An Environmental History of Nacre and Pearls: Fisheries, Cultivation and Commerce

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The world history of nacre and pearl fisheries, cultivation, and trade is a vast topic. From antiquity to the present, it takes us on a journey from myths about the origins of the pearls and their different traditional uses, to complex interactions between societies, economies, cultures, and environmental issues. Such a history needs the support of different disciplinary approaches. Biological and ecological studies tell

us how oysters develop and form a pearl. Socioeconomic studies of pearls fisheries show several historical constants, such as excessive fishing, a specific organization of labor, and an unequal distribution of benefits. Studies on the trade of nacre and pearls highlight the cultural characteristics of different markets in the world. History of science emphasizes the link between the depletion of this natural resource and the scientific investigations that led to the development of pearl oyster and pearl culture technologies.

Nevertheless, the most interesting way to look at the exploitation of pearls is from the perspective of environmental history, to highlight their important role in humanity's evolving relationship with natural resources. An environmental historical approach can explain the constant attraction that nacre and pearls exerted on many civilizations, and why they were invested with such high sumptuary and ornamental value that practically all wild stocks were eventually exhausted. A historical approach can also improve our understanding of the conditions under which pearl oyster farming and pearl culture started and developed in the different regions.

The objective we pursue in the present study is to show how, by studying nature management models in the specific context of pearl and nacre world fisheries, environmental history can point out opportunities for modern regional sustainable development. At present, any alternative management plans involving renewable natural resources should rely on detailed examination of these resources' environmental history, and of the broader context of causes, effects, and interactions.

Natural characteristics of pearl oysters

In world history, pearls are the earliest and most cherished gem, mentioned in some of the very earliest literatures (such as the Rig Veda, ca. 1000 B.C.). Pearls are also accidents of nature and, hence, rare. Mollusks can produce pearls as the result of self-defense reactions against external mechanical stimuli caused by irregular solid particles or foreign organisms that lodge into the animal and can-

not be expelled, provoking irritation in exposed body tissues. In Bivalves, such intrusive objects may enter via filter-feeding. In Gastropods, sores or abrasions can occur as a consequence of their habits (vagile and direct feeding, as herbivores, scavengers, or predators). Water currents carrying debris also provoke the same sort of reaction in both faunistic groups.

Mollusks are also able to produce plug-like nacred blisters or protuberant concretions on the inner face of their shell after surviving attacks by certain shell-drilling species (e.g., radular predatory snails) and borer-dweller species (barnacles, sponges, *Polydora sp.*, *Lithophaga sp.*, etc).

Nacre and pearls are produced by certain Bivalve (freshwater mussels and pearl oysters of the genus *Pinctada* and *Pteria*) and Gastropod mollusks (*Haliotis spp.*, *Strombus gigas*, and some members of the Trochidae and Turbinidae families). Nacre and pearl-bearing mollusks share the same basic aptitudes regarding their natural capacity to build up and reconstruct their shell, and to activate pearl formation with self-defense purposes. They also share several characteristics that are the ultimate reason of their usefulness for the production of ornamental objects and, hence, economic value.

A complex coincidence of natural conditions is required for these various species to produce nacre and pearls, especially when quality criteria become a factor. External conditions include the variation of a number of oceanographic parameters (such as water circulation and current patterns, content, composition, and concentration of nutrients and dissolved elements, turbidity affecting the penetration of light through the water, temperature, salinity, pH, etc.). Source and type of pollutants, when present, and alterations to the coastal environment also play a critical role.

The quality of nacre is judged by its texture, color, and luster. Bigger and thicker shells have better plus. The value of pearls is judged by the same criteria and, in addition, by their size, shape and symmetry. “Orient”, a special smoothness and homogeneous gleam of the surface, is also an important criterion, which usually applies to both nacre and pearls. Weight was a commercial factor in natural pearls, but is less significant today for cultured ones. Rarity can also

be a value factor (e.g., natural or cultured pearls of *S. gigas*, *Haliotis, Turbo* and *Trochus*).[1]

Pearl oysters are marine Bivalves of the family Pteriidae, which includes 4 genera (including *Pinctada* y *Pteria*) and more than 300 species, subspecies, and varieties. Few species of Pteriidae have been exploited commercially in the history of human communities. Those that have are widespread in intertropical sea regions. Only two commercial species are found north or south of the tropics of Cancer or Capricorn; respectively, *Pinctada martensii* in Japan and *P. nigra* in Southeast Africa. Pearl oysters usually live at depths between 1 and 35 m along the littoral belt of many sheltered seas, coastal lagoons, bays and estuaries. Natural beds thrive in areas protected against strong marine currents that could detach the animals from the substrate. Some species of *Pinctada* (*P. maxima, P. margaritifera varss., P. mazatlanica*) and *Pteria* (*Pt. penguin*, *Pt. sterna*) can live as deep as 70 m.

Like other Bivalves, adult pearl oysters reproduce by releasing millions of spermatozoids and ovules in the water. The probability of encounter and fertilization is extremely low. Larvae remain afloat for 30-35 days, at the mercy of oceanographic variations and predators, and then seek favorable substrates for fixation. Very few are lucky enough to accomplish metamorphosis. In the juvenile stage they are still exposed to numerous risks. Only a handful of them manage to reach adult age and reproduce. Small species like *P. martensii* and *P. fucata* attain sexual maturity at 6-8 months of age, while *P. maxima*, the largest of the family, requires up to 2.5 years.

Considering these vulnerabilities, it is easy to understand why overexploitation can be disastrous for oyster populations. Species having commercial value cannot withstand extraction beyond certain parameters (e.g., volume of extraction, size/age selectivity, extension and duration of fisheries, natural recovery rate, etc.). In pearl-oyster fisheries, larger animals were usually the main target; as

[1] M. Monteforte, "Ostras perleras y perlicultura: situación actual en los principales países productores y perspectivas para México", in *Serie Científica*, Vol. 1, (Special Number of AMAC, Asociación Mexicana de Acuicultores), Universidad Autónoma de Baja California Sur, La Paz 1990, pp. 13-18.

they got scarce, however, the fishermen would turn to the smaller ones. The introduction of diving suits aggravated overfishing and soon many areas showed alarming signs of exhaustion.

Aquaculture has provided some solutions for the replenishment and recovery of overexploited populations. In special cases, such as that of pearl oysters, it has totally replaced fisheries with their hazardous benefits. Today, pearl farming has evolved into a highly profitable endeavor, but the process was strenuous and full of incidents.

Nacre and pearls fisheries

The main purpose of pearl oyster fisheries was to obtain pearls, but the shell of some species also had high value. In the latter case, the benefit from pearls was left to chance and marginal, but nevertheless welcome. Species valued for their pearls are found in Sri Lanka (*Pinctada fucata*), Venezuela (*P. imbricata* and *Pt. colymbus*), the Persian Gulf (*P. margaritifera erythraensis*), and Sharks Bay in Australia (*P. maxima*). Those of the Torres Strait and the Malayan archipelago – both *P. maxima* – are primarily valued for their nacre. The species commercially exploited for both their shells and their pearls are those of the Gulfs of California and Panama (*P. mazatlanica* and *Pt. sterna*), the Red Sea (*P. m. erythraensis*), and the South and Central Pacific (*P. maxima* and *P. m. cummingi*).[2]

On the basis of biogeographic data and the intrinsic profile of populations, we can identify eleven marine pearling regions, differing in aspects such as the presence of one or another species, the size and density of oyster populations, incidence of natural pearls, and quality of nacre. These factors were decisive in regional economic and commercial dynamics, as well as in determining the degree of exploitation of pearl resources, whose socio-economic implications varied from one region to another. Thus, in the Gulf of Mannar, the Persian Gulf, the Gulfs of Panama and California, and in the

[2] M. Cariño, M. Monteforte, *Une historie mondiale des perles et des nacres: pêche, culture et commerce*, Ed. L'Harmattan, Col. Maritimes, Paris 2006, p. 97.

Red Sea, pearl-oyster fishing was an essential economic activity. Today, pearl oyster culture is important in Australia, the Philippines, French Polynesia, and Japan.

We can also classify pearling regions according to the period of their exploitation:[3]

1) from antiquity onward, beginning 2000 years ago (Gulf of Mannar and Persian Gulf, and Red Sea);

2) from the sixteenth century onward, after the Spaniards' arrival in America (coasts and islands of Venezuela, Panama and Gulf of California);

3) starting in the nineteenth century (coasts and islands of Southeast Asia, north and northwest coasts of Australia, south and central Pacific archipelagos, coasts and islands of east Africa, and southern coasts of Japan and China); these regions were later impacted by capitalism expansion.

The opening of fisheries in new regions occurred when formerly exploited regions had lost their profitability due to overexploitation. Only three fishing methods have ever existed: traditional apnea, fishing with diving equipment (diving suits or scubas), and dredging. The first one was commonly employed in all regions where pearl oysters were fished for food, ornamentation, or commercial purposes. The fishermen dove almost naked using a stone as ballast. They were equipped with a tool to detach pearl oysters from the bottom and a basket or net to gather the mollusks. Some wore a bone nose clip to help them equalize the pressure on their ears, although most just used their fingers. They also carried a knife or spear to defend themselves against sharks. In the Gulf of Mannar, shark attacks were so common that every boat required the presence of a "shark charmer", whose job was to keep these predators away from the working sites.[4]

[3] M. Cariño, *Les mines marines dans le golfe de Californie, Histoire de La Paz à la lumière des perles,* Thèse de Doctorat en Histoire et Civilisations, École des Hautes Études en Sciences Sociales, Paris 1998, pp. 198-237.

[4] G.F. Kunz, C.H. Stevenson, *The Book of the Pearls,* Dover Publications, New York 1993, (first ed.: The Century Company, New York 1908), pp. 99-104.

The exploitation of divers was a trait common to all pearling regions. The only thing that varied was the harshness of their working conditions, which often bordered on cruelty. In general, they were poorly paid and underfed, kept in endless debt by merciless bosses, and always exposed to illnesses and risks. However, pearl fishing was a source of employment for divers and workers, and generated considerable revenues for managers and merchants.

Diving equipment only began to be employed in the second half of the nineteenth century and was used in pearling regions where the species had good nacre quality. Nacre provided the raw material for the manufacturing of combs, hilts, buttons, works of inlay and jewelry, etc. While the shells were traditionally worked on location, the industrial use of nacre was largely controlled by Great Britain, which annually imported hundreds of tons from all the pearling regions in the world. Unsurprisingly, the leading companies, as well as all diving apparatuses, are of British origin.

The diving suit was introduced in the 1870s in Australia, the Gulfs of Panama and California, and some South Pacific islands. The divers of the Persian Gulf and the Gulf of Mannar refused to use this dangerous equipment. The use of diving suits sharply accelerated the exhaustion of wild stocks since it made them accessible at greater depths and for longer diving times (4-5 hours), and throughout the year. Of course, the leading companies were located in England. They imported hundreds of tons of shells from all the pearling regions, which rapidly faced depletion.

The exploitation of pearl oysters in the Gulf of Mannar, the Persian Gulf, and the Red Sea dates back more than two thousand years. Pearls were the chief luxury commodity from antiquity to the twentieth century, so the oyster populations of these areas were intensively fished.

The Persian Gulf was the top world producer of natural pearls, mainly from Bahrein Island. Its oysters had a high incidence of pearls of great beauty and variety of color. Pearls lost their importance in the regional economy in 1932, due to the impoverishment of oysters beds as a consequence of excessive fishing and the commencement of the oil industry.

The fisheries along either side of the Gulf of Mannar (India and Sri Lanka) gave fame to Indian pearls, which were the most appreciated after those of the Persian Gulf. On Sri Lanka side, the fisheries were controlled successively by the king of Kandy, the Portuguese, the Dutch, and the British, until 1887, when a sand tide covered most of the natural beds. Fisheries in this region were authorized after prospecting in the field. When the season was opened, almost ten thousand divers participated in this intense exploitation, installed in temporary camps that could house up to forty thousand people. Red Sea pearl oysters had low incidence of natural pearls, but their quality was excellent and the fishing was thus highly lucrative.

In the sixteenth century, the exploitation of pearling regions began in the New World as the Spaniards colonized the continent. Christopher Columbus was the first to discover the pearling wealth of the Venezuela coast islands. He even named the smallest *Isla de Las Perlas*. The Spaniards immediately proceeded to exploit the oyster beds, first forcing the native population to work for them as divers and then replacing them with black slaves. Once the pearling resources of Venezuela were exhausted, those of the Gulf of Panama were exploited until a first phase of exhaustion in the seventeenth century; then intensively again beginning in 1740, after their natural recovery. In 1535 Hernán Cortés started pearl fisheries in the Gulf of California, which was thus the third of the American pearling regions in time.

American pearls became the most sought after treasure in Europe, and one on which the wealth of Spanish cathedrals was based. They remained the main New World import until the discovery of gold and silver mines by the middle of the sixteenth century,[5] and even thereafter ranked among the most valuable raw materials imported from the Americas. The Spanish Crown maintained a monopoly on pearls and exercised a strict control on licenses for pearl oyster fisheries, on which it imposed the *Quinto Real* (a tax equal to 1/5 of

[5] J.I. Arnaud Rabinal, "Perlas y aljófar", in *Buena Vista de Indias*, 1, 2, 1992, p. 59.

the total value). The search of new locations for pearl fisheries also provided a stimulus for the mapping of unknown coasts.

The pearl oysters of Latin American coasts went through a phase of modern exploitation starting from the first decades of the nineteenth century, but by this time the main resource were no longer the pearls, but the shells. The fishing was intensive and conducted by European companies using local divers employing traditional diving methods, until the introduction of diving suits around 1870, which allowed divers to work longer and deeper, with significant economic consequences, but inevitably drove the resource to exhaustion by the third decade of the twentieth century.

In the nineteenth century, other pearling regions as well were opened to intensive exploitation under the impact of capitalist expansion, notably along the coasts and on the islands of Southeast Asia and north and northwestern Australia, in the archipelagos of the south and central Pacific, and along the coasts and islands of eastern Africa and the southern coasts of Japan and China.

The coasts of Australia possessed the most abundant and richest pearling resources in the world, and also the last to be discovered.[6] This because the continent's colonization is recent and pearl oysters were not part of the Australian aboriginals' diet. The Australian oyster populations included two species of great commercial importance (*P. maxima* and *P. margaritifera*), and were distributed in three vast areas: the Arau islands, the Torres Strait, and the northwest coasts.[7] Natural pearls from Australian oyster species were extremely rare, and this, along with their extraordinary size and beauty, made them exceptionally valuable. The nacre of these pearl oysters was considered the most valuable in the world: in 1868, 200 tons of shells were sold in London for 60,000 sterling pounds. Australia was the first pearling region outside of Japan where the Japanese made major investments, and after 1890 most diving-suit fishermen were Japanese.

French Polynesia was another major source of nacre and pearls.

[6] J. Taburiaux, *La perle et ses secrets,* Hemmerle Petit et Cie, Paris 1983, p. 49.

[7] H. Coupin, "Le récif-barrière d'Australie", in *L'Illustration*, Paris, 5 janvier 1895, p. 238.

At the beginning of the twentieth century, the shells fished during each season were estimated at 450 tons. Nearly four thousand people depended on this industry. The Polynesian divers were the most skilled in the world. They traded pearls and shells to Chinese and European merchants for goods that were worth less than the tenth part of their value.[8]

Before the twentieth century, the production and trade of pearls did not hold great importance in Japan, although oyster fishing was an ancestral cultural tradition. In Japan, oyster fishing was done by women called *ama*, who dove naked. *Ama* are still employed on modern pearl oyster farms. The low-quality Japanese pearls were sold to the Chinese, who used them as nuclei for the cultivation of pearls in freshwater mussels, mainly *Cristaria plicata* and *Hyriopsis* sp.

Market centers and trade

Despite the fact that the taste for pearls was extraordinarily widespread throughout history, there have been only two market centers for natural pearls: Bombay and Paris. When cultivated pearls eventually replaced wild ones by the middle of the twentieth century, the control of the market moved to Tokyo.

Bombay was the commercial capital of natural pearls from the twelfth to the nineteenth century, for several reasons. The city was strategically located between traditional pearling regions (Persian Gulf and Gulf of Mannar, and Red Sea), and was the most important commercial port along the East-West naval route. Financial support of fisheries, control of fishing sites, and commercialization were exclusive monopoly of a few rich Indian and Arab merchants, and of the Persian *Bunnias* – merchants who specialized in the classification, estimation, and commercialization of pearls. Indian and Persian sovereigns and magnates regarded hoarding jewels as a lucrative investment, and hence acquired fantastic amounts of nacre and pearls. The only exception to Bombay's hegemony was Spain's

[8] K. Joyce, S. Addison, *Pearls, Ornament and Obsession,* Thames and Hudson, London 1992, p. 125.

monopoly of American pearls in the sixteenth and seventeenth centuries, although this parallel circuit was no match for the Bombay market, either in commercial exuberance or as regards the intrinsic value of the pearls.

At the end of the nineteenth century, colonial policies spelt the ruin of the Bombay pearl market. The French jewelers saw their opportunity to step in to control prices and dictate criteria for pearl classification. As they filled the gap left by the *Bunnias*, they concentrated the whole world supply of pearls and transformed Paris into the new world pearling center. By that time, the exploitation of pearl beds, now mainly for nacre, had extended to all the pearling regions of the world. The fishing volumes already showed signs of exhaustion and pearls were becoming rare. Nevertheless, the demand continued to increase and Parisian jewelers, who were still able to provide an abundant and good quality supply, greatly profited from this situation.

On the Paris market, pearls were classified in over ten categories according to shape and appearance; in 1920, however, to simplify the trade, the jewelers reclassified them into just four groups: fine pearls, half-pearls or blisters, nacre pearls (with the qualities of the fine ones, but with small flaws), and baroques, i.e., fine pearls with non-spherical shapes. The classic criteria for fixing the prices of pearls have always been luster, orient, shape, and color, whose relative impotance weight varied with the demands of fashion. Weight was another important criterion for natural pearls, while size is essential for cultured ones. Natural pearls were first classified by their place of origin, then offered for sale in different ways: gems of extraordinary quality were sold by piece, baroque ones by weight, and the rest were grouped in different ranges and sold by volume or weight, in lots or threaded on a silk thread. Pearls matching in shape, size, and color fetched higher prices when sold as a group.[9]

On the Parisian market, the pearls from the Persian Gulf, the

[9] L.G. Seurat, *L'huître perlière. Nacre et perles,* Masson & Cie**.,** Paris 1912, pp. 15-18.

Gulf of Mannar, and the Red Sea were called "Oriental pearls", without distinguishing the region of origin. Likewise, those from the American continent were called "Panama pearls" even if they came from other regions, such as the Gulf of California or the Caribbean. Notwithstanding their provenance, the price that pearls sold for in jewelry stores in Paris was more than a thousand times what they had cost in their region of origin.

The demand for pearls increased around the turn of the nineteenth century, just as the supply kept becoming scarcer. This situation caused their price to increase, with a peak in the 1920s. The world expansion of markets, the growing wealth of Western countries, the sustained demand for pearls in the East, the use of diving suits, and the advent of the USA as a new buyer, caused the price of pearls to skyrocket so high that only the very rich could afford them, such as European nobles and clergymen, or Arab sheiks who wished to convert their oil fortunes into pearl treasures.

The 1929 and WWII economic crises dramatically affected the market for sumptuary goods. By the time the world economy had recovered in 1950, natural pearls were completely exhausted and had been replaced by cultured ones. Although it was unquestionable that the latter had completely lost the symbolism and magical allure of the former, the overexploitation of natural beds did not allow any other option. The time of natural pearls had ended forever, and Tokyo was to replace Paris.

The nacre market was less vulnerable to subjectivity and speculation, since nacre was not a sumptuary good but simply a valuable raw material. The shells were sold by the ton and only two or three ranges of quality were recognized, depending on the size of shells and the thickness and quality of nacre. The price was mainly determined by the balance of supply and demand, and thus varied considerably from one region to another. As in the case of pearls, differences in price between the areas of production and the seaports of Europe (Liverpool and Hamburg) or America (San Francisco and New York) where nacre was imported was enormous (70 to 100 fold). While the pearl market was centralized, shells were sold directly by the producing regions to industrial buyers. Two events spelled

the end of this trade: the substitution of nacre with plastic and the exhaustion of natural beds.

The development of pearl oyster culture and pearl production

"The man that solves the problem of pearl oyster cultivation, will not only have the privilege of contributing to scientific and industrial progress: his name will deserve the honor of being included among the founders of empires."[10] This comment from Alexander Lyster Jameson illustrates the degree to which producers and merchants of pearl oysters hoped that scientists would find a technique for their cultivation. The reactions of governments facing the exhaustion of pearl oysters ranged from the dictating of urgent measures to displays of indifference.

In Ceylan, starting from 1890, the government ruled that the decision as to whether to open the pearl oyster fishing season or not would be left to the Pearl Fisheries Establishment, whose task was to assess the state of the banks.[11] This institution also saw to the preparation and cleaning of seabeds, and the transplanting of pearl oyster juveniles to replenish local populations. Besides, it imposed quotas on fishing volumes, the number of boats allowed during each fishing season, and the minimum allowed size for captured oysters. This organization, unique in the world, is an example of rationality in the exploitation of natural resources. India undertook similar initiatives, founding the Tuticorin Fisheries Research Station to train divers and staff, and to start investigation on pearl oyster culture and pearl production.

In French Polynesia, two centuries of uncontrolled intensive fishing led to the extermination of the wild stocks. Quotas were imposed at the beginning of the twentieth century, as well as a manda-

[10] L.H. Jameson, "The Pearling Industry", in *Scientific American Supplement,* Vol. LXXVII, No. 1983, New Cork, Jan. 1914, pp. 12-16.

[11] G. Darboux, P. Stephan, J. Cotte, F. Van Gaver, *L'Industrie des pêches aux colonies. Nos richesses coloniales 1900-1905*, Exposition Coloniale de Marseille, Barlatier, Paris 1906, p. 152.

tory five-month rest period and the restricting of fishing seasons to once every three years. These measures were somewhat slackened under the pressure of pearling businessmen. The decline of fisheries continued, inevitably giving rise to the need for breeding farms where young adults were gathered in baskets and cages. Here the research on pearl cultivation and production started at a later date, in the 1950s.

The regulations on pearl fisheries in the Gulf of California were the first in the world (1857),[12] although they mainly concerned the working conditions of divers. Later on, further regulations were issued to forestall the imminent exhaustion threatening most fishing grounds. In 1874, the gulf coast was divided in four sections. Fishing was allowed in one section at a time, with a two-year rotation period, extended to four in 1878. Managers, however, usually did not comply with those restrictions and continued to exploit the beds without any control, as official monitoring was difficult to implement. Cultivation work undertaken by Gastón J. Vives, a local scientist and businessman of French origin, allowed the natural replenishment of the banks, thus delaying their exhaustion until the late 1930s. Indeed, the Gulf of California was one of the last bastions of pearl oyster fishing. In 1940, when the activity had ceased being profitable since 4 or 5 years earlier, the Mexican government finally imposed a permanent ban on pearl oyster fishing, declaring the species "in danger of extinction". This ban remained in force until 1994, when the definition was changed to "species under special protection"; but the fisheries were not reopened.

In the Torres Strait and Broome (Australia), Saville-Kent conducted important experiments in pearl oyster and pearl culture. Between 1890 and 1893, he produced the first half-pearls and proved the feasibility of transplanting pearl oysters from productive beds to sites suitable for cultivation. However, he was not successful in collecting spat. In 1906, he founded the Natural Pearl Shell Culti-

[12] J.M. Esteva, "Memoria sobre la pesca de la perla en la Baja California (1857)", in *Las perlas de Baja California*, Departamento de Pesca, México 1977, pp. 30-45.

vation Co. Ltd. Despite positive results in replenishing the natural beds, the Australian government did not show any interest and the cultivation was abandoned.[13]

Gastón Vives was the first marine aquaculturist in America, and the first in the world to achieve mass cultivation of a pearl oyster species (*P. mazatlanica*). In 1903, Vives founded the *Compañía Criadora de Concha y Perla de Baja California, S.A. (CCCP)*, which became the first pearl emporium in the world.[14] This company was also the largest in the history of pearl oyster culture. By 1905, Don Gaston was harvesting more than 10 million adult *P. mazatlanica* annually, a quantity never reached before by any other pearling enterprise. The technology involved a three-stage production cycle: spatfall capture, fattening, and out-growing. Vives created ad-hoc apparatuses and built complex facilities at Bahía San Gabriel (Espiritu Santo Island) in Bahía de La Paz.

The *CCCP* was pillaged and destroyed in 1914, during the Mexican Revolution. This event opened up the pearl oyster business – formerly reserved to foreign and local private enterprises – to anyone who wished to try his luck, unleashing an authentic "pearl rush". Without the enormous supply of larvae that the *CCCP* had released into the environment, less than two decades of intensive exploitation were enough to deplete the natural resource in the Gulf of California, thus marking the end of the Mexican pearling wealth.

In French Polynesia, towards the end of nineteenth century, Ranson achieved remarkable progress in the cultivation of *P. margaritifera*, and his followers obtained great success around 1950. Spat collectors and out-grow culture installations were established in reserve areas, improving the productivity of atoll lagoons and allowing fishing to continue. Presently, several atolls of the Tuamotu archipelago

[13] D. George, "The Cultured Pearl. Its History and Development to the Present Day", in *Lapidary Journal,* Sep-Oct 1967, p. 4.

[14] M. Cariño, M. Monteforte, *El Primer Emporio Perlero Sustentable del Mundo: la Compañía Criadora de Concha y Perla de la Baja California S.A., y sus perspectivas para Baja California Sur*, Universidad Autónoma de Baja California Sur, SEP, FONCA-CONACULTA, México 1999.

are among the foremost world pearl oyster culture and pearl production centers.[15]

Between 1905 and 1922, upon request of the Sudanese government, the British scientist Cyril Crossland set up one of the largest pearl oyster culture companies in Dongonab Bay, Sudan. Crossland performed detailed studies on the local species, *P. margaritifera erythraensis*, as well as the bioecological conditions of production sites, developing a whole array of methods, techniques, and devices for the three-stage cultivation process defined by Gaston Vives in Mexico. Using special spat collectors, from 1920 onward Crossland was able to obtain 4 millions juveniles annually. The total cost of shell production was £ 80 per ton and the shell sold for £ 100 per ton, yielding a satisfactory profit.

Crossland's organization of work contributed significantly to his success. His company provided employment for many people. Thousands of tons of Sudanese nacre were marketed in London, but only 1% came from the farms in the Dongonab region. The rest was fished in the natural banks whose replenishment was assured by Crossland's farm. The value of nacre exports increased by nearly 85% between 1907 and 1922.[16] Unfortunately, just when Crossland had finally perfected his methods and production was completely under control, the Sudanese government closed down the company, as the price of nacre had gone down to £ 40 per ton. This successful aquaculture experience was never resumed.[17]

Although Japan is not the pioneer of pearl oyster cultivation, it owes its present leading position to innovations in pearl culture technology. Contrarily to Vives and Crossland, from the beginning Kokishi Mikimoto aimed at inducing the production of pearls; in the first place, because the Japanese species, *P. martensii*, is small and its nacre is

[15] G. Ranson, "Rehabilitation of Pearl Oyster Beds in French Oceania", in *Quarterly Bulletin South Pacific Comm.*, 5, 3, 1955, pp. 22-24.

[16] C. Crossland, "The Pearl Shell Farm at Dongonab on the Read Sea", in *Sudan Notes and Records,* Vol. XIV, part II, Sudan 1931, p. 164.

[17] C. Crossland, "The Cultivation of the Mother of Pearl Oyster in the Red Sea", in *Australian Journal of Marine & Freshwater Research,* 6, 2, 1956, p. 112.

of poor quality, and secondly because through his contacts with China he had learned about the making of nacre-covered Buddha figures and saw the possibility of applying the same method to pearl cultivation. Besides, Mikimoto had several advantages: favorable environmental conditions, a body of scientific knowledge to draw on, and financial support from the Japanese government. He was thus able to begin large-scale production of half-pearls. Having obtained his first half-pearls in 1893, he acquired a patent three years later and went into industrial production.[18] He later produced the first free round pearls.

Many scientists claim the scientific merit of round pearls should go to Tatsuhei Mise, whose work was not taken seriously because it lacked scientific basis, and who was denied a patent just one month after one had been granted to Mikimoto. Tokichi Nishikawa was apparently the first to produce spherical pearls, in 1909, employing scientific methods which were perfected after his death by his two assistants, the Fujita brothers. Mise and Nishikawa mutually recognized their accomplishments and worked together. The Japanese method of pearl culture actually bears the name of these two investigators, but it was Mikimoto, together with a dentist named Otokishi Kuwabara, who defined the instruments and techniques.[19]

From 1920 on, Mikimoto achieved great success, relegating to forgetfulness the names of Mise, Nishikawa and Fujita, to whom he largely owed his technology. Nevertheless, without Mikimoto's industrial and commercial talents, as well as the government's financial help, Japan would not occupy the place it has in pearl production ever since the mid twentieth century. Japan granted a total of 17 patents to Mikimoto, as well as many distinctions. He soon became rich. By 1940 he owned 360 pearl farms producing ten million pearls annually. By 1952 the production had increased to 31 millions. Improvement and control of pearl culture technology have allowed Japan to establish itself as the world leader in pearl cultivation and trade. Pearls have been Japan's main marine export product

[18] Joyce, Addison, *Pearls, Ornament and Obsession* cit., p. 31.

[19] A.R. Cahn, *Pearl Culture in Japan,* United States Department of Interior, Fish an Wild Life Service, Fishery Leaflet 357, Washington, November 1949, p. 5.

since the 1970s, fetching more than thirty million dollars annually. This explains the government's support to this industry.[20]

India, French Polynesia, Sudan and Mexico have all surpassed Japan in pearl oyster culture and pearl production, as regards methods, technical innovations, and yields. Currently, successful experiences in Japan, French Polynesia, India, Australia, Mexico, Indonesia, Cook Islands, China, etc., have ensured that pearl oysters will not reach extinction, in spite of centuries of intensive and irrational exploitation. The contemporary pearling industry is completely dependent on the cultivation of pearl oysters. In most cases, it relies on extensive culture techniques (beginning with the collection of spatfall in artificial collectors), and therefore on cultivated oysters' capacity to replenish natural beds. Nevertheless, to achieve control of production cycles, over the last few decades scientists have turned to laboratory reproduction. Although this is a crucial mean to ensure successful completion of the cultivation cycle, hatchery production is a complex and expensive process that is usually inaccessible to developing countries and small farms.

In Australia, pearl farmers had no governmental support and were hence forced to accept the conditions imposed by Japanese enterprises. Thus, they began exploring cultivation possibilities in Australian seas with the Mitsubishi enterprise, managing to produce their first pearls in 1928. The whole production was exported to Japan. Presently Australia is the first exporter of cultivated pearls in the world, accounting for 27% (59.4 million dollars) of the total value of world exports of cultivated pearls. However, almost all pearl culture technicians are still Japanese.[21]

The exportation of the pearl industry in French Polynesia is comparable to that of Australia, with 19.6% (44 million dollars) of the world pearl market in 1992. The exceptional beauty of the local black pearls has contributed to this success. While the technical know-how is supplied by Japanese technicians, the country derives

[20] F. Ward, "The Pearl", in *National Geographic*, 168, 2, 1985, p. 217.

[21] D. Doubilet, "Australia's Magnificent Pearls", in *National Geographic*, 180, 6, 1991, p. 114.

its commercial experience from the descendants of Rosenthal, one of the most important pearl jewelers in Paris. In 1976, fourteen thousand oysters were operated. Japanese technicians are still in charge of production on the main farms, and the Japanese market is the main destination of French Polynesian pearls, which since 1983 have been the region's first export.[22] Although French Polynesia is one of the major world producers, its pearl cultures face serious problems, notably devastating hurricanes and pollution generated by tourism as well as the Center of Atomic Experimentation.

Another important South Seas pearl producer is the Sulu archipelago. Its pearls are among the finest, most beautiful, and most expensive in the world. The methods employed here are similar to those applied in Australia: wild pearl oysters are used for pearl culture, and production is entrusted to Japanese technicians, but with the obligation of training native personnel.

Presently, almost all Indopacific countries having larger native pearl oyster species than Japan are trying to include pearl culture in their development policies, avoiding Japanese control. A most unusual event occurred in Burma, where some Japanese technicians were actually kidnapped and forced to train Burmese technicians in the technology and organization of pearl farms.[23] The Japanese government has agreed to create bi-national companies in Borneo, Thailand, Indonesia, and Korea.

In early 1960s India, Dr. Quasim Alagarswami and his team, after 10 years of work, managed to develop their own instruments and techniques for laboratory pearl induction and seed production at a commercial scale. Despite their scientific advancements, India is not an important pearl producer, since the small size of *Pinctada fucata* does not allow the insertion of nuclei more than 5 mm in diameter. Furthermore, the east coasts of India are frequently plagued by hurricanes that cover the sea bottom with sand. Thus, the Indians have

[22] A. Intes, "La nacre en Polynésie Française (*P. margaritifera* Linné, Mollusca Bivalvia*)*. Évaluation des stocks naturels et de leur exploitation", in *Notes et Doc, Océanographiques,* 16, 1982, p. 26.

[23] J. Taburiaux, *La perle et ses secrets* cit., pp. 91-92.

been offering their oyster and pearl culture technologies to other countries with more favorable natural conditions, helping them to develop their own small-scale experiences.[24]

In the state of Baja California Sur, northwestern Mexico, a group of scientists under the guidance of the coauthor of the present study set up a culture of pearl oysters based on bioecological research and innovative low-cost modern technology. Despite lack of institutional support, in 1993 they successfully achieved cultivation of *P. mazatlanica* and *Pteria sterna* at pilot scale, as well as the production of half-pearls in both species. The Pearls '94 International Congress, held at Honolulu, Hawaii, can be regarded as a landmark in the history of modern pearl oyster and pearl culture in México. On this occasion, the "Pearl Oyster Research Group" of CIBNOR presented ten papers illustrating all the advancements in research and technology since 1986.[25] Other Mexican scientists drew on this knowledge to further develop the technology and form two private companies, one in Guaymas, state of Sonora, in 1996, and another in La Paz in 2001. One of the most remarkable aspects of these experiences is that the cultivation of pearl oysters and pearls was achieved in a totally original way, without any dependence on foreign technology. The Guaymas experience also set an important precedent for the production of excellent round pearls, principally in *Pteria sterna*.

These new endeavors to cultivate pearls in the region may eventually manage to reestablish the importance that pearl culture had for the regional economy at the beginning of the twentieth century, while remaining within sustainability parameters.

Natural vs. cultured pearls

Mikimoto's cultured pearls sparked a fiery polemic between scientists who applauded his discoveries, and Paris and New York jewelers who feared to lose their control of the pearl market. Many of

[24] D.S. Dev, "Pearl Culture Project in India", in *Pearl Oyster Information Bulletin*, 7, 1994, pp. 5-6.

these jewelers had considerable investments in natural pearl fisheries and commerce. We have already published a detailed study analyzing the long and endless discussions and confrontations involving many important personalities in both camps;[26] here we shall limit ourselves to briefly remarking that the debate was heated, with each party vehemently trying to impose its point of view. The naturalists rejected the opinions of the jewelers who dared to question the authority of their publications and knowledge. The jewelers argued that scientists did not understand a thing about market mechanisms and that their opinions could negatively affect their business and the national economy. The researchers responded by expressing regret at the jewelers' attempt to reassure pearl owners with false statements. An example of such an attempt was Rosenthal's book *Japanese Pearls and Reconditioned Rubies*,[27] where the author claimed that cultivated pearls were an industrial product, as false as the rubies described in his book, even though they originated from epithelial tissue.[28]

The consequence of these lingering polemics, as some businessmen had foreseen, was the loss of the pearl buyers' trust. Between 1920 and 1930, the demand for pearls on the Parisian market considerably decreased. Cultivated pearls ended up costing a fifth of natural ones of the same size and equivalent quality. This allowed people with lower incomes to buy pearls of extraordinary quality at good prices. It was in this context that the United States became the first importer of cultivated pearls, ending up buying more than half

[25] From 1988 to 2004, the Pearl Oyster Research Group of CIBNOR had published more than 70% of the total information available for *P. mazatlanica* and *Pt. sterna.*

[26] M. Cariño, "The Cultured Pearl Polemic. Science and Business Went Face to Face when Cultured Pearls First Entered the International Market", in *World Aquaculture*, 27, 1, 1996, pp. 42-44.

[27] L. Rosenthal, "Perles japonaises et rubis reconstitués", in *Mercure de France,* 1-IV-1922, Paris 1922, pp. 76-92.

[28] L. Boutan, "Nouvelle étude sur les perles naturelles et les perles de culture", in *Ann. Des Sc. Nat. Zool.*, 10a. série, N. VI, Paris 1922, pp. 36-48.

of the Japanese production in 1954.[29]

In the 1960-1970 decade, the value of the worldwide export of cultured pearls rose to more than 7 million dollars, and constituted 40% of Japan's external trade. Paris no longer controlled either the fishing or the sale of pearls. By that time, New York was dictating fashions as regarded color, size, and shape. In 1985, pearls were the most important Japanese marine export product, with a value exceeding 300 million dollars per year, the United States still being their main buyer. Around 1970, to meet the growing demand, Japan sacrificed quality for quantity.[30] This discredited their production, which ended up being no match in beauty, quality, and size for the pearls that were beginning to be produced in large quantities in the South Seas, mainly in French Polynesia and Australia.

At present, both the marketing and the wholesale of all cultivated pearls, regardless of their origin, are controlled by Japan, which still holds the industrial secret of implant techniques, has a very significant production, works in most of the major pearl farms of the world, and fixes the prices of South Seas pearls, excepting that of Polynesian black pearls. French Polynesia holds the second place, after Australia, among suppliers of pearl oysters to the Japanese market, and has been able to retain a certain independence from the Japanese monopoly, thanks to the French government's researching and managing strategies.[31]

Although the natural pearl market has disappeared forever, cultivated pearls and nacre are still one of the most important aquaculture industries in the world. However, there is still a significant difference between natural and artificial pearls: whereas the former carried an aura of mystery and myth – and unleashed passions – the latter is merely a luxury commodity like any other.

[29] Y. Okada, *Pearl Industry and Research in Japan,* Report of Faculty of Fisheries, Prefectural University of Mie, Vol. 2, Oct.30, 1955, p. 151.

[30] George, "The Cultured Pearls" cit., p. 13.

[31] F. Doumenge, A. Toulemont (eds.), *Nacre et perles,* Musée Océanographique, Monaco 1992, p. 43.

Conclusion

The history of pearl fisheries and trade provides a vivid example of a shift from the overexploitation of a valuable natural resource to its sustainable management. The change was forced by the depletion of pearl oyster natural stocks just as demand was growing, fomented by the inexhaustible greed of capitalist society. This transition was not brought about by a conservationist movement, but by the efforts of scientists under the pressure of the economic interests of governments and merchants who feared the extinction of the pearl beds.

With the achievement of pearl oyster cultivation and culture pearl production, fishing pressure on local environments ceased completely. This brought about radical changes to the economy of pearling regions and the pearl trade. Socio-environmental conditions before and after the transition from fishing to cultivation are comparable and indicate a positive qualitative change. Well-paid aquaculture technicians took the place of the harshly exploited divers, and environmental depredation gave way to the sustainable management of natural resources.

Not everything has changed. The production and commercialization of nacre and pearls is still one of the most lucrative and productive activities in the world. Today, over 1500 pearl *Pinctada spp*. and/or *Pteria spp*. farms yield around 40 tons of pearls annually. As this elite market enters the twenty-first century, one feels the need for new ways to assess its possible future. The integration of sustainable aquaculture into socioeconomic development programs addressed at regional communities is a complex task, and pearl farming is especially unique.[32] Traditionally, "pearl-tourism" has been the engine of development in certain regions, but the production and trade of sumptuary goods may witness unpredictable fluctuations in the short and long run. On the other hand, the technology

[32] M. Monteforte, "Modelos de desarrollo acuícola en Baja california Sur: saqueo o alternativa sustentable", in *Del saqueo a la conservación: historia ambiental contemporánea de BCS, 1940-2003*, M. Cariño, M. Monteforte (eds.), SEMARNAT-INE, CONACYT, UABCS, México 2008, pp. 337-364.

is being continuously improved and practically anyone can access a huge amount of information in scientific literature, books, congress papers, photographic and video documents, the Internet, etc. Both pearl production and the number of pearl farms in the world is growing, especially in China. Hatchery technology is improving, and naturalists and scientists are devoting increasing efforts to the domestication of the species.

Under the present conditions, smaller producers and newcomers seeking to establish independent pearl producing businesses will be confronting tougher competition, unless they receive some form of support from regional development plans.

The historical traits of change and persistence we have highlighted in this historical overview provide evidence that the managing of natural resources does not automatically lead to sustainable development. Although pearl oysters have been saved from extinction and humanity will hence be able to continue to rejoice in the beauty of their gems, the intelligent and sustainable management of a natural resource requires more than conservation and scientific investigation. Pearl farms can be a viable option for regional sustainable development, as long as decision-making entities provide the necessary synergic impulse.

The achieving of sustainability is a complex and subtle process involving both natural and social components, but it is fundamentally an historical process. As such, it requires the will of stakeholders. The cultivation of pearls has improved standards of living in several South Pacific islands that were previously sunk in black misery that the tourist market dissembled behind a paradisiacal façade. These success stories must be reproduced in all the pearling regions in the tropics where sustainability is still an urgent issue. Environmental history can make the difference by contributing a critical and integral vision of the past, as well as a hopeful perspective on the future.