Developing Commercial Inland Saline Aquaculture in Australia: Part 1. R & D Plan

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The Steering Committee for this project included: Dr Chris Barlow (QDPI), Mr Damian Ogburn (NSW Fisheries), Mr Geoff Gooley (Marine and Freshwarer Resources Institute, Victoria), Mr Greg Paust (WA Fisheries) and Mr Wayne Hutchinson (SA Research and Development Institute). Input from Mr Simon Benison (Aquaculture Council of W.A.), Dr Nigel Preston (CSIRO), Mr George Wilson (Rural Industries Research and Development Corporation), Mr Dan Liszka (Pisces marine Ltd) and Mr Peter Shelley (Chairman Tasmanian Aquaculture Council) at the Workshop held in Sydney in June 1999 to develop the Research and Development (R&D) Plan is also gratefully acknowledged.

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Disclaimer

3. NON-TECHNICAL SUMMARY

98/335	Developing Commercial Inland Saline Aquaculture in Australia: Part 1. R & D Plan

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OBJECTIVES:

1. Review the developmental status of inland saline aquaculture in Australia.

2. Evaluate likely obstacles and limitations to the commercial expansion of Inland Saline Aquaculture and the ability for R & D to address these limitations.

3. Develop a R & D plan to address these obstacles and limitations in consultation with the aquaculture industry and related disciplinary experts (Part 1).

4. Document the distribution and characteristics of inland saline groundwaters and their potential use for the farming of aquatic organisms (Part 2).

NON TECHNICAL SUMMARY:

The National R&D Plan for Inland Saline Aquaculture arose following a workshop on Inland Saline Aquaculture run by ACIAR. Two of the main outcomes of the Workshop were identification of the need for a national, strategic R&D Plan for Inland Saline Aquaculture (Part 1) and identification of the need for an inventory of inland saline resources and assessment of the potential of these for aquaculture (Part 2).

Existing Inland Saline Aquaculture in Australia

There are small-scale research and development or commercial inland saline aquaculture projects in all states except Queensland, Tasmania and the ACT. Current activities include:

- NSW - NSW Fisheries investigating snapper culture, with funding from the CRC for Aquaculture; one commercial barramundi farm; CSIRO (L & W) Project on serial biological concentration to combine irrigation and saline aquaculture.
- Victoria - Inland Mariculture Scoping Study was undertaken on a range of sub-tropical and temperate species; funding from the State Government and Murray-Darling Basin Commission. Rural Industries Research & Development Corporation (RIRDC), ACIAR, and the State Government are funding other smaller-scale saline water studies with silver perch and rainbow trout. One commercial operation producing Artemia (brine shrimp) and salt.
- SA - investigating production of Artemia, Dunaliella and finfish in poly-tunnels as part of salt-water management procedures; RIRDC funding. Commercial farms for barramundi and other finfish being developed.

- WA - extensive interest in inland saline aquaculture - Outback Ocean project by WA Fisheries to trial black bream and winter trout production in saline ponds and dams. A detailed resource inventory is also being compiled.
- NT - has undertaken successful pilot-scale Dunaliella (micro-algae) production near Alice Springs; commercial venture currently being established. Experimental production of the tiger prawn *Penaeus monodon* using saline bore water is underway at the University of NT.
- Qld - presently no inland saline aquaculture.
- Tas – presently no inland saline aquaculture.

R&D PLAN

A formal mission statement was developed and the status in 1999 and vision for 2004 for inland saline aquaculture were prepared to help focus R&D.

The R&D Plan was needed to help guide R&D across geographical areas, land/water disciplines, taxa, industry sectors and potential investment groups, and between funding, research and management agencies. The contract to prepare this Plan was won by the consultants Business Generation Pty Ltd. It included a wide-ranging interview program with researchers, commercial aquaculturalists and other interested parties across Australia and overseas during March/April 1999. Findings and implications from the review were then assembled in a draft Discussion Paper which reviewed current activities and issues related to commercial development of inland saline aquaculture in Australia.

In late June 1999 an R&D planning workshop of researchers and industry representatives was convened in Sydney to review emerging findings and to agree priorities for future R&D. The group identified seven project areas that would explore specific commercial development opportunities for inland saline aquaculture or address emerging constraints. Preliminary research parameters were then developed for each of these project areas. These project areas were:

1. Grow-out of Marine Species Using Shallow Aquifers

Of the 13 highest-ranking commercial prospects, five (including the top 4) fitted within the broad category of 'Grow-out of marine species using shallow aquifers'. The nominated species included barramundi, silver perch, prawns, mulloway and snapper. Of these, barramundi and prawns are warm temperature species; the remainder are temperate. If commercial production of nominated species from shallow aquifer water were to involve semi-intensive open pond systems – as is probable – there are clear climatic restrictions as to where these should be located. There is a separate constraint as to the actual availability of (shallow aquifer) inland saline water of suitable quality and quantity, within such climate zones. There is the further question as to which of such locations might meet various commercial criteria (such as local infrastructure, labour and social amenities).

2. Aquaculture from Deep Artesian Water

Deep aquifers extend across much of Australia and much of the water is salty. It has already been demonstrated that marine species of finfish can be successfully grown in recirculation and flow-through systems using inland saline water from deep aquifers. There is a small commercial operation in southern NSW which uses deep aquifer water and recirculation systems to produce barramundi. There is another small commercial barramundi operation in Robe SA that also uses deep aquifer water in a flow-through system; it capitalises on the elevated temperature of the emergent water to produce fish outside their natural climatic zone. Research has not yet addressed the technical or commercial feasibility of applying deep aquifer water to pond-based systems, although clearly the water itself can prove satisfactory.

3. Winter Culture of Salmonids Using Shallow Aquifers

Research in Victoria and WA has indicated that salmonids (specifically, Rainbow trout) will survive and grow during winter. A number of possible commercial applications are under consideration as a result. A farmer in Victoria is trialing winter trout and summer silver perch in shallow aquifer saline water, and WA Fisheries is sponsoring a trial program, "Outback Ocean", where trout are being grown out over winter in ponds and dams across more than 100 farms. Potential problems include the cost and risk of accessing advanced fingerlings for stocking because the trout need to be harvested before the onset of summer temperatures. Reliance on natural feeding systems reduces effluent problems but will increase the challenge of achieving satisfactory growth rates. The risk of losses from unseasonally hot weather also needs to be addressed.

4. Artemia from Existing Facilities

Artemia (brine shrimp) may be particularly suited to cultivation in existing evaporation ponds because:

- they are euryhaline, but thrive in hypersaline environments;
- they are generally hardy and easy to grow; (availability of sufficient appropriate nutrient at appropriate cost is likely to be the key limit to production;)
- they are an ideal mechanism for cleaning up residual organic waste, and hence a complement to adjacent production of conventional species;
- they are prized as a fishfeed, and can be harvested for live feeding to adjacent finfish; (a project with these elements is being commercialised in South Australia); and
- they can be harvested either as cysts or as live biomass, processed as appropriate (eg dried flakes) and marketed locally and overseas.

Establishing a commercial Artemia enterprise will involve evaluating the available species and sites and assessing production costs and market opportunities.

5. High Health Prawn Hatchery

Australian mariculture is dependent on coastal hatcheries for the supply of grow-out stock. Production of fingerlings and post-larvae in this environment means that they are more easily exposed to disease through the water itself and from other species. Viral diseases are a particular concern, and their epidemiology and impact are not well understood. As a result, considerable effort and expense is invested in systems to minimise the likelihood of infection. Inland Australia offers the potential to access disease-free saline water in locations that are free of other marine species, thereby providing an ideal context for the establishment of "specific pathogen-free" (SPF) hatcheries. Depending on their location, these hatcheries could service adjacent (inland) grow-out operations, coastal grow-out operations and/or export markets.

6. Environmental Guidelines for Inland Saline Aquaculture

From an aquaculture perspective, inland saline water is a valuable asset, and there is increasing interest in its responsible use. From an environmental perspective, inland saline water is the biggest single environmental problem facing Australia. The aquaculture industry is acutely aware of the importance of responsible environment management to its own sustainability. From the outset it has adopted a strong policy position on the subject. This is reflected in a paper on 'Environmental considerations in the use and management of inland saline water bodies for aquaculture' given at the ACIAR Workshop in August 1997. Two fundamental objectives of aquaculture development are that it be environmentally sustainable and that it be economically viable. Any aquaculture development using saline water must not increase salinisation and must minimise the release of nutrients to waterways.

7. Research and Extension Networking.

Industry consultation would suggest that there is relatively high optimism as to the technical feasibility of inland saline aquaculture and reasonable confidence as to commercial prospects in specific contexts. However, there is also almost unanimous recognition that before significant commercial investment in inland saline aquaculture occurs, more R&D is needed to reduce investment risks. Industry representatives stressed that they believed that this was a key role for government. The topic of inland saline aquaculture competes for scarce R&D resources with other aquaculture, with wild-caught fish, with agriculture, and so on. Given the limited R&D resources, the large number of possible variables and the desire to achieve 'realistic and meaningful commercial outcomes', it was imperative that relevant R&D be coordinated nationally. This imperative stimulated the development of this plan but it also needs to carry into project implementation. **There is also a critical need that the integration of aquaculture with saline groundwater interception schemes is considered in the context of other salinity control planning.**

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4. BACKGROUND

This project arose from a national workshop on Inland Saline Aquaculture held in Perth on 6-7 August 1997. The Workshop was funded primarily by ACIAR, with co-funding support provided by FRDC and RIRDC. It was convened because of the high level of interest in inland saline aquaculture in Australia, and the need to coordinate R&D activities from a national perspective. The Workshop brought together selected aquaculture and land/water specialists from Australian States and Territories, along with representatives from ACIAR, FRDC and the CRC for Aquaculture. Workshop sessions addressed current activities in the country, key technical and environmental issues, and major opportunities and constraints to the development of inland saline aquaculture ventures. A comprehensive report of the proceedings and outcomes was published by ACIAR in 1999.

The main outcome of the Workshop was identification of the need for development of a strategic plan to provide a national framework for R&D on inland saline aquaculture (Part 1). The plan was needed to help guide and facilitate the integration of R&D across geographical areas, land/water disciplines, taxa, industry sectors and potential investment groups and between funding, research and management agencies. In addition, the need for an inventory of inland saline groundwater resources and an assessment of their aquaculture potential was also recognised (Part 2).

4.1. Current Activities in Inland Saline Aquaculture

Research activities in inland saline aquaculture are comparatively recent, but are being undertaken in several States.

- NSW - NSW Fisheries investigating snapper culture, with funding from the CRC for Aquaculture; one commercial barramundi farm; CSIRO (L & W) Project on serial biological concentration to combine irrigation and saline aquaculture.
- Victoria - Inland Mariculture Scoping Study was undertaken on a range of sub-tropical and temperate species; funding from the State Government and Murray-Darling Basin Commission. RIRDC, ACIAR, and the State Government are funding other smaller-scale saline water studies with silver perch and rainbow trout. One commercial operation producing Artemia and salt.
- SA - investigating production of Artemia, Dunaliella and finfish in poly-tunnels as part of salt-water management procedures; RIRDC funding. Commercial farms for barramundi and other finfish being developed.
- WA - extensive interest in inland saline aquaculture, “Outback Ocean” project by WA Fisheries to trial winter salmon production in saline ponds and dams.
- NT - has undertaken successful pilot-scale Dunaliella production near Alice Springs; commercial venture currently being established. Experimental production of *P.monodon* using saline bore water is underway at the University of NT.
- Qld - presently no inland saline aquaculture.
- Tas – presently no inland saline aquaculture.

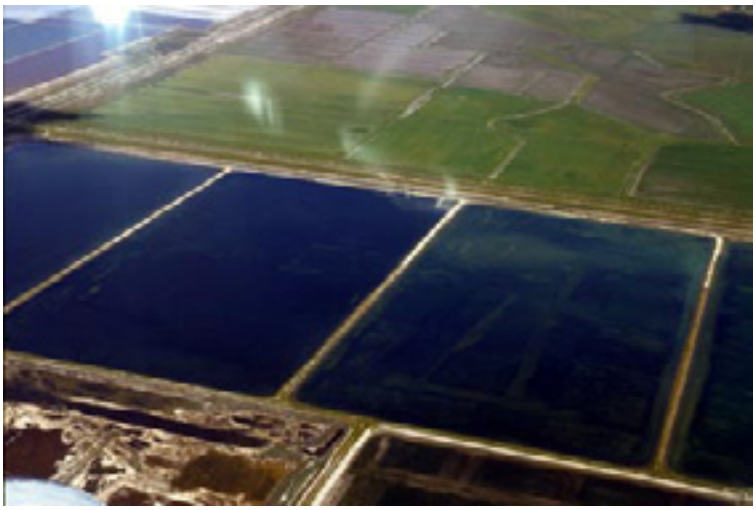
5. NEED

There is considerable interest in the potential for inland saline aquaculture in Australia. Several developmental projects are currently underway. While these are appropriate regionally, they are being undertaken in the absence of planning and review at the national level. There is an urgent need for national planning to ensure that current and future R&D is coordinated, focused, avoids duplication, and is targeted at realistic and meaningful commercial outcomes. The mapping and classification of inland saline groundwater resources will provide a valuable information bank for both researchers and investors. Successful development of inland saline aquaculture will generate employment opportunities in rural areas, and may defray costs associated with management of shallow saline aquifers.

ATTRACTIVENESS:
The development of a national plan for coordinating R&D on inland saline will have benefits for all stakeholders. The industry will benefit from streamlined research aimed at commercial outcomes. Funding agencies and research providers will have guidelines indicating priorities, and a plan for where particular projects fit into the bigger scheme of R&D in inland saline aquaculture.

FEASIBILITY:
The recent workshop on Inland Saline Aquaculture in Perth has laid much of the groundwork for the present project. The Aquaculture Committee, on which all State fisheries management agencies are represented, committed its support for the project. There are no technical constraints to satisfactory completion of the project.

RISKS:
The major risk is that a consultant sufficiently knowledgeable and experienced to prepare the R&D plan is not available for the consultancy. However, the steering group for the project will actively solicit appropriate people if necessary.



Evaporation basins - Wakool

6. OBJECTIVES

1. Review the developmental status of inland saline aquaculture in Australia.

2. Evaluate likely obstacles and limitations to the commercial expansion of inland saline aquaculture and the ability for R&D to address these limitations.

3. Develop an R&D plan to address these obstacles and limitations in consultation with the aquaculture industry and related disciplinary experts (Part 1).

4. Document the distribution and characteristics of inland saline groundwaters and their potential use for the farming of aquatic organisms (Part 2).

Evaporation basins - Wakool

7. METHODS

7.1. Steering Group Formation

- A small interdisciplinary steering group (representatives from industry [such as NAC and other relevant groups], research and management) was formed to provide expert input into the development of the R&D Plan. Members of the Steering Committee met with the Consultant appointed to help prepare the R&D Plan individually and then collectively in a workshop to review and prioritise R&D activities.
- The type of inland saline water resources identified by the Steering Committee to have the highest priority for commercial aquaculture developments were identified. These were then nominated as key types of resources to help focus the Resource Inventory and Assessment component of the project (Part 2).

7.2. Development of the R&D Plan

A decision was made to appoint a consultant to assist with the task of preparing the R&D Plan. This decision was made to help avoid any parochial interests influencing the nomination of priorities. The consultant was chosen after advertising nationally in the "Australian" newspaper. There were eight excellent applications. The successful applicant, Business Generation Pty Ltd, was selected on the basis of price, demonstrated experience and the definition of a process designed to clearly identify obstacles to early commercial exploitation of inland saline aquaculture.

Saline groundwater evaporation basins - Wakool

8. A RESEARCH & DEVELOPMENT PLAN FOR THE COMMERCIALISATION OF INLAND SALINE AQUACULTURE

8.1. About this Plan

This R & D Plan is a strategic plan designed to address opportunities for the development of aquaculture using inland saline water. Existing inland saline aquaculture and research in this area are described in Section 4.1 of this report. The project areas were identified on the basis of commercial potential and the extent of existing knowledge needed to realise this potential.

The Plan has been written with regard to priorities and strategies from other relevant planning documents including:

1. Fisheries Research and Development Corporation, 2000. Investing for Tomorrow's Fish: the FRDC's research and development plan, 2000 to 2005. FRDC, Canberra, 165 pp.
2. Gooley, G., 2000. R & D Plan for Integrated Agri-Aquaculture Systems 1999-2004. A report for the Rural Industries Research and Development Corporation. RIRDC Publication No 99/153. Rural Industries Research and Development Corporation, Canberra, 29 pp.
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9. Western Australia Government, 1996. Salinity Action Plan 1996. State Salinity Council of W.A. http.//www.wrc.wa.gov.au/protect/salinity
10. Smith, B., Barlow, C. (eds.) 1999. Inland Saline Aquaculture Workshop. Proceedings of a Workshop held in Perth, Western Australia, 6-7 August 1997. ACIAR Proceedings No. 83. Australian Centre for International Agricultural Research, Canberra, 61 pp.

8.2. Executive Summary

In early 1999 the FRDC commissioned a project to investigate the potential for use of inland saline water for aquaculture. The R & D planning objectives of that project were to:

- review the development status of inland saline aquaculture in Australia;
- evaluate likely obstacles and limitations to the commercial expansion of inland aquaculture and the ability for R&D to address these limitations; and
- develop an R&D plan to address these obstacles and limitations in consultation with the aquaculture industry and related experts.

The study was undertaken with the assistance of Business Generation, a business development consultancy.

The review built deliberately on the baseline and momentum established by an earlier ACIAR workshop conducted in August 1997. It included a wide-ranging interview program with researchers, commercial aquaculturalists and other interested parties across Australia and overseas during March/April 1999 to update developments. Findings and implications from the review were then assembled in a draft Discussion Paper that was circulated widely for comment.

In late June 1999 an R&D planning workshop of researchers and industry representatives was convened in Sydney to review emerging findings and to agree priorities for future R&D. The group identified seven priority project areas to develop specific opportunities for inland saline aquaculture or address emerging constraints. These project areas were:

- Grow-out of Marine Species Using Shallow Aquifers
- Aquaculture from Deep Artesian Water
- Winter Culture of Salmonids Using Shallow Aquifers
- Artemia from Existing Facilities
- High Health Prawn Hatchery
- Environmental Guidelines for Inland Saline Aquaculture
- Research and Extension Networking.

Specific research issues, key objectives and summary information has been developed for each of these project areas.

8.3. Introduction

The world faces an increasing shortfall in the supply of seafood for human consumption. To cater for Australia's predicted population in 2020, an estimated 80 000 tonnes of seafood will need to be sourced. Wild fishing stocks are being progressively depleted, and while aquaculture is growing strongly and now accounts for 22% of word fish production, the majority comes from freshwater species. There is a decreasing supply of suitable coastal sites that can be used for marine aquaculture to address the growing demand for saltwater species.

At the same time, dryland salinity, Australia's biggest environmental problem, has already affected in excess of 2.5 million ha (5% of cultivated land) and experts predict that this may rise by as much as 400% in the next couple of decades. One engineering solution to this problem is to construct expensive groundwater interception schemes and evaporation ponds where saline water is pumped out of the ground before it can rise to the surface. In the Murray-Darling Basin there are already more than 11 schemes, with over 6250 ha of pond surface area disposing of 49 000 ML of water/year through evaporation. There are many more schemes planned. More than 74 cities and towns in rural and metropolitan NSW are affected by rising saline groundwater.

The availability of inland saline waters opens up the potential for development of a saline aquaculture industry remote from the sea and offers a productive use for huge volumes of waste inland saline water.

In August 1997 ACIAR sponsored a national workshop in Perth on inland saline aquaculture, with support from FRDC and RIRDC. The main outcome of the workshop was identification of the need for development of a strategic plan to provide a national framework for R&D on inland saline aquaculture.

In early 1999 FRDC commissioned a study to investigate the potential for use of inland saline water for aquaculture. In particular the study was to:

- review the development status of inland saline aquaculture in Australia;
- evaluate likely obstacles and limitations to the commercial expansion of inland aquaculture and the ability for R&D to address these limitations; and
- develop an R&D plan to address these obstacles and limitations in consultation with the aquaculture industry and related experts.

The study included a limited review of relevant research papers and media sources, and a wide-ranging interview program with researchers, commercial aquaculturalists and other interested parties across Australia and overseas conducted during March/April 1999 to update developments. The Discussion Paper built deliberately on the baseline and momentum established by the earlier ACIAR workshop. The Discussion Paper summarised the current situation as follows:

> "At this time it appears that no-one (whether as a research or commercial initiative) has succeeded in growing a single crop of marine fish to marketable size in an *open pond* environment in Australia using *inland* saline water. There is nonetheless still every reason to believe that the objective is technically feasible. Most of the unit technologies are sufficiently established, but they require integration and demonstration in carefully designed and well-managed development projects. Conjecture as to likely commercial feasibility currently relies on too many assumptions.
>
> *Intensive systems* appear quite capable of producing marketable fish from inland saline water of suitable quality. Again there are no clear examples yet of commercially viable operations.
>
> There are *international* precedents of successful production of both finfish and crustaceans from inland saline water, but thus far relatively few of these initiatives have led to sustainable commercial operations."

The Discussion Paper also noted that the range of possible variables (water source, production system species, nutrition etc) was still daunting, and that it had already tended to generate breadth rather than depth in the related R&D program across Australia.

The Discussion Paper concluded as follows:

> "The FRDC brief calls for R&D to be targeted at *realistic and meaningful commercial outcomes*. If these are to be achieved, and within a reasonable timeframe, certain key things need to happen:

- ❖ R&D projects need to be defined which look promising on paper (technically and commercially) when reliant principally on proven unit technologies and established best practice from elsewhere in aquaculture;
- ❖ applied research on unit technologies needs to be focused on those gaps which need to be filled in order for the above projects to proceed;
- ❖ remaining research needs to focus on the successful *integration* of these unit technologies in relevant demonstration projects, using appropriate local and international best practice for both design and management;
- ❖ successful demonstration of technical feasibility, and the incorporation of findings into revised bio-economic models, will then provide a confident basis for sub-commercial projects, with increasing private sector collaboration."

The Discussion Paper was then circulated for comment, together with a proforma seeking readers' resultant views as to the best prospects for *realistic and meaningful commercial outcomes*.

In late June 1999 an R&D planning workshop of researchers and industry representatives was convened in Sydney to review emerging findings and to agree priorities for future R&D. The following prospects (in rank order) were collectively identified by aggregating the assessments of individual attendees for technical and commercial feasibility:

Species	Activity	Water Source	Score
Barramundi	Grow-out	Shallow aquifers	80
Silver perch	"	"	72
Prawns	"	"	65
Mulloway	"	"	55
Barramundi	"	Deep aquifers	54
Salmonids	"	Shallow aquifers	53
Artemia	"	"	53
Prawns	Hatchery	"	52
Barramundi	"	Deep aquifers	51
Barramundi	"	Shallow aquifers	50
Snapper	Grow-out	"	49
Salmonids	"	Deep aquifers	44
Prawns	"	"	41

The group then identified seven project areas that would explore specific development opportunities for inland saline aquaculture or address emerging constraints. These project areas were:

- ❖ Grow-out of Marine Species Using Shallow Aquifers
- ❖ Aquaculture from Deep Artesian Water
- ❖ Winter Culture of Salmonids Using Shallow Aquifers
- ❖ Artemia from Existing Facilities
- ❖ High Health Prawn Hatchery
- ❖ Environmental Guidelines for Inland Saline Aquaculture
- ❖ Research and Extension Networking

Brief justification, suggested research strategies, planned outcomes, potential areas and summary information for each project area were developed. The summary information links back to the initial Discussion Paper, expands on the justification for the proposed project, and provides further detail on implementation where appropriate.

The original Discussion Paper is not included in this report but can be obtained from the authors on request.

8.4. Mission and Planned Outcomes

A five-year timeframe was adopted as meaningful for the purposes of relevant R&D planning, while recognising that full-scale commercialisation would likely entail a longer time frame. The current status of relevant R&D was then used to provide a baseline for projecting a medium term future for the commercialisation of inland saline aquaculture.

A formal Mission Statement was developed to reflect the FRDC study objectives:

Inland Saline Aquaculture R&D Plan 2000-2005
Mission
To establish commercial inland saline aquaculture in Australia through applied research and extension

8.4.1. Inland Saline Aquaculture – Current Perspectives

The status in 2000 was as follows:

- Inland saline water resources poorly documented
- Primary R&D activity in NSW,VIC,SA,WA
- Relevant R&D projects often *ad hoc*, regionally driven, site-driven
- Focus on survivability, technical feasibility, specific water resources
- No unequivocally commercial operations
- The most propspective water resources are shallow and deep aquifers
- The most prospective commercial production systems are semi-intensive open ponds
- The most prospective species are barramundi, silver perch, prawns, mulloway, salmonids and artemia
- Most prospective technologies 'imported' from local coastal and/or freshwater aquaculture
- Communications networks developing
- Public interest accelerating
- General industry optimism re commercial feasbility

8.4.2 Inland Saline Aquaculture – (planned outcomes arising from successful completion of activities described in the plan)

1. High potential inland saline water resources identified and characterised
2. Commercial potential validated through R & D projects
3. Inaugural commercial enterprises established in target areas
4. Bio-economic models substantiating target activities
5. Incorporation of inland saline aquaculture into existing and planned saline groundwater interception schemes
6. Updated nationally coordinated R&D plan reflecting commercial perspectives
7. Improved formal and informal communications networks, including international, to improve success ratios
8. Best practice guidelines documented and available for new entrants in target activities

9. Industry development phase to generate critical mass for species, regional markets, processing facilities etc
10. R&D shift from core technologies and pilot commercial projects to productivity improvement, enhancement, value addition, marketing, export, industry extension
11. Skills development
12. Public education and promotion

8.4.3. Links with other Priorities and Plans

See Figure 1 for compatability of identified priorities for research and development of inland saline aquaculture with other planning documents.

Snapper – one of the candidate species for inland saline aquaculture

Figure 1: Compatability of identified priorities for research and development of inland saline aquaculture with other planning documents

Plans/Strategies[1]	**Inland saline aquaculture R&D Priorities**[2]						
	Grow-out of marine species using shallow aquifers	Aquaculture from deep artesian water	Winter culture of salmonids using shallow aquifers	Artemia from existing facilities	High health prawn hatchery	Environmental guidelines for inland saline aquaculture	Research and extension networking
1. FRDC	P	P	P	P	P	R	R
2. Gooley	P	P	R	C	C	R	P
3. SCARM	P	P	P	P	N	R	R
4. Nat. L&WRA	C	R	R	C	N	R	R
5. National Action Plan for Salinity & Water Quality	P	P	P	P	N	R	R
6. Basin Salinity	P	P	C	P	N	R	R
7. NSW Salinity	P	P	N	P	N	P	R
8. State Water Plan S.A.	P	C	N	P	N	R	R
9. Salinity Action Plan W.A.	P	C	P	P	N	R	R
10. ACIAR inland saline aquaculture	P	P	P	P	P	P	P

[1] Full reference are made to these plans/strategies in Section 8.1 of this report.
[2] These proposed R & D project areas are outlined in Section 8.5 of this report.

Key:
P = Priority
R = Clearly relevant
C = May be compatible
N = Not relevant

1. Investing for Tomorrow's Fish: the FRDC's Research and Development Plan, 2000-2005 (FRDC, 2001).

FRDC list "increasing production through aquaculture' as one of the nine challenges for Australia in increasing supply of fish. Growth in aquaculture will require access to suitable sites. FRDC (2001) note that "utilizing saline groundwater may offer significant opportunities for inland aquaculture of marine species." The opportunity to use large groundwater interception schemes with evaporation ponds was also noted (FRDC, 2001).
Link with Program & Strategies:
Program 2: Industry Development
Strategy: Aquaculture Development
Sub-Strategy: Site selection and access for marine and land-based aquaculture.

2. R & D Plan for Integrated Agri-Aquaculture Systems 1999-2004 (Gooley, 2000).

The Mission Statement for this plan is "to develop, promote and coordinate integrated agri-aquaculture system practices within Australian to enhance overall farm productivity and water use efficiency…". One of the eight ways listed in the Mission Statement to achieve this is by "containing and utilising on-farm otherwise wasted resources such as inland saline and nutrient rich waste waters."

Inland saline aquaculture is specifically mentioned in two of the five key industry needs listed in the plan. The first is "the need for relevant background information as an extension resource" (Gooley, 2000). The resource inventory produced as part of this current FRDC project addresses this need (see Part 2). The second is "the need for more biological and technical information relevant to development and implementation of Integrated Agri-Aquaculture Systems in Australia". Information on system design and impacts of saline aquaculture are a key component of this need. Among the strategies listed to address this need is "through appropriate *in situ* industry trades design and evaluate suitable system design requirements for Integrated Agri-Aquaculture Systems operations on a species by species basis; to include evaluation of fresh and saline waters, pond, tank and cage-based systems, use of surface and ground waters, mono and polyculture systems."

3. Management of Dryland Salinity: Future Strategic Directions. (Standing Committee on Agriculture and Resource Management, [SCARM] 2000).

This document lists aquaculture as one of the ways of "living with salt." It is recognised as an opportunity for land already salinised (where water tables are less than 2 metres below the surface). Within the section on "Focus of the National Policy Framework" in the document, significant opportunities to accelerating the development of new industries such as aquaculture are highlighted. This report includes an appendix (Appendix 2) that gives examples of initiatives undertaken by states to address salinity. Many of these specific initiatives also include reference to the potential of aquaculture as an opportunity in salt affected areas. Specific plans and documents referred to in Appendix 2 include:

- Queensland: Salinity Initiatives in Vegetation Management; Salinity Initiatives in Land & Water Management; Salinity Risk Assessment for Potential Irrigation Developments.
- Western Australia: Salinity Action Plan 1996, redrafted in 2000 (State Salinity Council of W.A.).
- South Australia: State Dryland Salinity Strategy and Short-Term Action Plan. (The Soil Conservation Council of S.A); Mapping of Salinity in S.A. (Primary Industries & Resources S.A.). Comprehensive mapping of the State's agricultural regions for dryland salinity.

- The Upper South East Drainage & Flood Management Plan (Commonwealth, State governments and local land holders).
- Catchments Back in Balance. Funded by NHT. Provides Salinity Action Plans to local communities and provides support services for successful implementation of the plans. (Highly acclaimed).
- Mapping and Monitoring – National Land & Water Resources Audit. A range of projects through NLWRA.
- R & D – Using saline resources for new farming systems and industries, PIRSA commissioned a new NHT funded project to examine productive uses for salt affected land – including aquaculture. This project is called "Using Saline Resources for New Farming Systems and Industries", funded to $107,000.

4. National Land and Water Resources Audit – Strategic Plan 1998-2001.

The six objectives of this plan were:

i. Providing a clear understanding of the status of, and changes in, the nation's land, vegetation and water resources and implications for their sustainable use.
ii. Providing an interpretation of the costs and benefits – economic, environmental and social – of land and water resource change and any remedial actions.
iii. Developing a national information system of compatible and readily accessible resource data.
iv. Producing national land, vegetation and water – surface and groundwater – assessments as integrated components of the Audit.
v. Ensuring integration with, and collaboration between, other relevant initiatives.
vi. Providing a framework for monitoring Australia's land and water resources in an ongoing and structured way.

One of the key challenges identified by the plan was to promote diversity in resource use. While not specifically mentioned, aquaculture in inland saline areas is entirely consistent with this challenge and with meeting objective ii) above.

5. National Action Plan for Salinity and Water Quality

A National Action Plan for Salinity and Water Quality (called the National Action Plan) was endorsed by the Prime Minister, Premiers and Chief Ministers at the Council of Australian Governments on 3 November 2000. The funding package is $1.4 billion from the Commonwealth, States and Territories over seven years and compliments the existing $1.5 billion National Heritage Trust.

The Action Plan identifies high priority actions to address salinity and deteriorating water quality to ensure that land and water management practices will sustain productive and profitable land and water use as well as our natural environments. The Plan reviews the current situation with salinity and lists the following:

i. 2.5 million ha (5% cultivated land) currently affected by dryland salinity. This could rise to 12 million ha.
ii. One third of Australian rivers are in extremely poor condition.
iii. Land and water degradation, excluding weeds and pests, is estimated to cost up to $3.5 billion/year and affect biodiversity.
iv. Infrastructure is being severely damaged in many rural and urban centres.

The National Action Plan builds on the work established under the National Heritage Trust, the MDBC, State and Territory Salinity Strategies at the GAG Water Agreement, particularly through the following:

- targets and standards for national resource management
- integrated catchment/regional management plans
- capacity building for communities
- improved governance framework
- clearly articulated roles for the Commonwealth, State/Territory, local government and councils
- a public communication program

The potential role for inland saline aquaculture is specifically mentioned under "capacity building for communities in development of production systems attuned to Australian conditions that "….include new commercial opportunities in saline environments (such as brine shrimp and the development of new salt-tolerant crop and pasture species)…" (AFFA, 2001).

6. Basin Salinity Management Strategy 2001-2015 (Draft) (Murray-Darling Basin Commission [MDBC], 2000).

The draft Basin Salinity Management Strategy takes a 100-year view of the salinity threats to the Murray-Darling Basis (which impacts on the four States – Queensland, NSW, Victoria and South Australia) and the potential benefits of salinity control options (MDBC, 2000). The draft Strategy is supported by salinity strategies or initiatives in each state and works towards the same objectives.

The four key objectives of the Strategy can be summarised as follows:

- ❖ to maintain water quality of the Murray-Darling rivers
- ❖ to control the rise in salt loads in all tributary rivers
- ❖ to control land degradation and protect eco-systems, productive land, cultural heritage and built infrastructure
- ❖ to maximise the benefits for salinity control across the basis (MDBC, 2000)

In the implementation of this Strategy, the completion of salt interception works and the planning and construction of new salt interception works are related to saline aquaculture. Commercially driven aquaculture will offset the huge cost of running salt interception schemes and with careful planning, greatly reduce the public cost of building new schemes. Using salt as a resource, including the evaluation and validation of saline aquaculture is listed as a priority in the implementation of the new Strategy.

7. Taking on the Challenge: NSW Salinity Strategy. (Department of Land and Water Conservation [DLWC], 2000).

The NSW Salinity Strategy has been introduced "to slow down the increase in salinity over the next ten years and lay the foundation for salinity management well into the future" (DLWC, 2000). Six key "goals" to achieve this are listed:

i. protect and manage our native vegetation
ii. use our land so less water goes into the water table
iii. use water more effectively or efficiently
iv. use engineering solutions
v. make better use of land affected by salt; and
vi. focus our efforts on priority salinity hazard landscapes

The engineering solutions include groundwater interception schemes and saline aquaculture is listed as a key salinity-related business opportunity

8. State Water Plan 2000. South Australia Vol. 1: Policies for a Sustainable Future (SA Department of Water Resources [SADWR], 2000).

This plan identifies the importance of disposal of saline water collected in salt interception schemes by evaporation and notes the potential for more productive uses of these waters, including aquaculture.

There are a number of other planning documents for South Australia that address salinity. The Direction for Managing Salinity in South Australia Statement is an umbrella document to more specific draft state strategies.

9. Salinity Action Plan 1996, updated 2000 (State Salinity Council of WA, 2000).

The WA government released a 30 year Salinity Action Plan in 1996 and redrafted it in 2000. The body responsible for this was the State Salinity Council of W.A. Considerable effort in WA has gone into developing productive systems for salt affected land and results have indicated such land can be cost-effective. (Initiatives to cultivate aquatic organisms in saline lakes have been described earlier).

The WA Salinity Council also formed a "Salinity R & D Steering Committee" in 1998 to oversee a review of salinity research and development needs for the State and to promote a cross-agency approach to seeking funding. Twelve discipline areas were identified for review. These included "aquaculture in inland saline water".

10. Inland Saline Aquaculture Workshop. Proceedings of a Workshop held 6 & 7 August 1997, Perth, W.A.

This workshop was held by ACIAR to examine prospects for aquaculture using inland saline water and identify constraints. A collection of papers from around Australia highlighting the interest in and progress with various projects to develop inland saline aquaculture were presented. Three key areas of interest are:

- the development of aquaculture as a component of an integrated agricultural production system that could optimise and maintain the long-term productivity of inland, salt-affected lands and waters (similar to Geoff Gooley'' Integrated Agri-Aquaculture System proposal)
- the use of inland saline groundwaters for the culture of marine fish and aquatic products
- the possibility of ACIAR-mediated research collaboration with developing countries, several of which face salinisation of farm land and which share a potential for inland aquaculture.

8.5. The Basis for the Proposed R&D Project Areas

8.5.1. Grow-out of Marine Species Using Shallow Aquifers (e.g. evaporation ponds constructed as part of groundwater interception schemes)

Justification:

- ❖ Australian and world supplies of fish are falling below demand and Australian imports of seafood products are increasing rapidly.
- ❖ Sea-based and coastal sites are increasingly scarce and expensive
- ❖ Marine species command premium prices
- ❖ Large volumes of apparently suitable water are available
- ❖ Large pond systems (evaporation ponds) or shallow aquifers are available

- ❖ The necessity to construct future evaporation ponds as part of new groundwater interception schemes offers considerable potential to integrate aquaculture into future salinity control measures.

Suggested Strategies:

⇒ Identify resources
- match the extent and nature of resources to species/groups of species. Obtain further information on saline groundwater resources where this information is lacking.

⇒ Development/validation of production systems.
- develop or validate all areas of production including source of seed stock, stocking strategy (e.g. density), diets and feeding strategies, health management, water quality management, water supply and effluent disposal.

⇒ Commercialisation and extension strategies.
- Identify constraints to commercial development and methods of overcoming these.
- Incorporate aquaculture into existing and planned groundwater interception schemes.

Planned outputs (should include):

1. Laboratory based bioassays to confirm survival and short-term growth of selected species in saline groundwater (compared with oceanic seawater)
2. Selection of suitable species matched with sites (including existing and planned groundwater interception schemes)
3. Growth and performance data
4. Water budget, usage and efficient planning (confirms value of further investigation)
5. Bioeconomic model for species/culture systems
6. Commercialisation plan, including extension strategy and marketing plan.

Potential areas with previous related activities:

- ❖ Wakool/Tullkool Sub-Surface Drainage Scheme
- ❖ Undera
- ❖ Cooks Plains
- ❖ Griffith
- ❖ Saline lakes in WA

Discussion:

Of the 13 highest-ranking commercial 'prospects', five (including the top 4) fitted within the broad category of 'Grow-out of marine species using shallow aquifers'.

The nominated species included barramundi, silver perch, prawns, mulloway and snapper. Of these, barramundi and prawns are warm temperature species; the remainder are temperate. If commercial production of nominated species from shallow aquifer water were to involve semi-intensive open pond systems – as is probable – there are clear climatic restrictions as to where these should be located. There is a separate constraint as to the actual availability of (shallow aquifer) inland saline water of suitable quality and quantity, within such climate zones. There is the further question as to which of such locations might meet various commercial criteria (such as local infrastructure, labour and social amenities).

At this point it is clear that various areas in the Murray Darling basin meet these requirements for temperate species for much of the year. In addition this is where the vast majority of relevant research has been undertaken to date. It is therefore appropriate to build on this knowledge and experience base.

As to species, production factors currently appear to favour mulloway, and marketing factors to favour snapper. Silver perch are an appropriate complement in areas with lower salinity. Prawns could also be grown in temperate areas, although this would limit the growing period. Whichever

species are adopted for the next phases of research, many of the findings are expected to be applicable to other species. In Western Australia, black bream have been stocked in shallow saline lakes to enhance recreational angling. Future prospects for commercial "fish-out' schemes warrant investigation.

The pursuit of research projects involving grow-out of barramundi and prawns in warm weather areas is assisted by the completion of a national assessment of inland saline water resources (Part 2). Some preliminary bio-economic modelling needs to be undertaken to determine the case for using (shallow aquifer) inland saline water rather than extending existing coastal production. It is clear from the existing industry that open pond production of barramundi is increasingly compromised at higher latitudes. In 1999 the most southerly viable open pond farm is located at Townsville.

The grow-out period for nominated temperate finfish species ranges from 1 to 2 years. This implies a development timeframe of at least 3 to 6 years, based on completion of a successful pilot followed by completion of two successive grow-outs on a sub-commercial scale. Use of purpose-designed facilities and application of best practice are strongly indicated to maximise prospects of a successful outcome.

8.5.2 Aquaculture from Deep Artesian Water

Justification:

- ❖ Australian and world supplies of fish are falling below demand and Australian imports of seafood products are increasing rapidly.
- ❖ Sea-based and coastal sites are increasingly scarce and expensive.
- ❖ Marine species command premium prices.
- ❖ Low cost/free water may be available at positive pressure; might be put to constructive use.
- ❖ Elevated water temperature may facilitate production of species in out-of-range areas.
- ❖ Disease-free water source.
- ❖ May allow aquaculture where other water sources are lacking, allowing benefits of scale, regional initiatives etc.

Suggested Strategies:

⇒ Identify resources
- match the extent and nature of resources to species/groups of species. Obtain further information on saline groundwater resources where this information is lacking.

⇒ Development/validation of production systems
- develop or validate all areas of production including source of seed stock, stocking strategy (e.g. density), diets and feeding strategies, health management, water quality management, water supply and effluent disposal.

⇒ Commercialisation and extension strategies.
- Identify constraints to commercial development and methods of overcoming these.

Planned outputs (should include):

1. Laboratory based bioassays to confirm survival and short-term growth of selected species in saline groundwater (compared with oceanic seawater)
2. Water disposal (e.g. through evaporation ponds) plan and water budget.
3. Selection of suitable species and culture technologies matched with site (especially for uncapped bores or effluent from mineral springs). Focus on both pond and tank (including intensive recirculation systems).
4. Growth and performance data.
5. Bioeconomic model for species/culture systems.
6. Commercialisation plan, inlcuding extension strategy and marketing plan.

Potential areas:

- Moree (effluent from mineral springs)
- Barraclear
- Gascogne pilot
- Robe, S.A.
- NTU

Discussion:

It has already been demonstrated that marine species of finfish can be successfully grown in recirculation and flow-through systems using inland saline water from deep aquifers. In particular:

- a small commercial operation in southern NSW uses deep aquifer water and recirculation systems to produce barramundi, and has operated successfully for many years (albeit at a modest scale);
- a second small commercial barramundi operation in Robe SA is also based on deep aquifer water, and uses a flow-through system; it capitalises on the elevated temperature of the emergent water to produce fish outside their natural climatic zone;
- a research project in Gascoyne WA using deep aquifer brackish water and a flow-through system was successful in producing barramundi of market size; there was not however sufficient water available at any single location to make such a project commercially viable;
- Israel boasts a number of ventures utilising brackish deep aquifer water.

Research has not yet addressed the technical or commercial feasibility of applying deep aquifer water to *pond-based* systems, although clearly the water itself can prove satisfactory. (Research projects in both Australia and the USA have demonstrated the technical feasibility of growing finfish and/or prawns in ponds using shallow aquifers.)

Deep aquifers extend across much of Australia. Where drilling has located water that is too salty for agricultural use the bores have generally been capped. Much of the water from remaining bores has been allowed to run free, resulting in wastage and salination, and also allowing positive pressure heads to fall. A national government-funded program is seeking to restore the situation by capping such wells.

There is also some overlap in the location of deep and shallow aquifers. Water from shallow aquifers may be easier and cheaper to access. However, the quality of deep aquifer water is generally more stable through time than is that from shallow aquifers.

Relevant questions relating to deep aquifer aquaculture include:

- Are satisfactory water disposal strategies and technologies available?
- Can the water be accessed, and at what set-up and operating costs?
- What quantity of water is available as a continuous supply? (For example, would it be sufficient to support pond-based systems, or only closed systems?)

- ❖ Is the quality of the water suitable for fish production, or does it require pre-treatment?
- ❖ Which of the locations are attractive (on other economic and social criteria) as a base for the establishment of commercial enterprises?
- ❖ Does the site imply net addition of salt at the surface?
- ❖ Do future plans to "cap" free-running deep aquifer bores impact on potential aquaculture?

8.5.3. Winter Culture of Salmonids Using Shallow Aquifers

Justification:
- ❖ Australian and world supplies of fish are falling behind demand
- ❖ Sea-based and coastal sites are increasingly scarce and expensive
- ❖ Current knowledge base suggests salmonids have prospects in VIC and WA using this approach
- ❖ Opportunity for farm diversification and to offset costs of land remediation

Suggested Strategies:
- ⇒ Review project underway in W.A. and collate growth and performance data (especially with regard to possible disease and mortality problem associated with elevated temperatures).
- ⇒ Identify constraints to further commercial development and address these where possible.
- ⇒ Identify further R & D priorities if results warrant further involvement.

Planned outputs (should include):
1. Bioeconomic model based on results from projects underway in W.A.
2. Water effluent and pond sediment control plan developed if results warrant it.
3. Commercialisation plan developed.
4. Further R & D planned if results encouraging and further research constraints are identified.

Potential areas:
- ❖ Saline lakes in WA and Victoria
- ❖ Shallow aquifer saline water in Victoria

Discussion:
Research in Victoria and WA has indicated that salmonids (specifically rainbow trout) will survive and grow during winter. A number of possible commercial applications are under consideration as a result:

In Victoria, shallow aquifer saline water is available in the irrigation areas, and may offer potential for diversification of farm income and to help defray the costs of saline water intervention schemes; rainbow trout are seen as possibly complementary species to silver perch in a partial grow-out program over winter and summer respectively; a farmer who provided an earlier research site is now pursuing a sub-commercial trial on his own initiative;

In WA, shallow aquifer water is similarly available in the wheatfields areas; fish could be harvested for market, possibly collaboratively, or provide the basis for fish-out (subject to the short growing season); WA Fisheries is sponsoring a trial program, "Outback Ocean", where trout are being grown out over this winter in ponds and dams across more than 100 farms; the trout need to be harvested before the onset of summer temperatures, and hence are stocked at an advanced size (to achieve marketable weight at harvest). Reliance on natural feeding systems reduces effluent problems but will increase the challenge of achieving satisfactory growth rates.

The WA trial will allow the biological feasibility of this approach to be tested across a wide number of sites. Successful harvesting of marketable fish from the Outback Ocean will then provide some meaningful basis for considering operational issues associated with harvesting, processing and marketing, and also forming some clearer views of likely commerciality.

Specific issues which attach to winter culture of salmonids include:

- costs and risks of supplying advanced fingerling stock to a range of sites;
- losses from unseasonally hot weather; and
- the mechanics and economics of end-of-season harvesting, processing and marketing; and
- rehabilitation of ponds for the next production cycle (including water removal and disposal, if necessary).

8.5.4. Artemia from Existing Facilities

Justification:
- Artemia offer greater potential to use existing salinity management infrastructure (evaporation ponds) than any other candidate species
- There are immediate markets for cysts, Artemia biomass and derived products for the aquarium trade and other aquaculture. These markets have been expanded by global shortages in Artemia, rapidly expanding demand and prices that have tripled over recent years
- Artemia grow and reproduce easily in high salinity environments, subject to the availability of food
- Expanding knowledge base will facilitate wider use of Artemia in remediation of waste water, including saline water
- Artemia culture will become more attractive in association with other forms of agriculture that may provide some of the essential nutrients needed for Artemia

Suggested Strategies:
⇒ Identify resources
  - Review current Artemia production methods and identify potential (and constraints to) for utilizing existing evaporation ponds for commercial Artemia biomass and/or cyst production. (Particular attention needs to be paid to the scale necessary to be internationally competitive).
  - Identify translocation issues and methods of minimising risks.

⇒ Development/validation of production systems.
  - develop or validation of methods for production of biomass or cysts (provided earlier review indicates potential).

⇒ Commercialisation and extension strategies.
  - Identify potential commercial pointers and initiatives for pilot-scale production project.
  - Prepare technical and marketing information package and extend these to potential investors and operators of evaporation schemes.

Potential areas:
- Cookes Plains, S.A.
- Pyramid Hill, Victoria
- Saline lakes in W.A.
- Evaporation ponds in Murray-Darling Basin.

Discussion:
Australia has a substantial investment in saline water intervention schemes, including the associated evaporation ponds. Much of the discussion on the potential for inland saline aquaculture has centred on the possible use of these ponds directly.

There are some major limitations to the direct use of existing evaporation ponds for mainstream aquaculture species (finfish, penaeid prawns etc):

- the ponds are designed to concentrate and precipitate out salt, so the water becomes successively more concentrated as it moves through the ponds;
- their large surface area and shallow depth are not ideal for commercial production or harvesting;
- drainage and fallowing of the ponds may adversely affect their performance in their primary (evaporative) role;
- if the ponds were stocked, and assuming supplementary feeding, the nutrient load would increase; and
- any significant increase would raise issues of water interchange, and also of impact on any downstream activities (such as salt production).

Artemia, by contrast, may be particularly suited to cultivation in evaporation ponds:

- they are euryhaline, but thrive in hypersaline environments;
- they are generally hardy and easy to grow (availability of sufficient appropriate nutrient at appropriate cost is likely to be the key limit to production);
- they are an ideal mechanism for cleaning up residual organic waste, and hence a complement to adjacent production of conventional species;
- they are prized as a fishfeed, and can be harvested for live feeding to adjacent finfish; (a project with these elements is being commercialised in South Australia); and
- they can be harvested either as cysts or as live biomass, processed as appropriate (e.g. dried flakes) and marketed locally and overseas.

Countries with commercial Artemia enterprises include the USA (California), the Philippines and Vietnam.

Establishment of a commercial Artemia enterprise would involve exploring the above issues, evaluating the available species regarding suitability for particular products and markets, and assessing the availability of suitable sites.

Commissioning of a commercial or sub-commercial operation would likely deliver insights on the possible incorporation of Artemia into other grow-out projects, and their applicability in the treatment of industrial wastes generally. A feasibility study would be a logical precedent to any such initiative.

8.5.5. High Health Prawn Hatchery

Justification:
- ❖ The Australian prawn industry needs increased supplies of disease-free, high quality post-larvae
- ❖ Coastal hatchery sites are scarce and have greater risk of pathogens
- ❖ Inland saline aquaculture offers advantages
- ❖ Significant export potential also exists for disease-free stock
- ❖ Potential extends to other marine species such as finfish, molluscs and other crustaceans.

Suggested Strategies:
⇒ Identify resources
- select candidate sites with required quantity and quality of saline water.
- select species with most potential (i.e. market demand, proven technology and availability of broodstock).

⇒ Development/validation of production systems
- conduct laboratory-based bioassays using target species to compare inland saline water from identified sites with oceanic water.
- conduct pilot-scale trials to develop and define protocols for broodstock management, spawning, larval rearing and live food production.
- develop protocols to dispose of effluent saline water without returning it to natural waterways.
- develop a bioeconomic model.

⇒ Commercialisation and extension strategies.
- prepare or adapt hatchery manuals specifically for inland saline hatchery development
- prepare investment brief.
- disseminate results and extend technology to land managers in suitable areas and potential investors/hatchery managers.

Planned outputs (should include):
1. Identification of suitable sites/species
2. Hatchery manual
3. Bioeconomic model
4. Investment brief
5. Commercialisation and extension plan

Discussion:
Australian marine aquacultlure is dependent on coastal hatcheries for the supply of grow-out stock. Production of fingerlings and post-larvae in this environment means that they are more easily exposed to disease through the water itself and from other species. Viral diseases are a particular concern, and their epidemiology and impact are not well understood. As a result, considerable effort and expense is invested in systems to minimise the likelihood of infection.

Experience suggests that if grow-out stock can be produced in a disease-free environment, this provides them with a head start before encountering any disease load that may exist in their final environment. Anticipated benefits include improved survival, enhanced production and increased feed conversion efficiency plus more uniform size distribution at harvest.

In 1989 the US Marine Shrimp Farming Program began developing Specific Pathogen Free (SPF) species for distribution. Prawn farmers in Southeast Asia now import post-larvae as 'specific pathogen-free' (SPF) from the Americas, and pay a significant premium for them. Preliminary research indicates that the three northern states of Australia are highly supportive of a similar initiative, with the intent of testing the benefits of SPF post-larvae in Australia.

The FRDC Prawn R&D Plan refers to this specific issue of SPF post-larvae, and notes that the high health program must be viewed as a one way process.

Inland Australia offers the potential to access disease-free saline water in locations that are free of other marine species, thereby providing an ideal context for the establishment of SPF hatcheries. Depending on their location, these hatcheries could service adjacent (inland) grow-out operations, coastal grow-out operations and/or export markets.

The establishment and successful operation of such inland hatcheries would also add to overall knowledge and skills in inland saline aquaculture, including the limited use of saline deep aquifers (if these are the preferred source).

It is therefore proposed to pursue the establishment of an inland tiger prawn hatchery in a location with access to suitable saline water via an existing bore, and good road access to the coast. However, this will be dependent on the proven commercial reality of closed cycle production for this species.

The project will address an immediate need of increasing importance for the local prawn industry, and provide insights applicable to other similar production contexts.

Commercial involvement from the outset would be an integral part of the project.

8.5.6. Environmental Guidelines for Inland Saline Aquaculture

Justification:

- ❖ Salinity is a key environmental concern, and any related activities can anticipate intense scrutiny
- ❖ Water access and disposal will be critical to inland saline aquaculture projects
- ❖ Aquaculture industry has taken an erly policy position re responsible use of saline water ("at least no worse off")
- ❖ Responsible aquaculture has the potential to improve the overall utilisation of degraded resources (land and water)
- ❖ Issues associated with translocating species outside their natural ranges need to be coordinated (to minimise genetic and health impacts)

Suggested Strategies:

- ⇒ Review existing environmental guidelines and codes of practice for other aquaculture industries (in Australia and overseas).
- ⇒ Review salinity strategies to ensure proposed aquaculture is consistent with the priorities contained within these plans.
- ⇒ Review national and state-based translocation policies.
- ⇒ Review general and specific health issues with high priority species.
- ⇒ Draft specific inland saline aquaculture environmental guidelines and codes of practice.
- ⇒ Circulate, edit and codify environmental guidelines and codes of practice.

Planned outputs (should include):

1. Review of relevant environmental guidelines and codes of practice for aquaculture.
2. Development of specific inland saline aquaculture environmental guidelines and codes of practice for high priority targe species/culture systems.

Discussion:

From an aquaculture perspective, inland saline water is a valuable asset and there is increasing interest in its responsible use.

From an environmental perspective, man-made inland saline water is the root cause of the biggest single environmental problem facing Australia.

The aquaculture industry is acutely aware of the importance of responsible environment management to its own sustainability. From the outset it has adopted a strong policy position on the subject. This is reflected in a paper on 'Environmental considerations in the use and management of inland saline water bodies for aquaculture' given at the ACIAR Workshop in August 1997:

Two fundamental objectives of aquaculture development are that it be environmentally sustainable and that it be economically viable. Any aquaculture development using saline water must not increase salinisation and must minimise the release of nutrients to waterways."

The ACIAR workshop concluded that there was need for a policy framework and guidelines for future investigations. Specific points suggested for such a policy included:

- that there would be no export of salt from aquaculture to freshwater systems, and
- that aquaculture would add no extra nutrient load to freshwater systems.

This policy position has been summarised as the no-worse-off position. It does not assume direct responsibility for fixing what has resulted from unwise practices by others. It does commit to avoiding such practices itself. Moreover it does propose that aquaculture has the potential to extract value for the community from what is viewed by many as a waste material rather than an asset.

The development of such guidelines and their proactive use in the design and conduct of R&D projects is seen as important in anticipating and addressing the reasonable concerns of others, and in maintaining the momentum towards establishment of commercially viable enterprises based on inland saline aquaculture.

8.5.7. Research and Extension Networking

Justification:

- Resource constraints together with large number of possible sites and species and culture systems make coordination necessary to minimise duplication and waste
- Many potential stakeholders, e.g. land managers wishing to construct groundwater interception schemes, have little or no knowledge of aquaculture
- Successive incorporation of knowledge base in new projects will maximise probability of successful outcomes
- Investment attraction and market development require communication, education, pre-marketing to target audiences
- Geographic spread of relevant projects and emerging information will help build national momentum for inland saline aquaculture

Suggested Strategies:

⇒ Establish a mechanisms to coordinate research and development through a new subprogram or other formal management process.
⇒ Conduct regular workshops targeted at researchers developing technology for inland saline aquaculture and at land managers faced with dealing with saline groundwater and salinisation.
⇒ Review research and extension strategies and direct methods to improve outputs and outcomes.
⇒ Develop generic bioeconomic and environmental guidelines and codes of practice.
⇒ Promote and publicise inland saline aquaculture.

⇒ Coordinate links with all other stakeholders including other R & D corporations, land management agencies (e.g. MDBC), state and commonwealth governments departments, land owners affected by rising saline water.
⇒ Periodically revise R & D plan.

Planned outputs (should include):
1. Workshops and workshop proceedings
2. Guidelines and models
3. Promotional material
4. Established linkages and communication framework with other stakeholders
5. Extension strategies
6. Revised R & D plan.

Discussion:
Industry consultation would suggest that there is relatively high optimism as to the technical feasibility of inland saline aquaculture, and reasonable confidence as to commercial prospects in specific contexts. There is however also general recognition of the very large number of possible variables that could be researched while pursuing that outcome. This is exacerbated by the fact that the States and territories vary significantly in their natural resources, climates and local interests.

The topic of Inland Saline Aquaculture competes for scarce R&D resources with other aquaculture, with wild-caught fish, with agriculture, and so on. Given the limited R&D resources, the large number of possible variables and the desire to achieve realistic and meaningful commercial outcomes, it was imperative that relevant R&D be coordinated nationally, and that is reflected in the development of this Plan.

The Plan builds on the important groundwork done in the 1997 ACIAR workshop. Synergies also emerge from the networking and collaboration of State fisheries staff, industry representatives and funding bodies on other topics. It is believed, however, that a more deliberate approach to research coordination, ongoing networking and information sharing will be necessary for the future if objectives are to be achieved within a meaningful timeframe.

Some particular concerns include:

- reinforcing the focus reflected in the R&D Plan, including proactive distribution of economic and commercial guidelines as available;
- efficiently tapping the existing knowledge base in the design and conduct of each successive R&D project;
- logging, tracking and proactively guiding pilot and commercial projects initiated by others, to improve their prospects of success and also to leverage from them;
- successively updating the knowledge base; and
- being able to respond in an informed and responsible way with information on existing best practice to any enquirers seeking information on inland saline aquaculture. (This would include referral to other industries, organisations and individuals where appropriate.)

Silver perch – another candidate species for inland saline aquaculture in waters of lower salinity

9. BENEFITS

The R&D Plan (Part 1) and Resource Inventory and Assessment (Part 2) will assist existing and potential aquaculturists, R&D funding agencies, research providers, planners and managers involved with saline groundwater control and rural communities.

Existing aquaculturists will benefit from having major constraints to commercial development identified and brought to the attention of potential research funding agencies and research providers. This should improve funding opportunities to address these constraints. The Project will also benefit this group by focusing attention on the merit of utilising degraded resources (saline groundwater and saline affected land) for a commercial business. Aquaculture is one of the few business opportunities with saline groundwater. This recognition should generate increased government and community support for aquaculture using saline groundwater.

Potential aquaculturists will benefit for reasons given above and also because planners and managers involved with saline groundwater control will be aware of opportunities to integrate aquaculture with new saline groundwater control schemes. This integration could help defray capital and operating costs (for water supply and disposal) for the new aquaculture operation and make obtaining government approvals much easier.

R&D funding agencies and research providers will benefit by having genuine commercial opportunities identified and research issues listed.

Planners and managers involved with saline groundwater control will benefit by having access to information on aquaculture opportunities which will help them plan for integration of aquaculture in new saline groundwater control schemes. As these opportunities are realised, and commercial inland saline aquaculture develops, the costs of saline groundwater control schemes will be considerably reduced. Aquaculture ponds are just as effective for evaporation as purpose built evaporation ponds. New control schemes might include high-capacity groundwater pumps (maybe from many bores) and relatively small evaporation ponds. The operators of the schemes could "sell" saline water to aquaculturists and then "sell" the right for them to dispose of their effluent in the schemes' evaporation ponds.

Rural communities should benefit from the Project as it will speed up commercial development of commercial inland saline aquaculture. New business opportunities from this new industry will provide economic development and employment.

10. FURTHER DEVELOPMENTS

The enormous problem with rising saline groundwater is achieving increased national recognition. The National Dryland Salinity Program (NDSP) that was established in 1993, entered a second phase in 1998/99. The NDSP was established as a means of improving research, development and extension coordination to better manage dryland salinity across Australia. The threat to productive agriculture from salinity has long been recognised but it is only since the establishment of the NDSP that the extent of the salinity problem has become apparent. In particular, the threat to rural and even some metropolitan infrastructure (including roads, buildings and properties), environmental resources and access to quality drinking water supplies have recently become apparent. Research, development and extension to make better use of degraded land and saline water is a key objective of the Phase 2 NDSP.

The Dryland Salinity Program has established a new unit called "Options for the Productive Use of Salinity (OPUS)". This unit has recognised aquaculture as having potential in saline affected areas.

At the launch of the Murray-Darling Basin Commission's 1999 salinity audit, the Federal Minister for the Environment described rising salinity as "the worst environmental problem Australia faces".

In Dubbo, NSW on 16-17 Mach 2000, the Premier convened a Salinity Summit to address problems, causes and opportunities in a coordinated approach. Over two hundred people attended this Summit including eight government ministers, twelve Department heads and senior officials and representatives of community groups across NSW. Aquaculture was identified as having real potential in saline affected areas. The recommendations from the working group established to identify ways of encouraging business initiative included the following:

- Encourage farmers to diversify into new salinity compatible products, such as aquaculture in saline ponds (4 other products were also listed);
- Support research to develop or validate business initiatives in aquaculture research and development, including the need for demonstration farms and effective extension services, in inland saline affected areas.

11. CONCLUSION

This project had two planned outcomes. These were the preparation of an R&D Plan for inland saline aquaculture (Part 1) and a resource inventory and assessment (Part 2) of inland saline resources for aquaculture.

The R&D Plan developed the following mission statement: "To foster the establishment of commercial aquaculture activities in Australia based on the use of inland saline water through relevant applied research to remove identified impediments". The status of inland saline aquaculture in 1999 was described and a vision for 2004 developed to help guide the R&D Plan.

An R&D planning workshop of managers, researchers and industry representatives was convened to review emerging findings and to agree on priorities for future R&D. The group identified seven project areas that would explore specific commercial development opportunities for inland saline aquaculture or address emerging constraints. Preliminary research parameters were then developed for each of these project areas. These project areas were:

1. Grow-out of Marine Species Using Shallow Aquifers.
2. Aquaculture from Deep Artesian Water.
3. Winter Culture of Salmonids Using Shallow Aquifers.
4. Artemia from Existing Facilities.
5. High Health Prawn Hatchery.
6. Environmental Guidelines for Inland Saline Aquaculture.
7. Research and Extension Networking.

The inland saline aquaculture opportunities with the highest potential for commercial development, which were identified in the R&D Plan were used to help guide the preparation of the Resource Inventory and Assessment (Part 2). To prepare the resource inventory, information was identified and collated from a wide range of sources, including the Internet, abstracting and subject-specific databases, agency libraries, unpublished reports, the scientific literature, as well as discussions with agency staff. Broad screening criteria were used to avoid collecting detailed information and assessing resources that are clearly unsuitable for the establishment of a saline aquaculture industry.

A diverse range of saline water resources was identified as having potential for inland saline aquaculture. These resources included:

1. Existing large-scale groundwater interception schemes and associated disposal basins located in three main areas of the southern Murray-Darling Basin. In total, the pond area in existing groundwater interception schemes and associated disposal basins, identified as having aquaculture potential, exceeds 6,300 ha in 11 schemes. These schemes were constructed at a cost of more than $108 million and cost more than $3 million per year to operate. They are used to dispose of more than 50,000 ML/yr.
2. A number of new proposed and planned saline groundwater interception schemes in these same regions. There are another 8 schemes being constructed or planned which could also have aquaculture potential. These new schemes will cost more than $50 million to build and more than $2 million per year to operate. They will dispose of a further more than 13 100 ML/yr.
3. Permanent natural saline lakes in Victoria.

4. Saline and brackish groundwaters from sedimentary basins and fractured rock aquifers around Australia. These were found in all states except Tasmania. A number of brackish geothermal groundwaters were also identified.
5. Urban groundwater pumping to protect urban infrastructure and property in areas affected by dryland or irrigation-derived salinity. These opportunities for cost-sharing were located in the Murray-Darling Basin and the wheat belt area of southwest Western Australia. There are some 74 rural towns (24 in Victoria, 21 in NSW, 1 in South Australia and 28 in Western Australia) which are experiencing or threatened by rising saline groundwater tables.
6. Proposed shallow groundwater pumping in the Ord River Irrigation Area around Kununurra in northern WA.
7. Two other unusual saline water resources with exceptional aquaculture potential were also identified. These were the proposed Esperance-Kalgoorlie seawater pipeline and saline drainage water associated with coal mines in NSW and Queensland.

Thirteen criteria were developed for a preliminary assessment of the potential of these identified saline water resources for the establishment of different aquaculture types (eg hatcheries, growout of euryhaline or stenohaline fish in ponds or recirculation units, etc). These criteria included the availability of land and freshwater, the nature of the surrounding environment, existing infrastructure and services and opportunities for cost sharing. The application of the developed criteria to potentially suitable saline water resources provided an indicative assessment of the suitability in relation to the various aquaculture types. A number of saline resources were identified as being attractive for a range of aquaculture types. (This is based on a preliminary and indicative assessment using tentative scoring criteria, and often with limited resource information.) These were in particular:

- The Esperance-Kalgoorlie seawater pipeline.
- Most groundwater interception schemes.
- Most of the Kerang Lakes.
- Urban groundwater pumping.
- The aquifers of the Murray Hydrogeological Basin.
- Coal mine drainage water.

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