Focus

AQUACULTURE ADVANCES

Australia's focus on sustainable systems that minimise pollution and disease has been a good thing . . .

Left: Abalone on the way to grading at a farm on the east coast of Tasmania. CSIRO

In the past decade, aquaculture has become a $100 billion global industry – the fastest growing food-production sector since the advent of intensive agriculture in the 1950s. Australia's industry, while still relatively small, is setting high standards for quality, environmental rigour and innovative research. **Graeme O'Neill** reports.

Ten years ago, farmed species provided only 35 per cent of the world's fish consumption. Recently the Food and Agriculture Organization of the United Nations (FAO) estimated that aquaculture now produces almost 50 per cent of the world's food fish.[1]

This success is no surprise given that, with the world's population peaking towards 9 billion by 2050, and fisheries already under severe pressure, there is a protein supply shortage that is growing particularly acute in poorer tropical regions.

Seafood – fish, crustaceans and molluscs – is an excellent source of dietary protein and healthful omega-3 fatty acids, and a primary protein source in many countries. While agriculture has only a limited ability to increase production (especially of protein crops) because of the scarcity of new arable land and water shortages, aquaculture – particularly mariculture (aquaculture in the ocean) – has significant potential to maintain its growth, and to produce the extra protein needed by the swelling population.

Standard setting

Australia has the world's third largest Exclusive Economic Zone – 15.8 million square km – but its aquaculture industry accounts for only 0.8 per cent of global production.

Output has grown by only 4 per cent annually over the past decade to around $800 million a year. Tuna accounts for 34 per cent of production, Atlantic salmon 16 per cent, prawns 8 per cent and abalone 4 per cent.

Slow production growth is partly a consequence of Australia's international reputation as a leader in 'clean, green' production, according to Dr Nigel Preston, Theme Leader for Breed Engineering with CSIRO's Food Futures Flagship.

'Arguably, we have the world's most stringent controls on both sea-cage aquaculture and pond culture,' Dr Preston says. 'And every prawn producer requires a licence that sets strict limits on nutrient discharges.'

He says the Australian aquaculture industry, research agencies and funding and regulatory agencies are cooperating well to balance economic benefits with conserving coastal environments.

Australia's focus on sustainable systems that minimise pollution and disease has been a good thing, argues Dr Preston, but it has impeded the prawn industry's expansion.

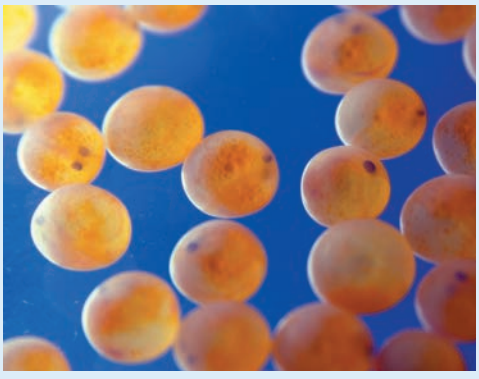
Options for mass-producing fish cheaply for the Australian market are limited, but Dr Preston believes Australia can still expand its aquaculture industries within its strict nutrient-discharge requirements.

Carp (*Cyprinus* spp.) actually accounts for 35 per cent of the world's aquaculture harvest.

1 Food and Agriculture Organization of the United Nations (2006). State of world aquaculture: 2006.

Juvenile abalone on growth plates at a Tasmanian abalone farm. CSIRO

Prawn rearing tanks at the CSIRO Cleveland laboratory, south of Brisbane. CSIRO



Atlantic salmon roe in care before hatchlings emerge. CSIRO

***Penaeus monodon*, the black tiger prawn.** CSIRO

But the European carp (*Cyprinus carpio*) is a major pest in the Murray–Darling River system and Australia is making intensive efforts to eliminate it.

Dr Preston says aquaculture producers recognise the importance of integrating production systems with good environment-protection practices.

Australia has learned rapidly from nations like India and China, where aquaculture is an ancient industry, and has developed efficient systems for dealing with its wastes.

But Dr Preston says the industry feels unfairly singled out, because upstream emitters of nutrients and sediments, including agriculture and urban areas, are not subject to the same strict controls and monitoring of nutrient discharges.

Australia's most lucrative aquaculture industry is sea-cage farming of the critically endangered southern bluefin tuna, *Thunnus maccoyii*, which began in 1991, after wild stocks crashed from overfishing.

The industry, now worth $300 million a year, is predicted to reach $600 million by 2010.

Between December and March, trawlers net around 5000 tonnes of juvenile tuna averaging around 20 kg each in the Great Australian Bight. They are fattened to around 30 kg in sea cages off Port Lincoln, on a diet of fresh local sardines or frozen imported baitfish. But it typically takes between 12 to 15 kg of baitfish to produce 1 kg of tuna meat.

Dr Preston says finding alternatives to wild-harvested fishmeal is a critical issue for both the Australian and global aquaculture industries.

He points out that current plant-based fishmeal options lack the health-promoting omega-3 fatty acids found in baitfish, which derive ultimately from marine microalgae.

However, fish nutrition expert Dr Geoff Allan, of the NSW Department of Primary Industries, rejects claims that harvesting small baitfish – like pilchards, sardines and anchovies – for fishmeal is unsustainable (see 'Concerns about aquaculture'), saying the Australian baitfish industry is well managed and environmentally sustainable.

He says baitfish represent about a third of the global fish harvest, and annual production has been stable, at 6–7 million tonnes, for decades. Production, he asserts, far exceeds demand for human consumption, and even with the rapid growth of aquaculture, there is no evidence that the resource is overfished.

He also points out that Australia sells around 50 000 tonnes of lupins a year into the world aquafeed market, as an alternative to soy bean, the global expansion impacts of which are raising new concerns.

Pollution management

Dr John Volkman, a chief research scientist with CSIRO Marine and Atmospheric Research in Hobart, and leader of the environment program for the Cooperative Research Centre for Sustainable Aquaculture of Fin Fish (the Aquafin CRC), says the CRC has analysed the environmental performance of both the salmonid and tuna-farming industries through a large, multi-agency research program over the past six years.

It has developed a computer-based hydrodynamic and geochemical model with which sea-cage developers can explore the dispersal and environmental impact of nutrient inputs from uneaten fishmeal and fish

faeces on natural nutrient cycles in a defined coastal area.

'When any fin-fish industry reaches a certain scale, it produces a lot of nutrients – mainly nitrogen and phosphorus,' Dr Volkman says. 'We need to know how those nutrients will be dispersed by sea currents, and whether they could cause plankton blooms that will transfer the extra nutrients into biomass.'

The Aquafin CRC has modelled the impacts of established tuna sea-cage aquaculture off Port Lincoln, and produced a low-resolution model of nearby Spencer Gulf, a potential site for future expansion.

'We found that nutrients would be dispersed fairly rapidly, and it was difficult to pick up any effect on phytoplankton – in fact, it would be a challenge … to detect these effects at all,' says Dr Volkman.

'Excess nutrients are much less of an issue for the tuna industry than for the Atlantic salmon industry.'

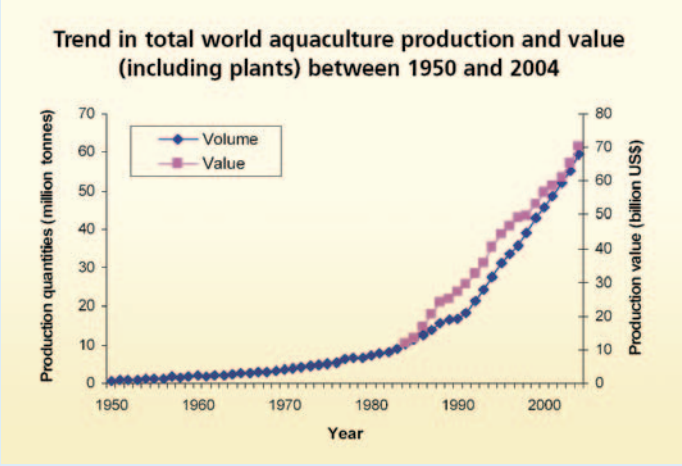
With the capture of juveniles strictly regulated, the industry has two avenues to increase production: holding the tuna longer, or closing their life cycle by developing hatcheries.

The Port Lincoln-based Stehr Group has invested millions of dollars in a project to develop a tuna hatchery to close the breeding cycle.

Dr Volkman says this strategy involves higher risks, including disease, and faces a wider range of issues than the present on-growing of captured fish. But the potential environmental gains are considerably greater.

He points out that while Australia's salmonid aquaculture industry is very small by international standards, it is now a vital part of Tasmania's economy.

'It's producing a high quality product, and the environmental effects are well understood and closely monitored.



Supply meeting demand: the FAO estimates global aquaculture production now provides 50 per cent of the world's food fish, with that figure increasing each year. FAO

'The great thing about Atlantic salmon is that they are very sensitive to water pollution, so in terms of environmental issues they are like canaries down a coal mine.'

The industry is concentrated in the d'Entrecasteaux Channel and Huon Estuary, off southern Tasmania, Macquarie Harbour on the west coast, and Launceston's Tamar River. Water temperatures limit its expansion beyond Tasmanian waters.

Both the tuna and salmon industries are substantial employers in regional Australia. Their requirement for labour rules out more remote areas of coastline – or moored sea cages in deeper waters.

Dr Catriona Macleod's research team in the School of Aquaculture at the University of Tasmania, a partner in the Aquafin CRC, has investigated the environmental effects of nutrient pollution associated with caged Atlantic salmon, and been surprised by the health of the invertebrate and microbial communities in the sediments below and around sea cages.

Concerns about aquaculture

The Australian Marine Conservation Society (AMCS), an NGO specialising in marine environmental issues, is one organisation concerned that current aquaculture systems are unsustainable.

It opposes the use of protein fishmeal from wild-caught species such as sardines and pilchards to feed carnivorous and omnivorous species such as southern bluefin tuna and Atlantic salmon.

AMCS Sustainable Fisheries Officer, Craig Bohm, says aquaculture can offset the demand for protein and provide affordable products in the marketplace, but that AMCS opposes sea-cage aquaculture and advocates the development of closed systems for intensively farmed species.

Mr Bohm says that while some state governments, like the Tasmanian Government, are very pro sea-cage aquaculture, coastal communities have resisted proposals for sea-cage aquaculture developments at Moreton Bay, in southern Queensland, and in Darwin and Bynoe harbours in the Top End.

'Because of community opposition, and the commercial risks involved, the industry is not booming in places where one might previously have expected it to do so.'

He says aquaculture does not necessarily reduce the impact on wild fish stocks, or replace wild fisheries, because global demand is enough for both, and the limited range of species suited to aquaculture could never replace the 'wondrous diversity' of wild-caught species.

The AMCS also opposes using imported fish or fishmeal to feed species such as Atlantic salmon and southern bluefin tuna, because of the potential to disrupt marine food chains dependent on small fish, and introduce exotic diseases.

The AMCS also opposes using soy in fishmeal, because soy grown as a cash crop in poorer nations is exported to wealthy nations and fed to intensively farmed livestock.

AMCS's concerns extend from the supply of marine baitfish species for fishmeal, to the impacts of sea-cage farms on local ecosystems and communities. CSIRO

Tim Lang, of the Centre for Food Policy, framed the problem thus: 'In Brazil alone, the equivalent of 5.6 million acres of land is used to grow soya beans for animals in Europe. These "ghost acres" belie the so-called efficiency of hi-tech agriculture.'

More information:
AMCS: www.amcs.org.au

She has recorded marked changes in benthic (sea-bed) communities, as organisms that are well adapted to breaking down organic material move in, and flourish. The opportunists include polychaete worms, gastropod and bivalve molluscs such as dog whelks, and crustaceans such as squat lobsters.

'The worst-case scenario is that they can't cope with the extra nutrient load, and it all breaks down into a nasty, anoxic mess,' Dr Macleod says.

'We've developed an objective scale of impacts, but in the past three years, we've never seen that level of pollution.'

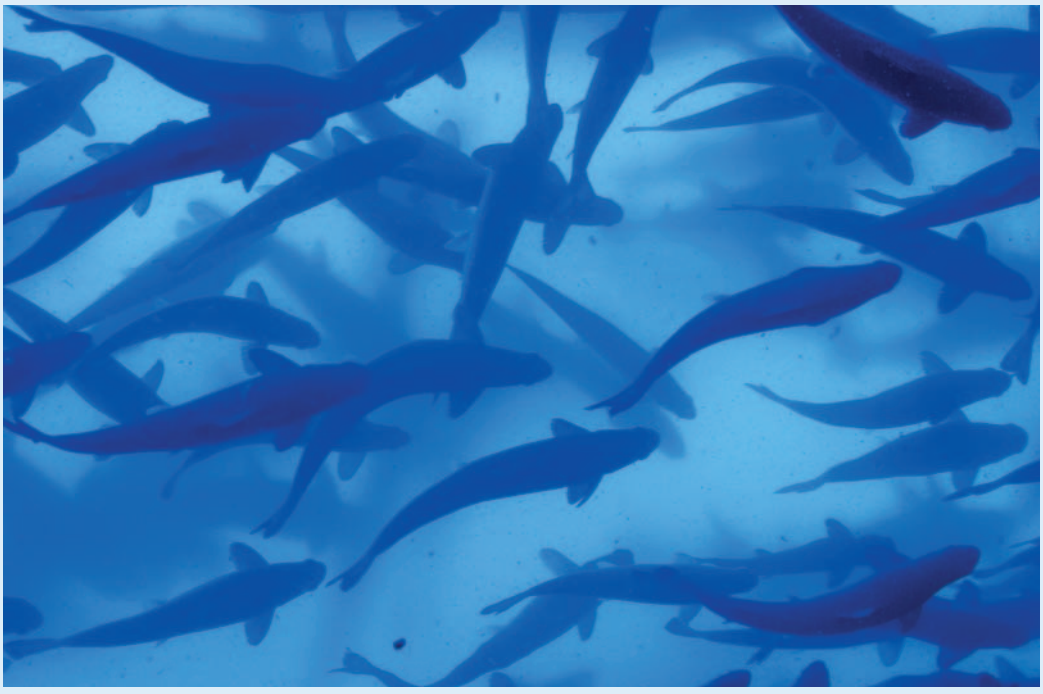
Other research shows that some species disappear, but the effect is highly localised – undetectable beyond a 35 m radius – and substantial recovery occurs within three months of the cages being removed, or after fallowing. By 18 months, the original community has largely recovered.

'This is interesting in the light of the push for salmon farms to move offshore to reduce the impact on shallow-water areas. Offshore cages would disperse nutrients over a much larger area, among a marine flora and fauna that might not be as well adapted to higher nutrient loads.'

Dr Macleod says flows from the Huon River into d'Entrecasteaux Channel are naturally high in organic material, and the benthic fauna is pre-adapted to the higher nutrient loads.

'If the farm is completely removed, we can expect total recovery in around three years, but the dynamics of recovery are quite complex – some species have life cycles longer than three years,' Dr Macleod says.

Farmers, meanwhile, apparently have an excellent empirical knowledge for the changes that occur, and are good environmental managers. 'They have the experience of 40 years of salmon farming in Norway, Scotland and Canada to draw upon,' says Dr Macleod.



Atlantic salmon in freshwater rearing tanks at Salmon Enterprises of Tasmania, Wayatinah, Tasmania. CSIRO

'The good news is that the technology is there, and working well. Every time we go overseas feeling that we might be a little backwards, we find we're close to the forefront of many issues.'

CSIRO's Dr Nigel Preston says Australia excels in breed improvement in aquaculture species such as prawns, abalone and oysters.

'CSIRO's Food Futures Flagship and the aquaculture industry have co-invested a lot of resources in projects to develop elite genotypes from wild, unselected stock.

'It took thousands of years to develop domesticated cattle, pigs and chickens. We aim to shorten that timescale to a decade or so, to achieve higher returns.'

Dr Preston is skeptical about the get-rich-quick aquaculture schemes touted by entrepreneurs, most of which have resulted in big losses to Australian investors.

'Balancing the level of investment in established industries and potential new species is a continuing challenge. Investment in species that have yet to demonstrate commercial viability is clearly a higher risk than backing those that have done the hard yards and are making a profit.'

Even established barramundi and prawn farms face significant competition from imports from South-East Asia, where production costs and labour are much cheaper.

Dr Preston believes the future lies in further exploiting the internationally acknowledged high quality of Australian seafood products and outcompeting imports on both quality and freshness.

'We've also given thought to cultivating native species that might provide better nutrition, and be better able to survive drought, as well as integrated, multi-species aquaculture systems that would produce protein for higher-value species.'

'The essence of the challenge is to provide investment security, and create the public confidence to expand this industry – not at the expense of, but in addition to terrestrial industries.

'We need to know how long it will take to develop a $5 billion aquaculture industry, to match the value of the beef or wheat industry,' Dr Preston emphasises.

New industry focused research initiatives, including those by the CSIRO Food Futures Flagship, the newly formed Australian Seafood Cooperative Research Centre and the Fisheries Research and Development Corporation, are focusing on the key research hurdles and the potential health benefits of consuming seafood, sustainably produced in a safe environment, without depleting wild stocks.

Dr Preston says that, at a time when many of Australia's terrestrial agribusiness sectors are drought affected, investment in marine aquaculture could be very timely.

More information:
Aquaculture Council of Western Australia (ACWA): www.aquaculturecouncilwa.com

Aquafin CRC: www.aquafincrc.com.au

Food Futures Flagship: www.csiro.au/org/FoodFuturesFlagship.html

Focus

SALT OF THE EARTH

The innovative research and demonstration facility at the Inland Saline Aquaculture Research Centre, Wakool. ISARC

'Inland ocean' trout from the Wakool facility are already popular in the marketplace. ISARC

Could one man's problem provide another man's meat? If the Australian fish supply's future lies with aquaculture, why not exploit the continent's unwanted, saline groundwaters to grow marine or salt-tolerant fish inland?

In New South Wales, Dr Geoff Allan, from NSW Department of Primary Industries (DPI), supervises a multi-species pilot project at Wakool, in south-central NSW, location of Murray Irrigation Ltd's Wakool-Tulkool SubSurface Drainage Scheme.

Saline groundwater from 70 saline bores is pumped into 1600 ha of evaporation ponds to produce salt. The facility is extremely effective at protecting surrounding land from effects of salinity – approximately 50 000 ha have been rehabilitated after being ravaged from salinity – but it is expensive to maintain and operate.

On the other hand, suitable sites for aquaculture can be difficult to find, so the project team is investigating the economic and biological feasibility of incorporating aquaculture into the interception/evaporation scheme.

NSW DPI and Murray Irrigation Ltd established and operate a research and demonstration facility at Wakool with funding from the Australian Centre for International Agricultural Research (ACIAR) and other sources.

NSW scientist Dr Stewart Fielder discovered that saline groundwater from the Murray–Darling Basin was deficient in potassium and how to cheaply remediate it (by adding potash fertiliser) so marine and estuarine species could thrive.

The project has trialed snapper *(Pagrus auratus)*, mulloway *(Argyrosomus japonicus)*, silver perch *(Bidyanus bidyanus)*, rainbow trout *(Onchorynchus mykiss)*, black tiger prawn (*Penaeus monodon)* and Japanese tiger prawn *(P. japonicus)*.

These species were chosen for their potential tolerance to variations in salinity, but the long cold winters, short summers and large variations in temperature have proven a stumbling block to economic viability of the warm temperate species.

However, trout thrive and large-scale commercial development of an 'inland ocean' trout industry based on results is underway.

Several tonnes of rainbow trout, mulloway and tiger prawns have been produced for commercial evaluation and market trials. Officer-in-charge of the research facility, Grant Webster, says all the product from Wakool has been enthusiastically accepted in the marketplace.

There are ongoing research challenges, such as how to best manage effluent from the fish farm, and how to adapt farming infrastructure to best suit the operation of the interception/evaporation scheme, and these research questions are likely to form a major project under the new Seafood CRC.

A natural advantage of saline groundwater is that it is free of pathogens and this raises the possibility of using inland saline water for production of pathogen-free prawns post-larvae and fish fingerlings.

A natural advantage of saline groundwater is that it is free of pathogens . . .

Dr Allan also coordinates a national research and development project, funded by the Fisheries Research and Development Corporation, to develop inland saline aquaculture (ISA). This involves South Australia (SARDI), Western Australia (Challenger TAFE) and Queensland (QDPI&F). Each state has saline water with potential for aquaculture but each area has different characteristics.

South Australia's scientists are trialing mulloway at a saline interception scheme on the Murray at Waikerie, where geothermal activity keeps saline groundwater at a constant 22 degrees Celsius. This site has great potential, but ensuring safe effluent disposal in the receiving basin is a research challenge.

In Western Australia, barramundi and trout are being tested in the new Semi-Intensive Floating Tank System (SIFTS) housed in saline ponds in the wheat belt. As the saline ponds in this area have little capacity for water exchange, effective aquaculture systems will need to incorporate nutrient removal and aeration.

In Queensland, black tiger prawns have been grown in moderately saline groundwater (~10 per cent seawater) from bores in irrigation areas. This has proven successful but the small scale of ponds and water supply facilities combined with downward pressure on prawn prices has restricted large-scale development at this stage.