10.1071_ISSN0311-4546EC104p11

A cultured life

Securing a future for Australia's prawn-farming industry

CSIRO

2. A cultured life

AUSTRALIAN prawn farms have the potential to be world leaders in production, disease management and environmental sustainability, thanks to research efforts by science and industry.

On the production front, CSIRO Marine Research, the Australian Institute of Marine Science and various industry partners have developed domestication strategies for farmed prawn species which reduce reliance on the diminishing wild prawn stocks and give farmers greater control over when they stock.

Domestication has also opened the door to genetic the enhancement of farmed prawns. For example, selective breeding trials for increased growth rate could soon see increased production efficiency. The construction of a genetic map of the prawn genome and the identification of genes for commercially useful traits such as disease resistance or greater meat-to-tail ratio, will boost production and market value further.

While disease threatens the sustainability of the prawn industry overseas, local research aims to maintain Australia's low-disease status. Through the CRC for Aquaculture, CSIRO Livestock Industries has developed screening tests and disease management strategies to limit the impact of native viruses on prawn production and prevent exotic viruses entering the country.

The impact of prawn farming on the environment has also been addressed through research into the composition of effluent being discharged from prawn farms. Rather than discharging wastewater into the ocean, prawn farmers are starting to use treatment ponds that trap sediment and recapture nutrients.

In the next decade, the full extent of these production, disease management and environmental strategies should be realised, enabling Australia to take its place among the world's leading aquacultural producers.

The Kuruma prawn, *Penaeus japonicus*.

Making a splash on the market

It's been a long wait, but prawn farming is finally being rescued from the whims of nature. Wendy Pyper outlines the rewards of collaboration.

It's 9 pm and the shed is humming to the sound of heavy machinery, running water, and workers bustling about in aprons and rubber boots. A tractor pulls up outside the door and two men quickly transfer crates from a water-filled trailer to a chilled water trough inside. As I peer over the rim, the water churns with the movement of hundreds of Kuruma prawns, (*Penaeus japonicus*) destined to reach the Japanese market in less than 36 hours.

Here at the Rocky Point Prawn farm on the Logan River near Brisbane, it's harvest time. In the cooler months, from March to August, the farm's total stock of Kuruma prawns – about 55 tonnes – will end up on the plates of Japanese businessmen. At $70–120 a kilogram, it's a lucrative market.

The profitability of the Kuruma prawn industry is linked to production efficiency and export prices. Science can do little to change the latter, but it can influence production through advances in aquacultural practice.

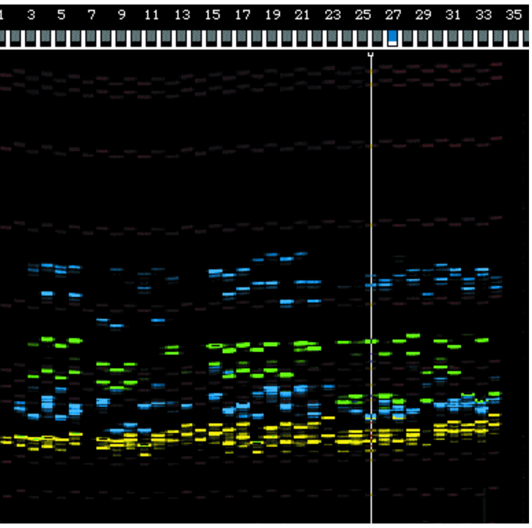
This has been the aim of a six-year collaboration between CSIRO Marine Research, CSIRO Tropical Agriculture, Rocky Point Prawn farm and two other industry partners, Tomei Australia and Seafarm. The group's domestication, selective breeding and disease prevention strategies aim to raise the productivity and sustainability of all Australia's farmed prawns: the Kuruma prawn, the giant tiger (*P. monodon*), the brown tiger prawn (*P. esculentus*) and the banana prawn (*P. merguiensis*).

The research will also help the industry to depend less on wild broodstock to produce prawn larvae. Wild 'spawners' are often difficult to obtain due to variations in catch rates, seasonal breeding cycles (often in spring) and adverse weather conditions. A three-week delay in the supply of Kuruma broodstock can mean missing peak market prices, at a cost of hundreds of thousands of dollars. Longer delays can cause production losses because mortality rates among young prawns are high during summer. But the greatest long-term constraint to using wild broodstock is that it offers no opportunity for selective breeding.

From pond to plate: Kuruma prawns harvested from Queensland's Rocky Point Prawn Farm will reach the lucrative Japanese market in less than 36 hours, commanding a price of $70–100 a kilogram.

Selecting the best

Researchers at the Cleveland laboratories of CSIRO Marine Research have been studying the ecology, reproductive biology and nutrition of penaeid prawns



for almost 30 years. In the early 1990s, Dr Nigel Preston, Dr Peter Crocos and their research team began a program to domesticate the lucrative Kuruma prawn and selectively breed for increased growth.

'When we started in 1992, the normal industry practice was to take wild broodstock, spawn them and rear their progeny in ponds,' Preston says. 'New spawners would be required the following year.

'We took some of the largest progeny at the end of the "grow out" season and moved them into a controlled-environment maturation facility at CSIRO. Here we over-wintered them, allowed them to reach adult size and conditioned them for spawning. Their progeny were then stocked in farm ponds at Moreton Bay Prawn Farm for commercial production.'

With a domestication strategy in place, the scientists turned their attention to selective breeding. They began by crossing different sized prawns in a classic 'controlled environment' selective breeding experiment. This involved crossing small prawns with small prawns (lowline), large with large (highline) and large with small (midline).

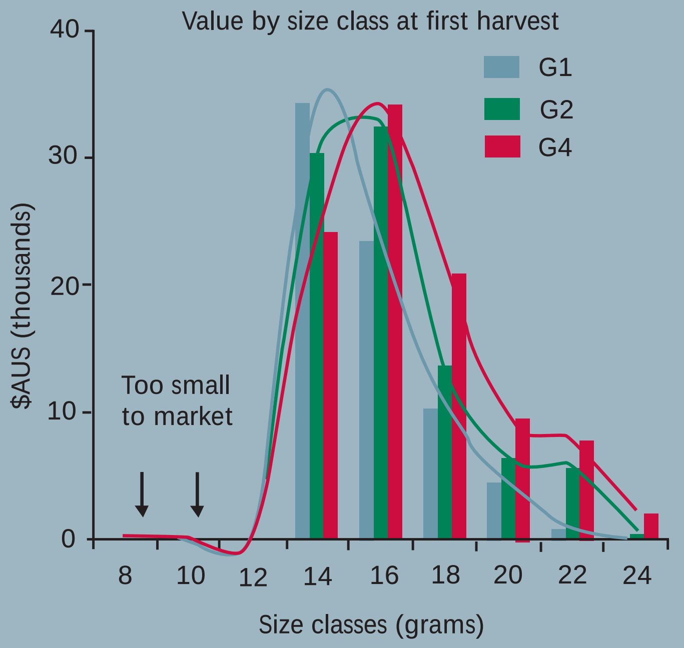
'From this experiment we were able to quantify the prawns' response to growth selection in a controlled environment,' Crocos says. 'By removing environmental effects, we could see what proportion of the size difference was due to genetics alone.'

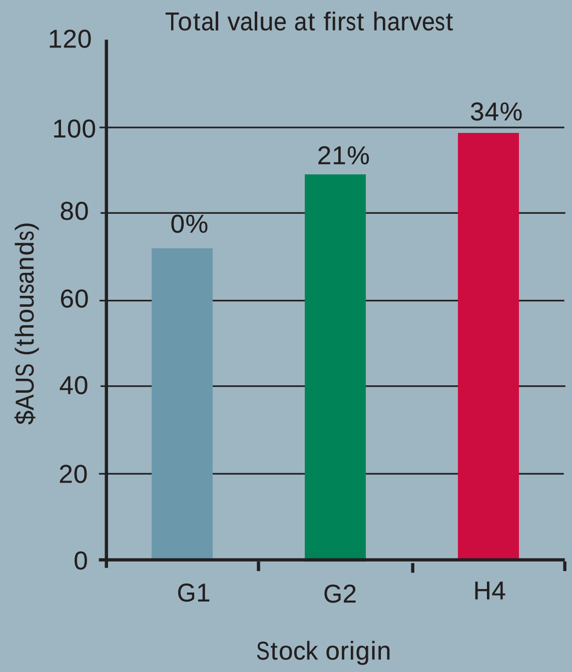
They found that by crossing large prawns, an 11% increase in growth could be achieved in one generation.

At the same time, the scientists established a line of 'hothouse flowers': large, 'highline' prawns reared from egg to adult for four generations in the resort-

Above left and left: The size variability of Kuruma prawns has a genetic component. DNA fingerprinting techniques have been developed that can be used to select for commercially-useful traits using natural mating.

Below and right inset: Broodstock conditioning tanks at CSIRO Marine Research, Cleveland.



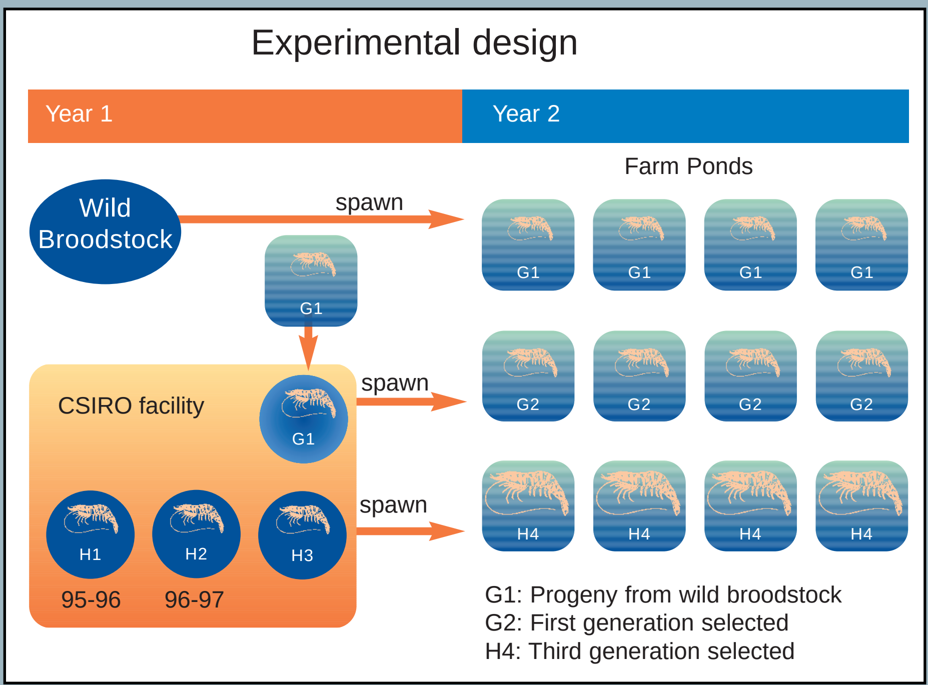


Scientists have quantified the relative growth of progeny from wild and domesticated broodstock in controlled environment tanks and commercial ponds.

In farm trials, selectively-bred stocks had gained significantly more weight than wild stocks at first harvest. There was a 5% increase in the mean size of the first generation stocks, and a 10% gain in the third generation stocks. These results indicate that improvement in growth of between 5% and 10% per generation can be achieved by mass-selection of farmed Kuruma prawns.

The market benefits of selective breeding are even higher, because large prawns generally command a higher price than small prawns. The market price for the first generation selected Kuruma prawn stocks was 21% higher than the progeny from wild broodstock and the market price for the third generation selected was 34% higher.

The ability of the third generation stocks to retain their capacity for superior growth in farm ponds has significant implications for selective breeding programs. They will also will provide a valuable genetic resource for re-establishing farm populations in the event of stock losses due to disease, floods or other external factors.



style accommodation of the CSIRO's domestication facility. The next step was to see if these hothouse flowers could continue to perform in the harsh reality of a commercial pond.

'The selective pressure on animals in controlled conditions may be different to the real world, where oxygen, salinity and ammonia levels are relatively uncontrolled,' Preston says. 'So we wanted to see if the prawns would keep their high growth rate or whether there would be some loss.'

The researchers set up a commercial scale comparative experiment at Rocky Point Prawn farm, in 12, one-hectare ponds.

Four ponds contained offspring from seven wild parents. These represented conventional farmed prawns. Another four ponds contained the offspring of large parents derived from wild progeny and maintained in CSIRO's domestication tanks.These prawns provided an intermediate level of domestication and selective breeding. The last four ponds contained fourth generation 'hothouse flowers'.

At the first harvest, about six months later, 200 males and females from each line were weighed.

'We found that on average the "hothouse flowers" were larger than the other lines,' Preston says. 'They had retained their genetic capacity for increased growth under real conditions, which is a great result.'

The 'hothouse flowers' gained 34% in value on the Osaka market.

Preston estimates that with the application of molecular marker technology (see story on page 23) for the identification of commercially important traits such as colour intensity, meat to tail ratio, temperature tolerance and disease resistance, production increases could amount to increases of 50% above current returns. Increased growth rates will also enable savings through reduced production time, and economic analysis has shown that domesticated broodstock are more cost-effective than wild broodstock.

'Despite having to overwinter captive broodstock in tanks for six months, they are cheaper to produce than buying wild broodstock,' Preston says. 'More importantly, hatchery managers and farmers can stock precisely when they want to and with stocks that they have had time to screen for disease.'

The success of this venture so far has led to industry confidence and the construction of 12, 12-tonne CSIRO-designed tanks at Rocky Point Prawn farm, for the maturation, spawning and over-wintering of selected stock.

Taming the recalcitrant tiger

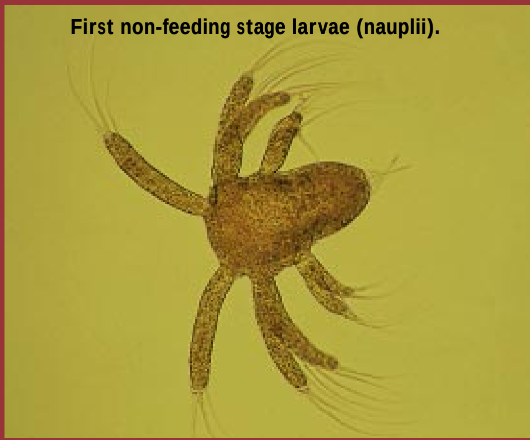
CSIRO Marine Research is now applying the domestication and selection technology developed for the Kuruma prawn, to the giant tiger prawn. The giant tiger is the dominant prawn species farmed in Asia and Australia, but progress in producing domesticated stocks on a commercial scale has been slow.

At Cardwell in Queensland's north, Seafarm, in collaboration with CSIRO, has produced prawns that reproduce as well as wild broodstock. These results were achieved by recreating natural spawning conditions, and by maturing the prawns for a further six to eight months after harvest (prawns are harvested at six months of age) in controlled environment tanks or special farm ponds.

Research is now focussed on improving the average reproductive output of the giant tiger prawn, improving the capacity for the farms to stock ponds with progeny from domesticated broodstock, and developing and introducing selective breeding for commercially useful traits.

In their two-week planktonic life, prawn larvae experience 11 different stages, each of which has a different dietary requirement.

Third feeding stage larvae (protozoea).



First non-feeding stage larvae (nauplii).

A newly-hatched egg.

Two weeks of **transformation**

THE GIANT tiger prawn has many stages in its life cycle. Eggs are broadcast in one or two major spawning seasons (September–December and March–June) and hatch within 24 hours.

In their two-week planktonic life, the larvae undergo some 11 different stages. At the end of their planktonic life they assume the form of a prawn and settle on the ocean floor, where they feed on benthic invertebrates. The prawns mature in six to 12 months and shed their exoskeleton every three to four weeks. Adults live for about two years and can reach 20 cm in length.

In culture, the prawns are stocked into ponds 15 to 25 days after the last mysis stage. They are known as post-larvae or by the industry standard term 'PL15'. Ponds are stocked with 350–400 000 PL15, which can result in four to 10 tonnes of mature prawns after six months. Individual prawns usually weigh 20–25 grams at harvest.

Larval rearing tanks at the Cleveland laboratories of CSIRO Marine Research.

Precision farming, from pond to p

AT ROCKY Point Prawn farm on the Logan River near Brisbane, the Zipf family has been farming prawns for 15 years. The farm has 20 ponds, ranging in size from 0.4 to 1.2 hectares, from which about 55 tonnes of Kuruma prawns are produced annually.

The prawns are grown from tiny 15-day-old postlarvae until harvest at five or six months of age, during the warmer months of the year. The postlarvae are obtained from either wild broodstock, or domesticated broodstock grown on the farm and transferred to CSIRO for further growth and conditioning for spawning. During the farm 'growout' period, the prawns are fed twice a night on specially formulated pellets imported from Japan. When they begin to reach harvest size, a one-hectare pond containing about 320 000 prawns can consume 60 kilograms of pellets in a night.

To maintain a healthy growout environment, water for the ponds is pumped in from Moreton Bay for six to eight hours, twice a day and circulated using long arm paddle wheels. This circulation aerates the pond and ensures any waste material and sediment is washed towards the centre of the pond, so that the sides of the pond, where the prawns feed and live, are clean.

Healthy ponds develop an algal bloom that absorbs ammonia and supports other zooplankton, which make up a small amount of the prawns' diet. The bloom also prevents unfavourable benthic algae from growing across the bottom of the pond and fouling both the prawns and their living environment.

Kuruma prawns are nocturnal and burrow into the pond floor during the day, so they must be harvested at night. On the sides of each pond are 10 poles to which the farmers tie 'opera house traps' (shaped like the Sydney Opera House). The prawns are lured into the traps by a piece of fish.

The traps are covered in a mesh that allows smaller prawns to slip through, ensuring that the largest prawns are caught at each harvest. Rocky Point Prawn farm manager, Rohan Koenig, says he tries to take only 100 to 200 kg of prawns from each pond a week, to give smaller prawns time to grow.

'Last year we started trapping when the prawns averaged 15 grams, but our average harvest size during the six months was 20.4 grams,' he says.

The prawns are harvested when night time pond temperatures reach about 24°C. If the temperature is much higher than this the prawns will die, as the temperature drop from pond to packaging (13°C) is too steep. Captured prawns are loaded onto a trailer filled with water at 20°C. They are then unloaded into holding tanks chilled to about 16.5°C.

'We have two milk vats – refrigerated tanks – for cooling the water,' Koenig says. 'We then mix warm and cool water to get the temperature we want.'

The prawns are then graded according to their length and packed into chilled sawdust for shipment to Japan.

'You have to ensure the prawns are the same length or the Japanese won't like it. It's a no-no in terms of etiquette for the boss to get an underling at lunch,' Koenig says.

Rocky Point Prawn farm also produces about 40 tonnes of giant tiger prawns annually. Most of their efforts are focussed on Kuruma prawns because they have a higher value and research into animal husbandry and selective breeding techniques is more advanced.

Main picture: The prawns are harvested at night using baited, mesh-covered traps that allow only the largest prawns to slip through.

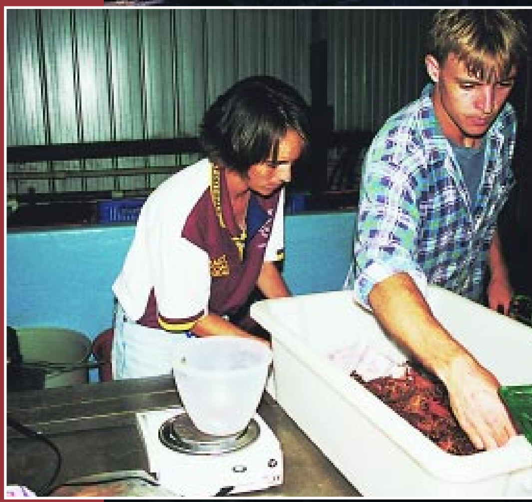
Inset below right: CSIRO Marine Research assistants Sandy Keys and Stuart Arnold weigh Kuruma prawns from the first harvest of the season to determine the size range. Prawns in the top 5% of the size scale will be taken to the CSIRO domestication facility and raised for the selective breeding program.

Far right, top to bottom: Rocky Point Prawn Farm owner, Murray Zipf, shows off the final product: a box of 61 live prawn 'pieces'.

Prawns are sorted into five size categories or grades. In Japan, it is the length of the prawn rather than the width that matters and graders must have impeccable judgement. At $70-120 a kilogram, and with Japanese etiquette at stake, it's important to maintain a consistent high standard.

A tray of Kuruma prawns freshly harvested from ponds at Rocky Point Prawn Farm.

Research assistant Russell McCulloch cleans tanks containing giant tiger prawns. The prawns are being used in the study of gill-associated virus.



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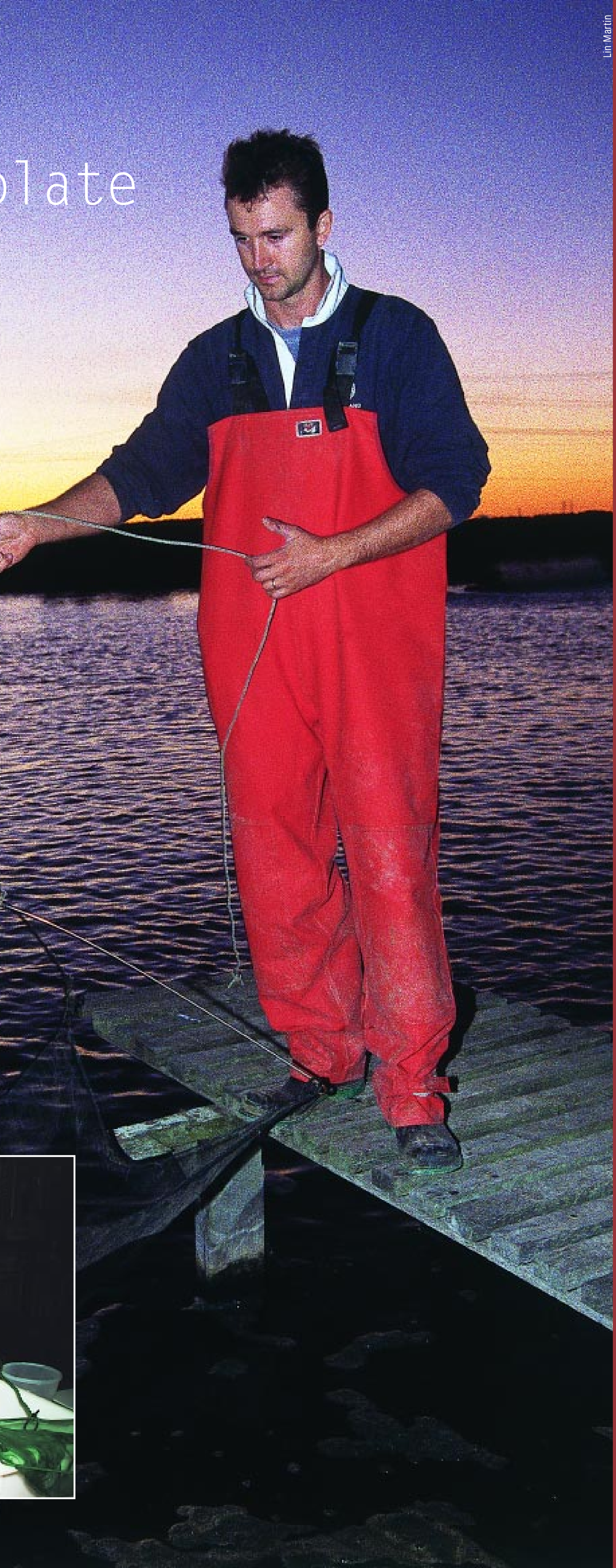


Lin Martin

Viral profiling: o

A growing understanding of prawn viruses is helping to protect and improve Australia's low-disease status and to rescue the Asian industry from viral demise. **Wendy Pyper** reports.

Neighbourhood watch

IN ASIA, scientists and farmers face an uphill battle in their attempts to domesticate prawns in an environment where yellow-head virus and white-spot syndrome virus are endemic.

Dr Peter Walker and his team are taking Australian technology to Thailand, to help develop molecular tools for the detection and diagnosis of these diseases, to understand their 'epidemiology' (occurrence, transmission and control) and to develop disease management strategies.

'By helping to reduce disease problems in Asia, we can reduce the threat of importing disease to the Australian prawn farming industry,' Walker says.

The group, in collaboration with Professor Tim Flegel from Thailand's Mahidol University, is also training scientists in the Asian region in molecular diagnostic methods and developing an international epidemiological database.

'We're adopting a new approach to epidemiology which looks at the genetic changes that occur in a virus as it spreads through a population,' Walker says. 'This will enable us to trace epidemics and figure out how viruses are moving around.'

Walker says the database will help national and international policy and decision-makers such as the World Trade Organisation and the Australian Quarantine Inspection Service to assess disease risks associated with foreign trade.

Viral disease presents a serious threat to the sustainability of the prawn farming industry. In 1996, the World Bank estimated the annual cost of disease to prawn farming worldwide was US $3 billion: 40% of total production capability.

Much of this loss stems from outbreaks of the highly virulent and widespread yellow-head virus and white-spot syndrome virus in Asia. Disease problems in Australia have been relatively small, but sporadic, serious outbreaks have occurred in tiger prawns (*Penaeus monodon*) since 1994, largely caused by gill-associated virus.

Through the CRC for Aquaculture, a team of biologists and virologists led by Dr Peter Walker from CSIRO Livestock Industries is investigating the structure, causes and biology of gill-associated virus and developing screening tests and disease management strategies to limit its impact.

The team is also involved in an ACIAR project with Mahidol University in Thailand to characterise and develop diagnostic tests for yellow-head virus and white-spot syndrome. This research will not only help the embattled Asian industry, but will enable the viruses to be identified if they emerge in Australia.

Testing times

Gill-associated virus was first isolated from Queensland farmed prawns in 1996. DNA sequence analysis showed it was closely related to yellow head virus, so one of the first challenges for Walker and his team was to provide the industry with a simple way of distinguishing between them.

They have developed a DNA-based test which CSIRO, the Aquaculture CRC and collaborators in Thailand are considering making available in kit form. Using their own laboratory equipment, hatcheries and farms could quickly screen newly acquired animals for gill-associated virus and yellow-head virus, to prevent contamination of farm stock.

Importantly, the test also detects a non-pathogenic form of gill-associated virus, which is present in the lymphoid organ (a primitive spleen) of almost all healthy wild and farmed tiger prawns in Australia. The virus, called

ur first line of defence

Lin Martin

Gill-associated virus has caused sporadic, serious disease outbreaks in Australian farmed tiger prawns since 1994. The CRC for Aquaculture is investigating the structure, causes and biology of gill-associated virus and developing screening tests and disease management strategies to limit its impact. The CRC is also involved in joint research to help the embattled Asian industry, and to identify Asian viruses should they emerge in Australia.

lymphoid-organ virus, is usually harmless, but under certain conditions the pathogenic capability of the virus is unleashed, allowing it to enter the prawns' gills and cause disease.

Early experiments by Walker's team suggest that some form of environmental stress, such as rapid changes in water salinity or dissolved oxygen, could play a role in this 'Jekyll and Hyde' transformation. As the majority of wild tiger prawns carry lymphoid organ virus, screening newly caught spawners for the virus would benefit domestication programs by ensuring that the pathogenic, gill-associated form of the virus is absent.

Walker suggests the DNA-based test could be performed on a small gill biopsy when new animals arrive at a farm, then after spawning (when stress levels increase) and again with the next generation.

'If you tested from one generation to another and continually got negative results, you could be sure your animals were clean,' he says.

Future work will look at extending the DNA-based test to other viruses found throughout Asia.

'We have a prototype test, but we need more information on viruses present throughout Asia,' Walker says. 'As we gather more information we'll develop a test that will embrace all of these and then discriminate between them.'

Interrupting transmission

These DNA-based tests will be vital to the success of domestication and selective breeding programs, but the ultimate aim is to produce prawn broodstock free of lymphoid-organ virus. This requires understanding viral transmission.

Studies by Walker and his team have shown that lymphoid-organ virus is transmitted vertically, from generation to generation, possibly via semen. As the virus is carried by most, if not all, tiger prawn spawners used on farms, some form of intervention in the breeding process would be required to 'clean up' progeny.

'If we can understand more about how lymphoid-organ virus is transmitted, perhaps we could do something, such as wash the eggs, to ensure the next generation isn't infected,' Walker says. 'With with Dr Mike Hall at the Australian Institute of Marine Science we're studying the process of vertical transmission to see how we might intervene.'

Despite problems caused by the virus in farmed tiger prawns in Australia, there are no inherent diseases in other farmed species, such as the Kuruma prawn (*P. japonicus*) or the banana prawn (*P. merguiensis*). Domestication of the Kuruma prawn by CSIRO Marine Research and industry partners (see story page 13), ensures a supply of disease-free spawners, maintained under biosecure conditions, which will be available to restock ponds should a disease outbreak occur. Domestication of other species will provide similar assurances.

Coping with disease

While disease diagnostic tools are essential to the future growth and sustainability of the aquaculture industry, so are guidelines for coping with disease when it strikes. Dr Peter Walker's CRC group is compiling an industry manual to provide farmers with information on preventative and post-outbreak practices.

'Farmers need to know how to clean up the farm if they have an outbreak of disease,' Walker says. 'They need an effective but benign treatment, such as hyperchlorite, but alternatives that are even more environmentally acceptable are being investigated.'

Walker also hopes farmers will support the development of domestication programs to help rid Australia of gill-associated virus. While this research continues, however, he suggests the best preventative strategy is to look after the prawn's living environment.

'Controlling water quality appears to be one of the best ways of ensuring the gill-associated virus doesn't develop into a disease problem. But if disease does occur, harvest any prawns that aren't showing signs of disease quickly, clean up the environment and dry out the ponds. If you look after the environment the environment will look after you.'

Reproductive **switch**

TO PRODUCE commercial supplies of larval prawns for farms, breeding stocks are induced to spawn through a process called 'eye-stalk ablation' (where the eye-stalk and therefore the eye, are removed). This removes the source of a reproduction inhibiting hormone, thereby enabling spawning to occur almost continuously, until the female dies. While this technique increases the spawning rate, eggs are usually only harvested from the first and second spawnings, as their quality and that of the resultant larvae, drop with each spawn. The technique also disrupts many of the prawns' physiological processes, so that the animals must be replaced every year.

Replacing eye-stalk ablation with a reproductive on/off switch is the focus of a project coordinated by the Australian Institute of Marine Science and the CRC for Aquaculture. Recently, a peptide for the reproduction-inhibiting hormone was isolated, which the team hopes will provide the switch.

'The aim is to get antibodies to the hormone and immunise the prawns, by injection or orally,' project leader, John Benzie, says. 'The antibodies will then float around in the prawns' haemolymph (body fluid) and neutralise the hormone. This will not only be more specific than eye-stalk ablation, but the animals will be healthier and the effect will last only as long as the dose lasts.'

Tigers in their tanks

As any farmer of terrestrial livestock will tell you, the path to premium prices lies in delivering quality products when demand is high. Successful producers employ advanced techniques for selective breeding and controlled reproduction, and ensure optimum conditions for survival and growth.

In prawn farming the aim is no different, but these delectable creatures have done their best to defy domestication. Attempts to reproduce giant tiger prawns in culture have encountered problems of inbreeding, low spawning and hatch rates, low egg numbers and low egg quality.

But now the domestication of the giant tiger prawn is within sight, thanks to research at the Australian Institute of Marine Science at Townsville. The institute's mariculture team, led by Dr John Benzie, has coaxed captive tiger prawns to breed in commercial quantities. As well as granting prawn farmers control of the production cycle, the work will enable the culturing of giant tiger prawn larvae, which are traditionally sought from wild stocks in the sea.

The institute's domestication program began in 1988, with the artificial insemination of tiger prawns harvested from the wild. The resulting larvae were raised in tanks until mature and the adults were tagged to keep track of their pedigrees. The next batch of larvae then underwent the same maturation and insemination process as their parents and successfully produced a third generation of prawns in culture.

'From our pedigreed lines we produced about 40 individual families,' Benzie says. 'Importantly, egg numbers were close to the numbers produced in the wild and all the larvae were of a very high, consistent quality.'

Having stocked and restocked their tanks with tigers, Benzie and his team began their ongoing program of selective breeding.

'We are selecting for increased growth rate,' Benzie says. 'That's not simply a larger animal, but an appropriately sized animal for the market, in a shorter time. That will lead to greater flexibility for the farmers because they'll have more control over when they can stock.'

To determine whether a selective breeding program would be successful, the team conducted heritability studies to estimate the influence of genetics over prawn growth. These studies involved mating two females with one male (using about 34 males and 68 females) and measuring the characteristics of the young in different families.

'Heritability is the degree to which the character you're interested in is controlled genetically, as opposed to being the result of environmental influences,' Benzie says. 'If there's no genetic control, then you can't select for it. We found that in the tiger prawn, the heritability of increased growth was at least 10%.' This means there is a good chance the tiger prawns will respond to selective breeding for the trait.

'We've calculated that if we want our animals to grow at twice their current rate, we could achieve that by improving them by 10% every generation for 10 generations,' Benzie says.

The next step for the mariculture team is to adapt their domesticating strategies to open-pond conditions. This work is likely to begin next year, in partnership with the prawn-farming industry.

The mariculture team at the Australian Institute of Marine Research has coaxed captive tiger prawns to breed in commercial quantities.

Yutao Li of CSIRO Livestock Industries.

Shrimp map to guide genetic selection

AUSTRALIAN scientists are working with colleagues in Thailand, Hong Kong, France and the United States to construct a genetic linkage map of the tiger prawn genome.

This map will flag the position of 'anonymous' DNA markers (random pieces of DNA of known sequence) on the genome. These markers will be used as reference points from which genes for commercially important traits are sought. For example, anonymous markers always present in prawns that grow quickly, but never in prawns that grow slowly, have a high chance of lying close to a gene for rapid growth.

Kate Wilson, a molecular biologist at the Australian Institute of Marine Science, and Sigrid Lehnert and Yutao Li, of CSIRO Livestock Industries, have mapped 54 anonymous markers in three prawn families, and hope to have at least 300 mapped by the end of the year. To speed the process, they have offered DNA to other national and international groups wishing to map their own markers on the genome.

'We send them our DNA samples, so all the markers go on the same prawn families and we can build up the map very quickly,' Wilson says.

The AIMS tiger prawn work follows the successful collaboration between CSIRO Marine Research and CSIRO Tropical Agriculture, to map the Kuruma prawn (*P. japonicus*) genome. This collaboration led to the first ever gene map for crustaceans and may eventually help speed the process of mapping the tiger prawn genome.

'We'd love to be able to use the Kuruma prawn map to help us find related genes in the tiger prawn,' Sigrid Lehnert says. 'But we'll need to map a lot more markers on the tiger prawn genome before we can compare the two maps.'

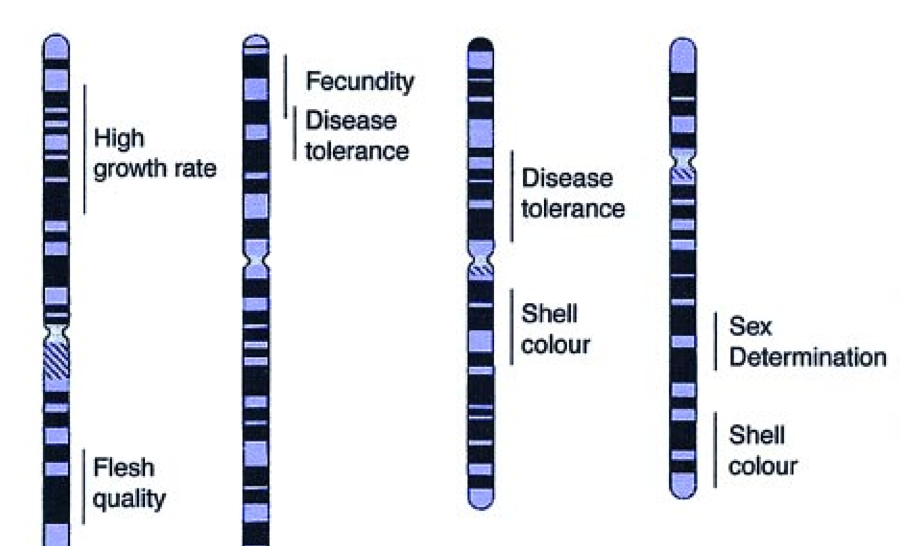
The CSIRO group has mapped about 350 anonymous markers on the *P. japonicus* genome and identified three regions that could potentially harbour commercially useful genes.

In the future, it is hoped genes such as those for improved colour and a greater meat-to-tail ratio, may be identified.

'Colour intensity is important on the Japanese market,' Yutao Li says. 'Customers prefer bright stripes on prawns rather than pale ones. And if we could increase the amount of meat on a prawn, in comparison to its head, we could increase its market value.'

Genes for disease resistance would also be valuable.

'Our understanding of how farmed prawns deal with pathogens is limited,' CSIRO Marine Research scientist, Nigel Preston, says. 'But as our knowledge of the factors that determine prawn health improves, genetic selection is likely to play an increasingly important role in combating prawn diseases.'



The genetic linkage map of the tiger prawn genome will flag the position of 'anonymous' DNA markers. These will be used as reference points for seeking commercially important traits.

Australia's prawn farmers are keen to avoid making the same environmental blunders as their overseas counterparts.

Louise Ralph describes the outcomes of industry-funded environmental investigations.

A three-year study of pond and effluent management practices at Australian prawn farms has yielded innovative ways of reducing the nutrient and suspended sediment content of pond water discharged to rivers and creeks.

The study was carried out by the Aquaculture Cooperative Research Centre and funded by the Australian Prawn Farmers' Association, the CRC and the Fisheries Research and Development Corporation. It was initiated by the association amid community concerns that water discharged from prawn ponds may increase turbidity and eutrophication in sensitive coastal regions such as those adjacent to the Great Barrier Reef Marine Park. There were fears that Australia might follow the example of some Asian and South American countries where unregulated industry expansion has harmed the environment.

Much of the discharge from prawn farms is inorganic material such as silt and soil. This influx of silt (turbidity) could smother and shade seagrass meadows, an essential nursery ground and food source for marine life. Untreated water discharged from prawn farms can also contain elevated levels of nutrients, which can stimulate phyto-plankton, causing algal blooms.

But according to the study leader, Dr Nigel Preston of CSIRO Marine Research, the negative experience overseas provided incentive for the Australian industry to work towards sustainable growth. He says a conservative, highly regulated approach to aquaculture in Australia has prevented uncontrolled development.

Between 1984 and 1999, Australian prawn farm production increased from 15 tonnes to 2400 tonnes. Some 600 hectares of ponds are now in production. In contrast, countries such as Thailand increased production from 20 000 tonnes in 1984 to 200 000 tonnes in 1999.

'From the outset, all Australian farms have had to negotiate water quality conditions in order to operate,' Preston says. 'The licences differ from state to state, but the industry and regulators are moving towards standard industry practice.'

Sediment in, sediment out

A major part of the research involved analysing the composition of farm effluent.

'Unlike the run-off from most agricultural activities, prawn farms have a specific point of discharge,' Preston says. 'This has made the comparatively tiny prawn farm industry an easy focus of environmental concerns, but has the advantage of allowing the effluent to be easily captured and treated.'

The study team based its assessments of nutrient discharges on water quality data automatically collected at four-hourly intervals for the entire prawn production period. These were used to quantify the flows of suspended solids, nitrogen and phosphorus through farms adjacent to tidal creeks or rivers.

Effluent loads varied according to factors such as location, rainfall, species farmed, farm production phase and management practices. This variation complicates the task of designing waste management systems, and the setting of water quality standards by regulatory authorities.

In most prawn ponds, however, suspended solids are the main waste stream, with 70–90% comprised of inorganic matter, regardless of location. A major source of this inorganic matter is

Lin Martin

Nature takes its course in treatment ponds at Rocky Point, Queensland, where the Aqualab (above centre) provides continuous automatic sampling of pond water. In these ponds solids settle out, while posts support shadecloth and mesh structures for filtering animals such as barnacles, mussels and tubeworms to grow on.

Left: As the production season progresses, pond aerators re-suspend sediments and erode pond floors and banks. This can result in a net export of suspended sediment when water is discharged.

agriculture and other land clearing activities upstream. Prawn farms near major rivers frequently have high levels of suspended sediment in the intake water.

Preston says farm ponds can act as sediment sinks during the early part of the production cycle. Water discharged during this period has a lower concentration of suspended sediment than water entering the farm. As the production season progresses, pond aerators re-suspend the sediment and erode the pond floor and banks. This can result in a net export of suspended sediment when water is discharged.

The study also examined the use of settlement ponds to treat water before discharge or recirculation, and the use of marine plants and animals to remove excess nutrients.

Settlement ponds large enough to hold discharge water for one day or more – one-third the size of the prawn ponds – halved nitrogen levels by trapping particulate nitrogen from waste feed and prawn faeces in their sediments. This outcome was improved by stocking the settlement ponds with marine plants, which readily absorb dissolved nitrogen. By adding racks of filter feeders such as oysters, barnacles and mussels, a further reduction in dissolved nitrogen levels was achieved. The use of oysters and mussels has the added benefit of generating extra income.

Larger plants such as reed beds can also be included in the treatment system. This involves transferring the discharge water to a shallow pond after passing through an initial settling pond and filter feeder section. High light levels in the shallow pond encourage plant growth.

The researchers are investigating the potential for harvested plants to be leached of salt and mulched as fertiliser. Other plants being trialled include the red algae *Gracilaria edulis*, a source of plant gelatine in food and medical products.

Preston says that at the beginning of the study one farm began using effluent settlement ponds to minimise the net export of suspended solids. Now eight farms are using treatment systems, and all new farms must use some form of treatment.

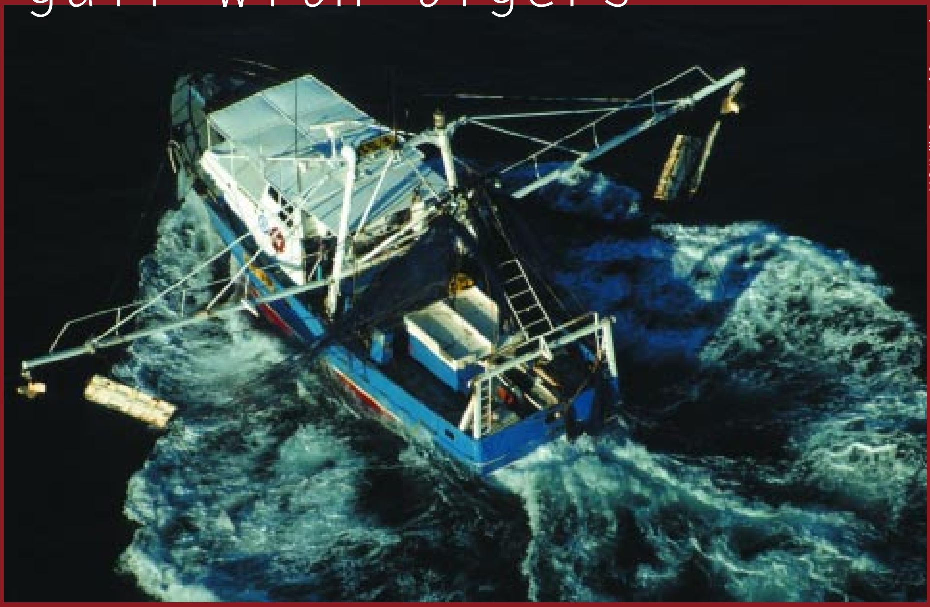
'The real consequence of having done this research is that it has allowed the industry to base decisions about environmental management on rigorous science,' Preston says. 'Although the research has taken considerable time and resources, the benefits of developing sound environmental management strategies will last forever.'

In May this year, CSIRO Marine Research and the Australian Prawn Farmers' Association (APFA) held a conference to convey the research findings to policy makers, regulators, research bodies and industry. It was supported by Environment Australia, the Fisheries Research and Development Corporation and the CRC. The participants are developing an action plan for the environmental management of prawn farming in Australia.

APFA executive officer, Martin Breen, says the uptake of research into daily farm management practices is a major challenge. 'APFA is continuing to work with the research community and all levels of government to develop incentives and methods to facilitate this uptake,' he says.

Preston says future research will focus on increasing our understanding of the key processes for maximising the efficiency of integrated waste management. This includes improvements to farm site selection, feeds and feed management in ponds as well as sediment and nutrient management in treatment ponds. If the efforts of industry, scientists and regulatory agencies are any indication, the future looks good for the environment.

Stocking the gulf with tigers



MG Kailis Group of Companies

The release of farmed prawns into nursery grounds has the potential to increase fishery yields and lessen fluctuations in the catch, but its success relies on understanding the biology of the species, particularly the production of juvenile stock, their environmental requirements, predators, and the environment's carrying capacity.

CSIRO Marine Research, the Kailis Group of Companies and Fisheries Western Australia are collaborating in a stock enhancement study that focuses on the brown tiger prawn (*Penaeus esculentus*) in Western Australia's Exmouth Gulf.

The study, funded by the Fisheries Research and Development Corporation, will develop techniques for releasing farmed prawns into nursery grounds to enhance prawn fisheries, and will also test its feasibility. An earlier study in Exmouth Gulf indicated that stock enhancement of tiger prawns in the region could be profitable.

The release of farmed prawns into nursery grounds has the potential to increase fishery yields and lessen fluctuations in the catch, but its success varies greatly in different countries and depends on the size and species of prawn. It also relies on a solid understanding of the biology of the species, particularly the production of juvenile stock, their environmental requirements, predators, and the environment's carrying capacity.

This means that before undertaking any commercial enhancement of prawn stocks in Australia, the costs and benefits for a specific region and fishery must be assessed. The species must be well understood, and techniques must exist to monitor and assess the success of releases.

Exmouth Gulf is an ideal location to conduct the study for a number of reasons. The fishery has a long history of successful management and research by Fisheries WA and industry partner, the Kailis Group of Companies. The project will therefore aim to boost prawn numbers in an already healthy stock.

Land is available to develop suitable hatcheries and aquaculture ponds where four to six million juvenile prawns could be produced at a reasonable cost. The study also has the full support of the industry partner, which has facilities close to Exmouth Gulf and is the major licence holder in the fishery.

There has already been extensive research on tiger prawns in the Exmouth Gulf region by the Fisheries WA Research Division, which maintains a comprehensive database on the prawn stocks. Further, the Exmouth Gulf fishery is a distinct fishery that is fully exploited and closely monitored. This means that the probability of capturing released prawns in the fishery is high, enabling the success of stock enhancement efforts to be assessed.

The Exmouth Gulf fishery is also ideal for investigating the potential for stock enhancement to reduce year-to-year variation in catches. Exmouth Gulf tiger prawn catches show high levels of variation, some of which is likely to be due to the effects of cyclones. Annual catches have ranged from 205 to 682 tonnes since 1987.

These variations in catch create uncertainty in supply of prawns to export markets, and force fishing operators and processors to have excess capacity to deal with high-catch years. Reducing these fluctuations would therefore maximise the efficiency and profitability of the fishery and the processing operation.

The research team plans to 'fingerprint' the larvae before their release off the coast of Western Australia using microsatellite markers (DNA markers that contain repeating sequences). When the stocks are trawled several months later, the hatchery-reared prawns will be identifiable from the wild prawns by their DNA fingerprint. If the hatchery-reared prawns survive, several million juvenile prawns will be released.

In addition to boosting wild prawn stocks, the post-release tracking of hatchery-reared juveniles will provide a powerful tool for examining natural processes such as mortality rates, growth rates, habitat requirements and dispersal patterns of prawns in their natural environment.

Katie Johnson and Wendy Pyper

This lift-out booklet is part of the July–September 2000 edition of *Ecos*, CSIRO's quarterly magazine about science and the environment. A yearly subscription to *Ecos* costs only $30. Contact CSIRO Publishing, PO Box 1139, Collingwood 3066, Vic., free call 1800 626 420, fax (03) 9662 7555, email: sales@publish.csiro.au. *Ecos* can be viewed on the World Wide Web from http://www.publish.csiro.au/.

For more information about CSIRO prawn research, contact:
Genetics and environmental management: Nigel Preston, (07) 3826 7221, Nigel.Preston@marine.csiro.au.
Disease control: Peter Walker, (07) 3214 2758, Peter.Walker@tag.csiro.au.
Molecular genetics: Sigrid Lehnert, (07) 3346 2445, Sigrid.Lehnert@tag.csiro.au.