

This is demonstrated by the data in Table 2 showing that Australian pearls made up approximately 32 percent of total white South Sea pearl production in 2005 but accounted for almost 50 percent of the total value. However, Australia faces increasing competition from other producers who, one would assume, will be seeking to improve pearl quality. The Australian pearl industry is based primarily on adult oysters that are collected from the wild and used directly for pearl production (Wells and Jernakoff, 2006). The proportion of hatchery produced oysters used by the industry is therefore small (approximately 20 percent). Given that hatchery production provides the basis for selective breeding programmes, this strategy may, in the long term, favour other producers of white South Sea pearls, such as Indonesia, that rely on hatchery production.



Pearl farm workers clean nets containing cultured *Pinctada maxima* from a floating pontoon at a farm in West Irian, Indonesia. The nets are suspended from a long-line which is held on the surface using floats.

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Indonesia, Philippines and other countries

The Indonesian cultured pearl industry began in the 1970s when new laws enabled foreign companies to invest in Indonesia. The 1990s brought much-needed modernization of pearl farms resulting primarily from investment by foreign companies, which entered partnerships in Indonesia. The Indonesian Pearl Culturer's Association (ASBUMI) was founded in 1995 to develop marketing strategies. By 1999, Indonesia supplied more than a third of the world's South Sea cultured pearls and by 2005 production had risen to more than 3.7 tonnes (Table 2). There are currently around 107 pearl farms in Indonesia. All commercial pearl production is hatchery-based and the industry is supplied by at least 36 hatcheries.

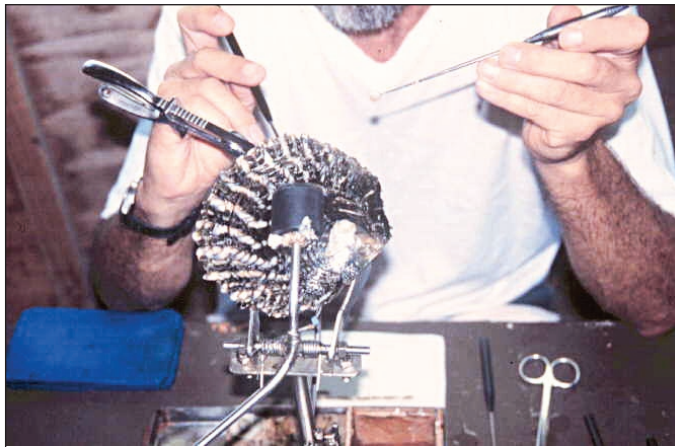
Production of South Sea pearls from around 30 farms in the Philippines has risen from approximately 0.5 tonnes to 2 tonnes a year since 1999. Many of the farms have Japanese partners and much of the crop is exported to Japan. The pearl farms are centered to the north of Palawan Island and the adjoining Calamian group, in Samar and Cebu Island around the southern tip of Palawan and in Mindanao Island. Only wild collected *P. maxima* were used for pearl production until about 1990; however, hatchery-produced oysters have played an increasingly important role since the end of the 1990s.

Other countries producing significant quantities of cultured South Sea pearls from *P. maxima* include Myanmar, Malaysia and Papua New Guinea (Table 2). Small-scale pearl production from *P. maxima* also occurs in Thailand (Bussarawit, 1995), northern Viet Nam and south-western China.

Black-lip pearl oyster, *Pinctada margaritifera*

Pinctada margaritifera has a wide geographical distribution from the Red Sea and east Africa to eastern Polynesia. Despite its vast range, this species is used for commercial cultured pearl production almost exclusively within the atoll lagoons of Polynesia, in French Polynesia and the Cook Islands. It is the second largest pearl oyster species and generally produces cultured pearls in the 9–20 mm size range.

Kokichi Mikimoto established a pearl farm at Ishigaki, Okinawa in 1914 and a second farm in Palau in 1923 from where he succeeded in producing round pearls from *P. margaritifera* (Hisada and Fukuhara, 1999). In 1951, there were nine companies



A technician inserts a nucleus and a piece of mantle tissue from a donor oyster into the gonad of a host oyster (*Pinctada margaritifera*) for cultured pearl production. This process is called "seeding", "grafting" or "nucleation".

COURTESY OF JOHN LUCAS

in Okinawa producing cultured black pearls. Only one of these survived and it reports annual production of approximately 2 000–3 000 pearls annually (Hisada and Fukuhara, 1999). Okinawan pearls provided the basis for market acceptance of cultured black pearls in Japan and, when French Polynesia became the dominant producer of these pearls in the mid-1970s, their product found a ready market.

French Polynesia

The cultured pearl industry in French Polynesia is based on collection of wild pearl oyster spat (juveniles), which are grown to a size suitable for pearl

production (approximately 100 mm). Spat are easily collected by immersing a suitable substrate into lagoon waters when pearl oyster larvae are abundant. The larvae attach to the "spat collectors" and grow into juveniles, which are removed to become culture stock when required. The geomorphology of the atolls of eastern Polynesia, and their limited flushing by oceanic water, support abundant aggregations of pearl oyster larvae and high rates of spat collection. Using natural spat collection, it was easy for island residents to develop their own farms throughout the archipelagos of French Polynesia and there was a rapid increase in the number of authorized leases for pearl farms throughout the 1980s and into the late 1990s. By 2001, the number of pearl farms in French Polynesia had reached more than 2 500.

The first 71 cultured round black pearls were harvested in French Polynesia in 1972 and by 1977 the harvest had risen to 28 000 pearls. The rapid increase in the number of pearl farms during the 1980s and 1990s supported an exponential rise in pearl production, which peaked at approximately 11 tonnes in 2000 with a value of approximately US\$170. However, over-production, declining pearl quality and a flood of lower grade pearls brought prices for black pearls down and market demand declined. Pearl exports from French Polynesia between 2000 and 2005 declined by more than 20 percent and their value declined by approximately 40 percent. Total production in 2005 was in the range of 8–9 tonnes and currently represents approximately 20 percent of total pearl market value (Table 1). Government regulatory measures now maintain a minimum standard for pearls exported from French Polynesia.

Recent years have seen a decline in the number of pearl farms in French Polynesia to 516 in 2006. They vary from small (approximately <5 ha. in area) to large (>40 ha in area). Most farms are situated in the Tuamotu and Gambier archipelagos. Pearl culture is French Polynesia's second largest economic resource after tourism and the first in terms of exports. The industry generates employment for thousands of families spread over 30 islands in French Polynesia and is an essential part of the social and economic life of the country.

Cook Islands

Cook Islanders generated income from the collection and sale of *P. margaritifera* MOP until the early 1970s (Strack, 2006). Round pearl culture from *P. margaritifera*, using the technique developed in French Polynesia, began in 1972 and in 1991 the Cook Islands Pearl Farmer's Association offered 30 000 pearls for sale at its first auction. The industry peaked in 2000 with export revenue of US\$18 million, accounting for

20 percent of the country's gross domestic product. However, poor farming practices, particularly overstocking, meant that the oysters were susceptible to disease. The industry was virtually decimated by a disease outbreak towards the end of 2000 when a rise in water temperature resulting from limited flushing of the Manihiki lagoon, combined with a mass spawning of oysters, triggered a rapid rise in the levels of pathogenic bacteria (Heffernan, 2006). To help ensure the long-term sustainability of the Cook Islands pearl industry and avoid further problems with disease, on-going monitoring of water quality and a greater understanding of the bathymetry and hydrodynamics in Manihiki lagoon have been critical in developing a Pearl Farming Management Plan for Manihiki (Heffernan, 2006).

There were 205 pearl farms in the Cook Islands in 2003 with an estimated 1 million cultured adult oysters. However, as a result of increasing pearl production in French Polynesia, low international pearl prices and the continuing impacts of the year 2000 disease outbreak, pearl export revenue from the Cook Islands declined to about US\$2 million in 2005. Currently, 78 percent of the Cook Islands black pearl farms are within the lagoon of Manihiki Atoll where 90 farms nucleate approximately 900 000 pearl oysters annually to produce approximately 300 000 saleable pearls. The remaining 20 percent of pearl culture occurs on Penrhyn Atoll where pearl culture began in 1994. Pearl production in the Cook Islands amounts to approximately 5 percent of world production of black South Sea cultured pearls.

Other countries

Cultured pearl production from *P. margaritifera* has received considerable research attention in other parts of the Pacific and some has resulted in commercial production. In 2000, a pearl farm was established in the island of Vanua Levu in Fiji. The farm is situated in a deep bay on a high island, and subject to nutrient-rich upwelling – a situation that differs greatly from that of pearl farms in the oligotrophic atoll lagoons of eastern Polynesia. Approximately 80 percent of the farmed oysters are obtained from spat collectors. Local communities are engaged in spat collection, which provides the much-needed income to communities close to the farm. The first auction of “Fiji pearls” in Japan in 2007 offered 30 000 pearls (Anon., 2007).

Cultured round pearls from *P. margaritifera* have been produced from a number of research and pilot projects in other Pacific nations including Solomon Islands, Kiribati and Micronesia (Fassler, 2002; Ito, Jackson and Singeo, 2004; Southgate, 2004). *P. margaritifera* has also been used for trial mabé pearl production in Tanzania in a project to determine the potential of small-scale pearl production to generate income for coastal communities in support of marine conservation efforts (Southgate *et al.*, 2006).

Akoya pearl oyster, *Pinctada fucata*

There is considerable taxonomic confusion about the Akoya pearl oyster which at this stage is probably best considered as an unresolved species complex encompassing *Pinctada fucata*, *P. imbricata*, *P. martensii* and *P. radiata*. Members of this complex have a wide distribution from the Mediterranean Sea, through the Red Sea and Indian Ocean, including the Persian Gulf, into the Pacific Ocean and throughout southeast Asia and northern Australia. It also occurs in the Caribbean Sea.



Cultured “black” pearls produced from *Pinctada margaritifera* in Kiribati, central Pacific. The pearls are held in a *P. margaritifera* shell.

COURTESY OF BEERO TIOTI



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Akoya pearls being sorted in a factory in Guangdong Province, China.

Japan

The technique for culturing round pearls from pearl oysters was developed in Japan using the Akoya pearl oyster. Regular mass production of cultured pearls using this method has occurred in Japan since 1916. By 1926, there were 33 pearl farms in Japan and by 1938, this number had increased to 360, which produced more than 10 million pearls. Harvests of cultured pearls in Japan increased rapidly from the 1950s. In 1952, production was almost 10 tonnes; this increased to 52 tonnes in 1960 and reached a peak of 230 tonnes in 1966 produced from 4 700 farms (Strack, 2006).

Pollution of pearl farming sites became an increasing problem and in 1976, only 2 000 pearl farms remained. This number had declined further to approximately 1 000 farms producing about 35 tonnes of pearls by 1977. In the 1980s, production could not meet demand for high quality pearls and large quantities of low quality pearls flooded the market. By this time, there was also strong competition to the Akoya pearl market from China's increasing production of freshwater pearls. Following greater emphasis on larger and better quality pearls in the early 1990s, which saw prices increase, in 1996 an epidemic claimed vast numbers of pearl oysters in Japan and was a catastrophe for the industry. It is estimated that the epidemic caused the loss of approximately 75 percent of the oysters in Japanese pearl farms. By 1999, annual pearl production had declined to < 20 tonnes with a value of approximately US\$130 million, compared to an annual value of US\$550–600 million in the early 1990s. Annual production levels have since remained at about 20–25 tonnes.

Mie Prefecture today produces about 33 percent of the total Akoya pearl harvest in Japan (Strack, 2006), with Ehime and Kochi Prefectures also contributing significantly to the total. Kyushu Island has produced slightly greater volumes of pearls than Mie and Ehime Prefectures since 1996, with about 40 percent of total production coming from Nagasaki Prefecture (Strack, 2006). Constraints affecting Akoya pearl production in Japan include: (1) the impacts of parasites such as *Polydora* spp., boring sponges and trematodes (e.g. Mizumoto, 1975); (2) periodic abnormal blooming of toxic dinoflagellate algae or "red tide" (e.g. Honjo, 1994); (3) seasonal changes in seawater temperature and reduced food availability (e.g. Tomaru *et al.*, 2002); and (4) mass mortalities associated with pollution, over-crowding and viral infection (e.g. Miyazaki *et al.*, 1999). Pearl farm management practices that reduce the risk of mass mortalities of oysters have been recommended to pearl farmers, and genetic programs to breed resistant strains of oysters have been initiated (Uchimura *et al.*, 2005).

China

Marine pearl oyster cultivation began in China in 1961 and pearl production increased rapidly during the 1980s when private farms became established (O'Connor and Wang, 2001). Annual Akoya pearl production was estimated to be greater than 20 tonnes at the start of the new millennium (Wang *et al.*, 2007). The major culture areas are in the southern provinces of Guangxi, Guangdong and Hainan with Guangxi Province producing about 8–9 tonnes of pearls annually. There are over 1 000 pearl farms along the coast of Leizhou in Guangdong Province which, together with farms in

Xuwen, harvest approximately 9-10 tonnes of pearls annually; Akoya pearl production from Hainan Province is less than one tonne (A. Wang, pers. comm., 2007).

China produced 5-6 tonnes of marketable cultured marine pearls in 1993 and this stimulated Japanese investment in Chinese pearl farms and pearl factories. Pearl processing is done either in Japan or in Japanese-supported pearl factories in China. The majority of the higher quality Chinese Akoya pearls are exported to Japan. Additionally, MOP from pearl shells is used in handicrafts and as an ingredient in cosmetics, while oyster meat is sold at local markets.



Pearl farm workers clean and sort nets used for pearl oyster culture on a floating pontoon in Li'an Bay, Hainan Island, China.

India and other countries

India began Akoya pearl culture research at the Central Marine Fisheries Research Institute (CMFRI) at Tuticorin in 1972 and the first experimental round pearl production occurred in 1973. Although a number of farms have been established, particularly along the southeastern coast, commercial pearl farming has not become established on a large scale (Upare, 2001). Akoya pearls from India generally have a diameter of less than 5-6 mm (Mohamed *et al.*, 2006; Kripa *et al.*, 2007).

Halong Bay in the Gulf of Tonking in Viet Nam has been famous for its natural pearls for many centuries (Strack, 2006). Since 1990, more than twenty companies have established Akoya pearl farms in Viet Nam and production exceeded 1 000 kg in 2001.

Akoya pearl culture has also been investigated on the Atlantic coast of South America (Urban, 2000; Lodeiros *et al.*, 2002), in Australia (O'Connor *et al.*, 2003), Korea (Choi and Chang, 2003) and in the Arabian Gulf (Behzadi, Parivak and Roustaian, 1997). However, information on commercial production of cultured pearls from these regions is not yet available.



Young women clean pearl oysters and culture equipment from boats in Li'an Bay, Hainan Island, China.

Winged pearl oysters, *Pteria* spp.

The common name "winged pearl oyster" relates to the elongated hinge of *Pteria* spp. There are numerous species of *Pteria* but only two, *Pteria penguin* and *Pteria sterna*, are used for commercial scale pearl culture. *Pteria penguin* is cultured throughout Southeast Asia, in Australia and in some Pacific island nations (Beer and Southgate, 2000) and *P. sterna* is commercially cultured in the Gulf of California, Mexico (Kiefert *et al.*, 2004; Ruiz-Rubio *et al.*, 2006). *Pteria* spp. are generally used for mabé pearl (also called half pearl or blister pearl) culture and less commonly for round pearl culture. It is generally acknowledged that this is more difficult to achieve with *Pteria* spp. than