australia, cage culture is used for offshore culture of Atlantic salmon in Tasmania and tuna in South Australia. It is becoming increasingly popular in inland waters with commercial units farming barramundi in freshwater in Lake Argyle (Western Australia) and in ponds in Queensland (Gooley *et al.,* 2000a). Individual cage units come in all shapes and sizes and can be tailored to suit individual farmers needs. They can be purchased through commercial outlets but can also be made from readily available construction materials (such as PVC, poly pipe, polystyrene, galvanised steel, timber and aluminium).

Semi-intensive cage culture systems are those where fish are stocked at relatively high density and are mostly fed exclusively on pelleted or other artificial diets. Appropriate stocking densities will depend on the species stocked and prevailing environmental conditions. Apart from barramundi, the adaptability of Australian native species to cages is currently unknown, but research is underway to assess the suitability of Murray cod and silver perch to culture in cages. Barramundi are known to tolerate high stocking densities (15-25 kg/m^3) in freshwater cages (Gooley *et al.* 2000a).

Cage culture can be integrated into almost any standing water, provided that the water quality is suitable and there is adequate water depth beneath the cages to allow water movement. "Adequate depth" depends on the depth of the net and intensity of production, but should be sufficient to keep the nets clear of the sediment and allow water exchange beneath the nets.

Weather and shelter are important considerations in determining the suitability of a site for cage culture as they can impact on both the cage structure and enclosed fish (Beveridge 1987). The cage units should be built to withstand prevailing wind and wave conditions at the selected site. Good water exchange is also important in cage culture to replenish oxygen and to flush away wastes.

Water quality factors such as temperature, salinity, pH, suspended solids and the presence of algal blooms can potentially influence the growth and survival of the fish. In addition, pollution and the thermal stratification of a water body during the summer can also negatively impact on water quality. Other problems with cage culture in Australia are likely to included predation and/or harassment for birds such as cormorants, water rats and nuisance fish (such as carp) which may be co-resident in the water body.

The success of cage culture depends on maintaining good water quality around the fish cages and so it is in the farmer's best interests to minimise environmental impacts. Ensuring that the size and intensity of the operation is appropriate to the size of the water body and the rate of water exchange is the key to avoiding adverse impacts on water and sediment quality. Impacts from cage culture are largely from uneaten feed and fish excreta, which can alter water and sediment chemistry if the wastes accumulate near to, or under, the cages. Good water exchange and Best Practice husbandry can prevent a build up of these wastes. The use of nutrient mass balance estimates and other simple models can be used to estimate the “carrying capacity” of inland waters for cage culture and assist farmers in achieving Best Practice husbandry (*e.g.* Gooley et al. 2000b).

A summary of the production systems characteristics described above is shown in Table 5.3. The choice of culture system to be employed to establish an IAAS enterprise will be related to the practicalities of integration with existing or proposed agricultural operations, infrastructure and resources. Where possible, maximum use should be made of buildings, watering systems (ponds, pumps, pipes and tanks) and human resources. Furthermore, the re-use of water and disposal of effluent for other agricultural crops on the farm is critical, *i.e.* the intended means of integration of the aquaculture and agriculture enterprises.

Table 5.3: Summary of production system options

	Stocking density	**Advantages**	**Disadvantages**
Farm dams	Low (< 500 fish/ha)	• Low cost • Low maintenance	• Low yield
Ponds	Moderate- High Flow through: > 30 kg/m^2 Static: 4-5,000 fish/ha	• Relatively cost-effective, especially if gravity fed and drained • Optimises ambient growing conditions • Minimises stock losses through escape or predation	• Moderate to high land requirement and construction costs • Little control over ambient environmental conditions • Stock management may be difficult • May have high water consumption
Tanks (flow-through)	Moderate 20-30 kg/m^3	• Less maintenance and training required for operation • Relatively inexpensive set up costs compared with ponds and RAS • Can use existing shedding or buildings • Easier to observe and harvest stock	• Higher water use than recirculation and static ponds • Little control over water temperature (some protection from elements)
RAS	High >100 kg/m^3	• All production variables may be controlled to achieve optimum growth • Low water consumption per tonne of fish produced • Impact on external environment minimised by containing and treating wastewater • Year-round production	• High capital costs ($250-500K for 20 tonne system) • High operational costs ($7-10/kg fish) • Skilled management and constant maintenance required
Cages	Moderate 15-25 kg/m^3	• Use existing waterbodies. • Technical simplicity with which farms can be established or expanded. • Lower capital cost compared with land-based farms. • Easier stock management and monitoring	• Stock vulnerable to external water quality. • Stock vulnerable to predators (water rats, seals and birds). • Growth rates determined by ambient water temperatures.

Aquaculture Species Options for IAAS

The choice of appropriate species for an IAAS venture will require consideration of a number of inter-related factors. The biological requirements, aquaculture status and market potential of the intended species must be assessed in the context of site specific attributes before the technical and economic viability of the venture can be fully evaluated. Legislative and regulatory constrains will also dictate the availability of certain species in most parts of Australia.

- **Biological requirements.** Temperature, salinity and water requirements of the selected species will be the first criteria used to assess suitability. For open aquaculture systems (farm dams, ponds, flow through tanks and cages), the choice of species for IAAS will essentially be dictated by the geographic location, climate and the quality and quantity of water available. Closed systems can overcome these limitations, however, the species chosen must have a market value which will justify the investment in this relatively expensive and sophisticated technology.

- **Aquaculture status.** The current aquaculture status of the species is important as species that are commercially cultured will usually have a reliable supply of seedstock provided by hatcheries. The performance of these species under aquaculture conditions will also be documented, making estimates of productivity and time to market more reliable and business planning projections more realistic. Commercial aquaculture species may have specifically formulated diets which will improve growth, and husbandry methods will be known and mostly routine. In addition, common diseases of these species will be documented and manageable.

- **Market potential.** The market demand, location of the market (see Chapter 9) and expected price are important considerations to justify the level of intended investment. Capital intensive RAS systems must grow high value species at intensive stocking densities to realise returns on their investment, whereas smaller investors can afford to adopt a lower risk approach and stock at lower densities in less intensive systems.

- **Site specific factors.** The geographic location will dictate the ambient climatic conditions, liability to drought and flooding, soils, geology and topography. There are often restrictions placed on stocking species which are non-endemic to the catchment area or region. This may restrict the choice of species or reduce the options for production systems. Transport and communication infrastructure is important for moving stock onto and away from the farm.

Species that are currently aquacultured on a commercial basis in Australia have the most potential for ready adoption in IAAS systems as the technology for farming is already developed. Other species may have potential for IAAS, but aquaculture development is still experimental and at this stage the risks are higher. The species options given in this chapter will be restricted to those currently commercially ongrown in Australia, but it is recognised that many other species show potential for production within IAAS.

Aquaculture species and system integration

Research and practical experience has suggested that there are four main categories of IAAS applicable to Australian:

Farm diversification.

The integration of aquaculture into farming irrigated farming systems presents the greatest opportunity for the development of IAAS in Australia. Each state has existing irrigation infrastructure and access to groundwater, as detailed earlier, and these resources must be used more efficiently to increase farm sustainability. Existing on-farm infrastructure and resources can be usefully employed in aquaculture to increase efficiency.

Water for aquaculture can be drawn from many sources, *e.g.* run-off, rivers, creeks, dams, lakes, irrigation canals and under ground, as previously outlined. Table 5.4 summarises appropriate aquaculture system options for different water source types.

Table 5.4: Aquaculture system options by water source.

Water source	Aquaculture options	Production intensity	Level of investment	Yield
Farm dams	Free-range/ extensive	Extensive	Low	Low
	Cages	Semi-intensive	Low-moderate	Medium
Irrigation water	Ponds	Semi-intensive	Medium	Medium
	Tanks/RAS	Semi-intensive/ Intensive	Medium-high	Medium-high
	Cages	Semi-intensive	Low-medium	Low-medium
River water	Ponds	Semi-intensive	Medium	Medium
	Tanks/ RAS	Intensive	Medium-high	Medium-high
Groundwater	Ponds	Semi-intensive	Medium	Medium
	Tanks/RAS	Intensive	Medium-high	Medium-high
Town water	Tanks/RAS	Intensive	Medium-high	Medium-high

Species options for farm diversification have been summarised in Table 5.5, assuming that the water source will be freshwater (for saline water sources see Inland Saline Aquaculture section). These species have been selected on the basis that they are already commercially cultured in Australia to some degree, so there is a supply of juveniles and market acceptance. Culture characteristics for the most popular species are summarised in Appendix III of this Handbook. Further information on these species can be obtained from your state fisheries agency (Appendix I of this Handbook).

Inland saline aquaculture

The salinisation of land and water has become a serious problem in many areas of Australia since European settlement. Saline groundwaters that increase land and stream salinity result from the replacement of perennial, deep-rooted natural vegetation with annual, shallow-rooted agricultural crops and pastures (Nulsen 1997). The change in land use and thus vegetation allowed additional recharge to reach groundwaters, which rise to the surface carrying dissolved salts with them. In 1996, it was estimated that about 2.2 million ha of once productive agricultural land was affected by salinity; some 70% of that in Western Australia (Robertson 1996). Recent estimates have suggested that up to 4.6 million ha of agricultural land is under threat from salinity; much of which is Australia’s most productive land (www.audit.ea.gov.au/ANRA). Figure 5.7 shows the areas of Australia where salinity is a major problem for water resources.

Table 5.5: Freshwater species options for IAAS.

D=farm dams; P=ponds, T=tanks; C=cages; R=recirculating.

Common name	**Scientific name**	**Optimum Temp (°C)**	**Optimum Salinity ppt**	**Systems**	**Time to market**	**Notes**
Atlantic salmon	*Salmo salar*	10-16	0-35	P, T, C, R	1-2 yrs juvenile (freshwater) 2-3 yrs market	Exotic, optimal salinity depends on life stage.
Aquarium fish (native and exotic)	Various	Various	Various	P, T, C, R	Various	See Appendix III
Barramundi	*Lates calcarifer*	28-32	0-35	P, T, C, R	5 m (RAS)	Native to tropical coasts of Australia
Brown trout	*Salmo trutta*	8-18	0-35	P, T, C, R	12 m	Exotic
Eels	*Anguilla australis* *Anguilla reinhardtii*	23-28	0-5	P, T, R	18-24 months	Native to eastern state, Tas & SA
Golden perch	*Macquaria ambigua*	23-28	<8?	P		Native
Jade perch	*Barcoo grunter*	20-30	<5	P, T, C, R		
Murray cod	*Maccullochella peelii*	20-25	<8	P, T, C, R	12-18 m RAS 24 m ponds	Native to MDB
Rainbow trout	*Oncorhynchus mykiss*	8-18	0-35	P, T, C, R	9 m ponds	Exotic but widely stocked in southern states
Silver perch	*Bidyanus bidyanus*	23-28	4 15 max	P, T, C, R	10-24 m ponds	Native to MDB
Crustaceans						
Marron	*Cherax tenuimanus*	24	<6-8	D, P	6-12 m	Native to WA
Redclaw	*Cherax quadricarinatus*	23-31	<6-8	D, P	6-12 m	Native to N Queensland, NT.
Yabbies	*Cherax destructor*	25-28	<6 8 max	D, P	6-12 m	Native to MDB

Broadacre cereal crops and traditional pasture species do not tolerate salt and are seriously affected when salt concentrates in the root zone. Table 5.6 shows how the usefulness of a water source for agriculture decreases with increasing salinity.

At a farm level, the most obvious impact of increasing salinity is loss of production and income. However, additional less obvious impacts such as decline in land value, damage to infrastructure, salinisation of storages and loss of farm flora and fauna also occur.

Although several approaches are being undertaken to combat the salinity threat in Australia, the construction of large-scale evaporation basins to collect water from groundwater pumps offers the greatest opportunity for aquaculture integration. Aquaculture offers an opportunity to recover some productivity from otherwise unproductive resources which can be used to offset the costs of managing the salinity problem at a farm and/or regional scale (Smith and Barlow, 1997).

The development of inland saline aquaculture is still in the experimental phase in Australia (*e.g.* Ingram *et al.In press*) and Table 5.8 summarises the fish species currently under consideration (Jenkins 1997). These species have been selected predominantly because the culture technologies are reasonably well known and there is a ready supply of juveniles. In the future, as aquaculture technology develops, it is anticipated that other species will become available for incorporation into inland saline aquaculture systems. The likely species include mangrove jack, estuary perch, King George whiting and various other marine and estuarine species.

Table 5.6: End use of water by salinity range (www.audit.ea.gov.au/ANRA).

Class (TDS of applied water)	Vegetables	Crops	Livestock	Other Uses
A (0-500)	All	All	All (Poultry, Dairy, Beef, Pigs, Horses)	Maintenance of ecosystems, potable supply, parks and gardens, industrial, primary contact recreation. Building and structures
B (501-1000)	Orchards, grapes, veg, olives, tomatoes, broccoli.	Oats, wheat, ryegrass, millet, clover, lucerne, beans, barley, cotton, canola, sunflower, sugarcane, corn, rice.	All	As per A
C (1001-1500)	Orchards, grapes, veg, olives, tomatoes, broccoli.	Oats, wheat, ryegrass, millet, clover, lucerne, beans, barley, cotton, canola, sunflower, sugarcane, corn.	All	All except potable water supplies
D (1501-3000)	Orchards, grapes, veg, olives, tomatoes, broccoli.	Wheat, ryegrass, millet, barley, cotton, canola, sunflower.	All	As per C
E (3001-5000)	-	Barley, cotton, canola.	Dairy, Beef, Pigs, Horses	Ecosystems, Stock, Industrial, Primary contact recreation, buildings and structures.
F (5001-14000)	-	-	-	As per E
G (>14000)	-	-	-	Ecosystems, Industrial, buildings and structures.

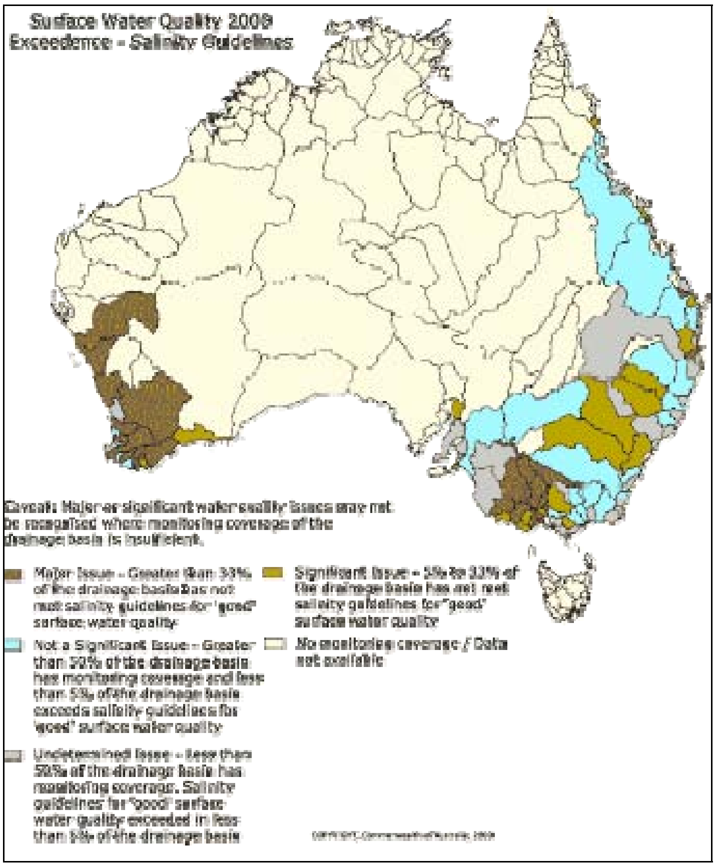

Figure 5.7: Water resources affected by salinity.

Of the species in Table 5.8, those which have shown most potential in research trials are silver perch, rainbow trout and Atlantic salmon (Ingram *et al*. *In press*); snapper (Fielder *et al. In press*); barramundi and mulloway (O'Sullivan and Ryan 2001). Black bream showed good survival, however, growth rates appear to be too slow to make commercial aquaculture viable.

Crustaceans identified as having potential for inland saline aquaculture are also shown in Table 5.8 (Allan and Fielder 1997). The "best" candidate was identified as penaeid prawns, which are already widely cultured in coastal areas of northern NSW and Queensland. Brine shrimp is another species with great potential and preliminary trials have shown that they can be successfully grown in inland saline waters (Hutchison 1997). There is a large potential market for home-grown brine shrimp in the feeding of native and ornamental fish larvae prior to weaning onto artificial diets. Other species with potential are mud crabs and other soft-shelled crabs.

There is little information on the aquaculture of molluscs in inland saline waters nationally and internationally (Lee 1997), but species with potential are listed in Table 5.8. Of these species only three have been trialed in inland saline waters. The ionic composition of inland saline waters is sometimes different from that of seawater and this may have large effects on the growth and survival of euryhaline finfish and mollusc species and hence determine the suitability of the water source for mollusc culture (Lee 1997). The culture of plankton in inland saline waters has been trialed commercially and the species with potential for integration with inland saline waters are shown in Table 5.8 (Borowitzka 1997). An example of this form of inland saline aquaculture operated in South Australia (Hutchison, 1997).

Factors to consider when selecting species for inland saline aquaculture include:

- Salinity of water source and the salinity tolerance of the species;
- Variation in the temperature and salinity of the water source over time;
- ionic composition of the water source compared with seawater or the requirements of the target species.

Due to the range of species with potential for inland saline aquaculture, there is good potential for the polyculture of various species within the same aquaculture operation. The species groups within Table 5.8 feed differently and they can be grown in the same pond without competing for the same food source. For example, fish can be fed on commercial pelleted diets, which add nutrients to the pond ecosystem. Seaweed and algae absorb nutrients from the water column as they grow, whereas bivalve molluscs feed on algae in the water. Gastropods and crustaceans can scavenge organic wastes on the bottom of the pond.

In Queensland, research is being carried out using prawn farming wastes to grow algae on plastic "aquamesh". The algae are browsed by estuarine mullet (*Mugil cephalus*) and rabbit fish (*Siganus nebulosus*)- which can then be harvested (Erler *et al.* 2000). Other waste management options being studied for saline water farms use seaweed or mangroves in aquaponics. Western Australia has also carried out research into the nutrient stripping capability of seaweed (Jenkins *et al.* 2000). A review of the use of integrated biological treatment systems (fish, seaweed, bivalve molluscs, mangroves) to treat shrimp farm effluents in Thailand found that although there were many benefits with this form of integration, there were also a number of logistical constraints to be considered (Gavine *et al,* 1996). This study also showed that finding markets for the produce from inland saline aquaculture is equally important as simply growing aquatic species.

A key issue in the use of saline water for IAAS is the need to ensure that effluent can be appropriately managed. IAAS use of saline waters should result in no discharge of effluent to the wider environment and access to on-farm evaporation basins is critical to this form of aquaculture.

Table 5.8 Species with potential for inland saline aquaculture.

Common name	Scientific name	Optimum temp (°C)	Optimum salinity (ppt)	Comments
Fish				
Barramundi	Lates calcarifer	28-32	0-35	Already commercially in saline water
Black bream	Acanthopargus butcheri	22-24	24 Up to 140	Extremely slow growth rates
Eel	Anguilla sp.	23-28	0-35	
Flounder	Rhombosolea tapirina	18-20	>15	
Mullet	Mugil cephalus	3-35	0-38	Hatchery in Queensland can supply juveniles
Mulloway	Argyrosomus hololepidotus	15-30	5-35	Trials in NSW successful
Rainbow trout	Oncorhynychus mykiss	8-18	0-35	Trials successful in Victoria
Silver perch	Bidyanus bidyanus	23-28	4	Trials successful in Victoria
Snapper	Pargus auratus	20-28	>8	Trials in NSW
Crustaceans				
Freshwater crayfish	*Cherax* sp.	23-31	0-5	
Freshwater prawns	*Macrobrachium sp.*	23-32	Up to 10	
Prawns	Peneaus sp.	25-30	15-25	
Mud crabs	*Scylla serrata*		28-34	
Brine shrimp	*Artemia* spp. *Parartemia* sp.	25-30	30-35 up to 180	
Molluscs				
Abalone	*Haliotis* spp.	15-18	34-37	
Blue mussels	*Mytilus edulis*	12-26	0-35	
Edible oysters	*Crassostrea gigas* *Saccostrea* spp.	>20	23-28	
Pearl oysters	*Pinctada* spp. *Pteria penguin*			
Scallops	*Pecten fumatus*			
Trochus	*Trochus niloticus*	28-30	35	
Plankton				
Phytoplankton	*Dunaliella salina*	12-35	>200	Beta carotene
	Aphanothece halophytica	-	>200	Polysaccharides, phycobilin pigments
	Isochrysis,	25-30	30	Feed for molluscs, crustacean & fish
	Tetraselmis,	20-28	30-40	
	Chaetoceras,	25-35	20-35	
	Pavlova	15-30	10-40	
	Spirulina platensis	-	30	Health food
	Porphyridium cruentum	-	<30	Polysaccharides, pigments for cosmetics
Seaweed	*Gracilaria* spp.	20-30	15-24	Feed for abalone, source of agar.
	Ulva spp.		30	Feed for abalone.
	Caulerpa spp.		30	Luxury food in Japan.

More recently a national R&D strategy for inland saline aquaculture has been prepared which includes detailed information on inland saline aquaculture has been prepared which includes detailed information on inland saline water resources and suitable species and system options.

Aquaponics

Aquaponics is a term used to describe the use of aquaculture effluents for the hydroponic production of plants, *i.e.* the integration of aquaculture and hydroponics. Hydroponics is the growing of plants without soil. Nutrients are dissolved in water and the nutrient solution is offered to plant roots in a variety of ways, such as in sand beds, scoria rock or sawdust, and from thin films or misted sprays (Wilson 2001). Until recently, most commercial hydroponics have been undertaken with inorganic nutrients, or artificial fertilisers but now, organic hydroponics is being studied as a means of more effective management of wastes. In aquaponics, much of the plant food nutrients can come from organic sources - such as fish excreta, fish food wastes or the break-down of algae and other micro-organisms growing in the water.

Plant requirements in Aquaponics (after Carruthers 1993)

In hydroponics all essential elements are supplied to plants in the form of nutrient solution and the success or failure of the venture depends primarily on strict nutrient management, which is achieved by carefully manipulating the pH level, temperature and electrical conductivity.

- pH. Most hydroponically grown plants require a slightly acidic pH with the optimum being between 5.8 and 6.5. pH levels above 7.5 will limit the availability of trace metals to plants.
- Temperature. Temperature fluctuations in a hydroponic solution can affect the pH of the solution and the solubility of nutrients. Ideal water temperatures are 20-20^{o}C.
- Electrical conductivity (EC). EC is used as a measure of the nutrient concentration of the hydroponic solution. Nutrient requirements of plants can generally be categorised as low, medium or heavy feeders (Table 5.9).

In commercial operations, the quality of hydroponic solution is monitored constantly and adjusted automatically as required. Ambient air temperature is also an important crop requirement as plants generally grow well within a specific temperature range. Warm season vegetables and most flowers prefer a temperature range between 15^{o}C and 24^{o}C. Cold season vegetables, such as lettuce and spinach, grow best between 10-21^{o}C. A variety of fruits, vegetables, herbs and flowers is listed in Table 5.9 along with their pH and EC requirements. This is only a sample of the number of species which have potential with this technology. In this context, EC is a measure of the nutrient content of the prevailing water and L= 0.6-1.5 mS/cm, M=1.5-2.4 mS/cm and H=2.4-5.0 mS/cm.

The most appropriate plant species to be grown with aquaculture effluent will depend on the quantity and quality of effluent available and the temperature at which it enters the system. Heating or cooling the effluent to optimal conditions and supplementing the nutrients can widen species options, if required. The use of greenhouse technology to raise ambient air temperature is another way to increase the species options available. One important constraint to aquaponics is the use of salt in routine fish farming activities. Plants with a low salt tolerance will suffer from excess salt in the system and this will have to be carefully managed.

The most suitable combination of fish species and culture system to integrate with hydroponics will vary according to the ability of the farmer to match the outputs of the aquaculture system with the requirements of the hydroponic system. Nutrient-rich discharge from RAS operations is likely to be suitable for hydroponics and examples are already apparent in Australia (*e.g.* barramundi and lettuce in NSW). Similarly, the use of trout farming effluent for hydroponic production of wasabi is operating in Victoria (see Chapter 6 for details).

Table 5.9: Hydroponic plant species water requirements (Carruthers 1993).

		PH	EC
FRUIT	Banana	5.5-6.5	M
	Melon	5.5-6.0	H
	Strawberries	6.0	M
	Water melon	5.8	M
VEGETABLES	Broad bean	6.0-6.5	M
	Capsicum	6.0-6.5	M
	Cucumber	5.5	M
	Lettuce	6.0-7.0	L
	Pak Choi	7.0	M
	Tomato	6.0-6.5	H
	Zucchini	6.0	M
HERBS	Basil	5.5-6.0	L
	Fennel	6.4-6.8	L
	Mint	5.5-6.0	H
	Mustard cress	6.0-6.5	M
	Watercress	6.5-6.8	L
FLOWERS	African violet	6.0-7.0	L
	Crysanthemum	6.0-6.2	M
	Gladiolus	5.5-6.5	M

Wastewater aquaculture

Wastewater aquaculture is the production of fish using nutrient-rich wastes (*e.g.* domestic sewage, livestock manures and industrial effluent) as the principal source of fish nutrition. It is conceptually very similar to other forms of agriculture with nutrients, water and solar energy being used to produce organic matter and ultimately plant and animal biomass (Gooley *et al.* 2001). The key to successful wastewater aquaculture is the use of fish that feed low in the food chain (*i.e.* eat plankton). Unfortunately, there are few native species with such aquaculture potential that eat plankton (mullet, rabbit fish and rainbow fish are currently being investigated) and there may be difficulties in some states obtaining permission to use exotic species which may be suitable (*e.g.* carp and goldfish).

Trials have been carried out using carp and goldfish in dairy processing effluent (Gooley *et al.* 2001) and domestic sewage (Gooley *et al.* 2000) in Victoria. These trials showed that wastewater aquaculture is technically feasible in Australia, however, the Victorian climate is not ideal for the culture of warmwater fish, other than on a seasonal basis. Water quality in the wastewater ponds must also be carefully managed to ensure that conditions remain optimal for fish growth. Marketing essentially determines the economic feasibility of wastewater aquaculture produce. The supply of large volume, low value "trash fish" for the petfood market was the original driver of recent wastewater aquaculture R&D projects in Victoria. However, an analysis of the economic feasibility of the venture suggested that the identification of niche markets (such as supply of live food for native fish broodstock) would be a more profitable avenue. Ornamental fish were another market with huge potential for exploitation. In general, fish grown in wastewaters are regarded as unsuitable for human consumption. Table 5.10 lists some of the species with potential for use in wastewater aquaculture in Australia.

Table 5.10 Fish with potential for wastewater aquaculture in Australia.

Common name	Scientific name	Optimum temp (°C)	Optimum salinity (ppt)	Comments
Aquarium fish (native)	Various	Various	Various	See Appendix III
Aquarium fish (exotic)	Various	Various	Various	See Appendix III
Carp	*Cyprinus carpio*	20-30	0-5	
Mullet	*Mugil cephalus*	3-35	0-38	
Rabbit fish	*Siganus nebulosus*			

Aquatic Diseases and Fish Health

Since the management of aquatic diseases and fish health in an IAAS context is largely consistent with aquaculture practices and requirements in general, this topic will not be addressed in detail here. However, a brief summary of the key issues that farmers need to be aware of in relation to fish health is given below.

In any aquaculture operation, farmers can expect to have to deal with various ectoparasitic, bacterial, protozoan and fungal infestations, most of which are endemic in Australian surface waters. Disease outbreaks can occur as a result of environmental (*i.e.* water quality related) and/or handling and husbandry stress. These problems tend to reflect poor management practices on the farm. Susceptibility to disease is species and system specific and can result from various pathogens. There are a range of therapeutic treatments available to deal with most outbreaks.

Parasitic infections such as internal worms (nematodes and trematodes) and external crustaceans (*e.g.* mites and *Lernea* sp) may require more intensive treatment. The use of certain chemicals will be restricted in open systems where effluent waters are unconfined. The use of chemicals in aquaculture is increasingly being brought into line with national standards for the agriculture industry. However, since uniform standards are still not in place farmers are advised to consult with state government animal health agencies, local vets and aquaculture extension officers for more detailed advice and information.

More detailed information is also available from the following sources: Shepherd and Bromage (1988); Rowland and Bryant (1995); Piper et al. (1982); Stickney, 1979; Herbert and Rawlin (1999); Noga (2000); Rowland and Ingram (1991); Ingram (2000).

Australia's aquatic animals are generally free from many of the diseases affecting the industry overseas. A recent Federal Government initiative, AQUAPLAN, is designed to provide a strategic framework for the management of aquatic animal health in Australia (www.affa.gov.au).

Conclusion

In conclusion, it is clear that the selection of appropriate species and systems for an integrated agri-aquaculture venture requires careful consideration of a number of inter-related factors. The geographic location of the proposed site and the local climate are important as are the physical characteristics (geology, soils and topography). The quality and quantity of water available are key factors in the selection of aquaculture systems and species, as access to water resources becomes increasingly constrained. However, the choice of system and species will also depend on the level of intended investment, marketing and economic factors which will be more fully discussed in subsequent chapters.

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Chapter Six

Australian Case Studies for Integrated Agri-Aquaculture Systems

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Introduction

The practical application of the concepts of IAAS in Australia may be best illustrated by presenting case studies of farmers who have already implemented IAAS into their farm. It is hoped that these case studies will convey some of the practical problems experienced by these farmers as well as the benefits derived in terms of farm productivity and resource-use efficiency. The case studies have been written using the words of the farmers themselves and reflect their personal views and experiences as far as possible. Table 6.1 gives an inventory of farmers known to be practising integration in each state. There are three distinct classes of case studies presented in this chapter, related to the integrated systems options identified in Chapter 5:

- Farm diversification
- Inland saline aquacutlure and
- Aquaponics - the use of aquaculture effluents for the hydroponic production of fruit and vegetables.

The farm diversification case studies include examples from large-scale irrigators such as rice (no. 2) and cotton farms (no. 5) in irrigation networks, as well as an example from sugar growing country in north Queensland (no. 12). Small cattle farms in NSW and Victoria (nos. 1 and 3) are described as are marron farmers in Western Australia (no. 11). Inland saline aquaculture is well represented in the case studies, reflecting the increasing problem of salinity in Australia. The farms presented include extensive culture of trout in farm dams in Western Australia (no. 10), to sophisticated agro-forestry, evaporation basin systems (no. 4) and intensive recirculating systems in South Australia (no. 8). Finally the relatively new "aquaponics" industry is represented by an example from NSW and Victoria (nos. 6, 7 and 9).

Table 6.1: State-based inventory of IAAS practitioners in Australia.

State/Area	IAAS Option	Aquaculture Species	Agriculture Species	Contact details
NSW				
Barrington	Farm diversification	Silver perch	Pasture/cattle, olives	Marsia Thomson, Gloucester, NSW Marsia@bigpond.com.au
Port Stephens	Aquaponics	Barramundi	Lettuce	Tailor Made Farms Bobs Farm NSW 0249826600
Wakool	Government experimental station (inland saline)	Snapper	-	Stewart Fielder, NSW Fisheries 0249821232
Karuah	Farm diversification	Silver perch	Tourism	Laurie Tomlin 0249975697
Barrington	Farm diversification	Silver perch	Dairy cattle	Lindsay Fraser 0265587571
Caroona	Farm diversification	Silver perch, golden perch, yabbies	Irrigation (legumes, cotton *etc*)	Sam Clift 0267445852
Jerilderie	Farm diversification	Silver perch, golden perch, yabbies	Cotton	Rick Mailer Kularoo, Jerilderee 03 5886 1290
Milrea	Farm diversification	Silver perch, Murray cod	Cotton	Steve Martin 0268289399
Howlong	Farm diversification	Silver perch	Olives	Paul Trevethan 0260265276

State/Area	IAAS Option	Aquaculture Species	Agriculture Species	Contact details
Queensland				
Dalby	Farm diversification	Silver perch, Murray cod	Cotton	Paul Mc Veigh, Loch Caton, MS 35, Dalby 4405 Pmcveigh@bigpond.com
Cairns	Farm diversification	Barramundi	Sugar cane	Mark Fantin, Edmonton QLD 07 4055 5676, mfantin@ozemail.com.au
Townsville	Aquaponics	Redclaw, silver perch	Horticulture	Ian and Melissa Fletchett, Majors Creek, Townsville 07 4778 8664 majorscreek@aol.com.au
Brisbane	Farm diversification		Vegetables	Paul Ziebarth PO Box 19, Rocklea, QLD 4106 Pziebarth@qfvg.org.au
Walkamin	Freshwater Fisheries & Aquaculture Centre Walkamin	Barramundi, redclaw	Agro-forestry	Max Wingfield, Aquaculture Extension Phone: (07) 4092 9908 wingfim@dpi.qld.gov.au
South Australia				
Kangarilla	Aquaponics	Barramundi	Watercress	Danielle & Glen Sheehan Kangarilla, SA Inish@bigpond.com
Meningie	Inland saline	Black bream, mulloway	Artemia	Roger Strother Meningie West 08 8575 4254
Victoria				
Tongala	Farm diversification	Silver perch, Murray cod	Cattle	Adrian Kay 1810 Wilson Road, Tongala 3621 03 5859 0244
Undera	Inland saline	Rainbow trout	Trees	Ken Warren 1445 Mulcahy Rd Undera 3629 03 5826 0257
Rutherglen	Farm diverisfication	Murray cod	Trees	Simon & Philippa Noble Brimin Lodge Rutherglen 3685 02 6035 7245
Snobs Creek	Aquaponics	Rainbow trout	Wasabi	Paul Gilmore Rubicon Mountain Pty. Thornton 03 5773 2252
Western Australia				
Wheatbelt	Inland saline	Rainbow trout	-	Various
South-west	Farm diverisfication	Yabbies/ marron		Various
Gasgoyne	Farm diversification	Ornamentals		Andrew Beer GIAG, WA Fisheries Abeer@fish.wa.gov.au

CASE STUDY 1: BEEF CATTLE - NATIVE FISH HATCHERY

Adrian & Anna Kay, Mooravale Fishery, Tongala, Victoria.

Background

The Central Goulburn irrigation district is one of the largest irrigated areas in northern Victoria. More than 2,800 irrigated holdings are serviced in this area through an extensive network of distribution channels and drains. The total water right of the area is 415,000 ML supplied mainly from Lake Eildon at the head of the Goulburn River. A diverse range of irrigated agriculture can be found in this area, including dairy farming (covering 46% of the area), cropping and grazing (48%) and horticulture (mainly stone and pomme fruits, covering 6%).

Until 1995, Adrian and Anna Kay operated a conventional dairy farm at Tongala in the Central Goulburn irrigation district, milking around 85 cows. However, over their 25 years as farmers, the Kays have routinely altered their farming practices to address market needs and have produced sheep, arable crops and beef cattle.

In the mid-1990's, the Kays became disillusioned with the highly structured marketing systems of the large regulated dairy and livestock industries. The Kays felt that the overbearing bureaucracies associated with these industries left the individual farmer with no opportunity to control the market or price for their product. Since then, de-regulation of the industry has also meant that many of the smaller dairy farms are not economically viable.

For Adrian and Anna, diversifying into aquaculture was a means of regaining control of their product and market as well as increasing the productivity and economic viability of their farm. They recognised that aquaculture was a new and expanding industry in Victoria and Australia and integrating it into their farm business allowed them to be a price asker instead of a price taker. The Kays selected native fish as their target aquaculture market (Murray cod, silver perch and golden perch) and identified a market niche for the production of larvae and weaned juveniles to other growers. Environmental sustainability was another key factor in the decision to integrate aquaculture into their farm as the Kays believe that they have a moral obligation to future generations to conserve water and use it wisely.

System Details

The total farm area of the Kay's property is 32 ha with 28 ha dedicated to livestock grazing and the production of beef cattle. The aquaculture operation has developed over recent years from a simple grow-out system with 4 ponds to the current, improved site which has 15 ponds and a fully equipped hatchery. The aquaculture part of the farm currently occupies 4 ha and was completed this year. Water supply to the farm comes from a 135 ML water entitlement from the Central Goulburn Irrigation network and 85 ML from a private bore. In addition to the aquaculture ponds, there are a further 2 water storage dams; the total on-site water storage capacity is 26 ML.

The hatchery facility consists of a 15 m x 5 m insulated room with hatching troughs and associated equipment. The hatchery also contains 7 x 2,000 litre tanks and has the capacity to hold 150,000-200,000 fingerlings.

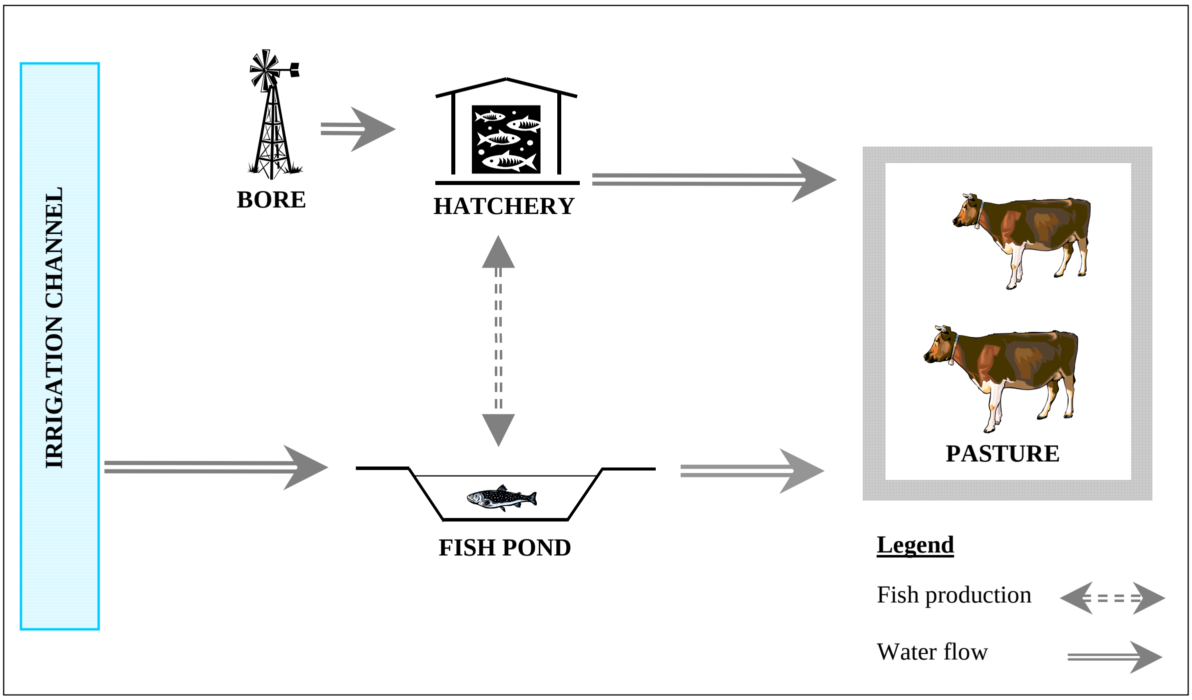

Figure 6.1: Schematic layout of the integrated native fish – cattle farm.

The ponds have a capacity of 2 ML each and are used to either hold broodstock (5 ponds) or as first-feeding ponds (10 ponds) for fish larvae. The ponds are custom-built to make harvesting easier and are aerated.

In the first three years of operation, production steadily increased from around 40,000 silver perch and golden perch fingerlings sold in 1997/98 to nearly 80,000 in 1998/99 and 170,000 in 1999/2000. This season (2000/2001), Murray cod were spawned for the first time and 50,000 larvae were sold to ongrowers, together with a production of 50,000 silver perch.

Effluent from the ponds and hatchery is drained to a collection channel and pumped into the irrigation system. No problems have been recorded with solids in the irrigation system. The water is used to irrigate the cattle pastures and has resulted in the need for no additional fertiliser on the paddocks. Figure 6.1 shows schematically how water moves around the farm; water from irrigation channels is used for the fish ponds and bore water is used for the hatchery. Prior to irrigating with aquaculture effluent, around 8 tonnes of fertiliser was used each year at an annual cost of $1,800. The paddocks support livestock which produce approximately 10 tonnes of meat per year.

Adrian and Anna both work on the farm, but no additional labour is used.

Marketing

There is a ready market for good quality native fish juveniles in Victoria as the ongrowing sector of the industry continues to develop. This is likely to continue to be the case for the forseeable future, particularly for Murray cod juveniles. The demand for silver perch juveniles appeared to drop this year, possibly due to a lower rate of new farm start-up this year. Another factor was last-year's customers were still waiting for a crop and were not buying juveniles this year – most of the Kays customers are small operators with limited tank or pond capacity for growout.

Problems

The most significant problems encountered by the Kays include:

- Maintaining water quality – water from bores often has low dissolved oxygen and ponds (particularly the ones that are fertilised) have to be carefully managed to maintain good water quality.
- Predators – cormorants, pelicans and cranes are the main problems. Ponds need to be netted to protect the stock.
- Lack of support and experienced advice to guide farmers through the steep learning curve of this new industry. This is particularly important when farmers are designing farms and planning the scale of the integration. There should be grants available to assist farmers with this crucial stage.
- Training - there is a need to develop marketing skills within the industry, particularly to demonstrate how fish should be presented to potential buyers. Training is also required in proper purging techniques.

Vision for the Future

For the industry to develop, a co-operative approach is required between farmers to cover the different stages in native fish life-cycles (from broodfish to market size progeny). Some growers could concentrate on producing juveniles for a network of ongrowers, whilst other farmers could specialise in purging and marketing to maintain product control and ensure markets are consistently supplied. Such vertical integration will require the establishment of regional business network clusters.

For most traditional farmers, aquaculture is a new and bewildering industry. For the IAAS industry to be stimulated on a large scale, the Kays envisage a focal point where farmers can get all the information and support that they will need at many stages through their development. This information will cover the planning stage (choice of appropriate species and culture system), through management of the production system (fish health, water quality, fish husbandry) to purging and marketing the final product.

To maximise the performance of our native fish in aquaculture systems, selective breeding needs to take place to improve the genetics of broodstock. The development of techniques for year-round spawning is important for further development of the industry.

Integration can provide real opportunities for farmers to gain a better sense of control over their products and markets, and respond to local niche markets. It also offers the opportunity to play an active role in wise water usage, to demonstrate this to others, and to thereby contribute to the environmental sustainability of our industries.

Acknowledgements / Key References

Additional information for this case-study was sourced from www.g-mwater.com.au.

CASE STUDY 2: RICE-NATIVE FISH-FORESTRY

Rick Mailer, "Kularoo"
Jerilderie, NSW.

Background

Rice is the major irrigated cereal crop in Australia and (apart from a small area in the Northern Territory) is grown entirely in the Murrumbidgee and Murray Valleys of south-west New South Wales. Each year around 150,000 ha of rice is sown, with around 1.2 million tonnes produced. The industry has a farm-gate value of around $300 million and earns more than $500 million in exports. Australia is one of the most efficient rice producers in the world, with average annual yields of over 9 tonnes per ha.

One of the major constraints to the future expansion of the industry is resource availability. Rice paddies have a very high demand for water (12-16 ML/ha) which places heavy demands on irrigation networks. In addition, the flood irrigation methods used to produce rice can add to the problems of rising watertables. With increasing emphasis on environmental issues, if the rice industry is to have a secure future in Australia it must demonstrate that it has a commitment to the sustainable use of water resources, by reducing water use.

In the early 1990s Rick Mailer realised that environmental concerns were becoming increasingly important and that to improve the sustainability of his property, he would have to diversify and make better use of the resources available to him. When considering diversification options, Rick wanted to use products which were limited or dwindling natural resources. He selected timber and fish.

System Details

Rick's farm is located on the banks of Yanco Creek near Jerilderee in NSW. The total farm area is 2,030 ha, with 400 ha of rice paddy planted each year. The farm uses a continuous rotation farming system. The agroforestry plantation is around 81 ha with four tree species (spotted gum, flooded rose gum, Queensland western white box and iron bark) under culture. The agroforestry plantation is a long-term investment with growout to market size being approximately 20 years. Trees are periodically harvested during the growout period to control density.

Water supply to the property comes from irrigation supplies (5,000 ML). Water quality is generally good at the property and no pre-treatment is required prior to its use for aquaculture. Figure 6.2 shows how water is first used for aquaculture and then used for agro-forestry and finally rice.

The total aquaculture production area is around 26 ha and includes broodstock ponds, extensive yabby ponds and intensive growout ponds for silver perch. The intensive part of the farm covers 9 ha and comprises 6 ha of growout, 1.5 ha of nursery and 1.5 ha of juvenile ponds. This part of the farm is netted to exclude predatory birds. The ponds have supplementary aeration. Growout ponds are rectangular; mostly 100 m x 30 m (0.3 ha).

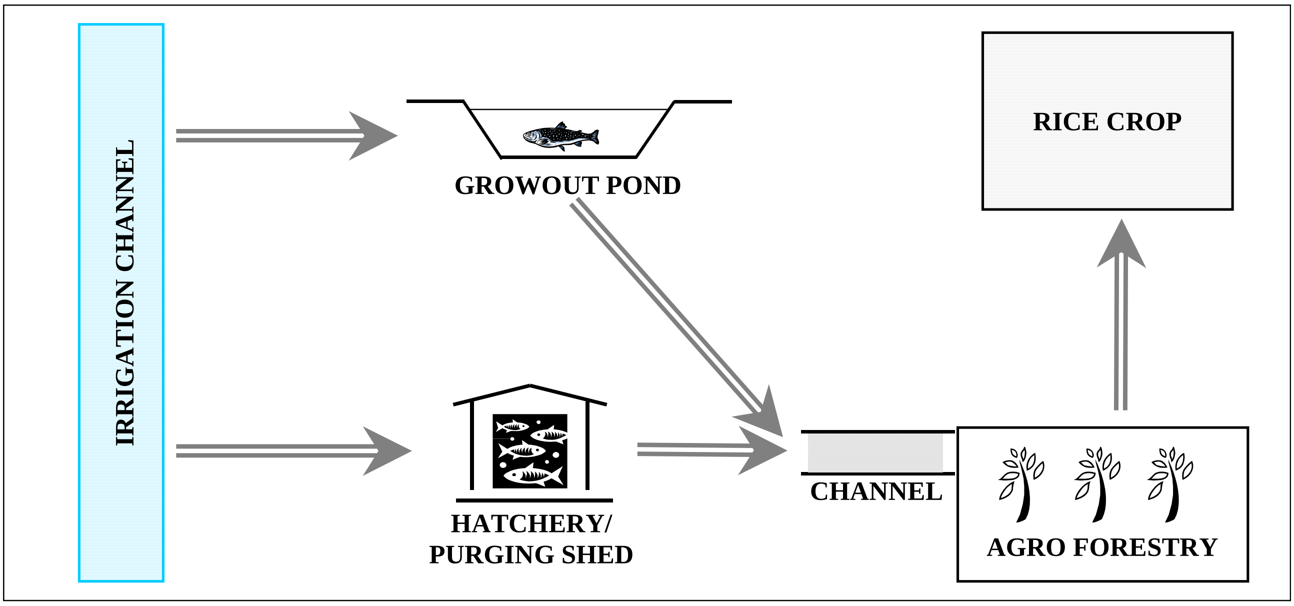

Figure 6.2. Schematic plan of water flow from fish to agro-forestry to rice.

Stocking densities are related to the age class of the fish and can be broadly summarised as:

Fry:	100,000-150,000 in 0.3 ha pond (350,000-500,000/ha)
Nursery:	20,000/ha in 0.2 ha (100,000/ha)
Growout:	5,000 in 0.3 ha pond (15,000/ha)

There is a hatchery on-site which produces silver perch juveniles for the farm, plus Murray cod and golden perch juveniles for sale to other on-growers. The hatchery shed also has purging facilities where fish can be held for 5 days. Development of the commercial fish farm began in 1995 and has now been fully operational for 2 seasons.

Fish are generally spawned in November to January and hatched fry are transferred to fertilised fry ponds for first feeding. Fry are over-wintered in these nursery ponds and then transferred to ongrowing ponds (at 50g) in the spring. The fish are harvested at the end of the following summer at 500-600 g.

Environmental Benefits

The water demands of aquaculture growout fit well with the demands of rice paddy culture, as both require the most water over summer. The water requirement of the rice means that water is exchanged in the growout ponds every 3 days (on average) during the summer. This helps to stabilise ammonia and pH levels in the ponds and maintain good water quality.

Since irrigating his rice paddies with aquaculture effluent, Rick has recorded a decrease in the requirement to use supplementary inorganic fertilisers such as urea. In summer, tissue tests are carried out on the rice to determine whether it is receiving adequate levels of nutrients.

Marketing

Juvenile native fish are sold to both government agencies (in NSW and Victoria) and to fishing clubs, for restocking programs.

Market sized silver perch are transported and sold in Sydney or Melbourne. Fish from the Mailer's property is marketed under the brand name "Australian Kularoo Perch" after rigorous purging and quality control. The markets for silver perch have been badly affected in the past by poor quality product from other farms (*i.e.* not properly purged, or jade perch being incorrectly labelled as silver perch). Incidents like this have caused significant damage to the reputation of silver perch at the markets.

The market price for silver perch had also declined since the fish farm was initially constructed which has influenced the financial viability of the operation. It is hoped that the market will recover sufficiently in the future and in the meantime the Mailers are looking at other species options.

Problems

The main problems encountered by Rick during the first years of production were predators (mainly birds) and disease. The predator problem was tackled by installing predator control measures with varying degrees of success. The disease problems encountered are ongoing and are a major constraint to further development. Currently, the industry does not have chemicals which are cost-effective and safe to use. Until such chemicals are readily available to fish farmers, further growth of the silver perch industry will be constrained. The lack of qualified staff to assist with aquaculture management has also been a problem for the Mailers.

Vision for the Future

The integration of aquaculture and rice (irrigation) works very well, resulting in both water use and labour efficiencies. The current problems with disease control in warmwater aquaculture may be alleviated in the future with better availability of good husbandry advice and effective and safe treatments.

There is a real opportunity for integration to contribute significantly to the continued success (and secure future) of the rice industry, given the increasing pressure for commitment to more sustainable use of the water resource.

Acknowledgements / Key References

This case study was completed with the assistance of Australian Freshwater Aquaculture. The following sources were also used for background information:

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CASE STUDY 3: BARRINGTON PERCH - CATTLE AND AN INTEGRATED MARKETING NETWORK

Marsia Thompson,
Gloucester, NSW

Background

Gloucester is a small town in the Great Dividing Range west of Newcastle on the New South Wales central coast. The region is well known for the Barrington Tops National Park, which has World-Heritage listed rainforests and scenic areas. The area is also home to a thriving and diverse agricultural community dominated by the beef, dairy and timber industries.

Marsia Thompson moved to the area from Sydney eleven years ago searching for a change of pace and lifestyle. When she purchased her 30 ha property it was operating as a beef cattle farm, but she quickly realised that to remain financially viable it was necessary to diversify. Aquaculture was an obvious choice for Marsia as there was an existing network of silver perch growers in the Gloucester area. The property already had a large catchment-fed dam so there was a reliable source of good quality water for diversification into aquaculture.

System Details

The total area of the property is 30 ha, with approximately 0.8 ha dedicated to aquaculture growout ponds. The remainder of the property is used for breeding Aberdeen Angus cattle (around 25 head) and Marsia is currently experimenting with 2 ha of olives. Marsia began to develop her aquaculture operation in 1997.

There are 4 growout fish ponds (0.2 ha each); each pond holds approximately 3,500 fish. The ponds were custom designed to specifications of the NSW Environmental Protection Agency and can be fully gravity drained. Marsia buys in silver perch juveniles at between 1-5 g in February of each year and over-winters them in a heated, recirculating tank system in the sheds near the house. They are transferred to the growout ponds in September (at 65g) and harvested from the following May onwards at around 500g. She aims to refine this system and hopefully reduce the growout cycle to less than one year.

Fish are harvested every two weeks by seine netting the pond and Marsia currently delivers 200 fish per week to the market (totalling an annual production of around 8 tonnes). Purging facilities are located in a shed near the house, where fish are purged for a minimum 4 days on-site prior to being taken into a central purging facility owned by the Gloucester Native Fish Co-operative. The fish are then kept in clean water until they are taste-tested to ensure quality prior to being sold as Barrington Perch.

Effluent from the fish ponds and tanks is drained to an effluent pond from where it is pumped into an irrigation system which provides water to the paddocks and olive plantations. Figure 6.3 shows how the water flows from the fish ponds to the wastewater pond, prior to use in irrigation.

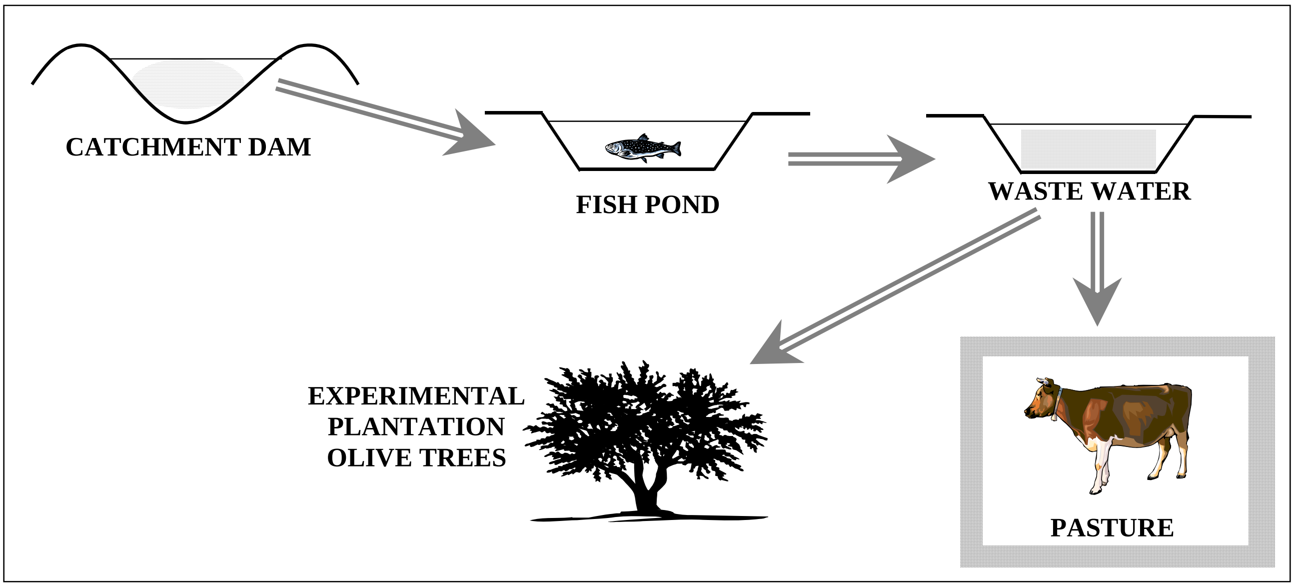

Figure 6.3. Schematic layout of integrated silver perch- cattle

Environmental Benefits

Environmental benefits are chiefly through the multiple use of water, with higher farm productivity per ML utilised. No effluent from the farm drains into natural waterways and Marsia expects to see a reduction in the need for inorganic fertilisers over the next few summers.

Marketing

Marsia is part of a network of growers in the Gloucester area who share purging and processing facilities and collectively market their fish as **"Barrington Perch"**. The Gloucester Native Fish Growers Co-operative (GNFGC) was formed in 1994 to develop a strong base for the emerging fish farming industry in the Gloucester area. GNFGC currently has 7 active members producing fish all year round to service markets in Sydney, Newcastle and the Hunter Valley. Like Marsia, all of the other co-operative members have diversified their conventional dairy or livestock farms into aquaculture.

The GNFGC operates central processing and marketing facilities in Gloucester township and has minimum orders for a set quantity of fish per week. These orders are shared between all of the farmers in the co-operative. There is a constant year-round demand for the premium quality Barrington Perch, with peaks in demand at Easter and over summer. The co-operative approach to processing and marketing increases efficiency and also allows for good quality control. Only fish which pass through the processing facility can be labelled Barrington Perch; any fish sold directly to the Sydney Fish Market or at the farm gate must be called silver perch.

GNFGC was supported in the development of its processing facilities by the local shire council who assisted with a loan for the purchase of the land and shed. The Department of State and Regional Development's establishment grant assisted with the purchase of infrastructure and the shortfall was made up by the co-operative members.

Problems

Marsia acknowledges that there is a steep learning curve associated with both diversification into pond aquaculture and the co-operative marketing system. In many ways the farmers in the Gloucester area were lucky as there were other people in the area who had already done it and could offer help, advice and guidance along the way.

Market awareness for the silver perch product is another impediment to industry growth. However, Marsia has observed an increasing demand for the quality product marketed by the co-operative over the past few years.

Vision for the Future

To be able to produce a constant supply of high quality fish to niche markets in Sydney and overseas is a prime objective of Marsia's. The farmers forming the GNFGC have created a truly effective network; such networks could be established successfully in other areas and make significant contributions in many fields.

Marsia intends to develop the on-farm integration by further developing her experimental olive plantation. She hopes that there will be a significant reduction in the need for inorganic fertiliser application to pastures as a result of effluent irrigation.

Acknowledgements/ Key References

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CASE STUDY 4: INLAND SALINE AQUACULTURE IN EVAPORATION BASINS

Ken and Anne Warren
Undera, Victoria

Background

Land salinisation occurs naturally in parts of the Murray-Darling Basin of Australia, but has been accelerated since European settlement through unsustainable land and water management practices. Land clearing and the replacement of deep-rooted native vegetation with shallow-rooted crops and pastures has resulted in a significant reduction in water use and increased quantities being added to water tables. As the groundwaters rise, naturally occurring salts are dissolved and brought to the surface where the salt is concentrated by evaporation. Both irrigation-induced and dryland salinisation are present over large areas of the Murray-Darling Basin.

In Victoria alone, the direct cost of salinity is estimated to be $50 million per year with some 140,000 ha of irrigated land and 120,000 of dryland significantly affected.

Ken Warren began to notice scalded patches (a characteristic feature of salinisation) in his paddocks around 10 years ago. At the time his 250 acre property was a conventional dairy farm which had some diversification into raspberries and blackberries. Jams and sauces produced on the farm were marketed under the brand name “Warren’s Country Produce”. In 1992, 66% of the property was classified as having a moderate or high salinity and the raspberries began to die due to the high water table. To accommodate the pasture requirements of his dairy herd and to provide more land for fruit production, Ken bought the property next door but he realised that this was only a short-term solution to his problem. In the long-term, the water table had to be lowered to rehabilitate the salinised land.

System Details

In the mid-1990’s, Ken’s salt affected land became part of a Murray Darling Basin Commission study which aimed to rehabilitate the salinised land on Ken’s property using a Serial Biological Concentration System (SBCS) (Figure 6.4). This system lowers the water table by pumping groundwater, irrigating agroforestry plots and collecting the drainage water in evaporation basins with the ultimate aim of producing salt. The project was co-ordinated by the Institute for Sustainable Irrigated Agriculture at Tatura, Victoria, which designed the system and monitored tree growth. The Marine and Freshwater Resources Institute introduced aquaculture to the evaporation ponds and carried out a number of trials using both marine and freshwater species. The experimental trials were completed in1998, but Ken has continued to operate the system since then.

At Ken’s site the agro-forestry plantation covers around 3 ha. The trees planted (*Eucalypt* sp., *Melaleuca* sp. and *Populus* sp.) were selected for their tolerance of salinity and waterlogging as well as the value of the end-product (timber and oil production). Potential gross annual returns from the site were around $500/ha and $1,200/ha for eucalyptus and melaleuca, respectively.

The aquaculture component of the project was conducted in cages within two of the four evaporation basins. The evaporation basins were 0.5 ha in size and approximately 1.5 m deep. Although a number of marine and estuarine species were trialed, Atlantic salmon and rainbow trout were found to be most successful in the winter months with silver perch and Australian bass most promising during the summer. Growth rates were similar to those found in conventional commercial enterprises.

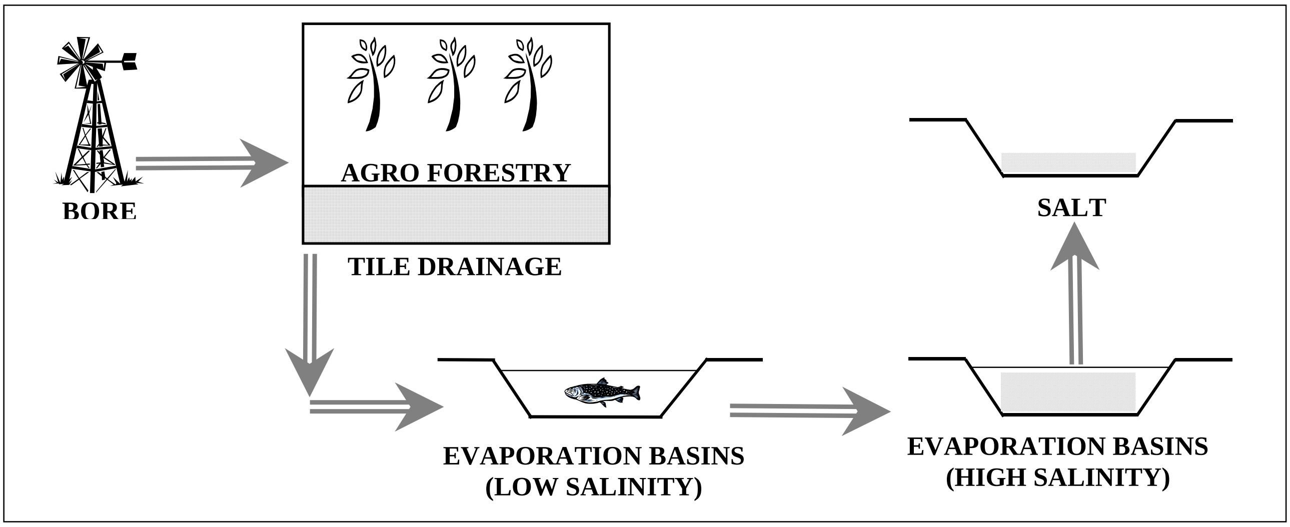

Figure 6.4. Schematic diagram of SBCS at Undera

The cages were 4.5m square with nets 0.9 m deep, providing a culture volume of 20 m^3. Under semi-intensive culture conditions, stocking densities of up to 20 kg/m^3 could be maintained in the cages. However, in a system such as Ken's, where water exchange is limited, stocking densities have to be carefully balanced with water exchange to ensure there is no accumulation of wastes in the pond waters.

During the trial 16 ML of groundwater was pumped onto the 3 ha woodlot annually at an EC of 10 dS/m (around 6ppt). The tree lots concentrate the salt by extracting water which then has an EC of 18 dS/m (12 ppt) when it reaches the first evaporation basin.

Environmental Benefits

The primary environmental benefit of inland saline aquaculture is the rehabilitation of salt-affected land. Over the period of the trial, water table levels around the groundwater pump dropped and the land around it was rehabilitated and returned to productive use. In this instance, aquaculture did not directly influence groundwater levels, however, the production of value-added products will offset the capital and operational costs of SBCS. Other forms of aquaculture which directly use groundwater may rehabilitate salinised land, however effluent disposal is an important consideration in these circumstances.

An unforseen consequence of the development of woodlots and evaporation basins on Ken's farm was the return of abundant native bird life to the property.

Marketing

Ken believes that marketing is the key to successfully integrating aquaculture into the farming operation. He believes that the fish produced on his property can be marketed locally to hotels, restaurants and fishmongers as a "niche" product for a premium price. He has carried out preliminary market research to identify the size, quantity and appearance of fish that the local market requires.

Problems

Water temperatures are a major constraint to the viability of Ken's operation. The market is looking for larger fish (up to 1 kg), but water temperatures do not stay optimal long enough to grow out either coldwater fish or warmwater fish to the required market size. Ken is currently looking at ways of extending the growing season at the site through using greenhouses and indoor tanks.

Production from the evaporation basins is finite and will have to be matched to the carrying capacity of the basins.

Vision for the Future

Saline evaporation basins for the specific purpose of managing waste saline groundwater are expected to become more common throughout the Murray-Darling Basin. These basins will predominantly be developed using local, State or Federal Government money and offer an opportunity for individuals who may wish to lease or rent areas of the pond to produce fish.

Recently, Ken's farm has shifted from primary production (dairy and fruit) into various value-added products (jam and honey) and he sees the opportunity presented by aquaculture as another stream of income to the farm. In the future, Ken doesn't believe that fish will dominate their farm income, but it will contribute a percentage alongside other ventures such as timber, tourism and fruit conserves.

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CASE STUDY 5: INTEGRATED COTTON- NATIVE FISH

Paul Mc Veigh
Dalby, Queensland

Background

Cotton is one of Australia's major agricultural industries and 80% of the crop is grown under irrigation. Over 90% of this cotton is grown in the Murray-Darling Basin, particularly along tributaries of the Darling River in northern New South Wales and southern Queensland. In 1999/2000 the growing area for cotton was 452,000 ha, with 300,000 ha in NSW and the remainder in Queensland. The Australian industry produced just over 3.2 million bales in 1999/2000 with a gross production value of $1.54 billion. Over 90% of Australian cotton is exported with an export value in excess of $1.6 billion. Average farm yield is 1,574 kg/ha.

To produce a quality cotton crop requires a considerable investment of time, energy, and money as well as water and chemicals. Cotton's average annual water requirement is 8 ML/ha, but the majority of cotton is grown in areas where rainfall and irrigation each contribute half of the crop's water requirement. Although the cotton industry is a major consumer of irrigation water, it uses less water per hectare than other crops such as rice, maize, soybeans and citrus. It also has a higher unit weight return per megalitre of water than other crops, with on average 227 kg of lint produced for every ML of water used. The industry is continually trying to improve irrigation methods to reduce water consumption.

Paul McVeigh's property is on the Condamine River, west of Dalby in the Darling Downs in south-west Queensland. The McVeigh family originally settled in the area in the 1960's, and became involved in cotton farming in the 1980's. At present 80% of Paul's farm is utilised for irrigated cotton production while the other 20% is used for grains production (sorghum, corn, wheat).

Paul first became interested in the concept of growing fish on his property after taking part in a trade delegation to Israel in 1999. The delegation, organised by the Queensland Department of Primary Industries, aimed to study examples of integrated agri-aquaculture in Israel to explore the potential for IAAS in Australia. Upon his return Paul began investigating the potential for using his existing on-farm water storage dams (known as 'ring tanks') to produce a significant quantity of fish, to improve the return on each ML of water used, and to develop new options for irrigated farms in his region.

System Details

Paul's property is around 270 ha, with 200 ha used to grow cotton and grain and 40 ha devoted to agro-forestry. The property also has a number of ring tanks alongside the Condamine River, from which it draws its water. The property is not within an established irrigation area (with the associated regulated supply) so water is harvested by pumping from the river into the first of the series of water storage ring tanks. As the first ring tank is filled the overflow passes into the next in the series until all are filled or pumping is ceased. The annual surface water allocation is 600 ML with a further 470 ML available *via* groundwater.

The growing season for the cotton is November to February, which coincides with the optimum growing conditions for the fish. The water from the ring tank used for aquaculture is further used to directly irrigate crops *via* furrows, or can be passed to other storages (Figure 6.5). The land is laser-levelled so that any water draining from the irrigation ditches is collected and drained into a tail dam. This water is the first to be used for subsequent irrigation events. No water collected from tail drains passes back into the ring tank used for aquaculture. The ring tank currently being used for fish culture is 5.5 ha in surface area and approximately 5 m deep when full. During the irrigation season, water exchange through the tanks is rapid, although water harvesting will continue if required and assuming the farm's allocation is not exceeded. This means that each tank is completely flushed at least once per year.

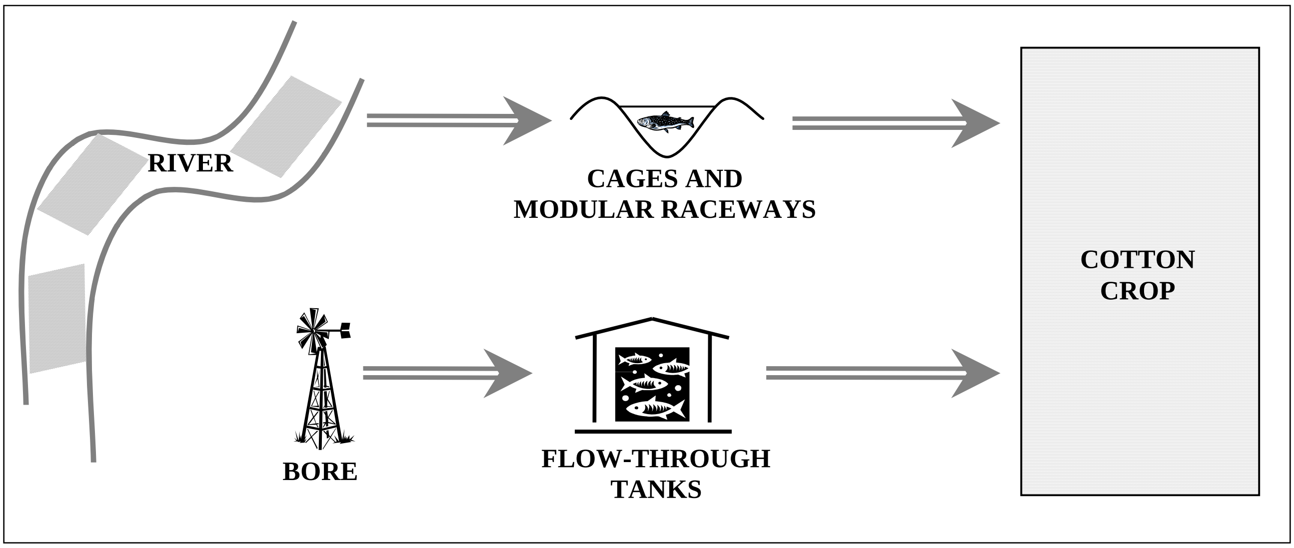

Figure 6.5. Schematic diagram of cotton-native fish integration.

Ring tank water temperatures from September to May range between 18ºC and 26ºC with an average over this period of 23ºC. In winter water temperatures reach as low as 12ºC. Dissolved oxygen levels are typically favourable although large pumping events can result in low levels of dissolved oxygen through the introduction of large volumes of highly turbid floodwaters. Despite their depth (4 to 9m), little to no stratification has been observed in these water bodies possibly as a consequence of their large surface areas and location in a region of high wind activity.

The aquaculture component of the farming system is still under development but will concentrate on the production of native fish (silver perch and Murray cod). Initial trials used floating cages within the ring tanks. This approach was taken to minimise the footprint of this activity on existing farm activities and reduce the need for further infrastructure development.

<u>Cage culture.</u> Paul initially purchased a number of small, square net cages (2m x 2m x 2m depth) and a series of larger circular floating cage units (8m diameter x 4m depth) for silver perch production. The smaller cages were stocked with silver perch fingerlings in September of 2000 and grew at a favourable rate compared to fish grown in earthen ponds. However, by late January a large pumping event increased the turbidity of the ring tank and reduced dissolved oxygen levels. Feed conversion rates and growth decreased markedly during this period. In conjunction with reduced growth performance, difficulties were experienced with the durability of the net cages and the activities of predators (birds and turtles). Bird strikes were a chronic problem as both cormorants and other water birds were attracted to the large numbers of fish. Turtles also proved a concern with dead fish attracting them to the bottom of cages where they would damage the nets while attempting to eat the dead fish. Damage to net cages by turtles resulted in a significant loss of fish through escape. Net fouling was also a significant problem with rapid algal growth necessitating regular and labour intensive net changes and cleaning.

<u>Floating Modular Plastic Raceways</u>. As a result of the difficulties experienced with the net cages Paul investigated alternative production methods. These investigations led to the development and trialing of Modular Plastic Raceways® (MPRs®) which could also be located within the ring tanks. These MPRs® possess the characteristics of land based raceways (high stocking rates, directional and rapid water flow, predator proof) while also retaining the benefits of net cages (flexibility of use, relocatable, cost effective). The raceways are still being trialed, but food conversion, stocking density, stock retention and survival have markedly improved. Predation by birds and turtles has also ceased. Productivity gains have also resulted from the use of the MPRs® as one person can easily harvest, grade or isolate and treat large numbers of fish. In comparison with cages, where disease treatment in caged fish is often labour intensive and difficult, the raceways have enabled more regular and effective treatment of winter diseases. Fish health, husbandry practices, and general fish condition have all improved upon the transfer of fish from net cages to MPRs®. The use of floating

feeds and high stocking densities have resulted in strong surface feeding responses by all species, which has made the monitoring of feeding behaviour a simple task even in highly turbid conditions.

Indoor Tank System. Inside one farm shed there is a series of six 10 tonne tanks which are used to quarantine juvenile fish upon delivery and to purge fish prior to marketing. The indoor tank system uses groundwater on a flow-through basis, although the installation of a recirculation system for purging activities is planned.

Environmental Benefits

Environmental benefits derived from integrating fish production into cotton farming include more efficient use of water and nutrients and most importantly better control and management of on-farm chemicals. The cotton industry uses a variety of pesticides and insecticides to combat pests that attack the crops. Most of these chemicals are toxic to fish even at low concentrations and so the integration of aquaculture into cotton farms requires the careful management of the timing and method of chemical application to ensure that there is no drift by aerial spraying onto the area used for aquaculture. Chemical management is vital, not only at a farm level, but Paul must also ensure that the activities of his neighbours are not going to adversely affect the fish.

The on-farm integration of aquaculture therefore requires co-operation between all farmers in an area to ensure that chemical use does not adversely affect the fish. Preliminary monitoring of ring tank water, river water and the fish themselves indicates that no contamination of the aquaculture site occurred during the first 12 months of the operation.

Marketing

Initially, Paul will market his fish locally, but recognises that market-development is an area which requires a lot of work. As a stand-alone “pioneer” of aquaculture in his region he will have to develop and service markets to sell his produce. If other farmers in the area become involved however, the scope for co-operative marketing and processing will develop.

Problems

In the first year of fish production the primary production difficulties included:

- Predation by birds and turtles on fish in net cages, resulting in injury, mortality and escape.
- Durability of net cages, which require constant changing and cleaning due to algal growth.
- High turbidity resulting from harvesting of floodwaters resulting in reduced feed efficiency and growth.
- Diseases - primarily winter disease of silver perch - were difficult to treat in net cages given the large volume of the ring tank.
- Labour required to service predator damage, disease and general maintenance issues for net cages.
- Level of training required for farm staff to successfully operate and integrate aquaculture operations.

Vision for the Future

To develop cost effective and manageable production systems which can be readily introduced to irrigation storages and which provide additional returns and opportunities for regional Australia.

The systems provide an opportunity to make better use of the water resource, and also necessitate very careful use of chemicals; both outcomes would support a stronger future for the cotton industry.

Development of this farm will require more research on system design and functionality and will include the assessment of its economic performance and impact on other traditional farming activities.

Acknowledgements/Key References

This case study was prepared with the assistance of Adrian Collins of Bribie Island Aquaculture Research Centre, DPI Queensland. Other sources of information include:

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Cotton Australia Website: www.cottonaustralia.com.au

CASE STUDY 6: BARRAMUNDI RECIRCULATION AND LETTUCE

Tailor-Made Fish Farm
Port Stephens, NSW

Introduction

Tailor-Made Fish Farm is located just outside Port Stephens near Newcastle in NSW, and was one of the first wholly commercial aquaponic ventures in Australia being designed and built as a fully integrated system. Aquaponics is the term used to describe the integration of aquaculture and hydroponics.

At Tailor-Made, the idea of integrating effluent from an aquaculture system with hydroponic production of vegetables was developed when the two key partners, Rocky de Nys (an aquaculture consultant) and Nick Arena (a builder), met by chance in 1997. After recruiting several other private investors to form a consortium of local business people, the idea began to take shape and plans were developed. The farm received its aquaculture licence in July 1998 and has now been in operation for 3.5 years. It currently has seven full time employees.

System Details

The integrated system at Tailor-Made Fish Farm consists of an intensive recirculating aquaculture system to produce fish and a hydroponic system to produce vegetables (lettuces). The total area of the farm is 17.4 ha, including an aquaculture shed (1200 m^2) and hydroponic units (0.5 acres; 0.2 ha), and the remainder of the property is devoted to pasture for livestock or crops. The components of each system will be discussed separately.

Recirculating Aquaculture System (RAS)

The growout production area of the RAS consists of 10 x 30,000 litre tanks. The system currently holds approximately 60,000 fish at various sizes, with over 800 being purged for market at any one time. Fish in the growout system are held at a maximum stocking density of 50 kg/m^3 and the system currently produces 50 tonnes of fish per annum. The main species cultured is barramundi, usually grown to a market size of between 450-500g. Some fish are grown up to 1kg for premium markets. Smaller quantities of Murray cod, jade perch and mulloway are also being trialed.

A nursery building has recently been completed containing 18 x 2,000 -3,000 litre custom designed tanks. The farm currently buys juvenile barramundi (at 30 mm) as seed stock and there is a 7 month growout to final market size (500g).

Water supply to the aquaculture system is from a bore abstracting 30,000 litres of fresh groundwater per day. Water temperature in the growout system is maintained at 25-27^oC all year round to promote optimal growth conditions for the fish. Although water is recycled using mechanical and biological filters, up to 10% of the total system volume is exchanged per day (30,000 litres). The Tailor-Made Farm differs from other recirculating systems in that the effluent from each tank is filtered individually using specially designed filters. The nutrient rich effluent from the filters is drained to three concrete tanks where it is stored prior to use in the hydroponic unit (Figure 6.6). The stored effluent is aerated which provides a consistent supply of good quality, nutrient-rich effluent to the hydroponic system. Other water taken directly from tanks with low nutrient loads is irrigated onto a 4 ha pasture and crop area.

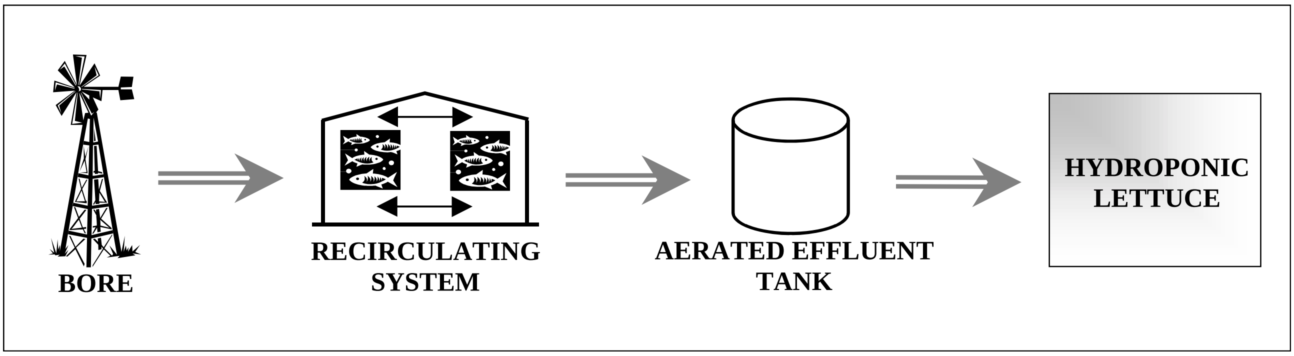

Figure 6.6. Water flow through at Tailor Made Fish Farm

Hydroponics

Effluent from the recirculation system, particularly after flushing of filters, is gravity-fed to a 5,000 or 8,000 litre hydroponic nutrient tanks, where the quality is monitored and additional nutrients added if required. Nutrient addition is regulated by an automatic monitoring unit which monitors C/F (conductivity factor) and pH. The hydroponic unit consists of 4 km of chest-height rectangular channels with holes for 22,000 lettuce heads. The lettuce has an average growth cycle of 5 weeks (6 weeks in the winter and 4 weeks in summer). Around 1800 lettuce are harvested each week for local supermarkets.

At full capacity, the lettuce use most of the aquaculture effluent - 10 lettuce plants use 1 litre of water per day (5,200 litres per day with 22,000 lettuce). Any effluent remaining is used to irrigate surrounding pastures and crops.

Environmental Benefits

Environmental benefits of the integrated aquaculture-hydroponic unit are clearly the productive utilisation of otherwise wasted resources (water and nutrients). The food fed to the fish in intensive aquaculture systems produces nutrient-rich effluent that can be difficult to dispose of in conventional systems. The use of this water for hydroponic production of lettuce value-adds the wastewater and reduces the unit cost of operating the hydroponic unit. Hydroponic production costs at the Tailor-Made Farm are 50% of similar hydroponic growers due to reduced fertiliser and water requirements.

Marketing

Tailor-Made Farms currently supply live and fresh barramundi to the Sydney and local market. Fish over 700g derive a premium price and are sold live for Asian banquets. Prices range from $11.50/kg for the live markets and $14/kg for direct sales to restaurants. Fish are not sold through wholesalers due to un-met demand. All fish are purged under a quality assurance program prior to sale to ensure a consistent and premium quality product.

Lettuce are marketed to local retail outlets in the Port Stephens area and the Hunter Valley (average price $5.50 / box of 8 lettuce). The hydroponic system at Tailor-Made Farms was designed specifically for lettuce and is not readily adaptable to the production of other vegetables. If channel sizes in the hydroponic units were more adaptable, other crops could be stocked to capitalise on niche/one-off marketing opportunities.

Problems

Major problems encountered in early years of production were predominantly aquaculture-based. Water temperatures, and consequently growth rates, would fall in the winter because the shed was not properly insulated. The shed is now fully insulated which makes temperature control easier. Supplementary heating is not required.

Salt, used to treat fish for health reasons, is a potential problem for hydroponics crops which have limited salt tolerances. This problem is avoided by Tailor-Made Farms by careful co-ordination of salt treatments on-site. The 10 tanks on-site are individually treated, which dilutes treatment concentration by 10 (10 ppt treatment = 1 ppt in effluent). This is further diluted with existing stored water.

The initial scale of development was a 30 tonne per annum aquaculture system. To achieve economies of scale, initial establishment of 60 tonnes or more annual production capacity is recommended from the outset of the development of the business.

Vision for the Future

Tailor-Made has developed aquaculture technology that is profitable, functional, easy to operate, and uses the waste stream as a resource. The vision is to be a leader in integrated aquaculture technologies by making technology and systems management available to the Australian agriculture and aquaculture industries. The company sees outstanding opportunities for the use of this technology in inland freshwater irrigation streams that exist for agriculture and horticulture. The technology simply slots into these systems as a stand-alone value-adding stream that has the benefits of year round controlled production with quality assurance. The technology also has outstanding potential in inland saline groundwater use. Advantages above pond aquaculture in inland areas include temperature-controlled year round production and value-adding to groundwater extraction schemes.

In addition, Tailor-Made plans to expand their own production to meet the high demand from markets for a product of guaranteed size and quality that can be delivered with certainty to markets that rely on consistent supply.

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www.tailormadefishfarms.com.au

CASE STUDY 7: BARRAMUNDI RECIRCULATION AND WATERCRESS

Glen And Danielle Sheehan
Kangarilla, South Australia

Background

Kangarilla is about 35 km south-east of Adelaide in picturesque rolling hills to the east of the Fleurieu Peninsula. Horticulture, cropping, grazing and viticulture dominate land-use in the Kangarilla area - indeed Kangarilla is close to the renowned McLaren Vale wine growing area.

In the early 1990's when Danielle and Glen Sheehan were looking for a business opportunity, Primary Industries SA introduced them to a promoter selling "turnkey" recirculating aquaculture systems. The business was one of four enterprises built in a custom-built aquaculture complex near the Kangarilla township. The concept behind the complex was that the promoter took care of all aspects of system development (including licensing) and the new owners had a fully operational system on delivery. The close proximity of other aquaculture facilities also meant that there was potential for co-operative processing and marketing. The Sheehans were impressed by the potential of the fish-farm and influenced by the recommendations of the SA Government Department which had financed the research phase. Their farm started operations in January 1994.

After the system was operational, Danielle became increasingly interested in using the wastewater for producing vegetables and has experimented with hydroponic production of various species. From 1996-2000, Danielle produced 1-2 tonnes of watercress per annum using recirculated wastewater from the farm.

System Details

The layout of the complex at Kangarilla is shown in Figure 6.7. Effluent from the four aquaculture production units drains to a common sedimentation tank and then through a series of storage dams before finally being used to irrigate pastures. Danielle has used water from Dam 2 to produce hydroponic crops. The components of the aquaculture and hydroponic system will be discussed separately.

Aquaculture System

The production system purchased by Glen and Danielle had a design production level of 24 tonnes per year and consists of two 120,000 litre tanks with a central biofilter in each tank. The primary species farmed is barramundi, but Danielle and Glen have also experimented with silver perch and mangrove jack.

The water supply comes from a groundwater source providing each farm with around 20,000 litres per day at a salinity of 1ppt. Juveniles are sourced from Queensland or from a local hatchery. The system is run at a temperature of 28^{o}C with stocking densities of 20-30 kg/m^3. FCRs average 1.4:1 and mortality rates are generally low (less than 10% per annum). The fish are grown to plate size (400g) or larger for the live market (> 600g).

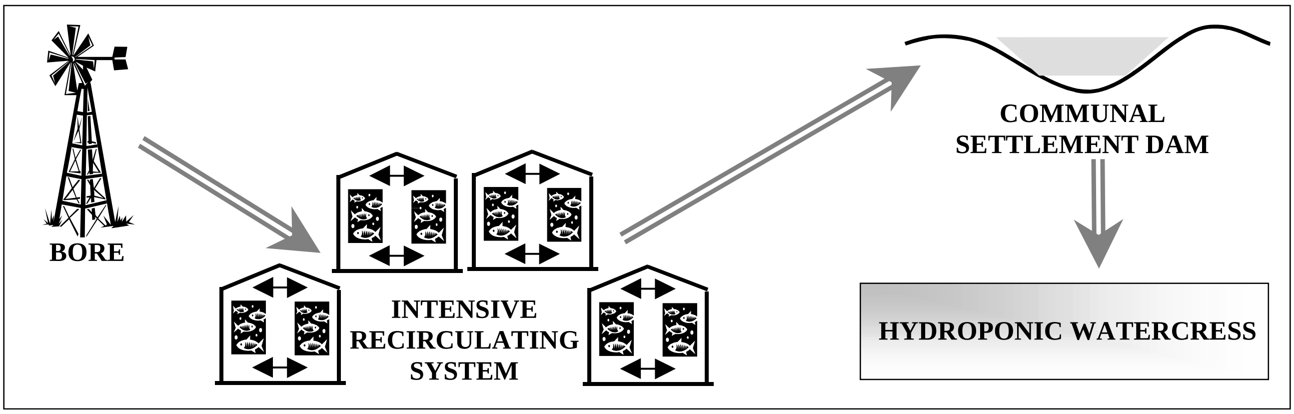

Figure 6.7. Water flow and use at Kangarilla

Hydroponics

Danielle has experimented with many vegetables in her hydroponic system over the past few years and has had varying degrees of success with water chestnuts, Asian greens, mixed lettuce and watercress.

Initially, paddies were dug for the culture of water chestnuts. Although they grew well, harvesting and grading were difficult and time-consuming. Marketing also proved to be a problem as tins of peeled water chestnuts were cheaper than the fresh product.

The starting point for the hydroponic system was to level the ground and prepare gravel beds, trenches and boxes. The total hydroponic area is 120 m^2.

The lettuce mix was more successful than the water chestnuts and sold very well locally. However, Danielle found that the channels in which the lettuce were grown were continually clogged with the wastewater. This problem could be overcome with some form of prior settlement or filtration.

The watercress started experimentally around 5 years ago and was successfully grown and marketed for 4 years. Yields were very high using the recirculated aquaculture effluent – exceeding the average yield overseas of around 80t/ha. The average time from planting to harvest was 3 weeks (2 weeks in summer and 4 weeks in the winter) with growth rates of 5-10% per day. Average production was between 1.5-2 tonnes per annum which was either packed into individual 100g punnets or sold in bulk. In November 2000, however, there was a heat wave and the whole crop went to seed in a matter of days.

Danielle estimates that 15-20 hours per week were required to harvest, pack and deliver the watercress and that income was between $1,200-1,500 per month. Casual labour costs could take up 50% of the income and Danielle required larger areas to make the venture economically viable.

Environmental Benefits

The main environmental benefit of using wastewater for the production of vegetables is the removal of nutrients from the effluent flow. Watercress in particular has a relatively high N and P content (6.7%and 0.98% respectively) which means that it removes proportionately higher amounts of N and P compared with other vegetables.

The multiple use and value adding of water is another key environmental benefit. The additional income generated by the hydroponic vegetables increases the productivity of the farm without any increase in water or external nutrient use.

Marketing

The majority of fish produced (75%) are sold live to markets in Sydney and Melbourne. The remainder is sent to the Melbourne Wholesale Fish Market chilled. Plate-size fish are sold to Adelaide wholesalers.

The watercress is cut, rinsed, sorted and packed on the premises. Around 200 punnets (100g each) per week are delivered to a network of local shops and the remainder sold in bulk to a herb farm.

Problems

Glen and Danielle would caution potential investors interested in recirculating aquaculture systems to ensure that they deal with reputable consultants before they commission them. The capital investment involved in recirculation technology often means that it is a long road (7-9 years in their case) to profitability for the small-scale operator. This is particularly true if there are operational/design flaws with the system as was the case with the system Glen and Danielle bought.

The selection of vegetables for hydroponic production should be based on a thorough understanding of the husbandry requirements of the species and also the markets available locally. A potential constraint with integrating hydroponics and aquaculture is the use of salt as a prophylactic treatment in fish farming. Most plants have restricted salt tolerances and so treatments at the fish farm must be carefully balanced to ensure that plant growth is not adversely affected.

Vision for the future

Glen and Danielle would be keen to see good advice and support available to investors in similar systems. Establishing good, appropriate systems, with appropriate species should result in a much better and quicker route to profitability. If more producers combine aquaculture and hydroponics, the quality of effluent water will be dramatically improved, and farm productivity will increase with no increase in water or nutrient costs. There is great potential for developing strong networks for co-operative processing and marketing.

CASE STUDY 8: SALINE RECIRCULATION-PLANKTON PRODUCTION

Roger Strother
MeningieWest, South Australia

Background

The town of Meningie lies on the eastern shore of Lake Albert in Coorong, South Australia, approximately 150 km south-east of Adelaide on the Princes Highway. Meningie used to be on the main transit route between Adelaide and Melbourne, but it is now a service centre for the dairy and irrigated fodder cropping industry in the area.

Roger Strother has farmed in the Meningie area for many years, producing mainly beef cattle on his 1,000 acre property which lies on the western bank of Lake Albert. A farm accident meant that Roger was no longer able to work the farm and the concurrent decline in beef prices persuaded him to consider diversification options. Roger's property has been progressively affected by salinisation attributed to the containment of water, for irrigation and private supply, by a system of barrages near the mouth of the Murray River. Diversification would ideally involve utilisation of the saline groundwater. Roger did not have to look far for inspiration as the Coorong District Council had recently set up the Bedford Groundwater Interception Scheme (funded by RIRDC) to develop ways of using saline groundwater. The project investigated the potential of polytunnel technology for the culture of finfish and algae (as a source of beta carotene).

Roger decided that aquaculture would be a suitable diversification option, but that an intensive recirculating system, producing marine finfish was more appropriate for his circumstances.

System Details

Roger commissioned a consultant to design and build his recirculating aquaculture system and a schematic diagram of the layout is shown in Figure 6.8. It includes 12 x 10,000 litre tanks contained in an insulated shed of around 300 m^2 (33m x 9.25m). The system is designed to produce around 20 tonnes of fish per annum and was completed in (month) 2000. The water from each tank is filtered individually using a biofiltration unit and a custom-built mechanical filter designed and developed by Roger.

Saline groundwater supplies the aquaculture system at a rate of 20,000-22,000 litres per day. Initial investigations indicated that the groundwater had a salinity level of 25 ppt – ideal for culture of the fish species he was considering. However, once pumping started, the salinity rose steadily to 48 ppt and required dilution with freshwater before it could be used. The freshwater supply brought additional problems as it contained solids and high iron levels which precipitated out on mixing with the saline water. A settlement tank was installed for the mixed water before it was transferred to the fish.

After these initial problems had been overcome, Roger and his partners stocked the system with 24,000 black bream. The system was run at 23-24^{o}C for optimal fish growth. The fish survived in the saline water, however growth rates were poor over the first year and Roger is now trialing mulloway and considering other marine fish options (such as whiting).

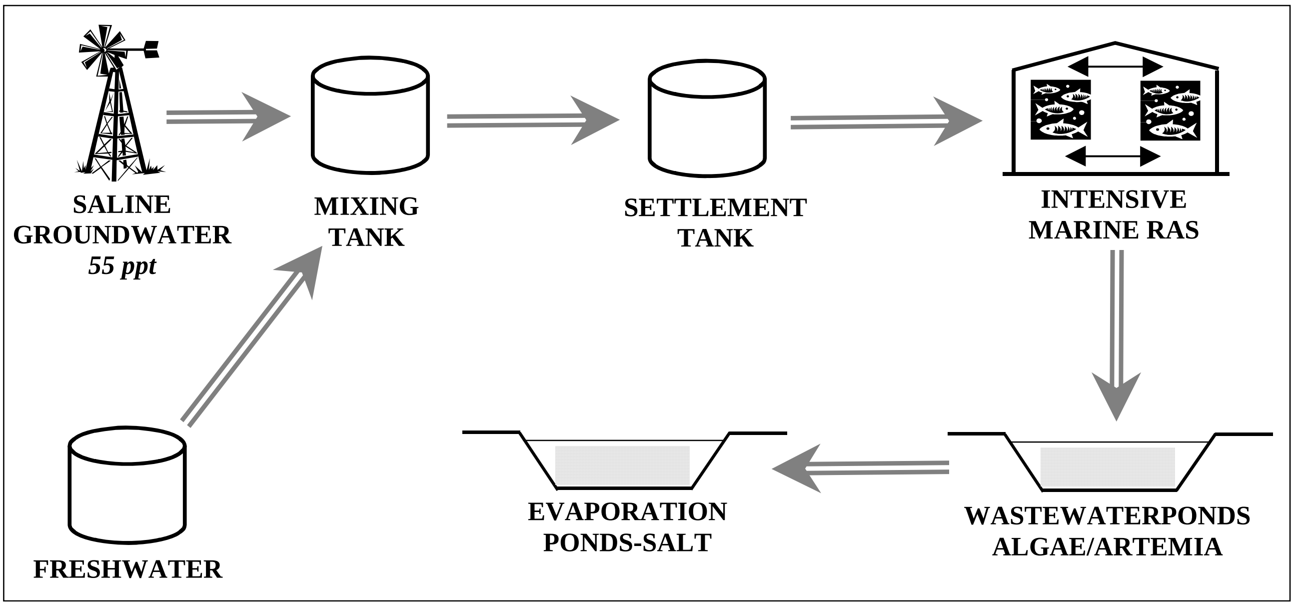

Figure 6.8: Schematic of water flow at Meningie West

Water is exchanged in the system at a rate of 10% per day and the wastewater is drained to 5 septic tanks before being discharged to fully lined wastewater ponds of 37.5 m^2 (25m x 1.5m). Roger intends to develop the wastewater ponds for the production of brine shrimp (artemia) or algae for beta carotene. After this production stage the water will be passed to evaporation ponds for salt production.

Environmental Benefits

The pumping of saline groundwater from aquifers not only provides a source of water for inland saline aquaculture, but also lowers the groundwater level around the pumping zone allowing the surrounding land to be rehabilitated. The net environmental benefits of inland saline aquaculture are two-fold with the value-adding of otherwise wasted resources and also the potential return to productivity of degraded land.

Marketing

Roger has not yet produced market-sized fish but intends to exploit local niche markets and the Adelaide market. When his production justifies it, he will then try to capitalise on interstate and overseas markets.

In the future, specialised purging or processing facilities may be needed depending on the species finally cultured.

Problems

Culture system

Roger encountered many unexpected problems in setting up his system, and as a pioneer of saline recirculation systems found good advice very hard to obtain. The high set up costs of these systems are a major constraint to further development and the lead time from project commissioning to a marketable crop can be significant.

Culture species.

Black bream were an unfortunate first choice of culture species for Roger as they grew very slowly and there are also problems with locating seedstock. In Roger's opinion, the most significant problem for the future development of inland saline aquaculture is the lack of research into the viability of marine species in saline recirculation systems. Broodstock for marine species need specialised breeding so that they grow at acceptable rates in aquaculture systems.

Vision for the Future

Roger would like to see good advice and support available to people interested in such systems, to enable them to make good decisions about appropriate systems and species. Further development of such systems in areas like his do offer great potential for keeping people (including families) on their land when circumstances change or when salinisation affects productivity. Using the saline groundwater offers a real opportunity for more farmers to improve the productivity of their property, through the rehabilitation of degraded land.

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CASE STUDY 9: INTENSIVE TROUT-WASABI

Paul Gilmore, Rubicon Mountain Pty Ltd
Thornton, Victoria

Introduction

Trout culture is the major aquaculture activity in Victoria with around 1,400-2,000 tonnes produced annually. Most of the trout are produced in intensive flow-through systems with an average water use of around 0.5-1.0 ML/tonne trout, which gives an annual volume of effluent of approximately 1,400-2,000 ML. Routinely this is returned to the river from which it is abstracted , but concerns have been raised by relevant environmental agencies and others over the level of nutrient concentrations and solids in the effluent flow, even though aquaculture effluents are fairly dilute compared with other point source effluent streams.

Wasabi (*Wasabia japonica Matsum*) is a perennial herb belonging to the same family of plants as broccoli, cabbage and mustards, the Brassicaceae. In Japan, Wasabi is grown commercially in beds of sand or gravel through which water is constantly flowing. Wasabi production in Japan has been declining over the past five years as the younger generation loses interest in continuing family traditions. Aquatic Wasabi farming space has also diminished due to urban encroachment and escalating problems with pollution and contaminants. Current Japanese production is around 5,000 tonnes (fresh weight) per annum.

Paul Gilmore of Thornton in Victoria is a green tea farming entrepreneur and horticulturist by profession, who became interested in Wasabi - primarily because of the high market price that can be obtained. Paul's research into the culture conditions required showed that Wasabi requires a constant supply of cool water with a low concentration of nutrients. Living close to the Victorian State Government's hatchery at Snobs Creek, Paul saw the opportunity to capitalise on an otherwise wasted resource by using the hatchery's trout farm effluent to grow Wasabi. He formed a joint-venture company with Ito-En (the largest green tea marketer in Japan) to investigate the opportunity.

System Details

The Wasabi production utilises effluent water from the outflow of the settlement pond of the intensive trout farm located at Snobs Creek. The trout farm produces approximately 360,000 – 400,000 juvenile (100g-200g) rainbow trout and brown trout for the Victorian government recreational fisheries program. It is operated under lease by Narangi Trout Pty Ltd, which also produces rainbow trout for ongrowing to market size (for human consumption) at Snobs Creek and on other commercial farming sites. The Victorian Snobs Creek facility uses approximately 30 ML of water per day.

The Wasabi growing system consists of two parallel beds, each 100 m long and 1.5 m wide. The beds are filled with 20mm diameter river gravel to a depth of approximately 30 cm deep. A 1m walkway separates the two gravel beds and the entire production unit is covered with a shade cloth tunnel.

Plants are located evenly along each of the growing beds at a density of 16 per m^2. The beds receive a year-round flow of nutrient enriched water, of fairly constant temperature, from the trout farm (Figure 6.9). The unit presently produces 300-350kg of Wasabi per year and uses between 2.0-2.5% of the total effluent available from the fish farm.

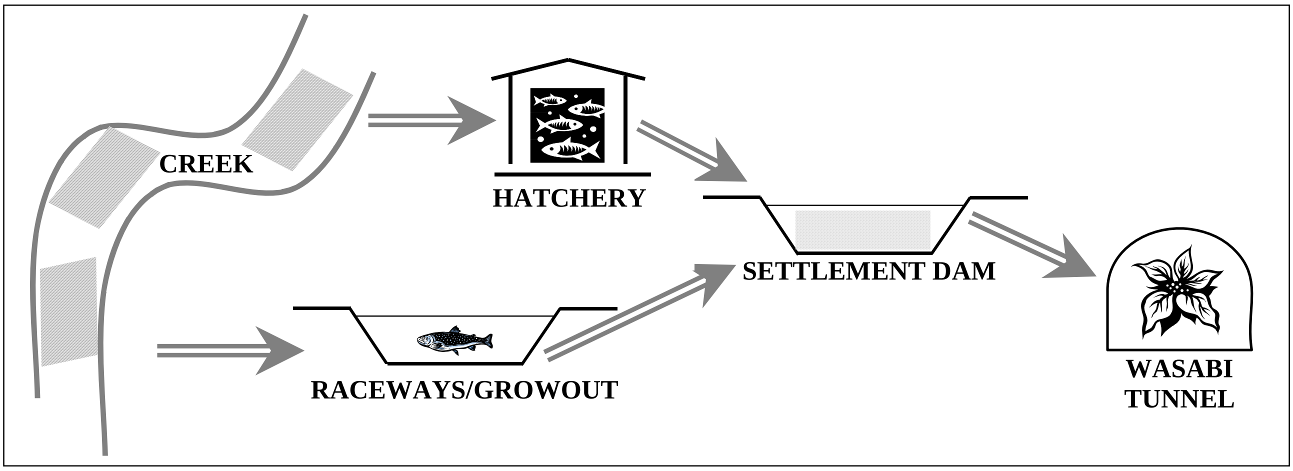

Figure 6.9: Schematic of integrated trout-wasabi culture

Environmental Benefits

High quality Wasabi grows at an even rate, which requires regular applications of small amounts of nitrogen over the growing season, such as that provided by trout farm effluent. The Wasabi removes nutrients from the effluent flow of intensive trout farms; this has the potential to improve the long-term environmental sustainability of the trout industry. Reduced nutrient levels returning to natural watercourses reduces the downstream cumulative impact of eutrophication and associated frequency of nuisance algal blooms.

Marketing

The export market for Wasabi in Japan is complex and unstable and cannot realistically be tackled without a Japanese partner. The major advantage for Australian aquatic wasabi production is the ability to supply during the off-season market in South-East Asia

Current Japanese production is around 5,000 tonnes (fresh weight) per annum. Additional opportunities also exist for import replacement in the Australian domestic market. There is a strong demand for high-quality, fresh produce by the Japanese catering and food industry. Fresh roots fetch up to $AUD100/kg on the domestic Japanese market during the colder months. This demand currently cannot be met because of the progressive contraction of traditional production sites for reasons already outlined. While there is a high demand for fresh quality stems, an important mark*et al.*so exists for processed product in the form of pastes, purees and powder. There is also a large domestic Australian market for processed and, in particular, fresh Wasabi for the restaurant trade.

Problems

In its current state the industry is too small to make a substantial impact on the Japanese or domestic market. Government support is required to realise the real market opportunity presented by this venture. A major infrastructure constraint to the large-scale uptake of Wasabi production on trout farms is the amount of land and gravel required to construct a large-scale facility. Trout farms are typically purpose-built facilities which do not readily enable retro-fitting of Wasabi plots in the effluent stream.

Vision for the Future

An aquatic Wasabi industry, if properly managed, adequately resourced and carefully developed has the potential to become a $50 million per year industry and provide 80 full-time jobs to regional and rural communities in Victoria, NSW and Tasmania (where the land based trout farming sector exists). The industry could potentially utilise some or all of the effluent produced by the trout culture industry in Victoria. There are currently 38 salmonid farms in Victoria with the potential to establish an aquatic Wasabi enterprise, either as an adjunct to their principle farming activity or as a stand-alone business unit under the management and operation of a second party.

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CASE STUDY 10: OUTBACK OCEAN PROJECT

Mark Wallace, Mount Barker, Western Australia

Background

The wheat-belt region of Western Australia extends from the Indian Ocean in the north-west to the western edge of the goldfields, to the Darling Scarp. The total area of the wheatbelt is around 155,000 km^2, which is twice the size of Tasmania. The wheatbelt region is affected by dryland salinity with approximately 1.8 million hectares (18,000 km) of farmland suffering from salinisation. This had led to reduced productivity on many traditional farms across the region with consequent economic problems at both the farm and community level. The Wheatbelt's economy has historically been based predominantly on cropping, particularly wheat which was valued at $1.1 billion in 1996/97. Other major rural industries in the area are wool production and livestock disposals, valued at $262 million and $202 million, respectively.

In recent years, the relationship between traditional annual cropping farming practices and rising salinity has been become apparent. However, there has been no reduction in the land area devoted to cropping, due to the lack of on-farm diversification options and the low prices of other commodities. Strategies to reduce the scale of cropping and ameliorate rising salinity levels must offer options for farmers to develop alternative income streams – one such option is utilising the brackish water for aquaculture. The diversification of farm income will also reduce the risks associated with the concentration of farm income in cropping.

The Outback Ocean Project was a joint initiative of Fisheries WA and Agriculture WA to assess the feasibility of aquaculture in salt affected inland waters. The project began in 1997, and by 2000 more than 200 farmers were trialing fish in their farm dams. The farmers grow out yearling trout over the winter months when water temperatures are relatively cool. The production system varies between farms, with some farmers stocking extensively and others employing semi-intensive modes of production.

Mark Wallace from Mount Barker was an enthusiastic supporter of the Outback Ocean project. Mark had experienced increasing problems with salinisation on his 440 ha property near Mount Barker in Western Australia. Dams on his property had become increasingly salty and large areas of land had become unsuitable for sheep farming which was the core business of the property. Mark currently has a flock of around 2000 sheep on his farm.

System Details

Before becoming involved in the Outback Ocean project, Mark had run several trials stocking black bream into his salty farm dams. Although the fish survived, growth was disappointing which seems to be a characteristic of this species in aquaculture systems.

Participation in the Outback Ocean project meant that Mark had to build some additional dams. He built four dams; 15 m x 30 m in area and around 1.5 m in depth, which rapidly filled with salt water from the water table. Mark then transplanted aquatic plants from his existing dams to establish habitat for the fish.

Mark generally stocks rainbow trout fingerlings at 80-100 g in May-June, when water temperature is around 17 ^{o}C. He buys fingerlings from a local hatchery in Pemberton and stocks around 150-500 fish per pond, depending on size of pond (average 300 fish per pond). Although he initially fed the fish pellets, Mark found that the fish flesh developed more colour eating the natural food in the pond, and so he reduced the amount of pellets fed.

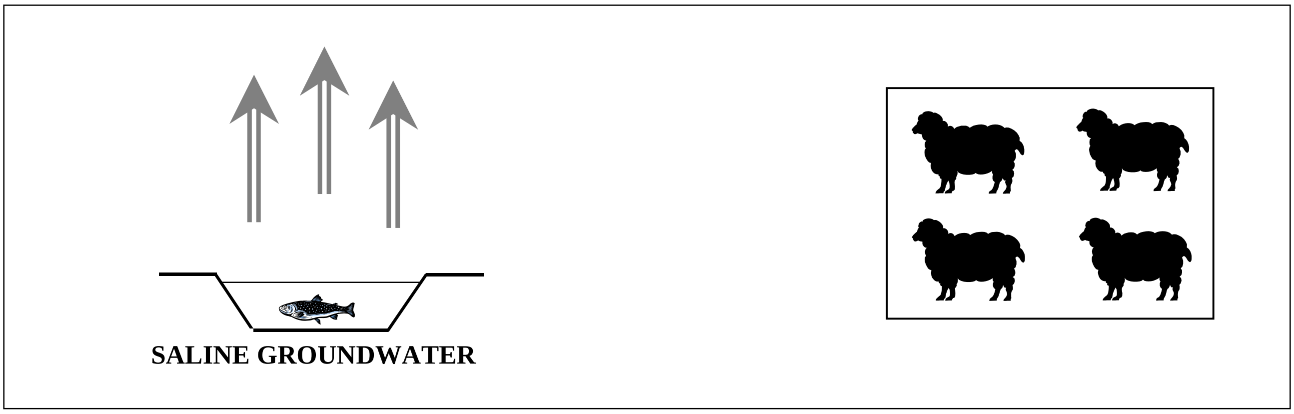

Figure 6.9: Culture of trout in saline ponds in Western Australia

Mark's production has become increasingly extensive now and relies mainly on the natural food available in farm dams. The fish are grown for around 5 months and harvested in September using gill nets and hand lines. The average size of the fish at harvest is 350g, with around 80% survival.

Environmental Benefits

The environmental benefits that stem from this form of integration are related to the productive uses of otherwise useless resources. Allowing farmers to generate income from areas of their farm affected by salinisation will give them additional scope to help them deal with the salinisation problem. Exposing more saline groundwater will also increase evaporation rates, reducing the water table.

Marketing

A local supermarket absorbs all of Mark's fish produce (around 1,000 fish per annim, 350-400 g) – and could take a lot more. One of the aims of the Outback Ocean project was to establish a network of growers who could co-operatively market their produce, making fish production viable at a regional rather than just an individual farm level. This is happening in Mark's region, but he has not joined yet.

Problems

Growth rates of the black bream initially stocked were extremely low, so Mark eventually exchanged them for the faster growing trout.

Bird predation is a big problem at Marks property, which he has tackled by buying nets to hang over his ponds. Netting is very expensive for a small scale operator, so he has decided to cover 3-4 of his 9 ponds and concentrate production in his netted ponds. This also means that he can rotate production and fallow ponds some years.

Vision for the Future

Mark is currently satisfied with the scale of his operation and the fact that he can market all of this produce, although he does not rule out further expansion in the future. Mark is interested in the possibility of culturing brook trout, but this is subject to the relevant approvals as the fish will have to be brought from inter-state.

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This case study was documented with the assistance of Jasper Trendall of WA Fisheries.

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Wheatbelt Development Corporation www.wheatbelt.net
WA Government www.commerce.wa.0gov.au

CASE STUDY 11: FRESHWATER CRAYFISH IN FARM DAMS

Pemberton Aquaculture Products, Western Australia

Background

Western Australia is the most prolific producer of freshwater crayfish in Australia. In 1998/99 it had a total production of 207.4 tonnes or yabbies (*Cherax destructor* and *Cherax albidus*) and marron (*Cherax tenuimanus*), which was equivalent to 56.5% of the total Australian of freshwater crayfish (O'Sullivan and Dobson, 2000). To break this down further, Western Australia is responsible for 85% of Australia's marron production and 69% of yabby production. It does not currently culture redclaw (*Cherax quadricarinatus*), which is endemic to the tropical north Queensland, on a commercial scale.

The development of the crayfish industry in Western Australia has been a resounding success by any standards. The WA experience can provide a template for other states in Australia to turn a "cottage" industry into a thriving aquaculture sector.

Development of the yabby industry was initially stimulated in the early 1990s by a change in legislation which licensed processors rather than individual farmers. This meant that individual farmers could stock and harvest their farm dams without the need for the red-tape involved in licensing. As a result the harvesting and stocking of yabbies in farm dams spread rapidly throughout the south-west of WA.

The marron industry, conversely, is generally based around semi-intensive purpose built ponds and individual production sites must be licensed. In both industries, crayfish are supplied by a multitude of small farmers and processed and marketed co-operatively. This case study will explore the marron industry in Pemberton, which is 350km south-east of Perth on the South West Highway. The Pemberton area is predominantly agricultural with horticultural crops such as broccoli, cauliflower and potatoes commonly grown.

System details

Marron are native to Western Australia and are one of the largest crayfish in the world. They are also farmed in South Australia and New South Wales, but are not permitted in Victoria. Marron farmers are typically small-scale, harvesting from licensed waterways (such as irrigation dams), farm dams or custom-built ponds, but the efficiency of farm dams and ponds varies considerably. Unfed farm dams can produce 100-300 kg/yr of marron. Purpose built ponds, however, can produce 1,000-4,000 kg/ha/year, depending on the stocking rate.

Ideally, semi-intensive growout ponds are 1,000 m^2 in size, with a maximum width of 20-25m. Ponds should be aligned lengthwise with the prevailing wind direction to increase aeration and cooling. The pond bottom should slope from a minimum depth of 1.5 m to a maximum depth of 1.75 m. Specifications for the design of marron ponds are detailed on the WA Fisheries website (www.wa.gov.au/westfish).

In semi-intensive systems, juvenile marron (< 1 year old) are stocked in June-July at a density of 3-5 per m^2. Most marron farmers produce their own juveniles, however, there are several commercial hatcheries. The feeding strategy is the key to determining marron production from the ponds. Commercial operators use a combination of pelleted diets and natural feeds in the pond. Marron can grow to 60-100g within 12 months and 100-300g in 24 months.

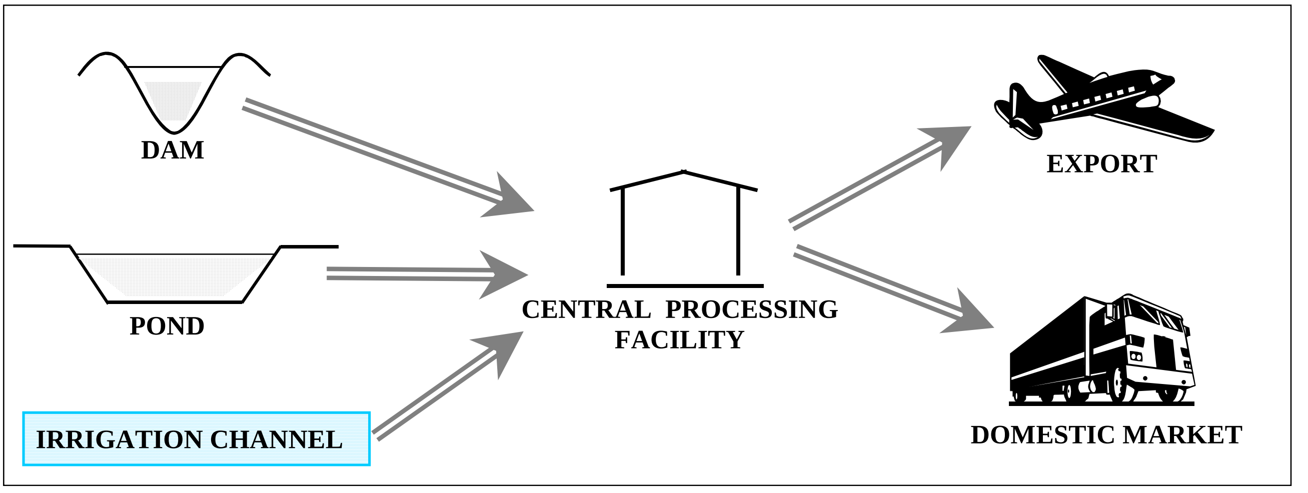

Figure 6.11: Co-operative processing and marketing of marron in Western Australia.

Marron are not as tolerant to environmental fluctuations as yabbies and the optimum growth temperature is 24^{o}C and do not grow at temperatures below 12.5^{o}C. Mortalities occur and growth declines rapidly above 30^{o}C.

Harvesting of marron is generally easier than yabbies as they do not burrow. Marron are usually harvested by draining the ponds and collecting the animals by hand, however, traps may also be used, particularly during the summer when draining the pond may stress the marron.

Marketing

Pemberton Aquaculture Products (PAP) is an example of a co-operative processing and marketing operation which collects produce from 68 farmers in the Pemberton area.

The co-operative collects, purges, markets and sells marron under the brand name of "Forest Fresh Marron". After delivery to the processing plant, PAP grade their marron according to weight and have eight size classes:

1. 100-300 g
2. 130-160 g
3. 160-200 g
4. 200-250 g
5. 250-300 g
6. 350-400 g
7. 400-500 g
8. 500-650 g

The larger size classes of marron compared with yabbies, which are generally harvested at 40-50g (up to 100g), means that marron is regarded as a luxury product and attracts higher prices than both yabbies and redclaw. After grading, the marron are placed in special purging tanks for 24 hours at a temperature of 23-24^{o}C. The purged marron are transferred to holding tanks which have been cooled to around 12^{o}C for 3-4 days, prior to dispatch. PAP has a 36 m^{2} packing room which designed and built to AQIS standards which allow the product to be packed to export-quality. The room has refridgerators which cause the marron to "shut down".

Forest Fresh Marron's main market is for 150-250g which is popular in the European market. Larger marron (> 400g) are more popular in the South East Asian market. The marron are delivered to these markets live (packed in ice) with a maximum delivery time of 24 hours to anywhere in Australia.

Environmental Issues

Farm diversification into marron culture may not have the obvious environmental benefits of other integrated agri-aquaculture systems (e.g. reduction in inorganic fertiliser use), however, the multiple use of water to provide additional farm income is a key environmental benefit.

Problems

Marron Culture

Where the marron are collected from influences the quality of the product. Marron harvested from licensed waterways tend to be larger, but not as clean or as healthy as those from purpose built ponds.

Predators are a major consideration for most commercial marron farmers. Birds in particular can do a lot of damage to stock and ariel netting over the ponds is often required to keep predators out. Fencing is also required around the perimeter of the ponds to keep water rats out and prevent the marron from walking out.

Processing Co-operative

Co-ordinating freight from the small country town of Pemberton was initially a problem for the co-operative as a number of different companies had to be used even to get the product to Perth. They have overcome this problem by delivering larger orders directly to the airport themselves.

Vision for the Future

Pemberton Aquaculture products is confident that the marron aquaculture industry has a bright future and intends to continue to capitalise on the expanding markets for marron both domestically and overseas.

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Chapter Seven

Legislative Framework for Integrated Agri-Aquaculture in Australia

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Introduction

Australia's aquaculture landscape is dominated by government legislation, policy and regulatory instruments aimed at managing sustainable industry development, whilst balancing the interests of competing natural resource users. The general lack of awareness of aquaculture within the community and across government agencies is a constraint to its broader acceptance and facilitation. As an emerging, diverse and relatively small primary sector, aquaculture frequently suffers an identity crisis.

Integrated agri-aquaculture is long established and widely practiced throughout Asia. In Australia however, it is not well understood by government, the community or investors. This inevitably leads to protracted delays in government approvals processes, excessive application information demands and ultimately a lack of investor confidence. In some cases, applicants find themselves performing the reluctant role of government educator and public relations campaigner while at the same time securing and balancing the needs of investors.

With a few notable exceptions, Australia's aquaculture regulatory framework is delivered through state based legislation. Each state government therefore invests in administration, licensing, policy development and research functions, typically through a lead fisheries agency. While statutory planning provisions that affect aquaculture have emerged from a similar historic precedent, the regulatory environment is changing as some states move to establish separate aquaculture legislation with an overriding head of power. Other states continue to deal with a multitude of approvals processes and agencies dependent on the scope and location of the aquaculture proposal.

In the last decade increasing recognition of integrated agri-aquaculture as a farm diversification opportunity has lead to the natural conclusion that aquaculture can add value to existing agricultural practices. This view has caused a convergence of government investment from those agencies facilitating agricultural farm diversification on one hand and aquaculture driven fisheries agencies on the other. This convergence is finding common ground by promoting the benefits of integrated agri-aquaculture. As a result, in the last few years policy makers have become increasingly aware of the benefits of agri-aquaculture. Some of the drivers for change include:

- The capacity of agri-aquaculture to deliver 'whole farm' water re-use efficiencies;
- The recognition of the environmental benefits of agri-aquaculture especially in saline land rehabilitation, and;
- The capacity to service growing seafood markets through reliable and efficient production systems.

Notwithstanding the dominant role of state government in managing industry development, the commonwealth government has increased their stake-hold in aquaculture, particularly through regulation of export controls and environmental legislation.

Federal legislation / influence

The federal government's impact on agri-aquaculture to date has primarily focused on research and development support through agencies such as RIRDC and FRDC. While no specific commonwealth legislation is in place to regulate agri-aquaculture, a range of federal policies has aided industry development at a strategic level.

The Aquaculture Industry Action Agenda Discussion Paper, June 2001 identified that the key objective of a regulatory framework for aquaculture was to ensure an efficient business environment. From a national (commonwealth) perspective, the discussion paper went on to identify key areas covered by commonwealth legislation including:

- Taxation
- Environmental Legislation (ESD)
- Food Safety
- Chemicals and residues
- Aquatic animal health
- Quarantine
- Trade

The *Environment Protection and Biodiversity Act (EPBC) 1999* is the commonwealth's new environmental legislation. This legislation establishes triggers where commonwealth approvals would be required for an aquaculture proposal. The key matters of national environmental significance to aquaculture development are:

- RAMSAR wetlands;
- Nationally threatened species and communities;
- Migratory species protected under international agreements,
- Commonwealth marine environment;
- World Heritage properties.

In September 2000, the federal government amended Schedule 4 of the *Wildlife Protection (Regulation of Exports and Imports) Act 1982*, to require appropriate Ecologically Sustainable Indicators (ESI?) be established prior to allowing the export trade of cultured endemic aquatic produce. State governments and industry are responding to this challenge by developing a common framework for environmental management within statutory management planning processes.

The National Aquaculture Strategy, first released in 1994, recognised the important role of government in "setting a positive policy direction aimed at overcoming constraints on the aquaculture industry and creating an environment in which aquaculture industry can capitalise on its advantages". More directly, the strategy established a goal to coordinate a government framework to support industry development. Since that time most states have moved to establish their own state-wide aquaculture strategies.

State government

State government shapes the way in which aquaculture develops through a complex array of regulations administered by agencies whose service is delivered centrally or by delegation at the regional level. The administrative, legislative and management arrangement under which the government manages aquaculture varies between each state. Table 7.1 illustrates a number of key tools each state government uses when regulating and facilitating aquaculture. Note: dedicated aquaculture- based legislation may be typically influenced by each state's respective industry presence, production and investment scale *i.e.* Tasmania and South Australia.

Table 7.1. State government regulation and facilitation impacting on agri-aquaculture

	VIC	SA	NSW	QLD	WA
Regulation					
Separate aquaculture legislation?	No	Yes	No	No	No
Catchment/regional based management?	Yes	No	Yes		
Integrated approvals process?	No	No	Yes	Yes	No
Facilitation					
Annual research & development investment in integrated agri-aquaculture ($)	$120K		$176 K inland saline		-
Extension service?	Yes	No	Yes	Yes	Yes

Appendix I provides further detail on the relevant policies, legislation and extension support in the states in which IAAS is most likely to develop (excluding Victoria, which is examined below).

Local Government

In all states and territories, legislation empowers local government to make planning schemes over land, including in some cases land covered by water *i.e.* jurisdiction extending out to sea. The objective of such planning schemes is to facilitate local authority regulation of the land use activity *e.g.* industrial, residential, rural *etc*. As some state planning provisions do not include a definition of aquaculture, there is a tendency to arbitrarily consider aquaculture under other more generic planning zone descriptors *e.g.* agriculture.

In the past, some aquaculture proponents have identified local council unfamiliarity with aquaculture as a significant barrier to development. Equally however, most local governments now employ economic development officers whose role it is to identify regionally significant industry opportunities. Integrated agri-aquaculture is increasingly short-listed as one of the key strategic development priorities. As a result there is now a tendency for closer and more productive working relations between state lead agencies and supportive local governments.

International Agreements & Conventions

The following list of international agreements and conventions may be relevant to integrated agri-aquaculture development, dependent on the proposal's proximity to the area covered by such agreements.

- Intergovernmental agreement on the environment;
- National Strategy on the Conservation of Australia's Biodiversity;
- RAMSAR Convention;
- Chinese Australian migration birds agreement (CAMBA);
- Japanese Australian migration birds agreement (JAMBA).

In some cases state government and federal government approvals processes use these agreements and obligations to trigger a higher level of environmental assessment. For example, the *EPBC Act 1999* recognises the above agreements as triggers for national environment significance.

Ministerial Council and Standing Committee

Federal, State, Territory and where appropriate, the New Zealand Government's vehicle for the development of government policy is the [1]Ministerial Council framework, including the Ministerial Council on Forestry, Fisheries and Aquaculture (MCFFA). The Ministerial Council forum is consultative only, with final decisions remaining with member governments. Reporting to each Council are the related Standing Committees representing *e.g.* Agriculture and Resource Management (SCARM) and Fisheries and Aquaculture (SCFA). The five committees formed by SCFA include:

- Research Committee;
- Aquaculture Committee;
- Environment and Health Committee;
- Compliance Committee; and
- Management Committee.

In 2000, the MCCFA agreed to establish a joint SCFA and SCARM high-level working group to facilitate integrated agri-aquaculture. This development recognises integrated agri-aquaculture as an ecologically sustainable and efficient farm diversification opportunity. Equally however, its pathway to commercialisation would benefit from the collaborative skills and expertise within Fisheries or Agriculture Government programs.

The formation of the high level working group is consistent with the *Integrated Agriculture-Aquaculture National Research & Development Plan's* objective to establish a national expertise based coordination group to oversee the Plan's implementation.

The Victorian experience

Victoria has taken a lead role in the development of integrated agri-aquaculture systems through research undertaken by the Marine and Freshwater Resources Institute in collaboration with Fisheries Victoria and:

- Rural Industries Research Development Corporation (RIRDC);
- Australasian Centre for International Agricultural Research (ACIAR);
- Murray Darling Basin Commission (MDBC);
- Dairy Research and Development Corporation (DRDC),
- Uncle Ben's Australia (UBA) and the North East Regional Water Authority (NERWA); and
- Science, Technology and Innovation Fund (DNRE).

Much of this research has been conducted on agricultural farms with the private sector.

Government Administration & Legislation

Within Victoria, the Department of Natural Resources and Environment (DNRE) has the broad objective of ensuring Victoria's natural and cultural assets are managed to secure social, environmental and economic benefits for both current and future generations. DNRE activities are overseen by three ministerial portfolios, including:

- Energy and Resources;
- Environment and Conservation; and
- Agriculture and Aboriginal Affairs.

[1] At the time of writing this paper, the structure of the SFCA and MCFFA was being reviewed with an expectation for structural reform in the near future.

DNRE service delivery is broken up into functional divisions and regions. Those Divisions that may relate to integrated agri-aquaculture include:

- Fisheries
- Parks, Flora and Fauna
- Agriculture
- Forests
- Aboriginal Affairs
- Catchment and Water
- Land

Primary legislation impacting on Victorian integrated agri-aquaculture development includes:

- *Fisheries Act 1995*
- *Environment Protection Act 1970*
- *Flora and Fauna Guarantee Act 1988*
- *Lands Act 1958*
- *Planning and Environment Act 1987*
- *Water Act 1989*

Other legislation with potential impacts on integrated agri-aquaculture development includes:

- *Heritage Act 1995*
- *Victorian Health Act 1989*
- *Livestock Disease Control Act 1958*
- *Heritage Rivers Act 1992*
- *National Parks Act 1975*
- *Reference Areas Act 1978*
- *Archaeological and Aboriginal Relics Preservation Act 1972*
- *Environmental Effects Act 1978*
- *Australian Heritage Commission Act 1975*
- *Aboriginal and Torres Strait Islands Heritage Protection Act 1984.*

In 1996, an investigation into the farming of pacific oysters in Victorian waters considered the extent of government management of the aquaculture industry. The report identified that within Victoria there were 24 separate pieces of legislation with approval powers over aquaculture development. In addition, a further five state, federal and international agreements and obligations were considered relevant. The report went on to recommend that planning approvals for aquaculture should be rationalised into one act of parliament.

The Victorian Aquaculture Strategy, released in 1998, identified seven goals and 42 actions aimed at developing a profitable, diverse, ecologically sustainable and well managed aquaculture industry. Arguably the most important policy legacy of the strategy was the recognition of the need for a "whole of government" approach to development and a risk management approach to conserve bio-diversity.

Implementing this policy driver has seen cross agency collaboration at the application assessment level, policy level and in some cases through amendments to legislation. Given the extent of legislation that can impact on aquaculture, and the large number of agencies and individual government officers involved, the need for efficient processes to manage cross agency collaboration cannot be overstated.

In the context of a coordinated and whole of government response to aquaculture development, there is often reference to the establishment of a “one stop-shop” or an “integrated approvals package”. The idea being to present a seamless face of government to aquaculture investors delivered through a single reference point or agency. The Office of Regulatory Reform (ORR) Taskforce, in their 1999 Review of the Regulatory Arrangements in the Victorian Aquaculture Industry recommended the establishment of a one-stop-shop. Under this recommendation a summary of the process would involve:

- The applicant providing the required information and state government fees and charges;
- The lead agency distributing the relevant information, fees and charges to the responsible government agencies or departments;
- The lead agency liaising with both state and local government departments and the applicant during the assessment process.

The difficulty with this model is that without legislative reform or a clearly defined head of power, there is an over reliance on the assumption that policy differences between government agencies can be resolved expediently. It also assumes that each agency has a shared vision and awareness of the nature of the industry. The outcomes of this approach inevitably see the role of the lead agency shift to provide an educative and brokerage role. Regardless of the mechanism or consultative processes undertaken, the collective outputs should:

- Identify, clarify and document the application information needs;
- Promote the criteria on which the decision making is based;
- Implement feedback management controls *e.g.* compliance auditing.

Local Government

Local government triggers for Planning Permits may include reference to infrastructure (costs or dimension), visual amenity, environmental values and other planning overlays / restrictions. The requirement to apply for a planning permit for the purposes of aquaculture raises the prospect of third party objections and, if unresolved, lengthy and costly delays associated with appeals through the Civil and Administrative Appeals Tribunals.

The ORR taskforce recommended that some forms of aquaculture *e.g.* enclosed recirculation aquaculture systems, should be recognised within state-wide planning provisions as an “as of right” activity within industrial zones. Under this arrangement a Planning Permit would not be required. This approach would reduce costs of obtaining permits, reduce approvals times and improve investment confidence. A logical extension of this rationale could see other forms of aquaculture be considered in the same way, subject to a systems based categorisation, assessment of the impacts and amendments to planning provisions.

Integrated agri-aquaculture could benefit from a review of state-wide planning schemes and improved systems based definition of aquaculture to establish relevant planning approval triggers. It would appear that in some circumstances aquaculture proposals are subject to excessive planning approvals while other more established and better defined agricultural pursuits are allowed to proceed unencumbered. This apparent inconsistency was demonstrated recently when a modest expansion of an aquaculture facility triggered a Planning Permit application, while one of Australia's largest turf farms was established across the river without local government or state government intervention.

Statutory Authorities

Catchment Management Authorities

A total of nine Catchment Management Authorities (CMAs) were created across Victoria in July 1997 to create a whole of catchment approach to natural resource management. The primary goal of each CMA is to "ensure the protection and restoration of land and water resources, the sustainable development of natural resources-based industries and the conservation of our natural and cultural heritage". The Goulburn Broken Catchment Authority, for example, has a far reaching role to:

- ensure the sustainable development of natural resource based industries;
- maintain and where possible improve the quality of land and water resources;
- conserve natural and cultural heritage;
- involve the community in decisions relating to natural resource management within their Region;
- advise on matters relating to catchment management and land protection and the condition of land and water resources in the Region;and
- promote community awareness and understanding of the importance of land and water resources, and their suitable use, conservation and rehabilitation.

One of the outcomes of the Goulburn Broken CMA to date has been the proposal to establish an annual cap of 26 tonnes per annum of phosphorus to surface waters from fish farms. In 1997, by comparison, total catchment contribution of phosphorus from agriculture (dryland and irrigation) was estimated at more than 2400 tonne annually.

The potential for agri-aquaculture to re-use nutrients and or recover costs of water use externalities such as catchment scale nutrient impacts is particularly relevant to the role of CMAs. Agri-aquaculture is currently being discussed in the context of the applicability of overseas models of tradeable emission policy for Victoria.

Water Authorities

Across Victoria 17 statutory Rural, Regional and Metropolitan Water Authorities have been established for the management of supply water for stock, domestic, and irrigation purposes and in some cases sewerage requirements.

The role and scope of service delivery by Water Authorities varies according to the location and the nature of surrounding land use activity ie. rural, horticultural, metropolitan *etc*. Water Authorities manage the allocation and delivery of water supply to rural water services under a “bulk water entitlements” licensing structure. Management of the water resource may include gravity irrigation, pumped irrigation, surface and sub surface drainage, surface and groundwater diversion, domestic and stock water supply and flood protection. In some cases water is allocated to other supply management organisations that deliver water for irrigation, domestic and stock, private diversion and urban consumption.

Water Authorities typically hold significant infrastructure including supply channels, reservoirs, pumping stations and land across regional and rural areas. These assets may offer some prospect for prospective aquaculture developments, however, access to this resource for commercial use would need to be consistent with the Authority’s management objectives and address issues of public liability.

At the time of writing this paper, Goulburn Murray Water (GMW) were in the process of developing a policy position on integrated agri-aquaculture. The draft policy supports, in principle, the development of agri-aquaculture utilising the assets under it’s control. Applications should be assessed on a case by case basis and where appropriate a licence could be issued over an initial period with indemnity, environmental monitoring and performance guarantee bonds established. Such conditions tend to reflect state-wide aquaculture licensing requirements for Crown land aquaculture.

Murray Darling Basin Commission

The Murray-Darling Basin Commission is the executive arm of the Murray-Darling Basin Ministerial Council. It's broad terms of reference include the management of the River Murray and the Menindee Lakes system of the lower Darling River, and advising the Ministerial Council on matters related to the use of the water, land and other environmental resources of the Murray-Darling Basin. More specifically, the Commission is required to:

- advise the Ministerial Council in relation to the planning, development and management of the Basin's natural resources;
- assist Council in developing measures for the equitable, efficient and sustainable use of the Basin's natural resources; and
- coordinate the implementation of, or where directed by Council to implement, those measures; and give effect to any policy or decision of the Ministerial Council.

Summary

The breadth of integrated agri-aquaculture activity (species, systems, locations *etc*.) poses a regulation and facilitation challenge for private and public sectors alike. In dealing with the resource management implications of agri-aquaculture an investor faces a host of government agencies administering an array of legislation, any one of which could potentially stop development in it's tracks. Add to this a layer of local government, statutory bodies and other agencies and the scene is potentially set for a highly regulated environment. Victoria's case study revealed more than 50 local government Shires, 17 Water Authorities, nine Catchment Management Authorities and 16 relevant pieces of legislation administered by at least seven state government agencies. Inconsistencies in assessing development applications also arise from administrative staff's limited recognition and awareness of the industry. A summary of the types of approval which may be required to develop an IAAS venture in Victoria is shown in Table 7.2.

Table 7.2: Summary of approvals which may be required for a land-use change to aquaculture in Victoria

Activity	Approval Required	Contact Authority
Aquaculture		
Growing fish for sale	Aquaculture Licence	Fisheries Victoria
Vegetation		
Removal of native vegetation	Planning Permit	Council/ Shire(or: Local government)
Animals		
Taking/destroying native animals on Crown land	Permit/Advice	DNRE
Land		
Earthworks	Planning Permit or Certified Whole of Farm Plan	Council/ Shire
Disposal of solid wastes	Licence/ Advice	EPA/ DNRE/ Council/ Shire
Water		
Earthworks	Planning Permit or Certified Whole of Farm Plan	Council/ Shire
Abstracting water	Licence	Water Authority
Bore construction and abstraction	Licence	Water Authority
Undertaking works on Crown land stream frontages	Licence and approval	DNRE/CMA
Disposal of drainage/ runoff	Licence/Permit or advice	Council/Shire/CMA/ Water Authority

As a new kid on the block, the emerging aquaculture industry faces this regulatory challenge to a greater extent than long-established agricultural farming practices. If the full external costs of environmental management are factored into the equation, well managed integrated agri-aquaculture is more likely to improve ecologically sustainability than compromise it, when compared to some more traditional intensive agricultural practices.

In many cases, the triggers for government regulation are environmentally based, particularly where development impacts extend beyond the boundaries of freehold land or are close to areas of high conservation value. Conversely, appropriately located and designed integrated agri-aquaculture systems can contribute toward positive environmental outcomes *i.e.* rehabilitation of salt affected areas by saline groundwater extraction and more efficient use of increasingly valuable water resources. It is in response to these opportunities that governments are increasingly investing in research and development in integrated agri-aquaculture.

The Victorian aquaculture experience highlights, through applied research, that existing farm based natural resources, combined with typical farming infrastructure can provide a basis for diversification into aquaculture. In the absence of appropriate business investment disciplines, this next step however may prove to be a leap of faith.

In some cases poorly planned agri-aquaculture has compromised investor confidence, through:

- the proliferation of unreliable small scale aquaculture production systems;
- the tendency for a production rather than market driven approach to investment;
- limited availability of technical, husbandry and water quality management skills;
- recognition of suitable aquaculture species.

Integrated agri-aquaculture presents an opportunity to reflect on current agriculture farming practices and to investigate the benefits of multiple water use, product diversification and skills development. In some cases this will require a paradigm shift as farmers move away from single-use conventions to squeeze more value out their existing natural and man-made assets. The role of government in this field remains central. The national campaign to tackle agri-aquaculture through the high level working group of the Standing Committee is a positive step, building the formative research and moving toward private sector ownership through commercialisation.

To combat the complex array of government legislation, policy and administrative processes, the prospective agri-aquaculture investor will need to plan carefully, advocate sustainable practices and be patient. Despite what might appear to be a difficult development path, the agri-aquaculture opportunity is well placed to deliver substantial regional growth through farm diversification.

APPENDIX I

Policies, Legislation and Support in Other Key States

NSW

NSW	NSW has actively embraced IAAS systems and developed specific strategies and policies to encourage sustainable aquaculture, simplify the development approval process and provide support & extension. The NSW State Government is committed to aquaculture industry development along best practice principles for environmental protection and ecologically sustainable development.

NSW Fisheries is responsible for industry development, delivering the Aquaculture Strategy, assessment and approval of proposals, monitoring and extension. Other organisations involved in natural resource management, environmental regulation and primary industries include the Department of Urban Affairs & Planning, Department of State & Regional Development, EPA, Department of Land & Water Conservation, National Parks & Wildlife Service and NSW Agriculture. The NSW government is committed to a whole of government approach on aquaculture decisions.

NSW has two regional Aquaculture Strategies (North Coast, and Hunter and Central Coast Aquaculture Strategies) for land-based aquaculture. The EPA also administers the State Environmental Planning Policy No 62 (SEPP) – Sustainable Aquaculture. There are 13 Acts or Regulations which may be relevant to aquaculture developments (eg. *Fisheries Management Act, 1994; Environmental Planning and Assessment Regulation, 1994; Rivers and Foreshores Improvement Act, 1948; Soil Conservation Act, 1938* and *Pesticide Act.*). Investors should approach NSW Fisheries as their initial contact and study the relevant Aquaculture Strategy for their region.

The regional Aquaculture Strategies assist investors and planners to prepare and submit appropriate development applications, assist regulatory agencies to assess proposals, and facilitate an integrated approvals process. A ‘Project Profile Analysis’ has been developed to provide an assessment of the likely level of environmental risk from a proposal, and streamline the approvals process. Lower level risk proposals only require a Statement of Environmental Effect to demonstrate that they will comply with best practice. Higher risk developments require an Environmental Impact Statement (EIS). The Strategy provides a framework for linking the technical provisions of the Aquaculture Industry Development Plan (AIDP; from the *Fisheries Management Act*) and the land use planning and environmental regulatory provisions of the *Environmental Planning and Assessment Act.*

The Aquaculture Strategies actively recommend IAAS, suggesting that, in some areas, relationships may be able to be established with nearby agriculture, hydroponic, or other users to ensure efficient use of water resources following aquaculture use.

QUEENSLAND

QUEENSLAND	The Queensland State Government is committed to "Triple Bottom Line" sustainable development; ecological, economic and social. It is on this basis that the State Government supports the development of IAAS within Queensland.

The Department of Primary Industries (**Queensland Fisheries Service**) is the lead agency for aquaculture development and administers the *Fisheries Act, 1994.* The DPI is committed to streamlining assessment & approval processes. Other government organisations involved in natural resource management, environmental regulation and primary industries include the EPA and the Department of State Development (DSD). The EPA ensures a safe and ecologically sustainable environment through the protection and restoration of air, land & water quality, and the control of unwanted noise. The DSD has the lead role in promoting a whole of government approach to accelerating aquaculture in Queensland. It also leads an Inter Departmental Committee, including all stakeholder agencies, to minimise impediments to aquaculture development and maximise support and services for significant new developments.

There is a Queensland Aquaculture Development Strategy (1997) and regional Aquaculture Development Plans are under consideration. Other relevant policies concern sustainable rural development, groundwater resources and water quality.

Fifteen Acts cover issues of relevance to aquaculture. The *Fisheries Act, 1994*, for example, concerns licensing aquaculture activities and regulating licensed activity. It supports the development of the aquaculture industry. The *Integrated Planning Act, 1997*, allows the granting of leases (max 21 years) over unreserved Crown Land for industrial, commercial, agricultural and other purposes. It also gives local government the lead role in invoking a package of licence requirements for aquaculture development. The *Environment Protection Act, 1994* covers licensing of Works Approvals and Discharge, required before wastes can be discharged. Other Acts which may be relevant include the *Murray-Darling Basin Act, 1996*; the *Nature Conservation Act, 1992*; the *Native Title (Queensland) Act, 1993* and the *Rural Lands Protection Act, 1985.*

The Queensland government does see a need for further policy development for the development of IAAS, addressing issues such as market establishment, extension to agricultural communities, national co-ordination of R&D and market development, national identification through trademarks, new species development and consistency in multiple water use.

SOUTH AUSTRALIA

SOUTH AUSTRALIA	The South Australian Government is positively disposed to IAAS, but does not actively promote it. South Australia does not have any large scale irrigation networks so there may not be the same scope as in other states.

PIRSA, including Aquaculture SA and Fisheries SA, is the lead agency for aquaculture development. Aquaculture licences are assessed by Aquaculture South Australia for technical merit, compliance with Fisheries Act and sustainability issues. Licenses are granted by Fisheries SA. Other government organisations involved in natural resource management, environmental regulation and primary industries include the Department of Environment and Heritage (including the EPA), the Development Assessment Commission (DAC), and local government.

PIRSA has developed an Inland Aquaculture Development Strategy and a SA Translocation Policy and, with the Regional Development Boards, is undertaking a Scoping Study for Inland IAAS. Other relevant government policies concern salinity, catchment management, food safety and water quality.

For IAAS to develop, further policy development would need to address cage culture (very little information is available in South Australia), irrigation of aquaculture effluent onto crops (especially with respect to nutrient loadings), and quality and quantity of effluent (especially in relation to soil and crop types).

Fourteen Acts cover issues relevant to aquaculture development. A specific *Aquaculture Act* is in preparation. Existing Acts include the *Fisheries Act, 1982*, which ensures sustainable development of aquatic resources, the *Environment Protection Act, 1993*, for protection of the environment and promoting principles of ESD (ecologically sustainable development), and the *Development Act, 1993* (administered by the DAC for marine sites and Local Government inland). Other Acts which may have relevance include the *Water Resources Act, 1997*; the *Environment Resources And Development Act, 1993* and the *Aboriginal Heritage Act, 1988*.

WESTERN AUSTRALIA

WESTERN AUSTRALIA	The Western Australian State Government is committed to Ecologically Sustainable Development. It is on this basis that the State government encourages the development of IAAS within Western Australia.

The Department of Fisheries is the lead agency for aquaculture development; it administers the *Fish Resources and Management Act, 1994* plus licensing and control of aquaculture activities. It is responsible for aquaculture planning in WA (www.wa.gov.au/westfish/aqua/broc/plan/index.html) and has developed two regional plans; the Gascoyne Regional Aquaculture Development Plan (www.wa.gov.au/westfish/aqua/broc/devplan/gassum.html) and the Kimberley Regional Aquaculture Development Plan (www.wa.gov.au/westfish/aqua/broc/devplan/kimsum.html). The EPA ensures a safe and ecologically sustainable environment through the protection and restoration of air, land and water quality, and the control of unwanted noise. The Ministry of Planning has the responsibility for leading strategic planning, integration, development and management of public transport, roads, ports, land-use planning, heritage, building and local governance. The flow chart below indicates the connections and responsibilities of the various government organisations.

Other relevant government policies concern aquaculture and recreational stock enhancement of non-endemic species in Western Australia, new industries, trade and market development, sustainable rural development (salinity sub-program), integrated land use planning, water resources, environmental health and water quality. There are no specific IAAS policies.

Sixteen Acts cover issues relevant to aquaculture. They include the *Fisheries Resource Management Act, 1994* and the *Fisheries Resource Management Regulations, 1995*, which cover licensing of aquaculture activities & regulation of licensed activity. The *Lands Administration Act, 1997* grants leases (max 21 years) over unreserved Crown Land for industrial, commercial, agricultural and other purposes. The *Environment Protection Act, 1986* concerns Licensing of Works Approvals and Discharge, required before wastes can be discharged. Other relevant Acts include the *Town Planning and Development Act, 1928; Water & Rivers Act, 1995; Water & Rivers Act, 1995; Local Government Water Supply Preservation Act, 1892;* and the *Soil and Land Conservation Act, 1945*

Chapter Eight

Economic Analysis of the Australian IAAS Opportunity

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Introduction

Irrigated agriculture, with a gross value of AUD$7.25 billion pa, is the largest net user of water in Australia, totalling 15.5 million ML pa (or approximately 70% of total annual consumption). During the period 1993/94 to 1996/97 total net water consumption rose by 19% in Australia, with over 95% of this increase being accounted for by the irrigated agriculture sector. Pastures cover the largest area of irrigated land, accounting for approximately 935,000 hectares or 45% of total irrigated area in Australia. This pasture is predominantly used for livestock production, with 46% of the irrigation water being self extracted (ABS 2000).

Efficient water use is becoming increasingly important for irrigated industries within Australia. Limited availability of water, rising costs and environmental issues such as salinity, nutrient runoff, and erosion have raised the need for improving water-use efficiency. In the past some irrigation industries have been able to use their water resource more effectively than others by adopting more efficient processes and technologies (farming systems, irrigation techniques *etc*), subsequently realising more profitable returns per ML of water used. Most sectors, however, have been unable to effectively gain "more for their megalitre". These imperatives have led to investigation of the concept of Integrated Agri-Aquaculture Systems (IAAS) and how it could provide traditional irrigators with a greater economic return on their water usage and still meet overarching environmental sustainability criteria (Gooley 2000).

With such large quantities of irrigation water being held in storage in Australia at any one time, ostensibly for single purpose/use, water is considered to be a significantly under-valued and under-utilised resource. Through providing a growing medium for aquatic species, this resource may be used for the purpose of aquaculture prior to, and/or during its customary irrigation use. In doing so extra nutrients in the form of phosphorous and nitrogen are also introduced into the irrigation network from feeds and fish waste, effectively reducing fertiliser costs for irrigators. Such a scenario assumes that these nutrient streams can be retained on, and directed to, private lands to enhance soil productivity, although this will benefit some sectors more than others. Either way, through investigating respective nutrient budgets and associated costs, the positive economic impact that aquaculture can potentially have on 'whole farm' budgets of irrigators within Australia will become clearer.

In the absence of any commercial scale IAAS case studies and any validated IAAS economic performance data at this early stage of the Australian industry development, preliminary analyses must be solely of a conceptual nature. More specifically, they must be based on a combination of intelligent assumptions drawn from R&D experience and industry sources, as well as what little real data can be extracted from existing stand-alone aquaculture and agriculture production systems.

This paper seeks to analyse the economic merits of integrating Australian agriculture and aquaculture farming systems within such a conceptual framework. It is also intended that this analysis provide some broad and relative, but quantifiable measure of the potential outcomes and associated flow of benefits to key stakeholders/investors in IAAS. Effectively, the information provided here is intended to be used only as an initial guide in order to determine indicative benchmark financial parameters for native finfish production in pond/cage and tank/recirculation-based IAAS options.

The analysis identifies key irrigated agriculture sectors, characterises key production aspects (with an emphasis on land, water and fertiliser usage), and uses linked estimates of Gross Margins (GM) to compare economic viability for each sector. Hypothetical IAAS operations based on tank and cage culture designs are then economically evaluated under a range of operational production scenarios to estimate comparable Gross Margins. A similar approach to the use of GM for economic analysis of integrated cage aquaculture in public irrigation storages in the Goulburn-Murray Irrigation District of Victoria, has been described by Gooley *et al.* (2001a).

Irrigation Sector Land and Water Use, Techniques and Costs

Table 8.1 outlines the irrigation techniques used by the various agricultural sectors within Australia, the average cost of water per ML, and the irrigation rate (ML/ha). The unit cost of water varies considerably between irrigation sectors, with horticulture (predominantly fruit) and viticulture (*e.g.* Loddon Murray Region, Victoria) paying over 4 times more for water than cotton farming ventures in NSW.

Table 8.1: Irrigation techniques and water costs by sector/region.

Agricultural Sector	Irrigation techniques	Cost of water ($/ML)	Data source (see Appendix)
Dairy	Flood	$21.10	Northern Victoria and Southern NSW
Hort – Stonefruit	Trickle	$54.00	Loddon Murray, Victoria
Hort – Vegetables	Trickle	$20.00	NSW
Viticulture	Trickle	$54.00	Loddon Murray, Victoria
Rice	Flood	$15.15	Southern NSW (Murray)
Cotton	Furrow	$12.44	Murrumbidgee Irrigation District, NSW

Table 8.2 summarises the consumption of water for the average farm size on a sectoral basis. Of the six existing Australian irrigation sectors considered in this paper, the rice sector consumes the most water per hectare (10.8 ML), with each average farm consuming over 3,000 ML pa. The viticulture sector is the next highest water user on a per ha basis, but the farm sizes are considerably smaller so overall average farm consumption is much less in real terms.

Table 8.2: Land and water use by sector.

Agricultural Sector	Land use (ha) Irrigated	Water Use (ML)	ML per ha	Average farm area (ha)	ML Per Farm	Data source
Dairy	241,650	1,884,870	7.8	75	585	Armstrong, 1998
Horticulture (Veg)	88,782	634,913	7.2	10	72	NSW Govt.
Horticulture (Fruit)	82,316	703,878	8.5	10	85	ABS, 2000
Rice	152,367	1,643,306	10.8	300	3,240	ABS, 2000
Cotton	314,957	1,840,624	5.8	400	2,320	ABS, 2000
Viticulture	70,248	648,574	9.2	18	167	ABS, 2000

Sectoral Gross Margins

Gross Margins are defined as the gross income ($) derived from the farming enterprise minus the variable ($) costs (those costs that are dependent on the output or size of the farm). Usually the margin is expressed in relation to the most limiting resource *e.g.* land area (ha) and water (ML). Gross Margins used in the present study are summarised on a sectoral basis in Table 8.3.

Table 8.3: Gross margins by agricultural sector.

Agricultural Sector	Gross Margin ($) per ha	Gross Margin ($) per ML	Data sources
Dairy	1,435	184	
Horticulture (Veg) [1]	3,825	630	NSW Agriculture (average tomatoes, potatoes, capsicum, Carrots, Onions, Asparagus, Broccoli and Zucchini)
Horticulture (Fruit) [2]	13,237	1,927	Downs (1999)
Rice [3]	1,192	92	NSW Agriculture.
Cotton [3]	1,738	238	NSW Agriculture.
Viticulture [4]	14,010	2,802	Downs (1999)

Sectoral Fertiliser Usage

Fertiliser usage varies from sector to sector. Table 8.4 below outlines the usage of fertiliser type by ha.

Table 8.4: Fertiliser usage per sector

Agricultural Sector	Fertiliser Type	Nutrient content (N:P:K:S:Zn)	Application (Kg/ha/P)	Kg of P per tonne of fertiliser	$ Cost per tonne of fertiliser
Dairy	Single Super	(0:9:0:11:0)	65	90	210
Horticulture – Veg	Double Super	(0:17:0:4:0)	125	170	450
Horticulture – Fruit	Double Super	(0:17:0:4:0)	125	170	450
Rice	Single Super	(0:9:0:11:0)	125	90	210
Cotton	M.A.P	(10:22:0:1:0)	120	220	440
Viticulture	Triple super	(0:20:0:1:0)	100	200	500

Integrated Agri-Aquaculture System Options

Various IAAS design options are likely to be suitable for development and adaptation to Australian farms. Many of these are based largely on overseas experience and/or are simple variations on existing stand-alone aquaculture systems here in Australia. Typically, these systems are also sufficiently versatile to accommodate one or more culture species. A brief summary and general description of system and species options for Australian IAAS applications is provided in Chapter 5 of this Handbook.

As previously mentioned, for demonstration purposes this paper undertakes an analysis of two hypothetical IAAS applications, *viz.* intensive, tank/recirculation and semi-intensive, cage/pond-based systems, each capable of producing a variety of native finfish species such as Murray cod, barramundi, silver perch under specific operational conditions.

The physical scale and production capacity of the IAAS systems are limited to that which can be reasonably considered to be a practical means of farm diversification *i.e.* an adjunct to, not a replacement for, existing sources of farm income *via* traditional irrigated crops and pasture. It is intended for the purposes of this analysis that such a form of diversification can be readily accommodated into the daily, operational routine of the farm without the need to incur significant extra capital or staffing costs.

The ‘demonstration’ species that will be used to construct production scenarios for these two aquaculture systems in this paper is Murray cod, *Maccullochelli peelli peelli*, which is becoming a popular species for aquaculture in south-eastern Australia (Ingram 2000). Commercial Murray cod stocking densities under intensive conditions have been reported at over 100kg/m^3, with little mortality and a grow out period to plate size (500-1000gms) in as little as 10 months for some fish. Trials are now underway to determine suitability of Murray cod for cage culture. More details on the aquaculture performance criteria for Murray cod are provided in Appendix III of this Handbook.

Intensive Tank-Based Recirculation Aquaculture Systems

High-density (intensive), tank-based recirculation aquaculture systems (RAS) consist of relatively new technology with a wide variation in system design and performance. Not surprisingly, RAS are receiving increasing interest in stand-alone, intensive fish culture operations in Australia as technological advances in closed systems technology indicate commercial potential for small-medium scale ventures within regional and peri-urban areas of Australia. Through the effective management of key production parameters, RAS technology may offer relative independence from the external environment and can be readily integrated into many existing irrigation farming systems.

Before considering their role in IAAS however, some characteristics of RAS need to be considered in more detail. In broad terms RAS offer several advantages to the aquaculture producer, including:

- water and heat conservation,
- environmental control,
- biosecurity and disease control,
- stock management,
- site flexibility,
- increased stocking density.

Recirculation systems are extremely efficient water users with limited effluent in which nutrient wastes are highly concentrated at a controlled, point source *i.e.* negligible environmental impact. Moreover, the nutrient rich effluent can be used as fertiliser, which offers an added benefit to the diversified farmer. Irrigation water can be used twice, with aquaculture getting first use, and can be enhanced on the way with high quality nutrients for subsequent plant production. A more detailed description of RAS is provided in Chapter 5 of this Handbook.

One of the greatest problems associated with this technology is that many technical solutions to RAS operational problems proposed by industry may not be *economically* viable. Indeed as RAS producers intensify their aquacultural activities, the margin for management error becomes more acute as the more intense ‘bio feedbacks’ occur. Clearly there is an inevitable link between higher fish stocking densities in RAS, necessary to cover the attendant higher fixed and variable costs associated with RAS as compared to other more traditional semi-intensive and extensive aquaculture systems, and increased risk of operational error. This further suggests that economic success in RAS operation and integration with other farming systems is more elusive perhaps than is often first apparent.

Typically more than 90% of the water in a RAS at any one time is passed through a series of special biological and mechanical filters for re-use in the system. Only a fraction of the water in the system (10% of the total capacity of the RAS or less per day) is actually being ‘consumed’. For this reason the efficacy of the biological filtration capacity of the RAS, which removes toxic nitrogenous waste compounds from the re-use water, is critical to the viability of the operation.

Semi-intensive, Cage-Based Pond Aquaculture System

The development of semi-intensive, cage-based aquaculture systems using existing irrigation infrastructure such as on-farm storage ponds has the major benefit of lowering up front capital costs. This is because such systems are inherently versatile in that they can invariably be retrofitted to most locations where suitable water storages and associated support infrastructure (*e.g.* water reticulation, power *etc*) already exist.

Typically, minimal capital outlay and relatively simple operational technologies are required, with the overall scale of the operation being easily changed to suit prevailing circumstances on the farm. Furthermore, cage culture systems can be adapted to a range of water storage pond types, subject to the choice of suitable culture species. Storages could include everything from fresh to saline (*e.g.* evaporation basin) water, surface to groundwater, and nutrient poor (*e.g.* first use irrigation water) to nutrient rich (waste) water. Cages and attendant support infrastructure such as walkways and aerators can also be readily and cost-effectively constructed on-farm and/or purchased locally.

Although still subject to ambient environmental conditions, cage culture enables a higher level of control over key production parameters (feeding, grading, harvesting, predator control, fish health, water quality *etc*), than compared with extensive, free-range pond culture systems. There are however spatial limits, in turn linked to critical, minimum water quality requirements that dictate the sustainable levels of cage culture production in ponds.

A more detailed description of cage-based pond aquaculture systems is summarised in Chapter 5 of this Handbook.

IAAS Fish Production Gross Margins

In this paper, the Gross Margins generated by the selected IAAS fish production options, *viz*.:

(i) Intensive, tank-based recirculation system in a controlled environment, and
(ii) Semi-intensive, cage-based pond system under ambient environmental conditions,

are estimated using a modified version of the proprietary software package *AQUAFarmer* (DNRE 1999). *AQUAFarmer* is a package which develops aquaculture farm scenarios and produces a comprehensive series of feasibility accounts and indicators over a ten year period.

For each system a number of assumptions are made about levels and costs of key production and market parameters. Fish growth curves for each system have been constructed from a combination of existing (stand-alone), commercial data and experimental scale data, and standardised at approximate median values to be moderately conservative. Each scenario assumes no additional labour costs on the assumption that existing farm staff can undertake all routine operational tasks. The capacity of each of the chosen IAAS operations to support extra labour costs can be gauged from projections of the annual earnings generated (defined as Earnings before Interest, Tax and Depreciation or EBITD).

Internal rate of Return (IRR) is used as the key financial performance indicator and is calculated on three risk scenarios. Risk scenario ‘0’ accounts for no risk, and risk scenarios ‘1 and 2’ show a learning curve in the first years, and a one in ten year stock loss of 80% due to disease occurring in year five. The risk scenarios are summarised as follows:

- **Risk 0**: Optimum harvest with no risk (any stock loss is insured)
- **Risk 1**: 75% production in year 1 and 20% production in year 5.
- **Risk 2**: 65% production in year 1, 75% production in year 2 and 20% production in year 5.

Intensive (tank-based) IAAS

Three intensive, tank-based IAAS production scenarios have been constructed for this evaluation, being 5, 10 and 25 tonne (of marketable fish) pa, where annual production tonnages represent an approximate average over 10 years. Each of the systems will have no extra labour costs (feeding, monitoring, harvesting, processing *etc*) imposed or water costs as these are considered already part of the farm enterprise. The analyses for each of the three systems make the following additional capital and operational/variable costing assumptions:

- Purpose built insulated shed: 5 tonne @ $15,000; 10 tonne @ $25,000; 25 tonne @ $50,000.
- Three phase power and water connection $10,000.
- Weaning tank (2 m^3 capacity) @ $500/$m^3$.
- Growout tank (20 m^3 capacity) @ $250/$m^3$.
- Fingerling seedstock @ $0.50 per 1g initial stocker fish.
- Growout stocking density @ 75 kg/m^3 (with 75% of tanks in use at any one time due to such things as: grading, cleaning, fish health control, maintenance and harvesting).
- Growout period 10 months to final fish weight range of 500g – 1000g.
- Feed costs @ $1.80/kg (typically 30% of variable total costs).
- Electricity cost @ $0.95/kg of fish biomass ie. standing crop (directly influenced by pumping, aeration and water temperature maintenance).
- 10% exchange of water/day.
- Mortality rate @ 10%/month for the first 3 months; nil % thereafter other than specified risk scenario losses.
- Stock insurance cost @ 4% of turnover/annum.
- Equipment insurance @ nominal $1,000/annum.
- Repairs and maintenance @ nominal cost of $1,000/5 tonne production/annum.
- Fees and licence charges @ nominal $2,000/annum.
- Farm gate sale price of fish (HOGG: 85% fish weight) @ $12.50/kg.

A summary of capital costs and associated IRRs for each of the specified production and risk scenarios is provided in Table 8.5. Gross margins in absolute terms, as well as in terms of a ratio of water (ML) used, are summarised in Tables 8.6 and 8.7 respectively for each of the specified production scenarios at zero risk (R0).

Table 8.5: Summary of capital costs of recirculation systems and associated IRR under risk scenarios

Annual Production	Capital Costs [1]	No. of Tanks	Feed Cost [2]	IRR (%) R0/R1/R2
5 tonnes	$80,000	3	$8,000	7/5/3
10 tonnes	$155,000	5	$17,000	12/9/6
25 tonnes	$400,000	13	$40,000	16/13/11

1. Includes purchase of fingerlings in Year 0
2. Based on 1 output batch per financial year.

Table 8.6: Summary of Gross Margins and EBITD for selected tank/recirculation systems at zero risk (R0)

Annual Production	Revenue	Variable costs [1]	Gross Margin	EBITD
5 tonnes	$40,000	$22,000	$18,000	$10,400
10 tonnes	$86,000	$49,000	$37,000	$33,000
25 tonnes	$200,000	$114,000	$86,000	$82,000

1. Includes feed, juveniles, electricity, stock insurance.

Table 8.7: Summary of Gross Margin/ML at zero risk (R0)

Annual Production	K/L in system	M/L used per year	Gross Margin Per M/L
5 tonnes	60	2.2	$8,000
10 tonnes	100	3.7	$6,400
25 tonnes	260	9.5	$9,000

Semi-intensive (cage-based) IAAS

As for the intensive IAAS option, three different production scenarios are evaluated for the semi-intensive IAAS option. In this case however, the production scenarios are based in the first instance on a nominal area of ponded water storage available for cage culture on farms, *viz*.: 1, 2 and 5 ha pond systems. In turn, the available pond area dictates the number of cages, fish stocking density and production capacity for each system. Furthermore, a cage culture operation in south-eastern Australia would typically be undertaken on a seasonal basis to coincide with the irrigation season within the warmer months of the year. Accordingly the growout season would be limited to about 8 months under suitable ambient water temperatures, dictating the need for use of advanced sized seedstock. Also, final weight of marketable fish is estimated to be about 500g only.

In this analysis the ponds are assumed to already exist for irrigation purposes, and therefore require no extra capital costs other than three phase power to operate mechanical aerators. As for the intensive system analysis, each of the cage culture systems will have no extra labour or water costs imposed as these are considered already part of the irrigation farm enterprise.

Growout cages within the system are 25m^3 capacity, with a maximum growout stocking density of 15 kg/m^3. A total of 75% of the cages are assumed to be in use at any one time due to such things as: grading, cleaning, fish health control, maintenance and harvesting. Cages are anchored to, and accessed *via*, a floating walkway. All systems are supplied with supplementary mechanical aeration, with fish husbandry undertaken by existing farm staff, including feeding, monitoring, harvesting, processing *etc*. The analyses for each of the three systems make the following additional capital and operational/variable costing assumptions :

- Growout cage (25 m^3 capacity) costs @ $750 each (inc. walkways).
- Cages occupy max. 5% of surface water area (ie. 20 cages/ha) and there is a min. 100% daily water exchange through the cages; discharged water from the pond is used for irrigation of crops/pasture.
- Capital cost of putting in 3 phase power to ponds @ nominal $10,000.
- Mechanical aerator costs @ $750 each with 4 units/ha (or $3,000/ha total cost).
- Growout stocking density @ 15 kg/m^3 (final maximum density of cages prior to harvest).
- Cost of advanced (fully weaned) seedstock @ $2.50/100g stocker.
- Grow out period 8 months (stocking in October and harvesting in May), with final weight of fish @ 500g.
- Mortality of 1%/month over growout period.
- Feed costs @ $1.50 per kilo (typically over 50% of total variable costs).

- Operational cost of aeration (electricity) @ $24/day/ha (continuously operational); approximate total cost of $6,000/ha/annum.
- Cost of pumping (electricity) $600/ha/annum.
- Stock insurance @ 4% of turnover/annum.
- Repairs and maintenance @ nominal $1,000/ha/annum.
- Fees and licence charges @ nominal $2,000 per year
- Farm gate sale price of fish (HOGG: 85% fish weight) @ $12.50/kg.

Table 8.8 below details the estimated annual production capacity and associated capital costs and IRRs for each system and risk scenario being evaluated. Gross margins in absolute terms, as well as in terms of a ratio of water (ML) used, are summarised in Tables 8.9 and 8.10 respectively for each of the specified production scenarios at zero risk (R0).

Table 8.8: Capital costs and IRR

Pond Area	Annual Production	Capital Costs [1]	No. of Cages	IRR (%) R0/R1/R2
1 hectare	7.5 tonnes	70,000	20	6/-14/-18
2 hectare	15 tonnes	135,000	40	12/1/-3
5 hectare	37.5 tonnes	328,000	100	14/-8/-11

1. Includes purchase of fingerlings in Year 0 (1 ha = $45,500, 2 ha = $87,500, 3 ha = $213,000).

Table 8.9: Summary of Gross Margins and EBITD for selected cage/pond systems at zero risk (R0)

Pond Area	Revenue	Variable costs [1]	Gross Margin	EBITD
1 hectare	94,000	73,000	21,000	20,000
2 hectare	188,000	146,000	42,000	31,000
5 hectare	469,000	341,000	128,000	126,000

1. Includes aeration costs (electricity), maintenance, stock insurance, feed, juveniles for following year, pumping costs.

Table 8.10: Summary of Gross Margins/ML for selected cage/pond systems at zero risk (R0)

Pond Area	M/L per year	GM Per M/L
1 hectare	120	$175
2 hectare	240	$175
5 hectare	600	$213

Fish Production Effluent and Fertiliser Supplementation

The nutrient by-product of fish production as part of an IAAS enterprise provides benefits for farmers through reduced fertiliser applications on crops and pasture. In the following model, quantities of phosphorous present in the effluent of respective production regimes are estimated along with their impact on farm fertiliser budgets for various irrigated agricultural sectors suitable for IAAS application. Actual quantities of P discharged from the different production systems and scenarios are estimated using simple nutrient mass-balance models (Gooley *et al.* 2001b). A nominal economic value of P is estimated at $2/kg (current approximate retail value), and it is assumed that the aquaculture effluent is used for irrigation purposes and can achieve a cost offset against the existing variable farm costs of inorganic fertiliser application.

In tank-based recirculation systems, approximately 10% of the water in the system is exchanged on a daily basis with fresh water. The resultant effluent discharged from the system is typically rich in both solid and dissolved organic waste nutrients, particularly nitrogen and phosphorus (N and P). Estimates of the annual quantity and value of P discharged are summarised in Table 8.11 for each of the system production scenarios under consideration.

Table 8.11: Effluent P production of recirculation systems

Annual Production	Water Used M/L	Kg of P in Effluent	$ Value of P in Effluent
5 tonnes	3	84	168
10 tonnes	5.8	168	336
25 tonnes	9.5	420	840

In a semi-intensive cage culture system the storage pond is assumed to exchange on average 0.5 ML/day/ha of pond surface area during any one irrigation season/fish growout period. This water exchange is assumed to be for routine, operational irrigation purposes in the first instance. However it is also necessary to ensure adequate fish waste removal and maintenance of water quality for cage culture fish production in the pond. As for the intensive tank-based system, the exchanged water is nutrient rich and it is assumed that 100% of the dissolved P can be used to supplement inorganic fertiliser application on the farm. Estimates of quantity and value of P discharged to the pond and subsequently made available for irrigation purposes to offset existing on-farm fertiliser application costs are summarised for each production scenario in Table 12 at zero risk (R0). Using a simple mass balance model, approximately 31.2 kilograms of P are wasted/tonne fish produced per year (Gooley *et al.* 2001b).

Table 8.12: Effluent P production of cage culture systems

Annual Production	Water Used M/L	Kg of P in Effluent	$ Value of P in effluent
7.5 tonnes (1 ha)	120	234	468
15 tonnes (2 ha)	240	468	936
37.5 tonnes (5 ha)	600	1,170	2,340

Economic Viability of 'Whole of Farm' IAAS Operations

On a stand-alone basis, IRRs for intensive IAAS options in the present study are commercially viable with risk at production levels of 10-25 tonnes, suggesting that smaller, more risky operations may not be viable in the long term. However, IRR of such smaller operations (*e.g.* 5-10 tonnes pa) may be enhanced through reducing capital costs associated with initial set up *e.g.* use and retrofitting of existing shed(s) cf. purchase and construction of a new, purpose built shed.

In all cases GMs on a per ML basis are much higher than for irrigated agriculture sectors, suggesting that intensive aquaculture use can provide an increased economic return for the same amount of water use when compared with irrigated agriculture.

On a stand-alone basis, IRRs for semi-intensive IAAS options in the present study are commercially viable only for pond production areas ≥ 2ha (≥ 15 tonnes fish pa) at nil risk levels. This is largely due to the limited growing period and increased seedstock costs. GMs for these scenarios on a per ML basis are comparable to some irrigated agriculture sectors (*e.g.* dairy, rice and cotton), but relatively low compared to others (*e.g.* horticulture and viticulture).

However when the economic benefits of water and nutrient (P) re-use are factored into the GM analysis on a 'whole-of-farm' basis, the results provide another perspective on the economic viability of IAAS application. Indeed the integration of both intensive, tank-based, recirculation and semi-intensive, cage-based pond aquaculture, at all evaluated levels of production (Tables 8.13 and 8.15 respectively), with various irrigated agriculture sectors results in substantial increases in GM for dairy and horticulture sectors, under all aquaculture production scenarios. At higher production levels (25 tonne annual production for intensive tanks, and/or 3 ha pond area for semi-intensive cages), aquaculture integration also markedly increases GMs for the rice, cotton and viticulture sectors (Tables 8.14 and 8.16 respectively).

The increase in economic benefits of IAAS to irrigated agriculture on a water consumption basis are in part directly proportional to the amount of water used by agriculture, and what percentage can be used by the aquaculture operation first. For example, the horticulture (vegetable) sector, due to its small average farm size and associated annual consumption of water (72 ML), will use between 35% and 70% of its water for fish production first before it goes onto irrigation. Accordingly significant savings and additional revenue can be generated through adoption of IAAS at the 'whole-of-farm' level, which in turn results in substantial potential increases in GM.

Table 8.13: Gross Margins with fertiliser savings (F) for intensive, tank-based recirculation aquaculture

Annual Production	Gross Margin (Fish)	Extra Revenue (F)	Total Gross Margin
5 tonnes	$18,000	$168	$18,168
10 tonnes	$37,000	$336	$37,336
25 tonnes	$86,000	$840	$86,840

Table 8.14: Increase in 'Whole-of-Farm' Gross Margins due to intensive, tank-based IAAS (recirculation)

Principle Activity	Gross Margin [1]	5 tonne % increase	10 tonne % increase	25 tonne % increase
Dairy	$107,600	17	35	81
Hort.(V)	$45,400	40	82	191
Hort.(F)	$163,800	11	23	53
Rice	$298,000	6	13	29
Cotton	$552,000	3	7	16
Viticulture	$468,000	4	8	19

Notes: Gross margin per average farm (principle activity)

Table 8.15: Gross Margins with fertiliser savings (F) for semi-intensive, cage-based pond IAAS

Annual Production	Gross Margin (Fish)	Extra Revenue (F)	Total Gross Margin
1 hectare	$19,000	$437	$19,437
2 hectare	$34,000	$874	$34,874
5 hectare	$77,000	$2,184	$77,840

Table 8.16: Increase in 'Whole-of-Farm' Gross Margins due to semi-intensive, cage-based pond IAAS

Principle Activity	Gross Margin [1]	1 ha % increase	2 ha % increase	3 ha % increase
Dairy	$107,600	18	32	72
Hort.(V)	$45,400	43	77	171
Hort.(F)	$163,800	12	21	48
Rice	$298,000	7	12	26
Cotton	$552,000	4	6	14
Viticulture	$468,000	4	7	17

Notes: 1. Gross margin per average farm (principle activity).

Conclusions

On a conceptual basis this analysis shows that opportunities exist for the Australian irrigated agriculture industry to integrate various forms of aquaculture systems onto existing farms in order to increase profitability. Such benefits are best evaluated on a 'whole-of-farm basis which factors in not only increased revenue from fish production, but also synergies with other aspects of farm enterprise, *viz*. multiple water use and nutrient/waste re-use. Indeed, the integration of aquaculture with irrigated farming needs to be viewed essentially as diversification of the farm business into another relatively high value crop, for which there are inherent operational efficiencies and associated cost savings.

The specific economic merits of one aquaculture system or species over another will also depend very much on the inherent characteristics of the different systems and species and the suitability of each to conform with the specific objectives and targets of the broader business plan , such as:

- Length of grow out time to market size,
- Seedstock costs,
- Stocking density,
- Efficiency of feed conversion,
- Survival rates, and
- Market price/demand.

Cost-effective options for integration of aquaculture include the use of intensive and semi-intensive production systems of the type evaluated in this paper, although other system designs also exist and are likely to be equally feasible in certain circumstances. Furthermore, although Murray cod is used in this paper for demonstration purposes, many other species are considered suitable for IAAS production. Indeed, in many cases the profitability of various IAAS system and species combinations, other than those described in this paper, is likely to exceed the financial projections made here.

Ultimately the choice of IAAS design (and species) will vary from farm to farm, ultimately depending on key, very practical criteria such as ambient climatic conditions, availability of suitable infrastructure, market demand, availability of human resources and associated skills, acceptable risk and preferred revenue targets, and compatibility with existing farm operations/business *etc*. These criteria vary little from stand-alone aquaculture suitability criteria. As always therefore, aquaculture investors, be they IAAS compliant or otherwise, need to undertake appropriate financial due diligence as a necessary precursor to preparation of a comprehensive business plan prior to committing themselves. Profitable IAAS investment in Australia is ultimately about making correct business decisions at the 'whole-of-farm' level to address the triple bottom line imperatives for Australian irrigated agribusiness of social, economic and environmental sustainability.

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Appendix A: Sectoral average irrigated land sizes

Data Sources:

- Horticulture – Vegetables (N.S.W) Average farm size under irrigation and fertiliser application is 10 ha. (www.agric.nsw.gov.au)

- Horticulture – Fruit (AUST) 7,977 establishments growing fruit with 82,316 ha under irrigation. Average farm area 10ha.

- Dairy Pastures - 54 ha irrigated perennial pasture, 21 irrigated annual pasture. Total area equal to 75 ha. (VIC/NSW) (Water use efficiency on irrigated dairy farms in Northern Victoria and Southern NSW)

- Rice (AUST) – Average farm size from ricegrowers association of Australia (www.rga.org.au) at 300 ha.

- Cotton (AUST)– Average farm size from cotton Australia webpage (www.cottonaustralia.com.au) at 400 ha.

- Viticulture (AUST)– 107,900 ha of irrigated grapevines in Aust with 5,770 farms Australia wide. Average irrigated area = 18ha.

Chapter Nine

Marketing of Inland Aquaculture Produce in Australia – an Integrated Agri-Aquaculture Systems Perspective

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Introduction

It has been recognised for some time that the aquaculture industry in Australia has enormous potential. This potential exists both as a stand-alone industry or as part of the broader seafood industry. As the wild caught fisheries sector approaches a 'fully exploited' status, the aquaculture industry can act in a complementary capacity supplementing the shortfall in fish. Significant barriers exist as this 'new' industry attempts to move, in many cases, from an embryonic stage to mainstream commercial status. The potential of this industry therefore still requires successful conversion to commercial viability in many sectors.

One of the critical development issues for the aquaculture industry in Australia has been its general lack of market focus to date, albeit with some notable exceptions (*e.g.* cultured Tasmanian salmon, South Australian blue-fin tuna and Western Australian pearls). This lack of market focus is particularly relevant to inland aquaculture in Australia, which is still relatively small in comparison to the marine and coastal sector. Indeed the majority of producers have a very limited understanding of the market requirements for the product that they are producing, or in some cases whether a market even exists. Investors have typically entered the industry very focused on production and have only realised the importance of marketing at a much later stage. Perhaps the one obvious exception is the land-based production of rainbow trout in south-eastern Australia, which not surprisingly is one of the oldest and most mature inland aquaculture sectors in Australia. Few other inland sectors are anywhere near as well established.

For these newer entrants to the industry it is critical that they focus on the customer and put those needs at the forefront of all aquaculture business decision making. Indeed such market research should be undertaken prior to making any investment in this industry. Moreover, it is apparent that the Australian inland aquaculture industry needs to develop an industry-wide marketing strategy, which incorporates deliverable standards of high quality, graded, 'tasty' produce that can be supplied consistently to consumers.

This paper intends to provide a general, introductory guide to the key principles of marketing seafood produce for the inland aquaculture sector in Australia, with an emphasis on the needs and opportunities of the developing integrated agri-aquaculture systems (IAAS) sector. It should be noted however that in many cases these principles and guidelines differ little in practice from those that apply to all forms of aquaculture and indeed agribusiness in general.

Overview of Marketing

Australian primary producers have a history of 'selling' products rather than marketing them. 'Sellers' are very focused on their production system and tend to work out where a product will be sold only after it has been produced. These businesses use a variety of selling methods or outlets to pursue customers to buy their product. This approach results in producers having little control over their markets and the price they receive. Generally speaking, this has been the approach of many new and developing Australian inland aquaculture businesses.

A successful 'marketer' is customer-focused and is able to identify the needs of their customers. They can then provide the right product, at the right price, in the right place, which attracts the customer to buy their product. Most markets are price conscious and increasingly competitive. A 'marketer' therefore needs to give careful consideration to the customer's demands and perceptions of quality and value. These areas need to be developed and promoted as important attributes of the business.

In summary, marketing is about:

- Identifying the needs of customers and potential customers as an integral component of business planning,
- Providing products that satisfy these needs, and
- Developing efficient systems to supply the product to the market when, where and how the customer wants it.

Developing a Marketing Plan

A marketing plan should be developed for an individual enterprise, as part of its overall business plan. This plan should also complement any relevant industry-wide marketing plans, should they exist. A marketing plan can take many different forms and should be developed in a format that is most useful to the person expected to implement it. However, the following elements are a general guide as to what should be incorporated into such a plan:

1. **Vision:** that has been developed for the business (during the business planning stage) should be at the forefront during this process. The marketing strategy contributes to achieving this overall vision for the business in question.

2. **Market Research:** a planned approach to identify potential customers and to define their needs (including product specifications). A SWOT analysis is a useful tool for analysing the information identified in this process, which considers the Strengths, Weaknesses, Opportunities & Threats of the potential market segments or customers. Websites such as:
   - the Sydney Fish Market (http://www.sydneyfishmarket.com.au), and
   - C.H. Smith (http://www.chsmith.com.au/fish-prices/melbourne.html)

   are useful sources of information for determining broad market trends (species, price, volume traded *etc*.), and various popular media publications such as "The Age Good Food Guide" (in Victoria) are useful tools to identify specific potential market segments, such as restaurants. Developing a network with other producers and operators within a defined supply chain can also facilitate access to other important sources of market information.

3. **Key Market Variables:** The following key market variables need to be considered when developing marketing goals and formulating a marketing plan:

   - Product: is the item being offered for sale, including physical aspects such as taste, appearance, size, weight and quantity, and other product attributes such as after sales service. Other examples include quality assurance accreditation (disease, food safety, environmental management *etc*.), packaging, and value adding of your product. Indeed product specification, which is backed up by independently accredited/certified protocols such as HACCP, ISO14000 *etc*, is likely to be essential in the future, to maintain and/or increase market access. In short, it is critical to get the product 'right', according to consumer needs and specifications, in particular its quality and consistency of supply. Diversification by developing different product lines, particularly through value adding and portion control (supplying different sized/shaped portions of the whole product), also increases interest from a wider range of potential buyers.

- Price: is usually determined by how much the customer is prepared to pay, matched with how much the producer is prepared to accept (largely determined by production costs and associated target profit margin). However, for many agribusiness commodities, the cyclical (typically seasonal) patterns of supply have a major effect on demand and price. A marketing plan should incorporate a competitor analysis, to take into account regional/global supply patterns for the product they are producing. Pricing of aquaculture products specifically must be competitive with other seafoods (wild caught and cultured), but also to a large extent with other agricultural commodities which consumers will readily substitute for fish, if prices are too high. Price setting by a producer may be a useful marketing tool to achieving better farm gate prices. The advantage of this situation is that buyers can know costs and estimate profit margins in advance. For the food service sector in general, knowing prices well in advance is invaluable to costing portions and the projected financial return from the menu that is set.

- Place: where the customer wants to purchase the product (which typically must be convenient to, or readily accessible by them). Issues such as distribution, freight and storage logistics and location of outlets are important factors to consider. This will involve segmenting the market into different target audiences. To reduce risk, most producers try to diversify and develop a number of different market outlets for their product. Considerable ongoing investment is required in maintaining existing markets, but also in identifying and developing new (alternative) markets.
- Promotion: how effectively the 'marketer' lets the customer know that the product will meet their needs. It is critical that these messages are realistic and do not over emphasise features that the company or product cannot deliver. It is about getting the right message to the right people and may include personal contact, internet, in-store promotions, conventional advertising (various means), product brochures (with cooking suggestions/menus and demonstrations), and targeted trade and food shows. Building strong 'whole-of-supply-chain' relationships is very important for promoting your product, as this will ensure you are receiving direct feedback from consumers. In this context the 'branding' of cultured seafoods in Australia is likely to be critical to achieving significant market access, particularly for export purposes. This is particularly relevant with the present heightened recognition by consumers and authorities around the world of the need for accredited/certified disease-free, safe food products. Producers can certainly gain competitive advantage in the marketplace by implementing relevant Best Practice standards and associated Codes of Practice, which become valuable promotional tools for the industry. Some of the more established inland aquaculture producers in Australia have found that using a direct mail-out, followed by individual visits, has been effective for them in promoting their products. Producers have also found that educating potential buyers about specific products is critical. This has been achieved by providing a variety of product information such as consumer handling guides (which can have a major effect on the end quality of the product) and providing free samples to wholesalers, retailers and consumers.

4. **Implementation**: is about developing the processes to make it all happen.
   - Plan of Action: who, how and by when? A decision making process for achieving the required sales results.
   - Processes: to determine how things are done in the organisation to ensure the business maintains its customer focus. This will include internal procedures for dealing with customer inquiries and monitoring their satisfaction.
   - Resourcing: adequate budget, adequately skilled people and time allocated to make it happen. The business must have experienced people readily accessible and in constant contact with the buyers.
   - Positioning: the strategies needed to get a share of the available market, which is particularly important when there is competition between suppliers. Techniques such as pricing, promotion, and special services can improve and develop a more positive perception about the product, over its competitors.

There appear to be significant opportunities and benefits in developing a centralised marketing network and distribution system in Australia, particularly for smaller inland aquaculture producers. This network would require producers to adhere to strict quality parameters, and to ensure that the production integrity of all suppliers is maintained. This is particularly important if a product brand is developed for this centralised or networked supply.

5. **Review and Evaluation**: is about ongoing assessment, through feedback loops linked into the supply chain, of what you are doing, including evaluating the success of your plan and addressing the question as to whether it is achieving your strategic vision and business objectives. When measuring the 'success' of your plan, it is necessary to consider not only economic/ financial outcomes but also social impacts (*e.g.* at the employee/family/community level *etc*). Environmental sustainability outcomes are also increasingly important key drivers of market access and commercial success in aquaculture and agriculture enterprises. The ability to integrate both disciplines within an IAAS framework enables producers to legitimately market their produce in an environmentally sustainable context, and thus gain a competitive advantage over producers that do not comply with such rigid standards.

A Marketing Plan for the Australian Aquaculture Industry

Australia has a plethora of high quality aquatic species suitable for commercial inland aquaculture production, including both introduced and endemic species. Some of these species are currently being produced and are well established in the market place, however many more are new and developing species, which have yet to establish themselves as commercially viable products.

The Australian industry, if it is to respond to the needs of the market, must supply consistent quantities of safe, high quality products (which have a competitive advantage over our major competitors). The challenge for industry is to substantiate claims of quality and safety, and to develop reliable lines of supply.

Either way, planning for the growth and marketing of the increasing supply of Australian inland aquaculture products for both domestic and export consumption is seen as essential. Such planning is required in the first instance at different levels (*e.g.* national, state, regional and/or species specific), and needs to take account of the diversity in structure and operational philosophy of the businesses it is intending to assist. This is particularly important for a new and developing sector such as IAAS with its diversity of potential species, inherently innovative production characteristics and potential competitive market advantage.

An industry-wide marketing plan should start with a broad national strategy relevant to all producers, which might then ultimately filter down to a more detailed plan, such as a joint marketing strategy for a specific species, region or network of producers. The more established and experienced producers will need to be the key drivers of this planning process; as such a plan would require their experienced input and must be applicable to them if it is to be implemented immediately.

Developing export markets for species that are relatively 'unfamiliar' to consumers can be a very costly exercise. It is logical that the Australian industry works together to prepare an export market development strategy, which will ensure that Australian suppliers/ exporters do not directly compete against each other in these markets. The perception that Australia is a relatively 'clean and green' supplier should be the basis of any industry-wide, export marketing strategy (provided that the production/ QA systems are in place to substantiate such claims). Australia's proven track record in the supply of high value marine, wild capture species, such as abalone and rock lobster, can also be built on, to the advantage of the aquaculture industry.

As previously indicated, part of this planning process could include the development of a product brand, compatible with the needs of consumers, as a means of securing a market profile. Such an exercise would require careful consideration of producers' ability to maintain consistent supply, substantiation of the image or claims being portrayed by the brand, and the logistics of physically labelling or identifying a fresh, unprocessed product. The ability of producers to support a product brand in the market place in an effective and efficient manner will be critical to the ultimate success of such a brand. Part of this requirement dictates the need for the establishment of viable production and marketing ('supply chain') networks, together with the development, adoption and implementation of appropriate Best Practice management guidelines and associated Codes of Practice for quality assurance and sustainability purposes. Supply-chain networks are also conducive to the concept of 'single desk' marketing (single point of access for buyers to the supply chain) which provides a coordinated market 'shop front', and in many ways can facilitate more effective and efficient market access to the advantage of all participants.

A Supply Chain and Networking Approach to Marketing

The Australian aquaculture industry needs to develop stronger links along its supply chain, from farm, processor, exporter/ importer, distributor(s) and retailer(s), through to the end consumers. Indeed this need is absolutely critical to the long-term viability of the existing inland sector, which is currently relatively small, diverse and commercially fragmented, even without any of the expected new investment in the IAAS sector.

Supply chain management is about developing an integrated approach that aims to satisfy the expectation of consumers through continual improvement of processes and relationships that support the efficient development and flow of products and services at all key stages from producer to customer. An efficient supply chain is able to guarantee satisfaction for consumers as it improves the quality and consistency in supply of products, reduces costs and ensures that open communication occurs along the supply chain in both directions.

Such a supply chain relies on a strong element of understanding between all players, which is maintained through open and clear communication. Retailers must listen to the needs and demands of consumers, and pass this information back along the supply chain so that all players understand and can respond to these needs. For example, within the aquaculture industry, importers may need to purchase products more often, the processors may need to use different packaging and the farmers may need to alter their management practices (such as increased purging) to alter the taste of the product. The consumer should predominantly drive any such changes.

Improvements in the supply chain can often be made by including additional players in the chain, which is often contrary to the belief that the fewer 'middle men', the better. Many industries have benefited from incorporating specialists in the supply chain, particularly when exporting to countries like Japan, where trading houses play a major role. The addition of skilled partners or mechanisms into the supply chain may involve the development of a supply network and/or technical support system, or a joint marketing company. Such networks can provide critical mass in quantity, which provides smaller independent operators with far greater flexibility and opportunities in marketing, particularly for export. In addition, such networks readily enable specialist operators (*e.g.* hatcheries, nurseries, growers *etc*.) to cost-effectively link up or integrate both vertically and/or horizontally with other strategic 'partners' within a functional supply chain. Apart from providing increased market access, these networks also facilitate better use of limited and specialised expertise and infrastructure.

Studies have shown that a number of Australian aquaculture producers have been unaware or belatedly informed of consumer dissatisfaction with their product. This situation has caused a loss of market share and income, which was for no apparent reason at the time. The fostering of feedback mechanisms within the supply chain is invaluable for producers to receive information on their product from their customers, and the end consumer, and to identify areas for improvement or value adding. This system can also enable producers to communicate short-term supply problems (should the need arise) and any production issues that may be posed by buyers' preferences.

Post Harvest, Food Safety and Quality Assurance

Prescribed post-harvest handling and processing procedures are necessary to ensure that the cultured product gets to the market effectively and efficiently. For aquaculture, this is a specialised topic which is beyond the scope of this paper to deal with in any detail. However information is available from various sources (see Appendix I) and producers are encouraged to investigate all relevant post harvest requirements at the earliest possible stage of establishing their enterprise. Again, industry peak bodies and existing codes of practice will be very helpful in this respect. Also, small scale IAAS producers specifically should seek to achieve economies of scale in terms of post harvest infrastructure and expertise requirements through the networking approach mentioned previously, including engaging other existing aquaculture and seafood sectors with existing capacity in this area. One area which requires concerted effort is in relation to live purging of cultured products to avoid 'off flavour' and to achieve minimum QA standards.

This latter issue, along with the broader issue of food safety and the avoidance of 'problematic' chemical residues in cultured product will be critical to the developing IAAS sector in Australia. Thus far, there have been no records of problem residues in inland cultured seafoods in Australia, nor by and large in associated water supplies. However, clearly some risk does exist where aquaculture production occurs alongside, and integrated with, irrigated agriculture in which various chemicals are routinely used to enhance productivity. Likewise, responsible use of prescribed chemicals in aquaculture is also a key issue in relation to achieving adequate standards of food safety and QA, and industry-wide standards for such use are inevitable in the future (if not presently). It is also noted that the successful integration of aquaculture and agriculture may provide a useful marketing and environmental management tool for the IAAS sector in which the aquatic production component of integrated farms may serve as a *defacto* monitor or 'sentinel' of responsible on-farm chemical practices. In short, if a problem regarding on-farm chemical use exists with IAAS, it is likely to be most obviously and rapidly detected within the resident aquatic species in question.

Approval for domestic seafood processing operations, and food safety standards for human consumers in Australia, are largely regulated by state-based legislation implemented at the local government level ie. v*ia* local council health regulations and licensing procedures. For export purposes, processing facilities require Australian Quarantine & Inspection Service (AQIS) approval and licensing, along with actual testing of equipment, products and/or water in some cases for specified 'problem' pathogens and/or residues of various types. These standards typically require individual producers to have in place Hazard Analysis Critical Control Point (HACCP)-based food safety plans for each enterprise which are intended to ensure appropriate minimum standards of food safety and quality control for regulatory purposes. It should also be noted that importing countries may also typically have a suite of quality control/food safety regulations and licensing requirements which have to be addressed by the exporter.

In addition to these more formal procedures, many industry associations/peak bodies and individual producers in Australia have established species specific, quality assurance-based Codes of Practice to facilitate the maintenance of product quality standards in order to gain and/or maintain market access and to promote consumer confidence and demand. More detailed information is available on the development of such quality assurance and food safety standards and practices, all relevant to the inland aquaculture industry, *via* the literature and the internet (see Further Reading and Appendix I of this Handbook for further details).

The Australian Domestic Market for Inland Aquaculture Produce

A new inland aquaculture enterprise should generally identify and establish a foundation outlet for its products on the domestic market before attempting to develop markets overseas. This will enable a business to get its supply chain in place and to get the product meeting customers' exact specifications, prior to entering the often more challenging export environment. Producers need to keep in mind, however, that the domestic market is limited in size and has already felt the impact of increasing production levels, which will be even greater over time.

Although the per capita consumption of seafood in Australia is low compared with overseas, consumption has doubled since the 1950's, from 4-5 kg per capita per year, to a little over 10 kg per capita per year at the present time. There appears to be potential to progress this trend, up towards the consumption levels seen in other western countries, such as the United States of America, which has almost double the per capita consumption of seafood seen in Australia. It is anticipated that the transition towards healthier diets and lifestyles will improve domestic seafood consumption over time. However, it is still important to note that the predicted increase in levels of production, coupled with the ongoing competition from imported products means that the Australian industry will become increasingly reliant on the establishment of export markets.

Australian inland aquaculture products are mostly sold on the domestic market in the following form:

- Whole, cooked and chilled (*e.g.* freshwater crayfish such as yabbies and redclaw);
- Whole, fresh chilled, head-on, gilled and gutted (*e.g.* finfish such as rainbow trout, Atlantic salmon, silver perch, jade perch, Murray cod, barramundi and eel);
- Live (*e.g.* Murray cod, barramundi, silver perch, jade perch and eel);
- Fresh, value-added (*e.g.* trout fillets); and
- Processed products (eg: smoked trout, yabby mousse).

Australia is presently a net importer of edible fisheries products. However, the majority of imports are low value, frozen or canned fish. Imported products can pose strong competition on the domestic market for Australian aquaculture produce. The inherently high labour, establishment and feed costs of the Australian industry mean that it is unlikely to ever be in a position to compete with imported seafood at the lower end of the market.

Considerable market research should be undertaken prior to investing in the inland aquaculture industry. While government agencies are largely available to assist Australian companies to access information and support on export markets, this has not typically been the case for the development of the domestic market. However, extensive information is readily available to producers from various sources, some of which are listed in the Appendix I of this Handbook. In a practical sense, the best means of identifying and understanding specific market opportunities is to talk to potential buyers from the various market segments, whether it is restaurateurs, wholesalers, retailers, or supermarket buyers. This will also enable producers to start developing an important relationship with these potential 'clients'. More recently, most state government departments of 'State and Regional Development' (or similar) have 'Small Business Offices' (or similar), which can provide much relevant advice and sometimes funding support in this area (*e.g.* for preparation of business and/or specific marketing plans - see Appendix I of this Handbook).

The most common domestic market outlets used by Australian aquaculture producers are the wholesale markets in Melbourne and Sydney, local regional markets and direct sales to selected wholesalers, retailers and restaurants.

Wholesale Fish Markets

The traditional method of selling farmed product has been through a wholesale fish market. The two principle markets are in Sydney and Melbourne, which are Australia's two largest and most influential wholesale markets and which set benchmark prices for the entire domestic seafood market.

The Melbourne and Sydney wholesale market systems vary in their mode of function, but essentially operate around a 'commission base principle' in the first instance. More specifically, Melbourne is based around an agency system that relies on a commission per kilo of product sold. The revenue base is generated from larger quantities of wild caught species, in addition to a few specialised aquaculture lines.

On the other hand, the Sydney wholesale selling system is dominated by the Sydney Fish Market (SFM) auction system. This system is deemed to be transparent and it is believed that the strong competition forces premium prices to be paid for the higher quality product.

The Sydney wholesalers compete not only between themselves but also with the SFM auction system. For aquaculture species in this situation, the system operates differently to the Melbourne wholesale market as the wholesalers do not derive their income *via* commission, but rather by profit margin added to the cost of purchase. Most price structures are derivatives of the SFM auction prices with consideration given to other factors such as supply volume or consumer demand.

Aquaculture production is viewed as an important 'future' source of product for these markets. Accordingly, proprietors have a desire to see increased production of inland aquaculture species in Australia. Currently however, farmed product makes up a very small percentage of supply and is exposed to considerable fluctuations when additional product is put through the market, even by one supplier. This can be a particular problem when such product is of less than optimal quality. In this situation, prices and consumer perceptions can quickly deteriorate, and this can have an effect on the entire industry.

Generally, wholesalers will not see it as their responsibility to create a market for a new species, whether Australian, cultivated or wild, unless there is a financial return to themselves. It is therefore essential for producers, or producer networks, to work hard to establish strong partnerships with wholesalers, based on regular communication and unfailing attention to detail and feedback on consumer needs and product quality.

Direct Sales – Retail and Food Service Sector

The greatest increase in seafood consumption in Australia is occurring outside the home. Penetration into the broader community is therefore likely to follow the promotion of aquaculture products within the restaurant and catering industries. The 'trendsetting' capacity of these industries is not to be underestimated.

Indeed the more established producers (particularly in the rainbow trout and, more recently, native fish sectors) have extended considerable effort to establish direct lines of supply to various retailers and restaurateurs. By supplying direct, producers can by-pass the wholesale market. However it should also be noted that many of these outlets are niche markets which are particularly sensitive to increases in supply. Considerable price reductions can often result, as supply can readily outstrip the level of demand, particularly for new and developing industry sectors as production capacity increases.

Demand for Australian aquaculture products is currently strongest amongst the restaurant, catering and Asian communities. Amongst direct consumers of cultured seafoods in Australia it is considered that 'convenient to prepare' and 'fail proof' products are most preferred, with the strongest demand being in the higher socio-economic segment of the market.

Domestic Opportunities for Live and Chilled Fish

Live fish are sold, almost exclusively, directly into the retail and seafood market sector, targeting tourists and communities of Asian ethnic origin, all of whom are generally prepared to pay premium prices for such a product. Farmed barramundi, Murray cod, jade and silver perch have become the dominant species in this very competitive, live fish market, particularly in Sydney and Melbourne.

Farmed native fish (*e.g.* silver perch and Murray cod) at a size between 600g and 1.5kg are preferred by many Asian communities, particularly due to the high fat content of the flesh. However, as previously stated, the market for this category is relatively limited and may soon become saturated, thus restricting further domestic growth. Presently, farm-gate prices in the range of AUD$8-15/kg can be expected, based on recent experience for various inland finfish species such as Murray cod, silver perch and barramundi.

Sales of chilled, plate-sized, whole fish are presently stabilising across retail, supermarket and restaurant market sectors. It is suggested that this may be due to the increased demand for more convenient, pre-prepared meals. The ability to cost-effectively culture larger fish, which will enable processing of ‘portion-controlled’ products also appears to be a key requirement of producers. Furthermore, the fresh, whole fillet seafood market is presently highly dependent on wild harvest (the main exception in Australia being farmed Atlantic salmon and trout). Depending upon the aquaculture industry’s ability to develop consistent lines of supply of these larger sized fish at a competitive price, this market also has significant growth potential for the aquaculture industry.

To be competitive in this sector of the domestic seafood market in future, preferred products will be generally white-fleshed, with a good dressing percentage (meat yield), and a farm gate price (for the whole fish) at or below approximately AUD$10-12/kg (before filleting). Provided the quality is right, white-fleshed cutlets and steaks could also establish a market in the mid-upper restaurant market sector, perhaps at a farm-gate price for the product of around AUD$12-15/kg. The whole fish for such products would typically need to be above 2-3kg in size and of a suitable body shape.

Whole fish are also used for display purposes, albeit in small quantities, to demonstrate the quality of the merchandise in retail outlets and in restaurant-style banquets. Furthermore, the previously mentioned demand for ‘convenience’ and pre-prepared foods presents market opportunities for other innovative products, such as butterflied whole fish, which maintains the advantages of a whole fish, in a more convenient form. The Australian aquaculture industry needs to invest in the development of such products.

Domestic Opportunities for Freshwater Crayfish

The domestic market for most crustacean species is relatively strong. However, demand for freshwater crayfish products specifically, such as yabbies, is very price sensitive and fluctuates accordingly. Around 70% of current Australian yabby production is consumed locally, with the bulk going to restaurants and the remainder to wholesalers and retailers. Intermittent purchasing patterns of consumers, coupled with irregular (often seasonal) supplies, collectively contribute to an uncertain market for these products.

The future success of this industry is dependent on the development of adequate and consistent volumes of high quality supply. If the predictions of industry expansion are realised, adequate marketing by the industry will become of paramount importance. Once producers are able to meet these requirements of the market, then they are more likely to at least maintain acceptable minimum prices when production levels and supply inevitably increase in the future. The national trend in Australia towards multi-water licensing of yabby producers which provide commercial access to captive, but otherwise wild yabby stocks in farm ponds, is facilitating the establishment of a viable industry networking approach to production, quality assurance and marketing of freshwater crayfish such as yabbies.

Export Market Opportunities for Inland Aquaculture Produce

The Australian domestic market for locally farmed seafood products is limited due to our limited population, with a relatively small level of demand. This will undoubtedly have an increasingly negative effect on prices and profitability for producers that focus exclusively on the domestic market. For this reason, the development of export markets will need to be the long-term goal for the Australian inland aquaculture industry if individual businesses are to sustain reasonable profits into the future.

Australia is renowned as a supplier of high value, wild caught seafood products, such as abalone and rock lobster. With the ongoing development of aquaculture, our key export markets need to be made aware of other species and products that are becoming available from Australia. Moreover, importers view Australia as a source of high quality product that is produced in a healthy and safe environment. This presents a considerable opportunity for the promotion of Australian seafood products branded for their safe, quality assured nature. Such claims must be substantiated to customers in these markets, which increases the importance of adequate quality assurance and production systems. A targeted, perhaps nationally coordinated marketing campaign for such products should seek to differentiate cultured Australian seafood products in an attempt to attain greater demand and better prices for producers, and ultimately to improve the viability of exporting.

Inland aquaculture species or products that are currently being exported include:

- salmonids (*e.g.* frozen, chilled and smoked rainbow trout),
- barramundi (fillets and processed whole),
- yabbies (live and processed products, such as paté),
- eels (live and processed whole), and
- Murray cod (processed whole, with some trials of live product).

The strongest global demand for finfish, particularly in Asia, is for marine species with a white or red flesh, that is relatively firm (doesn't disintegrate when cooked), has a sweet and clean flavour, with minimal bones, and weighs between 0.6-1.0 kg. These consumer preferences present a major challenge to the inland aquaculture industry as the development of export markets will require considerable investment in promoting and educating buyers and end-consumers about species with which they are unfamiliar and may not initially prefer. Accordingly, producers may need to be prepared to incur some significant costs to establish market access, until their 'new' species or products effectively infiltrate the market. Often this requires that suppliers make free samples available for targeted 'in-market' product launches and promotions. At the preferred size, inland aquaculture producers can presently expect farm gate prices for various export quality finfish species in the range AUD$8-20/kg (FOB).

Singapore and Hong Kong are seen as two of the more progressive seafood markets in Asia, as consumers are more willing to try new products. Several importers in these countries have expressed strong interest in working with reliable Australian suppliers to develop these markets for inland aquaculture species. It needs to be recognised, however, that these markets face strong competition from other suppliers around the region and are fairly price sensitive.

Practical advice on how to establish and enter export markets is available through various government agencies, including the Commonwealth Government agency, Austrade. This agency has offices located in various countries around the world and provides support and services to Australian companies, including market research, and identifying and introducing potential importers. Contact the Austrade hotline on: 132878 or visit www.austrade.gov.au for more information (also see Appendix I of this Handbook for further details).

Conclusions and Future Directions

Marketing is a critical component of any successful business and should therefore attract a significant investment of time and resources. Marketing should be undertaken right from the initial formation stages of a new business idea and **not** just after the first batch of fish has been produced. By this stage it is too late, as significant areas of market research may have been overlooked, leading to the costly production of unsuitable product.

A marketing plan is a 'living' document (needs to be reviewed and updated regularly), and entails extensive research to understand the needs of consumers, establishing and maintaining relationships with buyers, and identifying specific market opportunities. These all have a major influence on the way the business is run and need to be reviewed regularly.

There is a need for the Australian inland aquaculture industry to develop a level of critical mass, which allows it to adequately service the marketplace (particularly for export). This 'critical' level of production can be broadly defined as a level of supply that meets the immediate needs of a specific market, that provides some capacity for expansion, and that allows for relatively speedy responses to any changes in consumers' needs.

Industry association(s) should play a key role in coordinating all or part of the marketing of Australian inland aquaculture species, whether it is establishing supplier networks, undertaking market research, or a targeted promotional campaign. This may be undertaken at a national and/or state, regional and/or local level.

Acknowledgments

This report incorporates information and thoughts from a wide range of authors and industry personnel. Much of the themes and information contained in this text has been extracted from the literature listed in the further reading section of this chapter, but has not been specifically referenced. Specifically, the author would like to sincerely acknowledge the time, expert information and cooperation of the following people:

John Roach and associates, *John Roach Seafood Solutions, Marouba, Sydney*.

Aquaculturists
Brendan Larkin, *Australian Aquaculture Products*
Greg & Helen Williams, *Central Victorian Yabby Farm*
Hugh & Edward Meggitt, *Goulburn River Trout Pty Ltd*
Ron & Sharon Elton, *East Coast Eels*

Peak Industry Bodies
Louis Vorstermans, *Chief Executive Officer, Victorian Aquaculture Council*
Don Mowbray, *Fisheries Co-Management Council, Victoria*

Government Representative
Geoff Gooley, *Marine and Freshwater Resources Institute, Victoria*

Wholesalers and Retailers
Malcolm McLaughlin, *Consolidated Fish, Melbourne Wholesale Fish Market*
Andy Ariss, *Racovoli`s, Melbourne Wholesale Fish Market*
James Dellas, *Dellas Seafoods, Melbourne Wholesale Fish Market*
Nick Miriklis, *N.A.K. Seafoods, Melbourne Wholesale Fish Market*
Graham Turk, *Chief Executive Officer, Sydney Fish Market*
George Costi, *DeCosti's Seafoods, Sydney Fish Market*
Terry Poulos, *Poulos Brothers Wholesale, Sydney Fish Market*
Kevin Delaney and Graham Marr, *St George Fish Markets, Brighton Sydney*
Anthony Mercir, *Tassal Ltd, (ex. Operations Manager, Christie Seafood's Sydney Fish Market)*
Jack Costi, *Claudio's Seafoods, Sydney Fish Market*
Martin Palmer, *Martin's Seafoods, Sydney*

Food Service Industry Representatives
Nick Manettas, *Nick's Cockle Bay Wharf Seafood, Cockle Bay, Sydney*
Mr Tom, *East Ocean Chinese Restaurant, Haymarket, Sydney*
and the management of :
Golden Century Chinese Restaurant, Haymarket, Sydney
Edna's Table, Sydney City, Sydney

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Chapter Ten

Integrated Agri-Aquaculture Systems and Water-use Sustainability

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Introduction

In a relatively dry country like Australia, important environmental issues relate to the sustainable utilisation and protection of water resources. Threats to water resources in irrigation areas occur through over-abstraction, salinisation of surface and groundwaters and catchment-scale nutrient enrichment (eutrophication). In the long term, globalisation and environmental sustainability imperatives dictate that the Australian irrigated agriculture sector must move towards Best Practice production systems which conform with the principles of Ecologically Sustainable Development (ESD)(ESDSC 1992).

Water use sustainability within the irrigated agriculture areas in Australia is central to the rationale and ultimate feasibility of integrated agri-aquaculture systems (IAAS) development. Water is increasingly being recognised as a finite commodity in Australia; one which has to be allocated on a fair and sustainable basis. Moves have already been made towards this allocation process with the development of tradeable water entitlements within irrigation districts. With increasing concern in the country over the impacts of agricultural practices on water quality, particularly in terms of salinisation and nutrient enrichment of surface waters, it is likely that in the future this approach could be extended to include nutrients and salt-affected water.

This chapter explores the background behind the development of “tradeable emissions” policy (TEP) - type management tools in Australia. It also reviews future directions in this area, including the influence of ESD and “green economics” (GE) policies on water management practices, which are likely to significantly impact on the longer-term economic viability of IAAS in Australia.

ESD and Green Economics

Globally, the two concepts of ESD and GE are key drivers in future developments in relation to sustainable utilisation of natural resources. GE essentially redefines the meaning of wealth from the traditional role of money and capital alone, to include the added economic dimensions of social and environmental values (www.greeneconomics.net). GE markets are considered to more adequately express the values of the community at large, rather than just a select or “non representative” subsection of beneficiaries. This is particularly the case where the utilisation of a common pool natural resource, such as water, is involved.

Therefore, from a practical perspective, the GE paradigm is likely to underpin the new economic markets which will ensure that all common pool natural resources (including waste/emissions), are utilised in an optimal manner consistent with the principles of ESD. These markets are likely to provide the necessary commercial incentive and framework for industry to achieve satisfactory standards of sustainability. The existing water entitlement trading mechanisms developed in some Australian irrigation areas are perhaps a step in that direction.

Australian Water Industry Reform and IAAS

A report to the Council of Australian Governments contains an outline of processes which have been put in place to facilitate the ongoing reform and restructure of the Australian water industry (HLSGOW 1999). The key imperatives identified in this report include:

- the need to address the longer term ecological sustainability of irrigation water usage;
- the need to provide the flexibility for commercial water users to move to higher value commodities; and
- the need to fully account for the external costs associated with irrigation water usage, *e.g.* eutrophication and salinisation of inland waterways (HLSGOW 1999; Thomas 1999).

Australian water industry reform has recently seen the establishment of commercial markets for trading of water entitlements, and the progressive separation of water property rights from land within the rural sector. The commercial trading of water rights specifically allows water to move to more profitable uses, and facilitates restructuring of irrigation away from environmentally degraded areas, wasteful practices and low value/productivity crops spread across relatively large areas (for more information see www.awa.asn.au 1999; www.affa.gov.au 2000; www.mdbc.gov.au 2001).

In relation to the issue of "environmental pricing and resource rentals" the Environmental Policy of the Irrigation Association of Australia (IAA - irrigation industry peak body) acknowledges the growing momentum to include pricing for cost recovery of water-use externalities. "Externalities" is an economic term used to describe the instances where the activities of one producer changes the "production function" of another producer, without any compensation (Wijkstrom 1995). For example, salt leaching from land upstream in a catchment can drastically reduce the productivity of that water for downstream users, but the downstream user is not compensated by the upstream users. To put such externalities into context, the full external costs (including projected environmental clean-up costs) of farming in Britain have been quoted as exceeding £2.3 billion annually, almost equal to the industry's income (Pearce 1999).

A related issue is described by FDIRC (2001), which prescribes a suite of recommendations designed to regulate the harvesting of water within the Murray-Darling Basin *via* catchment-fed, on-farm storage dams. Central to these recommendations is the need to ensure sustainability of water resources through formal regulation of such practices, including the issuing of licences and associated cost recovery, and the establishment of water harvesting caps and market trading of entitlements.

Future Tradeable Permits

In the future it is anticipated that the development of TEP at a state and/or national level will also inevitably see the commercial trading in waste/emission (*e.g.* nutrients and salinity) "quotas" for primary producers, at least within specific catchments or other bio-regions. This will occur as part of a more equitable, economically driven resource allocation process designed to encourage more efficient and effective use of water and recovery of external costs.

The international commercial trading in carbon credits, likely to provide the necessary incentive to industry to reduce and optimise the utilisation of fossil fuels, is somewhat analagous to the proposed trading in "waste" quotas and associated permits.

Holland and Brown (1999) infer that resource conflicts in aquaculture are partly attributable to society's inappropriate reliance on conventional markets. They further suggest that in the absence of appropriate markets, inefficient allocation of resources may result, to the detriment of aquaculture development, but that increased use of more effective and efficient economic instruments may have the reverse effect. Wijkstrom (1995) describes the appropriate use of economic instruments such as TEP to enforce environmental policy within the industrialised world, with the clear inference that this approach is directly relevant to the aquaculture industry.

Stoneham *et al.* (2000) describe a conceptual model that combines waste emitters with other industry sectors that can provide pollution-offset activities in a single "environment economy", thereby demonstrating societal benefits beyond those typically emanating from more conventional regulation of waste emission. Such a model could readily provide the economic rationale for linking aquaculture and traditional land-based irrigated agriculture within a common tradeable emissions market, and therefore also provide the fundamental economic rationale for IAAS development in Australia.

Within a GE/IAAS framework specifically, TEP is simply a bureaucratic or legislative tool designed to facilitate development of an economic market for selected water-use externalities, such as nutrient enriched and/or saline waste typically emanating from various developments, including agricultural and/or aquacultural practices. Apart from creating the ability to place an economic and marketable value on waste, and thereby the means by which the full cost of waste can be identified and recovered by the key stakeholders, TEP also:

- creates bio-regional, typically catchment-scale, boundaries within which realistic ESD-based resource utilisation and management can be undertaken; and
- facilitates waste minimisation by optimal utilisation, through integration of different primary production sectors and various stages within the primary production chain for any one sector.

ABARE (2000) refers to the use of various economic instruments to manage waste impacts in the Australian aquaculture industry, including the potential use of tradeable pollution permits. Although pointing out limitations of a tradeable permit system, including the inherent costs of pollution monitoring and the likely spatial differentiation of many otherwise potentially tradeable waste commodities, it also highlights the many benefits, including:

- the ability to recognise trade-offs between aquaculture benefits and environmental impacts;
- the provision of valuable business incentives to practitioners to adopt more innovative Best Practice waste minimisation standards;
- the ability to transfer waste disposal rights from inefficient to more efficient producers or those that can reduce waste at lower costs, either within or between aquaculture and other industry sectors; and
- the potential synergies associated with trading waste emissions and recognising the net benefits specifically between agriculture and aquaculture.

The inherent logic and rationale behind the development of IAAS and its relevance to the GE, ESD and TEP-type legislative tools are manifest in many of the above-mentioned scenarios and imperatives. However, to what extent this is a pragmatic view remains to be seen.

Conclusions

The traditional single use of irrigation water is intrinsically inefficient and the increasing cost of irrigation water and fertilisers for agriculture highlights the benefits of IAAS to the traditional farmer. In this context, the integration of aquaculture and traditional irrigated agriculture is considered both logical and inevitable in order for industry to achieve both full cost recovery of water-use externalities and to shift towards higher value production from this water use (Gooley 2000, Gooley *et al*. 2001). In addition, farmers with lands already degraded through salinisation have an opportunity to recover some productivity and perhaps rehabilitate existing salinised land through integration into the farming system of inland saline aquaculture practices.

Farmers need access to new integrated aquaculture technologies that allow them to effectively realise opportunities presented by the increasing separation of water property rights and land within established irrigation areas. IAAS also presents opportunities in anticipation of possible future developments such as the creation of Green Economy markets for tradeable emissions (*e.g.* salt and nutrients) and associated cost-recovery mechanisms. Once the full cost of water-use externalities for the irrigation industry is factored in to catchment-scale socio-economic analyses in which nutrient budgets have been established, the commercial competitiveness and investment potential of integrated aquaculture are considerably enhanced against traditional land-based agricultural alternatives (*e.g.* see Gooley *et al. In press*). The added bonus of course is that the water is simply "borrowed" by aquaculture and not consumed.

Other commercial benefits for practitioners going down this path include the increased marketability of aquaculture businesses and associated produce, which can clearly show the adoption of ESD principles in the course of day to day operations. Such a tangible commitment to environmental sustainability within the commercial sector is likely to provide significant incentives and longer term economic dividends within the business market place, perhaps far exceeding the real costs incurred. Successful commercial fisheries enterprises which have achieved the international endorsement of the Marine Stewardship Council (MSC) through employing environmentally sustainable practices are arguably a fitting testament to this concept. The MSC's fisheries certification program aims to encourage sustainable fishing practices through a consumer-targeted product labelling scheme (www.msc.org 2001).

Finally, in terms of pending issues pertaining to the development of tradeable emissions policy, it is interesting to speculate on the means by which Government and relevant management/regulatory authorities will utilise the revenue generated by industry through this process to offset environmental management costs. Clearly, unless such revenue is reinvested directly back into environmental protection and rehabilitation initiatives, there will be little encouragement for the community in general, let alone the industry payees, to accept and support an economic market based around tradeable emissions. Appropriate funding programs will therefore need to be put in place, underpinned by effective and efficient strategic planning and on-ground actions plans, so that all stakeholders can be satisfied that the process is both feasible and indeed working. At a policy level, the IAA succinctly states that if any externalities are recovered, the costs should be re-invested into environmental restoration and adoption of more efficient farm irrigation systems (IAA 1997).

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Chapter Eleven

IAAS Investment Risk, Industry Development and Business Planning

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Introduction

A recent study funded by the National Farmers Federation (NFF) and the Australian Conservation Foundation (ACF) examined long-term investment strategies for the primary industries sector to improve environmental sustainability. The report recognised that the environmental problems facing rural Australia (notably salinity, soil degradation and eutrophication) are too large to be addressed by the farming community or government alone and that a strategic coalition of investors is required to effectively repair existing damage and arrest further environmental degradation (TAGC 2001). The report identified the need to promote substantial private sector investment in Australia to provide leverage to government and industry funding and develop a co-ordinated approach to improving the sustainability of farming systems (TACG 2001).

The outcomes of the NFF/ACF study are entirely consistent with the principles and concepts of integrated agri-aquaculture systems (IAAS) particularly in relation to the stated focus on "…investment associated with changes in the mix of existing types of agricultural land use…", including addressing measures such as more efficient water use and development of salt tolerant aquatic industries (TACG 2001). IAAS have the potential to offer both farm level and catchment scale environmental benefits which can improve the sustainability of traditional farming systems. To capitalise on these benefits, however, will require the sector to develop strategically according to an agreed plan at farm, catchment and state/ regional level. Furthermore, the implementation of strategic industry development plans will need the support of relevant industry representative peak bodies and regional aquaculture and agriculture industry associations to ensure appropriate levels of coordination and cooperation from all stakeholders.

IAAS Investment and Risk

The profitability of agribusiness investment is generally influenced by a range of risk factors, including technical, biological, environmental, financial, marketing, administrative and bureaucratic (legislative/regulatory) processes. According to Bacon *et al.* (1993), one of the most critical risk management decisions that farmers have to make is in relation to output diversification. The integration of agriculture and aquaculture systems (IAAS) is one means through which Australian farmers can achieve output diversification with the selection of appropriate species and systems for an IAAS enterprise synonymous with diversification in conventional agriculture. A thorough knowledge of the risks and returns of alternative enterprises is required to enable farmers to effectively analyse the trade-offs between existing and new on-farm business practices (Bacon *et al.* 1993).

Investment in IAAS development in Australia needs to be effectively risk managed not only at individual farmer level, but also at other stakeholder levels, including government, private and financial sectors. Risk assessments should be conducted using practical and accepted methods applied across the key areas of socio- economics, the environment and technology. Accordingly, risks also need to be assessed at different operational levels including on-farm, catchment and regional/ state.

Farmers will be responsible for ensuring that each individual on-farm IAAS enterprise broadly complies with broader scale industry development strategies and is underpinned by a comprehensive, "whole-of-farm" business plan which provides a framework for managing risk.

Profitability is likely to be the dominant consideration for adoption of IAAS and subsequent investment by existing farmers and landowners in Australia. Each IAAS must therefore be tailored to optimise the available resources, skills and level of capital investment available to the individual proponent, and must comply with the prevailing regulatory environment. In short, profitability of IAAS can be effectively maximised through optimising the three inter-related components of relevant production, economics and environmental issues.

For the purposes of this discussion, the risks associated with integration of aquaculture into existing Australian agriculture are embodied within selected key investment criteria which should be evaluated during the pre-feasibility and business planning phase of a new enterprise. These criteria are summarised in this chapter under the headings of Production Technology and System Design, Economics/Marketing and Environmental Issues, along with some general guidelines to facilitate IAAS industry development and business planning processes. Although there is an emphasis here on developing IAAS within the irrigated agricultural sector, (that being the most appropriate in Australia given the infrastructure and resources available) it should be noted that many of the principles apply equally to integration with other forms of agriculture.

IAAS investment criteria for Australian industry

Potential investors in IAAS must be cognisant of both the opportunities and constraints presented by the natural resource base and climate of the specific geographic region in which any development is proposed. Ultimately the choice of culture species will be determined by a range of issues – some related to the production system and location, others dictated by external factors. The criteria for selecting commercially viable aquaculture species for integrated production will differ little from the process used in conventional, stand-alone aquaculture systems, and will be broadly dictated by:

- value/demand of intended market;
- biological/husbandry attributes;
- access to technology and training/education/extension support;
- system design and cost of production;
- geographic area and ambient climate;
- availability of water and land resources;
- availability of seed;
- level of proposed capital investment and projected revenue/income;
- quality and quantity of effluent and associated disposal/re-use options.

The ability to adopt appropriate IAAS production technologies which meet the needs of the target aquaculture species and which are compatible with the existing farm business, is critical to achieving success.

Production Technology and System Design

Production system design for any one integrated farming model is likely to fit into one or more of the following three categories:

- Intensive systems: typically high stocking density, and relatively high levels of capital investment, management and control (*e.g.* tank-based recirculating systems).
- Semi-intensive systems: medium stocking density, and medium level capital investment, management and control (*e.g.* cage culture in existing on-farm storage ponds and/or purpose built fish ponds).
- Extensive systems: low stocking density, generally using existing infrastructure with little or no modification, management or control (*e.g.* farm dams *etc*).

Specific details regarding these systems are provided in Chapter Five of this Handbook, from the literature (see References throughout this Handbook), as well as the documented case histories (see Chapter Six of this Handbook).

Semi-intensive and/or extensive IAAS systems operating under ambient conditions (*e.g.* use of pond or cage culture) are constrained to a large extent by local ambient climatic conditions. Temperature has a direct influence on the growth and survival of all fish and most species have specific temperature ranges within which their growth is optimal.

Despite these limitations, such constraints can sometimes be readily overcome by utilising temperature-controlled recirculation aquaculture systems (RAS) under "bio-secure" conditions. However, the investment criteria and associated evaluation of IAAS using RAS systems will be quite different, given the relatively capital intensive and skilled management requirements. For example, warmwater/tropical species such as Murray cod and barramundi will perform far better under ambient conditions in ponds or cages at warmer, more northerly latitudes than they would further south in a cooler climate. However, these species may be produced profitably in tanks at more southerly latitudes as part of an intensive, controlled environment recirculation system.

Given that fish growth and survival are key factors in the profitability of an aquaculture venture, along with production costs and market price, matching suitable fish species to the climatic zone and system design is critical to the success of an IAAS venture. In addition, there are legal restrictions on stocking fish species outside their natural range which will limit where some species can be stocked and what production system can be used within any one state or geographic area. It may simply not be viable to attempt aquaculture production of some species in certain geographic areas, unless controlled environment recirculating systems are used. Under ambient conditions in cages or ponds, the selected species should be able to achieve market size within a reasonable time frame. Alternatively producers may have to utilise larger-sized advanced "stockers" to shorten the production cycle, or simply rely on agisting fish for short periods before on-selling to other producers to finish off to market size.

The production system selected will therefore depend on the natural resources available to the investor, the chosen culture species, the availability and reliability of production technology, the availability of expertise or access to training and education support, ambient climatic conditions (where applicable), the level of capital investment they are willing to make, as well as the specific business objectives of the proponent.

Economics / Marketing

The primary economic benefit from aquaculture integration with irrigated farming systems is clearly from producing marketable aquatic products without any net increase in water consumption. The effective marketing of aquaculture produce from small-scale IAAS operators will be an important factor in the long-term economic sustainability of the industry and will demand innovative and cooperative production and marketing strategies.

Where an existing aquaculture industry sector is already catering for the market demand for a certain species, constraints to market access for small-scale operators may impact on the economic feasibility of the integrated operation. Existing market pricing structure, contractual agreements (between producers and buyers) and quality assurance/food safety standards may again eliminate certain species from consideration, or may force small-scale IAAS operators to strategically align themselves with existing aquaculture industry producers.

Either way, IAAS investors need to ensure that they meet minimum production levels and quality assurance and food safety standards to realistically access seafood markets in a cost-effective manner. The primary means by which this can be achieved is through business networking, including pooling of produce, sharing of infrastructure (*e.g.* purging, processing, packaging, storage and freight facilities), and collaborative and/or coordinated marketing. This "whole-of-production" chain, vertically integrated approach to the IAAS business in Australia would also allow small-scale producers to achieve the economies of scale that they could not otherwise realise by working autonomously. Further information on IAAS business management and marketing of IAAS produce is provided in Chapter 9 of this Handbook.

Further on-farm and catchment-scale economic benefits can also be achieved through implementation of IAAS practices in Australia through the more efficient use of existing farm resources, including water (already mentioned), salt (if saline water is utilised for producing salt tolerant species), nutrients, capital, infrastructure and personnel. The various "market" strategies designed to maximise broader enviro-economic benefits of IAAS, together with a more detailed economic appraisal of the IAAS opportunity in Australia are provided in Chapter 8 and 10 of this Handbook.

Environmental Issues

The traditional single use of irrigation water in Australian agriculture is intrinsically inefficient and the increasing full cost (ie. both direct and external to the actual user) of this precious resource highlights the potential benefits of IAAS to the farmer. IAAS principally aims to value-add existing water and nutrient use by facilitating the production of a more diverse and marketable product base on any one farm. In addition, farmers with land already degraded specifically through salinisation may have an opportunity to recover some productivity and perhaps rehabilitate existing land through integration into the farming system of inland saline aquaculture practices (Smith and Barlow 1999).

Recently, reform of the Australian water industry has seen the establishment of commercial markets for trading of water entitlements, and the progressive separation of water property rights and land within the agricultural sector. In the future it is anticipated that, as part of the “green economics” debate, the development of “tradeable emissions” policy at a state and/or national level will see commercial trading in nutrient and salinity “quotas” or permits for primary producers. This will occur as part of a more equitable, economically driven resource allocation process designed to encourage more efficient and effective use of water and recovery of external costs. In this context it is suggested that the integration of aquaculture within irrigation farming systems will be able to meet all reasonable financial and environmental targets set by farmers/investors, environmental regulators, and the community in general (Gooley and Gavine *In press*; see also Chapter 10 of this Handbook).

Relevant Issues and Requirements

Based on these broad, key investment criteria headings, the main requirements and issues that will need to be addressed for successful, risk managed application of IAAS principles and concepts in Australia are summarised as follows:

Identification of optimal species, system design/capacity and production levels.

- Suitable species should be selected according to the geographic location of the enterprise, unless bio-secure, controlled environment production systems are to be used.
- System design should optimise the use of readily available/existing resources and infrastructure in a way to minimise start-up and recurrent costs and external energy inputs, without compromising fundamental system requirements and profitability.
- The choice of culture species, system and scale of investment should be based on commercial opportunities which are cognisant of "whole-of-production" chain needs of the existing seafood industry.
- The integration of the aquaculture enterprise within the existing farm operation should be based on thorough "whole-of-farm" business planning.
- Integrated aquaculture produce needs to conform to the premium standards set by the Australian seafood industry for quality control and food safety.
- Relevant technical and business training and support services need to be accessed by producers as a matter of routine.

Achievement of appropriate economies of scale through establishment of business networks.

- The economic viability of the proposed development should be fully assessed prior to implementation, based on an objective and comprehensive analysis of cost-benefits which includes setting realistic/reasonable profitability targets for the enterprise.
- Cost-benefit analysis should factor in the economic value of linked environmental benefits associated with integration, particularly in relation to land rehabilitation, reduced nutrient and/or salt emission and multiple water use.
- A preference for focussing, where possible, on aquaculture production in higher value markets for both export and domestic consumption.

Optimise natural resource utilisation and sustainability.

- Natural resource utilisation should not result in any net increase in environmental emissions or associated external environmental costs, or any net increase in water consumption.
- Systems should be designed with future developments in establishment of waste or emission trading markets in mind, to optimise commercial viability and environmental sustainability of the proposed enterprise.
- All proposed developments should be cognisant of and compliant with all relevant legislative and associated regulatory requirements at local, state and federal Government levels.

Issues that should be considered in the planning phase of IAAS development are summarised in Table 11.1. These criteria and additional relevant information on IAAS development opportunities and constraints in Australia are further summarised in Gooley and Gavine (In press) and Chapters 5 and 7 of this Handbook.

Industry Development

For the concept of Integrated Agri-Aquaculture Systems (IAAS) to be fully realised on a commercial basis within regional Australia, it will be necessary to ensure that such development is underpinned by sound business principles and supported by clear, strategic planning guidelines. To implement such a strategy farmers will require the support of key stakeholders including industry peak bodies, respective state fisheries and state and regional development agencies, relevant water authorities, local government and training providers, to name a few.

Extension, Training and Education

To reduce risk and encourage investment by IAAS farmers, education, training and extension support will need to be provided to ensure adequate levels of expertise exist in the industry and that Best Practice management and production techniques are implemented.

Extension support will typically be provided by state-based aquaculture (fisheries) and agriculture agencies (see Appendix I of this Handbook for contact details). On the other hand, education and training is typically the role provided by registered training organisations (RTOs), such as universities and TAFE colleges. A nationally accredited seafood industry training course is now available in Australia; the Australian National Training Authority and various RTOs are offering specific aquaculture components of this course in many regional and urban areas. Graduate and post-graduate training in aquaculture is also available from selected institutions, and farmers are encouraged to consider taking on both local education and training courses as well as those offering distance education in aquaculture (*e.g.* Deakin University in Victoria).

Table 11.1: A summary of issues/risk factors to be examined during feasibility/ business planning.

Issue	Potential risk	Comments
Natural resources (see Chapter 5)	Geology	Suitability for the construction & operation of ponds Accessibility of underground water resources
	Topography	Likelihood of flooding Suitability for the construction & operation of ponds and irrigation systems (use of gravity).
	Soils	Water retaining properties Presence of acid sulfate or sodic soils Contamination – soil should be tested for residues of herbicides and pesticides. Suitability for irrigated crops
	Climate	Assess likelihood of flooding, drought or storms Ambient temperatures, rainfall, evaporation, sunshine, wind speed and direction.
	Water Supply	Seasonal changes to quality and quantity. Sources of pollution Access – allocation permits Cost of purchasing water and supplying site Long-term data should be collected
Aquaculture System (See Chapter 5)	Farm dams	Recommended stocking densities
	Ponds	Abundant supply of good quality water, suitable geology, topography, soils and climate required.
	Tanks	Abundant supply of good quality water, suitable climate, suitable topography, soils for effluent disposal.
	RAS	Access to reliable supply of water, suitable topography, soils for effluent disposal. Level of capital investment.
	Cages	Access to lake/ standing water with adequate depth and good water quality. Permission from relevant authorities if public waters
	Species	Biological requirements (temp, salinity, water) Market demand and price Aquaculture status – availability of juveniles Legislative restrictions Time to market (growout)
Effluent disposal (See Chapter 5)	Irrigation	Suitable topography, soils for wastewater irrigation. Quantity and quality of effluent sufficient to meet crop requirements.
	Hydroponics	Quantity and quality of effluent sufficient to meet plant requirements.
	Evaporation	Sufficient storage areas to cope with effluent. Protection of adjacent soils and water sources (use of pond liners)
	Remediation	Choice of appropriate species to remediate wastewaters (algae, mollusc, crustaceans, fish, trees). Appropriate stocking densities, markets.
General	Planning	Whole of farm plan (physical) Whole of farm plan (business) Marketing strategy
	Economics	Cost benefit analysis using realistic market prices, setup and production costs
	Training	Access to technical training/ support and extension
	Quality Assurance	Relevant quality assurance and food safety standards known and requirements met (*e.g.* purging facilities)
	Aquatic animal health	Access to diagnostic veterinary service; basic training in diagnostic techniques and treatments.

Practical short courses and associated field days, offered by industry associations and private consultants, are also often very relevant and useful. Local industry extension officers can usually direct farmers to the most appropriate courses available to meet specific needs. Most RTOs also widely promote available courses on the internet.

Potential IAAS investors and operators should also be aware of government funding assistance to undertake targeted training designed specifically to improve business management skills in the areas of primary production, fisheries and aquaculture. Financial assistance is available at the present time through the FarmBi$ initiative, specifically for training to improve skills such as financial management, marketing, risk management, Best Practice and natural resource management. Further information is available on the Agriculture, Fisheries and Forestry – Australia website (www.affa.gov.au/farmbis) and from respective state-based Departments of Primary Industries (agriculture, fisheries/aquaculture or equivalent).

IAAS "Nodes" and Management of Regional Business Enterprises

The development of a viable IAAS industry sector in Australia, as described by Gooley (2000) and Gooley and Gavine (*In press*), is likely to be based initially around regional nodes, probably centred on discrete irrigation areas, catchment or water management authority boundaries. This formal IAAS regional business structure would oversee the implementation of various initiatives designed to facilitate regional scale IAAS investment and associated development. The ultimate objective would be to secure the broad scale establishment of sustainable, IAAS enterprise on Australian farms. Individual farms are likely to be heavily dependent on the establishment of business networks or clusters within these nodes, not only for production purposes but also for post-harvest handling and marketing purposes.

The underlying rationale is that the commercial development of IAAS in Australia is likely to be *via* a commercial joint venture approach between the irrigation industry (farmers, water authorities *etc*) and Government at a State and National level, and necessitate the establishment of regional scale IAAS business units. The strategic direction of each regional IAAS business or 'node' may be undertaken under contract by a consortium or working group made up of key, skills-based stakeholders. The day to day administrative/secretarial function of the consortium could be further sub-contracted to a private company/operator with assistance from relevant government agencies where appropriate. The mission of the regional nodes would be to develop, promote and coordinate IAAS Best Practice to enhance overall farm productivity and water-use efficiency for a specified network of farmers and other stakeholders.

Each node should be operated on a commercial project management basis, with full financial accountability. Measurable performance criteria should be outcome-focussed and should include use of appropriate economic (including market-based) and environmental indices, at a site, catchment, regional, and national scale. The secretariat would make extensive use of electronic media for routine communications, promotion, marketing and training, including internet and associated distance education platforms, in addition to providing appropriate levels of personal contact time where required *via* more conventional extension methods. Peak aquaculture and agriculture industry bodies, as well as regional industry associations may well play a pivotal role in this area.

The focus for IAAS investment and formation of commercial networks should be on existing, major irrigated agri-business sectors including horticulture, viticulture, dairy and grains (particularly rice). It should further focus on those sectors which have existing cooperative business networks or clusters which can readily facilitate the development of a diversified farming base. Engagement of these sectors should be pursued broadly through the popular media using conventional promotional techniques, as well as through the use of more targeted extension resources (electronic, hardcopy *etc*) and through personal contact (meetings, workshops *etc*). The latter contact should focus on key industry peak bodies, management advisory committees and relevant Government agencies. Detailed and comprehensive resource inventories and associated databases are being compiled by various state agriculture and natural resource management agencies around Australia and should be available for further market appraisal purposes.

The primary value to IAAS "customers" of the regional business networks is in providing the information, technology and extension support necessary to diversify the existing farm enterprise to accommodate production of high-value cultured finfish species on-farm using much of the existing irrigation infrastructure and available personnel. There is no competition to this approach at the present time as IAAS practice to date in Australia is largely *ad hoc*, fragmented and opportunistic at best.

Risks do exist however in relation to practitioners pursuing IAAS enterprise in isolation and without the requisite information and support. Such practices will inevitably fail to achieve consistent Best Practice standards, will result in some commercial failures, and will create negative perceptions within Government, the community and industry as a whole. Furthermore, there is some institutional resistance to change within Government and industry in relation to adaptation of IAAS concepts. This resistance is based largely on lack of understanding of the benefits and costs of IAAS, as well as the often entrenched, ideological attitudes of some authorities engaged in large-scale land and water management issues. Community perceptions regarding the environmental performance of aquaculture are also often quite negative and will need to be addressed by promoting the net environmental benefits of aquaculture.

A coordinated and well managed and resourced response to these challenges would be one of the many tasks confronted by the regional networks as the IAAS sector in Australia proceeds into the commercialisation phase.

Commercialisation needs for regional IAAS development

The imperatives of commercialising IAAS in Australia dictate the need for certain ‘must do’s’, including:

1) **Preparation of resource inventories, marketing, planning and extension tools**. Information will include:

- data on quality, quantity, location and cost of available water resources;
- type, location and cost of available infrastructure;
- suitability and availability of marketable species, including biological requirements (NB: seedstock supply and associated policy constraints);
- post-harvest handling requirements, food safety, processing, freight, storage and market needs;
- skills-based training and education and extension support availability.

Comprehensive information packages are becoming available, in some cases to assist farmers in the process of collating information as part of the investment process in commercial scale IAAS development (*e.g.* See Victorian IAAS Investment Portfolio 2001). Indeed this Handbook is a further contribution to the information resource base of the industry.

2) **Establishment of demonstration farms and implementation of on-farm R&D, environmental monitoring, training and education services** – demonstration farms to be strategically located within key regional areas to provide focus for:

- business development, promotion and marketing;
- R&D, extension and training and education support;
- baseline environmental monitoring programs as part of farm and catchment scale management planning;
- Economic evaluation of commercial performance.

R&D support would be targeted at industry priorities of both commercial outcomes and environmental sustainability. R&D investment by the IAAS enterprise would typically be on a joint venture basis with regional IAAS business networks, and broader IAAS stakeholders including government agencies, and water authorities. Resultant intellectual property would be reinvested back into the IAAS enterprise on a fair and equitable basis, but with the intention of enhancing the longer-term economic and environmental sustainability of the sector. Provision of skills-based training and education will be facilitated by collaboration through authorised education service providers delivering relevant nationally accredited training courses, with an emphasis on multi-skilling and distance learning methods.

3) **Establishment of IAAS business networks and marketing support** – administrative support to be provided to regional IAAS business networks with an emphasis on:

- initial start-up operations, including Whole-of-Farm planning incorporating IAAS system design and operation;
- development of network specific IAAS business plans including provision of comprehensive economic cost-benefit analysis and financial planning analysis;
- IAAS marketing and promotion, and establishment of appropriate post-harvest handling protocols and processes.

Financial planning analysis should be based on reliable, user-friendly and purpose built proprietary PC-based software packages which are able to simulate IAAS financial circumstances and produce standardised profitability indicators. Community based IAAS marketing and promotional support will be provided through a centrally coordinated, multi-media approach. Specific consultative support will also be provided, typically to effectively engage broader stakeholders such as regulatory agencies for the efficient establishment and operation of regional IAAS business networks.

'Whole-of-Farm' IAAS Business Plans

General guidelines for business planning are readily available on the internet, typically *via* websites for various Australian departments of state and regional development (or similar), and specifically for the primary industries sector from the federal government's AFFA (Agriculture, Forestry and Fisheries Australia) website (*www.affa.com.au*)(see Annex I of this chapter for summary guidelines).

A comprehensive explanation of the rationale and process for completing a feasibility study and business plan for aquaculture is provided by PSMCG (1996). This plan, although not specific for integrated agri-aquaculture systems *per se*, is considered a suitable template for new IAAS investors as a starting point, after which the relevant components can be subsequently incorporated into what should be an existing, "whole-of-farm" business plan. This will then facilitate in a progressive, perhaps iterative manner, the process of defining and evaluating on paper the proposed integrated business in comparison with the existing stand-alone agricultural business. A broad outline of a simple business plan suitable for IAAS is provided in DNRE 2002.

Conclusions

In conclusion, new IAAS investors in Australia are encouraged to investigate all aspects of their proposed development before committing themselves financially and in any practical way on the ground. All pertinent issues, most of which have been only briefly touched on in this introductory chapter, need to be thoroughly evaluated using all available management tools and documented information. To this end, other chapters in this Handbook are also likely to be very informative. Furthermore, extension services and other like-minded practitioners within the agriculture and aquaculture sectors need to be effectively engaged to ensure that all available technical expertise and working models are accessed at the earliest possible stage of development.

Acknowledgements

The authors wish to acknowledge the assistance of Dr. Glen Whisson, Curtin University of Technology, Western Australia, who provided constructive comments on the draft of this chapter.

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ANNEX 1

BUSINESS PLAN GUIDELINES FROM AFFA

B U S I N E S S   P L A N

A business plan is a plan for the whole enterprise. It is a critical analysis of opportunities and challenges for an enterprise and provides strategic direction towards achieving its vision for the enterprise. Ideally a business plan should encompass the following elements:

1. **A brief history of the enterprise** from its incorporation to present time highlighting any change of its original line of business and range of products it produces, its performance over the years, impediments it faced and strategies it adopted to manage the business.

2. **Objectives (both short-term and long term**) - A short statement of objectives of the business, highlighting how the short-term objectives are aligned with the long term objectives.
   - A discussion of the relationship of the proposed project with the overall objective of the enterprise.

3. **Market analysis** of the range of products the enterprise produces:
   - ***Understanding of the market:*** identification of the markets for the products produced, both domestic and overseas; market segmentation; determination of the size of the market; identification of competitors who produce similar or complementary products; likely share of the market the product/business intends to capture; and identification of barriers, legal or otherwise, in marketing the product in the domestic and overseas market.

   - ***Marketing strategies*** - An analysis of how the business is envisaging to market its products in the domestic and overseas markets.

     - The analysis should focus on any competitive advantage the business holds over its competitors. The competitive advantage encompasses three aspects - technical superiority; price advantage and enhanced quality or wide range of uses of products.

       - Marketing strategies may include, for example:
         : strategic alliance with distributors or similar other arrangements to market products;
         : joint venture arrangements with other businesses in the domestic and overseas markets; and
         : opening distribution networks.

4. **Market Returns - Cash-flow analysis**

This section should include likely market returns of products from both domestic and overseas operations of the business. A cash-flow analysis is a report of the cash flow generated by the firm's operations, investments and financial activities. It is not an income-expenditure statement. It is based on the current and expected level of production, price of inputs and products and the market share the business is likely to capture.

5. Management Structure of business

This section sets out the skills of key personnel involved in the management of the business and their strengths and weaknesses. It also shows the line of hierarchy in the management of the business stipulating clearly key tasks and responsibilities of each person.

6. Financial Management

This section should include an analysis of:

- how the business envisages its funding requirements and how that requirement would be met from cash inflows that would be generated from its business operations;
- what risk management strategies it has in place for a back up arrangement in the situation, when it fails to realise its expected market returns; and
- the availability of financial management skills to the business.

7. Human Resources Management

An analysis of human resources should:

- identify the availability of in-house skills to manage human resources of the business;
- include a stock take of skills available to the business; and
- identify the required skills including how those skills are accessed during its business operations.

8. Risk Management

This section involves the identification of both technical and business risks and the development of appropriate strategies to address the identified risks. Risks should be prioritised in terms of the most critical risks, which will undermine the success of the business. This will enable risks to be anticipated and redressed earlier than otherwise.

9. Performance Monitoring and evaluation

This section deals with the identification of:

- key performance indicators and the strategies to monitor the performance of key personnel;
- the mechanism to evaluate the performance of its operations, including auditing of accounts;
- evaluation should include an analysis of:
  - effectiveness - the extent of achievement of the enterprise objectives;. and
  - efficiency – the success of the enterprise to achieve its objectives in the most cost effective way.

Appendix I

Key Contacts for Business Planning

Federal Government/ National Organisations

Agency	Web site	Contact details	Core Responsibilities
Natural resources			
Geoscience Australia AGSO and AUSLIG	www.ga.gov.au	GPO Box 378, Canberra ACT 2601 02 6249 9111	• Geology; • Topographic information and maps
Bureau of Meterology National Climate Centre.	www.bom.gov.au	Tel: 03 9669 4082 Fax: 03 9669 4515	• National and local data: • Meterological, hydrological and oceanographic
Australian Natural Resource Atlas	http://audit.ea.gov.au/ANRA	Tel: 02 6257 9516 Fax: 02 6257 9518 Info@nlwra.gov.au	• On-line database: • Agriculture, • Coasts, • Land, • People, • Rangelands, • Vegetation & biodiveristy, • Water.
Environment Australia	www.ea.gov.au		• ANZECC Secretariat • Biodiversity • Heritage • Inland waters • Land management. • Meterology • Parks and Reserves
Murray Darling Basin Commission	www.mdbc.gov.au	Tel: 02 6279 0100 Fax: 02 6248 8053	• Management of resources in the Murray Darling Basin
Primary Industries			
Agriculture Forestry and Fisheries Australia	www.affa.gov.au	Tel: 02 6272 3933 02 6272 5777 (Fisheries)	• Service to primary industries and sustainable management of resources
Australian Bureau of Agriculture and Resource Economics	www.abare.gov.au www.abareconomics.com	Tel: 02 6272 2000 Fax: 02 6272 2330	• Economic research and policy analysis for Australian Fishing Industries
Bureau of Resource Sciences	www.brs.gov.au	Tel: 02 6272 3933	• Scientific advice to government on industry and resource development
Australian Quarantine Inspection Service	www.aqis.gov.au	Tel: 02 6272 4523 Fax: 02 6272 3050	• Controls export of all seafood from Australia
Rural Development			•
Transport and Regional Services	www.dotrs.gov.au	Tel: 02 6274 7111	• Federal grants for infrastructure development
Trade, Marketing, value-adding			
Austrade	www.austrade.gov.au	Ph 13 28 78	• Export and investment facilitation service
Australian Seafood Industry Council	www.asic.org.au	Tel: 02 6281 0383 Fax: 02 6281 0438	• Peak body representing commercial fisheries, aquaculture and post-harvest seafood.
Seafood Services Australia	www.dpi.qld.gov.au/food	Tel: 07 3406 8595 Fax:07 3406 8677	• Information and advice on technical issues. Guidance on food safety, quality assurance and standards.
Research and development			
CSIRO Land and Water	www.clw.csiro.au		• Research organisation
Fisheries Research and Development Corporation	www.frdc.com.au	Tel: 02 6285 0400 Fax: 02 6285 4421	• Funds research into fisheries and aquaculture
Land and Water Research and Development Corporation	www.lwrdc.gov.au		• Funds research into sustainable land and water use
Rural Industries Research and Development Corporation	www.rirdc.gov.au	Tel: 02 6272 4539 Fax: 02 6272 5877	• Funds research into rural industry development

Agency	Web site	Contact details	Core Responsibilities
Industry organisations			
Irrigation Association of Australia	www.irrigation.org.au	02 9746 0531	Information about irrigation industry and practices.
Australian Barramundi Association		07 4055 5676	Respresents Australian barramundi growers.
Australian Freshwater crayfish Farmers Association		08 8758 4000	Promote and develop crayfish farming
Australian Prawn Farmers Association	apfa@gff.org.au	07 3255 1070	Represents interests of the Australian prawn farming industry

New South Wales

Agency	Web site	Contact details	Core Responsibilities
Natural Resources			
NSW Natural Resources Atlas	www.canri.nsw.gov.au/ atlas/	Ph: 02 9895 7700 Fax: 02 9895 7834	• Community Access to Natural Resources Information
Department of Land and Water Conservation	www.dlwc.nsw.gov.au	Tel: 02 9228 6415 Fax: 02 9228 6458 Infocentre@dlwc.nsw.gov.au	• Information on land, soils and water resources • Resource management
NSW Fisheries Aquaculture Extension Service	Www.fisheries.nsw.gov.au	Tel: 02 9527 8411 02 4982 1232 02 6959 9034	• Management of commercial fisheries and aquaculture • Port Stephens Fisheries Centre • David Glendinning, Southern Region • ?? Northern Region
NSW Agriculture	www.agric.nsw.gov.au	Tel: 02 6391 3100 Fax: 02 6391 3336	• Animals • Field crops and pastures • Horticulture • Natural resources and climate
National Parks and Wildlife Service	www.npws.nsw.gov.au	Tel: 02 9253 4600 Fax: 02 9251 8482 1300 361 967 (in NSW)	• Licences and tenders • Threatened species • Wildlife atlas • National parks
Department of State and Regional Development	www.business.nsw.gov.au	02 9228 3111	• Promotes business development in NSW
Environmental Protection Agency	www.epa.nsw.gov.au	02 9995 5000	• Pollution control • Environmental monitoring
Marketing and processing			
Sydney Fish Market	www.sydneyfish market.com.au	Tel: 02 9552 2180 Fax:02 9552 1661	
Aquaculture organisations			
Australian Freshwater Crayfish Growers Association		Tel: 02 6566 9207	• Promotes crayfish farming in NSW
Gilgandra Aquaculture Association		Tel: 02 6848 3526	• Aquaculture development in Gilgandra
Murray Regional Aquaculture Association		Tel: 03 5884 6649	• Aquaculture Development in Murray Region
NSW Aquaculture Association		Tel: 02 4997 3002	• Aquaculture development in NSW
NSW Silver Perch Growers Association		Tel: 02 6723 3357 Rhoades@northnet.com.au	• Peak industry body in NSW

Queensland

Agency	Web site	Contact details	Core Responsibilities
Natural Resources			
Department of Natural Resources and Mines	www.dnr.qld.gov.au	07 3896 3111	• Climate • Land • Vegetation • Water (inc hydrology and hydrogeology) • Mines • Water and soil testing
Department of Primary industries	www.dpi.qld.gov.au	Tel: 07 3409 6999 132523 (in Queensland)	• Agency for food and fibre sciences • Animal and Plant health service • Queensland Fisheries Service (inc Aquaculture) • Forestry • Office of Rural Communities
Aquaculture Extension Service		07 4092 9908 07 3400 2039 07 4160 0704 07 4131 5833	• Max Wingfield, Northern Region • Millin Curtis, Bribie Island • Rod Cheetham, Kingaroy • Chris Lupton, Bundaberg
Environmental Protection Agency	www.epa.qld.gov.au	07 3227 8185	• Cultural heritage • Recreation • Plants and animals (biodiversity) • National parks • Business and industry • Protecting the environment
Department of State Development	www.sd.qld.gov.au	07 3225 1915	• Promotes sustainable regional development through partnerships with industry • Advice in business planning
Marketing and Processing			
Queensland Seafood Industry Association	www.seafoodsite.com.au	07 3262 6855	• Information on food, safety, quality assurance and marketing.
Aquaculture Organisations			
Aquaculture Association of Queensland	Ausyfish@isisol.com	07 4126 2511	• Promotes and represents finfish aquaculture sectors
Mackay Prawn Farmers Association		07 4956 4309	• Promotes development of the industry in Mackay
Queensland Crayfish Farmers Association		07 5486 7367	

South Australia

Agency	Web site	Contact details	Core Responsibilities
SA Atlas	www.atlas.sa.gov.au	Webmaster@atlas.sa.gov.au	• Database of natural resources and economic activity in SA
Primary Industries and Resources South Australia Aquaculture Development Officers (PIRSA)	www.pir.sa.gov.au	Tel: 08 8226 0222 Fax: 08 8226 0476 Fisheries and aquaculture: 08 8226 0227 08 8226 0349	• Geology, mineral resources and energy • Agriculture • Sustainable resources • Fisheries and aquaculture • SARDI • Rural support • Soil and water testing • Tara Ingerson, Adelaide •
Department of Environment and Heritage	www.deh.sa.gov.au		• Heritage and biodiversity • Parks and Wildlife • Office of coasts and marine
Department for Water Resources	www.dwr.sa.gov.au		• Lead agency for water resources management
Planning SA	www.planning.sa.gov.au	08 8303 0600	• Development applications/ proposals • Maps and spatial information
Environmental Protection Agency	www.environment.sa.gov.au	08 8204 2004	• Environmental information • Waste and resource management • Atmosphere and noise • Water quality management • Environmental planning & reporting
Marketing and Processing			
South Australian Fishing Industry Council	www.safic.asn.au		• Information on food, safety, quality assurance and marketing.
Aquaculture Associations			
Inland Aquaculture Association of South Australia		08 8362 842 roger@lm.net.au	• Fosters unity within inland aquaculture sector

Victoria

Agency	Web site	Contact details	Core Responsibilities
Department of Natural Resources and Environment	www.nre.vic.gov.au	Tel: 136186	• Aboriginal affairs • Conservation and Environment • Farming and agriculture • Fishing and aquaculture • Forestry • Land and water management • Parks and Reserves • Plants and animals • Property, titles, maps • Soil and water testing
Aquaculture Extension Service		Peter Lawson 03 5774 2208	• Inland aquaculture advice
Victorian Resources Online	www.nre.vic.gov.au/web/root/domino/vro/vrosite.nsf		• On line database of natural resource information
Environmental Protection Agency	www.epa.vic.gov.au	03 9695 2722	• Air • Land and groundwater • Litter • Noise • Waste • Water
Department of State and Regional Development	www.dsrd.vic.gov.au		• Regional development • Assistance to small businesses
Marketing and processing			
Melbourne Fish Market	www.chsmith.com.au	Tel: 03 9417 1077 Fax: 03 9416 1171	• Information of fish prices and markets
Seafood Industry Victoria	www.siv.com.au	Tel: 03 9824 0744	• Information on food, safety, quality assurance and marketing.
Aquaculture organisations			
Australian Freshwater Crayfish Growers Association		Tel: 03 5433 2332	• Promotes Victorian yabby industry.
Gippsland Aquaculture Industry Network	www.growfish.com	Tel: 03 5143 2322	• Promotes industry development in Gippsland
Victorian Aquaculture Council	www.vicaquacouncil.com	Tel: 03 9372 5666	• Peak body representing Victorian aquaculture
Victorian Eel Fishermans Association		Tel: 03 5598 5364	
Victorian Ornamental Fish Growers		Tel: 03 5697 1693	
Victorian Trout Farmers Association		Tel: 03 5773 2483	
Warmwater Aquaculture Association		Tel: 03 9817 3403	

Western Australia

Agency	Web site	Contact details	Core Responsibilities
WA Land information System	www.walis.wa.gov.au	Ph: (08) 9273 7046 Fax: (08) 9273 7691 Email:walis@walis.wa.gov.au	GIS database of natural resource information
Fisheries Western Australia	www.wa.gov.au/westfish		• Aquaculture information • Commercial fishing information
Aquaculture development Officers		• 08 9841 7766 • 08 9881 0222 • 08 9941 1185 • 08 9192 1121 • 08 9168 2911 • 08 9482 7201	• Southern Region • Eastern districts • Gasgoyne/Mid West • Kimberley West • Kimberley East • Metropolitan
Agriculture Western Australia	www.agric.wa.gov.au		• Agriculture • Land use • Soil and water testing
Waters and Rivers Commission	www.wrc.wa.gov.au	Tel: 08 9278 0300 Fax: 08 9278 0301	• Information on water resources, allocations and licensing
Dept Conservation and Land Management	www.calm.gov.au	Tel: 08 9334 0333 Info@calm.wa.gov.au	• Plants • animals • Biodiversty and • natural ecosystems
Department of Environmental Protection	www.environ.wa.gov.au	08 9222 7000	• Air • Land and groundwater • Litter • Noise • Waste • Water
Department of Industry and Technology	www.indtech.wa.gov.au	08 9222 5555	• Industry and technology development
Regional Development Commissions	www.wa.gov.au/regional	1800 628 727	• Promotes regional development
Marketing and processing			
Seafood Quality Management Initiative	www.wa.gov.au/westfish/sqmi/index.html		•
Aquaculture organisations			
Aquaculture Council of WA		08 9244 2933	• Peak body for aquaculture industry in WA
Commercial Marron Farmers Association of WA		08 9317 2950	• Represents the interests of the marron industry
Marron Growers Association of WA Inc		08 9298 8425	• Represents the interests of the marron industry
Silver Perch Association of WA		08 9776 1240	• Represents growers of silver perch

Annex II

Water Quality Guidelines for the Protection of Aquatic Food Species (ANZECC, 1992)

	Guideline (mg/L)	
Compound	Freshwater production	Saltwater production
PHYSICO-CHEMICAL INDICATORS		
Alkalinity	50-100	>80
Biochemical oxygen demand	<15	<10
COD	<40	<40
Carbon dioxide	<10	<15
Colour and appearance of water	30-40	30-40
Dissolved oxygen	>5	>5
Gas supersaturation	<105%	<105%
Ph	5.5-8.0	6.5-8.0
Salinity (total dissolved solids)	See specific requirements in section 10.2.1.8, Vol 1	see specific requirements in section 10.2.1.8, Vol 1
Suspended solids (and turbidity)	<25	<10 (<75 Brackish)
Temperature	<2.0^{o}C change over 1 hour	<2.0^{o}C change over 1 hour
Total hardness ($CaCO_3$)	20-100	>50
INORGANIC CHEMICALS (METALS AND OTHERS)		
Aluminium	<0.03 (pH>6.5) <0.01 (pH <6.5)	<0.01
Ammonia (un-ionised)	<0.02 (pH>8.0) <0.01 (pH≤8.0)	<0.02 (pH>8.0) <0.01 (pH≤8.0)
Arsenic	<0.05	<0.03
Cadmium	<0.0002-0.0018	<0.005
Chlorine	<0.003	<0.003
Chromium	<0.02	<0.02
Copper	<0.005	<0.005
Cyanide	<0.005	not of concern
Fluoride	NR	NR
Hydrogen sulfide (sulfides)	<0.001	<0.002
Iron	<0.01	<0.01
Lead	<0.001	<0.02
Magnesium	<15	-
Manganese	<0.1	<0.1
Mercury	<0.001	<0.001
Nickel	<0.1	<0.1
Nitrate (NO_3^-)	<50	<100
Nitrite (NO_2)	<0.1	<0.1
Phosphates (phosphorus)	<0.1	<0.05
Selenium	<0.01	<0.01
Silver	<0.003	<0.003
Tributyltin	NR	NR
Total available nitrogen (TAN)	<1.0	<1.0
Vanadium	<0.1	<0.1
Zinc	<0.01	<0.01
ORGANIC CHEMICALS (NONPESTICIDES)		
Detergents and surfactants	<0.0001	NR
Methane	<65	<65
Oils and greases (including petrochemicals)	<0.1	<0.1
Phenols and chlorinated phenols	<0.0000006-0.0000017	NR
Polychlorinated bi phenyls (PCBs)	<0.000002	<0.000002

continued

PESTICIDES		
2,4-dichlorophenol	4.0	
Aldrin	0.01	NR
Azinphos-methyl (926) (Gunthion)	0.01	
Chlordane	0.01	0.004
Chlorpyrifos (2190) (Dursban)	0.001	
DDT(including DDD & DDE)(2832)	0.0015	
Demton (2875)	0.01	
Dieldrin (3093)	0.005	
Endosulfan (3529)	0.003	0.001
Endrin (3522)	0.002	
Gunthion (see also Azinphos-methyl)	0.01	
Hexachlorobenzole	0.00001	
Heptachlor (4576)	0.005	
Lindane (5379) (BHC)	0.01	0.004
Malathion (5582)	0.1	
Methoxychlor (5913)	0.03	
Mirex (6126)	0.001	
PAH		
Parathion (6983)	0.04	
2,3,7,8-tetrachlorodibenzodioxin		
Toxaphene (9478)	0.002	

Appendix III

Notes on potential culture species

1. Atlantic salmon

Scientific name: *Salmo salar* Linnaeus, 1758.

Environment and Status: Exotic (benthopelagic)- freshwater, brackish, marine.

Distribution: Naturally found in western Atlantic coastal drainages from northern Quebec in Canada to Connecticut in USA, and within the eastern Atlantic drainages from the Arctic Circle to Portugal. Unsuccessful initial stocking in Tasmanian and Victorian waters during the late 1860s. Re-introduced into New South Wales from Nova Scotia in 1963-65. Stocking of Burrinjuck Dam and Lake Jindabyne, New South Wales, on an annual basis (Davies and McDowall 1996).

Aquaculture Status in Australia: Now well established, the majority of Australia's Atlantic salmon industry is in sea cages in south-east Tasmania and began over 17 years ago (1984-1986). There are four licensed producers in north-east Victoria; a commercial-scale fish farm producing premium grade salmon caviar, and three tourist fish farms where fish are stocked for angling. South Australia produced around 14 tonnes in 1998/99. Total Australian production for the same period was 7,134 tonnes (O'Sullivan and Dobson 2000).

Broodstock: Atlantic salmon spawn once per year in May- June and may be artificially stripped in a hatchery environment. Female broodstock can lay up to 1,800 eggs/kg bodyweight, are fertilised by mixing with male milt and then placed in hatching troughs. Depending on the water temperature, the eggs hatch 40-80 days later and the young salmon feed on their yolk sac for a further 20-35 days. The fish are weaned onto artificial diets almost immediately and the larvae are held in freshwater raceways for a short period (approx. 20 days) before being transferred to large freshwater ponds or cages in freshwater lakes.

Hatchery/Juvenile Production: Atlantic salmon are anadromous fish, i.e they live most of their life in the sea, but migrate to freshwater to spawn. To achieve the best growth rates, the aquaculture production cycle mirrors the natural cycle and involves two distinct phases: juvenile production in freshwater (1-2 yrs), followed by growout in seawater. Juvenile fish grow rapidly in freshwater and after 8-15 months, a proportion of the stock are transferred to sea (at around 60-200 g) as salmon "smolts". Other fish grow more slowly, however, and will require a further year in freshwater before being transferred to sea.

Grow-out Systems:

Intensive: The most common growout systems for Atlantic salmon are sea pens/cages. These cages are moored in estuaries or offshore and are stocked initially at a rate of less than $1kg/m^3$, the aim is to reach a maximum density at harvest of $12\text{-}15kg/m^3$. This stocking density is low compared with those used overseas, but the fast growth rates compensate for the lower density. The fish are fed commercial pelleted diets and consistently achieve FCRs of 1.4-1.5:1. Salmon are harvested from the sea cages after one year at a weight of approximately 4kg.

Semi-intensive: Semi-intensive salmon farms in Victoria use flow through "Danish" pond systems similar to those used by the trout industry. Around 1 ML of water per day is used to produce 1 tonne of harvest sized fish per annum. One Victorian salmon farm does not have a sea phase in its production cycle; it's focus is on producing premium quality caviar rather than maximising growth rates. Salmon held in freshwater for their entire life cycle have slower growth rates than those transferred to sea. In Tasmania, smolts are produced in ponds or tanks.

Extensive: Atlantic salmon are often stocked into tourist fish ponds due to their superb fighting skills on rod and line.

Culture attributes:

- Techniques for breeding and ongrowing are well-established;
- Fry are easily weaned onto artificial diets and species-specific diets are readily available;

Atlantic salmon inhabit waters of 0-20^{o}C, but their optimum temperature is 10-16^{o}C (Shepherd and Bromage 1990).

Marketing attributes:
The flesh of the Atlantic salmon is pale to dark and reddish pink, it has soft medium-sized flakes with a mild, distinct flavour. Australian salmon is recognised as being amongst the highest quality in the world and this is a huge marketing advantage. The Australian industry does not suffer the same disease problems as salmon farms in other areas of the world. It is highly regarded in Asian markets (approx. 70% exported to Japan), with a premium price in excess of AUS$12/kg. Value-added products, such as caviar, f*etc*h premium prices (in excess of $80/kg). The majority of fish is sold as chilled whole, gilled and gutted, but other products include cutlets, fillets, smoked slices, smoked sides, paté, gravlax, and sashimi. There is a significant local market in Australia of several thousand tonnes of fresh and smoked products every year.

Industry Organisations:

Marine Farmers Association of Tasmania,
PO Box 83, Triabunna, TAS 7190.
Tel/Fax: (03) 6257 7466.

Tasmanian Aquaculture Council,
PO Box 878, Sandy Bay, TAS 7006.
Tel (03) 6224 2332 Fax (03) 6224 2321.

Tasmanian Salmonid Growers Association Ltd,
GPO Box 1614C, Hobart, TAS 7001.
Tel (03) 6224 2521 Fax (03) 6224 3006.

Key References/ Further Reading:

Davies, P. E. and Mc Dowall, R. M.1996. Family Salmonidae, salmons, trouts, and chars. P. 81-91. *In:* McDowall, R. M. (ed) Freshwater fishes of south-eastern Australia. Reed Books Australia, Chatswood, NSW.

O'Sullivan, D. and Dobson, J. 2000. Status of Australian Aquaculture 1998/99. Austasia Aquaculture Trade Directory 2000-2001.

Shepherd, C.J. and Bromage, N.R. (eds.), Intensive Fish Farming. BSP Professional Books, Oxford, pp 17-49.

Atlantic salmon Factsheet: DPIWE, Tasmania (www.dpif.tas.gov.au)

The Atlantic salmon Aquaculture industry in South Australia (www.pir.sa.gov.au)

2. Barramundi

Scientific name: *Lates calcarifer* Bloch, 1790.

Environment and Status: Native (demersal)-freshwater, brackish, marine; Common.

Distribution: Barramundi or sea bass (Asia) occur throughout the Indo-west Pacific region. In Australia they inhabit the tropical coastal and freshwater systems of the north.

Aquaculture Status in Australia: Primarily farmed in Queensland, Northern Territory, Western Australia, South Australia and New South Wales. Most producers in the northern parts of Australia grow fish in cages in freshwater ponds or estuarine waters. In the southern states, barramundi are mainly grown in heated indoor intensive recirculating tank systems - the only system permitted in Victoria. One producer in South Australia utilises hot artesian bore water in a flow-through system. Total Australian production for 1998/99 was 802.5 tonnes (O'Sullivan and Dobson 2000); an increase of almost 16% over the previous year.

Broodstock: In nature, barramundi spawn during full and new moons over the summer season. Barramundi broodstock can be spawned easily in captivity and can be kept in spawning condition all year round under controlled conditions (Barlow 1998). Females are capable of multiple spawnings and generally produce between 3-6 million eggs per season. Spawning requires the injection of reproductive hormone. Eggs and larvae require seawater for fertilisation and survival. Hatching takes about 14-17 hours and larvae commence feeding 1-2 days after hatching.

Hatchery/Juvenile Production: Juvenile production is now fairly established, and the development of extensive nursery culture has reduced the price for fingerlings. Larvae are either raised in tanks or more extensive rearing ponds and metamorphose into fry around 12-20 days after hatching (11-12mm in length). Fingerlings are maintained in the nursery facilities, where they are weaned onto artificial diets, until they are approximately 80mm. They are then transferred to growout systems. Regular grading is required as juveniles are carnivorous.

Grow-out Systems:

Intensive: Barramundi are grown in freshwater ponds and seacages in Queensland, and ponds in the Northern Territory. Intensive tank culture is underway in South Australia and New South Wales. The only growout systems approved for the culture of Barramundi in Victoria are intensive recirculating tank grow-out systems, as these systems are regarded as "bio-secure" and thereby minimise the risk of fish escape or disease transfer (DNRE 2000).

The most common growout system is pond culture in either brackish or fresh water, where fish are usually maintained in cages within the pond. Cages are usually 4-50m^2 in surface area and 2-4 m deep. Stocking densities are 15-40 kg/m^3 provided the cages are cleaned regularly. Water in the pond is exchanged at a rate of 5-10% pond volume per day.

Commercial growout in intensive recirculation systems starts once the fingerlings reach 30-80 mm. Stocking rates in tank systems vary depending on the intensity of the operation, but a medium stocking density of 30-40 kg/m^3 is generally adopted. More sophisticated systems may be able to increase stocking densities, depending on farm management skills.

Barramundi are carnivorous fish and require a high protein diet for efficient growth. Juveniles are readily weaned onto high quality extruded diets. Commercial barramundi diets are available from a number of feed suppliers and FCRs of 0.7:1 to 2.0:1 have been reported. The fish exhibits fast growth rates and can grow to 300mm/375g in 5 months.

Culture attributes:

- Fast growth rates;
- Readily weaned onto high quality extruded diets;
- Existing supply of juvenile stock for culture in grow-out facilities.
- Readily school and adapt easily to high stocking densities.

Marketing attributes: Barramundi is internationally regarded as a premium table fish. It has large firm flakes of tender white flesh. Australian barramundi is considered superior to those produced in other locations. Opportunities to develop overseas markets for barramundi are probably limited due to Australia's high production costs.

In local markets, barramundi has a well-established position in the market place and there are a number of products available to the producer. These include: live fish; plate sized whole (300-500g); and fillets or larger whole fish.

Industry Organisations:

Australian Barramundi Farmers Association (ABFA),
PO Box 35, Edmonton, QLD 4869.
Tel (07) 4055 5676 Fax (07) 4045 1121.

The Warmwater Aquaculture Association,
30 Cecil St, Kew, VIC 3101.
Tel (03) 9817 3043 Fax (03) 9816 9930.

References:

Grey, D. L., 1987. An overview of *Lates calcarifer* in Australia and Asia. pp 15-21, in *Management of wild and cultured sea bass/barramundi (Lates calcarifer).* Copland, J. W. and Grey, D. L. (ed). ACIAR Proceedings 20. Canberra: Australian Centre for International Agricultural Research.

Barlow, C. (1998). Barramundi. In: *The New Rural Industries - A Handbook for Farmers and Investors*. (ed. by K. Hyde), pp. 93-100. Rural Industry Research and Development Corporation, Canberra.

Barlow, C., Williams K., and Rimmer, M. (1996). Sea bass culture in Australia. Infofish International. Vol 2/96 pp 26-33.

DNRE, 2000. Guidelines for farming barramundi in Victoria.

O'Sullivan, D. and Dobson, J. 2000. Status of Australian Aquaculture 1998/99. Austasia Aquaculture Trade Directory 2000-2001.

Barramundi. DPI Note. www.dpi.qld.gov.au

Farming barramundi. www.wa.gov.au/westfish.

3. Eels (Shortfin and longfin)

Scientific name: *Anguilla australis* Richardson, 1841 (Shortfin) & *Anguilla reinhardtii* Steindachner, 1867 (Longfin).

Environment and Status: Native - fresh and salt water, Common.

Distribution: The shortfin eel is a temperate species but with a natural range which extends from southeast Queensland through to Victoria, Tasmania and the Murray River in South Australia. In contrast, the longfin eel is a typically a more sub-tropical species but also has a broad natural distribution extending from northern Queensland through to eastern Victoria and northeastern Tasmania.

Aquaculture Status in Australia: Commercial producers in Victoria, Tasmania, New South Wales, and Queensland rely solely on the capture of seedstock (glass eels and elvers) from the wild. Currently there is no commercial supply of Australian glass eels although a number of industry groups, in collaboration with state agencies in Victoria, New South Wales and Queensland, have obtained permits to capture glass eels (50-200kg/state). These eels are primarily used for commercial grow-out trials in intensive freshwater recirculation systems. Wild elvers and sub-adult eels are translocated from Victorian and Tasmanian coastal rivers to public and private lakes, swamps, wetlands and farm dams where they are left to grow (extensive) to marketable size. The majority of production is from Victoria with 225 tonnes produced in 1998/99 (O'Sullivan and Dobson 2000).

Hatchery/Juvenile Production: Due to the complexity of the eel's reproductive cycle there have been no successful efforts in spawning shortfin or longfin eels in captivity. Newly caught glass eels are usually fed a diet of minced fish or fish roe for 2-4 weeks before commencement of weaning onto artificial diets.

Grow-out Systems:

Intensive: Intensive grow-out systems for eels are recirculating tanks systems. Eels have a high stocking density tolerance (<100 kg/m^3) which means that a large number can be produced in a relatively small area. Food conversion rates in Asian and European systems vary between 0.9 and 1.9:1. Medium to fast growth rates are achieved in these systems with elvers growing from 2.5 g to 180-200g in 9-18 months. Survival rates (after 2-3 months) are 75%.

Semi-intensive: Semi-intensive culture of eels is usually conducted in earthen ponds. Growout ponds usually range in size from 0.2-2 ha and are 1-1.5 m deep. Glass eel seedstock to can be grown to a harvest size of 180-200g in 6-18 months in Queensland. In Northern NSW, it is expected that eels could reach market size (200-300g) in 18-24 months. High stocking densities (<50 kg/m^3) can be reached in pond systems. Efficient food conversions (1.1-1.5:1 FCR) can be achieved and survival rates (after 2-3 months) are 75->90%.

Extensive: Extensive grow-out can occur in public and private lakes, swamps, wetlands and farm dams. Stocking rates of 0.0045-0.1457 kg/ha (with an average of around 1000 elvers/kg) are equivalent to 4.5-145.7 fish/ha. Yields range from <3kg/ha/yr to 160kg/ha/yr, depending on the location of the pond and other environmental factors. Growth rates are slow (>1 kg took 8-13 years after stocking).

Marketing attributes:
Eels have firm to medium, white to pink flesh. Eels may be sold whole when fresh or frozen, but are usually smoked and also sold as cutlets. In Japan "kabayaki" (small skinned, steamed and grilled eels) is regarded as a delicacy. Eels are highly regarded in Asian markets and attract a premium price. Prices vary in local markets vary, with best prices are reached for live product.

Industry Organisations

Victorian Eel Fisherman's Association,
RMB 4220, Timburn, VIC 3268.
Tel (03) 5598 5364.

References:

Gooley, G. J., McKinnon, L. J., Ingram, B. A., Larkin, B., and Collins, R. O. 1999. Assessment of juvenile eel resources in South-eastern Australia and associated development of intensive eel farming for local production. Marine and Freshwater Resources Institute Final Report FRDC Project No 94/067.

Jones, J. B., Astill, M. and Kerei, E. 1983. The pond culture of *Anguilla australis* in New Zealand - with special reference to techniques and management of the experimental farm at The Kaha , Bay of Plenty. Riv. Ital. Piscic. Ittiopatol. 18 (3&4): pp 85-117 & 138-166.

Skehan, B. W. and De Silva, S. S. 1998. Aspects of the culture-based fishery of the shortfinned eel, *Anguilla australis*, in western Victoria, Australia. *Journal of Applied Ichthyology* 14 (1-2): pp 23-30.

Gooley, G. J.and Ingram, B. A. (2001). Assessment of Eastern Australian Glass Eel Stocks and Associated Eel Aquaculture. Final Report to Fisheries Research and Development Corporation (Project No 97/312). Marine and Freshwater Resources Institute, Alexandra, Victoria, Australia.

Gooley, G. J. (1998). Eels. In: *The New Rural Industries* **-** *A Handbook for Farmers and Investors*. (ed. by K. Hyde), pp. 101-107. Rural Industry Research and Development Corporation, Canberra.

O'Sullivan, D. and Dobson, J. 2000. Status of Australian Aquaculture 1998/99. Austasia Aquaculture Trade Directory 2000-2001.

Tesch, F.-W. (1977). The Eel. Biology and Management of Anguillid Eels. Chapman and Hall, London. 434 pp.

4. Marron

Scientific name: *Cherax tenuimanus* Smith.

Environment and Status: Native, freshwater, Common

Distribution: Marron are native to the permanent rivers in the forested rainfall areas in the south-west of Western Australia. The distribution of this species has extended as far east as Esperance and as far north as Geraldton.

Aquaculture Status in Australia: Western Australia is responsible for 85% of Australia's marron production, with a production of 42 tonnes in 1998/99 (total Australian production was 49.2 tonnes) (O'Sullivan and Dobson 2000). Other states which culture marron are NSW (0.2 tonnes) and South Australia (7 tonnes). Whilst most of the sector's production comes from a few large semi-intensive farms (>10 ha) with purpose-built ponds, the majority of licence holders farm extensively – usually in farm dams, or have 1-2 ha of ponds.

Broodstock: Marron can be spawned in captivity under appropriate light, temperature and dietary conditions. Farmed broodstock are usually 2-3 yrs old as reproductive output depends on size. Marron mate in early spring and females incubate 200-300 eggs for 12-16 weeks under their tail, from which 150-250 pre-juveniles are released in early summer.

Growout Systems:

Semi-intensive: Purpose built semi-intensive growout ponds can produce 1,000-4,000 kg/ha/year of marron, depending on the stocking rate. Ideally, semi-intensive growout ponds are 1,000 m^2 in size, with a maximum width of 20-25m. Ponds should be aligned lengthwise with the prevailing wind direction to increase aeration and cooling. The pond bottom should slope from a minimum depth of 1.5 m to a maximum depth of 1.75 m. Specifications for the design of marron ponds are detailed on the WA Fisheries website (www.wa.gov.au/westfish).

In semi-intensive systems, juvenile marron (< 1 year old) are stocked in June-July at a density of 3-5 per m^2. Most marron farmers produce their own juveniles, however, there are several commercial hatcheries. Feeding strategy is the key to determining marron production from the ponds. Commercial operators use a combination of pelleted diets and natural feeds in the pond. Marron can grow to 60-100g within 12 months and 100-300g in 24 months.

Marron are not as tolerant to environmental fluctuations as yabbies; optimum growth is achieved at 24^{o}C but they will not grow at temperatures below 12.5^{o}C. Mortalities occur and growth declines rapidly above 30^{o}C.

Harvesting of marron is generally easier than yabbies as they do not burrow. Marron are usually harvested by draining the ponds and collecting the animals by hand, however, traps may also be used, particularly during the summer when draining the pond may stress the marron.

Extensive: Extensive culture generally means stocking and harvesting of farm dams, with little attention paid to the animals in between. Unfed farm dams can produce 100-300 kg/yr of marron.

Culture attributes:

- Juvenile seedstock readily available;
- Relatively easy to grow and harvest.

Marketing Attributes:

Marron may be harvested at any time over 100g and up to 650g. The most popular size class is 150-250g which is popular in the European market. Larger marron (> 400g) are more popular in the South East Asian market. Because they are available at larger sizes than yabbies, marron are regarded as a luxury product and attract far higher prices than other freshwater crayfish. (Yabbies are generally harvested at 40-50g, with a maximum of 100g).

Industry organisations:
Marron Growers Association of WA (Inc),
PO Box 359, Midland, WA 6936.
Tel: (08) 9652 6066.

Further Reading:

Lawrence, C. S. 1998. Marron. *In:* Hyde, K. (ed). The New Rural Industries – A Handbook for Farmers and Investors. Rural Industries Research and Development Corporation, Canberra.

O'Sullivan, D. and Dobson, J. 2000. Status of Australian Aquaculture 1998/99. Austasia Aquaculture Trade Directory 2000-2001.

Farming marron. www.wa.gov.au/westfish.

5. Murray cod

Scientific name: *Maccullochella peelii peelii* Mitchell, 1838.

Status: Native (demersal)- freshwater.

Distribution: Naturally found north of the Great Dividing Range throughout the tributaries of the Murray River, and the Murray Darling Basin.

Aquaculture Status in Australia: There are currently 35 commercial producers in south eastern Australia of which 15 are producing fingerlings for stock enhancement and aquaculture. To date, 16 have produced table fish both in ponds, and intensively in freshwater recirculation systems.

Production/ value: In 1998/99, Australian production of Murray cod was 30.4 tonnes (20 tonnes from Victoria) Production of Murray cod in Victoria has increased rapidly over the past 2-3 years, primarily due to the success of one large recirculation system. The production of juveniles alone (162,000) had a value of \$559,000 (O'Sullivan and Dobson 2000). It is expected that production will continue to increase over the next few years as a number of hatcheries and growout systems are under development.

Broodstock: Murray cod broodstock are usually wild-caught as there is currently no supply of mature farmed broodstock. Procuring broodstock is likely to become more difficult in the future as there are restrictions on commercial fishing in NSW and Victoria. The industry is trialing the use of domestic broodstock and this should improve the genetic quality and disease status of juveniles. Broodstock are kept in small static ponds and fed yabbies, goldfish, trout or ox liver. The fish spawn in nesting boxes in the pond and the eggs are removed from the boxes and transferred to the hatchery. Smaller fish can be induced to spawn using hormones.

Hatchery/ Juvenile Production: In recent years techniques have been developed to enable large-scale hatchery production of Murray cod juveniles, however juvenile production is still largely seasonal. The eggs are incubated in tanks; and take about 6-11 days to hatch. The fry are then transferred to outdoor fertilised earthen ponds (stocking density 35 pcs/m^2) where they feed on natural food. Alternatively, techniques have been developed to wean juveniles directly onto commercial diets (Ingram *et al.* 2001). At 30-50 mm, juveniles are ready to be transferred to growout systems.

Grow-out Systems:

Intensive: The most popular growout systems for Murray cod are intensive recirculating tank systems (RAS). Murray cod has proved to be very tolerant of high stocking densities (80-150 kg/m^3) but oxygen injection is required. Murray cod display efficient food conversion (<1.5:1) in these systems with medium-fast growth rates (2g to 600g in 12 months). Survival rates are >80%, but this is dependent on the management of water quality and disease in the system and good fish husbandry techniques.

Smaller recirculation systems have stocking rates of 30-40 kg/m^3, achieve FCRs of 1.5-2.0 and fish reach market size in around 12-18 months. Lower stocking densities generally reduce the risk of system failure.

Semi-intensive: The most common semi-intensive systems for rearing Murray cod are ponds. These are not stocked as highly as the RAS systems, but can produce up to 14 tonnes/ha/year. Water is not exchanged regularly, but is added to the pond on a regular basis to compensate for evaporation and seepage losses. It takes longer for fish grown in ponds to reach market size; up to 24 months in northern Victoria.

Cage culture is another semi-intensive culture option, however there is limited information on the performance of Murray cod in cages. Trials are being carried out to determine optimal stocking densities and culture methods.

Extensive: Grow-out in farm dams and ponds commonly involve stocking rates of 300-500 fish/ha. These fish feed on predominantly natural feeds and have growth rates of 2-3 kg in about 3 years.

Culture Attributes:

- Existing juvenile production;
- Relatively tolerant to water quality conditions;
- Commercial diets are being developed for the species;
- Medium-fast growth rates;
- Efficient food conversion.

Marketing attributes: The eating quality (firm white flesh) of Murray cod is highly regarded by both domestic and export markets and is considered suitable for Chinese and Western cuisine. Recently, a taste-testing study was undertaken with representatives from three Asian countries with the fish very well received in terms of flavour, texture and colour (DNRE 2001).

Economic factors: Murray cod have enjoyed a relatively high market price in recent years and market size cod generally f*etc*h between $15-25/kg at the Sydney Fish Market. Cultured fish traditionally have a lower market price than wild Murray cod, which tend to be larger, but recent restrictions on wild fisheries may have a positive impact on wholesale fish prices. Higher prices can be gained by selling live fish directly to the restaurant trade ($ 20-30/kg). Weaned juveniles are valued at $0.60-1.10 per fish.

Industry organisations:

Warm Water Aquaculture Association,
30 Cecil St, Kew, VIC 3103.
Tel (03) 9817 3043 Fax (03) 9816 9930.

Further Reading:

DNRE, 2001. Murray cod taste testing for Asian markets: Preliminary market appraisal. Aquaculture Unit, Fisheries Victoria, DNRE, State of Victoria.

Ingram, B.A.(ed.), 2000. Murray Cod Aquaculture a Potential Industry for the New Millennium. *Proceedings of a workshop* (Held 18th January 2000, Eildon, Victoria. Department of Natural Resources and Environment, Marine and Freshwater Resources Institute, Victoria, 83 pp.

Ingram, B.A., Missen , R. and Dobson, J. L. 2001. Best practice guidelines for weaning pond-reared Murray cod fingerlings onto an artificial diet. Marine and Freshwater Resources Institute Technical Report No. 36.

O'Sullivan, D. and Dobson, J. 2000. Status of Australian Aquaculture in 1998/99. Austasia Aquaculture Trade Directory 2000.

6. Ornamentals

Scientific name: Various; see table below.

Status: Mainly exotic, some interest in native (especially tropical) species.

Distribution: Various.

Aquaculture Status in Australia: The culture of ornamental fish species is a growing industry in Australia. For many years the keeping of ornamental or aquarium fish has been a major activity in Australia with several million hobbyists. The majority of fish have come from overseas (mainly Singapore) but local farm production has been increasing. In 1998/99 more than 15 million fish were sold, of which 50% were produced locally, mainly in Victoria. (O'Sullivan and Dobson 2000). The popularity of tropical native species is also increasing, inspiring more investigations into their culture by local breeders. Some growers are interested in producing juvenile food fish (eg barramundi, cod, coral trout, snapper and giant clams) for the ornamental market. Many native freshwater species also offer aquarium potential, including smelts, galaxids, catfish, rainbowfish, hardyheads, perches, gudgeons and gobies.

Some ornamental fish species bred in Australia
(after O'Sullivan and Ryan 2001)

Common name	Origin	Scientific name	Water supply
Angelfish	Exotic	*Pterophyllum scatare*	Freshwater
Bristlenose catfish	Exotic	*Ancistrus dolichopterus*	Freshwater
Corydoras catfish (4 spp)	Exotic	*Corydoras spp.*	Freshwater
Goldfish	Exotic	*Carassius auratus*	Freshwater
Koi carp	Exotic	*Carassius carpio*	Freshwater
Guppies	Exotic	*Poecilia reticulata*	Freshwater
Platys	Exotic	*Xiphophorus variatus, X. maculatus*	Freshwater
Mollies	Exotic	*Poecilia latipinna*	Freshwater
Rams	Exotic	*Microgeophagus ramirezi*	Freshwater
Siamese fighting fish	Exotic	*Betta splendens*	Freshwater
Swordtails	Exotic	*Xiphophorus helleri*	Freshwater
Walking fish	Exotic	*Axolotl sp.*	Freshwater
Red tiger oscars	Exotic	*Astronotus ocellatus*	Freshwater
Gouramis	Exotic	*Trichogater spp, Colisa spp.*	Freshwater
Red rainbow	Exotic	*Glossolepis incisus*	Freshwater
Fat bellied seahorse	Exotic	*Hippocampus abdominalis*	Marine
Rainbowfish	Native	*Melanotaenia spp.*	Freshwater
Clown fish	Native	*Amphiprion spp.*	Marine

Production/ value: The total value of the exotic aquarium industry is estimated at $4.8M. Total sales for native species were worth over $0.5 M in 1998/99, and expected to grow significantly (O'Sullivan and Dobson 2000).

Hatchery/ Juvenile Production: Some popular aquarium species have not yet been bred successfully under culture conditions. Many species, however, are relatively easy to breed and a variety of different techniques exist, depending on the species. Breeding pairs are generally placed in individual tanks, with a spawning substrate. Many species spawn year-round. Eggs and parents are separated (to prevent the parents eating the young) and young fish transferred to growout units.

Breeding techniques for native species are also variable; some simply reproducing in small ponds and others requiring hormone induction.

Grow-out Systems:

Semi-intensive/ commercial culture: Most farms grow their fish in open ponds with at least some water exchange and fairly comprehensive predator protection. In southern latitudes, tropical fish production requires an insulated and heated building, housing many aquaria. Outdoor and indoor tanks are also used, depending on the species and location, and including indoor recirculating systems, enabling maintenance of appropriate water temperatures. Individual species are usually housed in separate units. Young are fed live feeds (eg *Daphnia, Artemia*), various mash feeds, crumbles and pellets, and ready for sale after three to four months.

There may be opportunities for growing ornamentals in wastewater aquaculture IAAS.

Culture Attributes:
- Many species hardy;
- Culture and breeding techniques well established for many species;
- High fecundity;
- Fast growout.

Marketing attributes:
There is a strong, existing domestic market for ornamentals and aquarium fish, with a growing interest in new species - including native fish. There is also potential for developing export markets, particularly with local species. Local production of exotics will continue to increase, led by culture of seahorses. Prices for individual fish vary from about A$0.35 to A$5, but an individual fish can reach more than $20 (Saratoga in Queensland). (O'Sullivan and Dobson 2000).

Industry organisations:

Victorian Ornamental Fish Growers
60 Station Rd, Wesburn, VIC 3799.
Tel (03) 5967 1693 Fax (03) 5967 1697.

Pet Industry Joint Advisory Council, pjac@fast.net.au

Further Reading:

Beesely, N. and O'Sullivan, D. 2000. Breaking new ground in ornamentals. Austasia Aquaculture. April/May 2000.

O'Sullivan, D. and Ryan, M. 2001. Ornamental fish: an opportunity for Australian growers? Austasia Aquaculture. April/May 2001.

O'Sullivan, D. and Ryan, M. 2001. Expanding world market sees new industry body formed in WA. Austasia Aquaculture. February/March 2001.

7. Redclaw

Scientific name: *Cherax quadricarinatus.*

Environment and Status: Native, freshwater, Common.

Distribution: Redclaw are native to the rivers and streams of tropical Queensland, the Northern Territory and southern Papua New Guinea.

Aquaculture Status in Australia: Redclaw are cultured primarily in Queensland and northern NSW. The total production in 1998/99 was 78.3 tonnes; 76.9 tonnes came from Queensland and 1.4 tonnes from NSW (O' Sullivan and Dobson 2000). In Queensland there are 13 farms each producing more than one tonne of product – these farms produced over 74% of the State's farmed redclaw in 1997-98.

Broodstock: Redclaw breeding occurs between September and April although on commercial farms continuous spawning can be stimulated. Usually selected broodstock are placed in "breeder ponds" where natural mating occurs. The female broods the eggs for 6-10 weeks and most can carry from 300-800 eggs per brood. Larvae stay with the female for several weeks.

Juveniles: In commercial systems, juveniles are harvested at around 10g (3-4 months) and sorted by size and sex. The sorted juveniles are then stocked in growout ponds.

Growout systems:

Commercial production of redclaw usually occurs in 0.1-0.25 ha earthen ponds, 30-100 m long and 15-25 m wide with a depth of up to 1.8 m. The ponds generally have sloping sides and bottoms to make draining and harvesting easier. Organic and inorganic fertilisers may be added prior to pond filling to stimulate productivity. Some growers also spread hay and lucerne on the pond to provide a habitat for the juvenile crayfish.

Sorted juveniles are stocked into the growout ponds at a rate of 5 to 15 per m^2. Redclaw feed primarily on decaying plant material and the bacteria and fungi associated with its decomposition. Water rich in plankton is essential to achieve good growth and survival of redclaw, but water quality must be carefully managed to maximise growth and optimise animal health. After the initial organic load is consumed, pelleted feeds are used. After 9-12 months the redclaw are harvested at an average weight of 70-80g. Mortalities of 20-50% may be expected over 12 months due to predation (mainly by birds), cannibalism and sometimes disease.

Redclaw do not burrow as much as other freshwater crayfish but pond yields can be increased significantly through the provision of artificial hides or habitats. They are nocturnal creatures and movement and feeding activities are highest in the ponds at night. Redclaw show a strong response to water current and move upstream into a flow of water; this has enabled farmers to develop flow traps for harvesting. Natural aeration of ponds is considered insufficient and supplementary aeration may be required to maintain dissolved oxygen levels. Experienced farmers can achieve pond yields of 2-3 tonnes per ha per year.

Tank production of crayfish has been unsuccessful to date as the higher stocking densities required to make the system economically viable, result in slower growth rates.

Culture Attributes:

- Prolific breeders;
- Farming does not require complicated hatcheries or equipment;
- Do not burrow as much as other crayfish.

Marketing attributes:

Most crayfish in Queensland are marketed live, ensuring maximum product quality and freshness. Higher prices are paid per kg for larger sized live animals. Most of the product is marketed in Queensland (65%) with interstate markets accounting for 29% and 6% sent overseas (DPI factsheet).

Industry organisations:

Queensland Crayfish Farmers Association,
Lot 4, Verne Rd, Wolvi, QLD 4570.
Tel/Fax (07) 5486 7367.

Bundaberg & District Crayfish Farmers Association,
M/S 315 Foleys Rd, Childers, QLD 4660
Tel (07) 4126 9129 Fax (07) 4126 9152.

South Queensland Crayfish Farmers Association,
MS 366 Hiddenvale Rd, Grandchester, QLD 4340.
Tel/Fax (07) 5465 5280.

Capricornia Crayfish Farmers Association,
Calliope Station, Calliope, QLD 4680.
Tel (07) 4975 7445 Fax (07) 4975 7788.

Further Reading:

About redclaw crayfish – technical stuff. Capricorn Crayfish Farmers Association.
Freshwater crayfish farming. www.dpi.qld.gov.au/fishweb.
O'Sullivan, D. and Dobson, J. 2000. Status of Australian Aquaculture in 1998/99. Austasia Aquaculture Trade Directory 2000.

8. Silver perch

Species: *Bidyanus bidyanus*, Mitchell, 1838.

Environment and Status: Native – freshwater.

Distribution: Naturally found throughout the tributaries of the Murray River, and the Murray Darling Basin.

Aquaculture Status in Australia: Commercial hatcheries are established in Victoria, New South Wales, Western Australia, Queensland and South Australia producing juveniles for ongrowing in most types of farming systems, both brackish and freshwater. Silver perch growout has been established for a number of years with most of the production in New South Wales. In 1998/99, silver perch production in Australia was 220 tonnes with a value of $2.15 million, including 0.5 million juveniles (O'Sullivan and Dobson 2000).

Broodstock: Silver perch broodstock are available from commercial producers in most states and should be held in earthen ponds for at least 7 months prior to the breeding season (Rowland 1984). Typical broodstock holding ponds are 0.1 ha. At spawning, the broodstock are moved to tanks and artificially induced. The eggs are then fertilised naturally.

Hatchery/Juvenile Production: The hatchery production of silver perch juveniles is well established (Rowland and Bryant 1995). Fertilised eggs are incubated in tanks for 5-6 days, but hatching is temperature dependent and can be accelerated to 24-30 hours at 24^{o}C. Larval feeding begins when yolk adsorption is complete; 6 days after hatching. The larvae (5mm long) are stocked directly into fertilised earthen ponds (stocking rates of 50-100 larvae/m^2) where they feed on natural food. This stocking density aims to yield 25-40 fry/m^2. After 5-8 weeks in the ponds, the silver perch are 25-30 mm in total length and are ready to be transferred to growout systems.

Grow-out Systems:

Intensive: Intensive growout systems are not commonly used for silver perch culture so there is limited data available. Some farmers are currently trialing intensive recirculation tank systems but high operating costs coupled with modest market prices make economic viability borderline.

Semi Intensive: The most popular method of silver perch culture is semi-intensive pond culture. Silver perch grow-out ponds should be built no larger than 0.25 ha, with aeration provided to achieve high yields. Stocking rates vary from 7,000 to 40,000 fish/ha; the optimum rate is around 20,000 fish/ha, but new entrants are recommended to start at 10,000 fish/ha. Good food conversion ratios are regularly achieved (<1.6:1) and growth rates can be as high as 2-3 g/fish/day in northern NSW. Optimal conditions can produce growth rates to marketable fish of 500g in 10 months and 600-800g in around 18 months. High survival of rates of >90% are also commonly achieved. Annual production rates of 10 tonnes/ha have been achieved in static ponds in northern NSW.

Cage culture of silver perch has been trailed at an experimental level in NSW and Victoria, but more work is required to optimise appropriate stocking densities and culture conditions.

Extensive: Silver perch can be stocked in farm dams at a rate of around 350 fish/ha (carrying capacity 200-500 kg/ha is reached in 2-3 yrs).

Culture Attributes:

- High survival and growth rates;
- Hatchery techniques for large scale production of juveniles well established;
- Easily weaned onto artificial diets;
- Uniform growth if graded regularly.

Marketing attributes: Silver perch has relatively good meat recovery of around 40 % and has excellent cooking and eating qualities. The flesh is firm and white with few bones. Pond-grown silver perch readily take up off-flavours present in the ponds and this can have a detrimental effect on markets. Poor quality fish have been released to markets in Australia and south-east Asia causing severe damage to markets. The fish must be purged (held in freshwater tanks) for several days after harvest. Quality controlled protocols must be observed to ensure that the fish going to market are prime quality. Small silver perch farmers may find it easier to build local business networks to share the cost of centralised purging, processing and marketing. Silver perch are now recognised and readily accepted in the market, although prices are relatively modest at $9-10/kg live to the Asian restaurant trade**.** At the Sydney Fish Market average prices varied between $6.66-$11.06/kg in 1999 (whole, gilled and gutted). Premium prices can be obtained through developing niche markets locally or product branding.

Industry Organisations:
Murray Region Aquaculture Association,
PO Box 273, Deniliquin, NSW 2710.
Tel/Fax (03) 5884 6649.

Warmwater Aquaculture Association,
30 Cecil St, Kew, VIC 3101.
Tel (03) 9817 3043 Fax (03) 9816 9930.

NSW Silver Perch Growers' Association Inc..
Tel/Fax (02) 6723 3357.

References:

Rowland, S.J. and Bryant, C. (eds) (1995) Silver perch culture. *Proceedings of Silver Perch Aquaculture Workshops*, Grafton & Narrandera, 1994. pp. 51-65.

Kibria, G., Nugegoda, D., Fairclough, R., and Lam, P. (1998). Biology and Aquaculture of Silver Perch, *Bidyanus bidyanus* (Mitchell 1838) (Teraponidae): A Review. *The Victorian Naturalist*. Vol. **115 (2)**. pp. 56-62.

Guo, R., Mather, P. B., and Capra, M. F. (1995). Salinity Tolerance and Osmoregulation in the Silver Perch, *Bidyanus bidyanus* Mitchell (Teraponidae), an Endemic Australian Freshwater Teleost. *Australian Journal of Marine and Freshwater Research*. **46**, 947-952.

O'Sullivan, D. and Dobson, J. 2000. Status of Australian Aquaculture in 1998/99. Austasia Aquaculture Trade Directory 2000.

Rowland, S. J. (1998). Silver perch. **In:** *The New Rural Industries - A Handbook for Farmers and Investors*. (ed. by K. Hyde), pp. 134-139. Rural Industry Research

9. Trout

Scientific names: Rainbow trout: *Oncorhynchus mykiss* Walbaum, 1792.
Brown trout: *Salmo trutta trutta* Linnaeus, 1758.

Environment and Status: Exotic (benthopelagic)- freshwater, brackish, marine.

Distribution: Rainbow trout are native to North America, from Alaska to Mexico, in rivers draining into the Pacific Ocean. They were introduced to Australia from New Zealand in the 1890's and are found from northern New South Wales to South Australia, and throughout most of Tasmania. They were introduced successfully into the south-west corner of Western Australia in 1942. Brown trout are native to Europe and were introduced into Australia's cooler waters in the 1860s. Their distribution is restricted mostly to the highlands from northern New South Wales to the coast of Victoria although stocks are maintained in the Adelaide region of South Australia, in south-west Western Australia and throughout Tasmania.

Aquaculture Status in Australia: Freshwater land-based aquaculture of trout is the second biggest finfish sector in the Australian aquaculture industry. In Victoria, land-based rainbow trout farming is by far the biggest, highest valued aquaculture sector. The majority of Australia's brackish water rainbow trout industry is in sea cages within Macquarie Harbour on Tasmania's west coast. Brown trout are produced mainly in New South Wales, Victoria, Tasmania, and Western Australia for recreational fisheries purposes.

Broodstock: Trout will not spawn naturally in artificial culture systems and juveniles must be obtained by artificial spawning. Fortunately, the reproduction of trout is well understood and the techniques are well developed (Shepherd and Bromage 1990, Sedgwick 1985). A female rainbow trout can produce up to 2,000 eggs/kg body weight and similar egg production is recorded from brown trout. In the hatchery, females are stripped of their eggs in June and July and the eggs are mixed with milt from the males. For spawning and egg production, brown trout need water temperatures of 6-10^{o}C and rainbow trout need 9-14^{o}C.

Hatchery/Juvenile Production: The fertilised eggs are placed in hatching troughs where, depending on the water temperature, they hatch after 4-14 weeks. The newly-hatched trout feed on their yolk-sac for the next two weeks before being weaned onto artificial diets. Four-12 weeks after hatching they are ready to be stocked into growout systems.

Grow-out Systems:
Trout require good water quality to grow fast, and semi-intensive and intensive grow-out systems for trout use flow-through systems were water is continually exchanged in the culture unit. These systems have a high demand for good quality water.

Intensive: Most intensive land-based culture is based on flow-through "Danish" pond systems or concrete raceways. High stocking densities of around 32 kg/m^3 are used in these systems, with water flow rates of 5-10 L/sec/ tonne of fish. Regular grading and splitting of stock is required to ensure fast growth. A proportion of the fish can reach market size (250g) in 9 months while the remainder will take longer, depending on husbandry practices. Some fish may be held back to ensure a consistent supply to market. FCRs range from 0.9-1.3 using extruded diets and 1.2-1.6 with pressed pellets. Typical survival rates of 60-80% are obtained from eggs to harvest.

Cage culture in both fresh and marine waters is a proven method of rainbow trout culture and high stocking densities of 30-40 kg/m^2 can be achieved. Larger fish cope better with being transferred to marine cages, where growth rates are faster. Fish from sea cages are grown to 2 kg before harvest.

Semi-intensive: Semi-intensive pond production uses the same technology as intensive culture, but stocking rates are lower. Stocking densities of 10-20 kg/m^3 are typical of these systems and water exchange is consequently lower. Trout also have good potential for semi-intensive pond or cage culture in inland saline waters. Research has shown that trout adapt well to culture in these systems.

Extensive: Extensive grow-out in farm dams and ponds is an option for farmers who wish to fish recreationally or have a small-scale aquaculture venture. Low stocking rates of 375 yearling fish/ha are used and low yields of 100 kg/ha/yr are recorded from dams. Survival may be less than 50% due to predation, but growth rates are generally fast.

Culture Attributes:

- Culture techniques are well established;
- Fry are easily weaned onto artificial diets;
- High tolerance to handling;
- Species specific diets readily available.

Marketing attributes: The flesh of trout is soft and delicate, white to pink in colour with a mild flavour (the pinker the better), and has fine bones. Currently most trout are sold domestically as chilled (50%) or frozen (25%) whole, gilled and gutted. Value-added products such as smoked trout (20%) and trout fillets (fresh and smoked), patés, terrines and trout caviar are sold throughout Australia, with little being exported to Asia (2-3%). The market price for rainbow trout is comparatively low at the farm-gate ($5.00-$6.00/gk fresh whole, gilled and gutted). Larger farms are better placed to cope with the low prices due to production economies of scale. Better prices can be obtained by small farmers by developing local niche markets with restaurants or supermarkets. Value-adding can increase the value of the product from $5-20/kg depending on the product. Small farmers may have to co-operate with processing and transport to make trout farming a viable option.

Industry Organisations:

Victorian Trout Farmers Association,
PO Box 258, Alexandra, VIC 3714.
Tel (03) 5773 2483.

Key References:

Gooley, G. J. (1998). Trout. In: *The New Rural Industries* **-** *A Handbook for Farmers and Investors*. (ed. by K. Hyde), pp. 140-146. Rural Industry Research and Development Corporation, Canberra.

O'Sullivan, D. and Dobson, J. 2000. Status of Australian Aquaculture in 1998/99. Austasia Aquaculture Trade Directory 2000.

Shepherd, C. J. & Bromage, N. R. (eds.), Intensive Fish Farming. BSP Professional Books, Oxford, pp 17-49.

Sedgwick, S. D. 1985. Trout Farming Handbook. 4th ed. Fishing News Books, England,

10. Yabbies

Scientific name: *Cherax destructor* Clark, 1936.

Environment and Status: Native- freshwater, Common.
Distribution: The most widespread species of freshwater crayfish, found in ponds, farm dams, billabongs, swamps, creeks, rivers, lakes, bore drains, irrigation channels and reservoirs throughout most of Victoria, New South Wales, South Australia, southern Queensland, and parts of the Northern Territory.

Aquaculture Status in Australia: In Victoria, there are approximately 135 commercial licence holders endorsed for yabby aquaculture, utilising existing farm dams or purpose built ponds under semi-intensive or extensive farming methods. This species is also farmed in South Australia and New South Wales. The Western Australian yabby industry consists largely of the species *Cherax albidus,* introduced from Victoria's south-west where the species is endemic. A total of 239.6 tonnes of yabbies were produced in Australia in 1998/99, with 69% produced in Western Australia, 17% in NSW, and 11% in South Australia (O'Sullivan and Dobson 2000). Yabby production tends to decrease during drought.

Broodstock: Yabbies are prolific breeders and spawn annually during the summer months in Victoria. Longer day lengths trigger egg development in females, and spawning is triggered by water temperatures., Yabbies spawn from early spring to mid-summer, when water temperatures rise above 15^{o}C. They can spawn continuously if water temperatures remain between 14 and 20^{o}C. An average yabby spawning produces 350 eggs per brood, but larger females can produce up to 1,200 young. The eggs are incubated under the tail of the female for between 19 and 40 days, and the juveniles are carried until they reach an advanced stage of development. After the young leave the female she is capable of spawning again immediately.

Hatchery/Juvenile Production: Given the prolific breeding characteristics of yabbies, hatcheries are not necessary to produce juveniles. Juvenile stocking in growout ponds can be achieved in a number of different ways:
- Stocking the pond with a parent population;
- Stocking the pond with broodstock at a rate of one male to three females;
- Stocking the pond with berried females;
- Breeding the yabbies in smaller ponds or tanks and re-stocking them into growout ponds.

Grow-out Systems:
Semi-Intensive: Semi-intensive growout systems use purpose built ponds with stocking rates of 5-10 juvenile fish/m². Feeding rates are between 2% and 4% biomass/day. Yabbies are fed artificial feeds which are supplemented by natural feeds in the ponds. Good growth rates are obtained; yabbies generally grow to 40g in 6-12 months. Annual yields of 1500-2500 kg/ha in about 12 months can be obtained from semi-intensive systems. Very efficient operators can produce 3-4 tonnes/ha. Food conversion rates of 4-5:1 have been recorded (with lucerne).

Extensive: Extensive grow-out in farm dams and ponds requires low stocking rates of less than 5 juveniles /m². The estimated annual yield of farm dam yabby culture is 400-690 kg/ha/yr.

Culture attributes:
- Prolific breeders, but this can result in overcrowding which can reduce growth rates. The density of yabbies in culture ponds must be controlled.
- Farming does not require complicated hatcheries or equipment.
- Industry Code of Practice for yabby farming has been developed (VAC 2001).
- Multi-waters licensing in Victoria will make it easier for yabby farmers to access more waters for culture.

Marketing attributes: Yabbies are popular domestically as table food and are also used as fish bait. They are sold live, cooked, or processed as paté. Acceptance by European markets as a replacement for their diminishing freshwater crayfish is the key to future export markets. However, product quality assurance and a consistent supply must be maintained to develop these markets effectively. Currently, the market is largely based on domestic restaurants but there is great potential for international market development.

One of the main advantages of yabbies is that they can be landed live, out of water, in major international markets, maintaining the freshness of the product.

Industry Organisations:
Australian Freshwater Crayfish Growers Association (NSW),
84 Wirrang Dr, Dondingalong, NSW 2440.
Tel (02) 6566 9207 Fax (02) 6566 9407.

Australian Freshwater Crayfish Growers Association (SA),
PO Box 683, Bordertown, SA 5268.
Tel/Fax (08) 8758 4000.

Australian Freshwater Crayfish Growers Association (Vic) (AFCGAV),
RSD 1920 Northern Highway, Heathcote, VIC 3523.
Tel (03) 5433 2332 Fax (03) 5433 3807.

Yabby Producers Association of WA Inc,
C/-ACWA PO Box 55, Mt Hawthorn, WA 6915.
Tel (08) 9244 2933 Fax (08) 9244 2934.

References:

Lawrence, C. S. (1998). Yabbies. In: *The New Rural Industries - A Handbook for Farmers and Investors*. (ed. by K. Hyde), pp. 147-152. Rural Industry Research and Development Corporation, Canberra.

Mills, B. J. (1983). Aquaculture of yabbies. *Proceedings of the First Freshwater Aquaculture Workshop* held at Narrandera, Department of Agriculture New South Wales.

VAC, 2001. Victorian Yabby Producer’s Manual. A code of practice for the Victorian Yabby Aquaculture Industry. Freshwater Crayfish Growers Association of Victoria and the Victorian Aquaculture Council.