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Brave new world of octopus farming

A clutch of octopus (*Octopus tetricus*) eggs.

AQUACULTURE

Countering territorial behaviour and the propensity of octopus to escape from even the most securely closed tank systems have been among a number of achievements and world firsts to come from Australian efforts to develop aquaculture techniques for the species

By Rose Yeoman

Octopus was once considered bycatch in the rocklobster industry and used primarily as bait, but is now considered a gourmet seafood and Australian consumers just cannot get enough. However, wild-capture fisheries are unable to keep up with demand, leading fishers to investigate the aquaculture potential of the species.

Western Australia's octopus fishery is relatively new; it was officially established in 1999 and targets *Octopus tetricus*. But even in its first few years, it was clear that demand exceeded supply.

Brothers Ross and Craig Cammilleri, who founded Fremantle Octopus Pty Ltd and its subsidiary Occoculture Pty Ltd, have been the main drivers behind research into octopus aquaculture. The brothers were keen to move from octopus fishing to 'ranching', where wild-caught juveniles, the bycatch of adult harvest, are grown in land-based tanks or offshore cages.

"Ranching is gaining popularity in Europe – especially in Spain, Italy and Greece, as well as in Mexico – and with its excellent eating qualities and high growth rates (up to three kilograms a year) *O. tetricus* offers real commercial possibilities," Ross Cammilleri explains.

The Cammilleris were granted an aquaculture licence and lease at Garden Island, WA, to ocean-ranch juvenile octopus, but Ross Cammilleri says it is not possible to source enough juveniles from the wild-capture fishery to make ranching independently commercially viable. This requires closing the life cycle of the species and developing tank-based production systems to breed juveniles in sufficient numbers to supply ocean-based ranches.

The dual advantages of this are the preservation of wild stock and the production of controlled-sized animals (about 1.5 kilograms) to meet the market.

In order to move from ranching to a whole-of-lifecycle approach in an aquaculture setting, the Cammilleri brothers approached the Department of Fisheries, WA.

Model octopus farm

Working with the Cammilleri brothers, Sagiv Kolkovski was appointed the principal research scientist to lead a four-year, FRDC-supported project, which has made major gains in understanding the behaviour and life cycle of *O. tetricus*, while analysing its commercial viability for aquaculture.

This includes the development of a 15-tank model octopus farm at the Western Australian Fisheries and Marine Research Laboratories (WAFMRL) based at Hillarys Boat Harbour, north of Perth.

The aim was to imitate commercial reality and develop a system that could be replicated in any country and be a profit-yielding enterprise. The costs of running the system – including equipment set-up, such as tanks and pumps, as well as resources, such as labour, electricity, water and feed – were analysed.

Ranching

Sagiv Kolkovski and his team had to solve several issues to develop the commercial tank-based ranching system. He explains that in the wild, octopus exhibit territorial behaviour and will aggressively defend their range. In Spain and other countries developing this type of aquaculture, this behaviour is controlled by providing hides in the form of PVC tubes, so each octopus has its own territory in which to grow and develop.

"But these hides limited the biomass in the tank and the harvesting and maintenance. This included cleaning, which was a huge issue," Sagiv Kolkovski says. "From day one, I wanted to grow octopus as I grow fish – without a hide."

He and his team discovered they could intensively grow octopus in tanks without hides when individuals were all of a similar size. "When this occurred, none of the individuals displayed aggression or cannibalism, as they inevitably did in a mixed-size population. We found there was an inverse relationship between octopus density in the tank and the degree of aggression and cannibalism. We added so many to the

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An octopus interacts with a researcher.

Sagiv Kolkovski (front), principal researcher for the octopus aquaculture study, developed a 15-tank model octopus farm at the WA Fisheries and Marine Research Laboratories based at Hillarys Boat Harbour.

tanks that we had to install flat PVC sheets so they would have more surface to attach to as the tank walls were completely occupied."

Not having hides saved up to 80 per cent of the tank cleaning and maintenance work that would otherwise have been required, which translated into cost savings. "It simplifies the whole system. A tank can be cleaned in just a few seconds, so there is no marine growth or bacteria on the walls," Sagiv Kolkovski says.

World firsts

In Spain, the maximum biomass harvested from aquaculture systems using hides is 15 kilograms per cubic metre of water. The WA octopus farm harvested 54 kilograms per cubic metre, a biomass production rate never before achieved in octopus aquaculture.

It was also a 'world first' to recognise that octopus could be tank-grown without hides and that in high-density, size-matched populations octopus behaviour was modified and switched from being individual and territorial to behaving as a 'school', with no signs of cannibalism or aggression.

Another first was developing a simple mechanical method of preventing them from engaging in the kamikaze habit of hurling themselves out of the tank and onto the floor. Octopus are known to be masters of escape and heavy steel mesh is usually used to cover tanks to prevent this.

Looking for alternatives, the research team first tried a low-voltage pulsing electric fence positioned a few centimetres above the perimeter of the tank, but the escapes continued.

The solution ultimately devised is both simple and elegant: a band of woven shade cloth around the perimeter of the tank.

Shade cloth has a porous, woven structure that permits airflow. This prevents an octopus latching on with the suckers on its tentacles, which require a vacuum to work. The solution completely prevents escape and has the added advantage of being easy to drop down during feeding or when cleaning the tank.

Breeding bottleneck

Early in the project it became apparent that survival rates of paralarvae represented a significant 'bottleneck' in the system and would be the most difficult aspect of closing the life cycle.

As Sagiv Kolkovski explains, octopus species display one of two types of egg production. In some species, up to 150 'large' eggs (like a ball bearing) are produced and the individuals that hatch are 1.5 to 2 centimetres and look and behave like miniature versions of the adult.

In the second form of egg production, which occurs in *O. tetricus*, 100,000 to 200,000 very small eggs are produced and they hatch to produce embryos (called paralarvae) with leg buds, an ink sac and a primitive digestive system. In nature, the chances of any one paralarva from this second group surviving to an adult are much lower than that of a juvenile octopus hatched fully developed.

In the ocean, *O. tetricus* paralarvae develop over a two-month period, and at 55

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A developing octopus egg.

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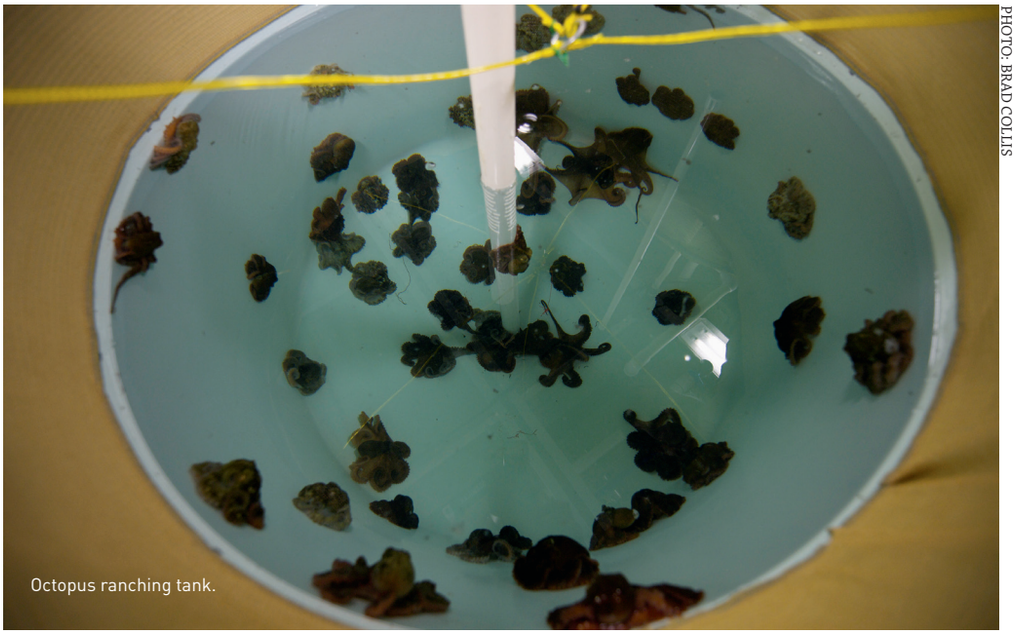
Hatching paralarva.



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Octopus ranching tank.

to 60 days post-hatching they metamorphose over 48 hours to become juveniles.

Yet in an aquaculture tank, among the hundreds of thousands of paralarvae produced during the course of the study, only one – an individual nicknamed 'Bob' – survived to develop into a juvenile octopus. This was such a rare and exciting event that technician Nicole Watts baked a cake and held a birthday party in Bob's honour.

Feed efforts

Sagiv Kolkovski says one of the main issues with rearing paralarvae is nutrition and little is known about their nutritional requirements.

"A great deal of effort was devoted to developing an optimal diet. Different protein and lipid sources and levels were tested. Levels and ratios of essential fatty acids were also manipulated.

"The way the diets or 'enrichments' were delivered to the paralarvae was through *Artemia*, also known as brine shrimp. They are filter feeders and were provided with the diets before being fed to the paralarvae," he says.

Other live feeds tested included wild-caught Blue Swimmer Crab (*Portunus armatus*) zoea and rocklobster phylosoma, but due to unpredictability of their supply *Artemia* was chosen as the feed.

An octopus paralarva displays unique feeding behaviour by feeding on adult *Artemia* – which are of similar size to itself – immediately after hatching. A paralarva will catch an adult *Artemia* (which may be bigger than the paralarva itself),

PHOTO: DEPARTMENT OF FISHERIES, WA

A juvenile octopus.

bite the head off and inject digestive enzymes. It then sucks the digested proteins from the *Artemia* body and discards the skeleton, which can become a source of contamination in the tank.

Discarded *Artemia* skeletons are an excellent breeding ground for bacteria, which significantly affect the growth and survival of the paralarvae. Flushing out dead *Artemia*, as is normally done in fish larvae tanks, is impossible due to the similarity of size of paralarvae and *Artemia*.

The issue of separating dead prey from living paralarvae was solved by developing a double tank system where one tank contained the paralarvae and the other clean water. A connecting pipe between the two tanks allowed a gentle current to carry paralarvae from the 'dirty' tank to a 'clean' tank as dead material sedimented out. This process occurred over several hours to reduce any stress on the paralarvae and although survival rates of paralarvae increased, metamorphosis to juvenile octopus was not achieved.

Aside from nutrition, environmental factors were also considered. The team investigated photoperiod and light intensity and found that paralarvae have a strong positive response to light in the first two weeks of life and then develop a more negative response. Light intensity was manipulated and adjusted to suit these physiological requirements as it affected feeding behaviour within the tanks.

'Green water', which is the addition of microalgae into the paralarvae tank, was also tested. While adding green microalgae, such as species in the genus *Nannochloropsis*, to finfish larvae tanks is a necessity and has become standard practice, it had no effect on octopus paralarvae survival or growth.

While the ultimate goal of closing the life cycle of *O. tetricus* was not fully achieved, major advances in understanding were made. Management and natural induced spawning of octopus broodstock was achieved and eggs and paralarvae can now be produced on demand. Larval systems, environmental conditions and nutrition were all developed and knowledge gained in these areas will assist in accomplishing a commercial octopus breeding program in the future.

Global industry

Both Sagiv Kolkovski and Ross Cammilleri acknowledge the need for more research to unlock the nutritional and environmental code required to close the octopus life cycle in aquaculture conditions. But what they have achieved is a number of world firsts in octopus aquaculture and the development of a model grow-out system, which Ross Cammilleri is keen to establish in developing countries such as South Africa, Mauritius, the Seychelles and Sri Lanka.

"When juveniles are captured, they could be taken back to the home where the family would care for them in tanks. This would provide working opportunities to a family and they could sell to a central cooperative, which could manage the advertising, sales and processing.

"We would manage the enterprise, whether it was a cooperative or another structure, but it has to be commercially viable," he says.

He sees it as a way that fishing families and, in particular, women and children in developing countries could earn extra income for the family, which would stimulate the local economy and assist communities. F