



Issue 19 – November 2011

PEARL OYSTER

information bulletin

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Editorial

The long awaited 19th issue of the *Pearl Oyster Information Bulletin* contains a diverse range of articles relating to the current status of the pearl industry, research articles, and news of new research projects and, as usual, a long list of abstracts from recent publications relating to pearl oysters and pearl production.

The “Industry Notes and Reports” section contains an overview of the pearl component of Ben Ponia’s recent review of aquaculture development in the Pacific Islands region over the past decade. It highlights interesting production trends in Polynesia and the increasing impact of the newer pearl producing countries in the region. This section also contains a summary of the main outcomes from a recent online conference hosted by Jewellery Net Asia, relating to “Markets, Opportunities and Challenges for the Pearl Industry in 2011 and Beyond” as well as a round-up of some of the latest trends at auction sales, and industry news from within the region.

The “Research Notes and Reports” section contains interesting papers relating to inducing anaesthesia for mabe production in *Pteria penguin*, and efforts to condition adults of this species using commercially available micro-algal pastes. There is also an interesting article on a major research project in French Polynesia focused on “professionalization and sustainability of pearl culture”, which addresses some of the bio-physical aspects impacting pearl culture and carrying capacity in atoll lagoon environments. This section is rounded off by an interesting article on the potential use of freshwater clams for pearl production in Mexico, news of hatchery production of pearl oysters in Eastern Africa, and overviews of new research projects within the region.

There has been a significant addition to the literature on pearl oysters over the past couple of years. Abstracts from many of the more relevant publications are presented in the “Abstracts, reviews and current contents” section of this issue. A large proportion of recent publications in the field relate to the molecular mechanisms controlling nacre secretion and nacre quality, with a huge contribution in this field made by Chinese scientists. I have had to be selective in our coverage of research in this field.

I would like to invite and remind readers that there is a standing invitation for contributions to the Bulletin. We have particular interest in reports or articles relating to pearl industries and research in the Pacific Islands region. Submission of longer articles is encouraged, and updates from research groups and country statements would be particularly appropriate.

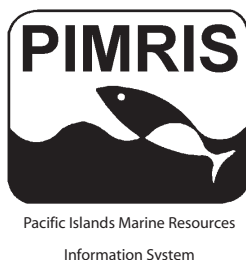
The required format for larger articles submitted to the Bulletin — as well as this and previous issues of the Bulletin in pdf format — can be found on the SPC website at: <http://www.spc.int/Coastfish/en/publications/bulletins/pearl-oyster.html>

Finally, it is 50 years since Jean-Marie Domard began growing pearl oysters in Hikueru, French Polynesia in 1961, with the help of Japanese pearl farmer Churoku Muroi. Global celebrations to commemorate the 50th anniversary of Tahitian cultured pearls are being overseen by La Maison de la Perle, which operates under the auspices of the Ministry of Pearl Farming in French Polynesia.

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PIMRIS is a joint project of five international organisations concerned with fisheries and marine resource development in the Pacific Islands region. The project is executed by the Secretariat of the Pacific Community (SPC), the Pacific Islands Forum Fisheries Agency (FFA), the University of the South Pacific (USP), the Pacific Islands Applied Geoscience Commission (SOPAC), and the Pacific Regional Environment Programme (SPREP). This bulletin is produced by SPC as part of its commitment to PIMRIS. The aim of PIMRIS is to improve the



availability of information on marine resources to users in the region, so as to support their rational development and management. PIMRIS activities include: the active collection, cataloguing and archiving of technical documents, especially ephemera ("grey literature"); evaluation, repackaging and dissemination of information; provision of literature searches, question-and-answer services and bibliographic support; and assistance with the development of in-country reference collections and databases on marine resources.



Pacific regional pearl production, 1998–2007

The recent review of Aquaculture in the Pacific Islands (Ponia 2010) showed some interesting trends in pearl production in the region. The following text and figures are reproduced from the following SPC publication:

Ponia B. 2010. A review of aquaculture in the Pacific Islands 1998-2007: Tracking a decade of progress through official and provisional statistics. SPC Aquaculture Technical Papers, Secretariat of the Pacific Community, Noumea. ISSN: 1683-7568

Pearls are the region's most valuable commodity. In 2007, the production was worth USD 176 million. The pearl oysters farmed in the Pacific include black-lipped pearl oyster (*Pinctada margaritifera*), silver-lip oyster (*Pinctada maxima*) and winged oyster (*Pteria penguin*), although black pearls from *P. margaritifera* make up the bulk of production.

Black pearls in French Polynesia

In 2007, the pearl production from French Polynesia was valued at USD 173 million (Fig. 1). This accounts for 98 per cent of the total value of production in the region.

Pearl statistics are normally based solely on export figures provided by the Institut de la statistique de la Polynésie française (ISPF). The SPC figures used in this report differ from the ISPF figures because they take into account additional data, including:

- Unreported pearls, which the Institut d'Emission d'Outre-Mer (IEOM) (2007) estimates to be about 20 per cent of raw pearls. This has been assumed for the period 2004–2007.
- Domestic production, which IEOM (2007) estimates to be about 10 per cent of raw pearls.

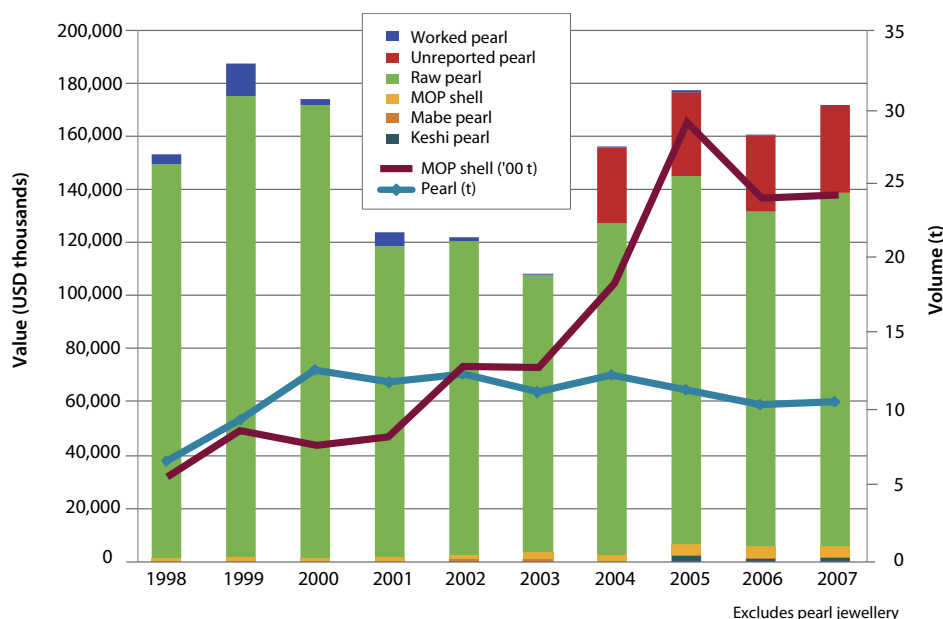


Figure 1. Pearl production in French Polynesia.

- Inclusion of worked pearls, including keshi and mabe. From 1998 to 2000, ISPF categorised pearls as either raw or worked. From 2001 onwards, the worked classification was expanded to include keshi, mabe and pearl jewellery. The first three classes are predominantly pearl pieces and so were included in the totals. The pearl jewellery classification was excluded.
- Mother-of-pearl (MOP) exports from the Service de la pêche (SPE) annual statistical reports.

The French Polynesia pearl industry has had two peaks. The first was in 1999 with USD 189 million earned. Continued mass production — 12.7 t in 2000 — led to a collapse in the price per unit value. Measures by government to limit quantity and focus on quality appear to have arrested this decline to some extent (Tisdell and Poirine 2008; Southgate and Lucas 2008). After a brief period of consolidation, a second peak occurred in 2005 with USD 178 million earned. It is not clear to what extent these sales included stockpiles from previous year's harvest. But the export volumes of MOP shell increased dramatically in this period, up to 2,900 t, suggesting that large-scale farming must have been occurring.

The 2007 value included "unreported" sales, which are assumed to be 20 per cent of the official statistic. Adding further ambiguity to the situation is the exclusion of pearl jewellery exports, which according to ISPF have gone from just USD 0.5 million (or 150 kg) in 2004 to USD 18 million (1.6 t) in 2007. Together, these data suggest more unofficial sales but at the same time a shift towards value-adding opportunities.

Pearl production from countries other than French Polynesia

The main producer of black pearls, aside from French Polynesia, is Cook Islands. However, poor

farm management practices led to a mass mortality from a disease in 2000 (Diggles and Hine 2001), causing sales to drop from USD 9 million to USD 2 million by 2003. In 2007, production appears to have stabilised, albeit still at low levels. Recovery is attributed in part to the country's vibrant tourism market and, after reviewing the census and export data on hand, it is estimated that domestic sales have risen from 10 per cent in 2000 to about 30 per cent in 2007.

In 2007, an additional five Pacific Island countries and territories were producing pearls at commercial levels, bringing the total value to USD 3.9 million. The significant new entrant is Fiji Islands, with sales valued at USD 1.2 million. One positive development is that the range of pearls is beginning to diversify and now includes white "south-seas" pearl from Papua New Guinea and purple *Pteria* mabe pearl from Tonga (Fig. 2).

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The full document can be downloaded from the "Publications" menu of the SPC Aquaculture portal at: <http://www.spc.int/aquaculture>

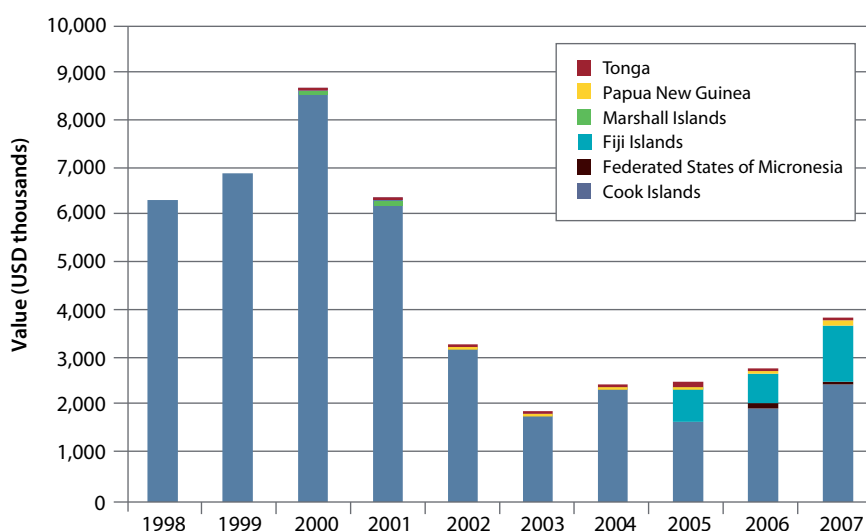


Figure 2. Pearl production in Pacific Island countries, excluding French Polynesia.

Markets, opportunities and challenges for the pearl industry in 2011 and beyond

Source: *www.JewelleryNewsAsia.com* (15 June 2011)

Leading experts in the pearl industry shared their insights and perspectives in an online conference hosted by JewelleryNetAsia and *Jewellery News Asia* on June 14 2011.

The panel of experts from the pearl farming, wholesaling and retailing sectors included pearl farmers Robert Wan, Jacques Branellac and Peter Bracher, and pearl wholesalers Rene Hodel and Andy Müller. All were online to answer questions about the challenges and opportunities facing the pearl trade. The following excerpts highlight the main points made by each of the participants and their responses to questions.

Pearl farming

Robert Wan — Founder and Chairman of Robert Wan Tahiti, French Polynesia

- French Polynesia produces 14 tonnes of Tahitian pearls, with a total value of USD 130 million.
- We wish to achieve price stability, and from there, we are willing to reduce our total production.
- In Tahiti, the pearl industry is the second-largest revenue generator after tourism.
- I believe that we need to push for creativity, and delight consumers with jewellery designs set with Tahitian pearls in all colours, sizes and shapes—from baroques to semi-baroques, not only round and semi-round pearls.
- We will conquer new markets through exhibitions, auctions and other activities. We are very confident about the future of Tahitian cultured pearls.

Jaques Branellac — Managing Director, Jewelmex, Philippines

- The Philippine golden pearl is onshore and, therefore, interacts with the people living in the coastal area and on small remote islands.
- It is really a symbiotic relationship between the pearl farm and the community living around it.

Peter Bracher — Executive Director, Paspaley Pearling Group, Australia.

- The global financial crisis of late 2009–2010 caused a dramatic reduction in demand for most luxury products, including obviously, South Sea pearl jewellery, and resulted in a corresponding fall in prices.
- In Australia, producers responded very quickly by dramatically reducing or completely ceasing virgin operations in 2009 and 2010.
- This resulted in most significant Australian producers either exiting the industry or consolidating their production efforts to allow cost efficiencies to be achieved.
- We estimate that these measures have resulted in Australian production being decreased by approximately 50% for at least several years from the forthcoming 2011.
- Paspaley will be reducing the number of auctions that we hold annually from five to four.
- However, the reduced output alone will be insufficient to ensure that the industry returns to sustainability or healthy growth.
- Coordinated marketing efforts are required to expand the market and to restore consumer faith in the pearl sector.
- Pearls are regarded as a single category by most retailers and end-consumers when in fact, each of the pearl categories —South Sea, Tahitian, Akoya and freshwater — are of the wider industry.
- Lack of understanding by retailers and end-consumers about how the various categories of pearls differ from each other in terms of appearance, rarity and value.

- The biggest challenge, however, is working with the *Pinctada maxima*, or the golden lip mother of pearl, which is a very, very sensitive lady.
- But in the past years, all South Sea pearl producers have been working together.
- We foresee a bright future because the next generation of pearl farmers — be it in Australia, Tahiti or the Philippines — are already mobilised.

Q: What is the quantity of Australian production and Philippine production?

Bracher: It's certainly less than a thousand kan at least for the next several years — significantly less. That's probably about much as I could say.

Branellec: The maximum output has never exceeded something like 600 kan: I believe the volume has gone down by maybe 25% or 30% for the past, maybe, two years.

Q: How do current prices compare to three years ago?

Wan: Three years ago, we were talking in terms of price per gram instead of per momme price. We were roughly around 1,000 francs (French Pacific franc) per gram and today, we only have half of that. This is because of the huge quantity of commercial and low-end quality pearls.

Branellec: Paspaley's view is that the Australian industry can only ensure its long-term survival by reducing focus on total output and concentrating on the production of high-quality, large-sized pearls, and by educating end-consumers through retailers about the qualities from other pearls.

Failure to disclose such treatments can result in pricing discrepancies that end-consumers don't understand, and in the absence of a rational explanation, this undermines both products — the natural products and the ones that have been enhanced.

Bracher: In the case of Australia, the price fell quite significantly from the beginning of the global financial crisis probably by about 40%, but actually we gained a lot of that ground quite rapidly within the 12 months that followed. Today, they are not back to pre-crisis levels (in Japanese yen terms) but in US dollar terms, probably quite similar than they were prior to the global financial crisis.

Q: There are a lot of cheap pearls being sold online. What is its impact on the pearl industry?

Wan: I am not doing much online sales. Quality is reserved for the auction. I personally don't see an online sales business yet at the moment.

Branellec: Well, some of our clients have done some positive experiments with online sales but I believe, it is more for first-comers who want accessible products. Internet sales for beginners? Why not? It's the way the new generation and the way young people like to buy. I think sooner or later, we will all have to go into it.

Pearl wholesalers

Rene Hodel — Managing Director, Hodel Hong Kong Ltd.

- In 1999, there were maybe 35 to 40 companies participating (in pearl auctions) and over the last 20 years, more and more people have been invited to pearl auctions.
- I have gone back to the traditional business — that is, dealing directly with pearl farmers. My question is, "Are these auctions the right way to market pearls?"
- In the past 15 to 20 years, so many new pearl farms have been established in Indonesia and in Tahiti. There are still too many farms producing too many pearls which are not good enough in quality.
- We need to produce less pearls but in much better quality.
- I think pearl prices in Tahiti, Indonesia, even Australia and the Philippines are too cheap.
- The pearl industry needs to get organised and start promoting pearls.
- We have to incorporate a properly functioning world body for pearls.
- In terms of pricing and grading, I believe we should have guidelines and standards. How should pearls be valued and graded?

Andy Müller — President, Hinata Trading Co Ltd, Japan

- We are in an industry, I believe, that has just about matured.
- We have seen that for the last, I would say, 30 years. We had experienced a seller's market. The goods were in short supply and people were running after the goods. Sourcing then was rather secret.
- Today, the situation is reversed. We have a buyer's market. We have oversupply.
- Demand today is sluggish, and prices have dramatically dropped.
- I see, however, the positive side of things. The lower prices that we have today in the distribution pipeline will eventually be reflected in the shops, and the final consumer will be confronted with lower prices. Lower prices mean a much larger customer base.
- I think we are just about at the point where confidence can be restored.
- Education is important. I think it is extremely important that we gather our forces and launch an education programme mainly targeting sales teams at retail shops.
- We have seen an extremely large improvement in Chinese freshwater pearls. Nowadays, when I go to the Hong Kong fairs, I see freshwater pearls in ever-increasing sizes and in ever-increasing quantities. Today, it is not surprising to see pearls that match the size of South Sea pearls.
- We no longer have a clear distribution line.
- Many or most of the big farmers of today have tried or are trying to have vertical integration by opening their own retail shops.

Q: How can we make pearls fashionable again?

Hodel: We have to be creative. We have to attract young people. We have to educate the end-consumer more. This can be done by spending money on advertising worldwide, by implementing education programmes that are being used on daily basis in the retail shops.

Q: Is it important for our business to brand pearls?

Müller: Let's be very honest. In the entire world, there is only so far one pearl brand, and it's called Mikimoto.

Hodel: To build up a brand actually takes years and years of hard work, and on top of that, a lot of money as well. Yes, branding is important because with a brand you can actually help the retailers — your customers — to educate their staff.

Q: Do you agree that Japan is losing its status as a pearl trading centre?

Müller: It's quite obvious that today, much more than 50 per cent of the South Sea pearls are sold by way of auction and it's also a fact that most of these auctions are being held in Hong Kong rather than in Japan. The majority of the raw materials, however, are still being sent to Japan, value-added in Japan, and then distributed.

The know-how, money and the tradition is, and will most likely remain, in Japan.

Q: Do you agree that certification would help promote the pearl business and build up consumer confidence? Do you also agree that there should be standardisation in pearl grading?

Hodel: When it comes to pearl grading and pricing ex-farms, yes, I do believe we need a certain standard. I still believe a 10 mm gem-quality pearl from Indonesia should fetch the same price as the 10 mm gem-quality pearl from Australia.

Q: How can a pearl trader be competitive with low-priced pearls?

Müller: We no longer have that situation where the market is dominated by one kind of pearl. If somebody is a little bit innovative, I think that a pearl trader can definitely find a niche market. With the quality of goods and the kind of prices that we have today, we should have a much, much larger customer base.

Q: Don't you think that the pearl dealers are the right people and the right companies to communicate about pearls to retailers?

Müller: Yes, we do. Even in Japan, we do organise seminars. These are being held annually. At these seminars, about 80 members — most of them are retailers — bring themselves up-to-date with (market developments).

Hodel: Yes, we are growing everywhere around in Asia, and we are actually training the staff of our customers. We have two courses: level 1 and 2.

Q: Jacques Branellec would you like to respond to some comments regarding pearl farmers who want to go vertical in business?

Branellec: You have to realise that if you are an importer or trader, you can buy less or you can stop buying and wait for the market to wake up again. If you are a farmer, you are carrying four to five years of deferred production costs, and usually for an average farmer, you have around a thousand people working full time in your farm. So when the market slows down, you cannot just tell the people to come back when things get better. People don't realise that farmers are going vertical because it's a matter of survival.

Q: How are Akoya pearl farming, wholesaling and retailing doing in terms of pricing? What is the future outlook for these pearls?

Müller: I think, quite surprisingly, the Akoya pearl industry in Japan has somehow found its ground, it is rebounding. Prices last year were at their lowest. The price of materials in the December–January period had increased slightly or even more than slightly, depending on the quality and the size, by maybe 15 per cent to 30 per cent. People who used to come to Kobe to buy South Sea pearls are now buying Akoya. I think the Akoya industry is turning north, turning positive.

Full transcripts of this online conference can be viewed at: <http://www.JewelleryNewsAsia.com>

Farmers promote consumer education

Source: *www.JewelleryNewsAsia.com (03 August 2011)*

Three of the world's leading pearl producers underscored the importance of consumer education, creativity and a sharply focused and sustained global marketing campaign in driving consumer demand for pearl jewellery.

Speaking at the second Jewellery Online Conference organised by leading trade platform JewelleryNetAsia and Jewellery News Asia, Tahitian pearl "emperor" Robert Wan of Robert Wan Tahiti, French periculturist Jacques Branellec of Jewelmer, and Peter Bracher of Paspaley shared their insights and approach to brand marketing and gem-quality pearl production in today's ever-evolving and challenging business environment.

Tahitian pearls

The global economic crisis of 2008 has changed the way companies do business, and the pearl sector is not immune to its effects.

According to Wan, Tahitian cultured pearl prices took a record-breaking dive in the last three years, with the financial tsunami driving prices down by

50 per cent from the average price of 1,000 French Pacific francs per gram in 2008.

"Today, we only have half of that," Wan said. "So we are down 50 per cent in three years' time. This is because of the huge quantity of commercial and low-end quality pearls that had been released into the market by small farmers.

"This happened because the government reduced the export tax from 200 francs a gram to 50 francs a pearl today. It is easier for the pearl farmers to export lower-end pearls. I also presume they used their inventories. They didn't want to export their pearls before because of the high export tax," said Wan.

French Polynesia produces 14 tonnes of Tahitian pearls annually, with a total value of USD 130 million. This figure does not include black pearls produced in other parts of the world, including the Cook Islands and Fiji.

"I hope that the price of good quality and gem-quality pearls would be maintained and go even higher," said Wan, who has engaged in a selective expansion in China's first-tier cities since last year.

"I would say, for my part, the price has been up 15 per cent during the last three years."

An industry restructuring is vital to the growth and development of French Polynesia's pearl sector, he continued.

Golden South Sea pearls

The Philippines likewise saw a 25% to 30 per cent decline in South Sea pearl production volume in the last two years, Branellec said. "The maximum output has never exceeded something like 600 kan; a big part of it being an estimate because there are other producers who do not necessarily release their figures. I believe the volume has gone down by maybe 25 or 30 per cent for the past, maybe, two years," he said.

Jewelmer's golden Palawan South Sea pearls, however, continue to command premium prices because of their rarity and incomparable beauty, said Branellec.

"You have to realise that not 100 per cent of what we produce are golden — so golden pearls are still very rare. We also lack in big sizes. I would say the price has been quite stable and we can even now foresee stability. We have some orders that we have not yet been able to fulfil. So, we are quite confident," he said.

"At the retail level, the price has not really moved so much. In the golden pearl category, we foresee stability and a tendency for an increase."

Australian production

Bracher of Paspaley said the crisis of late 2009–2010 caused a dramatic reduction in demand for most luxury products, including South Sea pearl jewellery. This resulted in a corresponding fall in prices at least at the wholesale level.

"In Australia, producers responded very quickly by either dramatically reducing or completely ceasing virgin operations in 2009 and 2010. The change in the market environment also resulted in most significant Australian producers either exiting the industry or consolidating their production efforts to allow cost efficiencies to be achieved," he said.

"We estimate that these measures have resulted in Australian production being decreased by approximately 50 per cent for at least several years from the forthcoming 2011 harvest. In reflection of this, in 2012, from next year, Paspaley will be reducing the number of auctions that we hold annually from five to four."

This reduced output will be welcome news for the pearl market which has held a perception of oversupply for the last four or five years, he continued.

"It's very difficult to estimate exactly what the Australian production is because most of the production is produced by private companies. It's certainly less than a thousand kan at least for the next several years, significantly less," Bracher said.

Australian pearl prices also saw a significant drop "from the beginning of the global financial crisis probably by about 40 per cent especially in the lower commercial qualities," he said.

"But actually we gained a lot of that ground quite rapidly within the 12 months that followed. Today, they are not back to pre-crisis levels (in Japanese yen terms) but in US dollar terms, probably quite similar if not in some cases more expensive than they were prior to the global financial crisis," he said. "It is obviously difficult to exactly estimate when you are producing in Australian dollars and selling in yen into a market that is predominantly US dollar dominated."

Educating the consumer

All three farmers highlighted the importance of consumer education, creativity and a sustained globally coordinated marketing programme in stimulating consumer demand for pearl jewellery.

"With regards to Tahitian cultured pearl supply and demand, we need transparency. We need some regulations. We wish to achieve price stability," Wan said. "We wish to implement a quality control system through 'labelling', and this is something we are working on. We also have to launch a sustained global marketing campaign, particularly in key markets such as Brazil, India, Turkey and China."

The Tahitian pearl farmer also emphasised the importance of design, innovation and creativity in inspiring consumer interest in pearl products. "We need to push for creativity, and delight consumers with jewellery designs set with Tahitian pearls in all colours, sizes and shapes — from baroques to semi-baroques, not only round and semi-round pearls. We need international promotions such as Tahitian pearl jewellery design contests," said Wan.

There is a growing awareness among industry stakeholders of the need to work together for the pearl sector to prosper, Branellec said.

"Before, there was stiff competition between different producers and farmers. Each one was working in his own corner in spite of some attempts to meet frequently with our friends and colleagues around the world. But in the past years, all South Sea pearl producers have been working together. Today, what we have is a complementary, not competitive, relationship. This mature attitude means all farmers are working hand in hand for the trade and the public to share the magic and love of pearls," he said.

Hong Kong rises as Tahitian pearl trading hub

Source: *www.JewelleryNewsAsia.com* (10 June 2011)

The significant increase in Tahitian pearl trading activity in recent years indicates that Hong Kong's importance as a trading hub for these lustrous gems is rising.

In 2010, Hong Kong was the largest importer of Tahitian pearls, with a 55 per cent share in total exports. Exports to Japan had dropped notably, although the Japanese market still accounted for 35 per cent of exports, down from 70 per cent about a decade ago. The US placed third, while France took the fourth spot, according to data released by the Statistical Institute of French Polynesia (see Table 1).

Hong Kong's rising importance in the Tahitian pearl trade is also reflected in the number of major Tahitian pearl auctions that are being held in Hong Kong. These auctions draw buyers from the Asia-Pacific region, Europe and the US, said Johnny Cheng, president of the Tahitian Pearl Association Hong Kong (TPAHK).

Fall in production

Tahitian pearl production fell by nearly 40 per cent to 10 tonnes in 2010, with many pearl farmers going into the red due to tumbling pearl prices some three years ago, Cheng said.

"Tahitian pearl prices, which were soft even before the global financial crisis, slid further when the downturn hit. Plummeting pearl prices forced

many farmers to reduce their production. In 2010, the total production of Tahitian pearls dropped to around 10 tonnes, down from 16 tonnes in 2009," Cheng said.

According to the Statistical Institute of French Polynesia, there are now just over 400 active Tahitian pearl farmers spread across French Polynesia, most of which are family-owned businesses, he added. "The Tahitian pearl producing industry is dominated largely by family-owned businesses. Usually, there are 8 to 10 family members working in a small farm. Large, professionally managed businesses take up less than 3 per cent of the industry," Cheng said.

Not all of these pearl farmers have been granted an export permit though, further limiting the supply of Tahitian pearls into the market, he said. "Even if you have a permit, your pearls must go through a very strict X-ray examination to ensure a minimum nacre thickness of 0.8 mm," said Cheng.

Tahitian pearl production in the first quarter of 2011 fell 3.0 to 4.0 per cent, while export prices grew 4.8 per cent compared to the same period last year – a trend that Maison de la Perle said is expected to continue well into the rest of the year.

Leading Tahitian pearl producer Robert Wan Tahiti concurred. Wan said he expects the total production of Tahitian pearls in 2011 to be 5 to 10 per cent lower than the previous year. "This will push up Tahitian pearl prices by at least 5 per cent in 2011," he said.

Rising prices

The dramatic fall in pearl production last year has ignited a hike in Tahitian pearl prices. Prices are up by at least 10 per cent, with higher quality pearls even commanding higher prices. "The average price of Tahitian pearls rose by 10 to 15 per cent in the past year, while prices of fine qual-

Table 1. Accumulated exports of pearl and nacre shell from French Polynesia in 2010.

Countries by destination	Weight (g)	Value in Pacific francs (XPF)	% of weight	% of value
1 Hong Kong	9,004,454	4,031,918,467	56.1%	54.8%
2 Japan	5,707,844	2,574,871,402	35.6%	35.0%
3 US	516,475	232,398,891	3.2%	3.2%
4 France	233,760	149,371,321	1.5%	2.0%
5 New Caledonia	133,528	97,574,585	0.8%	1.3%
6 China	182,017	68,455,865	1.1%	0.9%
7 Australia	50,555	67,072,637	0.3%	0.9%
8 New Zealand	87,186	66,696,915	0.5%	0.9%
9 Canada	60,314	24,128,817	0.4%	0.3%
10 Singapore	19,785	8,772,800	0.1%	0.1%
Others	57,554	35,967,424	0.4%	0.5%
Total	16,053,472	7,357,229,124	100.0%	100.0%

Source: Statistical Institute of French Polynesia

Note XPF 1.00 = USD 0.0116 (November 2011)

ity orbs — which have since become more scarce — increased even more,” Cheng said.

The insufficient supply of high quality pearls was evident at recent pearl auctions. “High-grade Tahitian pearls, measuring 14 mm to 17 mm in diameter, and in peacock colour are limited in availability at pearl auctions. Most of the pearls are in sizes ranging from 9 mm to 11 mm,” he said.

In addition to large sized pearls, demand for 8 mm Tahitian pearls has also outstripped supply. “Japan and China favour pearls of fine qualities but in smaller sizes, while the US and Europe prefer larger sized pearls,” he said. For instance, necklaces with pearls in smaller sizes, particularly pearls measuring 8 mm in diameter, enjoy strong demand in Japan, he continued.

Major markets

China has become the undisputed leader in terms of growth in demand for Tahitian pearls in recent years. “The wealthy locals have a particular fondness for Tahitian pearls because they believe that these gems do not only bring a rich element to jewellery designs, they also reflect the unique temperament of their wearers,” Cheng said.

Another potentially high-growth market for Tahitian pearls is India. “According to a recent market research conducted by Maison de la Perle, Indian consumers may not know much about Tahitian pearls for now, but the market potential for the gem in this populous nation is huge,” said Ida Wong, general manager of TPAHK.

Aside from Asia, Wan of Robert Wan Tahiti also noted great market potential in traditional markets like the US and Europe. “In 2011, demand for Tahitian pearls will be higher in Europe, the US and Asia, particularly China,” Wan said.

Positive outlook

The Tahitian pearl sector is facing brighter prospects in 2011, not only because of the anticipated solid demand from Asia, the US and Europe, but also because consumers are willing to pay a premium for innovative jewellery designs.

“More high-end manufacturers are using Tahitian pearls in their jewellery designs since the gems go perfectly with diamonds, coloured gemstones, coral and other precious materials,” Cheng said.

Positive outlook for South Sea pearls

Source: www.JewelleryNewsAsia.com (10 June 2011)

Asia has emerged as the top market for South Sea pearls. This is reflected in the significant increase in the number of Asian bidders at the Paspaley South Sea Pearl Auction in Hong Kong in recent years.

South Sea pearl production in 2010 dropped by nearly 15 per cent to an estimated 3,150 kan, following production cutbacks triggered by the global economic downturn of 2008, a pearl industry veteran said.

“Pearl farmers have reduced their production two to three years ago,” said Leung Sik Wah, director of Hong Kong-based Cogent Trading Co Ltd. Of the South Sea pearls harvested in 2010, only 2 to 3 per cent — or less than 100 kan — was gold in colour, Leung added.

Australia and Indonesia, the world’s two largest South Sea pearl-producing countries, harvested 1,200 kan and 1,350 kan, respectively last year, or down 20 per cent and 10 per cent, respectively in comparison to the 1,500 kan that each country produced in 2009.

South Sea pearl production in the Philippines dropped to 400 kan in 2010 from 500 kan in 2009. The output in Myanmar and other countries, however, remained unchanged at 200 kan.

Global South Sea pearl production for 2011 and 2012 is likely to remain at the same level as 2010, Leung said. The industry would gradually ramp up production in 2013, barring any natural disasters, he added.

Total production value

Despite a decline in production volume in 2010, Leung noted that the total production value last year was on par with 2009. “The global South Sea pearl production for 2010 amounted to approximately USD 260 million,” he said.

A recovery in South Sea pearl prices was one of the reasons behind this result. The average per-momme price of the Philippines and Indonesia’s South Sea pearls rose 25 per cent to USD 60.9 per momme in 2010. South Sea pearls from Myanmar and other countries fetched an average price of USD 85.2 per momme, up nearly 10 per cent compared to that of 2009. Australia’s South Sea pearls maintained the same level of USD 121.7 per momme on average.

Leung further said that Australia maintained its lead in terms of total production value, followed by Indonesia, the Philippines, Myanmar and other countries.

Table 1. World's South Sea Pearl production volume in 2010

Country	Volume (kan)	%
Indonesia	1,350	42.9
Australia	1,200	38.1
Philippines	400	12.7
Myanmar and other countries	200	6.3

Source: Leung Sik Wah, Director of Cogent Trading Co. Ltd., in Hong Kong

Major markets

Asia has emerged as the top market for South Sea pearls, accounting for approximately 40 per cent of production, Leung said. "Asia's vibrant markets contributed to South Sea pearl sales in 2010. China, where pearl jewellery demand has a huge room for growth, has overtaken Japan as Asia's biggest South Sea pearl market. It now accounts for about half of the total South Sea pearl sales in the Asia-Pacific region, while the rest is split equally between Japan and India," he said.

Sales to the US and Europe have not been as good in recent years, although the two markets still constitute at least a quarter of global South Sea pearl sales, down from 50 per cent some five years ago, Leung said.

Table 2. Comparison of the world's South Sea Pearl production volume (kan) between 2009 and 2010

Country	2009	2010
Indonesia	1,500	1,350
Australia	1,500	1,200
Philippines	500	400
Myanmar and other countries	200	200

Source: Leung Sik Wah, Director of Cogent Trading Co. Ltd., in Hong Kong.

Table 3. Average per-momme price (Yen) of pearls produced in major South Sea pearl-producing countries between 2009 and 2010.

Country	2009	2010
Indonesia	4,000	5,000
Australia	10,000	10,000
Philippines	4,000	5,000
Myanmar and other countries	6,400	7,000

Source: Leung Sik Wah, Director of Cogent Trading Co. Ltd., in Hong Kong.
Note: 1 ¥ = 0.0121733 USD

Popular pearl types

The popular goods are widely diverse in terms of size and quality. "Chinese consumers prefer higher quality pearls in bigger sizes, while the Japanese prefer pearls in smaller sizes. The Indians favour pearls of commercial qualities, but they will make the shift to better quality pearls in the future," Leung believed.

When it comes to the gem's shape, most buyers are partial to round-shaped pearls. "Demand for baroque pearls was very strong some time ago, but their popularity has faded following a significant increase in supply. Round-shaped pearls, which only account for about 10 per cent of the total South Sea pearl production, have made a strong comeback," he observed.

As for prices, buyers favour pearls that sell for around USD 60.9, he added.

Natural colour and lustre are also important criteria for pearl selection. Pearls offered at Hong Kong's pearl auctions, including the Paspaley South Sea Pearl Auction and Robert Wan Tahiti Perles Auction, were carefully scrutinised before going on sale to ensure that the pearls offered were of very good quality in terms of colour and lustre, Leung said. Looking ahead, Leung said he is confident that the South Sea pearl sector is facing positive prospects, bolstered mainly by the strong demand from Asia and a gradual economic recovery in the US and Europe.

Freshwater pearl prices on the rise

Source: *www.JewelleryNewsAsia.com* (13 July 2011)

Freshwater pearl prices have experienced double-digit growth since 2010, triggered by cuts in freshwater pearl cultivation in China. With China's maturing nucleated freshwater pearl sector, industry members are confident that the introduction of round, nucleated freshwater pearls into the market will further drive the demand for these gems.

Drop in production

Freshwater pearl prices have risen about 30 per cent since last year, and prices could rise even further this year, said Johnny Chan Yuk Kwong, president of the Hong Kong Pearl Association (HKPA). The price hike is partly driven by the Chinese government's policy of limiting the areas open for pearl cultivation in recent years. "Today, freshwater pearls are mainly cultivated in the provinces of Hunan, Hubei, Anhui and Jiangxi, which are rich in freshwater resource," Chan said.

Even in Hubei and Anhui provinces, the government has reduced the number of pearl cultivation areas, said Chai Mingjun, founder and board chairman of Zhejiang Eternity Jewellery Co Ltd.

Chai also cited other factors that affected freshwater pearl production: a shakeout in the pearl farming industry following the global economic downturn, and a number of ecological factors that have made some areas unsuitable for freshwater pearl cultivation.

"We expect the supply of Chinese freshwater pearls to drop by half this year," he forecast.

Chan shared similar insights. "The amount of Chinese freshwater pearls that will be harvested will shrink by 30 per cent in 2011 and 2012 due to a decline in pearl production," he predicted.

Higher costs

Rising production costs, mainly due to high labour, rent and material outlays, will further boost pearl prices. Chan estimated that the costs of pearl cultivation rose by more than 20 per cent in 2010, inevitably pushing freshwater prices up. For instance, the prices of small-sized pearls measuring less than 5 mm in diameter have doubled over the last 18 months, he added.

Chai also noted a sharp rebound in prices. Freshwater pearl prices rose in 2010 and have returned to 80 per cent of the pre-crisis levels, he continued.

Sustained demand

Chan predicted that Hong Kong's total export value of freshwater pearls in 2011 will exceed last year's level since high pearl prices have failed to dampen global demand. Rising demand was evident at the March Hong Kong Fair this year. Freshwater pearl dealers said European and American buyers were more willing to accept higher prices to replenish their stocks.

Nucleated pearls

Further developments in nucleated freshwater pearl production would likely boost sales. Regular freshwater pearls are only made of nacre. They do not have a nucleus — the absence of which results in the production of irregularly shaped pearls. One of the latest innovations in Chinese pearl production is the development of nucleated freshwater pearls. "A nucleus is inserted into the body of the mollusc to ensure the production of round-shaped pearls," Chan said.

"Round, nucleated freshwater pearl production has reached a relatively mature stage of development in China. These pearls currently account for more than 50 per cent of the total Chinese freshwater pearls produced. In two years' time, there will be a large supply of round-shaped pearls in the market," he said.

This cultivation method can also ensure the production of bigger pearls. "The size of round, nucleated freshwater pearls can reach 16 mm and up," he said.

Fine quality round, nucleated freshwater pearls are mostly sold as semi-finished products. "Finished jewellery may not meet the tastes and preferences of different markets, but semi-finished products can be tailored to local preferences," Chan said.

Industry support

HKPA's sustained freshwater pearl promotions have benefited the industry. The association will continue to raise the market's awareness of freshwater pearls, facilitate the exchange of market information, and enhance the role of Hong Kong as a key trading centre for freshwater pearls, Chan said.

In May 2011, HKPA hosted a spring tour to Xi'an City, Shaanxi Province, which doubled as a networking event among association members. Last year, it formed a strategic coalition with 18 jewellery industry associations in Guangdong, Hong Kong, Macau and Taiwan to promote industry growth.

"Undoubtedly, pearl farmers are seeing their profits shrink and pearl wholesalers are saddled with rising costs. But as long as the overall economy continues to pick up and farmers make a reasonable profit and sustain steady production, the freshwater pearl sector will continue to face bright prospects," Chan said.

Cook Islands pearl industry to be revived with New Zealand's support

Media statement from Hon. Murray McCully, Minister of Foreign Affairs, New Zealand, 15 July 2011.

New Zealand will contribute to the revitalisation of the Cook Islands pearl industry as part of a three-year programme funded through the New Zealand Aid Programme, Foreign Minister Murray McCully announced today.

"At the industry's peak in 2000, black pearls contributed NZD 18 million¹ to the national economy per year," Mr McCully said.

"Limited regulation and some unsustainable environmental and farming practices, coupled with a slump in international pearl prices saw production in the Cook Islands reach record lows."

"New Zealand, as part of our harmonised aid programme with Australia, will commit NZD 3 million to the Pearl Industry Revitalisation programme aimed at developing sustainable farming practices and increasing income for those involved in the black pearl sector," Mr McCully said.

"Our support will contribute to monitoring and regulating pearl farm production, local, regional and international marketing, and financial assistance and capacity development for farmers to enhance current and future prospects of the industry."

"Revitalising the industry will have immense flow-on benefits for outer island communities. Ninety per cent of Cook Islands pearls are produced in the northern island lagoon of Manihiki — 1,160 kilometres north of Rarotonga — where

employment and livelihood opportunities are limited," the Minister said.

"This programme builds on research already carried out into the ongoing viability of Cooks Island's marine resources, and an initial investment into market research aimed at helping to effectively position the Cook Island's pearl industry internationally."

"Investment in the pearl industry is a priority initiative under the New Zealand and Cook Islands Joint Commitment for Development, and is complemented by New Zealand's support for waste management and sanitation improvement in the Cook Islands which seeks to safeguard the country's lagoons for future generations," Mr McCully said.

The Joint Commitment for Development will serve to strengthen the development relationship and deliver real, long term outcomes for the people of Cook Islands.

Mr McCully is in the Cook Islands as part of the 2011 Pacific Mission.

The Minister's speeches and statements can be found at www.beehive.govt.nz

Cook Islands Pearl Forum: Shaping a sustainable future

The Cook Islands Pearl Forum, held on 11 August, included stakeholders from all sectors of the Cook Islands Pearl Industry. All of the participants agreed that the Pearl Forum should be held annually.

Industry presenters included the following speakers. Cook Islands Pearl Authority (CIPA) Chief Executive Officer (CEO) George Ellis gave a review of progress since the last forum. In its hey-day — 1990s–2000 — the industry was generating NZD 18 million per year or 90% of the country's total export value. The disease outbreak in November 2000 affected 85% of all oysters and, combined with the market slump in 2000, seriously affected the industry. Production dropped by half, and farm reputations and cash-flows were poor. The industry reached its lowest point in 2010 where it earned only NZD 1.2 million. It is hoped that by 2013, production capacity will double from 600,000 to 1.2

million oysters, which will increase export numbers in 2014 and 2015. CIPA hopes to become an industry that earns NZD 6.1 million by 2015.

1. CIPA's CEO also gave an overview of the stimulus package that includes NZD 3 million from the New Zealand Government, 1.5 million from the Cook Islands Government, and NZD 500,000 from Manihiki Pearl Farmers Association (MPFA) over a three-year period. The Cook Islands Government has agreed to assume one-third of the risk share of loans under the scheme and guarantees NZD 500,000 to cover defaults on loans.

¹ NZD 1.00 = USD 0.81 (as of October 2011)

2. Mike Hodge of New Zealand's branding firm, Brian R. Richards Ltd., spoke about the "Avaiki" brand strategy and how he believes it will save Cook Islands pearl farms. Branding is an alternative way of future proofing or protecting our pearl industry. "Avaiki" brand is pitching for the international market and carving a niche market for Cook Islands pearls. "Avaiki" is our own home-grown premium brand that allows us to set and meet particular standards so as to protect and ensure the integrity of the brand and our reputation.
3. Speakers representing the Cook Islands Ministry of Marine Resources (MMR), Manihiki Island Council, and MPFA discussed their roles in the industry. MMR monitors the lagoon and supports and/or advises CIPA, while the Island Council and MPFA (with the Manihiki Lagoon Management Plan) are involved in husbandry of the farms and the industry as a whole.

The Cook Islands Pearl Industry Support Program 2011–2013 goals will be achieved through three components that focus on production support, marketing support and capacity development.

These components will be managed and monitored under the above programme hosted by CIPA and assisted by MMR. The Production Support programme is a subsidised credit scheme for farmers and technicians, and will allow them access to a NZD 1.5 million fund to finance the purchasing of materials and equipment to assist with cash flow. The Marketing Support component will provide needed assistance for two key marketing initiatives of Cook Islands pearls: 1) whole crop marketing strategy for both "Avaiki" branded pearls and non-branded pearls; and 2) expanding the capacity of the Pearl Exchange. The third component, Capacity Development, will provide institutional strengthening assistance to MPFA, and specialist services to provide loans to farmers and mentoring training to key stakeholders. Investing in the capacity of pearl farmers is vital for the industry's growth and sustainability. CIPA, with assistance from MMR, will ensure that governance and management structures are established, resource inputs are delivered, and monitoring and reporting commitments are maintained. A programme coordinator will coordinate and monitor all programme activities.

Pearl Day at the Punanga Nui Market in the Cook Islands

Source: Dorothy Solomona, Ministry of Marine Resources, Cook Islands

Pearl Day on 14 July 2011 marked the launch, collaboration and support of the New Zealand Government and Cook Islands Government in the Cook Islands Pearl Industry Support Programme 2011–2013.

The theme was "Go Local" with pearl retailers, farmers, jewellers, Business Trade Investment Board, Bank of the Cook Islands, Ministry of Marine Resources, and Cook Islands Pearl Authority playing their part in the programme. Food

stalls and entertainment at the Punanga Nui Market kept the atmosphere festive. New Zealand Foreign Minister Murray McCully, with his delegation of 32, arrived at the market and reaffirmed his support for the revival of the million dollar industry in the Cook Islands. Five million dollars, contributed by the New Zealand Government, Cook Islands Government and the Manihiki Pearl Farmers Association, supports the programme and the revival of the pearl industry over a three-year period.



A: Business Trade Investment Board Young Entrepreneur's Programme for colleges display their business ideas.

B and C: Retailers, jewellers and farmers display their wares for the public.

D: The Cook Islands Pearl Association, which manages the Pearl Production Scheme and Marketing Support component of the Pearl Support Programme.

2011 GPS re-mapping project of Manihiki Lagoon

Source: Georgia Langdon, Ministry of Marine Resources, Cook Islands

One of the first components of the new NZAID funding programme is to undertake a complete re-mapping exercise of the entire Manihiki Lagoon and all its farms. Previous global positioning system (GPS) map work in Manihiki involved only marking out the boundaries of each farmed area (Fig. 1). These boundaries were quite vague and arbitrary, which resulted in many areas overlapping although actual lines were not. Since that time, many Manihiki residents have ceased farming for some time or abandoned their farms and left the island. The new mapping exercise involves mapping each individual farm line in the water where the geographical points of each line are input onto a handheld GPS device (Fig. 2). The exercise also aims to identify:

- 1) farms or farm lines that are currently operational;
- 2) those that are dormant and have been out of use for some time; and
- 3) farms that have been completely abandoned.

The goal of the new funding stimulus is to double current production levels of pearls from 600,000 shells to 1.2 million over the next three years. As the new mapping exercise ties in with the issuing of new farming permits, it is important to identify areas that are no longer in use, which will allow existing farms to expand or new farms to develop. With a new line-by-line map (Fig. 3) that overlays the depth contours of the lagoon floor, we will be able to recognise suitable areas that may be used for farming within the lagoon.

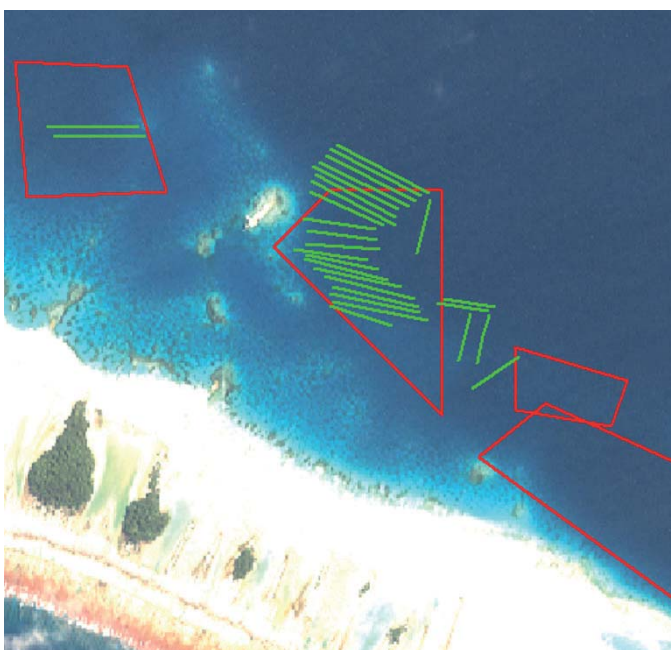
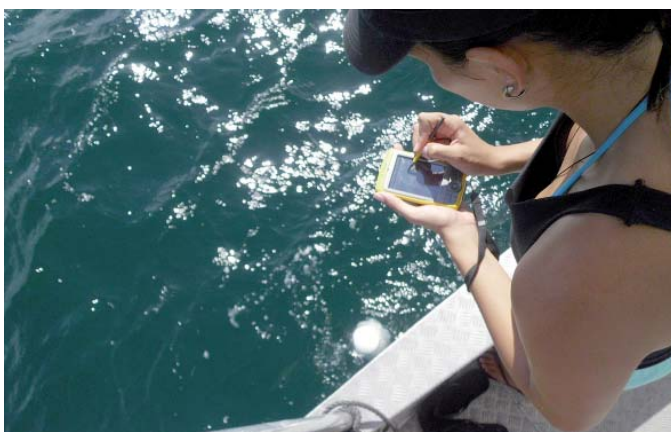
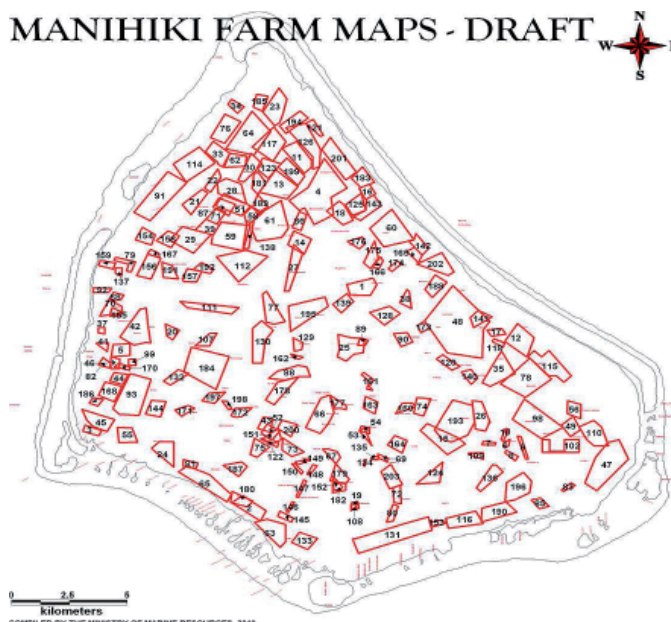


Figure 1 (top).
Map of old farm boundaries
within Manihiki Lagoon.

Figure 2 (middle).
Recording geographical coordinates
of individual lines with
a handheld GPS.

Figure 3 (bottom).
Mapped farm lines (green)
and old farm boundaries (red).

2010 Fiji Pearl Auction

Source: *J. Hunter Pearls Newsletter, August 2011*

Our fourth auction took us to bustling Hong Kong in September 2010. The devastation that Cyclone Tomas brought to our farms was evident in this small auction held over two days. On auction were 9,500 pearls sorted by colour, shape and grade into 24 different lots. Lots 1 and 2 contained the best fifty round pearls collected over two harvests, ranging in size from 9–16 mm. These pearls displayed strong lustre and held vibrant colours of

copper, chocolate, burgundy, pistachio and gold. In the cooler palette, J Hunter also featured for the first time a limited number of “ink-blue” pearls. Worth mentioning was the “nugget” of the harvest, the 18 mm gold circle pearl. The size and weight of this pearl is quite breath taking. To add to its brilliant gold body colour are chocolate-coloured rings that run around the surface of the pearl. A truly unique Fijian pearl.

News from J. Hunter Pearls, Fiji

Source: *J. Hunter Pearls Newsletter, August 2011*

Our last year was dominated by recovering from the effects of Cyclone Tomas that struck our islands in March 2010. We had some pretty significant damage to our farm infrastructure; losing some 200 spat collector lines, boats and barge's, our two seeding sheds at both farm sites and most damaging was the significant loss of post-implanted and young oysters.

2011 has really been about learning from this event and getting back on track, making ourselves better and stronger. The challenge we face this year is that it will be the first year in eight years that we will not have pearls for export available. As you can imagine this is quite a financial challenge for us. We have

persevered with great support and encouragement from many of our customers and we are well on our way to getting back on track. The demand for our Fijian pearls fortifies our resolve to bring these truly exceptional pearls back to our customers.

While our immediate supply is limited, the future of our pearl production is looking very bright. Over the course of the last year we have more than doubled our grow-out capacity, increasing our number of water leases and forming stronger relationships with the traditional fishing right owners. We now have twice the grow-out capacity we had just one year ago.





Research on pearl oyster aquaculture in French Polynesia

Serge Andréfouët¹

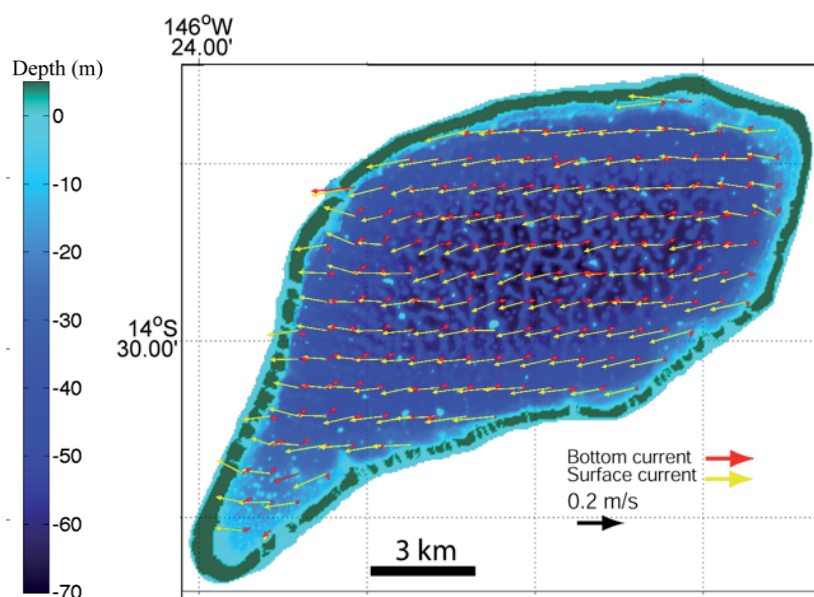
Between 2007 and 2010, the 9th European Development Fund (EDF) sponsored a large development plan in French Polynesia, called “Professionalisation and sustainability of pearl culture”. Spearheaded by the Service de la Perliculture (PRL, French Polynesia’s Pearl Oyster Aquaculture Service), which is based in Papeete, Tahiti, the project aimed to enhance the technical knowledge of *Pinctada margaritifera* pearl oyster farmers as well as their small-business economic management skills, and promoted innovative research by building on a number of previous research programmes that took place in the Tuamotu Archipelago after the 1980s.

A large training programme took place on all of the atolls that have aquaculture activities. Ahe and Takaroa atolls, two semi-closed atolls in the western Tuamotus, were selected as pilot sites for research.

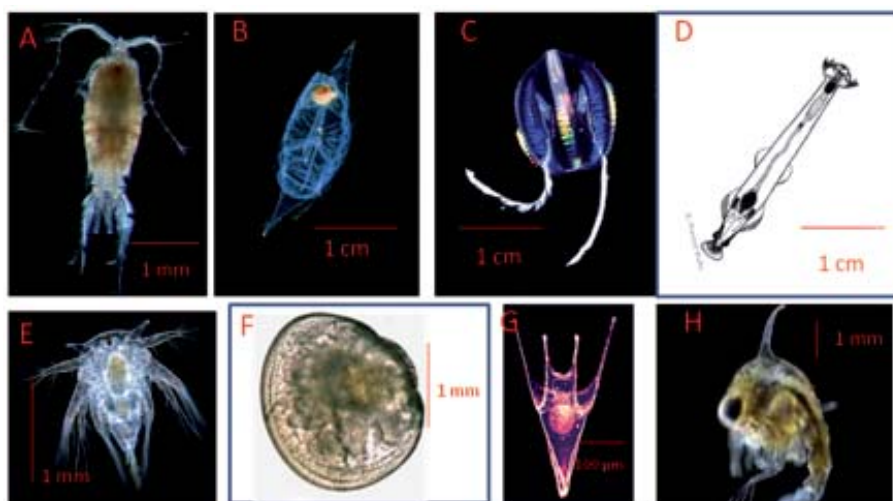
Research included four components:

1. A physical component aimed at studying the climatic regime of the western Tuamotus, and the hydrodynamic functioning of the lagoons. This included the use of various numerical models, remote sensing, and *in situ* measurement data. In particular, lagoon bathymetry was surveyed with acoustic technology, wave climate was studied at high resolution (5 km), and a three-dimensional model of lagoon circulation was created at 100 m-resolution. Field work provided one year of data to calibrate and/or validate the three-dimensional model, which required tide, wave, wind and current data measured in various atoll areas (forereef, pass, *hoa*, lagoon).
2. The biophysical modelling component took advantage of a large number of biological studies conducted on Ahe, several of which were initiated before the EDF project, and funded by other sources. In particular, larval concentrations, dispersal and collecting were studied *in situ* at different spatial and time scales during the previous two years, which provided invaluable data to validate the model.

A view of Ahe Atoll, showing the atoll’s bathymetry and a representation of surface and bottom currents during typical tradewind conditions. Courtesy of Romain Le Gendre (IRD/Ifremer).



¹ Chargé de recherche, French Research Institute for Development (IRD). Email: Serge.andrefouet@ird.fr



Examples of metazooplankton organisms, trophic competitors of the pearl oyster *Pinctada margaritifera* in atoll waters. Holoplankton: A) copepods (*Rhincalanus* sp.), B) salpe (*Salpa fusiformis*), C) *Pleurobrachia pilaus* D) Chaetognathes (*Sagitta* sp.). Bottom meroplankton (larvae): E) balane, F) bivalve larvae, G) urchin larvae, H) crab larvae. Courtesy of Marc Pagano (IRD, UMR 213 LOPB).

All of these activities were conducted by a large group of scientists from local, national and international institutions (see acknowledgments). In November 2010, farmers were invited to attend one day of presentations in Papeete where all useful practical outcomes were presented and discussed.

A special issue of the journal *Marine Pollution Bulletin* (edited by Serge Andréfouët and Loïc Charpy) is currently being compiled, and includes scientific results in the form of a dozen papers. In addition, the French Research

- The project also funded the characterisation of different *Pinctada margaritifera* pearl oyster food sources and the spatio-temporal variability. Thus, the planktonic food web, biomass, production and community structure of the different compartments (phyto- and zooplankton) were studied during five campaigns, including for the first time a focus on viral communities and their influence on bacterial mortality. Meta-zooplankton communities, which are pearl oyster trophic competitors and predators of the larval stage, were also studied. Eventually, the impact of aquaculture activities on the food chain and lagoon carrying capacity could be estimated.
- Finally, spawning and growth of pearl oysters was studied *in vivo* and *in vitro* on Ahe in order to identify triggering signals and limitations found in different environmental and trophic conditions. These studies have provided the foundation to establish an initial Dynamic Energy Budget for pearl oyster.

Institute for Development (IRD) is reviewing documents that present the main concepts, results and practical recommendations by the scientific teams. These will appear in the form of 40, 2–3 page fact sheets, each focussing on different scientific aspects. These fact sheets are written for the layman and are intended to bring scientific knowledge to farmers. PRL, through its *Te Reko Parau* newsletter, is also disseminating results to farmers. These documents are currently only available in French.

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Under the main donor logo (European Union) and the logo of the Pearl Oyster Aquaculture Service, the logos of the various participating institutions that contributed to the project are seen here. The project benefited from other funding sources, including the Contrat État-Territoire funding scheme, and the Délégation à la Recherche de Polynésie française (to IFREMER).

Using concentrated microalgae to condition winged pearl oyster (*Pteria penguin*) broodstock

Matthew Wassnig¹

Introduction

Pearl production from *Pteria penguin* is often limited by the availability of oysters, particularly in places where it is an exotic species and does not recruit reliably in the wild (Finau 2005; Southgate 2008). Hatchery propagation of *P. penguin* has now become a necessity in areas such as Tonga, where the collection of oysters from the wild can no longer sustain commercial pearl production (Teitelbaum and Ngaluafé 2008).

Hatchery production is reliant on the controlled spawning of mature broodstock during the natural spawning season, which for *P. penguin*, may only span a few months of each year (Milione and Southgate in press). Annual hatchery production of juvenile oysters is, therefore, limited by the short period during which broodstock possess ripe gonads. Due to the sensitivity of embryos and larvae to slight variations in water quality and environmental variables, hatchery rearing of pearl oysters is characterised by high mortality rates (Alagarswami et al. 1989; Rose and Baker 1994; Southgate et al. 2008). Hatchery facilities are, therefore, required to operate for the longest annual period possible in order to maximise the supply of juvenile oysters to the pearl industry.

Gamete production outside of the natural spawning season has been successfully achieved for species of scallop (e.g. Monsalvo-Spencer et al. 1997) and clam (e.g. Ojeda et al. 2008) via exposure to adequate water temperature and appropriate feeding regimes of live microalgae. In contrast, pearl oysters are notoriously difficult to artificially condition. Hayashi and Seko (1986) were the first to observe maturation of a pearl oyster species (*Pinctada fucata*) in response to cultured microalgae, although the monospecific diet used did not yield fully mature broodstock. Saucedo et al. (2001) used aquarium culture methods to successfully stimulate the development of ripe oocytes and active spermatozoa *Pinctada mazatlanica*, however, once again gonad development did not reach spawning condition. A recent study by Wassnig (2011) found that *P. penguin* increased filtration and digestion efficiency in response to rapid changes in food availability and elevated water temperature, highlighting the potential use of

these parameters to induce year-round production of gametes from broodstock.

Pearl oysters typically have a far greater filtering capacity than other commercial bivalve species, resulting in a high demand for cultured phytoplankton (Yukihira et al. 1998a). Suspension feeding of bivalves is optimised by maintaining a constant supply of food (Winter 1978), therefore systems for broodstock conditioning require large volumes of marine microalgae, which few pearl oyster hatcheries have the facilities and technical capacity to produce (Southgate 2008). The advent of commercially available concentrated microalgal products has meant that land-based culture of bivalves can be undertaken in areas where the infrastructure for live microalgae production is not available. This study assessed the viability of using concentrated microalgae to condition *P. penguin* broodstock in a flow-through aquarium system.

Materials and methods

The aquarium system used in this study consisted of 5 identical 30-L “flow-through” aquaria capable of holding 3 oysters each. Filtered seawater (FSW) (to 1 µm) was pumped from a temperature controlled 1,200-L tank to a heavily aerated header tank where it was channelled into flow-through aquaria at a rate of 60 ± 2 L aquarium⁻¹ h⁻¹ (Fig. 1), providing a 100% water exchange every 30 min. A diaphragm pump was used to continuously dose seawater with concentrated algae as it flowed from the temperature control tank to the header tank (Fig. 1). FSW entered each flow-through aquarium at a point near to the bottom and moved upwards past the oyster before flowing out at the top. Gentle aeration within individual aquaria was used to ensure that oxygen levels remained above 5.0 mg L⁻¹ and 75% saturation. Aquaria were emptied and cleaned once a day to remove faecal matter.

This study was undertaken at James Cook University’s Marine and Aquaculture Research Facilities Unit (MARFU) in northern Queensland, Australia, and used *P. penguin* collected from a wild population at nearby Orpheus Island (18°36’24 S and 146°29’10 E). The study was conducted for a period of 40 days from late August to early October, to

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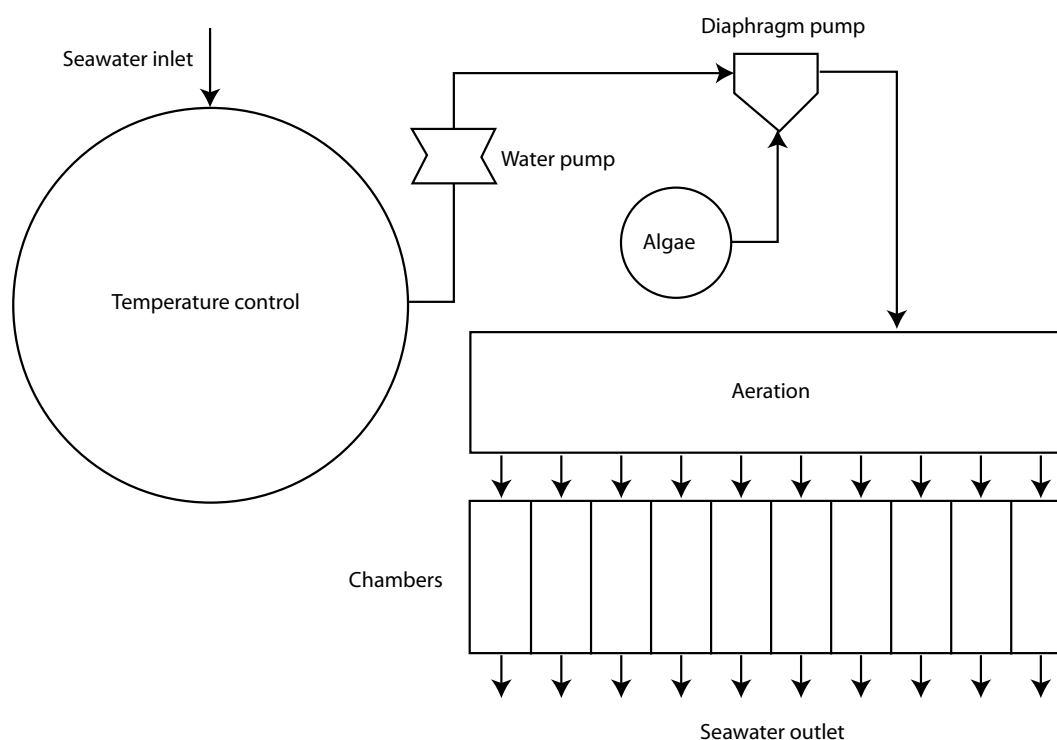


Figure 1. Diagram of the aquarium system containing *Pteria penguin* broodstock. Arrows indicate the flow of filtered seawater from inlet to outlet.

assess if aquarium culture techniques could be used to promote gamete production prior to the natural spawning season of December to March (Milione and Southgate in press). Fifteen adult *P. penguin* were placed among the 5 chambers (3 oysters per chamber), with no significant difference ($\alpha = 0.05$) in mean shell height (SH) between each chamber (overall mean SH = 204 mm).

A mixed diet of concentrated microalgae from the Instant Algae® range (Instant Algae®, Reed Mariculture Incorporated, Campbell, CA, USA 95008) was supplied to broodstock continuously throughout the study period. The diet consisted of, in terms of the number of cells mL^{-1} , 50% *Isochrysis* sp. (Haptophyceae), 25% *Pavlova* sp. (Haptophyceae), 15% *Thalassiosira weissflogii* sp. (Bacillariophyceae) and 10% *Tetraselmis* sp. (Chlorophycophyceae); 1 mg L^{-1} dry weight of the mixed diet was equal to approximately 10,000 cells mL^{-1} .

Broodstock were continuously provided with suspended concentrated algae, which at the beginning of the study period was supplied at a density of 10×10^3 cells mL^{-1} ; twice the average phytoplankton density experienced by pearl oysters in their natural habitat on the Great Barrier Reef (Yukihira et al. 1998a). Food density was increased by 10×10^3 cells mL^{-1} at 10-day intervals beginning on day 11. Water temperature was maintained at an ambient 23.5°C for the initial 10 days and was increased by 1.5°C at 10-day intervals beginning on day 11. This regime

was based on the results of Wassnig (2011), which showed an increase in energy absorption by *P. penguin* with food density and water temperature up to 40×10^3 cells mL^{-1} and 28°C , respectively.

The clearance rate (CR) (L h^{-1}), the rate at which ambient water is cleared of algae cells, was measured for each aquarium every 3 days beginning on day 4. CR was estimated using the equation by Hildreth and Crisp (1976): $\text{CR} (\text{L h}^{-1}) = F (C_1 - C_2)$, whereby:

F = the flow rate of water entering each experimental chamber (L h^{-1}),

C0 = the density of algae surrounding each oyster (cells mL^{-1}),

C1 = the density of algae at the inflow, and

C2 = the density of algae at the outflow of each aquarium.

Due to the large volume and high water flow in aquaria holding multiple broodstock, it was not possible to accurately measure CR per oyster; however, the pattern of feeding behaviour over time was monitored by plotting relative CR. Relative CR was calculated by having the uppermost CR measurement equal 100% and scaling all other measurements accordingly.

The faeces remaining in each aquarium were collected every 3 days to monitor absorption efficiency

(AE), the proportion of available organic material absorbed during digestion. AE was calculated using the equation by Conover (1966):

$$AE (\%) = 100 \times (a - f) / (1 - f), \text{ whereby:}$$

f = the fraction of dry faeces lost on ashing, and

a = the fraction of dry algae lost on ashing.

Energy absorption (EA) ($J h^{-1}$) per aquarium was estimated as the product of the energy content of the food source ($J mg^{-1}$), algal density ($mg L^{-1}$), relative clearance rate ($L h^{-1}$) and absorption efficiency (%) (following Widdows 1985). Relative EA was calculated by having the upper most measurement equal 100% and scaling all other measurements accordingly.

Assessing reproductive condition

The 15 *P. penguin* were dissected at the conclusion of the 40-day study so that their gonad tissue could be preserved within FAAC, a formaldehyde-based fixative solution (formaldehyde 4%, acetic acid 5%, calcium chloride 1.3%). Histological analysis was performed on samples of gonad tissue from each oyster according to the methods described by Milione and Southgate (in press). Small sections of tissue were removed from the concentrated gonads, embedded in wax and thinly sliced to provide cross-sections that could be mounted on glass slides and stained for observation under a high-power compound microscope. Images taken at 100X magnification were used to categorise each oyster's condition into one of the five stages of pearl oyster gonad development described by Tranter (1958): 1) inactive (gametes absent), 2) developing (partially filled follicles), 3) ripe (mature filled follicles), 4) spawning (partially emptied follicles), and 5) spent (empty follicles). To enable comparison with the reproductive condition of oysters from the same population remaining in the wild, histological analysis was also conducted on gonad samples taken from 15 similar sized *P. penguin* (mean SH = 201 mm) collected from the Orpheus Island population 3 days after the experiment was concluded.

Results

Regression analyses ($\alpha = 0.05$) revealed a significant difference in clearance rate (CR) over time ($F = 18.041$, $df = 1, 94$, $p < 0.001$). CR dropped roughly 10% with the first increase in food density and water temperature, before increasing a further 20% and staying relatively stable at food densities greater than 30×10^3 cells mL^{-1} and water temperatures greater than $26.5^\circ C$ (Fig. 2A).

AE decreased significantly with time ($F = 58.586$, $df = 1, 58$, $p < 0.001$) in an approximate linear fashion according to the equation $y = -2.61x + 93.98$ ($R^2 = 0.92$), dropping from 89% on day 4 to 62% on day 37. Despite decreased AE over time, an increase in CR and higher food availability resulted in a significant ($F = 481.119$, $df = 1, 94$, $p < 0.001$) increase in EA ($J h^{-1}$) of over 350% from day 4 to day 37. The most dramatic increase in EA occurred when increasing food density from 20×10^3 cells mL^{-1} to 30×10^3 cells mL^{-1} on day 21 (Fig. 2B).

The gonad condition of oysters ranged from being inactive (gametes absent) to ripe (mature follicles) (Table 1). Three experimental oysters had inactive gonads, indicating that not all animals obtained enough energy to develop gametes; however, of the remaining oysters, all were either in the later stages of gonad development or already ripe. The *P. penguin* collected from the wild at the conclusion of the experiment were also classified as either developing or ripe, although compared with experimental oysters, fewer had reached the ripe stage (Table 1). Example images of histological sections of developing and ripe gonad stages in both sexes are shown in Figure 3.

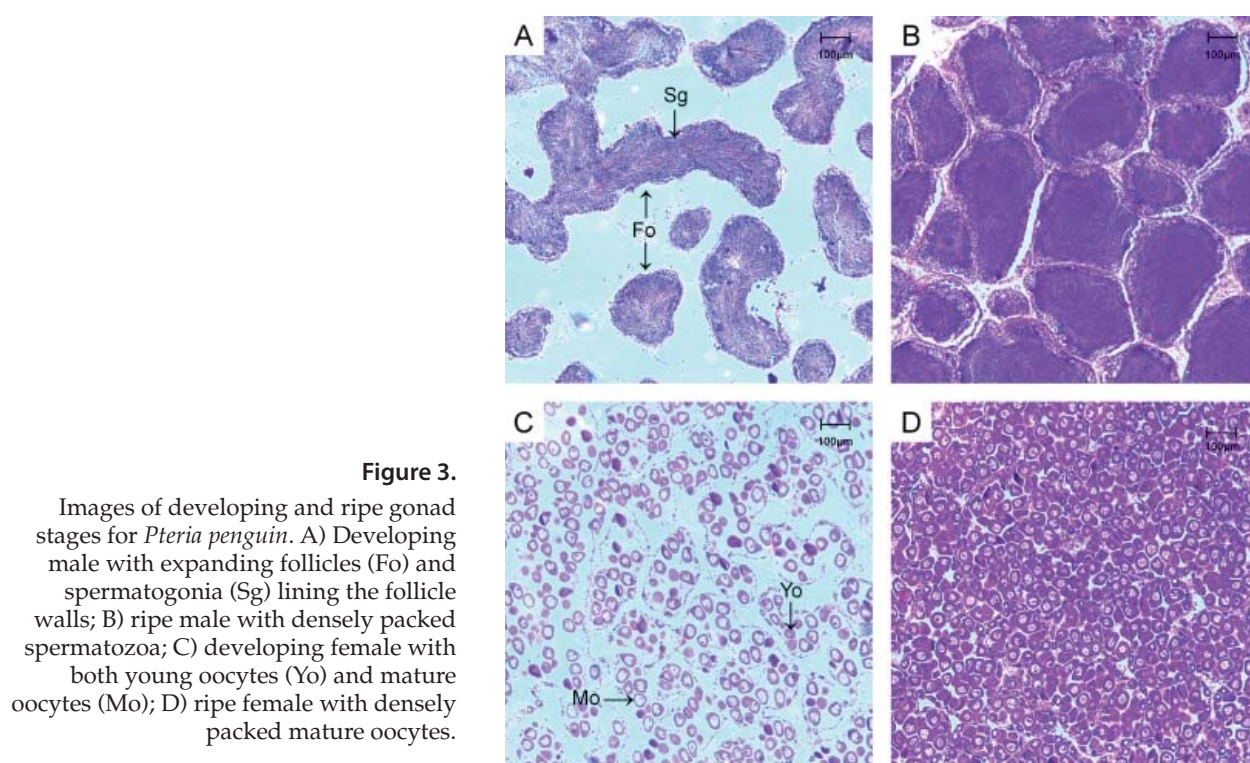
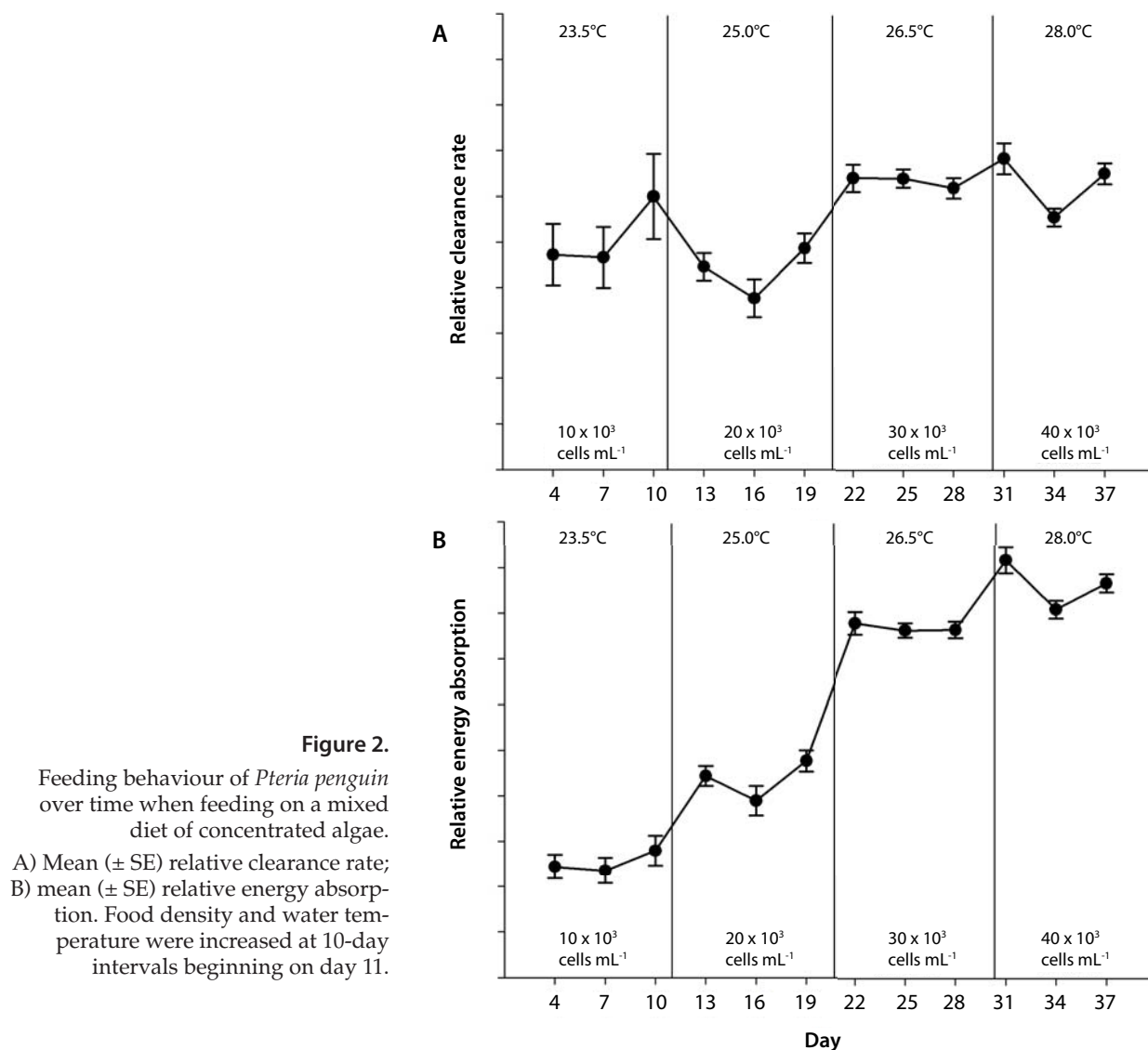
Table 1. Stages in the reproductive cycle of male (M) and female (F) *Pteria penguin* from experimental and wild groups, as determined via histological examination of gonad samples (see Fig. 3).

Group	No.	Inactive	Developing	Ripe	Spawning	Spent
Experimental	15	3	2 (M), 3 (F)	5 (M), 2 (F)	0	0
Wild	15	0	6 (M), 5 (F)	3 (M), 1 (F)	0	0

Discussion

CR escalated when food density exceeded 30×10^3 cells mL^{-1} and water temperature reached $26.5^\circ C$, which is likely to be a response to both variables. The results of Wassnig (2011) showed that *P. penguin* can increase CR in response to elevated food density, a response that has also been reported for other bivalve species and is thought to be a consequence of the ability to detect and capitalise on greater nutrient availability (e.g. Willows 1992). A positive influence of increased water temperature on ingestion is a phenomenon common to pearl oysters (Numaguchi 1994; Yukihiro et al. 2000). Higher water temperatures are assumed to facilitate greater ingestion by improving respiration and, thus, metabolic rate (Kobayashi and Tobata 1949; Lucas 2008).

Oysters did not eject excess food as pseudofaeces at any point during this study, including at the highest



food density of 40×10^3 cells mL^{-1} . This suggests that *P. penguin* has a superior ability to maintain ingestion efficiency at high food densities when compared with pearl oyster species belonging to the genus *Pinctada*, which typically begin producing pseudofaeces at algal densities between 10×10^3 cells mL^{-1} and 30×10^3 cells mL^{-1} (Yukihira et al. 1998b). CR of *P. penguin* stabilised at food densities greater than 30×10^3 cells mL^{-1} and water temperatures greater than 26.5°C . A plateau in feeding behaviour at high food concentrations has been seen previously in other bivalve species and is thought to be a mechanism for avoiding energy wastage associated with the production of pseudofaeces at food concentrations surpassing maximum ingestion capacity (Kobayashi and Tobata 1949; Lucas 2008). The short-term absorption efficiency of microalgae by *P. penguin* decreased with increasing ingestion rate, most probably due to decreased gut retention time and corresponding enzymatic digestion (e.g. Iglesias et al. 1992).

The reproductive condition of oysters after the 40-day study period suggested that male *P. penguin* were able to access the energy required to produce spermatozoa at a rate exceeding that observed in the wild environment over the same time period. The production of mature oocytes in females was less reliable. Milione and Southgate (in press) found that approximately 20% of adult *P. penguin* from the same Orpheus Island population used in this study, possess inactive gonads during the month of August. Therefore, it is possible that the oysters used in this study that were inactive at the end of the study actually entered the aquarium system in that condition. Ripe gametes are typically produced earlier in male than females oysters (Loosanoff and Davis 1952); thus the period of optimal energy absorption provided in this study (10–20 days) may not have been long enough to allow for the reliable production of energetically expensive oocytes. This notion is supported by the results of Saucedo et al. (2001) who found a positive relationship between the proportion of female *Pinctada mazatlanica* producing ripe oocytes and the period of exposure to high densities of microalgae (75×10^3 cells mL^{-1}), with periods of 45–60 days yielding the greatest oocyte production.

This study provides preliminary observations regarding the use of concentrated microalgae to prompt gametogenic activity in *P. penguin*, although more research is required to determine the nutrition and time period required to reliably bring female broodstock to spawning condition. Further research should also be conducted to assess whether the techniques used in this study can be used to extend the annual period of hatchery production by maintaining broodstock in a ripe condition in the months following cessation of the natural spawning season.

Acknowledgements

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Potential use of freshwater clams in Tabasco, Mexico for producing pearls and other products

Pedro E. Saucedo¹

Worldwide, the pearl industry has been sustained — and dominated — by a few species of marine bivalves that belong to the genus *Pinctada*: *P. fucata*, *P. margaritifera* and *P. maxima*, and to a lesser extent, to the genus *Pteria*: *Pteria penguin* and *Pteria sterna* (Haws 2002). This situation has been changing over recent decades since the global pearl industry has diversified and expanded into market segments where other kinds of pearls are experiencing increasing importance (Southgate 2007). This is the case with freshwater pearls, also called rice-type pearls, because they are formed only by a grafted saibo, not a round nucleus. While this kind of pearl was originally cultivated in Japan around 1910 in the Biwa River (and were therefore called “biwa” pearls), China is today its largest producer with 1,000 tonnes in 2007, of which 650 tonnes reached the retail jewellery market (Fiske and Shepherd 2007). Despite this success, quantifying freshwater pearl production in China is difficult, mostly because of the vast extent of the territory and the hundreds of individual pearl farms in certain areas (Fiske and Shepherd 2007). The species of freshwater bivalves initially used for pearl production belong to the family Unionidae, which includes the mussels named “karasu” *Cristaria plicata* (before 1990) and “ikecho” *Hydrobia cumingi* (after 1990), the latter producing pearls of larger sizes (3–10 mm) and a variety of shapes, colors, and luster.

Like China, Mexico has different species of freshwater mussels, which apart from being locally consumed, may be used for producing “mabes” (half-pearls) or “keshies” (baroque pearls lacking a round grafted bead or saibo), as well as other add-on value products obtained from the shell and nacre. In Mexico’s southern State of Tabasco, there are numerous lagoons, lakes, and ponds of many sizes (Fig. 1) that have abundant shellfish populations, according to reports from local fishermen, but all of them are completely underutilized. This regional situation offers a great opportunity for development of aquaculture projects intended to create pilot-scale pearl farms as a model of social and economic development in rural communities, where fishermen and their families can engage in cultivating freshwater bivalves (clams) to obtain employment and economic benefits. Despite this potential, we still lack basic information concerning:

1) the number, location, and character of water bodies that are suitable for a project of this nature; 2) information on the abundance and distribution of each of the freshwater bivalves in these water bodies; 3) biological information on growth rates, reproductive seasonality, quality of the nacre layer, resistance to manipulation (grafting of beads); and 4) other aspects related to commercial production of freshwater pearls. Obtaining this information in the near future has become of great interest for government agencies in the State of Tabasco.

Based on the above, the Ministry of Forest and Fishery Development of the Government of Tabasco (Secretaría de Desarrollo Agropecuario Forestal y Pesca or SEDAFOF), the Fundación Produce Tabasco (FPT, Mexico), and the Centro de Investigaciones Biológicas del Noroeste (CIBNOR) in La Paz, Baja California Sur, Mexico started a project to evaluate the potential use of freshwater clams in Tabasco for producing pearls and add-on value products derived from the shell and nacre. For this purpose, key information was collected from several lagoons and water bodies in the northern, central, and southern area of Tabasco from March through September 2011, including: 1) satellite position and size of the selected water bodies; 2) physical and chemical parameters of the water, such as temperature, salinity, dissolved oxygen, pH, suspended and dissolved particulates, transparency, and average depth; and 3) biological characteristics of the species (shell height, length, and width, total wet weight, distribution, abundance, number of live and dead specimens). We are also evaluating information concerning quality of the nacre layer and resistance to manipulation. So far, we have sampled 23 water bodies and identified 7 species of freshwater bivalves: *Lampsilis tampicoensis*, *Margaritifera auricularia*, *Potamilus* sp. (Unionidae), *Rangia cuneata* (Mactridae), *Polymesoda arcata* (Corbiculidae), *Megapitaria* sp. (Veneridae) and *Ischadium recurvum* (Mytilidae) (Fig. 2). *L. tampicoensis* is present in 50% of the lagoons, *R. cuneata* and *Potamilus* sp. in 42%, *P. arcata* in 33%, *Megapitaria* sp. in 25%, and *M. auricularia* and *I. tampicoensis* in 8%. Regardless of the composition of any of the water bodies, the most abundant species were, in decreasing order, *R. cuneata*, *L. tampicoensis* and *Potamilus* sp.

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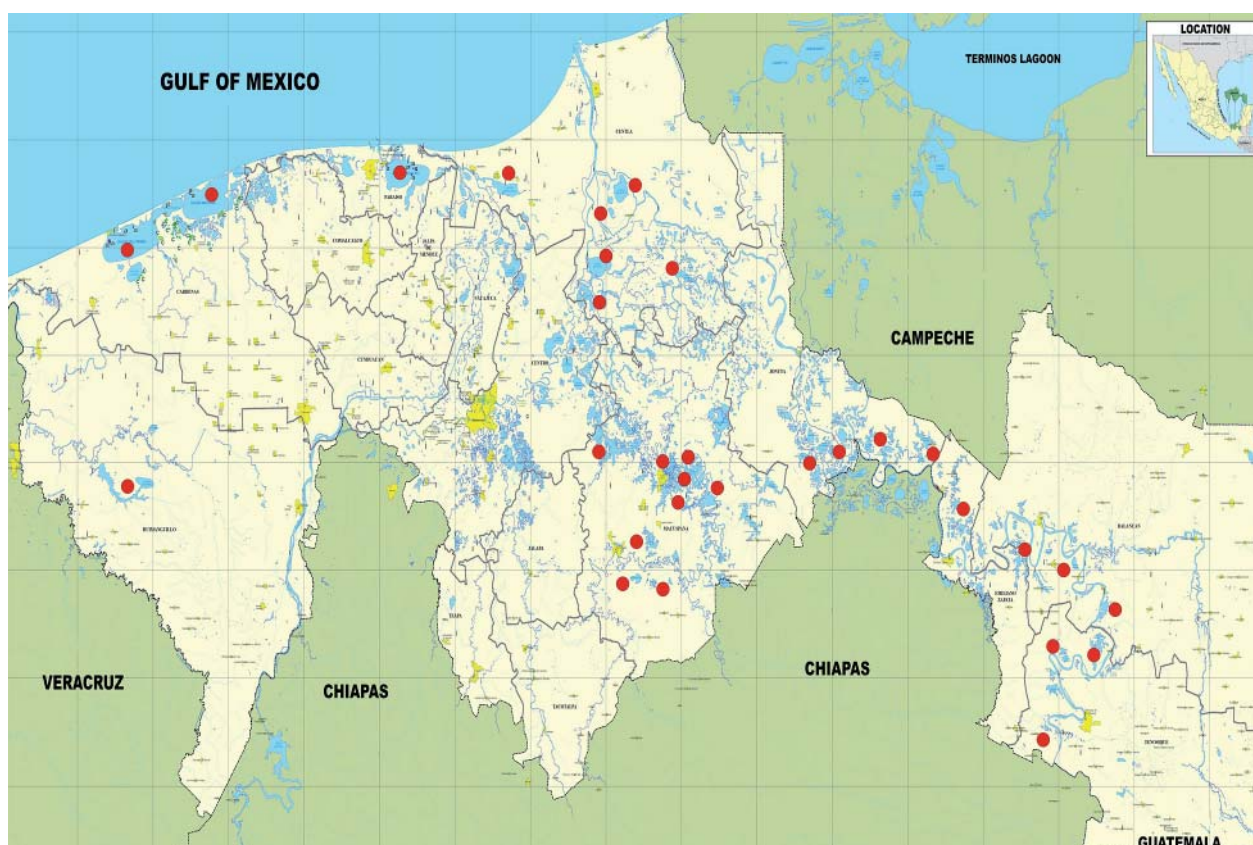


Figure 1. The State of Tabasco in the southeastern part of Mexico and the locations where lagoons and water bodies were sampled for freshwater bivalves (marked with red dots).



Figure 2. Species of freshwater bivalves identified in samples from water bodies in the State of Tabasco, Mexico. (Photo: Manuel Carranza)

A: *Lampsilis tampicoensis*; B: *Rangia cuneata*; C: *Potamilus* sp.; D: *Polymesoda arctata*;

E: *Margaritifera auricularia*; F: *Megapitaria* sp.; G: *Ischadium recurvum*

We are currently deciding which species and localities will support the project during its second phase in 2012. Once analysed with SEDAFOP authorities, workers will be trained in techniques to induce formation of half and keshi pearls, as well as making crafts and add-on value products from the shell and nacre, such as earrings and necklaces. After training the staff, the goal is to transfer these artisanal skills to fishermen and families in some rural communities to create one to three pilot-scale pearl farms that offer livelihood opportunities to the local population. Based on these results, the next objective is to support the project during 2013, but increasing the number of demonstration pearl farms and scaling production from pilot-scale to a pre-commercial level, involving several communities in Tabasco. The final goal is to promote continuous social and economical development based on truly sustainable aquaculture practices.

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Use of 1-propylene phenoxetol and benzocaine to anaesthetise *Pteria penguin* (Röding, 1798) for mabe production

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Abstract

Mortality among *Pteria penguin* can be caused by severe stress during the half-pearl (mabe) implantation procedure. Anaesthetics can play a major role in reducing stress and resulting mortality. Three different concentrations of 1-propylene phenoxetol (2.8 mL L⁻¹, 3.0 mL L⁻¹, 3.2 mL L⁻¹) and two different concentrations of benzocaine (500 mg L⁻¹, 1200 mg L⁻¹) were assessed for their effectiveness as anaesthetics for *P. penguin*. Different concentrations and anaesthetics tested had an influence ($P < 0.05$) on the period required for relaxation of the oysters. However, the recovery time and oyster mortalities at different concentrations were not significantly different ($P > 0.05$). 1-propylene phenoxetol at a concentration of 3.0 mL L⁻¹ was the best of the anaesthetics tested and brought about anaesthesia after an average of 15 minutes with an average recovery time of 12.5 minutes. This treatment also recorded the lowest mortality of the various treatments tested.

Introduction

Pteria penguin is commonly used for the production of half pearls (mabe), which are highly regarded (Tanaka and Yamamoto 1997). The process of mabe production involves adhesion of nuclei to the inner surface of the oyster's shell (Haws et al. 2006; Kripa et al. 2008) and nuclei may vary in shape (e.g. hemispherical, heart, tear drop, oval). The nucleus implantation process is simple compared with the round pearl production process (Haws et al. 2006); however, there are concerns regarding the difficulty of forcefully opening *P. penguin* shells prior to implanting, because the relatively large, non-nacreous shell margin in this species makes it difficult to use shell openers and is easily broken causing stress to the oyster. Stress during nucleus implantation has been reported for other pearl oyster species and it often results in mortality (Norton et al. 1996; O'Connor and Lawler 2002).

Stress and mortality of pearl oysters during the nucleus implanting procedure has prompted studies into the potential for using anaesthetics (relaxants) to reduce stress (Norton et al. 2000; O'Connor and Lawler 2002). Relaxants cause the adductor muscles of pearl oysters to relax, reducing muscularly stimulated haemolymph wastage, preventing muscle contractions, and allowing better access to the implanting site (Norton et al. 1996; O'Connor and Lawler 2002). Several relaxants have been assessed for pearl oysters, to which each species responded differently according to relaxant type and the concentrations used (Mamangkey et al. 2009). Kripa et al. (2008) used menthol crystals and

clove oil on *Pinctada margaritifera*, *Pinctada maxima* (Jameson 1901) and *Pteria penguin*. 1-propylene phenoxetol was used on *Pinctada margaritifera* (Norton et al. 2000), *Pinctada maxima* (Mamangkey et al. 2009), and on *Pinctada imbricata* and *Pinctada albina* by O'Connor and Lawler (2002). MS 222 was used on *Pinctada radiata* by Ehteshami (1995) while benzocaine has been used on *Pinctada maxima* (Mamangkey et al. 2009) and on *Pteria sterna* (Acosta-Salmón and Rangel-Davalos 1997).

Exposing oysters for too long to a relaxant solution can cause mantle retraction, mantle and body collapse and excessive mucus production (Norton et al. 1996; Mamangkey et al. 2009). However, while appropriate relaxants applied at the correct concentration facilitate pearl production in oysters, knowledge of appropriate relaxants and effective concentrations of those relaxants needs to be known in order to obtain favourable results. This paper determined the most appropriate of two commonly used relaxants for *Pteria penguin* at varying concentrations. Relaxants tested were 1-propylene phenoxetol at 2.5 mL L⁻¹, 3.0 mL L⁻¹ and 3.2 mL L⁻¹, and benzocaine at 500 mg L⁻¹ and 1200 mg L⁻¹.

Materials and method

The experiment was carried out at J. Hunter Pearls in Savusavu, Fiji (16°49'S, 179°19'E). *P. penguin* were collected from spat collectors and maintained on a long line until they were three years old and had a mean dorso-ventral measurement (DVM) of 250 ± 6.5 mm. They were scrubbed to remove unwanted fouling organisms before the

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experiment. Six randomly selected oysters were exposed to one of the five treatments tested in 20-L aquaria. Another six oysters were held in ambient seawater as controls.

Each aquarium was filled with 20 L of seawater. The different concentrations of 1-propylene phenoxetol (2.5 mL L⁻¹, 3.0 mL L⁻¹, 3.2 mL L⁻¹) were each vigorously shaken with seawater in a measuring cylinder before being added to aquaria. The solutions in each aquarium were swirled for an even dispersion of relaxants and solutions were brought to the desired concentrations. To prepare a benzocaine solution of 500 mg L⁻¹, 9.75 g of benzocaine was first dissolved in methyl alcohol to a saturation of 250 mg mL⁻¹. The solution was then poured into a small container (0.5 L) of hot (88–92°C) seawater to completely dissolve the benzocaine crystals (Acosta-Salmón and Davis 1997; Acosta-Salmón et al. 2005; Mamangkey et al. 2009). The solution was then poured into a container with 19.5 L of seawater to obtain the desired concentration. The 1,200 mg L⁻¹ solution of benzocaine was prepared by dissolving benzocaine in ethanol first (100 mg L⁻¹) and then mixing the solution with seawater (Acosta-Salmón et al. 2005; Mamangkey et al. 2009).

P. penguin shells were observed to be tightly closed during the first trial with 2.5 mL L⁻¹ of 1-propylene phenoxetol. The relaxants could not enter the shells to contact oyster tissues. This increased the time required for the oysters to relax. To counter this *P. penguin* were placed on their hinges out in the sun for a little while prior to exposure to anaesthetic solutions. This caused the valves to open slightly, and a wooden wedge was inserted in between to prevent the oysters from closing their valves. This method allowed direct contact of the anaesthetic solution with oyster tissues, which resulted in less time taken by oysters to relax. *P. penguin* were placed vertically resting on their hinges and leaned against the sides of aquaria (O'Connor and Lawler 2002).

Seawater temperature was maintained at 25.5°C while pH was maintained between 7.9 and 8.3. *P. penguin* exposed to relaxants were observed for 25 minutes (min). The mantles of the oysters were probed with forceps to determine whether the oysters had relaxed. The oysters were considered to be fully relaxed if there was no reaction by the mantle upon probing (Mamangkey et al. 2009). The time taken for *P. penguin* to fully relax in each of the relaxant solutions was recorded. Relaxed *P. penguin* from each aquarium were then placed in different containers with freshly aerated seawater for recovery. *P. penguin* were considered to have recovered when their mantles reacted or when they closed their shells upon being probed. The time taken for *P. penguin* to recover from each relaxant treatment was recorded.

Some *P. penguin* also experienced mantle and body collapse during the relaxation period. Mantle collapse is when mantle tissues are not rigid enough to adhere to the inner surfaces of the shells, while body collapse is characterised by all soft body parts losing their muscular strength (Acosta-Salmón et al. 2005; Mamangkey et al. 2009). Such oysters were removed from the relaxant solution and placed into containers with clean seawater. Recovered *P. penguin* were returned to farm conditions where they were further observed for seven days to note if there was any mortality.

Kruskal-Wallis analysis was done to determine the difference in time taken for the oysters to relax in each treatment. Pearson's Chi-square test was used to determine the difference between the recovery rates and mortality of the oysters for each of the different concentrated solution (Mamangkey et al. 2009). Both of the analyses were carried out using SPSS Version 13.

Results

All *P. penguin* became fully relaxed in 2.5, 3.0 and 3.2 mL L⁻¹ solutions of 1-propylene phenoxetol within 40 min (Fig. 1). Additionally, oysters exposed to 1,200 mg L⁻¹ of benzocaine were also fully relaxed after the same amount of time (Fig. 2). In contrast, only 12 *P. penguin* were fully relaxed when exposed to 500 mg L⁻¹ of benzocaine within the 40 min time allocation. 1-propylene phenoxetol, at a concentration of 3.0 mL L⁻¹ required an average of 15 min to bring about relaxation in all *P. penguin*. *P. penguin* in this treatment required a mean recovery time of 12.5 min (Fig. 3) and showed the lowest mortality (1 oyster after 7 days) (Fig. 4). *P. penguin* exposed to a 2.5 mL L⁻¹ concentration of 1-propylene phenoxetol required the longest mean time period to be relaxed (26.4 min) and a shortest time to recover (10.7 min) with mortality of 3 oysters after 7 days. 1-propylene phenoxetol, at a concentration of 3.2 mL L⁻¹ recorded the shortest mean time period (10 min) for the oysters to relax; however, this treatment also required the longest recovery time of 14.1 min and recorded the highest mortality (7 oysters) after 7 days. In contrast, oysters exposed to 500 mg L⁻¹ and 1,200 mg L⁻¹ concentrations of benzocaine required mean times of 25.0 min and 16.1 min to relax, respectively (Fig. 3), with average recovery times of 14.2 min and 13.9 min, correspondingly (Fig. 4).

The Kruskal-Wallis (χ) analysis, showed that the different concentrations of 1-propylene phenoxetol ($\chi = 36.55$, $p = 0.00$) and benzocaine ($\chi = 19.40$, $p = 0.00$) had an influence on the time required for *P. penguin* to be fully relaxed. However, the Chi-square analysis showed that the different concentrations of these relaxants did not have significance difference, 1-propylene phenoxetol ($\chi^2 = 0.17$, $p = 1.0$) and benzocaine ($\chi^2 = 0.05$, $p = 1.0$), on the recovery times

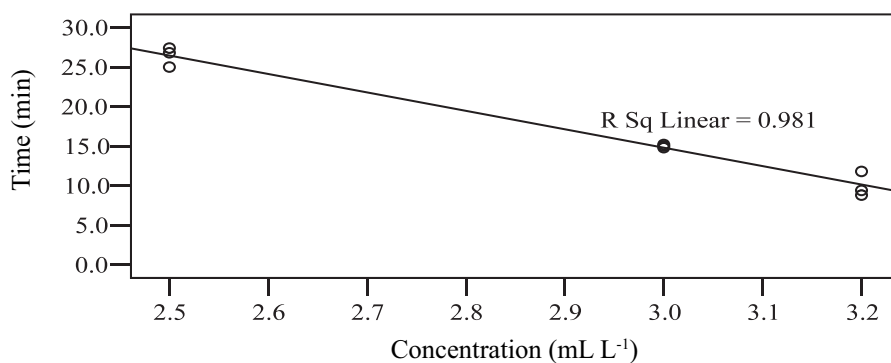


Figure 1. Mean time taken for *P. penguin* to relax at different concentrations in 1-propylene phenoxetol.

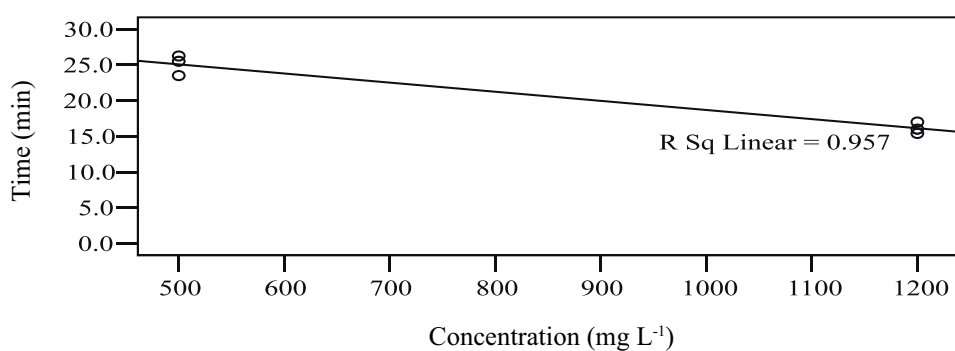


Figure 2. Mean time taken for *P. penguin* to relax at different concentrations of benzocaine.

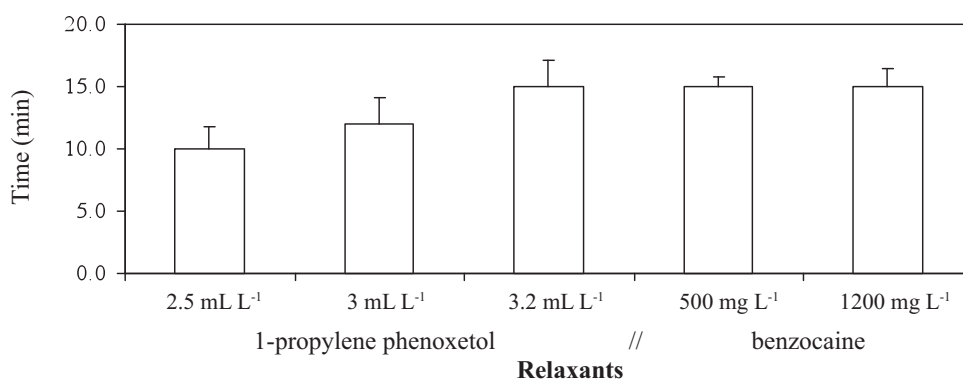


Figure 3. Recovery times of *P. penguin* after being relaxed at different concentrations in both of the relaxants.

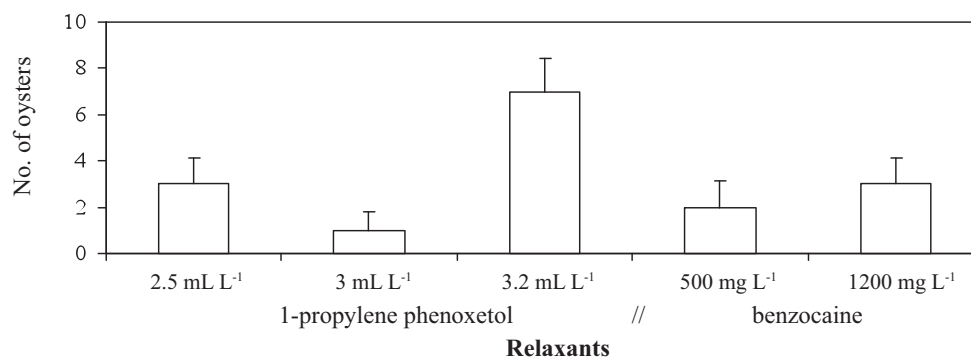


Figure 4. The number of oysters that died at different concentrations in both of the relaxants after 7 days.

required by the oysters. Moreover, the mortality rate of the oysters also did not differ significantly, 1-propylene phenoxetol ($\chi^2 = 0.17$, $p = 0.92$) and benzocaine ($\chi^2 = 0.00$, $p = 1.00$) after 7 days.

Discussion

Numerous methods are used to relax marine invertebrates (Sendall 2003). The effectiveness of the different relaxant on molluscs is species and concentration specific (Aquilina and Roberts 2000; Acosta-Salmón and Davis 2007; Mamangkey et al. 2009). The results presented here show that *P. penguin* responded differently to dissimilar relaxants with varying concentrations. As might be expected, as the concentrations of relaxants increased, the time required by *P. penguin* to relax decreased. A relaxant was considered to be most efficient if it induced relaxation in less than 15 min and had a recovery time of less than 30 min with minimum mortality among the oysters (Norton et al. 1996; Mamangkey et al. 2009). The 3 mL L⁻¹ treatment of 1-propylene phenoxetol proved to be the most appropriate concentration to be used with *P. penguin*. It relaxed the required number of *P. penguin* and had a reasonable and economical recovery time. There was also the least number of mortalities with this treatment.

1-propylene phenoxetol is a commonly used relaxant for molluscs. *P. penguin* required a higher concentration (3.0 mL L⁻¹), of 1-propylene phenoxetol compared to *Pinctada margaritifera* (Norton et al. 1996) and *Pinctada maxima* (Mamangkey et al. 2009), to bring about relaxation; 2.5 mL L⁻¹ provided favourable results for *Pinctada* species. According to O'Connor and Lawler (2002), 2.2 mL L⁻¹ of 1-propylene phenoxetol relaxed *Pinctada imbricata* and *Pinctada albina* within 15 min and the oysters had recovered within 10 min. However, 2.5 mL L⁻¹ of 1-propylene phenoxetol used to relax abalone, *Haliotis iris*, resulted in muscle contraction followed by mortality (Aquilina and Roberts 2000).

In addition, the average time taken for 1,200 mg L⁻¹ of benzocaine to relax *P. penguin* was slightly longer than the time taken to relax *Pinctada maxima* (10.5 min) (Mamangkey et al. 2009), *Pinctada fucata* (10.27 min) and *Pinctada margaritifera* (9 min) (Acosta-Salmón et al. 2005). Despite the slightly extended time required to relax *P. penguin*, the results were rather positive. Few cases of body and/or mantle collapse were noted among *P. penguin* exposed to 1,200 mg L⁻¹ of benzocaine, as reported by Acosta-Salmón et al. (2005) for *Pinctada fucata* and *Pinctada margaritifera*. Body and mantle collapse was mainly noted in the 3.2 mL L⁻¹ concentration of 1-propylene phenoxetol that resulted from the strong concentration of the solution and prolonged exposure of *P. penguin* to the relaxant. Excessive mucus production by *P. penguin*

was also noted in this treatment. *P. penguin* with body and mantle collapse had wider valve openings than normal and took more time to recover, or in most cases, died.

The type of relaxant used should also consider labour cost and preparation period. Preparation of 1-propylene phenoxetol solutions was simpler than that for benzocaine. 1-propylene phenoxetol was readily soluble in seawater while benzocaine required dissolving in methyl alcohol before being heated to 88–92°C to completely dissolve the crystals. Mamangkey et al. (2009) stated that the potential health hazards and toxicity to human users should also be considered when assessing the potential of various relaxants; however, 1-propylene phenoxetol and benzocaine pose very little risk to human health.

This research was performed as a part of a larger research project, which aimed to improve the quality mabe pearls. Mabe pearls are currently considered to be a future alternative livelihood for coastal communities in the region. The procedure and recommended relaxant reported in this paper will be of assistance to people at rural community level concerned with mabe production from *P. penguin*.

Acknowledgement

This project was funded jointly by Australian Centre for International Agricultural Research and University of South Pacific. The financial support by these two organisations is greatly acknowledged. The author is also grateful for the assistance provided by staff of James Cook University, University of the South Pacific, and J. Hunter Pearls.

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New regional research projects

ACIAR PARDI Pearl Project

The Australian Centre for International Agricultural Research (ACIAR) Pacific Agribusiness Research for Development Initiative (PARDI) began in 2010, in support of projects across a number of components, including fisheries. One of the fisheries projects focuses on “Supporting development of the cultured pearl industries in Fiji and Tonga”, and involves collaboration between James Cook University, the University of Adelaide, SPC, University of the South Pacific, pearl farmers, and fisheries departments in Fiji and Tonga.

The project builds on the activities and outcomes of prior ACIAR projects in both countries and has the following major research objectives:

- formulate pearl industry development plans for Fiji and Tonga;
- develop production and business capacity within Fijian and Tongan pearl industries;
- improve product quality, product diversity and value-adding; and
- develop a market structure and conduct an economic baseline review.



The principle behind the PARDI initiative is assessment of the value-chains for major commodities, with a view to identifying researchable issues. The major aim of the ACIAR PARDI Pearl Project is to facilitate pearl industry development in Fiji and Tonga at all levels. This includes increased supply of pearl oysters to pearl farmers, assistance in developing business capacity and business skills, product development (i.e. different types of pearls and pearl shell products for the jewellery and handicraft industries) and market and quality control issues. The project will also address capacity for potential import replacement and for the development of new products with potential for export.

Jamie Whitford of James Cook University was recruited as Senior Project Scientist for the ACIAR PARDI Pearl Project and is based at SPC's Nabua campus in Suva within the SPC Aquaculture Office. He will be responsible for implementing project research initiatives in Fiji and Tonga. Jamie took up his position in May 2011, and a large part of his project activities have included discussions with pearl farmers, industry associations and fisheries personnel in Fiji and Tonga. Stakeholder meetings later in 2011 in Fiji and Tonga will scope out specific research strategies for the project.

Research activities within the ACIAR PARDI Pearl Project will be assisted by the involvement of an Australian Youth Ambassador for Development position in Tonga, and a PhD student, Pranesh Kishore, from Fiji who began his PhD study at James Cook University in 2011 to address factors affecting pearl quality with a view to improving the yield of high quality pearls.

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Fiji pearl farmers
Justin Hunter and Ratu Jone inspect
spat collectors in Savusavu Bay

Hatchery production of black-lip pearl oyster in Tanzania

Since 2003, World Wildlife Fund (WWF) has undertaken research to assess the potential of pearl production as a source of income for coastal communities in Tanzania (see POIB #17, 2006). The project was recently expanded through the European Union's ReCoMaP programme — a regional programme for the sustainable management of coastal zones of Indian Ocean countries. The project includes an assessment of spat collection as a means of supporting industry development in southern Tanzania, and an assessment of hatchery production of black-lip pearl oyster. Two Master's students, working through the University of Dar-es-Salaam, are conducting pearl oyster surveys and spat collection studies, and are generating preliminary growth-rate data. As part of this initiative, a small hatchery was built at Chole Bay on Mafia Island in mid-2010. Initial work in the hatchery showed that ripe broodstock can be obtained during most months of the year at Mafia Island and can be readily induced to spawn. A number of spawnings occurred in 2010, all of which produced larvae; however, initial teething problems with the

hatchery, particularly maintenance of appropriate water temperature during cooler months, resulted in failed attempts to culture larvae through to settlement. Hatchery construction and initial training of hatchery staff in 2010 was overseen by James Cook University Australia, although the first batch of larvae were cultured through to settlement in early 2011, resulting in the first production of hatchery-cultured black-lip oyster spat in Africa. More significantly, the successful hatchery run was conducted by local WWF and fisheries staff overseen by WWF's Mariculture Officer, Ismail Saidi. The simple hatchery lacks micro-algal culture facilities, so larvae were cultured using commercially available microalgal pastes (Instant Algae®, Reed Mariculture Inc.). Resulting spat will be counted, graded and distributed to local pearl farmers in mid-2011.

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WWF Mariculture Officer (and Hatchery Manager/Operator) Ismail Saidi outside the small-scale pearl oyster hatchery built at Chole Bay within the Mafia Island Marine Park in southern Tanzania.



The mining of pearl formation genes in pearl oyster *Pinctada fucata* by cDNA suppression subtractive hybridization

Wang N., Kinoshita S., Nomura N., Riho C., Maeyama K., Nagai K., Watabe S.

Source: Marine Biotechnology (article in press, 2011)

Recent researches revealed the regional preference of biomineralization gene transcription in the pearl oyster *Pinctada fucata*: it transcribed mainly the genes responsible for nacre secretion in mantle pallial, whereas the ones regulating calcite shells expressed in mantle edge. This study took use of this character and constructed the forward and reverse suppression subtractive hybridization (SSH) cDNA libraries. A total of 669 cDNA clones were sequenced and 360 expressed sequence tags (ESTs) greater than 100 bp were generated. Functional annotation associated 95 ESTs with specific functions, and 79 among them were identified from *P. fucata* at the first time. In the forward SSH cDNA library, it recognized mass amount of nacre protein genes, biomineralization genes dominantly expressed in the mantle pallial, calcium-ion-binding genes, and other biomineralization-related genes important for pearl formation. Real-time PCR showed that all the examined genes were distributed in oyster mantle tissues with a consistence to the SSH design. The detection of their RNA transcripts in pearl sac confirmed that the identified genes were certainly involved in pearl formation. Therefore, the data from this work will initiate a new round of pearl formation gene study and shed new insights into molluscan biomineralization.

Growth and gonad development of the tropical black-lip pearl oyster, *Pinctada margaritifera* (L.), in the Gambier archipelago (French Polynesia)

Le Moullac G., Tiapari J., Teissier H., Martinez E., Cochard J.-C.

Source: Aquaculture International (article in press, 2011)

The growth and reproductive cycle of cultured black-lipped pearl oysters, *Pinctada margaritifera* (L.), were studied in the Gambier Islands (134°52' W, 23°07' S) from September 2002 to August 2003. Temperatures were recorded throughout the year, revealing seasonal temperature variations between 22.3 and 27.8°C. The mean annual chlorophyll a value, as computed from satellite data, was $0.188 \pm 0.075 \mu\text{g L}^{-1}$. To study growth and reproduction, 720 two-year-old individuals were ear hung on long-lines suspended at a depth of 7 m. Samples were taken twice a month to obtain the following measurements: shell height; wet weight of flesh and total oyster; dry weight of adductor muscle, mantle and visceral mass; and glycogen content. Gonad development was also studied by histology on parallel samples. Growth was relatively fast during the first 6 months of the study: average shell height increased from 89.1 ± 9.1 to 119.7 ± 10.8 mm and total weight from 93.4 ± 24.5 to 155.1 ± 33.6 g, between September and the end of March. Subsequently, from April to August, no significant growth was observed for shell and flesh, while the muscle weight decreased significantly. Condition index (CI), defined as the ratio of wet weight of the visceral mass to shell weight, and histological changes in the gonad revealed 3 significant reproductive events of different intensities. The analysis of correlations revealed a specific effect of the chlorophyll a concentration on the growth of shell and soma, and one of the temperature on tissue glycogen content. This study also showed also that CI could be an efficient indicator of reproductive events in pearl oyster. It thus appears that the development of gonads goes on throughout the year in the Gambier Islands, without any detectable phase of sexual rest.

In vitro effects of noradrenaline on Akoya pearl oyster (*Pinctada imbricata*) haemocytes

Kuchel R.P., Raftos D.A.

Source: Fish and Shellfish Immunology (article in press, 2011)

Exposure to fluctuating environmental conditions in bivalve molluscs can lead to physiological stress and up-regulated production of stress-associated hormones, such as noradrenaline (NA). Since environmental stressors have been found to have an immunosuppressive effect on *Pinctada imbricata*, we investigated the in vitro effects of NA exposure on their defensive haemocytes, focussing specifically on markers of apoptosis. Terminal dUTP nick-end (TUNEL) labelling was used to detect cells displaying DNA fragmentation within tissue exposed to NA. DNA fragmentation was most significant when haemocytes were exposed to 10.0 ng NA/ μ g protein relative to non-treated controls. Similarly, Annexin V-FITC staining, a marker of early apoptotic events, was evident in cells exposed to 5.0 and 10.0 ng NA/ μ g protein after 120 min ($p < 0.05$), and haemocyte adhesion to glass slides declined significantly when cells were exposed to 10.0 ng NA/ μ g protein ($p < 0.05$). A number of morphological and ultrastructural changes in NA-exposed haemocytes were also identified using transmission and scanning electron microscopy. These alterations included chromatin and cytoplasmic condensation, the formation of apoptotic bodies, vacuolisation and blebbing. In NA-treated cells, polymerisation of F-actin was observed around the periphery of the cytoplasm. All of these data suggest that NA induces apoptosis in *P. imbricata* haemocytes.

Diagnostic genetic markers unravel the interplay between host and donor oyster contribution in cultured pearl formation

McGinty E.L., Zenger K.R., Taylor J.U.U., Evans B.S., Jerry D.R.

Source: Aquaculture 316: 20–24 (2011)

To produce a cultured pearl, a mantle allograft originating from a donor oyster is surgically implanted along with a shell bead nucleus into the gonad of a recipient oyster from the same species (termed the host oyster). Whilst, studies have shown that genomic DNA from a mantle allograft remains present in the pearl sac at the time of pearl harvest, what remains unclear is whether biomineralisation genes from the donor mantle allograft are transcriptionally active and contribute to pearl formation. To help resolve the interplay between host and donor genetic contribution in pearl formation, xenografts were produced, using two *Pinctada* species, *P. maxima* and *P. margaritifera*, to examine which species-specific nacreous genes (N66 and N44) were expressed in the pearl sac. Diagnostic DNA tests revealed that donor oyster cells not only remained present in the pearl sac at the time of pearl harvest, but were found for the first time to be transcriptionally active in the expression of biomineralisation genes, N44 and N66. These results confirm that the donor oyster is an important contributor to the biomineralisation process in pearl culture. Understanding the role the donor and host oyster have in cultured pearl formation provides a solid foundation for elucidating the biological process in general, but it also provides valuable information that can be directly utilised for selective breeding programs in the cultured pearl industry.

Improvement of the production of high-quality pearls by keeping post-operative pearl oysters *Pinctada fucata* in low-salinity seawater

Atsumi T., Ishikawa T., Inoue N., Ishibashi R., Aoki H., Nishikawa H., Kamiya N., Komaru A.

Source: Nippon Suisan Gakkaishi (Japanese Edition), 77(1): 68–74 (2011)

We established a procedure that increased the production of high-quality pearls by keeping post-operative pearl oysters *Pinctada fucata* in low-salinity seawater. Oysters were implanted with a mantle graft and nucleus, and immersed in low (25 psu) or normal salinity (33 psu) seawater in tanks, or suspended from a raft in the sea for 14 days. Then, they were cultured in the sea by the ordinary procedure for several months until pearls were harvested. The harvested pearls were classified as nacreous, prismatic, organic or nucleus. Furthermore, nacreous pearls were classified as high or low quality, based on the proportion of blemishes. From the experiment, oysters immersed in 25 psu seawater showed the highest ratio of high-quality pearls, followed by those in 33 psu seawater. Another practical experiment with ten pearl farmers also showed that the ratio of high-quality pearls was significantly higher in 25 psu seawater than in the sea. These results indicated that the low-salinity treatment of oysters during the post-operative period could be an effective technique to increase the formation of high-quality pearls.

Genetic variation of hatchery and wild stocks of the pearl oyster *Pinctada fucata martensii* (Dunker, 1872), assessed by mitochondrial DNA analysis

Gwak W.S., Nakayama K.

Source: Aquaculture International 19(3):585–591 (2011)

In order to provide baseline information for the genetic resources, genetic variation in wild and cultured *Pinctada fucata martensii* from southern Korea and Japan was studied using nucleotide sequence analysis of 379 base pairs (bp) in the mitochondrial cytochrome oxidase subunit I gene (COI). The study included three hatchery stocks from Korea (Tongyeong) and Japan (Mie and Tsushima) and one wild stock from Korea (Geoje). A total of 3 haplotypes were identified in hatchery stocks of 78 individuals, of which 63 individuals shared 1 haplotype. Overall, nucleotide diversity (π) was low, ranging from 0.000 to 0.002, and haplotype diversity (h) ranged from 0.000 to 0.541. Considerably low haplotype and nucleotide diversities in hatchery stock indicated that low effective population size and consecutive selective breeding of *P. fucata martensii* could be responsible for the reduction in genetic variation. The wild stock exhibited low haplotype diversity (0.507 ± 0.039) with two shared haplotypes. The results of the present study with first record of wild pearl oyster in Korea support the possibility that the transplanted pearl oyster for overwintering experiments could have survived in winter. In order to enhance and/or maintain genetic diversity in the hatchery stock, further research should be directed toward genetic monitoring and evaluation of the hatchery and wild pearl oysters.

Proximate and fatty acid composition of the gonads of wild versus hatchery-conditioned *Pinctada margaritifera* broodstock

Ehteshami F, Christianus A., Rameshi H., Harmin S.A., Saad C.R.

Source: Aquaculture Nutrition 17(3): 675–682 (2011)

The composition of protein, carbohydrate, lipid and fatty acids of the gonad of wild female broodstock of black-lip pearl oyster, *Pinctada margaritifera*, was compared with oysters fed on a ternary combination of microalgae in hatchery. Artificial feeding was found to be as good as natural feeding in terms of number and size of released eggs. Lipid, protein and carbohydrate reserves of unfed oysters were found to be insufficient to complete oogenesis. The proportions of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) of the neutral and polar lipids extracted from female gonads were not influenced by variations in the fatty acid composition of the natural food and ternary combination of microalgae in hatchery. T-Iso, *Chaetoceros calcitrans* and *Chaetoceros muelleri* were able to provide sufficient 22:6n-3 (DHA) and 20:5n-3 (EPA), two of the most important essential fatty acids required for gametogenesis. The n-3/n-6 and 22:5n-3/20:4n-3 ratios were consistently higher in the neutral lipids than in the polar lipids. Conversely, the ratio of 20:4n-3/20:5n-3, 22:6n-3/20:5n-3 and PUFA/SFA was higher in the polar lipids.

Application of a bioenergetic growth model to larvae of the pearl oyster *Pinctada margaritifera* L.

Thomas Y., Garen P., Pouvreau S.

Source: Journal of Sea Research (article in press, 2011)

We applied, for the first time, a dynamic energy budget (DEB) growth model to the larval phase in the pearl oyster *Pinctada margaritifera* var. *cumingii* (Linnaeus, 1758) to evaluate the impact of spatio-temporal variation in the atoll lagoon environment on its capacity for development. The specific parameters of the model, which represent ingestion, temperature effect and the relationship between length and biovolume of the larvae, were determined from experiments or taken from the literature. The interpretation of the values of these parameters allowed us to identify the underlying adaptive character trait: *P. margaritifera* larvae have a good capacity to exploit low food concentrations and a narrow range of thermal tolerance restricted to hydrobiological conditions found in the tropical oligotrophic waters of its distribution zone. Growth simulations show a good fit with the observations made on reared larvae under different conditions: fed on either cultured algae or natural plankton, and with growth data from a natural cohort. Finally, a first application of the model to a pearl-culture lagoon reveals the predominant effect of the vertical structure of trophic resources in determining spatial variation in larval growth.

Integrating optical system designed for multimodal analysis of pearls and its mother oyster to distinguish and appraise cultured pearls

Ju M.J., Lee S.J., Kim Y., Shin J.G., Kim D.H., Kim H.Y., Lee D.S., Lee B.H.

Source: Progress in Biomedical Optics and Imaging — Proceedings of SPIE, 7892, art. no. 78920T (2011)

An optical integrating system composed of optical coherence tomography (OCT) and fluorescence spectroscopy (FS) has been designed and utilized to distinguish pearls by determining their mother oysters used in pearl culturing as well as discriminate and evaluate the pearls, nondestructively. By adopting a wavelength division multiplexing (WDM) and a double clad fiber (DCF) coupler, a FS system could be successfully combined with a fiber-based swept source OCT (SSOCT) system. Applying a common-path configuration, furthermore, the integrating system could be implemented in a simple and effective way with highly minimized group velocity dispersion (GVD) and polarization mismatch problems. The internal structure measurement and the fluorescence spectrum measurement, which were previously performed by two independent apparatus, were concurrently made with the proposed system. From the OCT measurement, we could measure the thickness of the nacre layer, observe the fine sub-structure of the nacre, and inspect the nucleus through the nacre of a pearl. With the fluorescence spectrum measurement, we could categorize the pearls by determining their mother oysters.

Quantitative expression of shell matrix protein genes and their correlations with shell traits in the pearl oyster *Pinctada fucata*

Zhang L., He M.

Source: Aquaculture 314:73–79 (2011)

Shell matrix proteins play an important role in the regulation of shell growth and formation in the pearl oyster, *Pinctada fucata*. This study compared the expression levels of seven shell matrix protein genes (aspein, prismaticin-14, n16, n19, nacrein, msi7, and efcbp) in pearl oysters of various sizes [large (L), medium (M), and small (S)] and analyzed the correlations between expression level and shell size. Except for efcbp and msi7, significant correlations were detected between the expression levels of matrix protein genes and shell size: n19 expression displayed a negative correlation ($P < 0.01$) with increasing shell size, whereas expression levels of aspein, prismaticin-14, n16, and nacrein were greater in oysters with larger shell sizes. Furthermore, stronger correlations were found with shell height for genes related to prismatic layer of shell than shell weight; and with shell weight for genes related to nacreous layer of shell, which makes sense because prismatic proteins are considered to contribute to the extension of the shell length; and nacreous proteins are responsible for the shell thickness. These results contribute to a better understanding of the shell growth mechanisms of the pearl oyster.

The effects of exposure to near-future levels of ocean acidification on activity and byssus production of the Akoya pearl oyster, *Pinctada fucata*

Welladsen H.M., Heimann K., Southgate P.C.

Source: Journal of Shellfish Research 30(1): 85–88 (2011)

Human activities since the beginning of the industrial age have greatly increased the amount of carbon dioxide in the atmosphere. Increased levels of atmospheric carbon dioxide have already caused a 0.1-U decline in global ocean pH, and a continuing decline of 0.3–0.5 U is predicted by the end of 2100. Acidification of the oceans has widespread effects on marine organisms, including reduced rates of calcification and interruptions to normal physiological functions. This study used gaseous carbon dioxide to maintain seawater at 2 treatment levels of pH: 7.8 and 7.6. When compared with controls held at pH 8.1–8.2, pearl oysters (*Pinctada fucata*, Gould) held at pH 7.8 and pH 7.6 showed no significant difference in the number of byssal threads produced or total distance traveled. Byssal threads produced by oysters in the pH 7.6 treatment were significantly thinner than those produced by oysters in the control. However, it is postulated that this was a result of the acute stress of transfer to treatment conditions and not a result of physiological stress caused by near-future levels of ocean acidification. The potential for *P. fucata* to adapt to near-future levels of ocean acidification is discussed.

The effects of egg stocking density and antibiotic treatment on survival and development of winged pearl oyster (*Pteria Penguin*, Röding 1798) embryos

Wassnig M., Southgate P.C.

Source: Journal of Shellfish Research 30(1):103–107 (2011)

Pteria penguin is an important commercial bivalve species that is used in the production of half pearls known as mabè. Expansion of this industry in places with low natural spatfall is reliant on hatchery production of juvenile oysters, which begins with the incubation of fertilized eggs. This study addresses the issue of mortality during egg incubation by examining the effects of egg stocking density and the application of antibiotics. A factorial experimental design was implemented combining 3 egg densities (10, 50, and 100/mL) and 3 antibiotic treatments (control, no antibiotic; 5 mg/mL streptomycin-sulfate; 5 mg/mL tetracycline-erythromycin 2.5:2.5 mg/mL). Antibiotics were added to the culture medium as a single dose and fertilized eggs were incubated for an industry standard period of 24 h. Despite a 23% increase in mean survival during incubation, aquaria treated with tetracycline-erythromycin (1:1) yielded an average of only 9% more veliger larvae than control aquaria as a result of interference with development during the transition of trochophore to shelled larvae (D-stage). Application of the antibiotic streptomycin-sulfate improved mean survival by 16% compared with control aquaria, without significantly compromising development. A high egg density of 100/mL did not significantly reduce survival, but resulted in a 5% reduction in normal development to D-stage. The results of this study show that if tank space is limited during egg incubation, utilizing a high stocking density of 100 eggs/mL will provide the greatest number of D-stage larvae. However, if the supply of eggs is limited, we recommend stocking *P. penguin* eggs at a density ≤ 50 /mL and minimizing mortality by treating the culture medium with the antibiotic streptomycin-sulfate.

Evolutionary patterns in pearl oysters of the genus *Pinctada* (Bivalvia: Pteriidae)

Cunha R.L, Blanc F., Bonhomme F., Arnaud-Haond S.

Source: Marine Biotechnology 13(2):181–192 (2011)

Pearl oysters belonging to the genus *Pinctada* (Bivalvia: Pteriidae) are widely distributed between the Indo-Pacific and western Atlantic. The existence of both widely distributed and more restricted species makes this group a suitable model to study diversification patterns and prevailing modes of speciation. Phylogenies of eight out of the 11 currently recognised *Pinctada* species using mitochondrial (cox1) and nuclear (18S rRNA) data yielded two monophyletic groups that correspond to shell size and presence/absence of hinge teeth. Character trace of these morphological characters onto the molecular phylogeny revealed a strong correlation. *Pinctada margaritifera* appears polyphyletic with specimens from Mauritius grouping in a different clade from others of the French Polynesia and Japan. Hence, *P. margaritifera* might represent a species complex, and specimens from Mauritius could represent a different species. Regarding the putative species complex *Pinctada fucata*/*Pinctada martensii*/*Pinctada radiata*/*Pinctada imbricata*, our molecular analyses question the taxonomic validity of the morphological characters used to discriminate *P. fucata* and *P. martensii* that exhibited the lowest genetic divergence and are most likely conspecific as they clustered together. *P. radiata* and *P. imbricata* were recovered as monophyletic. The absence of overlapping distributions between sister lineages and the observed isolation by distance suggests that allopatry is the prevailing speciation mode in *Pinctada*. Bayesian dating analysis indicated a Miocene origin for the genus, which is consistent with the fossil record. The northward movement of the Australian plate throughout the Miocene played an important role in the diversification process within *Pinctada*.

Effects of the toxic dinoflagellate *Heterocapsa circularisquama* on larvae of the pearl oyster *Pinctada fucata martensii* (Dunker, 1873)

Basti L., Go J., Higuchi K., Nagai K., Segawa S.

Source: Journal of Shellfish Research 30(1):177–186 (2011)

The effects of the toxic dinoflagellate *Heterocapsa circularisquama* on the activity rate, development rate, prevalence of damage, and survival rate of trochophore and D-shaped larvae of the pearl oyster *Pinctada fucata martensii* were studied in relation to *H. circularisquama* cell densities and exposure duration. In addition, larvae were regularly processed via scanning electron microscopy to investigate morphological damage. The activity rate of both larval stages was significantly decreased after 3–6 h of exposure to *H. circularisquama* at densities ranging from 100 to 2×10^4 cells/mL. The prevalence of damage was significantly high after 3–6 h of exposure to *H. circularisquama* at densities of 100 to 2×10^4 cells/mL and 5×10^3 to 2×10^4 cells/mL for trochophores

and D-shaped larvae, respectively. Cytoplasmic discharge, mass mucus production, irregular shape, delayed or inhibited mineralization of the shell, mantle protrusion, the appearance of abnormal masses in the velum, and the exfoliation of the larvae cilia coupled with epithelial desquamation were frequently observed. The activity rate of D-larvae transformed from trochophores exposed to *H. circularisquama* for 12–48 h at densities ranging from 10 to 2×10^4 cells/mL was significantly reduced. The survival of D-shaped larvae plummeted to less than 0.013 for densities $\geq 5 \times 10^3$ cells/mL. The results indicate that *H. circularisquama* blooms have detrimental impacts on bivalves at early life stages. Blooms of *H. circularisquama* occurring during the spawning periods will influence the natural recruitment in *P. fucata martensii* and will have profound impacts on its population biology. Therefore, shellfish farms should not be built in coastal areas where *H. circularisquama* occurs, or genitors should be relocated during potential blooming periods.

Seasonal changes in recruitment of *Pteria penguin* in north Queensland, Australia

Milione M., Southgate P.C.

Source: Journal of Shellfish Research 30(1):89–94 (2011)

Spat recruitment of the winged pearl oyster *Pteria penguin*, in relation to season, substrate type, and depth was investigated at Orpheus Island in north Queensland for 27 months, from February 2008 to April 2010. Two substrate types (70% shade cloth and open-weave polypropylene mesh bags) were deployed at 2 depths (4 m and 6 m) and checked every 6 wk for 3 spawning seasons to determine any differences in quantity of spatfall between these factors. No significant difference was found in spat recruitment between substrate types ($P = 0.158$) or depth ($P = 0.349$), although there was a significant seasonal effect on spat recruitment ($P < 0.001$), with a peak in the quantity of spatfall in late summer, from February to March, and no spat collected in the winter to spring (July to October). Maximum settlement of spat was 10.2 spat per mesh bag collector in February 2008. Recruitment was significantly reduced ($P < 0.001$) during the 2010 spawning season as a result of disturbance from severe storms generated by tropical cyclone Olga in late January.

Multimodal analysis of pearls and pearl treatments by using optical coherence tomography and fluorescence spectroscopy

Ju M.J., Lee S.J., Kim Y., Shin J.G., Kim H.Y., Lim, Y., Yasuno Y., Lee B.H.

Source: Optics Express 19(7):6420–6432 (2011)

We present an integrated optical system that consists of optical coherence tomography (OCT) and laser-induced fluorescence (LIF) spectroscopy for multimodal analysis of pearls and pearl treatments. The OCT source and the LIF excitation beams were aligned together to illuminate the same spot of a pearl fixed on the sample stage that was under rotation. As a result, both OCT images and LIF spectra of the pearls were detected at the same time and also at the same place. For OCT, a 1310 nm centered swept laser source was used. For LIF, a 405 nm laser diode was used and a lensed multimode fiber was utilized as a fluorescence probe. The tomographic investigation on the internal structure of a pearl allowed us to evaluate and categorize the pearl nondestructively as was previously reported. In addition, the measurements of fluorescence spectrum and its decaying rate helped to determine the species of mother oyster. The proposed multimodal analysis made it possible to classify the pearls and also to disclose the treatments made on the pearls.

Calcein staining of calcified structures in pearl oyster *Pinctada margaritifera* and the effect of food resource level on shell growth

Linard C., Gueguen Y., Moriceau J., Soyez C., Hui B., Raoux A., Cuif J.P., Cochard J.-C., Le Pennec M., Le Moullac G.

Source: Aquaculture 313(1–4):149–155 (2011)

Marine mollusc shell growth has been widely measured using fluorochrome marking. In order to test the efficiency and reliability of calcein staining on *Pinctada margaritifera* shells and pearls, the present study examined two administration methods, different concentrations and several immersion times. Immersion in a 150 mg L^{-1} calcein solution for 12 h to 24 h appeared to be the best method for marking *P. margaritifera* shells. For pearl marking, injection of a 200 mg L^{-1} calcein solution into the pearl pouch was the optimal method. Calcein marking was then used to measure the influence of food resource levels on the shell growth. Groups of 23-month-old *P. margaritifera* were fed at three trophic levels for two months. The two highest food levels tested ($6000 \text{ cell mL}^{-1}$ and $15000 \text{ cell mL}^{-1}$) induced uniform growth between the dorsal and ventral sides of shell, whereas the lowest food level (800 cell mL^{-1}) induced greater growth on the dorsal side. Shell deposits from the ventral side were observed using a scanning electron microscope, revealing that the difference of

the trophic level over two months had modified the thickness of the aragonite tablets formed. These results showed that the trophic level is a major factor conditioning *P. margaritifera* development.

Environmental influences on stock abundance and fishing power in the silver-lipped pearl oyster fishery

Hart A.M., Thomson A.W., Murphy D.

Source: ICES Journal of Marine Science 68(3): 444–453 (2011)

Stock variability, fishing power, and the contributing environmental factors were examined for the Australian silver-lipped pearl oyster, *Pinctada maxima*. The approach was to compare the longer-term time-series of stock abundance derived from catch per unit effort against the shorter-term 0+ spat-settlement index to seek agreement on causal factors. Indices of stock abundance were established with generalized linear models that simultaneously examined the influence of technological and environmental factors, resulting in a predictive model with a 3-year forecast. The advent of global positioning systems caused a 30% increase in fishing power. A negative relationship between abundance and rainfall, and a positive relationship between abundance and temperature, was detected for both spat settlement and fishery abundance. Northerly winds (negative northings) from December to February significantly enhanced settlement, but easterly winds (negative eastings) in the main fishing month of May influenced fishing power positively. After standardizing for the effects of fishing power, a 150% increase in stock abundance of the exploited component of *P. maxima* stocks was detected between 2004 and 2009. A major contributor to this increase was an exceptionally high settlement of spat in 2005, associated with a rare combination of environmental conditions. Once this year class grows beyond the target size classes, abundance is predicted to decrease to the normal levels.

The effects of dietary supplements of polyunsaturated fatty acid on pearl oyster, *Pinctada margaritifera* L., gonad composition and reproductive output

Ehteshami F., Christianus A., Rameshi H., Harmin S.A., Saad C.R.

Source: Aquaculture Research 42(4):613–622 (2011)

Black-lip pearl oyster, *Pinctada margaritifera* broodstock was collected from the wild. Egg production, hatching rate and larval development were compared between oysters induced to spawn within 2 days after collection in the wild (T1), oysters fed a pure microalgae diet during 24 days before spawning (T2) and oysters fed the same microalgal diet in which 10% of the algae were replaced with 2 µm polyunsaturated fatty acid (PUFA)-rich microspheres (T3). Administration of lipid microspheres resulted in larger sized eggs, a higher percentage of D-larvae and larger sized 48-h-old larvae ($P < 0.05$). The total and neutral lipid contents of the gonad increased after oysters were fed with microalgae only or with supplementary diet. The major neutral and polar fractions of saturated fatty acid (SFA) were 16C and 18C fatty acids, and not influenced by the diet ($P > 0.05$). The gonads of oysters fed supplementary PUFA contained more docosahexaenoic acid (DHA) and less monounsaturated fatty acids. Higher level of DHA in gonads of T3 was associated with oogenesis and embryogenesis success. The n-3/n-6 ratio in the neutral lipid fraction provides a good indication of the spawning condition and predicting egg size and hatching rate.

Distribution, abundance and population structure of *Pinctada radiata* (Mollusca: Bivalvia) in southern Tunisian waters (Central Mediterranean)

Derbali A., Jarboui O., Ghorbel M.

Source: Cahiers de Biologie Marine 52(1):23–31 (2011)

The pearl oyster *Pinctada radiata* is an alien species introduced to the Mediterranean Sea and recorded in Tunisia several years ago. However, since its record in the Gulf of Gabes, no studies have been carried out about the spread of this invasive mollusc. Thus, the status of this species is still poorly known and there is a knowledge gap about its distribution and abundance. The present work is a contribution to the knowledge of the pearl oyster distribution and densities in southern Tunisian waters, at depths between 0 and 100 metres. The results showed a scattered distribution pattern of the species according to location and depth ranging between 0 and 145 ind.m². *Pinctada radiata* was encountered from the intertidal zone to 40 m depth, with a highest population densities recorded at depth range of 2–20 m. The total stock was estimated to be 27584.9 ± 11504.5 million individuals. Oyster distribution seems influenced by the substrate type. This high population of pearl oysters was associated with large cover of seagrass *Posidonia oceanica* which provides an excellent substratum for attachment. The littoral zone seems not to be the preferred habitat for the prolifera-

tion of this immigrant species. Oysters' size increased steadily with depth, ranging from a mean of 37.98 ± 0.40 mm SH at 0–1 m to 60.98 ± 0.68 mm SH at 20–100 m depth range. Size structure analysis showed that deep water population was dominated by large individuals reaching 96 mm SH. Findings of this study suggested that *P. radiata* is well proliferate in the Gulf of Gabes.

Can the quality of pearls from the Japanese pearl oyster (*Pinctada fucata*) be explained by the gene expression patterns of the major shell matrix proteins in the pearl sac?

Inoue N., Ishibashi R., Ishikawa T., Atsumi T., Aoki H., Komaru A.

Source: Marine Biotechnology 13(1):48–55 (2011)

For pearl culture, the pearl oyster is forced open and a nucleus is implanted into the gonad with a mantle graft. The outer mantle epithelial cells of the implanted mantle graft elongate and surrounding the nucleus a pearl sac is formed. Shell matrix proteins secreted by the pearl sac play an important role in the regulation of pearl formation. Recently, seven shell matrix proteins were identified from the pearl oyster *Pinctada fucata*. However, there is a paucity of information on the function of these proteins and their gene expression patterns. Our study aims to elucidate the relationship between pearl type, quality, and gene expression patterns of six shell matrix proteins (msi60, n16, nacrein, msi31, prismaticin-14, and aspein) in the pearl sac based on real-time PCR analysis. After culturing for about 2 months, the pearl sac tissues were collected from 22 individuals: 12 with high quality (HP), nine with low quality (LP), and one with organic (ORG) pearl formation. The surface of each of the 12 HP pearls was composed only of a nacreous layer; in contrast, that of the nine LP pearls was composed of nacreous and prismatic layers. The six target gene expressions were detected in all individuals. However, delta threshold cycle (CT) for msi31 was significantly higher in the HP than in the LP individuals (Mann-Whitney's U test, $p = 0.02$). This means that the relative expression level of msi31, which constitutes the framework of the prismatic layer, was higher in the LP than in the HP individuals.

Comparison of expression patterns of shell matrix protein genes in the mantle tissues between high- and low-quality pearl-producing recipients of the pearl oyster, *Pinctada fucata*

Inoue N., Ishibashi R., Ishikawa T., Atsumi T., Aoki H., Komaru A.

Source: Zoological Science 28(1):32–36 (2011)

The production of a cultured pearl is the result of a complex interplay between the donor and recipient oysters. However, there is a paucity of information on the relationship between donor and recipient oyster gene expression patterns and pearl quality. Shell matrix proteins affect not only the formation of the shell, but also that of the pearls. We compared the gene expression patterns of five shell matrix proteins (msi60, nacrein, msi31, prismaticin-14, and aspein) in the mantle edge (ME), which forms the prismatic layer, and the mantle center (MC), which forms the nacreous layer, between high- (HP) and low quality pearl- (LP) producing recipient oysters. After culturing for about two months, ME and MC tissues were collected from nine recipient oysters: four with HP, five with LP. In the ME, the average threshold cycle (CT) for aspein was higher in HP than in LP (t-test, $p = 0.03$). Additionally, in the MC, the average CT for msi60 was lower in HP than in LP ($p = 0.06$). This means the relative expression level of msi60 in the mantle of HP was higher than that of LP, and expression level of aspein in the mantle of HP was lower than that of LP. Pearl quality was closely related to the expression patterns of shell matrix protein genes of recipient oysters.

Macrofauna associated with an introduced oyster, *Pinctada radiata*: Spatial scale implications of community differences

Tlig-Zouari S., Rabaoui L., Cosentino A., Irathni I., Ghrairi H., Hassine O.K.B.

Source: Journal of Sea Research, 65 (1), pp. 161–169 (2011).

The macrozoobenthos associated with the introduced pearl oyster *Pinctada radiata* has been sampled at two different spatial scales of three sectors (order of hundreds of kilometres) and of eight localities (order of tens of kilometres). Moreover, the NW sector was selected to compare three localities with the presence of *P. radiata* (low density) and one locality where it was totally absent. The first design was hierarchical, with random localities nested within sectors; the second one was an asymmetrical factorial design, in which the presence/absence of *Pinctada* and hydrodynamism were considered. Similarity relationships were investigated by means of multivariate clustering, similarity percentage analysis and nm-MDS ordination; the two experimental designs have been tested by permutational MANOVA and analysis of dispersion (PERMDISP). Most of the variability of the associated zoobenthic community appeared to be mainly captured by

local environmental factors; the meso-scale variability was more discriminating than differences at larger spatial scale. Large scale NW-SE biogeographic gradient may also have some effects in the assemblage composition. Although the whole arrangement of samples in the MDS plane showed a clear Bray-Curtis distance between the locality without *Pinctada* and all the remaining sites, pair-wise contrasts were not all significant. The factor “presence/absence” was not significant in this design, whereas the exposure was more indicative of differences in the local assemblage composition. These results may not confirm that the community structure variability is due to the impact of *Pinctada* invasion because the potential and subtle community shift may be masked by the overwhelming influence of just the local environmental gradients. In spite of this, the introduced oyster may play the role of an engineer species at high densities, contributing to the complexity of the benthic habitat and influencing the trophic pattern of its fauna.

Growth and survival of the Atlantic pearl oyster *Pinctada imbricata* (Röding 1798), under suspended culture conditions using hanging ropes and pearl nets

Semidey D., Marquez A., Lodeiros C.

Source: Zootechnia Tropical 28(4): 521–533 (2010)

Growth and survival of juvenile pearl mother *Pinctada imbricata* was evaluated through six months of culture in suspended hanging ropes and pearl nets using a longline in Turpialito Bay, Cariaco Gulf, Venezuela. Pearl oyster seeds 15 mm long were cultured, evaluating survival, shell length, muscle, rest of the body and byssus mass monthly. Variations of salinity, temperature, chlorophyll a, seston, solved oxygen and shell fouling, were determined every two weeks. After six months, the oyster reached dorso-ventral length close to 50 mm. Shell growth pattern was similar for both types of culture, although byssus mass was higher in hanging ropes, while shell length was greater in pearl nets. No significant differences were found in body mass. Survival showed similar patterns in both culture systems, although a decrease in numbers occurred in January for the oysters in pearl nets, associated to the presence of the gastropod *Cymatium* sp. The phytoplanktonic biomass was positively correlated to growth in *P. imbricata*, showing to be an important factor in growth modulation. The results suggest the use of the rope system for the culture of *P. imbricata*.

The molluscan bio-fouling community on the Red Sea pearl oyster beds

Wronski T.

Source: Zoology in the Middle East 51: 67–73 (2010)

In the Red Sea, pearl oyster banks occur most extensively around the Dahlak and the Farasan Islands. Pearl oysters (*Pinctada*, Pteriidae) form extended beds by attaching themselves to hard substrates. Such beds attract a diverse bio-fouling fauna. Most dominant are the molluscs, but little is known about the associated biota of pearl oyster beds, their distributional abundance, and the structure of this community. In this study, the macro-molluscan fauna living on pearl oyster beds in the Red Sea around the Farasan Islands was studied using a quantitative survey of the by-catch left by pearl oyster divers. Bivalvia represented 99.6% of the malaco-fauna on pearl oyster beds around the Farasan Islands, while gastropods and chitons represented only 0.4%. In total, 33 mollusc species were identified (24 bivalves, 7 prosobranch gastropods, one basomatophore gastropod and one chiton), with *Brachidontes variabilis*, a species which is not found on Arabian Gulf pearl oyster beds, the most common bivalve (71% of all molluscs), and *Diodora ruppellii* the most common gastropod (0.12% of all molluscs). The results are discussed and compared with the pearl oyster beds from the Arabian Gulf.

Estimating the heritability for growth-related traits in the pearl oyster, *Pinctada fucata martensii* (Dunker)

Wang H., Du X., Lü W., Liu Z.

Source: Aquaculture Research 42(1): 57–64 (2010)

Twelve paternal half-sib families (or 36 full-sib families) of the pearl oyster, *Pinctada fucata martensii* (Dunker), were produced according to the requirements of hierarchical genetic mating design. A total of 4320 individuals, aged 15 months, were measured for seven growth-related traits. Predicated upon the additive-dominance genetic analysis model, varying genetic variance components and then heritabilities of the growth-related traits of interest were estimated using analysis of variance. Results showed that seven growth-related traits had larger additive genetic variances ($P < 0.05$); the dominance genetic variance of shell weight (SW) was smaller ($P > 0.05$), the dominance genetic variances of other six traits were all larger ($P < 0.05$). Narrow- and broad-sense heritabilities for the seven traits were, respectively, 0.64 ± 0.10 and 0.78 ± 0.12 for shell length, 0.49 ± 0.06 and 0.63 ± 0.09 for shell height, 0.38 ± 0.14 and 0.54 ± 0.16 for shell breadth, 0.41 ± 0.17 and 0.56 ± 0.11 for hinge

length, 0.53 ± 0.11 and 0.68 ± 0.08 for body weight, 0.35 ± 0.07 and 0.55 ± 0.08 for tissue weight and 0.67 ± 0.10 and 0.75 ± 0.16 for SW. All heritability estimates were statistically significant ($P < 0.05$). According to these results, the mass selection procedure is suggested for the breeding of *P. martensii*.

Molecular phylogeny of pearl oysters and their relatives (Mollusca, Bivalvia, Pterioidea)

Tëmkin I.

Source: BMC Evolutionary Biology, 10(1), art. no. 342 (2010)

Background: The superfamily Pterioidea is a morphologically and ecologically diverse lineage of epifaunal marine bivalves distributed throughout the tropical and subtropical continental shelf regions. This group includes commercially important pearl culture species and model organisms used for medical studies of biomineralization. Recent morphological treatment of selected pterioideans and molecular phylogenetic analyses of higher-level relationships in Bivalvia have challenged the traditional view that pterioidean families are monophyletic. This issue is examined here in light of molecular data sets composed of DNA sequences for nuclear and mitochondrial loci, and a published character data set of anatomical and shell morphological characters.

Results: The present study is the first comprehensive species-level analysis of the Pterioidea to produce a well-resolved, robust phylogenetic hypothesis for nearly all extant taxa. The data were analyzed for potential biases due to taxon and character sampling, and idiosyncracies of different molecular evolutionary processes. The congruence and contribution of different partitions were quantified, and the sensitivity of clade stability to alignment parameters was explored.

Conclusions: Four primary conclusions were reached: (1) the results strongly supported the monophyly of the Pterioidea; (2) none of the previously defined families (except for the monotypic Pulvinitidae) were monophyletic; (3) the arrangement of the genera was novel and unanticipated, however strongly supported and robust to changes in alignment parameters; and (4) optimizing key morphological characters onto topologies derived from the analysis of molecular data revealed many instances of homoplasy and uncovered synapomorphies for major nodes. Additionally, a complete species-level sampling of the genus *Pinctada* provided further insights into the on-going controversy regarding the taxonomic identity of major pearl culture species.

Histopathology of oedema in pearl oysters *Pinctada maxima*

Jones J.B., Crockford M., Creeper J., Stephens F.

Source: Diseases of Aquatic Organisms 91(1):67–73 (2010)

In October 2006, severe mortalities (80 to 100%) were reported in pearl oyster *Pinctada maxima* production farms from Exmouth Gulf, Western Australia. Only *P. maxima* were affected; other bivalves including black pearl oysters *P. margaritifera* remained healthy. Initial investigations indicated that the mortality was due to an infectious process, although no disease agent has yet been identified. Gross appearance of affected oysters showed mild oedema, retraction of the mantle, weakness and death. Histology revealed no inflammatory response, but we did observe a subtle lesion involving tissue oedema and oedematous separation of epithelial tissues from underlying stroma. Oedema or a watery appearance is commonly reported in published descriptions of diseased molluscs, yet in many cases the terminology has been poorly characterised. The potential causes of oedema are reviewed; however, the question remains as to what might be the cause of oedema in molluscs that are normally iso-osmotic with seawater and have no power of anisomotic extracellular osmotic regulation.

Effects of glycopeptides on development, growth and non-specific immunity of pearl oyster *Pinctada fucata* (Gould)

Zhang S., Long L.J., Zhou Y.C., Yin H., Xiao Z., Chen Y.F.

Source: Aquaculture Nutrition 16(5):520–527 (2010)

The effects of glycopeptides, prepared from pearl oyster *Pinctada fucata*, on embryonic development, larval and juvenile growth and adult non-specific immunity of *P. fucata* were investigated in this study. Glycopeptides had a pronounced stimulatory effect on embryonic development and larval and juvenile growth of *P. fucata*, enhancing with increased glycopeptide concentrations. All of haemocytes, phagocytosis, aggregation, serum microbiostatic activity and bacteriocidal activity all showed significant increase after 60-day feeding, relative to unfed controls. The major conclusion is that glycopeptides had a pronounced stimulatory effect on the non-specific immunity of pearl oysters.

Java's forgotten pearls: The history and disappearance of pearl fishing in the Segara Anakan lagoon, South Java, Indonesia

Schwerdtner Máñez K.

Source: Journal of Historical Geography 36(4):367–376 (2010)

Pearls have been a valued resource in most cultures that had access to them. A number of historically important pearling grounds were situated in the waters around today's Indonesia. One of these areas, now largely forgotten, was the Segara Anakan lagoon in South Java. In the seventeenth century, Dutch colonists exploited the lagoon's pearls. Afterwards, the lagoon's oysters were locally exploited as a food item until the late 1970s. While the pearl fishery attracted considerable attention in the colonial literature, its disappearance, by contrast, went largely undocumented. Nowadays, the oysters no longer are found in the lagoon as a result of extensive sedimentation processes. Their former existence is only preserved in the memory of local people. This article examines the history and fate of the pearls of Segara Anakan, providing an example of a formerly valued species whose existence simply became forgotten outside the area.

Characteristics of biogenic calcite in the prismatic layer of a pearl oyster, *Pinctada fucata*

Okumura T., Suzuki M., Nagasawa H., Kogure T.

Source: Micron 41(7):821–826 (2010)

The fine structure of the calcite prism in the outer layer of a pearl oyster, *Pinctada fucata*, has been investigated using various electron beam techniques, in order to understand its characteristics and growth mechanism including the role of intracrystalline organic substances. As the calcite prismatic layer grows thicker, sinuous boundaries develop to divide the prism into a number of domains. The crystal misorientation between the adjacent domains is several to more than ten degrees. The component of the misorientation is mainly the rotation about the c-axis. There is no continuous organic membrane at the boundaries. Furthermore, the crystal orientation inside the domains changes gradually, as indicated by the electron back-scattered diffraction (EBSD) in a scanning electron microscope (SEM). Transmission electron microscopy (TEM) examination revealed that the domain consists of sub-grains of a few hundred nanometers divided by small-angle grain boundaries, which are probably the origin of the gradual change of the crystal orientation inside the domains. Spherular Fresnel contrasts were often observed at the small-angle grain boundaries, in defocused TEM images. Electron energy-loss spectroscopy (EELS) indicated the spherules are organic macromolecules, suggesting that incorporation of organic macromolecules during the crystal growth forms the sub-grain structure of the calcite prism.

Gene expression patterns in the outer mantle epithelial cells associated with pearl sac formation

Inoue N., Ishibashi R., Ishikawa T., Atsumi T., Aoki H., Komaru A.

Source: Marine Biotechnology 13:474–483 (2011)

For pearl culture, nucleus and mantle grafts are implanted into the gonad of the host oyster. The epithelial cells of the implanted mantle graft elongate and surround the nucleus, and a pearl sac is formed. Shell matrix proteins secreted by the pearl sac play an important role in pearl formation. We studied the gene expression patterns of six shell matrix proteins (msi60, n16, nacrein, msi31, prismalin-14, and aspein) in the epithelial cells associated with pearl sac formation. There were differences in the expression patterns of the six genes in the epithelial cells, and the relative expression levels for msi60 and aspein differed between the mantle graft and pearl sac (48 days after implantation). Therefore, the gene expression patterns of the epithelial cells were genetically undetermined, and changed between before and after pearl sac formation. The gene expression patterns of the epithelial cells of the pearl sac may be regulated by the host oysters.

Utility of shell-closing strength as the indicator of good health in breeding and culture management of Japanese pearl oyster *Pinctada fucata*

Aoki H., Ishikawa T., Fujiwara T., Atsumi T., Nishikawa H., Okamoto C., Komaru A.

Source: Aquaculture 308:S115–S118 (2010)

The aim of this study was to evaluate the suitability of shell-closing strength (SCS), a newly developed trait, as a physiological indicator in the Japanese pearl oyster *Pinctada fucata*. SCS is the load value necessary to open the shell of a pearl oyster to 10 mm using a shell opener. We developed a new instrument for the measurement of SCS consisting of a force gauge and a shell opener, and examined the relationship between SCS and physiological and nutritive indexes in pearl oysters. The results of the experiments showed that (1)

oysters exhibiting good physiological conditions can be selected by using SCS as the indicator; oysters with higher SCS showed lower mortality, higher condition factor, and glycogen content in the adductor muscles than those with lower SCS; (2) SCS varies remarkably among genetic oyster lineages through the culturing period, indicative of the involvement of genetic factors in the determination of SCS; (3) the SCS of pearl oyster tended to increase with the body and the adductor muscle weights, although the protein and glycogen contents of the soft tissue exhibited typical changes during the period in which the water temperature is high (spring to summer). These results suggested that SCS is an efficient indicator of health of pearl oysters, and is useful for breeding and culture management of this species.

Assessing pearl quality using reflectance UV-Vis spectroscopy: Does the same donor produce consistent pearl quality?

Mamangkey N.G.F., Agatonovic S., Southgate P.C.

Source: Marine Drugs 8:2517–2525 (2010)

Two groups of commercial quality (“acceptable”) pearls produced using two donors, and a group of “acceptable” pearls from other donors were analyzed using reflectance UV-Vis spectrophotometry. Three pearls with different colors produced by the same donor showed different absorption spectra. Cream and gold colored pearls showed a wide absorption from 320 to about 460 nm, while there was just slight reflectance around 400 nm by the white pearl with a pink overtone. Cream and gold pearls reached a reflectance peak at 560 to 590 nm, while the white pearl with pink overtone showed slightly wider absorption in this region. Both cream and gold pearls showed an absorption peak after the reflectance peak, at about 700 nm for the cream pearl and 750 nm for the gold pearl. Two other pearls produced by the same donor (white with cream overtone and cream with various overtones) showed similar spectra, which differed in their intensity. One of these pearls had very high lustre and its spectrum showed a much higher percentage reflectance than the second pearl with inferior lustre. This result may indicate that reflectance is a useful quantitative indicator of pearl lustre. The spectra of two white pearls resulting from different donors with the same color nacre (silver) showed a reflectance at 260 nm, followed by absorption at 280 nm and another reflectance peak at 340 nm. After this peak the spectra for these pearls remained flat until a slight absorption peak around 700 nm. Throughout the visible region, all white pearls used in this study showed similar reflectance spectra although there were differences in reflectance intensity. Unlike the spectral results from white pearls, the results from yellow and gold pearls varied according to color saturation of the pearl. The results of this study show that similarities between absorption and reflectance spectra of cultured pearls resulting from the same saibo donor are negligible and could not be detected with UV-Vis spectrophotometry. Nevertheless, this technique could have a role to play in developing less subjective methods of assessing pearl quality and in further studies of the relationships between pearl quality and that of the donor and recipient oysters.

Haemocyte morphology and function in the Akoya pearl oyster, *Pinctada imbricata*

Kuchel R.P., Raftos D.A., Birch D., Vella N.

Source: Journal of Invertebrate Pathology 105(1): 36–48 (2010)

The morphology and cytochemistry of *Pinctada imbricata* haemocytes were studied in vitro. Three distinct blood cell types were identified; hyalinocytes, granulocytes, and serous cells. Haemocytes were classified based on the presence/absence of granules, and nucleus to cytoplasm ratio. Granulocytes were the most common cell type ($62 \pm 2.81\%$), followed by hyalinocytes ($36 \pm 2.35\%$), and serous cells ($2 \pm 0.90\%$). Granulocytes, and hyalinocytes were found to be immunologically active, with the ability to phagocytose Congo red stained yeast. Of the cells involved in phagocytosis, granulocytes were the most active with $88.8 \pm 3.9\%$ of these haemocytes engulfing yeast. Cytochemical stains (phenoloxidase, peroxidase, superoxide, melanin, neutral red) showed that enzymes associated with phagocytic activity were localised in granules within granulocytes. Based on their affinities for Giemsa/May-Grünwald stain, haemocytes were also defined as either acidic, basic or neutral. Hyalinocytes and serous cells were found to be eosinophilic, whilst granulocytes were either basophilic (large granulocytes), eosinophilic (small granulocytes) or a combination of the two (combination granulocytes). Light, differential interference contrast and epi-fluorescence microscopy identified three sub-populations of granulocytes based on size and granularity; small ($4.00\text{--}5.00\text{ }\mu\text{m}$ in diameter, with small granules ($0.05\text{--}0.5\text{ }\mu\text{m}$ in diameter), large ($5.00\text{--}9.00\text{ }\mu\text{m}$ in diameter, with large granules ($0.50\text{--}2.50\text{ }\mu\text{m}$ in diameter) and combination ($5.00\text{--}9.00\text{ }\mu\text{m}$ in diameter, with both large and small granules). These observations demonstrate that *P. imbricata* have a variety of morphologically and functionally specialized haemocytes, many of which may be associated with immunological functions.

Gene expression patterns and pearl formation in the Japanese pearl oyster (*Pinctada fucata*): A comparison of gene expression patterns between the pearl sac and mantle tissues

Inoue N., Ishibashi R., Ishikawa T., Atsumi T., Aoki H., Komaru A.

Source: Aquaculture 308:68–74 (2010)

Shell matrix proteins play an important role in the regulation of shell and pearl formation in the Japanese pearl oyster (*Pinctada fucata*). There is a paucity of information on the function of these proteins and their gene expression patterns. The purpose of this study was to compare the gene expression patterns of six shell matrix proteins (nacrein, msi60, msi31, n16, prismalin-14 and aspein) in the mantle center (MC) (which forms the nacreous layer) and mantle edge (ME) (which forms the prismatic layer), with those in the pearl sac (PS) (which forms the nacreous layer on the pearl surface). There was a significant correlation between the PS and MC ($P < 0.05$) for the six gene expression patterns. In addition, cluster analysis showed that the expression patterns of the six genes were grouped into three clusters (nacreous cluster: msi60 and n16, prismatic cluster: msi31, prismalin-14 and aspein, and nacrein). These results indicate that formation of the nacreous and prismatic layers of the shell and pearl is affected by the gene expression patterns of the shell matrix proteins, and that the two genes of the nacreous cluster (msi60 and n16) and the three genes of the prismatic cluster (msi31, prismalin-14 and aspein) are regulated by unknown factors.

Quantifying sponge erosions in Western Australian pearl oyster shells

Daume S., Fromont J., Parker F., Davidson M., Murphy D., Hart A

Source: Aquaculture Research 41(9):e260–e267 (2010)

This paper describes several methods to estimate the amount of sponge erosion in pearl oyster shells (*Pinctada maxima* Jameson, 1901). Internal erosion can be calculated from non-destructive surface area estimates because a clear relationship was found between the eroded area on the surface of the shells and internal erosions. Grading shells into three different categories, according to the severity of erosion, also proved to be a suitable method to quickly assess the amount of sponge erosions. All methods were more accurate in shells with larger amounts of erosions. Using the described methods, the Lacepedes fishing ground was more diverse in bioeroding sponge species compared with sites at the 80-Mile fishing ground locations. *Pione velans* Hentschel, 1909 was the dominant bioeroding sponge species but *Cliona dissimilis* Ridley and Dendy, 1886 eroded more shell material than *P. velans*. Observed patterns suggest that *P. velans* had a more recent recruitment than *C. dissimilis*. We suggest that visual grading together with estimates from the shell surface will be sufficient to determine the general long-term trends in bioeroding sponge severity. However, results of monitoring programmes need to be supplemented by histological examination to confirm sponge activity and species identity.

Larval settlement and metamorphosis of the pearl oyster *Pinctada fucata* in response to biofilms

Yu X., He W., Li H., Yan Y., Lin C.

Source: Aquaculture 306:334–337 (2010)

Biofilms is an important mediator of larval settlement and metamorphosis for the pearl oyster *Pinctada fucata*, which is an important aquaculture species in South China. However, the role of biofilms in larval settlement and metamorphosis in this species remains unclear. This paper presents the first laboratory study investigating larval settlement and metamorphosis of *P. fucata* in response to natural biofilms of different ages and biofilm-conditioned seawater. Natural biofilms from 1 to 9 day-old except 6 day-old significantly induced larval settlement, while there was no obvious positive correlation between microbial abundance of the biofilms and percentages of larval settlement and metamorphosis. These results indicate that the inductive effect may be closely associated with biofilms community structure and extracellular products in the biofilms rather than microbial abundance. No inductive effects were observed when larvae were exposed to biofilm-conditioned seawater. Thus, the inductive cues from the natural biofilms seem to result from its surface-associated characteristic rather than waterborne. In addition, this study also provides valuable information for studies of mechanism of larval settlement and metamorphosis in this species, which is useful information for the hatchery industry of this pearl oyster.

The consequences of differential family survival rates and equalizing maternal contributions on the effective population size (Ne) of cultured silver-lipped pearl oysters, *Pinctada maxima*

Lind C.E., Evans B.S., Taylor J.J.U., Jerry D.R.

Source: Aquaculture Research 41(8): 1229–1242 (2010)

The effective population size (Ne) is a critical gauge of how efficiently an aquaculture operation is capturing or maintaining genetic diversity and can govern the long-term success of genetic selection programmes. In communally reared pearl oysters (*Pinctada maxima*), high variance in family sizes is a significant contributor towards low Ne and its severity may be compounded by differential survival rates of individual families. To determine the effect of variable survival on Ne in cultured *P. maxima*, families from two commercial populations were analysed using DNA parentage analyses to monitor survival and changes in relative contributions. Significant shifts in relative contributions were observed between 72 days and 18 months of age in both commercial cohorts ($P < 0.001$). Survival rates were found to be highly variable among families (ranging from 2.5% to 49.5%) when reared in a common environment. Additionally, we investigated whether equalizing maternal family sizes before communal rearing will reduce family size variance, and increase Ne, compared with stocking at naturally produced proportions. Family equalization (E) significantly improved Ne ($P = 0.013$) compared with rearing at natural (N) proportions (E: $Ne = 7.18 \pm 0.34$; N: $Ne = 5.60 \pm 0.15$); however, this practice may unintentionally magnify negative influences of poor performing families if survival is correlated with other commercially important traits. It is concluded that highly variable family survival will affect Ne in communally reared *P. maxima*, and the practice of equalizing family sizes in order to maximize Ne may only become consistently beneficial once further progress is made towards understanding, and then reducing variation in family survival rates.

Population and family growth response to different rearing location, heritability estimates and genotype \times environment interaction in the silver-lip pearl oyster (*Pinctada maxima*)

Kvingeda R., Evans B.S., Lind C.E., Taylor J.J.U., Dupont-Nivet M., Jerry D.R.

Source: Aquaculture 304(1–4): (2010)

Genetic parameters and genotype by environment interactions were estimated from the growth responses of silver-lip pearl oyster (*Pinctada maxima*) families originating from three populations (Aru, Bali, West Papua) reared at two Indonesian commercial sites (Bali and Lombok). Microsatellite-based DNA parentage analyses were used to assign oysters to their family and population of origin and four shell growth traits (anterior-posterior measurement (APM), dorsal-ventral measurement (DVM), shell width (SW) and wet weight (WW)) recorded at 14 and 18 months of age. Significant size differences were observed in all shell growth traits between oyster populations, and between oysters cultured at the different locations. Oysters from Bali and West Papua grew faster than those sourced from Aru at both culture sites, whilst the Lombok site produced the fastest growing oysters overall. Significant size differences were also present in shell traits among families, indicating a large amount of genetic variability present for potential breeding programs. Although there were significant familial size differences for shell traits, genetic correlation analyses showed little evidence for re-ranking of family performance among the two culture sites ($rg = 0.89-0.99$), suggesting low genotype by environment deviations among sites. Heritability of the shell traits DVM, APM and WW was moderate (0.15 ± 0.003 (DVM), 0.23 ± 0.030 (APM)) and as a consequence should respond to targeted selection.

Spat collection and experimental culture of the Atlantic pearl oyster, *Pinctada imbricata* (Bivalvia: Pteriidae), under suspended conditions in the Caribbean

Velasco L.A., Barros J.

Source: Journal of the World Aquaculture Society 41(3): 281–297 (2010)

Several suspended culture experiments of the Atlantic pearl oyster, *Pinctada imbricata*, were carried out in the Colombian Caribbean. Seed was collected at two seasons of the year (rainy and dry) using onion bags collectors. Shell growth and survival of the oysters, as well as frequency and size of predators, were evaluated under different stocking densities (10, 20, 30, and 40% coverage of the bottom of the net), culture systems (pearl nets and pocket nets), seasons (rainy and dry), and depths (4 and 9 m). A greater amount of *P. imbricata* spat was collected during the dry season (297 ind./m²) than in the rainy season (72 ind./m²). Density influenced significantly the growth of *P. imbricata* but not its survival. The highest antero-posterior measure (APM) values appeared at lower densities (10 and 20% bottom coverage). Growth and survival values of the pearl oysters were greater in pocket nets than in pearl nets. Culture season did not affect the survival of the oysters but their growth was greater in the dry season than in the rainy season. Culture depth influenced oyster growth but not their survival, with recorded shell APM being greater at 9 m than at 4 m. The follow-

ing predators: Cymatiidae, Portunidae, Majidae, and Xanthidae were found inside the culture nets. Highest mortality values of the pearl oysters coincided with high frequency and/or size of predators. Frequency of cymatids was higher during the rainy season and in pearl nets with high oyster density. Xantids appeared mostly in pocket nets and majids during the dry season.

Evaluation of natural and commercial probiotics for improving growth and survival of the pearl oyster, *Pinctada mazatlanica*, during late hatchery and early field culturing

Aguilar-Macías O.L., Ojeda-Ramírez J.J., Campa-Córdova A.I., Saucedo P.E.

Source: Journal of the World Aquaculture Society 41(3):447–454 (2010)

Survival and growth of pearl oyster, *Pinctada mazatlanica*, juveniles fed microalgae supplemented with natural and commercial probiotics were measured for 21 d at the hatchery. Probiotics tested were (1) a *Lactobacillus* sp., (2) a mix of two bacilli, *Burkholderia cepacia* and *Pseudomonas aeruginosa*, (3) a marine yeast, *Yarrowia lipolytica*, (4) Epicin-hatchery® as commercial probiotic, (5) an antibiotic oxytetracycline, and (6) the control group fed *Isochrysis galbana*, *Pavlova salina*, and *Chaetoceros muelleri* only. When the hatchery phase ended, the effects of probiotics were followed during the early stages of field cultivation (90 d). Different from the control group, natural probiotics significantly improved performance of juveniles during both phases, particularly in the field. The treatment with *Lactobacillus* sp. significantly increased survival by 72%, growth in shell height by 63%, and growth in wet weight by 83% over the control. The marine yeast and mix of bacilli provided intermediate results, enhancing survival by 55–65%, shell height by 55–58%, and wet weight by 70–76% compared with the control. Conversely, growth and survival in the treatments with Epicin and oxytetracycline were significantly lower than in the control. These results show the potential of natural probiotics for improving hatchery rearing of this pearl oyster.

Xenografts and pearl production in two pearl oyster species, *P. maxima* and *P. margaritifera*: Effect on pearl quality and a key to understanding genetic contribution

McGinty E.L., Evans B.S., Taylor J.U.U., Jerry D.R.

Source: Aquaculture 302(3–4):175–181 (2010)

Mantle xenografts between two *Pinctada* pearl oyster species, *P. maxima* (silver-lip pearl oyster) and *P. margaritifera* (black-lip pearl oyster), were used to examine their influence on pearl quality and to further our understanding of the respective contribution host and donor oysters have in pearl formation. Here, host oysters were implanted with mantle tissue originating from either the same species (allograft) or the other species (xenograft) and pearl formation allowed to proceed for 14 months, where after pearls were harvested and nuclei retention and pearl quality traits (nacre deposition/weight, shape, colour, complexion and lustre) recorded. Results showed that xenografts did not significantly affect pearl sac formation and subsequent nuclei retention ($2 = 5.64$, $df = 3$, $P < 0.05$), but did influence pearl colour, complexion, shape, nacre deposition and nacre weight ($P < 0.05$). Nacre deposition and weight were found to be higher in xenografts comprising of a *P. maxima* donor and *P. margaritifera* host, than in the reciprocal xenograft and allografts. Pearl colour and complexion were also strongly influenced by the donor oyster species used as xenografts, with *P. maxima* host oysters implanted with mantle from *P. margaritifera* producing generally black colour based pearls. Conversely, *P. margaritifera* hosts implanted with *P. maxima* mantle produced silver colour based pearls. This study demonstrates the potential of xenografts as a means to improve pearl quality traits such as pearl size, and highlights the role that donor oysters have in the realisation of pearl growth, colour and surface complexion.

Comparative morphometric study of the invasive pearl oyster *Pinctada radiata* along the Tunisian coastline

Tlig-Zouari S., Rabaoui L., Irathni I., Diawara M., Ben Hassine O.K.

Source: Biologia 65(2):294–300 (2010)

In order to study the relative growth of the pearl oyster *Pinctada radiata* in Tunisia, a total of 330 individuals of this species were collected from six sites along the Tunisian coastline. Quantitative measurements of collected oysters were conducted for shell height, shell length, shell width, hinge length, height and width of the nacreous part and wet weight. The size structure of the sampled populations was described and the relative growth between different morphometric characteristics was estimated as allometric growth lines for the six *P. radiata* samples. It appeared that the majority of examined samples were dominated by large individuals that exceed a shell height of 42 mm. The maximum size (100.5 mm), recorded in Bizerta lagoon, is bigger than that recorded elsewhere in particular in the Red Sea. Size distribution analysis also showed that the majority of *P. radiata* samples were dominated by two or more size groups. Differences of allometric regression were found between

the examined samples for the tested relationships. Moreover, the Factorial Discriminant Analysis, coupled with Ascending Hierarchic Classification, classified the sub-populations according to geographic locations.

A histological examination of grafting success in pearl oyster *Pinctada margaritifera* in French Polynesia

Cochennec-Laureau N., Montagnani C., Saulnier D., Fougereuse A., Levy P., Lo C.

Source: Aquatic Living Resources 23(1):131–140 (2010)

Pearl oyster grafting is a complex surgical operation that should lead to pearl formation after approximately eighteen months. Although this technique has been used for many years in French Polynesia, the grafting process is still not standardised. While studies have been carried out in order to improve graft performance and yield, these remain highly variable due to post-grafting mortality, nucleus rejection and unreliable pearl quality, all of which constrain pearl farm profitability. The present study uses histological analysis to monitor oysters that either rejected or retained their nuclei. Both groups of oysters are compared in terms of evolution of the graft, which could influence retention, and the development of a pearl sac in cases where grafting was successful. Data show that rejection phenomena are linked to a number of causes, notably an inflammatory reaction in the “receiving” oyster, the presence of numerous tissue lesions and the quality of the grafted tissue. These results suggest that study is needed on the different concomitant elements of the grafting process: the graft “donor” oysters, the nucleus and the “receiving” oyster and their interactions.

Occurrence of the protozoan parasite, *Perkinsus olseni* in the wild and farmed pearl oyster, *Pinctada fucata* (Gould) from the Southeast coast of India

Sanil N.K., Vijayan K.K., Kripa V., Mohamed K.S.

Source: Aquaculture 299(1–4):8–14 (2010)

The pearl oyster, *Pinctada fucata* (Gould), is a commercially important bivalve distributed in the Gulf of Mannar along the southeast coast of India and had supported a healthy, traditional pearl fishery until the 1950s. But, during the past few decades, the natural pearl oyster beds in the Gulf of Mannar have showed a sharp decline leading to the closure of the traditional pearl fishery and was presumed to be due to over-exploitation and pollution. Except for a preliminary report on *Perkinsus marinus* infection in *Crassostrea madrasensis* in 1988, no incidence of perkinsosis or other Office International des Epizooties (OIE) notified protozoan infections in mollusks has been reported from the Indian subcontinent and the pathogen profile of *P. fucata* from the region has not been studied. Since *Perkinsus* spp. is known to have destroyed many oyster beds worldwide, the present study was taken up to screen the pearl oyster population along the Gulf of Mannar coast for the presence of *Perkinsus* spp. and examine the probable role of *Perkinsus* in the decline of the natural pearl oyster beds. Thirty individuals of adult *P. fucata* were collected from wild populations at three different locations in the Gulf of Mannar and 10 individuals from a pearl farm containing hatchery reared stock at Tuticorin. The tissue samples were subjected to Ray's fluid thioglycollate medium (RFTM) culture, histology and polymerase chain reaction (PCR). All the samples showed enlarged blue-black hyphae in RFTM, indicating the presence of *Perkinsus* spp. *Perkinsus*-like organisms were also observed in the histological preparations. Screening of the tissues using the *Perkinsus* genus specific internal transcribed spacer (ITS) 85 and ITS 750 primers, amplified the product specific to the genus *Perkinsus* (ca. 700 base pairs) and further, the specific identity of the parasite was determined by sequencing the amplified PCR products which showed 99% identity to *Perkinsus olseni*. The pairwise genetic distance values and phylogenetic analysis also confirm that the present isolate from *P. fucata* is a member of the *P. olseni* clade. This preliminary investigation suggests a possibility that perkinsosis could be one of the major reasons for the decline of the *P. fucata* beds in the Gulf of Mannar over a period of time. This forms the first report on the existence of *P. olseni*, an OIE listed pathogen in the wild and cultured *P. fucata* populations from the Indian subcontinent.

A layered structure in the organic envelopes of the prismatic layer of the shell of the pearl oyster *Pinctada margaritifera* (Mollusca, Bivalvia)

Dauphin Y., Brunelle A., Cotte M., Cuif J.P., Farre B., Laprévote O., Meibom A., Salomé M., Williams C.T.

Source: Microscopy and Microanalysis 16(1):91–98 (2010)

The organic interprismatic layers of the mollusc *Pinctada margaritifera* are studied using a variety of highly spatially-resolved techniques to establish their composition and structure. Our results show that both the interlamellar sheets of the nacre and interprismatic envelopes form layered structures. Additionally, these organic layers are neither homogeneous in composition, nor continuous in their structure. Both structures play a major role in the biomineralization process and act as a boundary between mineral units.

Comparative regeneration of excised mantle tissue in one year and seven year old Indian pearl oyster, *Pinctada fucata* (Gould) grown under land-based culture system*Rao G.S., Pattnaik P., Dash B.***Source:** Indian Journal of Fisheries 57(1):39–43 (2010)

Excised mantle tissue (saibo) from the donor oyster is one of the important factors determining quality of cultured pearls. The present study was conducted to compare the process of regeneration of excised mantle tissue in one year and seven year old donor oysters, *Pinctada fucata* grown under land-based culture system. Menthol was used as relaxant prior to excision of mantle tissue, which was found to be effective at a concentration of 500 mg L⁻¹. The mantle tissue was found to regenerate within 3 months post-excision in both one year as well as seven year old *P. fucata*, with 100% survival. On gross examination, the regenerated mantle tissue of the 1 year as well as the 7 year old oysters appeared similar to that of the normal mantle tissue of the control group. Histological analysis demonstrated complete regeneration of the mantle tissue and its associated structures in both the groups. This is the first description of in vivo mantle regeneration in 7 year old pearl oyster, *P. fucata*. The findings revealed that even aged donor oysters yielding good quality saibo can be recovered after mantle excision and could be further used as saibo donors for quality pearl production.

Conference presentations

World Aquaculture Society Annual Conference: World Aquaculture 2011, Natal, Brazil**Breeding for perfection – A journey towards understanding the genetics behind production of gem quality South Sea Pearls***Jerry D.R., Evans B.S., Zenger K., Taylor J., Lind C.E., Kvingedal R., McGinty E., Safari A.*

The production of a cultured pearl is the result of a complex interplay between two pearl oysters, whereby a mantle tissue graft originating from a donor oyster is implanted along with a calcite seed nucleus into the gonad of a second host oyster. The donor tissue degenerates to a single epithelia cell layer which grows around the implanted nucleus to form a pearl sac and subsequently a pearl. Despite pearl aquaculture being worth ~USD 625 million dollars annually, there currently are few genetic improvement programs for pearl oysters. One of the major reasons for the paucity of improvement programs is a lack of understanding of the genetic basis of how a pearl is produced, and in particular whether traits such as pearl colour, lustre, shape and surface complexion are genetically determined and can be improved through selection. Additionally, given the potential role of the two oysters needed to produce a cultured pearl, it is not known if selection needs to be more targeted towards the donor or the host oyster.

In 2005, researchers at James Cook University were approached by a commercial pearling company to help them commence a selective breeding program for *P. maxima*, which produces the much sought after large “South Sea” pearl and we began for the first time to gather information on the genetic basis of pearl formation. In this presentation I will outline the journey we have taken to unravel the complex genetic basis of pearl formation starting from manipulating the phenotype of a pearl, determining the quantitative genetic basis of pearl quality traits, to ultimately sequencing the pearl oyster transcriptome in the search for quantitative trait locus (QTL) linked to quality traits.

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