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"Pearls '94"
by C. Richard Fassler
Conference Chairman

The scarcity of a gem and the degree of quality control by its producers or processors play major roles in determining its value. Pearls are no exception to this rule. For the past century, the Japanese, similar to De Beers with diamonds, have enjoyed a monopoly on cultured pearls—even on those produced outside of the country, because they were marketed through Kobe or Tokyo. This dominance has benefited the global industry, as both price and product quality have been preserved at high levels. However, in recent years, the situation has changed drastically, resulting in a crisis.

This change has come about because of several significant factors, including the meteoric rise of Chinese freshwater (and now saltwater) pearls; the decline of Japanese production, due to environmental considerations; and the spread of pearl farming to other areas of the world, mainly Southeast Asia and the South Pacific. Like De Beers, Japan now finds itself losing control. Without the traditionally strong Japanese involvement, the crucial question facing the industry is: can product quality and high prices be maintained? Another inportant concern is the endangered status of more than half of the American mussel species which provide nucleus material. A call to address these issues went out to pearl farmers, jewelers, scientists, equipment suppliers and government officials.

The response was most enthusiastic. The State of Hawaii and the Hawaii Jewelers' Association hosted, and the International Pearl Association sponsored, the largest and most diverse assemblage of the world's pearl community ever held. The meeting; from May 14 to 19 at the Sheraton Waikiki Hotel in Honolulu, attracted speakers and technical presentations from Japan, China, French Polynesia, Bahrain, Kuwait, India, Colombia, Canada, the U.S.A., French Polynesia, Australia, the Solomon Islands, Mexico, the Cook Islands, Myanmar, Vietnam, New Caledonia, Bangladesh, the Philippines, France, India, Taiwan, and Iran. Another 20 nations sent delegates. There was a wide range of topics, which included; the future of the American freshwater mussel; starting a pearl farm; pearl culture in India; the pearl resources of Bahrain; conch pearls; and abalone pearls.

Conference participants discussed both obstacles and opportunities. Marketing strategies were presented, and the exposition featured a vast number of pearls of all colors and sizes for sale. The Jewelers' Forum assisted the jeweler in selling more pearls through sessions that included pearl grading, stringing, peeling, design and quality control, and overviews from all major pearl producing countries. Importantly, the meeting provided an in-depth understanding of all aspects of the pearl business, and offered the participant the chance to influence the course of the industry over the next decade.

Pearls '94 was for persons who love pearls, and who wanted to be a part of the history—and future—of this ancient and most treasured jewel.

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INVASION AND IMPACTS OF THE ZEBRA MUSSEL IN THE UNITED STATES. **Steven A. Ahlstedt,** Clean Water Initiative, Tennessee Valley Authority, Norris, Tennessee 37828.

The zebra mussel, *Dreissena polymorpha,* was first discovered in North America in Lake St. Clair, Michigan in 1988. The species is native to Europe and is believed to have been introduced in 1983 or 1984 from transoceanic ships which discharged freshwater ballast containing planktonic larvae or young adults. Since its introduction, zebra mussels have quickly spread throughout the Great Lakes and into interconnected navigable waterways of the St. Lawrence, Hudson, and Mississippi River drainages. To date, zebra mussels are documented as far south as New Orleans, Louisiana.

This small mussel with zebra-like stripes has the potential to become the most serious biofouling pest of any exotic species introduced to North America, and also has the capability of seriously altering the ecology of lakes and streams where it occurs. Zebra mussels are sexually mature by the time they reach 8 to 10 mm shell length and can grow to 50 mm in length. Females are capable of producing as many as 1 million eggs in 2 years. The animal is able to colonize new areas quickly because planktonic larvae (veligers) drift or are carried by water currents great distances before they settle on firm substrates. Another mode of dispersal is attachment on commercial boat tows, barges and recreational boats. The mussels produce byssal threads which enable the animal to attach to a substrate and remain firmly anchored.

Zebra mussels pose serious economic and ecological threats because of the high population densities they have attained in the Great Lakes area. Municipal, industrial and power plant water intakes are especially vulnerable because of the mussels' ability to settle and clog raw water pipelines. Operating budgets for controlling zebra mussels at water-using utilities in the Great Lakes area are costing millions of dollars annually and are projected to reach billions in the next decade. Ecologically, the zebra mussel is a serious threat to native freshwater mussel populations because of the tremendous filtering capacity which strips the water column of food and the smothering effect of colonization on native mussel beds. The pearl industry would also be threatened since it is dependent upon North America commercial mussel species which provide the nuclei for pearl formation. Because native mussels are the preferred substrate for zebra mussel colonization, the damage and losses to the fauna have already begun in the Great Lakes and losses are starting to occur in the rich mussel beds of the Mississippi River drainage. Indirectly, native mussel host-fish species essential for mussel life-cycle/reproduction may also be affected during early life stages from disruption of the food chain by zebra mussels.

THE CURRENT FISHERY, POPULATION DENSITY, AND CULTURE FEASIBILITY OF PEARL OYSTER, *PINCTADA RADIATA*, IN KUWAIT WATERS. **S. M. Almatar, Xucai Xu and S. H. Alhazeem,** Mariculture and Fisheries Department, P.O. Box 1638. Salmiya, Kuwait 22017

The current fishing areas for pearl oyster, *Pinctada radiata* (Leach), in Kuwait waters are distributed between 29°06'N latitude, 48°12'E longitude and 28°33'N latitude, 48°30'E longitude at depths ranging from 10 to 20 m. The fishery was monitored daily from January 1989 to May 1990, twice a week from May to December 1992, and six to ten days per month in 1993. Pearl fishery in Kuwait relies on natural pearls only, with estimated annual worth of about KD 770,000 (US$ 2.5 million), of which approximately KD 330,000 (US$ 1 million) were paid to purchase pearl oysters from divers. The total landings of pearl oysters in 1989, 1992 and 1993 were 313 t, 129 t and 102 t, respectively. Average CPUEs in 1989, 1992, and 1993 were 117.6, 75.0 and 41.9 kg, respectively. There has been no apparent fluctuation in fishing efforts over the past decade.

From a total of 4,414 oysters sampled, 96 were found to bear one or more pearls, i.e., a bearing rate of 2.2%. Oysters with at least two pearls accounted for 17.7% of all oysters bearing pearls. All the pearls collected from the sample were smaller than the commercial size. The mean diameter of pearls in the sample was 1.53 ± 0.88 mm, ranging from 0.5 mm to 2.6 mm. A survey from 5.9×10^6 oysters landed from June 1989 to January 1990 indicated that only 400 large pearls (>4 mm) and 984 small pearls (3–4 mm) were sold in the market. Thus the probability of landing a commercial-sized pearl is one of 4,200.

Eleven major pearl oyster beds, varying in size from a little more than 1 km^2 to several km^2, were scattered in the fishing area. 110 sites were investigated by diving, short dip or grab. 27 of 59 dives observed no oysters. The densities in the remaining diving sites varied significantly from site to site, ranging from 0.3 to 832 pearl oysters per 200 m^2. High densities of pearl oysters were observed at an exploited bed which is located in the industrial area near the south of Mina Abdulla. The abundance and biomass of pearl oysters in the whole survey area was estimated to be 8.3 millions and 391 t, respectively.

The pearly oyster fishery in Kuwait has not been officially regulated, although several recommendations were proposed for the fishery management. The recommendations include: 1) establishment of a limited entry licensing regulation to prevent rapid increase in effort and to provide divers with some official sanction; 2) the number of licenses should be kept at the current level; fishing hours per day should be restricted to the currently working hours of 08:00 to 12:00; 3) a minimum size limit of hinge length of 40 mm was suggested to be established on a trial basis for one year, and it could be increased to 45 mm later.

The technical and economical feasibilities of pearl culture in Kuwait were studied in 1990. The study revealed that Al-hiran area in the south of Kuwait was a suitable site for oyster culture. Pearl farming can rely on wild oysters taken from the oyster beds. An experiment on pearl seeding was carried out during the study. A preliminary cost was estimated to evaluate the pearl culture in Kuwait, and the labor cost seems to be a large part of farm operating budget. A pilot-project study is strongly suggested to determine the technical aspects and also to evaluate the quality and the market price of the products.

INCIDENCE OF PEARLS OF VARIOUS SIZES IN THE PEARL OYSTER OF BAHRAIN. Mohammed Al-Rumaidh, Scientific Research Department, Bahrain Center for Studies & Research, Building 70, Flat 12, Road 30, Manama, State of Bahrain.

A pearl oyster resources survey was carried out in Bahrain waters during 1986 to 1989 to determine the yields of pearls and size ranges in oysters from different beds. A total number of 54,338 pearls were obtained from 1,145,420 oysters collected from 14 different oyster beds. Most of the pearls harvested (94.4%) were very small—less than 3 mm. 38.1% of the pearls were less than 0.9 mm; 37% were 1.0–1.9 mm; and 18.3% were in the 2.0–2.9 mm group. Larger pearls 5.0–8.9 constituted less than 0.4%.

VARIATION IN ABUNDANCE OF BLACKLIP PEARL OYSTER SPAT IN THE SOLOMON ISLANDS. Johann Bell, ICLARM Coastal Aquaculture Centre, P.O. Box 438, Honiara, Solomon Islands.

The Australian Centre for International Agriculture Research (ACIAR) has provided ICLARM's Coastal Aquaculture Centre with funding for two years to assess the feasibility of farming pearl oysters in Solomon Islands.

The project stems from the observation that reasonable quantities of blacklip pearl oysters have been harvested from many areas within the Solomon Islands on a regular basis. In view of the success of the blacklip pearl industry in Tahiti and the Cook Islands, ACIAR, ICLARM, and the Solomon Island Fisheries Division are collaborating to determine whether it is possible to establish blacklip pearl oyster farms in other types of coral reef habitats in the Pacific, e.g. the more open lagoon complexes of the Solomon Islands. The most important question in this regard is, "Are there sufficient wild spat of the blacklip pearl oyster in the Solomon Islands to set up a viable industry?" To answer this question, staff from the Coastal Aquaculture Centre have designed a sampling program to measure spatial and temporal variation in abundance of blacklip spat over a wide area of the Solomon Islands.

Spat of blacklip pearl oysters will be collected from three sites in each of five main areas (i.e., a total of 15 sites). At each site, a longline 100 m in length will be set up. Spat collecting bags will be suspended from the longline every three months and left to soak for six months to allow enough time for the spat to grow to a size where they can be identified easily. Two types of spat collecting material will be used in the spat collecting bags: shadecloth and black plastic sheet.

The five main areas to be sampled are Ngela, South Malaita, Seghe, Munda and Gizo. All these areas provide access to a range of sheltered reef habitats. Selection of the three sites in each area was based on aerial photographs and historical levels of blacklip harvests.

Blacklip spat collected at each site will be grown-out in nearby coastal villages using conventional methods.The hope is that the sampling program will identify areas where villagers can reliably catch and grow enough spat to establish their own farms, or to sell live oysters to an overseas pearl farming company.

GENETICS OF BLACK-LIPPED PEARL OYSTER (*PINCTADA MARGARIFERA*). John A. H. Benzie, Australian Institute of Marine Science, PMB No 3, Townsville MC, 4810, Queensland, Australia.

Genetic data now available from black-lipped pearl oyster stocks from Japan, French Polynesia, Kiribati, the Cook Islands, the Great Barrier Reef (GBR) and Mauritius are reviewed. *P. margaritifera* stocks have high levels of genetic variation within populations and high levels of gene flow between populations widely separated geographically. Early work emphasised the lack of geographic differentiation. However recent surveys of populations from the west and central Pacific have shown significant genetic differences, not only between the Great Barrier Reef and central Pacific populations, but between local populations within island groups. The implications of these findings for restocking and stock transfer are discussed.

POTENTIAL OF PEARL OYSTER CULTURE ON THE COLOMBIAN CARIBBEAN. Francisco J. Borrero. INVEMAR, Instituto de Investigaciones Marinas de Punta de Betín, A.A. 1016, Santa Marta, Colombia.

As part of a preliminary, but comprehensive program to assess the feasibility of culturing several species of bivalve mollusks from the Colombian Caribbean, we have initiated studies on the potential for cultivation of the mother-of-pearl oyster (*Pinctada imbricata*), and the winged pearl oyster (*Pteria colymbus*). We are carrying out five major studies related to elucidating aspects of the biology and ecology of local pearl oyster populations, which are critical to any culture plans: 1) we are surveying the extent and status of natural stocks of pearl oysters, including cartography of bottom types, abundance and oyster size distribution, and density; 2) we are studying the spatial (across bays, and bathymetric) and temporal variation of intensity in spat settlement to artificial collectors made of two different materials, and placed at several depths; 3) we are monitoring temporal changes in abundance of planktonic bivalve larvae, including those of pearl oysters, both at the surface and on deeper waters, with the goal of elucidating possible relationships between changes in environmental conditions and abundance of planktonic larvae, as well as examining the relation between changes in abundance of larvae in the water and of spat on collectors; 4) to elucidate the sexual system of these species, we are studying the relationships between size/age and sex, as well as fecundity of the two pearl oysters, and are monitoring the occurrence of the main spawning seasons; 5) in an effort to identify important seed collection areas, we are studying the local hydrographic patterns, and their relation to major seasonal changes of climate. In addition, we have built a small hatchery for artificial seed production, which will prove useful due to possible variability in spat settlement. These studies will result in a recommendation to the government of Colombia regarding the biological feasibility of pearl oyster cultivation.

GEMMOLOGY OF THE ABALONE AND OTHER GASTROPOD PEARLS. **Grahame Brown,** ALLGEM Services, 14 Allamanda Cres. Albany Creek Q 4053 Australia.

The pearls of commerce—nacreous aragonitic and/or calcitic concretions, of shell-like composition, secreted by specialised mantle epithelial tissues of the molluscan pearl sac—have traditionally been considered to be products of a few species of nacre lined fresh or salt water bivalves that belong to the Pelecypoda class of phylum Mollusca. Commercial pearl-producing bivalves are popularly termed pearl oysters or pearl mussels. In nature, pearls form in these bivalves as either free (whole), or attached (blister) pearls.

Gastropod and much rarer cephalopod pearls are less well known in both commerce and fashion. These quite unique univalve or 'sea snail' pearls are often non-nacreous, with smooth external surfaces either attractively coloured or aesthetically patterned. Both gastropod and cephalopod pearls are also secreted within mantle tissue-derived pearl sacs.

Although gastropods represent about 80 per cent of all living molluscs, pearl-producing species of the class Gastropoda are few—being restricted to those families of marine snails of the subclass Prosobranchia that secrete a calcareous shell. Gastropod pearl-producing molluscs can be further subdivided, on the basis of their evolutionary document, into three orders of genera:

- *Haliotis* (abalone), *Patella* (rainbow limpets), *Trochus* (top shells), *Turbo* (turban shells) . . . belonging to the nacre-secreting primitive order Archaeogastropoda;
- *Littorina* (periwinkle), *Strombus* (conch), *Cassis* (helmet shell) . . . belonging to the non-nacreous order Mesogastropoda; and,
- *Murex* (murex), *Xancus* (sacred chank shell), *Melo* (bailer shell) . . . non-nacreous shells belonging to the highest order, Neogastropoda.

Rare non-nacreous whitish cream pearls have also been reported to have been recovered from one species of caphalopod—the *Nautilus pompilius* or chambered nautilus.

In this presentation, the gemmology of abalone, trochus, conch, and bailer shell pearls will be described and illustrated. Those identifying features and properties, that contribute gem-like desirable attributes of beauty, rarity and durability to these gastropod pearls, will be presented for naturally occurring pearls, as well as pearls cultured in the abalone. In addition, methods used either to value-enhance these pearls, or to imitate them, will also be discussed. Available historical evidence, supporting recovery of extremely rare pearls from limpet, turban, periwinkle, helmet, murex, sacred chank, and nautilus shells will also be presented.

"Since pearly concretions partake of the characteristics of the shell within which they are formed, it follows that practically all species of mollusks whose shells have a well developed nacreous lining yield pearls to a greater or lesser extent. But the number of these species is small." (Kunz and Stevenson 1908).

CONTRIBUTION TO THE KNOWLEDGE OF THE DYNAMICS OF POPULATION OF THE BLACK PEARL OYSTER IN FRENCH POLYNESIA. **Nathalie Cheffort-Lachhar,** O.R.S.T.O.M. Papeete/Brest, P.O. Box 2089, Papeete, Tahiti.

Four atolls with different levels of pearl farming exploitation and geomorphology were investigated. Several dives were made in 1990 to estimate the density and size frequency distribution. A tagging procedure enabled us to estimate the growth and mortality coefficients.

COMMERCIAL HARVEST OF FRESHWATER MUSSELS IN THE UNITED STATES. **Nelson Cohen,** SEA, INC, Shell Exporters of America, PO Box 235, Terre Haute, Indiana 47808-0235.

The shell exporters of America, Inc. is an organization of the major exporters of freshwater shell in America. We have organized to be better able to follow the harvesting of the shell, to help in the preservation of this resource, and to assist the various state and federal agencies in their attempt to manage the freshwater shell and to eradicate the zebra mussel. The exporters banded together in this organization to better manage the resource and to sustain the industry's survival here in the United States, and also to assure our customers overseas that they will have a reliable source of this raw material. This industry in the last 15 years has become a major factor in the economics of many states with commercial fisheries. In many cases, the dollar volume now exceeds the dollar volume of commercial finfishing in these states. For these reasons and for the employment of approximately 10,000 persons in the commercial musseling industry, it is imperative that we develop a proper concept of shell harvesting management with all the agencies concerned. This will assure the ability of the resource to be harvested on a managed and sustained basis, giving employment to those involved, allowing ongoing research for the mussel populations and to maintain our ability to generate dollars for the United States in the international trade market.

EVALUATING PEARL SHELL HABITAT IN TORRES STRAIT AND THE ARAFURA SEA. **Kathy Colgan,** Bureau of Resource Sciences, John Curtin House, P.O. Box E11, Queen Victoria Terrace, ACT 2600, Australia.

Stocks of pearl shells have declined markedly in the Torres Strait and the Arafura Sea. Extensive surveys of historically important pearling beds were carried out in 1989. Environmental factors associated with presence/absence and abundance of pearl shell were monitored and relationships modelled.

QUEEN CONCH PEARLS—A UNIQUELY CARIBBEAN GEM. **R. Leroy Creswell**[1] and **Megan Davis-Hodgkins**[2], [1]Harbor Branch Oceanographic Institution, Inc., 5600 US Highway 1 North, Fort Pierce, FL 34946, and [2]Caribbean Marine Research Center, 805 46th Place E., Vero Beach, Florida 32963.

The queen conch, *Strombus gigas,* is an important fisheries resource and an icon of the Caribbean culture. This large marine gastropod produces a porcelainous pearl that is variable in shape from extremely baroque to very symmetrical, and ranges in color from beige, to yellow or pink; dark pink pearls are the most sought after. Conch pearls are sometimes enhanced by a characteristic called "flame structure," which has been described as having the appearance of watered silk. The deep, rich color of the conch pearl, in conjunction with these "flame structures" makes these unusual gems very attractive.

Unfortunately, the occurence of natural conch pearls is extremely rare—less than one in 10,000. A commercial supplier in the Lesser Antilles recovered only four large (5 to 10 carat), and a few dozen smaller pearls, from over 54,000 conch. In addition, only about 10% of the pearls found can be considered gem quality. But the rarity of conch pearls, and its unique linkage to Caribbean culture has enhanced their mystic. During the late 1800's and early 1990's, conch pearls played an integral role in fashioned jewelry of the Edwardian style, and they are found in the Crown Jewels of England. There has been a dramatic upsurge in interest for conch pearls during the past 10 years. A 17-carat oval conch pearl sold for $12,000 at a Paris auction in 1984, and in 1987, a 6.41-ct fine conch pearl, unmounted, sold at auction for USA $4,400 at Christies, London.

The beauty, rarity and unique marketing niche of queen conch pearls create an attractive opportunity for their cultivation. Preliminary research conducted by the authors indicates that queen conch can be easily anaethetized and the mantle manipulated for making surgical implants. Concretions of shell around implants appear to occur at a rapid rate, consistent with shell development of adult queen conchs. Finally, the benthic feeding strategy of the queen conch is conducive to adding pigments to formulated feeds to control and enhance pearl coloration.

There is a unique opportunity to develop a culture pearl industry in the Caribbean. Wild stocks of conch are plentiful in most locations, they are hardy and relatively easy to maintain, and the conch pearl can have a unique market niche by targetting tourists who wish to take home a symbolic memory of their Caribbean experience.

DEVELOPMENT OF THE PEARL CULTURE INDUSTRY IN INDIA. Daniel S. Dev, Pearl Culture Project, Tamilnadu Fisheries Development Corporation, 95A Kennedy Street, Nagercoil, Tamilnadu, Pin. 629 001, India.

Topic discussed includes: collection of pearl oysters (*Pinctada fucata*) from the wild; production of spats in the hatchery for commercial farming systems; culture of pearl oysters in different ecosystems; operation methods and management; harvest, pearl drilling, processing, and stringing; and marketing practices in India.

COMMERCIAL PRODUCTION OF INDIAN PEARL OYSTER (*PINCTADA FUCATA*) SPATS IN HATCHERY. Daniel S. Dev, Pearl Culture Project, Tamilnadu Fisheries Development Corporation, 95A Kennedy Street, Nagercoil, Tamilnadu, Pin. 629 001, India.

This paper discusses the infrastructural facilities for a commercial pearl oyster (*Pinctada fucata*) hatchery, induced spawning techniques, mass production of micro-algal feed for the larvae, open-mixed culture of algae for spat rearing and nursery rearing in farm implantation.

ON THE INDIAN PEARL OYSTER RESOURCES & CONSERVATION. Daniel S. Dev, Pearl Culture Project, Tamilnadu Fisheries Development Corporation, 95A Kennedy Street, Nagercoil, Tamilnadu, Pin. 629 001, India.

The paper discusses the history of the Indian pearl fishery; the present status of pearl oyster resources of different species and their suitability for pearl production; replenishment and conservation of pearl oyster beds; and ecological factors influencing the oyster beds and oysters.

INFESTATION OF THE PEARL OYSTER BY THE BORING AND FOULING ORGANISMS IN THE PEARL CULTURE FARM AND NATURAL BEDS FROM NORTHERN COAST OF PERSIAN GULF. M. S. Doroudi, Persian Gulf Shellfish Fisheries Research Center, P.O. Box 1416, Bandar-e-Lengeh, Iran.

Infestation of the pearl oysters, *Pinctada margaritifera* and *Pinctada fucata*, by the fouling and boring organisms in the pearl culture farm and natural beds have been studied from January to November 1993. Barnacles, spat of edible oysters and tubiculous polychaete were major fouling organisms in the pearl culture farms. In the natural beds, however, sponges, algaes and ascidians were considered to be the main fouling organisms. The boring sponges, *Cliona vastifica, Cliona margaritifera, Cliona carpenteri* and the boring mussels *Lithophaga hanlyana, Lithophaga malaccana* were the most important boring organisms among studied species, causing considerable damage to the shells. Pearl culture farms indicated more infestation than the natural beds. The pearl oyster, *Pinctada margaritifera* farmed in Kish Island were found to be the most affected. The maximum rate of mortality of the pearl oysters was apparently related to the invasion by predators. The relationship between frequency of cleaning and growth of the pearl oysters also was investigated during this study. The oysters were divided into four groups and cleaned after every 23 + 2, 45 + 2, 90 + 2 and 180 days, respectively. Statistical analysis indicated no significant difference in growth rate between the various experimental groups for a period of 6 months. There is a significant difference, however, in growth rates between the summer and winter seasons.

ABALONE PEARLS: PAST, PRESENT AND FUTURE. Peter V. Fankboner, Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6

Natural abalone pearls have a history which extends to at least 8th century Japan, and the data resulting from recent archeological digs in California suggest that natural abalone pearls may have been used as trade items by aboriginal peoples over 7000 years ago. The first recorded reference to abalone pearls occurs in one of Japan's oldest historical writings, the *Kojiki*, and in the ancient city of Nara, large, bluish, crescent-shaped abalone pearls appear in the crown of the Buddhist Goddess of Mercy (installed in 748 A.D.) located in the Sangatsu-do of the temple Todai-ji.

Tooth or tusk-shapes are a distinctive characteristic of many natural abalone pearls collected within the mollusk's reproductive organs, and this configuration likely reflects the physical limitations imposed by the horn-like tip of the abalone gonad. Other shapes occur in natural abalone pearls including ovoid, spherical and baroque forms. The largest known natural abalone pearl is the "Big Pink," a 470-carat baroque pearl owned by Californian Wesley Rankin. This pearl has been valued in the United States at $4,700,000.

It is evident that the development of natural abalone pearls follows the pattern of natural pearls found in the soft tissues of other Molluska; to wit, the stimulus for pearl formation is linked to the mistaken infection of the abalone's soft parts by a swimming cercaria larva of a parasitic flatworm. The invading worm larva is from a species which has evolved a parasitic relationship with a host of other than the abalone it has infected. When the worm enters the soft parts of the abalone, it is recognized by host tissues as material foreign to the abalone. The abalone's defense systems (mostly undifferentiated cells and amoebocyte blood cells) may react to an invading cercaria by entombing this larval flatworm in concentric layers of nacre. By so doing, a natural abalone pearl is formed. Invasive parasitic worm larvae likely originate from the feces of coastal sea birds. It is suggested that as coastal habitat for migrating sea birds becomes lost to development and other causes, the frequency of cercaria infections of wild abalone will decrease. As a consequence, fewer natural abalone pearls may be available in the future to the market place, and this situation may drive the already high price of natural abalone pearls higher.

Cultured abalone pearls are of far more recent origin. At Roscoff's Laboratory during the late 1890s, the French scientist Louis Boutan successfully cultured spherical pearls in the abalone *Haliotis tuberculata* using a technique (nucleus on the end of a hair or wire) similar to that used by the famous Swedish biologist Carl von Linnaeus during the mid-1700s to produce pearls in freshwater mussels. Bouton went on to successfully culture small blister pearls in abalone, but it was not until the pioneering work of the Japanese scientist Dr. Kan Uno, during mid-1950s, that any remarkable advances were made in the technology of cultured abalone pearls. It was Dr. Uno who realized that in order to precisely position (the site of optimal nacre deposition by the shell mantle) and to stablize a mabe nucleus against dislodgement by the abalone's powerful foot muscle, an opening had to be milled through the abalone shell through which the nucleus could be positioned and cemented in place. In the course of his investigations at the Tateyame Fisheries Station in Japan, Dr. Uno was very successful in his culture experiments on growing semi-spherical pearls in several abalone species including *Haliotis discus*, *Haliotis gigantea* and *Haliotis seiboldii*. Thirty years later, Mr. W. H. Jo of Korea Abalone Pearls began producing keshi (graft-nucleated) free pearls within abalone mantle tissues, and the author, working at the Bamfield Marine Station in British Columbia, developed the biotechnology (now described in 56 patent claims) for commercial production of both blister and free pearls in several abalone species. During 1986–1987, nucleus implants by the author in the pinto abalone *Haliotis kamtschatkana* led to the culture of the first gem quality marine pearls to be produced in North America. Abalone pearls are currently being cultured in Canada, the United States, and Korea. In addition, there is interest and/or research in abalone pearl culture technology occurring in Australia, China, Greece, New Zealand, and South Africa.

The use of hatchery produced abalone versus wild abalone stocks insures consistently higher nacre quality and success rates in producing gem quality cultured abalone pearls. In California alone, there are over 25 permits issued for abalone culture and the largest growers may inventory nearly 1,000,000 adult abalones. Species currently under intensive cultivation in California include the red abalone *Haliotis rufescens* (the largest abalone species in the world), and the green abalone, *Haliotis fulgens*. When transplanted to the cooler coastal waters of British Columbia, Canada, *Haliotis rufescens* still retains a very high rate of growth and the production of high quality nacre; in both Canada and the United States, this abalone has proved to be the species of choice for culture of abalone pearls. Current wholesale prices on grade C to grade AAA cultured mabe (10 mm–14 mm) abalone pearls typically range from $25 to $300 (U.S. dollars).

Whether of natural or cultured origin, abalone pearls express an orient which may include unique multihued tones of silver, orange, pink, green, blue and lavender. Natural abalone pearls of gem quality are very rare, and consequently costly. Abalone are technically difficult to nucleate, and recent mastery in producing gem quality abalone pearls owes its emerging success to unique implantation methods, modern nucleus materials, superb adhesives, flourishing abalone hatchery production and the perseverance of culturists.

PERSPECTIVES AND OPPORTUNITIES OF PEARL OYSTER CULTURE DEVELOPMENT ON THE COAST OF SONORA, GULF OF CALIFORNIA, MEXICO. **Sergio Farell, Douglas McLaurin, and Enrique Arizmendi,** AP 484, Goaymas Sonora, Mexico CP 85400

The potential of pearl oyster (*Pinctada mazatlanica* and *Pteria sterna*) culture in Mexico has been mentioned by various authors.

These two species inhabit the Sonora coastline in the Gulf of California, as a part of their natural distribution. In the 1950's there was a huge pearl oyster fishing effort done by the Seri Indians, especially on Tiburon Island and other pearly oyster banks along the Sonoran coast and consequently both species became overexploited. The general objective of this paper is to present preliminary results and advances on experimental spat collection and hanging culture of the mother-of-pearl, *Pinctada mazatlanica* and the mother-of-nacre, *Pteria sterna*.

Pearl oyster spat is collected in experimental mesh bags, used for scallop spat collection. The seed is placed in a nursery system consisting of plastic trays and pearl nets, and later transferred to lantern nets hanging in a long line system at a depth of 2.0, 2.5 m. Preliminary spat collection results show that an average of 220 *Pteria sterna* spat per collector can be achieved in the Fall season. The growth rate (in height) for this species was 9.48 mm/month, from 6.63 mm seed to 45.57 mm in 4 months. Intermediate growth of *Pinctada mazatlanica* has been from 6.88 mm seed to 22.20 mm in a 4-month period. The results of these experiments are preliminary, but clearly show that both species grow rapidly in suspended culture. The culture of these two species is important from a commercial point of view, and they offer good possibilities for promoting pearl culture in the Gulf of California, but further research is still needed.

The culture of the pearl oysters, *Pinctada mazatlanica* and *Pteria sterna* on the Coast of Sonora, Gulf of California, Mexico, shows a good potential as preliminary data demonstrates. Spat collection and growth in the hanging culture for these species are promising. The culture of these two species is important from a commercial point of view.

HAWAII'S IMPACT ON THE INTERNATIONAL PEARL INDUSTRY. **Richard Fassler,** Aquaculture Development Program, State of Hawaii Department of Land and Natural Resources, 335 Merchant Street, Honolulu, HI 96813.

The pearl oyster, *P. radiata*, occurs in close-in waters in Hawaii. Pearl Harbor, for example, was reputed to have an abundant supply of "pipi," which the early Hawaiians used for food. The deeper water *P. margaritifera* was also in abundance, especially in the northern Hawaiian island region. These oysters yielded few pearls, but the Hawaiians utilized the mother-of-pearl for implements, such as fishhooks.

Commercial pearling in the Island was initiated in 1927 and 1928 when an American fisherman harvested 100 tons of *P. margaritfera* from Pearl and Hermes Atoll, 1100 miles northwest of Honolulu. Concern over the possible depletion of the resource led to a joint State/Federal commission in 1930, which surveyed the oyster throughout the islands. The members concluded that conservation measures should be initiated, and these have remained to this day.

Modern pearl farming in the state has been impeded by environmental constraints, which have made utilization of the open ocean extremely difficult. Therefore, efforts have been directed to on-land operations. These have occurred at the Natural Energy Laboratory Authority of Hawaii (NELHA) site at Keahole Point, on the Big Island.

In 1990, Hawaii Cultured Pearl, Inc. attempted to raise the Japanese pearl oyster, *P. fucata*, by culturing algae in tanks and feeding this algae to oysters in raceways. A lack of success led to a halt in this experiment. Efforts have been made to resume operations.

The next attempt to raise pearls in Hawaii focused on utilizing freshwater lakes and reservoirs to raise American mussels. In 1992, Cross-Pacific Pearls of California was investigating this possibility, and applied for permits to import various species of mussels, but financial problems terminated the firm's plans.

In 1992, Black Pearls, Inc. developed hatchery methods for the Hawaiian blacklip pearl oyster, *P. margaritifera galtsoffi*, and is now examining the feasibility of commercial pearl culture in land-based or ocean-based systems in Hawaii. In addition to establishing commercial culture techniques, the company is testing methods for a stocking program to help re-establish the Hawaiian pearl oyster.

Black Pearls, Inc. is also using their hatchery technology to supply spat to other South Pacific islands. Black-lip pearl oysters from the Marshall Islands have been spawned, and the larvae successfully raised to settlement in the deep-OTEC water available at NELHA. Use of this pathogen-free water ensures that quarantine concerns are met. Spat recently returned to the Marshall Islands have shown good growth and survivorship.

The Black Pearls, Inc. effort has significance for islands and atolls in the South Pacific, like Namdrik, which are lacking a major source of mature oysters. Moreover, other areas that are rapidly depleting their oyster resource, may need to rely on firms, like Black Pearls, for future supplies.

In 1993, the Biosystems Engineering Department of the University of Hawaii, began experiments with raising algae to feed to *P. margaritifera* for on-land oyster culture. The successful production of three key species of diatoms directly from an ocean intake of seawater, without having to maintain expensive laboratory cultures, has pointed to cost-effective land-based culture. The University is attempting to repeat this success with *P. maxima*.

The University's experiments may lead to pearl culture on atolls or islands, like the Hawaiian Islands, or even in Mainland locations, where access to the open ocean is either difficult or impossible.

Perhaps Hawaii's most valuable contribution to the world pearl industry is *Pearls '94*, the largest and first truly international gathering of pearl farmers, researchers, government officials, jewelers and equipment suppliers. As originally conceived in 1991, the meeting would bring aquaculturists together to discuss ways to accelerate pearl farming in the South Pacific. In subsequent years, strong interest from other areas of the world considerably expanded the scope of the gathering. More than thirty nations will be represented in Hawaii.

Pearls '94 is expected to have a profound impact on international pearling by offering important opportunities, which include: 1) stimulating sales, through identifying and solving industry problems; 2) creating marketing strategies; 3) disseminating information on the latest farming techniques; 4) encouraging investments in farms; 5) heightening awareness of quality control; 6) informing pearl producers and buyers of the most recent developments in pearl production throughout the globe; and 7) formulating plans for future international pearl conferences.

CONCEPT OF THE SOUTH SEA PEARL AND ITS FUTURE FROM LESSONS OF THE PAST. C. Denis George,
P.O. Box 5811 Cairns, Qld. 4870 Australia

The pearls from the South Seas are a later addition to the ones since antiquity from the legendary pearl fisheries of Arabia, India, the Americas and elsewhere. With the exploration of the Indo-Pacific region, the much larger pearls discovered attracted more admiration—especially the black ones from Polynesia. As the fisheries were declining, advances in the alluring mystery of pearl-formation were promising new horizons in reproducing them at will.

After the ingenious Chinese pearly-images and the Linneous pearl in 1893, W. Saville-Kent published a half-pearl he had developed earlier, created an impetus with his first South Sea pearl farm in 1906 and a Royal Commission, he created a round pearl in situ. In 1894, K. Mikimoto made his first half-pearl and by-passed the controversy on the origination and Saville-Kent's influence. The fact is that by 1920 the Japanese mastered the cultivation of a pearl when Australia, with better resource potential and which had started to develop it, outlawed it as illegal.

Dr. Sukeyo Fujita, in visualising a better pearl, after years of trials, by 1928 achieved it at Celebes. By 1932, the Japanese initiated six pearl farms at Palau and an industry started. The concept of the South Sea pearl was created:

"A pearl equal to the natural one but at a ¼ of its value and, with a nucleus of ⅓ only to the overall diameter".

The standard was maintained in the post-war ear with the renown Burmese pearls until the late 60s, when Japanese in Australian joint ventures flooded the market with inferior pearls selling them as cheaply as $10.00 each. An all-around catastrophe took place, and a woman's "beloved-pearl" was devalued to her dismay.

There were similar crises: repetitive production calamities from continuing shell mortalities; a quality decline; uncontrollable production increases with deficient approach; whatever was produced was sold for as much as possible; new aspiring producers looking for profit; the over-priced thin-skin-large pearl; lack of overall coordination and expertise guidance. There was, then, an overall decline of the concept of the South Seas Pearl, with looming calamities and an uncertain future.

TRIBULATIONS OF PEARL CULTIVATION IN AUSTRALIA. C. Denis George, P.O. Box 5811 Cairns, Qld. 4870 Australia

At the termination of the Pacific War, Australia declared the Japanese pearl technique as a war reparation and decided to establish a pearl industry for Australians. The obstructive pearl law was repealed, aspiring farmers by 1956 made pearls and Australia, with an ideal ecology and a vast pearl-shell resource, was on the right track of developing a national pearl industry.

The Japanese, fearful of "Australia's Declaration," reacted with the 1952 Overseas Pearl Law stipulations. For example, a Celebes farm in 1952 was confiscated for exploiting. A Burmese Joint Venture in 1954 was also confiscated in 1965 for exploiting. In aiming at Australia and by maneuvering to placate anti-Japanese sentiments with "promises of good will," in 1956 a joint venture started in Kuri Bay—under the stipulations of the Japanese pearl-law.

Nineteen months later, Kuri Bay stopped the pearlers taking the shell by bankrupting them. Yet, unknown to Australia, button manufacturers were going bankrupt by shell shortages; the Japanese Arafura pearlers also went bankrupt and their 26 boat fleet was bought by the Kuri Bay; in 1960, the Japanese Government, in breach of their own law, granted illegally a second pearl licence to Kuri Bay—on behalf of the Arafura Fleet. Kuri Bay pearl production expanded enormously and the "plastic button" is generally still blamed as the sole culprit.

As the Australian farmer was resisting the Japanese policy in 1960 the Japanese Government, in abusing their own law ("One Joint Venture for each country"), rushed another six ventures to snowball him, and after six years of a fierce obstruction, he was eliminated. In the ensuing 17 years to 1983, the Japanese policy resulted in:

A. Japanese: Free-for-all exploitation of Australia's resources and in breach of the Japanese pearl-law limit of the 30,000-shell yearly quota, by exporting 1,500,000 shells—a vast quantity of pearl shells—to Japan at US $27,000 a kilo—in disregard of sizes and quality. Pearl shells were dying by the millions. By 1970, the Australian partners were short-changed and bankrupt and in 1983, Kuri Bay shut down. Australian farms sold cheaply and became 100% Japanese in breach of the Fisheries Acts. And, after *38 years of pearl-making,* Australia is still dependent on Japanese technicians, etc.

B. Australian Farmer: In between starting farms and losing them, the author motivated pearl awareness by television documentaries, round pearls and the training of the first two Western Australian farmers; gradually Indo-Pacific farmers have emerged.

JAPANESE PEARL POLICY LAW FOR OVERSEAS PEARL CULTIVATION; ITS IMPLEMENTATION AND EFFECTS ON THE INDO-PACIFIC. C. Denis George,

In the post-war reconstruction of the Japanese pearl industry by the Allied Powers, the Japanese Government enacted the "Pearl Raising Industry Law" No. 9 of 1952, particularising all components essential to promote their pearl industry: from mother-shell to pearl sizes, rafts and guidance; research, finance, inspection and exports; a Pearl Council for planning, etc. It was a unique law for development, yet with the ever-increasing pearl targets (e.g. 100 tons for 1962, but harvested 120 tons mostly of poor quality pearls) the law would cause a decline of the "Pearl Standing," repetitive production calamities and severe marketing crises.

Because of the Japanese Law's aim to "Secure reputation of their pearl by '*checking*' unhealthy development in the industry,'' and, because of their precept as ''Originators of the pearl-principle,'' other countries were not entitled to make a pearl. Japanese went too far by legalising ''means and method,'' that is, how to stop other pearlers and pearl-farmers and take their pearls for their own end.

The overseas policy, known as ''The Three Principles,'' dictated: *1*. Techniques secretive to Japanese; *2*. all pearls produced to be exported to Japan; *3*. production amount regulated by Japan.

To round out their control, the policy also dictated a ''Secret obligation to be undertaken privately'' by the overseas partners in joint ventures and as it was expressed by Hatsuro Sonahara of the Japanese Fisheries Agency in February 1958 (Special Report of Fisheries Agency ''The Pearl,'' p. 83 Clause V), to the effect:

''Overseas partners to make their utmost effort to find ways and means to stop their rival local pearlers and farmers''.

As it happened in the well-documented events of Australia since 1956, the Australian partners adhered to ''The Three Principles'' and in executing their secret obligation, bankrupted Australia's pearling industry in 1958. The original Australian farm was forced to become a Japanese one and for the ensuing 15 years to 1978 not one Australian could start a farm without a Japanese partner.

After Japanese law fulfilled its objective and was discarded as of no further use, the aftermaths continue in various forms to suppress true pearl development of Indo-Pacific farmers: ''As entity of their own, and for their own best benefit and of their future.''

ECOLOGICAL CHARACTERIZATION OF THE TONGAREVA LAGOON. **Maria Haws, Ben Ponia, Daniel Cheney,** and **Hugh Thomforde,** RDA International, Inc. % TMRC, Ministry of Marine Resources, Omotea, Tongarea, Cook Islands.

The ecological monitoring program has three objectives—1) to collect baseline data on the physio-chemical and biological parameters needed to form a database containing information on the hydrological and biological processes of the Tongareva lagoon, 2) to collect data relevant to oyster culture to benefit development of management plans, and 3) to monitor possible environmental impacts of farming or other human activities. Baseline water quality data was collected over the year prior to the start of intensive pearl farming. Periodic sampling included measurements at 40 stations around the lagoon, at both shallow and deep depths, of temperature, salinity, pH, dissolved oxygen, orthophosphate, silicates, ammonia, total dissolved nitrogen, chlorophyll, total organic carbon, and total dissolved phosphorus. The values obtained are typical of a tropical coral atoll with oceanic water exchange. Values for most parameters were highly variable throughout the lagoon and no spatial trends were detected. No indications of deleterious human impact were found. None of the values were suggestive of nutrient loading or eutrophication. This database will serve as a reference to assess environmental changes associated with farming and human activities in the future. Several patch reefs were surveyed for an assessment of coral type and fish abundance/diversity.

A stock assessment was conducted to estimate the standing stock of the *Pinctada margaritifera* population. It also established permanent sites to monitor the mortality and recruitment rates of the pearl oyster fishery. Total standing stock for the lagoon was estimated at 2 to 3 million oysters. Alternatives to collection of wild stock for farming purposes, such as spat collection and hatchery production, will be emphasized since these will reduce fishing pressure on the wild stock in the future.

Experiments were conducted to evaluate the feasibility of using spat collectors to obtain oysters for farming. Results to date are inconclusive and spat collection trials continue.

Oysters were collected for histopathological examination in 1992 and 1993. The *P. margaritifera* population appears to be generally healthy with no prevalent pathogenic or parasitic infection.

GROWTH AND MORTALITY OF *PINCTADA MARGARITIFERA* IN FRENCH POLYNESIA. **Andre Intés,** Institut Francais de Recherche Scientifique pour le Developpement en Cooperation (ORSTOM), Centre de Brest, B.P. 70.29.280, Plouzane, France.

In the early 80's, pearl culture was still exclusively dependent on natural populations prosperity and also providing livestock for farms. At least 70% of pearl oysters were caught by skin diving and the remainder came from the rearing of collected spat. But most of the required biological parameters were lacking to promote new management of these natural stocks: reproduction, growth, mortality, stock assessment.

To assess growth and mortality, among the most important parameters of the population dynamics, a tagging experiment was initiated. This species is particularly suitable, as in theory, individuals can be measured when wished. Individuals (505) were tagged from April 1983 to April 1984, and only 37 were present and still alive in June 1987.

The data collected over 4 years could have provided very valuable information on growth and mortality if some unpredictable climatic and biological events had not occurred.

During the late 1982 and early 1983, six hurricanes struck the Tuamotu archipelago, destroying most of the shallower bottoms and pearl farms. Two years later, from mid-1985 to 1986, high mortality affected both the farmed and natural populations, but no evident explicative factor, such as disease of hydrological perturbation, could be taken into account. As the mortality developed mostly in the more pearl productive lagoons, an overload of the carrying capacity was considered as a hypothesis. The year following the hurricanes, stock reproduction was exceptional and natural recruitment combined with rearing of the collected spat could have enhanced the biological trophic demand to an unsustainable level for the ecosystem.

Observing growth, the monthly mean length increment for individuals greatly decreased during the year with maximal mortality, but recovered prior levels at the end of the experiment. Examining growth of age classes, it seems that the maximum length increments do not occur during the same period for adults over three years old and for juveniles. Most of the trophic energy captured by adults is used in the maturation of gonads from January to March, when the juvenile growth rate is highest.

RESEARCH FOR WILD STOCK MANAGEMENT OF *PINCTADA MAXIMA*. **L. M. Joll,** W. A. Marine Research Laboratories, P.O. Box 20, North Beach, Western Australia 6020

Although the Western Australian fishery for the silver-lipped pearl oyster *Pinctada maxima* has a history going back to the 1860's, there is little published information on the biology of the species. A research programme has been underway since 1989 to examine the status of the wild stock and to provide a sound understanding of the reproduction, growth and recruitment of wild stocks.

Examination of the reproductive cycle over a large part of the species' range in Western Australia showed that, in the Broome/Eighty Mile Beach area, there was an extended period of gonad development with at least two spawinings (early and late summer). At Exmouth, near the southern end of the species' range, there was a shorter period of gonad development, with a single spawning in mid-late summer.

Natural growth rates of spat have been derived from spat caught on artificial collectors as well as from shifts in modal frequencies. Mark and recapture techniques have been used to examine the growth of larger (>30 mm DVL) animals. Over 4000 pearl oysters have been tagged and released in an area of 80 Mile Beach, with over 2000 recaptures or re-recaptures over a four year period. The growth rate data indicate that, in the main Eighty Mile Beach area, pearl oysters are about three years old at the legal minimum size of 120 mm.

Measurement of recruitment has been attempted using artificial spat collectors and the examination of catch rates of 'piggy-back' shell (spat attached to adult pearl oyster shell). However, the artificial spat collectors trialled were found to only have a low efficiency for collecting spat or, alternatively, were poorly located for spat settlement. The examination of catch rates of 'piggy-back' spat is a potentially more useful technique for the measurement of recruitment, as it has the capacity to integrate settlement events over a much wider area than spat collectors. However, high variability in 'piggy-back' spat rates means that large numbers of adult pearl oysters must be sampled to reliably differentiate between real changes in overall recruitment levels and random events.

Fishery data detailing the catch, effort and location of the vessel for every dive have been provide by all vessels in the fishery since 1979. These data show that CPUE remained relatively steady over the 1980's, at about 20 shells per diver hour, but that in the early 1990's catch rates increased by about 50%. Although there have been technological changes over the the period, the recent increase in CPUE appears to be the result of a real increase in the abundance of culture-sized pearl oysters rather than an increase in vessel or diver efficiency. Analysis of the fishery data indicates strongly that the Western Australian stock of *P. maxima* is being exploited at a level less than or equal to the production of the stock.

SOME RESULTS OF FRESHWATER PEARL CULTURE IN WEST LAKE (HANOI, VIETNAM). **Phan Ngoc Kim, Ngo Thi To** and **Vu Ngoc Tuan,** Ho Tay Fishery Development Investment and Exploitation Centre, 79 Yen Phu, Hanoi, Vietnam

Freshwater oysters are usually used to produce non-nucleated pearls in various countries of the world. In Vietnam, the freshwater oysters, *Hyriopsis cumingii (Lea), Cristaria bialata (Lea)* and *Anodenta jourdyi (Morlet),* are being reared to produce nucleated pearls.

The implantation of nuclei into the mantle of the *hyriopsis cumingii (Lea)* oyster has brought the best results.

Hyriopsis cumingi (Lea) is only distributed in some of the rivers in the north of Vietnam, such as the Cau River, Thuong River, Chau Giang River, and Day River. The bottom of these rivers is mud-sandy, with a slow flow of water. The oyster lives in the river's bottom at a depth of 4 m to 15 m. Its growth rate is slow, as it takes from 3 to 4 years to reach 14 cm to 16 cm in length, with a weight of 120 gr to 140 gr. However, this oyster grows rapidly when reared in a lake or fishpond where abundant phytoplankton is available. The shape and color of its shell can be changed slightly.

HoTay Lake (West Lake), located to the north of Hanoi City, has an area of 413 ha, and an average depth of 2 m, with a muddy and mud-sand bottom. The lake's water is supplied by rain water and waste water from the city. Four 5 mm to 6 mm nuclei were implanted in an oyster at the bottom of its mantle. These nuclei were manufactured from the shell of *Lamprotula* species. They were then suspended on rafts, and 40 days later, dead and nuclei expelled oysters were discarded. In a 1993 experiment, the survival rate of the implanted nuclei was 57.7%, with a mortality rate of 6.8%.

By means of the selection and treatment of the graft tissue, it is possible to change the color of the pearl to: pink (60%), gold (20%), white pink (10%), and cream (10%).

The pearl culture of Vietnam is only at a starting point, but we feel that the results of pearl culture of *Hyriopsis cumingii* in lakes or fishponds has good potential for creating a new industry for rural areas of Vietnam. Essential is the marketing of Vietnam's freshwater pearls to the rest of the world.

NATURAL ABALONE PEARLS. **Sarabeth Koethe,** KCB Pearls, P.O. Box 1737, Santa Monica, CA 90406-1737.

The paper presents an in-depth history of the Pacific Coast natural abalone pearl—distribution, statistical data, etiology of pearly rariety and future implications of current population decline. The discussion will also include examples of color, and type and size of natural abalone pearls, with emphasis on those specimens particularly suited for the gem industry.

TRENDS AND DEVELOPMENT OF THE PEARL OYSTER INDUSTRY IN THE PHILIPPINES. **Daisy F. Ladra,** Bureau of Fisheries and Aquatic Resources, 860 Arcadia Bldg., Quezon Ave. Q.C., Philippines.

The Philippines has substantial areas that support the favorable growth of pearl oysters. Despite the availability of several species of pearl-producing oysters, including freshwater mussels, the pearl industry has focused only on South Seas pearls using *P. maxima*. As of 1991, the industry was valued at $1.4 million, which the Philippines obtained through the export of pearls, live mother of pearl, pearl oyster shells and shell buttons.

Despite the value of the resource to the Philippine economy, the industry is undeveloped as very little information is known about the pearl oysters. Currently, there are 23 pearl farms situated in Mindoro, Palawan, Masbate, Cebu, Tawitawi and Pangasinan. This paper attempts to describe the pearl and pearl oyster industry, its development status, as well as trade and market situation. Traditional farming and pearl culture technology will also be discussed, as well as spat collection practices, utilization and postharvest handling of pearl oyster products. The income potential of pearl production will be considered, together with prospects for development. Recommendations for the development of the industry will also be presented.

RECENT DEVELOPMENTS IN ARTIFICIAL PROPAGATION OF THE GOLD- OR SILVER-LIPPED PEARL OYSTER *PINCTADA MAXIMA (JAMESON)*. **R. G. Lawyer,** Palawan Pearl Project, Inc., P.O. Box 878, Manila, Philippines.

The paper discusses recent developments at the hatchery of the Palawan Pearl Project, with specific descriptions of improved induced spawning techniques, spat settlement and grow-out techniques for artificial propagation of the *Pinctada maxima*.

ACIAR/JCU BLACKLIP PEARL OYSTER PROJECT. **John S. Lucas,** Zoology Department, James Cook University, Townsville, Queensland 4811 Australia

This three year project, 1993–1996, is funded by the Australian Centre for International Agricultural Research. It involves James Cook University, Queensland Department of Primary Industry and the Ministry of Natural Resources, Kiribati. There will also be some collaboration with ICLARM's Coastal Aquaculture Centre, Honiara.

The project is focused on the Republic of Kiribati, a Pacific nation consisting of a series of coral atolls. *Pinctada margaritifera,* through shell and/or cultured pearls, is one of a limited rangeof potential export commodities for this country. However, the pearl oyster stocks appear to be low, either intrinsically or from overfishing. Thus, the overall objective of this project is to build up the *P. margaritifera* stocks in selected atoll lagoons in Kiribati as a means to an appropriate pearl industry.

Initially, pearl oyster stocks will be systematically surveyed to establish in which atoll lagoons they occur and their abundances. Spat collectors on long-lines will be deployed at selected sites in lagoons to determine levels of natural settlement and the potential of settlement on these artificial substrates as a source of pearl oyster stocks.

The alternative source to spat collection is hatchery production of spat, and simplified hatchery methods, suitable to a coral atoll environmental, are being investigated. These are based on the system of flow-through culture with artificial diets that were developed for successful hatchery culture of giant clams. The objectives are to get away from air-conditioned culture rooms and sophisticated algal culturing facilities.

One further aspect of the project is related to the pearl bead insertion process. It addresses the trauma and infections of the operation, and considers how these can be reduced.

The first aspect of this research program, related to pearl oyster stocks and settlement in Kiribati atoll lagoons, is particularly applicable to that country; but if there are significant advances in the other two aspects, low-technology hatchery culture and aspects of bead insertion technology, these will have general application.

POTENTIALS OF FRESHWATER PEARL CULTURE IN THE PHILIPPINES. **Virginia S. Luyun,** Aquaculturist II, Bureau of Fisheries and Aquatic Resources, 860 Arcadia Bldg., Quezon Avenue, Quezon City, Philippines.

Pearl production in the Philippines has mainly centered in marine pearls. The Philippines has sizable quantities of Freshwater *Cristaria plicata* and *Anadonta* spp. which were accidentally introduced into the country and would be tapped for pearl production.

Freshwater pearl production is currently in its experimental stage where research expenses reached $1,176.50 for 750 pieces of operated mussels. Local production is sourced from Hong Kong, People's Republic of China and Thailand. Demand for freshwater pearl is strong in the domestic market due to the low prices of freshwater pearls and pearl jewelry as compared with South Sea pearls.

This paper attempts to present an overview of the freshwater pearl industry, domestic demand and market prospects in the country.

The results of the experimental pearl culture initiated in the country will also be discussed in the paper.

PERSPECTIVES FOR THE INSTALLATION OF A PEARL CULTURE ENTERPRISE IN BAHIA DE LA PAZ, SOUTH BAJA CALIFORNIA, MEXICO. **Mario Monteforte[1],** [1]Grantee International Foundation for Science, Centro de Investigaciones Biológicas del Noroeste, P.O. Box 128, La Paz, B.C.S. 23000, México. FAX (112)5.36.25.

Pearl resources in La Paz region have been overexploited since early XVI century, both by international companies and local fishermen. In 1940, the natural populations became almost extinct and a permanent banning was decreed, but furtive fisheries have continued until today. However, Bahia de La Paz is famous for the richness and high quality of its natural pearls, which are present in many royal treasures, personal collections and museums.

There have been many attempts to cultivate pearl oysters and produce pearls, but the only successful one was that realised by Don Gastón Vives in 1903. He founded a prosperous enterprise, the "Compañia Criadora de Concha y Perla" at Bahía San Gabriel in Isla Espíritu Santo, near La Paz city. This enterprise was known internationally and many pearls were sold by Mr. Vives in Paris and New York. Although the process of pearl oyster cultivation was extensive using an advanced technology, all the pearls were natural.

After the destruction of Mr. Vives' enterprise during the Mexican Revolution in 1914, there have been at least 15 or more different projects on pearl oyster culture and pearl production by grafting and nucleus implanting. All these projects failed or were interrupted and abandoned. So far, no positive results have been obtained.

At present, a research programme carried out in the Centro de Investigaciones Biológicas del Noroeste has developed an efficient technology for the extensive culture of *Pinctada mazatlanica* and *Pteria sterna* and has obtained positive results in the production of fine cultured mabes on both species. Production of round pearls is under study.

This project is feasible at commercial scale and has the advantage of being technologically independent. Several elements favor the possibility of a joint-venture enterprise on pearl production in La Paz.

First of all, the quality of the nacre of both pearl oysters is recognized as being one of the best in the world. Moreover, the new economic politics established in México concerning international investments, the facilities for obtaining territorial concessions and the inauguration of the NAFTA, make pearl production in La Paz a strategic activity.

Our results on pearl oyster culture and pearl production are starting to spread among the public and private sectors. Pearl culture is now being considered as an interesting alternative for regional socioeconomic development, and a joint-venture proposition would be most welcome.

Our figure of a pearl culture center could have an economic potential of up to $5 million U.S. annually from the 4th year of activities, starting with an investment of $1.5 million U.S. which would include the construction of a laboratory and other infrastructure in a site that would be the center of the operations. This benefit comprises the production of mabes only, without considering the aggregate value of jewelry, handicraft with shells and the use of nacre for cosmetology and dermatology. Besides, we have detected at least 15 other sites in Bahia de La Paz where additional "standard" pearl farms could be installed.

On the basis of our technology, a "standard" farm could produce a steady annual production between 120,000 and 300,000 mabes under a scheme with large margins of security in spat collection, mortality, mabe incidence, etc. We are estimating a price between $15 and $20 U.S. per piece, which we believe to be more than realistic, taking into account the quality we are able to attain.

Nevertheless, a potential pearl culture enterprise must consider the recovery and conservation of natural populations through aquaculture and repopulation activities and support research studies. The resource is fragile and scarce and will not resist long and massive grafting operations. Since both species are under legal protection, projects involving the management of wild individuals cannot be sustained.

SPAT COLLECTION, GROWTH AND SURVIVAL OF PEARL OYSTER *PTERIA STERNA* UNDER EXTENSIVE CULTURE CONDITIONS IN BAHIA DE LA PAZ, SOUTH BAJA CALIFORNIA, MEXICO. **Mario Monteforte,**[1] and **Cynthia Aldana,**[2] [1]Boursar International Foundation for Science, [2]Universidad Autónoma de Baja California Sur, Centro de Investigaciones Biológicas del Noroeste, P.O. Box 128, La Paz, B.C.S. 23000, México. FAX (112)5.36.25.

The present work resumes the experiences on spat collection and extensive culture of *Pteria sterna* since winter 1988. Because of repeated accidents and operative obstacles, the research sequence has suffered interruptions and several experiments were restarted. The general results for each phase of the culture process are the following:

1) Spat collection: the analyses and comparisons of spat yield were performed in control collectors (square bags 30 × 30 manufactured with black plastic screen 2 mm mesh, filled with gillnet). So far, three stations have been tested for spat collection of this species. Bahía Falsa, Isla Gaviota and Caleta El Merito, all of them are located at the continental coast near La Paz city. Gaviota and Merito have given the best results.

Spatfall of this species was generally continual during all the years but showed erratical patterns in its start, duration and abundance. Annual averages in control collectors during the main season (winter) have varied from 35 in to 120 individuals per bag in 1992–1993 and 1989–1990 respectively, while the start and duration of recruitment have been detected with differences of up to two months between years. Nevertheless, the start of the main spatfall season always coincided with a sharp decrease in water temperature.

Most spat always occurred between surface and 5–7 m depth during winter. When a recruitment was present in summer, the spat were collected mainly below 8 m and as deep as 15 m. Average spatfall in summer has also varied widely, from 0 to 65 individuals.

Concerning substrate selection for spat settlement, we tested natural (palm leaves, coconut halves and a local shrub called "chivato") and artificial substrates (gillnet, and black, green, red, yellow and white onion bags). The "chivato" was a good collector, followed by black onion bags. The rest of the artificial substrates gave diversified results which depended mostly on the abundance of spatfall. With the exception of the black color, no evident preference of spat settlement was detected for a special one among the others.

2) Growth and survival during fattening: several variables were studied during 5 months: density of individuals in trays (50, 75, 100 and 150), depth (in suspension and at bottom), and site (stations Bahía Falsa and Merito). Measurement of individuals includes shell height, width, length, wing length and weight. For the purpose of the present work, we will use shell height for the description of growth.

The best growth was recorded in the trays placed at Bahía Falsa with 100 individual density (from 13.4 mm to 42.2 m of average shell height). There were no significant differences of growth between suspension and bottom fattening, but the latter presented much less accumulated mortality (17% and 5% respectively). Fouling was also less in bottom. Bahía Falsa gave better results than Merito considering growth, but fouling and mortality was higher in the first.

3) Growth and survival during culture: this phase was performed at station Merito in bottom structures using individuals with different periods of fattening (2, 4, 6 and 8 months) at 80 individuals per tray. At the 12th month, individuals with 4 and 6 months of fattening presented the best growth during culture (average increment of 50.4 to 53 mm of shell height). No significant differences were detected between these groups, but it seemed that fattening during 6 months favored the increase in shell thickness, which represents and important factor for the production of mabe.

Individuals with 2 months of fattening also had good growth (increment of 44.6 mm), but total mortality attained 75% in the first two months of culture. However, we cannot conclude a clear relationship between this duration of fattening and the mortality since we had other problems that could have influenced this parameter.

Individuals fattened for 8 months presented small sizes, shell weakness and deformities in the wing, and mortality rates started to increase dramatically from the 7 of fattening.

So far, we suppose that the best elements for cultivating *Pteria sterna* in Bahia de La Paz are the following:

1. Spat collection: collectors should be installed in alternated monthly series from November to March, each series remaining at least 65 days in the water, from surface to 6–7 m depth. The best collectors could probably be "cloth-lines" with series of three "curtains" per system filled with dark colored netting, such as black onion bags.
2. Fattening: four to six months of fattening at 80 to 100 individuals per tray seemed adequate. Fattening should be carried out in protected, non-polluted sites. Bottom structures are desirable. Cleaning and maintenance every two months is probably enough, but the periodicity depends on the site where the cultivation is carried out. We have observed that this species stands better the manipulations and resists higher fouling than *P. mazatlanica*.
3. Culture: previous experiments realized in 1987 and 1988 tested suspended and bottom culture structures in Bahía Falsa. No significant differences were found. Nevertheless, our experiences using innovated bottom culture structures at Merito have yielded better results.

The site of culture appeared to be the main factor determining growth and survival. We believe that the oceanographic conditions prevailing at Caleta El Merito favored these parameters. Significant differences on growth, mortality and fouling rate were found between this site and Bahía Falsa, which receives the direct influence of the Pichilingue commercial port.

As seen, the information on this species is somewhat fragmented if compared with that of *P. mazatlanica*. This has been mainly the consequence of several accidents, vandalism and the lack of support for maintaining a continuous sequence of activities and supervision. However, we feel that *Pteria sterna* is as suitable as *P. mazatlanica* for a large scale commercial production. More studies are in progress for this species.

SPAT COLLECTION TRIALS FOR PEARL OYSTER *PINCTADA MAZATLANICA* AT BAHÍA DE LA PAZ, SOUTH BAJA CALIFORNIA, MEXICO. **Mario Monteforte**[1] and **Horacio Bervera,**[2] [1]Grantee International Foundation for Science, [2]Universidad Autónoma de Baja California Sur, Centro de Investigaciones Biológicas del Noroeste, P.O. Box 128, La Paz, B.C.S. 23000, México. FAX (112)5.36.25.

The first spat collection experiments on *Pinctada mazatlanica* started in spring–summer 1989 with the deployment of several series of "envelopes" (square bags 30 × 30 cm manufactured with black plastic screen 2 mm mesh, filled with 30 to 40 g of monofilament gillnet) at six different sites in Bahía de La Paz. From these results, we selected station Gaviota as a propitious site for further spat collection. Although spat yield was not the best, the site is more accessible and presents better facilities for surveying and operation.

From 1990 to 1993, a total of 11 different spat collectors for *Pinctada mazatlanica* were tested during the maximum recruitment season, from surface to 6 m depth at station Gaviota. The devices were named after the main variables to be tested, which were the structure, architecture and position. All the devices were filled with old gillnet as asubstrate, except in 1993 when we tested dark onion bags as a substrate. Evaluation of spat abundance between collectors considered a standard amount of these substrates which was adjusted to 40 or 50 g.

In 1990, we tested "envelopes" (square bags 30 × 30 cm manufactured with black plastic screen 2 mm mesh), onion bags of assorted colors (no special design for color testing was followed in this occasion) and HYSEX film protected with screen bags.

In 1991, we evaluated the effect of volume on spat settlement. The devices were "curtains" (envelopes of 1 m^2), "cylinders" (cylindrical structures manufactured with rigid plastic 1.5 m high per 0.5 m diameter) and "lanterns" (prismatic structures manufactured with rigid plastic 0.5 × 0.5 × 1.5 m containing five cubic boxes of black plastic screen).

In 1992, we tested the effect of the position and color of collectors. The devices were "pillows" (curtains positioned horizontally in series of 5), "cloth-lines" (curtains positioned vertically in series of 5) and plastic onion bags of different color (black, white and red).

In 1993 we also tested "pillows" and "cloth-lines" but in series of 3 curtains filled with dark onion bags.

Spat abundance was recorded into "curtains" and into each curtain of the "pillows" and the "cloth-lines" (1991, 1992 and 1993) under a strategy addressed at detecting differences of spat settlement between the outside and the inside of each "curtain" individually, and also between the outer and inner curtains of the "pillows" and "cloth-lines".

"Envelopes" were installed as controls from 1991 to 1993 to detect annual differences in spatfall. These results were taken into account when comparing the efficiency of the devices between years.

The criteria for the selection of the devices to be tested from one year to the following were dictated by the elements which showed propitious features for spat collection during each trial.

Comparing the spat yield in "envelopes," average spatfall presented small differences between years, but 1990 and 1992 seemed to be best with 18 to 23 individuals per bag.

In 1990, the "envelopes" yielded the best results for spat collection. Onion bags were rather poor collectors (average of 5 to 7 individuals), but we detected some preference for dark colors. The HYSEX films were ineffective. These results suggested the use of larger envelopes, and we produced the "curtains" in 1991, together with volumetric collecting devices.

The "curtains" collected an average of 25 to 30 individuals. An important proportion was recorded mainly on the black inner surfaces of the container. "Lanterns" and "cylinders" showed averages of 12 to 15 individuals. We observed that in "lanterns" most individuals appeared in the outer faces between the cubic boxes inside, suggesting that shaded sites enhance spat settlement. With these results, in 1992 we constructed the "pillows" and the "cloth-lines" (with series of 5 curtains), also introducing a test for color selection using dark and light onion bags as containers.

This time, the average spat yield increased to 137 individuals in the "pillows" and 132.4 in the "cloth-lines." Considering the average abundance on each curtain individually and comparing these results with the curtains of 1991, we observed a clear increase of spat yield (43 to 50 individuals per curtain). However, there were differences in spat abundance, depending on the place of each curtain into the system. The abundance was higher in the outer curtains, while the one in the middle recorded zeros quite often. These results suggested that larvae are "filtered" through the sucessive screens and are trapped mainly in the outer curtains. We also observed a clear preference for dark onion bags.

Based on these results, in 1993 we tested "pillows" and "cloth-lines" in a series of 3 curtains filled with dark onion bags. The spat abundance between the curtains was more uniform. The "pillows" yielded an average of 105 individuals, while the "cloth-lines" had 98. No significant differences were registered between the center and the outer curtains. Although these results seemed lower than in the previous year, we have to consider that the general recruitment in 1993 was also low as shown by the records in the control envelopes. Adjusting the equivalences, the best devices were definitively the "pillows" used in 1993.

However, we decided to retain the "cloth-lines" with 3 curtains filled with dark onion bags as the best device for massive spat collection because they presented better handling and facility in manufacture and spat harvest. This device uses less material than the "pillows," it is lighter and cheaper, and can be installed in vertical series of up to four systems. Besides, if the curtains are properly sewn, most of the material can be recycled, twice or more, after harvest operations.

We suppose that similar results could be achieved with *Pteria sterna.* A special study considering these variables is in progress for this specie.

ECOLOGY OF PEARL OYSTER SPAT COLLECTION IN BAHIA DE LA PAZ, SOUTH BAJA CALIFORNIA, MEXICO: TEMPORAL AND VERTICAL DISTRIBUTION, SUBSTRATE SELECTION, ASSOCIATED SPECIES. **Mario Monteforte**[1] and **Humberto Wright**[2,3], [1]Grantee International Foundation for Science, [2]Boursar PIFI of CICIMAR, [3]Boursar CONACYT, Centro de Investigaciones Biológicas del Noroeste, P.O. Box 128, La Paz, B.C.S. 23000, México. FAX (112) 5.36.25.

Experimental spat collectors (square bags 30 × 30 cm manufactured with black plastic screen 2 mm mesh, filled with different materials) were deployed at station Gaviota from 1991 to 1993, from surface to 15 m. The effect of exposure (2, 4, 6, 8 and 10 weeks of immersion) was tested in 1991 using gillnet only as substrate. Six substrates were evaluated in 1992: gillnet, onion bags (black, yellow and red), and two natural substrates (dry palm leaves and a Mimosoidae bush called "chivato"). These collectors had 8 to 10 weeks of exposure. The objectives were to determine, for pearl oysters: 1) temporal and vertical spat distribution, 2) substrate selection, 3) predators, competitors, noxious species and species that could be useful as index of spatfall start, and 4) adequate immersion time in function of spat size and mortality.

In 1991, the recruitment of *Pinctada mazatlanica* was short and scarce, starting in late August and finishing in late October with a maximum in September. In 1992, we detected two recruitments: June–July (intense) and September–October (moderate). These coincided with a water temperature of 28 to 30°C. Most spat were collected over 4 m depth.

Pteria sterna spat were present the whole year in 1991 and during winter only in 1992–1993. In 1991, the maximum recruitment occurred in December, which was much more intense than in January–February 1993. These coincided with low water temperature (22–24°C). During winter, spat appeared between surface and 6–7 m depth. In summer 1991, the few spat were collected only below 8 m.

Substrate selection analyses were performed during the seasons of maximum recruitment. For both species, the best substrate was the "chivato" bush followed from nearby onion bags. Palm leaves were poor collectors.

Pinctada mazatlanica seemed to prefer the dark colored netting, while no differences between colors were detected for *Pteria sterna*. Although "chivato" bush was the best material, it is difficult to handle in massive operations and cannot be recycled. We have chosen dark colored onion bags for future spat collection activities, but new substrates will be tested.

An exposure of at most 8 weeks seemed adequate for harvesting spat larger than 5 mm of shell height. This size is easier to manage and ensures higher survival during the first phases of cultivation. Spat mortality was 12 to 20% into this period. At an exposure of 10 weeks, spat attained nearly 11 to 13 mm of shell height, but mortality increased to 45% or more.

Concerning the associated species, we have identified about 120 different forms, but only 98 have been identified at species level. The rest (families and genera) were treated as "items." This strategy was applied because many of the collected organisms were present in juvenile forms or were incomplete. Crustaceans, polychaetes and bivalves amounted to more than 63% of the total species/items collected. There were 7 to 9 species of bivalves with actual or potential economic importance such as *Pinctada mazatlanica, Pteria sterna, Argopecten circularis, Pecten vogdesi, Pinna rugosa, Anadara* spp., *Spondylus princeps,* and *Lyropecten subnudosus*.

Among the species considered as predators, the most important were the Brachyurans *Pilumnus towsendi* and *Portunus xantusii*. During massive spat collection with larger collectors, many broken shells bore clear marks of chelipeds. Covariance analyses showed a strong inverse relationship between the abundance of any of these crabs and that of live pearl oyster spat.

Sponges, ascidians and barnacles were spatial competitors. In summer, these species are abundant and clog the collectors avoiding the arrival of new pearl oyster spat and reducing food availability for those that are already settled.

Noxious species coat the juveniles impeding valve opening. These are mainly sponges (*Hymeniacidon* sp.) and ascidians which have an important contribution to pearl oyster spat mortality.

The associated species were also used for the design of a strategy for improving spat collection efforts. We have selected the index conditions that could be easily surveyed.

The start of spatfall of *Pinctada mazatlanica* coincides with the decrease in abundance of *Pteria sterna* and *Argopecten circularis,* and a sharp increase in water temperature of at least 4°C in two months. The presence of the hydroid *Obelia* sp. (which is well-known by the local fishermen and divers), and *Pinna rugosa, Pecten vogdesi, Lyropecten subnudosus, Anadara* sp. and *Isognomon* sp., is also related with the recruitment of *P. mazatlanica*.

The start of spatfall for *Pteria sterna* is announced by a steep decrease in water temperature and the absence of *Pinctada mazatlanica, Pinna rugosa* and the stingy hydroid. The recruitment of *Argopecten circularis, Anadara* sp., *Laevicardium sp., Glycimeris gigantea* and *Anomia peruviana* is contemporaneous to that of *P. sterna*.

These indexes are not definitive. However, we have applied this strategy during massive spat collection operations with positive results.

GROWTH AND SURVIVAL OF PEARL OYSTER *PINCTADA MAZATLANICA* IN EXTENSIVE CONDITIONS AT BAHÍA DE LA PAZ, SOUTH BAJA CALIFORNIA, MÉXICO. **Mario Monteforte,**[1] **Horacio Bervera,**[2] **and Sandra Morales,**[3] [1]Grantee International Foundation for Science, [2]Universidad Autónoma de Baja California Sur, [3]Universidad Nacional Autónoma de México, Centro de Investigaciones Biológicas del Noroeste, P.O. Box 128, La Paz, B.C.S. 23000, México. FAX (112)5.36.25.

Growth curves and survival rates of *Pinctada mazatlanica* were evaluated in two related experiments testing different conditions of fattening at 8 m depth at station Merito. The individuals used in these experiments were collected in July 1992.

In the first experiment, 640 individuals were placed in Nestier trays during 2, 4, 6 and 8 months at a density of 40 individuals per tray. Each batch had two repetitions and an additional group of 160 individuals was reserved (in the same fattening conditions) to replace the dead juveniles of the main batches in order to maintain a constant density.

In the second study, the individuals were placed at densities of 25, 50, 75 and 100 per tray during 5 months of fattening. Each batch also had two repetitions. A group of 100 individuals was reserved for replacement of dead juveniles in the main batches to maintain constant conditions. This was placed in two trays each with 50 individuals.

The individuals were distributed into the trays until there were no differences in the starting average size, which was approximately 7.5 mm of shell height. Average weight was 0.32 g. This corresponds to an age of approximately 65 days.

Temperature, salinity and oxygen were recorded every month. Records of growth and mortality were also taken. We measured the height, width, length and weight on samples of 25% of total alive individuals in each tray. All deads were counted and measured (except weight) and replaced with the reserves. Unfortunately, there were some losses of batches during the experiment, and this problem had to be managed during the analyses. In some cases the repetitions were suppressed.

The first trial was followed in late bottom culture for an additional 6 months. The second trial considered the fattening period only.

For the purpose of the present work, we will analyse the shell height and the weight only, since these dimensions describe better the growth of juvenile individuals.

At the 12th month in the first experiment, the growth of *Pinctada mazatlanica* with 6 months of fattening was the best (increment of 45.36 mm and 24.5 g). The shells of these individuals showed better shapes (no deformations) and seemed to be more solid than those of the other groups.

In the second, after 5 months of fattening, the growth in densities of 25, 50 and 75 individuals did not show significant differences (increment in 18.02 to 18.62 mm). In 100 individuals density, the growth was only 15.5 mm. Increment in weight seemed to be better in densities of 25 and 50 (3.8 and 3.2 g respectively). At density of 100, weight increment was only 1.7 g. In the individuals placed at 50 and 75 per tray, we could detect that shells presented better shapes and seemed to be more solid. Some of the individuals at 25 per tray were quite large in shell height, but this was very heterogeneous. Individuals at 100 per tray had thin shells and presented some deformations. Shells were generally larger in length than in height and had less growth projections over the margin.

Mortality in both experiments did not seem to be influenced by the variables tested. We suppose that handling during spat harvest was the main element affecting survival, specially during the first month after this operation. Records of 25 to 35% of mortality were always observed in the first month and then it decreased to less than 3% (often 0% in some batches) from the 4th month on. Another element which seemed to affect survival was the handling of individuals during the monthly measurements. Average sizes of deads in one particular month were very similar to the sizes of alives of the previous month, suggesting that mortality took place just after the manipulation.

These results suggest that the best fattening conditions for *Pinctada mazatlanica* are 6 months of fattening at a density between 50 and 60 individuals per tray. It would be desirable to reduce handling to every 2 months and avoid excessive manipulation of individuals, specially during the first 3 or 4 months of fattening. A possible alternative would be to place the newly harvested individuals at densities of 100 individuals per tray during the first two months and then reduce the numbers to 50 or 60 until the transfer to culture structures.

We still need to compare growth and survival in other sites and depths (in suspension for instance), but this would be hazardous until we could count with protected sites where the installations could be properly surveyed. For the moment, station Merito and the underwater culture installations we use are giving satisfactory results.

RESULTS ON THE PRODUCTION OF CULTURED PEARLS IN *PINCTADA MAZATLANICA* AND *PTERIA STERNA* FROM BAHIA DE LA PAZ, SOUTH BAJA CALIFORNIA, MEXICO. **Mario Monteforte,**[1] **Horacio Bervera,**[2] **Sandra Morales,**[3] **Victor Pérez,**[4] **Pedro Saucedo,**[4] and **Humberto Wright,**[4,5] [1]Grantee International Foundation for Science, [2]Universidad Autónoma de Baja California Sur, [3]Universidad Nacional Autónoma de México, [4]Boursar PIFI of CICIMAR-IPN, [5]Boursar CONACYT, Centro de Investigaciones Biológicas del Noroeste, P.O. Box 128, La Paz, B.C.S. 23000, México. FAX (112)5.36.25.

Half and round nuclei implants were performed exclusively on cultured individuals of *Pinctada mazatlanica* and *Pteria sterna*. Two batches of 120 individuals of *P. mazatlanica* (22 to 30 months old), and two of 105 individuals of *P. sterna* (18 to 24 months old) were used. Half nuclei were hand-made from porcelain, shells of *P. mazatlanica* and *Strombus galeatus*, marble and plastic. Sizes of half nuclei were between 10 and 13 mm in diameter per 7 to 9 mm height. For round nuclei (also hand-made, between 5 and 7 mm in diameter) we only used shells of *P. mazatlanica* and *Strombus galeatus*.

The operations on *P. mazatlanica* were performed in late summer. For *P. sterna*, they were applied in late spring. This strategy ensures that gonads would be empty in every case, even if the implant experiment was to be made with half nuclei.

Several essays for pre-surgery sedation and recovery were applied. Treatment #1 was ineffective and produced frequent mortality; treatment #2 gave good results, while treatment #3 also gave good results, but the individuals produced too much mucus which made implants difficult to perform. With treatment #2, the organisms became almost unresponsive to surgery and implanting after 25 min of exposure. They produced practically no mucus and it was quite easy to open the valves. The organisms were completely recovered after 5 to 7 minutes in running water.

Once the sedation and recovery treatment was defined, we proceeded to the nuclei implantings. Three, and up to five half nuclei per individual, were implanted using a special cement. Distribution of these into the valves were 2–1 and 3–0 for the three nuclei, 2–2 for four and 3–2 for five. The sizes of half nuclei were selected in function of the size of the receptor, therefore, to avoid obstacles when the valves close. Several locations on the valves were also evaluated for mabe formation: muscular (very near the abductor muscle), paleal (in the center band of the valve) and marginal (near the margin of the nacre layer). This last site was not used when the half nuclei would obstruct valve closing. For *Pteria sterna*, we placed the larger number of half nuclei on the "flat" valve. No special design in this sense was followed for *Pinctada mazatlanica* since both valves are almost equal.

Round nuclei insertions (one per individual) were performed with our own techniques. We are using the traditional surgical instruments but some transformations were necessary, specially for the base, to adapt them to the shape, size and anatomy of our species. The insertions were made in the floor of the gonad and in the tip of the pearl-sac. Concerning this organ, *P. sterna* has a simple bag, similar to *Pinctada margaritifera* from French Polynesia and *P. fucata* from India, while in *P. mazatlanica* it is bi-lobulated. It is probable that this species is the only pearl oyster presenting this characteristic.

Donors of the grafting tissue were selected on the basis of the color of their marginal nacre layer. We chose those having the best iridescence ("aîle de mouche"). For mabes, we selected assorted individuals.

Both types of implants were realised in not more than 40 sec for round nuclei and 55 sec for half nuclei. We did not try to reduce this time, therefore, to ensure as much as possible a good insertion.

After the operations, the organisms were immediately replaced into the water, each one into a numbered bag. Since we do not have access to a laboratory (all the operations were performed at the field), it was not possible to realise a better convalescence treatment.

After 8 months, retention of half nuclei was 100% and accumulated post-implant mortality was 3%. Nearly 85% of nuclei were completely covered by nacre (1.2 to 1.7 mm width). Quality of mabes was better and more uniform in shells with 3 half-nuclei. Those with 4 and 5 were heterogeneous. Shell and porcelain nuclei had better response than mabe, while plastic gave poor results.

There were not particular differences on nacre covering between nuclei placed in different valves. However, the quality and homogeneity of nacre layers was higher in mabes formed on the paleal band. Mabes had different colors depending on the species and also on the site of implanting. Hues were varied in *Pteria sterna* (silvery, golden, purple, blue, gray), while blue-gray and dark-gray predominated in *Pinctada mazatlanica*. Mabes tended to be darker when they were formed near the margin of the valves, but imperfections were noted in the surfaces of the mabe facing this area, particularly when it was too near the margin. It was also noted that the mabes placed in the central sector of the valve had better quality. We suppose that at least 10 to 12 months are needed to obtain superior quality. From these preliminary results, we can expect a gem incidence (beautiful mabes) of more than 55% applying the best propitious elements obtained in this experiment.

Concerning round pearls, we obtained modest results. Post-surgical mortality after 8 months nearly approached 75%, but graft retention was 100% in survivants. Only four round pearls of standard quality (dark gray, 7.5 to 7.8 mm diameter) were obtained in *P. mazatlanica* and three (blue-gray to green-gray, 6.8 to 8.2 mm diameter) in *Pteria sterna*. There is 3.3% and 2.9% of round pearl incidence respectively. No further analysis is possible with these results. We can only say that much more work must be done about this aspect.

PROGNOSIS FOR THE FUTURE: CRISIS MANAGEMENT OF AN IMPERILED MUSSEL FAUNA. **Richard J. Neves,** National Biological Survey, Virginia Cooperative Research Unit, Virginia Polytechnic Institute, 100 Cheatham Hall, Blacksburg, VA 24060-0321

The recorded declines in both rare and common species of freshwater mussels have sensitized federal and state regulatory agencies to the need for conservation and management of this renewable resource. Up until now, the distribution of most federally protected species and commercially harvested species was allopatric; hence the take of protected species was inconsequential. However as the list of federally endangered mussels continues to increase beyond the 56 species currently protected, the co-occurrence of harvested and protected species will create management problems for state wildlife resource agencies. Similarly, the spread of the zebra mussel (*Dreissena polymorpha*) into rivers with commercially exploited native mussel species is beginning to generate reactionary responses to conserve and protect native species. The impact of zebra mussels on native mussels in rivers is currently being documented in the Illinois River. Zebra mussels were first collected in this river in summer 1991, and after 2 years, most of the native mussels are encrusted with zebra mussels. As judged by the infestations recorded in the Great Lakes and the extirpation of native mussels from Lake St. Clair, western basin of Lake Erie, and the Detroit River, I project a major die-off of native mussels in the Illinois River in summer 1994. If this die-off occurs, then many states will respond to the zebra mussel threat by restricting or closing harvest of live mussels in their respective waters. Many mussel species, once common in rivers, will become candidates for federal protection. The future of commercial musseling in the U.S. is in jeopardy.

STATUS OF THE FRESHWATER MUSSEL FAUNA IN THE UNITED STATES. **Richard J. Neves**[1] and **James D. Williams,**[2] [1]Virginia Cooperative Research Unit, Virginia Polytechnic Institute, 100 Cheatham Hall, Blacksburg, VA 24060-0321, [2]National Biological Survey, National Laboratory, 7920 NW 71st St., Gainesville, FL 32606, USA.

A comprehensive review of the conservation status of the 297 species and subspecies of native freshwater mussels in the U.S. was completed to assess present and future trends for the fauna. Distributional data, historic and recent collection records of biologists, and literature reviews provided sufficient information to categorize the status of each species. Twenty-one taxa (7%) are listed as endangered but presumed extinct; 77 (21%) are endangered but extant; 43 (14%) are threatened; 72 (24%) are of special concern, 14 (5%) are of undetermined status; and only 70 (24%) are considered stable at this time. The primary reasons for the

decline of freshwater mussels are habitat destruction from dams, channel modification, siltation, contaminants, and the introduction of exotic mollusks. Construction of dams within the Tennessee River system by the Tennessee Valley Authority, and dams and navigation projects in large rivers by the U.S. Army Corps of Engineers created impoundments and tailwaters that were unsuitable for many indigenous species. Nonpoint source pollution from agriculture and urban runoff, and point source discharges have contributed pollutants and contaminants to degrade water quality. Competition from non-native mollusks such as the Asian clam (*Corbicula fluminea*) has seemingly affected some mussel populations in streams, and the zebra mussel (*Dreissena polymorpha*) appears poised to decimate commercially important mussel populations occurring in large rivers. The high numbers of imperiled freshwater mussels in the U.S., which harbors the most diverse mussel faunal globally, indicate an impending extinction crisis that will severely reduce an important component of aquatic biodiversity. The harvest and export of mussel shells for the cultured pearl industry in Asia will be affected by the decline in mussel populations in the U.S.

THE DEVELOPMENT OF BLACK PEARL FARMING IN MANIHIKI. **Raymond Newnham,** Terone Pearls LTD, Tauhunu Manihiki, Cook Islands.

This paper looks at the development of black pearl farming in Manihiki, a coral atoll in the North Group of the Cook Islands.

The focus is on the three areas of the industry: access to technicians, material supplies, and marketing. The functions of the development agencies responsible for pearl farming in Manihiki are discussed.

Some considerations are offered to other countries comtemplating implementing pearl development programs.

NATURAL PEARL FARMING IN THE EARLY CENTURY AT BAHIA DE LA PAZ, SOUTH BAJA CALIFORNIA, MEXICO. **Martha Micheline Cariño Olvera,** Universidad Autónoma de Baja California Sur, Departamento de Humanidades, Km 5.5, Carr. al Sur, La Paz B.C.S., 23080, México. FAX (112)1.18.80.

The Bay of La Paz, during the first two decades of the century, was the stage of a unique event in the pearl world history: a large scale production of natural pearls through the extensive culture of *Pinctada mazatlanica*. The performance of this production was accomplished by Don Gastón Vives, based on his technological innovations and deep knowledge of the local environment.

In 1903, Vives founded the "Compañía Criadora de Concha y Perla de Baja California S.A." (CCCP), that employed more than 1000 workers and possesed a large infrastructure in the islands Espiritu Santo, San José and Cerralvo.

The success of Don Gastón has to be explained in the regional, national, and world historical context, because of the particular work and pearl/pearl oyster trade conditions of the early century and the close relations existing between the economic development and the political control of the Porfirian dictatorship.

The CCCP grew in exponential proportions until July 1914, when under the flag of the Mexican Revolution, a very staunch enemy of Vives destroyed his installations. Therefore, the study of these event in the pearl world history has to be analysed parallel to the historical and the scientific domains.

The technology of the CCCP was founded on the three traditional steps of the extensive culture of bivalves, although Vives adapted the process to the conditions of the local environment by designing original artifacts and installations.

The devices used for spat collection were wooden cases (2 m^3) with metallic net inside forming compartments that contained a substrate composed of branches and pearl oyster shells. These collectors were placed afloat near the natural banks, and they remained in the water for ten months. The juvenile pearl oysters were carefully harvested one by one and transported to a new site for the fattening phase.

It was in this intermediary stage when Vives utilized one of his most original inventions. The pearl oysters were arranged into baskets (15 $\times$ 30 cm) manufactured with metallic net that had individual compartments. These baskets were placed in the channels of a large nursery located at San Gabriel Bay in Espiritu Santo Island.

For the construction of this nursery, Vives made good use of the physographic features of San Gabriel Bay and its coastal lagoon that he had separated by a rubble-work dam 1 km long; on one side, he built 36 channels disposed in a zig-zag pattern. The water circulated through these channels by a flood-gate system that operated with the tides. These channels were protected by a palm roof that offered cool shade to the young oysters avoiding the negative effects of excessive illumination and high temperature.

When the individuals grew up to adult size, they were taken to the open sea and placed at the bottom on hand-made substrates. These had been previously prepared using huge quarry stones taken from the nearest islands. Each adult pearl oyster, before it was established on its permanent habitat, was covered by a metallic armour-plating with sharp points around the margin, and provided with a cork bark that helped the whole to have an orientation towards the substrate. In these artificial stone beds, and with their highly efficient protection against predators, the development of pearl oysters was set under a rigorous vigilance for two to three years until pearl harvest time.

The CCCP employed the traditional *armada* system for the harvest-fishery procedure. This system used one large boat (45 ft) and several canoes provided with 6 or 8 scaphander pearl divers. All the pearl oysters were opened in the boat or on the Espiritu Santo installations, under a strict surveillance.

All the product of these molluscs was used: the meat fed the workers, the shells were packed in wood cases ready for their export to the European and American markets, and the natural pearls that were found were taken by Don Gastón Vives to the Paris jewellers that appreciated very much their high quality orient, exotic colors, regular shapes and huge size. The profits, always very rich, were invested in the enterprise, either in the pearl oyster culture installations and operations, or in other economic activities developed with the purpose of making more profitable the pearling industry. These economic strategies are important factors that explain the fast improvement and growth of the CCCP activities.

The political activities and relations of Don Gastón, plus his personal business administration management, also led to the large expansion of the CCCP. From 1894 to 1911, he was the municipal president of La Paz—the second most important political post in the region—which offered him a privileged situation for eliminating almost every obstacle or enemy that the CCCP would meet. At that time, the socioeconomic local structure offered him numerous and cheap workmanship, from which he could obtain a maximum profit employing them in the day-labourer system that was current at that time. We cannot talk about any abnormal exploitation of workers: he paid them a good salary, fed them and their families during the time they were employed, and contributed to the education of their children; but the rules were very strict and so were the punishements when they were not respected.

In the sight of reducing the expenses of nourishing and transportation of the workers, Don Gaston developed, parallel to the CCCP, other economic activities, such as agriculture, in a farm called "Las Cruces," and cattle-raising in the natural enclosed fields of the islands included in the territorial concession. He also employed some resources undertaking commercial and shipping activities with the two steam boats of the enterprise. Through this diversification of economic activities, and considering that the CCCP employed (between 1912 and 1914) more than 16% of the whole population of La Paz, we may affirm the significant role that pearl oyster culture and pearl trading have had in the socioeconomic local structure.

Another positive consequence of these rational strategy of pearl oyster proficiency, was that the massive culture of this highly important resource had temporarily caused the overexplotation of the natural beds. After the destruction of the CCCP, no other culture experience was undertaken, but the unmoderated pearl oyster fisheries continued under the misunderstood principle of free exploitation of the national natural resources by any Mexican who wished. The consequence of 25 years of overfishing of the natural pearl oyster beds was that the most important local resource came to exhaustion and the Mexican Government declared a permanent banning in 1939. Nevertheless, furtive and uncontrolled extractions have continued until the present days. In several cases, these extractions are carried out by local institutions under the excuse of research purposes which have not produced any positive results.

We know that only one recent research program on pearl oyster culture, pearl production and repopulation, under the direction of Dr. Mario Monteforte from the Centro de Investigaciones Biológicas del Noroeste, has achieved positive and promising results. This program has brought new and solid hopes for La Paz to recover its worldwide reputation that once gave to this region the name of "Island of Pearls".

BLACK PEARL CULTURE DEVELOPMENT IN THE PACIFIC ISLANDS. **Gary L. Preston,** South Pacific Commission, Noumea, New Caledonia.

The paper describes the potential for, and constraints to, the development of black pearl culture industries in those South Pacific island countries where such industries do not yet exist. The paper also describes the international institutional arrangements presently in place to support marine resource development efforts in Pacific Island nations, and suggests ways in which they might be strengthened specifically to support pearl culture industry development.

PEARL OYSTER CULTURE IN MEXICO. **Dr. Carlos Rangel-Dávalos and Carlos Caceres,** P.O. Box 18-B, La Paz, Baja California Sur., Mexico C.P. 23081.

From 1900 to 1914, pearls were produced in Mexico by culturing oysters to obtain natural occurrence. Government formerly prohibited pearl oyster fisheries in 1940, in order to recuperate natural beds from strong catches. A group of professors researching in Baja, California Sur State University is doing research and development on the subject, together with training students. Aim is to initiate extension projects and offer technical advice.

SOCIOECONOMIC AND POLITICAL ASPECTS OF THE TUAMOTUAN BLACK PEARL INDUSTRY. **Moshe Rapaport,** University of Hawaii, Department of Geography, Porteus Hall, Honolulu, HI 96822.

Black pearl farming in the Tuamotus has experienced dramatic growth in recent years. However, among the atoll communities, there have been deep divisions on the criteria to be applied for allocating lagoon concessions. Management efforts by the Tahitian administration have been frustrated because of their insufficient attentiveness to local concerns.

PEARLS AND ECONOMIC DEVELOPMENT. **John T. Rowntree,** RDA International, Inc., 801 Morey Drive, Placerville, CA 95667.

Several international development agencies and South Pacific governments are actively encouraging the expansion of the cultured pearl industry as a technique for promoting economic development. This presentation will explore the role of pearl farming in stimulating economic development and in generating employment, income, and foreign exchange for developing island economies. It will also address the monetary and fiscal implications and some of

the socio-economic consequences of expanding pearl production to promote economic development.

AN OVERVIEW OF PEARL PRODUCTION TECHNIQUES IN AUSTRALIA. David (Dos) O'Sullivan[1] and Derek Cropp.[1,2] [1]Key Centre for Teaching and Research in Aquaculture, University of Tasmania at Launceston, PO Box 1214, Launceston, Tasmania, 7250, Australia. Tel: +61 03 243-448, Fax: +61 03, 243–449 [2]Aquatech Australia Pty Ltd and Abalone Pearls Pty Ltd, 15 Wignall St, North Hobart, Tasmania 7000, Australia. Tel: +61 02 349-337, fax: +61 02 311-627.

The pearl culture industry in Australia has been operating since the mid 1950s. The main production comes from the northwestern coast of Western Australia, although production is increasing in the Northern Territory and north Queensland, especially in the Torres Strait region. Shell are harvested at licensed collecting areas under a quota system to prevent overfishing of the stocks. Seeding is undertaken at the harvesting leases or on the farms.

On almost all the farms, the seeded pearl shells are held in specially designed net panels, each with about 6 or 8 mesh pockets in which to hold the shell. Farms are moving away from the traditional raft culture into the use of surface longlines or bottom fences, mainly as a preventative measure to avoid losses from cyclones. The shells are regularly cleaned using high-pressure water and are X-rayed after 6–8 months to check for the presence of the nucleus.

Harvesting of the pearls takes place about 2 years after implantation and some shells may be reseeded up to 3–4 times before being used for mabe production. With the advent of hatchery production of juveniles, technology is being developed for nursery culture and subsequent growout of these small shell until they reach a seedable size (1–2 years old).

STATUS AND POTENTIAL OF PEARL FISHERY OF BANGLADESH. Manamatha Nath Sarker, Marine Fisheries Survey, Management & Development Project, Cox's Basar, Bangladesh.

Bangladesh is famous for her natural pink pearl. These are obtained from the freshwater mussels, like *Lamellidens spp.* and *Ferreysia spp.* Another kind of small white pearls is obtained from marine windowpane oyster (*Placuna placenta*). Pearl oyster (*Pinctada fucata*) is reported to be available, but there is no information on collecting pearls from them. The species of *L. marginalis* reaches up to 10 cm and produces pink coloured pearls, whereas *P. daccaensis* grows up to 6 cm and produces golden coloured pearls. *L. marginalis* is abundant in almost all freshwater bodies of Bangladesh, particularly in lowland areas where water is available throughout the year. The main area of distribution comprises the greater district of Sylhet, Dhaks and Mynensingh. The natural pearls collected annually are estimated to be 150 kg, with negligible amount from farming. Mussel meats are used for poultry feed, while the shells are mostly used for producing shell craft and lime. Some shells are also used as a mineral source for poultry feeds. Although there is a great potential for pearl culture in both freshwater and marine water bodies, pearl culture has not yet flourished commercially in the country, due to lack of technical know how and financial constraints.

BREEDING CYCLE OF PEARL OYSTERS *PINCTADA MAZATLANICA* AND *PTERIA STERNA* IN BAHIA DE LA PAZ, SOUTH BAJA CALIFORNIA, MEXICO. Pedro Saucedo[1] and Mario Monteforte,[2] [1]Boursar PIFI of CICIMAR-IPN, [2]Grantee International Foundation for Science, Centro de Investigaciones Biológicas del Noroeste, P.O. Box 128, La Paz, B.C.S. 23000, México. FAX (112)5.36.25.

This study intends to increase our knowledge of the reproductive biology of the mother-of-pearl *Pinctada mazatlanica* and the rainbow mabe *Pteria sterna* from Bahia de La Paz. It is aimed at completing the spat collection strategies and enhance nucleus implanting operations for the production of cultivated pearls.

Between June 1992 and July 1993, gonad samples of cultured individuals of both species were collected monthly (10 individuals of each specie) and preserved in 10% formalin. They were then embedded in parafin, sectioned at 7 μm, colored with hematoxylin-eosin and observed at 10 and 40× magnifications. The reproductive cycle was studied by dividing it into five main gonadal stages: 1) indeterminate, 2) gametogenesis, 3) maturity, 4) spawning and 5) spent. The histological observations were supported by a gonadic index.

The sample size might seem rather small for the purpose of histologic studies. However, since this work was carried out using cultured individuals, and not many were available for being sacrificed, we had two options to choose from: either we increased sample size covering only a restrained temporal period, or we used smaller samples but we could cover an annual cycle. We decided for the second alternative which we believe to be richer in information.

In both species, gametogenesis was a continuous process through the year. *P. mazatlanica* bred once a year between August and September (summer), when water temperatures reached 28 to 30°C. It is a protandrous hermaphrodite which matured as female at a shell height greater than 100 mm (approximately 22 to 24 months old). Below this size, all organisms were males. Because we used young-adult organisms in this study, the sex-ratio we found was 0.12:1. Finally, the first gonad maturity was observed at a shell height of 50–55 mm (11 to 13 months old).

The breeding season for *P. sterna* was bimodal with two spawnings in the year, the main one in January–February (winter) when the water temperature was about 20 to 22°C, and another short one in May (spring) at 23 to 25°C. There was not enough evidence to conclude the species to be a protandrous hemaphrodite, but the highest proportion of females was found over 55 mm of shell height (older than 10 to 11 months). The sex-ratio also tended to male at young stages (0.38:1). The first gonad maturity of this species seemed to occur at a shell height of 40–45 mm (7 to 9 months old).

From these results, we could deduce that a periodical determination of the gonad maturity of the population by sampling some wild and/or cultured organisms (selecting medium to large sizes) could improve the strategy for massive spat collecting operations by previewing the right moment to install the collectors.

Additionally, from these observations we could advance that the best season for nucleus insertion (round pearls in particular) is between November and January for *Pinctada mazatlanica* and between April and June for *Pteria sterna*. We suppose that in these periods most of the receptors would present spent and/or indeterminate gonadal stages which is ideal for the surgery.

REPOPULATION OF NATURAL BEDS OF PEARL OYSTERS *PINCTADA MAZATLANICA* AND *PTERIA STERNA* IN BAHIA DE LA PAZ, SOUTH BAJA CALIFORNIA, MEXICO. **Pedro Saucedo,**[1] **Mario Monteforte,**[2] **Horacio Bervera,**[3] **Victor Pérez,**[1] and **Humberto Wright,**[1,4] [1]Boursar PIFI of CICIMAR-IPN, [2]Grantee International Foundation for Science, [3]Universidad Autónoma de Baja California Sur, [4]Boursar CONACYT, Centro de Investigaciones Biológicas del Noroeste, P.O. Box 128, La Paz, B.C.S. 23000, México. FAX (112) 5.36.25.

The natural beds of pearl oysters of Bahia de La Paz have been overexploited for more than 400 years. *Pinctada mazatlanica* and *Pteria sterna* are considered as endangered and have been under legal protection since 1940. Nevertheless, furtive fisheries are still carried out by fishermen and tourists who are influenced by the same Pearl Myth that motivated the Spanish empire and large fishing enterprises to colonize and exploit this aggressive and isolated territory.

Today, the resource is rare and the local populations are discontinuous along the coast. The "banks" present low densities and natural recruitment is also low. In addition to this, there are uncontrolled extractions, some of them performed by local institutions which use research purposes as a false excuse without any consideration about the fragile equilibrium of the resource and no intention to realize repopulations.

In our research program on pearl oyster culture, the repopulation of natural beds is considered as a main objective. With recovery and conservation of the resource in mind, the study on repopulation is aimed at defining adequate seeding techniques using cultured individuals and repeating these actions as frequently and extensively as possible.

In the present work, we report the results of two years of repopulation experiences.

Different seeding conditions were tested using two groups of 300 cultured individuals of *Pinctada mazatlanica* and *Pteria sterna* each year. Trials were carried out in one site (station Merito) in 1991 on protected and unprotected, natural and artificial substrates. Natural substrates were the *in situ* rocks; artificial substrates were boards (45 × 30 cm) made with cement, asbestos and fiberglass.

Protection was provided by the use of large soda plastic cases (45 × 30 × 14 cm) which had the bottom cut out and the top covered with 5 mm mesh net. Each individual was placed in the spaces originally used for bottles therefore to ensure direct contact with the substrate. In the unprotected experiment, the individuals were distributed into large-mesh net bags and placed in direct contact on the substrates. We also evaluated two additional variables: depth of seeding (3, 6 and 9 m) and organism size defining three groups (larger than 80 mm shell height, between 60 and 80 mm and smaller than 60 mm).

The observations were made at the second, seventh and fifteenth day after seeding. From the 15th day on, observations were taken monthly and bimonthly. We wished to assess mortality, settlement speed and strength and in situ growth of organisms.

Settlement strength was evaluated using the following indexes:

Index 0: there are practically no byssus threads attached to the substrate.

Index 1: some byssus threads are attached but the settlement is weak.

Index 2: there are more byssus threads attached to the substrate and the settlement is almost normal. The organism can still be moved side to side but possesses resistance.

Index 3: practically all the byssus threads are perfectly attached to the substrate. The organism is settled normally and possesses strong resistance of movements.

The degree of protection against predators was a very important factor for the survival of seeded individuals. Those placed on unprotected repopulation cells were rapidly consumed since the first or second day of seeding. From the observation of some of the broken shells we were able to recover, we suppose that large malacophage fishes (Tetrodontidae, Serranidae, Lutjanidae), as well as portunid crabs and lobsters could be the most common predators.

Protected natural substrates enhanced settlement speed and strength and organism growth, whereas artificial substrates did not. Among the artificial substrates, the asbestos gave better results than cement and fiberglass. This last was completely ineffective.

A seeding depth of 6 m gave the lowest mortality, the highest settlement speed and strength, and the best individual growth. Individuals of small to medium size, particularly the latter, gave the best responses to all the variables tested.

In 1992, from the results of the first experience, we used special large cages manufactured with rigid plastic 5 mm mesh with medium size flat stones (10 to 15 cm in diagonal dimension) arranged on the bottom. These cages are being used now as repopulation cells in the coast of El Merito and Bahía Falsa. So far, the results are highly positive. Every spat collecting season of *Pinctada mazatlanica* and *Pteria sterna,* we reserve half of the harvest for repopulation actions. We hope that the gradual recovery of pearl oysters in Bahía de La Paz is starting with our modest effort.

HATCHERY CULTURE OF THE BLACK-LIP PEARL OYSTER IN HAWAII—STOCK RE-ESTABLISHMENT AND EXPANSION OF COMMERCIAL PEARL CULTURE THROUGHOUT THE REGION. **Neil Anthony Sims** and **Dale J. Sarver,** Vice-President (Research), and President, Black Pearls, Inc., P.O. Box 525, Holualoa, HI 96725.

The establishment of a commercial hatchery for black-lip pearl oysters (*Pinctada margaritifera*) at the OTEC facility in Kona, Hawaii, has significance for the preservation of threatened populations, as well as opening up commercial pearl culture potential for Hawaii and other Pacific Islands.

The Hawaiian variety of black-lip (*P.m.galtsoffi*) was overfished in the past, and is now rare to the point of being protected by the State. Relict stocks in Pearl and Hermes Reef, Kaneohe Bay, and along the Kona Coast show no signs of recovery. Hatchery culture would allow a stock re-establishment program. Ocean-based pearl farming options are being explored at several sites throughout the Hawaiian Islands. Land-based pearl culture is also being developed at the OTEC plant in Kona.

The feasibility of using pathogen-free deep-OTEC water for broodstock maintenance, larval culture and early spat rearing has been proven in trials with Marshall Island pearl oysters. These techniques remove the risks of inadvertent transfer of exotic organisms (pathogenic or benign) and genetic mixing between stocks. Pacific Islands with small quantities of broodstock can now use this system to provide spat for stock re-establishment or development of commercial pearl culture.

With this technology, the natural scarcity of pearl oysters in a lagoon is no longer a principal constraint to the development of pearl farming. The Kona facility can operate as a regional hatchery for the central Pacific, obviating the need for expensive construction and operation of pearl oyster hatcheries on each island group.

FRESHWATER PEARL CULTURE IN INDIA. **Ajai Kumar Sonkar,** 557/470 Old Katra, Allahabad, UP 211 002, India.

Since time immemorial, the Indian Ocean was famous for natural pearls. In the late eighties, some natural pearls were found in a lake in Agartalla (capital of 'Tripura' State). Until then, pearl cultivation from fresh water was not well known in India.

Scientists from the Central Institute of Fresh Water Aquaculture (CIFA) have examined the feasibility for production of cultured pearl in fresh water.

A research project of the Dept. of Biotechnology on fresh water pearl culture was initiated in CIFA in the year 1982, when several successful experiments were undertaken on three species (*Iemellidens-marginalis, L. Corrianus, & Parreysia-corrugata*) for nucleated spherical pearls.

The author's involvement in fresh water pearl culture began in May 1991. In two fish ponds owned by his family, a natural stock of fresh water mussels was available.

In a small laboratory constructed on the farm premises, experiments on pearl culture were initiated. Initially, the author fabricated his own nuclei of caldiferous substance for implantation.

In the early trials, more than 20% operated mussels would to die due to surgery, and about 50% animals would reject the implantation.

After short term training at the Central Institute of Fresh Water Aquaculture in 1992, the author started experiments to determine the causes of mortality and rejections. Generally, species are not differentiated in pearl mussel surgery, often one species mantle tissues were implanted in other species.

In fact, two species (*L. marginalis & L. carrianus*) available in India are suitable for gonadal implantation and are often found together in the same pond or lake.

In experiments, the author used the same species' mantle for grafting in the same species, and sprayed steroid on the operated mussels to stimulate their immune systems and antibiotics to counter possible infections.

After surgery, the recipient mussels were kept in laboratory conditions up to 14 days for post-operative care under proper aeration and aseptic conditions. During the period feeding and movement were restricted.

Through the experimental process, 70% efficiency was achieved with a mortality rate of zero.

It is observed that an ideal pearl takes about six months to one year to form depending upon the size of the implanted nuclei. It is found that the Indian climatic condition in several parts of the country is favorable for pearl culture, and this field offers considerable commercial possibilities for India and neighboring countries.

PEARL FARMING IN VIETNAM. **Ha Duc Thang,** Marine Product Research Institute, 170 Le Lai Street, Haiphong, Vietnam.

Vietnamese understood the use of pearls a very long time ago, but scientists of the Marine Product Research Institute started research on pearl culture only in 1966.

In 1967, the first pearl farm was set up at Co-lo Island (belonging to Quang Ninh province of North Vietnam). It had produced many round pearls from *Pinctada martensi* mussels. However, in 1973, because of the war, it had stopped. In recent years, the pearl culture project was set up with assistance of government in Cat Ba Island (belonging to Haiphong Province). Some experts from Australia and Japan came and started producing pearls at Nhatrang Province and Halong Bay (in the north).

There are many species of pearl oysters in Vietnam namely: *Pinctada martensii, Pinctada margaritifera, Pteria penguin, Pictada maxima* and *Pteria formosa.* Vietnamese are farming *Pinctada martensii* mussels at Halong bay and Australians are farming *Pinctada maxima* at Nhatrang Sea.

In fresh water, there are 38 species of freshwater mussel, but only 5 species are used to produce pearls. They are: *Hyriopsis cumingi, Cristaria bialata, Anodonta eliptical, A. jondui, Lamprotula. sp*. All of them are distributed in rivers and ponds with a depth of 7 to 16 m.

The *Hamprotula* especially has a shell thickness ranging from 8 to 12 mm. All nuclei in Vietnam are made of Lamprotula mussels.

All culture systems and culture techniques are based on the techniques of China and Japan. The hanging method using rafts and long line is widely employed.

The nuclei implantation technique in marine pearl oysters is almost the same as that used for *Pinctada jucata* in Japan. There are 5 methods employed in the fresh water pearl culture. They are: Inserting graft tissue into the mantle of mother oysters (producing seed pearl). Implanting nucleis with graft tissue into the gonad of mother oysters (producing round pearl). Implanting nucleis with graft tissue into the mantle of mother oysters (producing round pearl). The results of research show that: implanting a nuclei with graft tissue into the mantle of a mother oyster is best because we can insert about 8 to 10 pieces of nuclei in each mussel (diameter of nuclei is 3 to 5 mm and the expulsion rate is 30 to 40%). After 18 months of culture, pearls grow to 7–8 mm (diameter of pearl). The color of the pearl depends on the tissue inserted.

Our research has found that if one uses the graft tissue of *Cristaria*, one will get pearls of silver or blue colors.

Graft tissue of *Anodonta* gives pink and cream pink pearls.

Graft tissue of *Hyriopsis* gives cream pearls and some gold. The mother oysters are *Hyriopsis cumingi*, and experiments were done at the same place and many times from 1986–1990 in Ho-Tay Lake and ponds of our Institute of Haiphong.

Halong Bay is not only famous for its beauty with thousands of small islands rising from the sea surface, but is also a good place for pearl culture.

The water depth ranges from 5 to 10m and the water temperature is about 20°C in winter 29–32°C in summer. The salinity ranges between 23–25 ppt during the rainy season, and between 31–35 ppt in the dry season. The density of phytoplankton is about $2\text{–}3 \times 10^6$ cell ml. There are many rivers and large ponds in the north which can be used for good pearl culture sites, and the resources for pearls are also rich.

PEARL CULTURE ON TONGAREVA, COOK ISLANDS: IMPACT OF COMMUNITY BASED MANAGEMENT. **Hugh Thomforde, Rorangi Tonitara,** and **Amelita Tabique,** RDA International, Inc., Tongareva Marine Research Ctr., Ministry of Marine Resources, Omoka, Tongareva, Cook Islands.

The authors live on Tongareva (also known as Penrhyn) in the Cook Islands. They review the development of the cultured pearl industry and the effects of traditional fishing and recent economic factors on that development.

Prior to 1992, the majority of the residents on Tongareva were either uninterested or opposed to pearl farming. A large share of the adult population feared loss of local control over lagoon tenure rights and increased control in all lagoon affairs by the central government. As many as 5% of adults in the village of Omoka feared pearl seeding would induce a biological catastrophe on the scale of a nuclear explosion with the consequent necessity to evacuate their homeland. This was apparently due to the incorrect association of the word "nucleus"—used to refer to the beads used in spherical pearl seeding—and the word "nuclear" in regards to the contamination experienced at Bikini and Enewetak atolls in the Marshall Islands. In March, 1993, the Penrhyn Island Council shifted from a policy of opposition to supporting pearl seeding, although public opinion remained highly divided on the issue. By November, 1993, pearl seeding licenses were initiated and prospective pearl farmers were required to apply for a permit from the Island Council. The economic potential of pearl farming was the overriding factor which influenced people to support commercial farming. The recent collapse in the copra industry due to reduced world market prices, and the steadily declining price for pearl shell have obviously been influential. From November, 1993 to January, 1994, support for pearl farming and commercial seeding ran at about 95% of the adult population in the village of Omoka. There is still lower support for pearl culture at the village of Tetautua because of a greater reliance on regular harvests of pearl shell for basic subsistence. It is anticipated that opposition for establishment of reserve areas, or for a total ban on wild harvesting, could come from Tetautua.

A BRIEF ACCOUNT ON MYANMAR'S PEARL CULTURE INDUSTRY. **Tint Tun,** 267 Bargaya Road, Myaynigone, Sanchaung P.O., Yangon, MYANMAR.

The history of Myanmar's pearl culture industry is 40 years old. It is significant that the whole operation of pearl cultivation, from fishing, through seeding, to harvest, has been carried out by Myanmar citizens for three decades. In accordance with its market economy system, local and foreign companies are interested in pearl cultivation in Myanmar.

According to Myanmar literature, the pearl is one of nine precious stones, and grace is an attribute of the pearl. Union of Myanmar is a South Sea Pearl (SSP) producer and pearls are cultivated by Myanmar culturists. It has been 40 years since Japanese technicians introduced pearl cultivation to Myanmar and four decades is considerable time since the birth of the pearl culture industry. Today's production of precious South Seas Pearls (SSP) is by Myanmar technicians and Myanmar citizens.

Pearl cultivation was commenced in Myanmar in 1954, although pearl oysters were exploited for mother-of-pearl shell trading since the 1890s. The Burma Pearl Syndicate was established in 1954 as a consequence of negotiations between Myanmar and Japanese (Takashima Pearl Company) businessmen to form a joint venture pearl culture industry. The syndicate started pearl cultivation and MOP shell collection at Mergui archipelago in Myanmar.

Myanmar citizens were appointed to work at the pearl culture station, but seeding was done by Japanese only. Japanese did not show or instruct Myanmar about seeding while they were working at the syndicate. The syndicate brought in modern diving equipment and diving boats. It is known that all pearls cultured by the syndicate were brought to Japan and they were sold under the name of "South Sea Pearl."

A new chapter in the history of Myanmar's pearl culture industry was started in 1963. On 16th, August, 1963, Burma Pearl Syndicate was nationalized and pearl cultivation became a branch of the People's Pearl and Fishery Board. Later, the Board was transformed into the state-run People's Pearl and Fishery Corporation.

A visit to Pearl Island was arranged in April, 1964, by an authority concerned for teachers and students of biology of Yangon (Rangoon) University. They were encouraged to do pearl cultivation at the Island. A group of four teaching staff was interested and were allowed to transfer from the University to Pearl Island. By appointing them as pearl culture officers, they became the first group of Myanmar pearl culturists.

As they were not taught anything about seeding and cultivation, pearl culturists tried to produce SSP with an all-out effort. Fortunately, they had the opportunity of thorough investigation on pearl cultivation themselves. As a result of coordination and cooperation among the technicians, doctors of medical college and military hospital, and personnel and department concerned, Myanmar culturists did, at last, succeed in seeding. Since that time, the whole operation of pearl cultivation has been controlled by Myanmar citizens. It is a significant fact in the history of Myanmar pearl culture industry. The first pearls—a hundred momme of SSP cultured by Myanmar technicians—was harvested in the 1967–68 fiscal year.

The relocation of the pearl culture branch was done in 1986. It was attached to the Salt Industries Corporation. However, in 1989, it became a separate state-run enterprise. The name was "Myanma Pearl Enterprise" and it was the only pearl cultivator in Myanmar until 1992. (Note: Myanma is an adjective form of Myanmar in Myanmar language).

Pearls were put on sale at successive auctions held at Yangon. A total of 40 lots of pearls fetched 413,034 at the 31st Myanma Gems Emporium which was held in March, 1994.

A VIEW ON SEEDING. Tint Tun, 267 Bargaya Road, Myaynigone, Sanchaung P.O., Yangon, MYANMAR.

Seeding can determine the quality of a pearl and seeding technicians play the most important role in seeding. Various grafting methods and nucleus sizes can be used commensurate with mother-of-pearl oysters. Research is important in all aspects of pearl cultivation.

To harvest a pearl, there are many processes in the way of its cultivation. Fishing, seeding and cultivation can be regarded as major phases and seeding can be said metaphorically as the heart of the whole process. Seeding can determine the quality of a pearl and, consequently, can determine the benefit of a farm.

Graft tissue plays an important role in pearl formation as it is responsible for secretion of nacre and it influences colour and lustre. Tissue transplantation can be achieved by three methods: autograft, homograft or heterograft.

In the autograft method, the operation, cutting graft tissue and transplantation, is done in each individual. In homograft method, a number of oysters are sacrificed so as to get mantle pieces to transplant in other of the same species. Homograft is a desirable method for small oysters such as *Pinctada funcata* but, autograft method is not preferable in such species. It is difficult to cut a piece of mantle from an oyster and then insert it in the same individual. It is certain that it will weaken the oyster much more than by the homograft method.

Autograft method is preferable in larger oysters such as *Pinctada maxima*. it could save oysters from undue killing just for mantle pieces although it takes much more time to do seeding for a large quantity of oysters. Since autograft and homograft methods are applied in the same species, there are no problems between graft tissue and host oyster. But, in heterograft method, it is important to know whether grafting is accepted by the host or not, because graft tissue is taken from other species. Heterograft method should be tried in experimental culture, as it can influence colour and lustre of a pearl.

Various sizes of nuclei are being used in seeding. Generally, small oysters can accept small beads whereas large oyster accept larger beads. However, seeding technicians use a range of size of nucleus for a species. There is no doubt about the fact that a large nucleus can produce larger pearls if the mother oyster can bear up to harvest. Therefore, the size of inserted nucleus strongly contributes to the size of pearl to be harvested.

Despite the fact that a higher rate of nucleus rejection or mortality of mother shells is more possible in large beads than small ones, technicians must be encouraged to use larger nuclei in order to produce larger pearls. Sometimes, targeting a quantity set for production can be a kind of constraint to seeding because technicians may not dare to use larger nuclei because it can affect the rate of success in seeding. A pearl farm must therefore consider a preference basis for production: quality or quantity.

Seeding technicians play an important role in seeding and the success or failure of the farm hinges on them. Skill and keen interest are significant qualification for seeding technicians. It is essential to know anatomy of the pearl oyster and to understand the theory of pearl formation and concept of seeding. They must be interested in seeding with heart and soul. Undesirable competition must not be observed among them and they must acknowledge each other. Discussion is an effective way to improve seeding techniques, although it is quite certain that each has his own secret. However, success rate is highly variable, especially in *Pinctada maxima*, in seeding in accordance with size or age or condition of mother oysters. *P. maxima* can grow beyond 25 centimetres in dorsoventral measurement.

Research is important in all aspects of pearl cultivation. Neglecting the important role of research or just having the satisfaction of previous achievement can lead to bring a once buoyant industry to hit rock bottom.

It will be best if seeding technicians are research-minded and like to collect data of their research. A number of oysters should be appropriated for research as it can provide positive or negative results. The results are invaluable indeed. Some experiment, such as the quality of the pearl, will take about three years to get a result and it is unpredictable whether it may be positive or negative. Pearl culturists should know that research cannot always give positive results. Trying to do research and to utilize the results will lead to a successful industry for many years.

LABORATORY GROWTH *RATES* OF PINCTADA *MARGARITIFERA*—A PRELIMINARY REPORT. **Jaw-Kai Wang,** Biosystems Engineering Department, University of Hawaii at Manoa, Honolulu, HI 96822.

Two groups of oysters were used in this preliminary experiment. In the first experiment, 75 *Pinctada margaritifera* were imported from Palau on March 15, 1993. Ten of the seventy-five were taken by the state quarantine officer. The oysters appeared to be healthy. The remaining 65 oysters went to a small integrated oyster-shrimp production facility on Coconut Island, Oahu. To meet the quarantine requirement, the facility was designed to sterilize its effluent before discharge into a drainage pit. Nutrients that came from shrimp production were used to produce algae to feed the oysters. As the water quality in the Kancohe Bay, where Coconut Island is located, varied greatly, we were unable to maintain a stable condition at the Coconut Island facility and the oysters growth rates varied greatly. On August 16, 1993, the oysters were moved back to the Aquacultural Engineering Laboratory, Biosystems Engineering Department, University of Hawaii at Manoa. Forty-six oysters died before we were able to stabilize them. Our growth experiment started on November 15, 1993 using the remaining nineteen oysters. The oysters were kept in 30 degree centigrade un-filtered sea water enriched with cultured algae at a density of 5×10^5 cells per milliliter. Algae were produced using sea water obtained from Kewalo Basin, Oahu, without inoculation. Under appropriate management practices, eighty percent Chactoceros dominate culture can be established without inoculation.

PEARL CULTURE IN CHINA. **Qiang Wang and Hualiang Wu,** Department of Agricultural and Resource Economics, Department of Biosystems Engineering, University of Hawaii at Manoa, Honolulu, HI 96822.

China is the world's largest potential pearl culture country. In 1992, China's export value of pearl reached 2.78$ million, which basically was primary pearl export. After the successful artificial pearl culture technique in *Pinctada fucata* in 1958, China set up the first pearl culture farm in 1964. However, China really developed the pearl culture at large scale after the end of 1970s. China's pearl culture can be classified into marine pearl culture and freshwater pearl culture. The major marine culture species of pearl oyster is *Pinctada fucata, P. margaritifera,* and *P. maxima,* which mainly distributes in Guangdong, Guangxi, and Hainan provinces of south China areas. The major freshwater culture species of pearl oyster is freshwater mussel, *Cristaria plicata* and *Hyriopsis cummingii,* which is generally distributed in the most East China, South China, and Central China areas. This paper will describe the history of pearl culture, especially oyster culture, present current principal culture methods, and examine main culture policies and problems, including the investment policy, culture technique, and market.

RECENT DEVELOPMENTS IN PEARL OYSTER RESEARCH IN INDIA. **A. C. C. Victor,[1] A. Chellam,[1] S. Dharmaraj,[1]** and **T. S. Velayudhan,** [1]Tuticorin Research Centre of CMFRI, 90, North Beach Road, Tuticorin-628 001, India. Central Marine Fisheries Research Institute, Cochin-682 014, India.

The occurrence of pearl oysters in the beds of Gulf of Mannar is known from time immemorial. The oysters were fished for their pearls whenever they were found to bear pearls and the fishing operations found to be economically viable. Research on such aspects of pearl oysters as farming, production of cultured pearls and pearl oyster seed, are of recent origin and in a period of 20 years, much information particular to Indian conditions has been collected and published in various journals.

Pearl oyster seed are produced in the hatchery. The scaling up of the seed production in the hatchery of the Central Marine Fisheries Research Institute at Tuticorin is achieved through investigations on oyster breeding, larval rearing, larval food production, spat-setting and in the rearing of juveniles.

The inshore waters in the southeast coast of Indian bordering the Gulf of Mannar are shallow and unprotected to a large extent from the vagaries of nature. A farming technology to suit local conditions has been developed and the juveniles and mother oysters farmed.

The formation of the nacreous coating on the implanted nuclei is rapid in the tropical Gulf of Mannar waters. Even though seasonal variation is not greatly pronounced here, experimental production of pearls during different periods has shown differential nacre growth and pearl quality. Unlike in temperate waters, all gonadial developmental stages can be encountered in the oysters throughout the year.

Many of these research and development efforts carried out on the pearl oysters at Tuticorin have streamlined cultured pearl production to develop into an industry in India.

A PEARL FARMING FAMILY. **Peter William,** William Family Pearl Farm, Manihiki Cook Islands.

The William family owns and operates the first and the largest local pearl farm in the Cook Islands. This paper reviews the history of the farm's development, and outlines the present status of the William family farm in Manihiki. The history of differences in development approaches and industry management between the local and the central governments are discussed. The paper describes the role these difficulties played in hindering development of the William farm, and the whole industry.

The importance of good seeding technicians is highlighted. Recent marketing strategies for Manihiki pearls are presented.

The socio-economic, cultural and political changes wrought by pearl farming are profound. These changes are described, and possible solutions are outlined.

STATUS OF PEARL CULTURE IN INDONESIA. **Tjahjo Winanto,** Seafarming Development Centre, PO Box 74/TK, Teluk Betung 35401, Indonesia.

Indonesia is an archipelago country with an extensive area of 13,667 islands. It has numerous bays and coves, and many sheltered areas which have good potential for pearl culture. Indonesia also has abundant pearl oyster resources. When properly developed, pearl culture can be one of the major non-oil commodity-generating industries, which can produce substantial revenues for the nation. The potential area suitable for pearl culture in Indonesia is at least 5,600 hectares.

At present, these wide areas for pearl culture are not yet managed properly. Most of the pearl companies are still managed by foreign investors and foreign experts. Just recently, some pearl culture has been handled by national investment and local, skilled experts. This situation has happened because of no special government institutional work in this activity. Considering this situation, Seafarming Development Centre, under the Directorate General of Fisheries, is the one government institution which has responsibility for pearl oyster farming and pearl culture, and also for transferring pearl culture technology. The results of this, compared to original expectations, leave much room for improvement, especially when the number of private pearl producers is taken into consideration.

The government action through the Seafarming Development Centre is not, however, of little value. The Centre helps to accelerate the process of the transfer of technology. This is demonstrated through the annual number of pearl exports (rounds, half-pearls, and mother-of-pearl shells), which is gradually increasing each year. In addition to that, many more pearl oyster companies have been successful in the mass production of seeds through hatcheries.