Aquaculture

Research to foster investor attraction and establishment of commercial Aquaculture Parks aligned to major saline groundwater interception schemes in South Australia

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Acronyms and definitions

ACIAR	Australian Centre for International Agricultural Research
ADU	Aquaculture Development Unit
AMR	Active metabolic rate
AWQC	Australian Water Quality Centre
CPISARC	Cooke Plains Inland Saline Aquaculture Research Centre
DSW	Diluted seawater
DWLBC	Department of Water, Land and Biodiversity and Conservation
ET	Evapotranspiration
CI	Condition index
CNRM	Centre for Natural Resource Management
CO_2	Carbon dioxide
DCLW	District Council of Loxton Waikerie
EPA	Environmental Protection Agency
ESAI	Ecologically Sustainable Agriculture Initiative
FCR	Food conversion ratio
FRDC	Fisheries Research and Development Corporation
GW	Groundwater
GWK	Salinity interception scheme groundwater with added potassium
IAAS	Integrated agri-aquaculture systems
ISAARG	Inland Saline Aquaculture Applied Research Group
ISARC	Inland Saline Aquaculture Research Centre
$K^+:Cl^-$	Potassium to chloride ratio
kWh	Kilowatt hours
MDBA	Murray Darling Basin Authority
MIL	Murray Irrigation Limited
MMR	Maximum metabolic rate
MRL	Maximum residue limits *[Non-Technical Summary, page vii]*
MS	Metabolic scope
NATA	National Association of Testing Authorities
NSGAE	Northern Spencer Gulf Aquaculture Enterprise Incorporated

NTU	Nephelometric turbidy units
ORL	Our Rural Landscape
PC	Personal computer
PCB	Polychlorinated biphenyl
pH	a measure of acidity
PIRSA	Primary Industries and Resources South Australia
PLC	Programmable logic controller
R&D	Research and development
RDC	Riverland Development Corporation
RMR	Routine metabolic rate
SAAM	South Australian Aquaculture Management Propriety Limited
SAASC	South Australian Aquatic Science Centre
SA MDB NRM	South Australian Murray Darling Basin Natural Resource Management
SARDI	South Australian Research and Development Institute
SD	Standard deviation
SE	Standard error
SIFTS	Semi-intensive floating tank system
SGA	Spencer Gulf Aquaculture Propriety Limited
SGR	Specific growth rate
SIS	Salt interception scheme
SPDB	Stockyard Plain Disposal Basin
SW	Seawater
WAP	Waikerie Aquaculture Park
WISAC	Waikerie Inland Saline Aquaculture Centre

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Non-technical summary

Project title: Research to foster investor attraction and establishment of commercial aquaculture parks aligned to major saline groundwater interception schemes in South Australia

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Outcomes achieved

The project described in this report was conducted by the South Australian Research and Development Institute (SARDI) between 1 July 2004 and 31 March 2008. The project was funded by the National Action Plan for Salinity and Water Quality and administered by the Centre for Natural Resource Management (CNRM) and the Department of Water, Land, Biodiversity and Conservation (DWLBC), South Australia. Research and development (R&D) and proof of concept activities of this project were conducted at the Waikerie Inland Saline Aquaculture Centre (WISAC), South Australia and the South Australian Aquatic Science Centre (SAASC), West Beach, Adelaide.

At the start of this project a workshop was convened to summarise past inland saline aquaculture R&D conducted by SARDI at the Cooke Plains Inland Saline Aquaculture Research Centre (CPISARC) and to introduce the objectives of this new project to stakeholders. At this workshop salt interception scheme (SIS) managers, and representatives of local and state government agencies, identified key issues that needed to be considered to allow use of SIS groundwater for aquaculture in South Australia.

Subsequently, a three week study tour was undertaken by key project personnel involving visits to research and commercial aquaculture facilities using saline groundwater in the United States of America and Israel. A report was compiled which summarised each facility visited and identified technologies that would be appropriate for using for SIS groundwater based aquaculture in South Australia.

Consultation with the District Council of Loxton Waikerie (DCLW) allowed the identification of an appropriate site for establishment of a proof of concept scale aquaculture facility near Waikerie, South Australia. The location was within 10 metres of the Woolpunda SIS pipeline and the land required was leased from a local landowner.

Between October 2004 and April 2006, WISAC was designed and constructed, including obtaining all necessary local and South Australian government approvals. The facility was commissioned in May 2006 when approximately 13,000 mulloway were stocked into production and nursery tanks supplied with SIS groundwater.

This project conducted the first comprehensive sampling program to determine the composition of groundwater from the Woolpunda, Waikerie and Qualco-Sunlands SISs and of water discharging from the combined SISs into the Stockyard Plain Disposal Basin (SPDB). The most significant finding of this 12 month sampling program was that, in general, the composition of the groundwater within the SISs was likely to be suitable for aquaculture of euryhaline species such as mulloway.

Subsequently, the performance of mulloway, snapper and yellowtail kingfish was assessed at an R&D scale using SIS groundwater transported from SPDB to the SAASC. This research showed that the growth and metabolism of mulloway and yellowtail kingfish were not significantly different in SIS groundwater, diluted seawater and seawater, while the growth of snapper was impaired in SIS groundwater compared to diluted seawater and seawater. These trials suggested that mulloway and yellowtail kingfish were potential species for culture in SIS groundwater, with mulloway likely to be the species of choice because of its known broad salinity tolerance.

From May 2006 until March 2008 mulloway were cultured to marketable size (>750 g) at WISAC in a semi-intensive aquaculture system, which achieved a final stocking density in excess of 30 kg per 1,000 L (1 kL). From this proof of concept scale production trial, 9,772 kg of fish were harvested and fish performance and operational aquaculture system data were collected. The mean total food conversion ratio (FCR) for all fish combined was 2.03. The mean specific growth rate (SGR) of the best performing batch of mulloway cultured at WISAC was 0.51%/day over the culture period of approximately 600 days, from when they were stocked at 2.0 g until harvest at >750 g.

Information from processors to whom these fish were sold, and an aligned marketing study commissioned by Primary Industries and Resources South Australia (PIRSA) Aquaculture and undertaken by the Ehrenberg-Bass Institute of Marketing Science, University of South Australia using fish supplied by this project, suggested that production of mulloway in excess of 1.5 kg would be desirable. It was estimated that a culture period of approximately 835 days would be needed to achieve this weight for mulloway using SIS groundwater in a semi-intensive aquaculture system at WISAC.

Production of mulloway at WISAC demonstrated that aquaculture could be effectively achieved in parallel with the operation of a major SIS. Risk management features that were included within the facility design (i.e. turbidity sensor controlling an actuated valve inlet valve and installation of water storage tanks) allowed maintenance procedures conducted by SIS operators (SA Water) to be completed without significant impediment to aquaculture operations.

The proof of concept production component of the overall project demonstrated that the growth rate of mulloway cultured in SIS groundwater at WISAC was substantially faster than wild caught mulloway and mulloway cultured commercially in the marine environment in Spencer Gulf within seacages. The growth rate was also faster than that reported for both European sea bass and sea bream, both species that support large established aquaculture industries in the Mediterranean region. Despite these promising results, researchers believed better mulloway performance could be achieved and sought to address some of the possible limiting factors.

Dissolved carbon dioxide (CO_2) was identified as the major issue impacting upon the performance of mulloway in the semi-intensive aquaculture system investigated at WISAC. The concentration of dissolved CO_2 was high in the SIS groundwater and degassing was required before this water was supplied to fish cultured at WISAC. While degassing greatly reduced the dissolved CO_2 levels entering the mulloway production tanks, dissolved CO_2 levels were still approximated 20 mg/L, which remained a concern although the effects of such concentrations on fish performance were ambiguous in the scientific literature reviewed. To better characterise the effects, an experimental system was constructed and a trial conducted. This demonstrated that the growth of mulloway was significantly reduced when the concentration of dissolved CO_2 was greater than 6 mg/L, the lowest value assessed. This suggested that any commercial aquaculture system developed should incorporate more efficient methods to remove dissolved CO_2, and that this was likely to enhance the growth of mulloway beyond what was obtained in the demonstration trials undertaken during this project. The use of a more intensive recirculation aquaculture system was proposed to optimise the use of the higher temperature of SIS groundwater for fish production while allowing management of the levels of dissolved CO_2 and oxygen.

During the culture of mulloway at WISAC the mean cost of production was $7.65/kg. The major costs considered were feed (47.7%), electricity (29.6%) and oxygen (19.8%). Based on the data collected it was suggested that cost reductions could be achieved through improved feed management to reduce FCR and improve growth, as well as selection of a commercial aquaculture site where wastewater need not be pumped back into the SIS pipeline discharging into the SPDB. An aligned project, commissioned by PIRSA Aquaculture and undertaken by Econsearch Pty Ltd, used information provided by this project to populate an economic model for potential commercial investors to assess the financial viability of commercial SIS aquaculture.

Analysis of flesh was conducted from a sample of mulloway cultured in SIS groundwater. Levels of all chemicals assessed were below the relevant Australian maximum residue limits (MRL) or were below the detectable limits of the methods used by the National Association of Testing Authorities (NATA) accredited laboratory employed. Prices received for the mulloway produced by the proof of concept trials were between $6.60 and $7.00/kg. The retail price of whole fish was between $12.00/kg and $14.00/kg and between $22.00/kg and $25.00/kg for fillets. A good recovery rate of between 45%% and 48%% was reported for market size fish (>750 g). Responses from chefs, fish processors and consumers during taste testings and an aligned marketing study confirmed that the product was well accepted and of high quality. This suggested that a commercial facility undertaking significant production and providing consistent supply would be able to implement a marketing plan to achieve improved prices for high quality fish produced using SIS groundwater. A large production facility should also be able to reduce cost of production through economies of scale.

An environmental monitoring program was conducted to satisfy the requirements of PIRSA Aquaculture and South Australian Environmental Protection Agency (EPA). This program demonstrated that the proof of concept scale production activities at the WISAC had minimal effect on the levels of key nutrients and suspended solids in the downstream water. However, any commercial aquaculture facilities aligned to SISs will need to address the relevant regulatory requirements of these state government agencies with their increased fish production levels likely to increase waste discharges. In recognition of this need, trials were commenced to investigate the use of a local halophyte (*Sarcocornia quinqueflora*) for treatment of waste water as an alternative to the more usual mechanical means used by aquaculturalists. While this was unsuccessful due to a lack of available knowledge about the biology and culture of the halophyte species selected, a review of relevant scientific information suggested that the concept had promise and was also likely to reduce the volume of water discharged to disposal basins, an outcome stated to be beneficial by SIS managers.

To begin to better understand the ecology of the SPDB, an aligned project was initiated, and managed to collect and assess monthly water quality and plankton data (a Flinders University Honours thesis) as well as complete a seasonal survey of the species of birds present (a consultant's report to SARDI).

To complete the project, a workshop was held to communicate the results and outcomes to those interested. Presentations covered not only the topic of this project, but also the key projects aligned to it. Following the presentations, a smaller group discussion session took place to review the project and make recommendations on the need and direction of future R&D.

Summary of progress against objectives

1. Summarise the planning and regulatory issues specific to development of commercial aquaculture aligned to SISs.

From the start of this project stakeholders involved with management and operation of SIS (i.e. Murray Darling Basin Authority [MDBA] and SA Water), inland aquaculture planning, regulation and industry development (i.e. PIRSA Aquaculture), and local and regional planning and industry development (i.e. DCLW and Riverland Development Corporation [RDC]) were consulted. On 24 and 25 June 2004, a workshop was held to summarise previous inland saline aquaculture R&D conducted by SARDI at the CPISARC, present the new SIS groundwater aquaculture project to a range of stakeholders, identify major planning and regulatory issues, and discuss future R&D directions.

Planning and regulatory issues required to support development of aquaculture aligned to SIS were identified as important matters that deserved to be further progressed during the conduct of this project to allow commercial developments. The activities of this R&D and proof of concept scale project initiated a consultation process conducted by PIRSA Aquaculture to gather information on the range of planning and regulatory issues to be addressed in order to allow commercial aquaculture aligned to SISs operating in the Riverland region. From this consultation the discussion paper, *Draft framework for inland aquaculture zones around salt interception schemes,* was prepared (PIRSA Aquaculture, March 2006, unpublished). This paper identified a range of issues that required input from a number of South Australian state and local government agencies. Ultimately this precipitated a 'whole of government' case management framework approach to be adopted and led by PIRSA Aquaculture. SARDI, as the organisation undertaking this project, was a key participant in the case management framework group. This approach facilitated preparation of the following reports to further support commercialisation of outcomes of R&D and proof of concept scale activities:

1. *Market research and analysis of finfish farmed using groundwater*
2. *Economic and sensitivity analysis for the use of SIS for aquaculture development*
3. *Site optimisation using geographic information systems.*

Based upon experiences and data collected during R&D trials, SARDI provided regular input on technical and operational matters to consultants and agencies responsible for the preparation of each of these reports.

2. Complete a desktop study of potential species and conduct an audit of culture systems and environmental control technologies suitable for commercial aquaculture using groundwater from SISs.

At the start of this project it was recognised that a limited number of species could be identified as showing potential for culture using saline groundwater available from SISs. A national inland saline aquaculture development workshop that canvassed the views of R&D and industry participants across Australia concluded that barramundi (*Lates calcarifer*), silver perch (*Bidyanus bidyanus*), prawns (*Penaeus sp*.), mulloway (*Argyrosomus japonicus*) and snapper (*Pagrus auratus*) were still among the top 13 prospects for commercial inland saline aquaculture (Allan *et al.*, 2001). The unique combination of water temperature, salinity, ionic composition and water volume available from SIS in the Riverland region dictated that mulloway and snapper offered the best prospects for aquaculture and were the first species evaluated by this project. Another major selection criterion is the availability of fingerlings or 'seed' to stock a commercial aquaculture venture, with commercial hatcheries in South Australia presently only producing yellowtail kingfish (although mulloway and snapper have been produced in the past). Yellowtail kingfish were also considered as a potential species for aquaculture using SIS groundwater as commercial seacage aquaculture of this species has developed rapidly over recent years in South Australia and is now also occurring in New South Wales and Western Australia. There is an established supply of hatchery produced fingerlings and an expanding market demand for this species.

Initial project planning activities included an overseas study tour of inland saline aquaculture facilities in the southern states of USA and Israel to identify culture methods and technologies that would be most applicable to utilise with SIS groundwater for commercial aquaculture. This tour included visits to five commercial farms and three R&D facilities in the USA, and 13 commercial farms and three R&D facilities in Israel. A report was compiled following this tour (Appendix A) summarising the operations and approaches to issues such as environmental control and waste management. From the information gained during this study, combined with consideration of accumulated knowledge of a range of aquaculture systems, proof of concept scale semi-intensive and intensive aquaculture systems were proposed for construction at WISAC. However, insurmountable difficulties were encountered relating to international procurement and a decision had to be made to proceed only with the construction of the locally sourced semi-intensive aquaculture system at WISAC.

3. Establish an R&D facility to underpin development of a commercial Aquaculture Park near Waikerie (WAP) in conjunction with local TAFE and indigenous organisations, incorporating a pilot scale commercial farm, R&D, demonstration and training facilities.

A major component of this project entailed the design, construction and operation of WISAC, which was officially opened on 23 September 2006 by Ministers Karlene Maywald and Rory McEwen (Figure 1). WISAC was constructed on a leased site with close access to the main Woolpunda SIS pipeline. WISAC operated from May 2006 until April 2008 and supported proof of concept trials of a semi-intensive aquaculture system that was evaluated for the culture of mulloway. Over this period 9,772 kg of mulloway were harvested and supplied to local fish processors, distributors and restaurants. Trials were also conducted at WISAC on the affect of dissolved carbon dioxide (CO_2) on mulloway performance and the growth of local halophytic plants in SIS groundwater discharged from aquaculture production tanks.

During this project, TAFE made a strategic decision to only conduct aquaculture courses at their facilities in Port Lincoln and Urrbrae (Adelaide) leaving no possibility for training activities to be undertaken at WISAC. However, while operating, WISAC hosted local secondary school and TAFE students for work experience, and technical staff who had completed TAFE aquaculture training courses were employed by SARDI. In September 2006, SARDI hosted a *Science Outside the Square* event at WISAC. This involved a bus tour for 120 people visiting SIS operations (SA Water), a tour of WISAC's aquaculture operations and a tour of SPDB. In August 2007, WISAC hosted a *Science Week* event that involved a day of aquaculture activities presented to groups of 30 students from six local primary schools. WISAC hosted visits by scientists from across Australia and overseas as part of tours for the Australasian Aquaculture Conference (2006) and the Second International Salinity Forum (2008). Numerous visits were hosted for local agricultural bureaus, community groups and visiting dignitaries during the conduct of this project (Appendix C).

Figure 1. Official opening of WISAC by Ministers Karlene Maywald and Rory McEwen, 23 September 2006.

4. Assess suitability of groundwater from SPDB for culture of two species with best potential from the desktop study. Specifically, early trials will focus on growth in water from SPDB compared to salinity adjusted seawater and development of commercially applicable methods to compensate for potassium deficiencies if this is problematic.

The suitability of SIS groundwater for culture of mulloway, snapper and yellowtail kingfish was evaluated (Chapters 4, 5 and 6). Growth trials and metabolic studies on each of these species were conducted at SAASC. These trials concluded that mulloway was suitable for culture in SIS groundwater while yellowtail kingfish may have potential in a production system that can support this species. Growth of snapper cultured in SIS groundwater was reduced compared to fish cultured in similar salinity seawater. This species is not recommended for aquaculture using the SIS groundwater assessed.

5. Measure growth performance of two species with best potential in water from SPDB until these achieve market size.

Two batches of mulloway were cultured to market size in three proof of concept scale production tanks (70,000 L) at WISAC using SIS groundwater. A total of 13,112 fish were stocked in a semi-intensive aquaculture production system. This species showed high survival rates and the growth performance achieved indicated that a culture period of between 18.6 and 19.7 months was required to produce market size fish (>750 g) starting with 2.0 g fingerlings. Market acceptance and product quality were high and the price achieved was between $6.60 and $7.00/kg for whole fish. It is suggested that further improvements could be achieved if problems identified could be adequately addressed. The two key issues to be addressed were reducing the elevated concentration of dissolved CO_2 that persisted in the culture system, and better feed management to improve growth and reduce production costs. It is suggested that higher prices could be achieved if a reliable supply of fish was maintained and a marketing plan undertaken that focused on the quality of this product and benefits of productive use of SIS groundwater.

Trials conducted at SAASC indicate that the SIS groundwater supports growth and survival of this species.

Two small batches of yellowtail kingfish were also stocked at WISAC, however, these fish showed progressive mortality. It was suggested that the production system used at WISAC was not suitable to support production of this fast growing and demanding species. Therefore, improved water treatment within an intensive system may be required to support production of yellowtail kingfish at WISAC.

6. **Evaluate the performance of the two most compatible culture systems identified by the desktop technology audit and modify these if necessary to include discharge water treatment systems to allow sustainable inland saline aquaculture operations using SPDB water.**

The design for WISAC proposed installation of a semi-intensive aquaculture system and an intensive aquaculture system. Only the locally constructed semi-intensive aquaculture system was installed due to international procurement issues preventing the purchase of the desired Israeli intensive system within the time frame available for this project.

The semi-intensive aquaculture system achieved the specified stocking density of 30 kg per 1,000 L (1 kL) when fish reached market size. Elevated concentration of dissolved CO_2 in culture water was identified as the major operational problem with this system. The results of this study showed that growth of mulloway reduced as the concentration of dissolved CO_2 increased. Appropriate and effective methods to reduce and utilise nutrients in saline water discharged from WISAC utilising SIS groundwater were also identified as issues that needed to be addressed if commercialisation is to proceed. Preliminary investigations of the growth of a local species of halophyte (*Sarcocornia quinqueflora*) undertaken at WISAC demonstrated that transplantation of young established plants was not successful and any future R&D will need to be undertaken using propagated seedlings or by considering the use of other species. The high cost of pumping water back into the SIS was also identified as an issue that could be addressed with better site selection for a commercial aquaculture venture.

7. **Generate performance and economic data from the demonstration farm for investment planning by industry and to support ongoing development of sustainable production systems aligned to SISs.**

Data for major operating cost items was collected during production of mulloway at WISAC. Feed was identified as the major production cost followed by electricity and then oxygen. It is suggested that improvements can be made to reduce feed and oxygen costs while better site selection could greatly reduce the cost attributed to electricity. Information generated was also provided to consultants engaged by PIRSA Aquaculture to prepare the report *Economic and sensitivity analysis for the use of SIS for aquaculture development*. Fish (approximately 100 kg) were supplied for consumer taste testing and surveys (Figure 2) conducted by other consultants engaged by PIRSA Aquaculture and were the basis for the marketing report *Market research and analysis of finfish farmed using groundwater from SIS*. These reports were prepared for the 'whole of government' Case Management Framework – Aquaculture Development Utilising Wastewater from Salt Interception Schemes, and will provide the information required by commercial investors to assist them to plan for the use of SIS groundwater available for aquaculture.

Figure 2. Consumer surveys and taste testing of Murray mulloway conducted at the Central Market.

Need

This project undertook R&D and a proof of concept scale trial to facilitate the development of commercial aquaculture based on select fish species and aquaculture systems, and in doing so also evaluated the composition of groundwater for the Woolpunda, Waikerie and Sunlands-Qualco SISs that discharge into the SPDB. The development of viable and sustainable aquaculture exploiting essentially a wastewater resource was considered to provide the potential for a significant new and much needed economic opportunity for the Riverland region of South Australia.

To undertake this project there was a need to establish an integrated R&D and proof of concept facility supplied with SIS groundwater from Woolpunda. This facility was used to undertake research needed to provide information required to attract private sector investment in potential commercial farms using SIS groundwater in the Riverland region of South Australia.

To provide this information there was a need to undertake activities targeting four main technical areas:

1. the suitability of the SIS groundwater for aquaculture
2. selection and performance evaluation of preferred aquaculture species
3. evaluation of preferred aquaculture systems
4. assessment of planning, regulatory and sustainability issues associated with SIS aquaculture development.