Salmon farming is one of the most valuable aquaculture industries in Australia.

Aquaculture

The blue revolution

Katherine Johnson outlines research aimed at ensuring Australia's 'fish' farms are sustainable, efficient and disease-free.

The black tiger prawn (*Penaeus monodon*) is a popular farmed species.

A blue revolution is sweeping Australia. From the tropical north to the temperate south, more aquatic species than ever before are spending their lives – from egg to adult – in ponds on the land and in coastal enclosures.

The reason is aquaculture. Primary producers are backing this burgeoning industry, encouraged by the clean water, large climatic range and scientific knowledge Australia has to offer.

Already more than 60 species of fish, shellfish and aquatic plants are being farmed, generating more than $400 million annually. Aquaculture, one of Australia's fastest growing primary industries, already supplies one fifth of the total value of Australia's fisheries production, and it seems our hunger for seafood just keeps growing.

In the past three years, aquaculture production in Australia has increased by 46% in tonnage and 80% in value. The dramatic increase in value is the result of a concentration on high-value species such as Atlantic salmon (Tasmania), Southern Bluefin Tuna (South Australia), oysters (Tasmania and NSW) and prawns (NSW, Northern Territory and Queensland). Emerging industries include barramundi, silver perch and abalone.

But it's not just Australia that is experiencing this boom. The United Nations Food and Agriculture Organisation reported the total world aquaculture production in 1994 reached 25.5 million tonnes valued at US$39.8 billion: an increase in tonnage of nearly 12% on the previous year. It is predicted aquaculture will meet at least 40% of the global demand for seafood in the next 15 years.

CSIRO aquaculture specialist Dr Peter Rothlisberg says the key to the success of aquaculture worldwide will be the adoption of sustainable farming practices. Importantly, aquaculture needs to occur alongside other coastal uses, with minimal environmental impact.

There is also a need to produce disease-free, superior animals, improved feeds, and value-added products such as pharmaceuticals.

In all these areas, Australian scientific research is providing answers, and in many cases generating novel techniques and technologies, that are giving the nation's aquaculture industry a competitive edge.

In CSIRO alone there are seven divisions involved in aquaculture research. Much of this is being carried out through the Cooperative Research Centre (CRC) for Aquaculture with funding from the Fisheries Research and Development Corporation.

Controlled development

Clean and Green: these words describe the reputation of Australia's aquaculture industry, and are perhaps its greatest market advantage. It is a reputation that cannot be compromised, Rothlisberg says.

Geographically we have had a head-start. Clean water and low farm density in relation to coastline are critical for a high standard of aquaculture product. Japan produces 3000 times more aquaculture product for a given area of coastline than Australia. Low farm density also reduces the potential impact of aquaculture farms on each other and on the surrounding environment.

Rothlisberg says sustainable farming practices are essential if the current rate of development is to continue while maintaining environmental quality. It is a fact that local governments and aquaculturalists are acutely aware of.

Uncontrolled aquaculture development overseas, together with unsustainable farming practices, have resulted in poor water quality, disease and, not surprisingly, severe losses in production.

'We have a completely different situation. Because Australian aquaculture is relatively new and community awareness of environmental issues is high, the industry here is subject to close scrutiny,' Rothlisberg says.

In Australia, aquaculture farms are licensed under strict state laws, which cover operations such as water supply and waste water and prevent uncontrolled or extensive development.

In addition, Australia leads the world in researching sustainable aquaculture practices, from farm site-selection to effluent management and disease prevention. This research is largely being carried out through the CRC for Aquaculture which involves CSIRO, the Australian Institute of Marine Science, universities, state agencies and aquaculture farms.

One of the most powerful tools being investigated for use in planning aquaculture developments is Geographic Information System (GIS) technology. By combining data on land elevation, slope, proximity to a water source, temperature range, rainfall and soil type, GIS technology offers land managers a birds-eye view of the best, and worst, locations for aquaculture farms on land.

In a pilot study of 35 kilometres of coastline in south-east Queensland, CSIRO showed that less than 4% of the land surveyed was suitable for prawn farming, and only 2% was considered optimal. The remainder was considered unsuitable.

Maps outlining the suitability of different coastal sites for prawn farming in northern Australia will be produced by CSIRO in collaboration with Queensland government agencies, providing managers and farmers with necessary information to help make informed, objective decisions about potential prawn farm sites. By avoiding unsuitable sites, farmers will be saving a lot of money in production losses and infrastructure expenses, Rothlisberg says.

The maps will also help land managers avoid establishing aquaculture farms in environmentally sensitive areas, or where there is a conflict in land or coastal usage.

In Tasmania, CSIRO researchers are monitoring salmon farms in the Huon and channel area in what is the first study

Bottom: Collecting prawns on a Queensland prawn farm to monitor improved growth rates resulting from selective breeding.

Below: Selective breeding of the prized Kuruma prawn has led to an increase in growth rate of 25%.

CSIRO's Mark Tonks examines juvenile prawns in the seawater facility at the Division of Marine Research's Cleveland Laboratory

involving whole-catchment environmental monitoring. The study, funded by the Fisheries Research and Development Corporation, will monitor the water quality around the farms and make recommendations for management that will help ensure the long-term sustainability of salmon farming in the region.

The research will also provide a new framework for environmental monitoring of the Australian coastal fish-farming industry in general.

Through the CRC for Aquaculture, Australian researchers have also pioneered systems for recirculating and purifying water in prawn ponds. CSIRO's Dr Nigel Preston is heading the research and says that while much attention is focused on the quality of water leaving the ponds, little attention is paid to the quality of water entering them.

Preston has shown that by not overstocking the ponds and using a combination of settlement ponds, plants and biological filters such as oysters and mussels, the quality of water leaving the ponds can be as good or better than the water entering the ponds from the coast.

'The farmer can literally close the pond system to incoming water and recirculate the water if required, giving them control over the quality of water in their ponds,' Preston says.

'Importantly, such systems also protect farms from events occurring upstream, such as heavy rains or a pollution incident, that could jeopardise their entire stock overnight.'

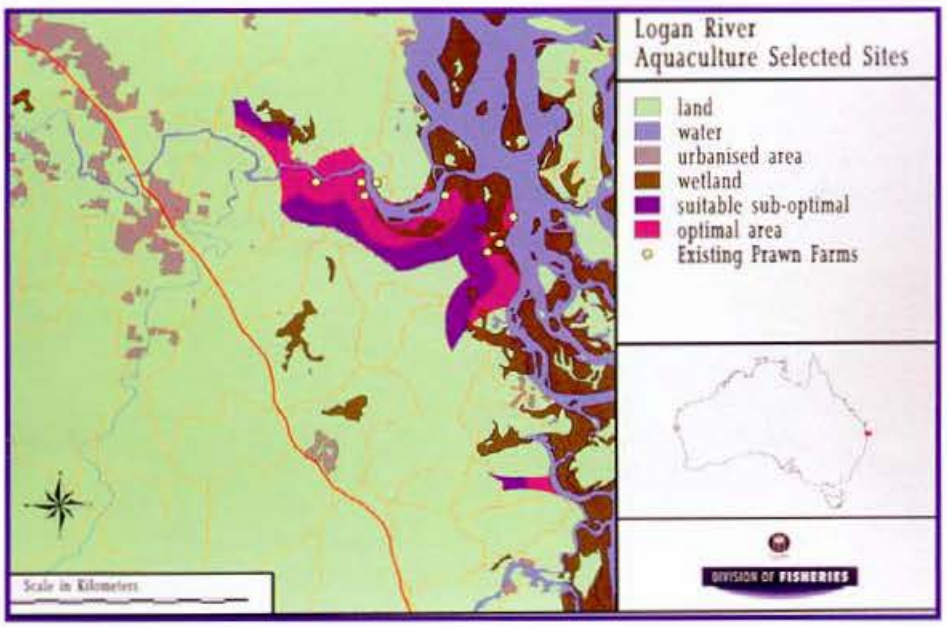
They also have the added benefit of introducing an additional income source, in the form of oysters and mussels.

Keeping disease at bay

Disease-free aquaculture is another market advantage afforded Australia that scientists are striving to maintain.

Just as stocking the ponds or enclosures too densely leads to a reduction in water quality, it also leads to a reduction in the growth rate of the farmed animals, and animal health problems, such as disease, Preston says. Disease is yet another reason to ensure that water entering aquaculture farms is of the highest quality.

Freedom from disease offers better market access and customer acceptance. Atlantic salmon, plagued by diseases such as furunculosis in other countries, is relatively disease-free in Australia, contributing to a premium in Japan, according to an Australian Bureau of Agricultural and Resource Economics report. The report warns that loss of such status would remove a market advantage.



Geographic Information Systems (GIS) are being used to identify the best sites – in terms of production and low environmental impact – for aquaculture farms.

Right: CSIRO is working with industry to produce local feeds superior to imported ones.

Above right: The microalga *Tetraselmis suecica* is a popular live feed for many aquaculture species. CSIRO operates a microalgal supply service providing algal cultures for industrial, research and teaching applications.

Above: Aquaculture feeds are analysed for essential lipids (or fats) to help industry formulate nutritious rations.

Sustainable management practices may minimise the threat of disease, but there is no room for complacency, says Dr Eva Bernoth of CSIRO Australian Animal Health Laboratory. Fortunately, Australia has a long-history of disease detection and management for livestock, a history that has underpinned a tenfold growth in beef exports since the 1950s.

The technologies developed to deal with disease problems on the land are now being applied to aquaculture. The aim is to rapidly identify any new disease problem and have the tools and strategies ready to combat the disease.

Much of the research aimed at achieving disease-free aquaculture in Australia is collaborative. A recent example is the CRC for Aquaculture's prawn virus research, a collaboration between prawn farmers and the CSIRO divisions of Tropical Agriculture and Animal Health.

Super foods on the way

Feed for aquaculture is another area being investigated by Australian scientists that promises to directly benefit the aquaculture industry. The development of superior, locally produced and environmentally friendly feeds will be of great benefit to the aquaculture industry, says Dr Kevin Williams, principal nutrition scientist at CSIRO Marine Research.

It's a statement that makes good economic sense considering that feed accounts for about 60% of on-farm grow-out production costs for aquaculture. In Australia, most of the feed used in prawn farming is imported, but other aquaculture industries including salmon, trout and barramundi rely almost entirely on domestic supplies.

Williams says only about 20 to 30% of the protein in aquaculture feed is retained by the animal with the remainder either not being eaten or being excreted. This inefficient use of feed leads to wastage and nutrient overload of the water and the potential to impact on the wider environment.

'By identifying the nutrient requirements of the animal being farmed and matching the feeds to those requirements, more of the feed ends up in the animal being farmed and less in the water it swims in,' he says.

Such a feed is being developed for prawns by CSIRO and Australia's largest stockfeed manufacturer, Ridley Corporation in a two year research and development project.

CSIRO, in collaboration with state agencies and universities, and with the support of the Fisheries Research and Development Corporation, is also developing improved feeds for farmed prawns and finfish, which would reduce our reliance on fishmeal. Fishmeal, a major constituent of many aquaculture feeds, is deemed an unsustainable use of wild fisheries resources. Williams says results are already encouraging, with meatmeal feeds achieving excellent results in terms of growth rate, taste and texture, for barramundi, silver perch and prawns.

Formulated feeds are also being developed for juvenile abalone to increase growth rates. Their success will be known in the next few months.

Another area attracting increasing interest for enhancing the growth rates of young aquaculture animals is the development of live feeds such as tiny plants (microalgae) which are only one cell big. A six-week study by CSIRO at Hobart has shown that supplementing the feed of juvenile Pacific oysters with certain microalgae halves production times.

Hobart algal biologist Dr Sue Blackburn says continuing research is committed to finding the best microalgae for the different species being farmed and for different farm environments.

The Hobart laboratory houses the largest collection of living microalgae in Australia and supplies algal cultures to hatcheries nationwide as well as an increasing market in the Asia-Pacific region.

Perhaps the most novel form of aquaculture feed being investigated involves feeding microalgae to tiny marine animals known as zooplankton and then feeding these zooplankton to larval fish as convenient nutrient 'capsules'.

Creating elite performers

Selective breeding and genetic enhancement also offer huge benefits to the aquaculture industry. Farmers on the land have been breeding animals with favourable characteristics to improve the quality of their stock for thousands of years. Domestication of aquatic species through aquaculture will offer the same stock improvement advantages, says Dr Steve Moore from the CSIRO Division of Tropical Agriculture.

'It took several thousand years, and many generations, to achieve stock improvements in cattle. We expect to see significant improvements in aquaculture species in our lifetime.' Moore says:

The research team headed by Moore and Preston, with the support of Moreton Bay Prawn Farm, has successfully reared the highly sought-after Kuruma prawn (worth $150/kg in Japan) in captivity, and has achieved increases in growth rate (and size) of 25%.

Moore says by increasing the growth rate of the prawns, producers can reduce production times considerably, saving money in feed, and electricity needed to turn the aerators.

Modern genetic techniques being developed at CSIRO's Division of Tropical Agriculture also will give marine producers certainty that their broodstock will produce young that will grow at the same fast rate, ensuring uniformity across the stock. 'These tests will also allow improvements in growth rate to be multiplied over successive generations of animals,' Moore says.

This multiplying effect can be seen in Scandinavian studies on salmon, where a 10% increase in growth rate has been achieved per year for seven years. Similar results are expected for prawns in the Australian research.

The same techniques can be used to select animals with favourable characteristics other than fast growth, such as disease resistance or attractive markings or colours that appeal to certain overseas markets.

Deriving valuable products from aquatic animals and plants is another area where Australian science is adding value to our fledgling aquaculture industry.

Marine organisms from microalgae to fish represent both a nutritional resource for use in aquaculture feeds, and a unique storehouse of biochemicals that may become valuable medicines, food additives, or cosmetic ingredients to name but a few applications.

The CSIRO Collection of Living Microalgae houses enormous potential for the discovery of unique biochemicals with pharmacological and other properties, Blackburn says.

Then there are the polyunsaturated fatty acids produced by microalgae, fungi, yeasts and Antarctic and other marine bacteria that are being investigated for their use in aquaculture feeds.

abstract

CSIRO research projects are helping Australia's aquaculture industry to compete on the burgeoning global market. They cover aspects such as maintaining water quality, sustainable management, selective breeding and genetic enhancement, disease minimisation and the formulation of nutritious feeds.

Keywords: Aquaculture; Fisheries; Sustainable agriculture; Livestock feeds; Animal health; Animal breeding

Fish are also more valuable to farmers than just the worth of their meat. Marine oils with nutritional qualities are being extracted from farm-grown fish and fish byproducts for use as human nutritional supplements and for use in aquaculture feeds.

All of these developments point to the massive potential for aquaculture in Australia as a supplier of quality seafood, medicines, marine oils and the myriad of products just waiting to be discovered. They also highlight the important role science plays in the sustainable development of a blue chip industry.

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Supplementing the natural diet of juvenile oysters with Australian microalgal strains has more than doubled the oysters' growth rates.