The American Mussel Crisis: Effects On the World Pearl Industry

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Introduction

A shell nucleus is needed to form the vast majority of cultured pearls, and that nucleus has most often been supplied by the American mussel. The world's cultured pearl industry is, therefore, highly dependent on a reliable supply of freshwater mussels from United States waters. This paper discusses the threatened status of these mussels and its possible effects on the future of the pearl industry.

Background

Pearls occupy a special place in the history of the world. Centuries before the birth of Christ, this gem was considered the most valuable commodity. The Chinese, the Persians, the Egyptians, the Romans — all treasured pearls as the ultimate symbol of beauty and value. Indeed, until the early part of this century, only the wealthiest individuals could afford them.

The pearl has enormous universal appeal, perhaps because it is produced by mollusks throughout the globe in virtually every body of water. However, by the end of the 19th century, overfishing of this natural resource had resulted in greatly depleted supplies of natural pearls which, in turn, led to increased efforts to produce mollusks to produce pearls on demand.

The Japanese Discovery

Success was achieved in Japan in 1904 when Tatsuhei Mise, a carpenter, discovered that the insertion of epithelia tissue from a donor oyster, together with a ball of some material (he used lead for a "nucleus" or "bead") could cause the mollusk to cover that material with nacre, thereby producing a pearl. At roughly the same time, Tokichi Nishikawa, a government fisheries bureau technician, also succeeded in producing a spherical pearl, but instead of lead, he used a gold or silver nucleus.

It was up to another Japanese, Kokichi Mikimoto, to discover the best material for the nucleus. After years of experimentation with the marine oyster, *Pinctada fucata* (Gould), commonly called "akoya," into which he inserted a variety of substances including clay, glass, lead, and wood, he determined by the 1920s that nuclei cut from the shell of an American freshwater mussel resulted in the highest rate of success.

Layers of nacre can be deposited around any irritant, but the calcareous material of the freshwater shell, with a specific gravity nearly identical to pearl nacre, worked best. Moreover, the nacre appeared to adhere better to freshwater than marine shell, and was less likely to fracture, an important factor when drilling pearls (Claassen 1994). Further, the white color of the nucleus could be easily disguised even under thin layers of nacre.

Unfortunately for Japan, there were insufficient quantities of unionids to support a major pearl industry. China and the United States possessed large shell populations. However, Chinese shell produced a less than perfect adherence of nucleus and nacre (Claassen 1994), shell sizes tended to be small, and it was far easier to obtain the American product because there was a well-established shell network for the button industry.

Thus, by utilizing American mussels and incorporating nuclei insertion techniques ("grafting") borrowed from Nishikawa and Mise, Mikimoto had mastered the art of producing a pearl. His next important test was to persuade a world used to the natural product that a "cultured" pearl was not only acceptable, but desirable. His persistence from the 1920s to the 1940s resulted in the gradual acceptance of cultured pearls and the loss of demand for the naturals. In a matter of decades, Mikimoto had transformed the "Queen of Gems" and the "Gem of Queens" into one of the world's most affordable jewels.

Freshwater Pearls and the American Pearl Button Industry

Native Americans wore pearls they had obtained from the considerable mussel resource in rivers and lakes spread throughout middle and eastern North America. During the latter part of the 19th century, there was even a "pearl rush" in the Midwest. However, overexploitation and pollution quickly led to a drastic decline in the supply. Just when it appeared that the mussel population was going to be spared, John Boepple, a German button maker, established the first freshwater pearl button company in Muscatine, Iowa, in 1891.

Soon, mussels large and small, young and old, were being harvested by the thousands of tons, with the general feeling in the button industry that the supply was endless. In 1916, the peak year in button production, American factories turned out 40 million gross, with a product value of $12.5 million. The button industry comprised 9,500 factory workers, 9,746 musselers, and 585 shoremen and boatmen (Claassen 1994). In Iowa alone, it is estimated that 4.5 million pounds of mussels were harvested in the peak harvest year of 1928 (Thiel and Fritz 1993).

The success of the pearl button industry began to take a heavy toll of the mussel resource. In order to survive, a young mussel passes through a larval stage by attaching itself to the gills or fins of a "host" fish. Dams built on the Mississippi River and throughout Kentucky and Tennessee restricted the movement of host fishes and, consequently, the ability of the mussels to reproduce. Coupled with increasing pollution, the result was a drastic decline in the mussel population. To stem the decline, Minnesota, Wisconsin, Iowa, and Illinois initiated closures of certain waters and imposed size limits and license fees. The Bureau of Fisheries began to aquaculture mussels through artificial propagation (Thiel and Fritz 1993). Unfortunately, these measures could make little progress against further overfishing, worsening pollution, and dredging.

What most likely "saved" the mussel resource was the gradual demise of the pearl button industry, with Japanese competition playing a major role. The Japanese entered the U.S. market in 1908, manufacturing buttons made from Chinese freshwater shells (called "dobu"), ocean snail and trocas shells, at a fraction of the U.S. shell or labor cost. With the advent of the plastic button in the 1940s, the pearl button industry was doomed. By the early 1960s, American buttons made from shells was virtually a thing of the past. The freshwater mussel shell had new life, but not for long.

Natural pearls had become a side product of the button industry, but it was the cultured pearl that brought new pressure on the mussel resource. Following the discoveries of Mise, Nishikawa, and Mikimoto, the Japanese began pearl farming in Ago Bay, Japan; the Mandated Islands; the Ryuku Islands (1912); Palau (1920); and Boetoeng Island, Indonesia (1921) (Claassen 1994). Mikimoto, who formed K. Mikimoto and Company, produced 15 million nucleated oysters in 1934. According to Joyce and Addison (1993), "By dominating the Japanese industry, Mikimoto controlled the international cultured pearl market." In 1938, Japan produced 10,883,512 cultured pearls from 13,351 water acres (Claassen 1994). Before his death in 1954 at the age of 96, Mikimoto could boast of two major accomplishments: he had established an important industry in Japan and a "national treasure"; also, he had succeeded in gaining such acceptance for cultured pearls that, by the 1950s, most buyers were unaware that their necklaces were the result of a unique marriage of Japanese and American mollusks.

The Export of Shell to Japan

Since the size of the nucleus determines the size of the pearl, the main requirement was that the shell be thick enough to be cut into strips, which are, in turn, reduced to cubes and then round beads. Also, the shell should be white, and of fine compact texture and sufficient hardness so that the nucleus will not crack or shatter when drilled. The Japanese sent a representative to the United States as early as 1910 to investigate American resources for nuclei, and 200 to 300 tons of pigtoes were exported to Japan in the 1920s, with 1 ton yielding up to 60 pounds of nuclei. However, before World War II, most shell material was taken from the Yangtze River in China. Following the war, the China-Japan political relationship changed, and by the late 1950s the Japanese were using North American shell exclusively (Claassen 1994).

American shell exporters found themselves at the mercy of a few Japanese importers who dictated the type of shell, the price, and even the location in the U.S. where it should come from (Cohen 1995). Based on Mikimoto's research, they insisted on the 2.5-inch pigtoe (*Fusconaia* sp.) because of its color (milk-white blue) and the fact that there was little throwaway after processing. They also stipulated that the shells come from the Tennessee River, which they felt produced better mussels. The importers supplied a half dozen makers of large beads who, in turn, distributed shell to, perhaps, 100 cottage shell cutters. The bead makers returned the shell in cubes for final rounding and polishing (Cohen 1995).

The North American shell exporters were a small group of midwesterners, many of whom had started in the button industry in the early 1900s. The Blumenfeld family shipped about 50 tons to Mitsubishi Trading Company in 1949 (Cohen 1995). John Rhee, Lee Garner, Dave Stafford, Olin Bishop, Vernon Hudson, David Fisher, and the Cohen family pioneered in selling shell to the Japanese in the 1950s (Claassen 1994; Ballenger 1995). John Latendresse, who began exporting in 1957 with partner Joe Seino, became the dominant force in the business. By the mid-1960s, according to Latendresse, he was supplying the majority of

Japan's nucleus needs (Fassler 1991a). In 1974, James Peach broke away from Latendresse to form his own company. Today, there are nine shell export companies (Table 1).

During the 1960s, pigtoe exports from the Tennessee River were in the 5,000 to 10,000-ton range. Because this volume was starting to have an effect on the resource, North American mussel exporters persuaded the Japanese to try other species. With the pearl business booming and no competitors on the horizon, Japan increased exports to 25,000 tons in 1968 (Cohen 1995). In 1988, Japanese pearl production totaled 71.6 tons, worth $482 million, making pearl farming one of the most valuable aquaculture industries in the U.S. (Fassler 1991b). U.S. shell export volume, however, declined to a level of 12,000 tons in 1990 and, with a drop in Japanese demand, further declined to a projected 6,500 tons for 1995 (Baker 1995a) (see Table 2). For an explanation of this decline, we need to take another look at what was happening with the Japanese cultured pearl industry.

The Japanese Monopoly

Mikimoto was the "Pearl King" and Japan was the "King of Pearl Nations." This monopoly position was derived from Mikimoto's insistence that "(1) No matter where pearls are farmed, the production shall be marketed in Japan; (2) only Japanese shall provide the technical expertise for Japanese-controlled operations; and (3) the technology for producing pearls, particularly the implant procedure, shall only be taught to Japanese" (Fassler 1991b).

During the 1950s and 1960s, Japan was by no means the only cultured pearl producer in the world. Pearl farming started in Australia in 1955 for "golden" pearls, using the large marine oyster, *Pinctada maxima*, and in French Polynesia in 1962 for black pearls, with *Pinctada margaritifera*. However, Japanese grafters (nuclei inserters) were required. Farming grew in both countries, but it was necessary to continue to employ Japanese technicians who brought with them the all-important beads. As part of the contract for the technician and the beads, the farmer signed a contract agreeing to sell his pearls to

Table 1. American shell export companies, October 1995

Name	Principal(s)	Location
American Shell	James Peach	Nashville-Camden, Tennessee
Borden Shell	George Borden	Savannah, Tennessee
M.D. Cohen	Nelson Cohen	Terre Haute, Indiana
Garner Shell	Lee and Ray Garner	Hollywood, Alabama
Hudson Shell	Peggy Linley	Decatur, Alabama
Leasure Shell	Robert Leasure	Bradford, Arkansas
Mississippi Valley	Butch Ballenger	Muscatine, Iowa
Tennessee Shell	Peggy Baker	Camden, Tennessee
U.S. Shell	Lonnie Garner	Hollywood, Alabama

Table 2. American Mussel Shell Exports, 1990-1995 (From Baker 1995).

Year	Approximate quantity (ST)
1990	12,000
1991	9,900
1992	7,000
1993	6,800
1994	6,500
1995 (projected)	6,500

a Japanese company. If he refused, there would be no farm because no other nation had the technology or the nuclei (Fassler 1991b). This arrangement worked well for the pearl industry. Because the Japanese controlled the market, they controlled the price and kept it high. Further, by purchasing only the finest pearls, they attempted to maintain a high-quality product.

Competition

At the end of the 1980s, the Japanese pearl industry began to decline. Problems began at home with increasing pollution from industrial and agricultural sources, and competing uses for pearl farming waters, including recreation and fish hatcheries. This led to overcrowding, increasing mortalities, and a shortened grow-out period, with fewer layers of nacre. Overseas, Australia and French Polynesia greatly expanded their pearl farming industries. By 1993, Australia was producing 878 kg of the large, valuable "golden," worth $110 million. One year later, the quantity grew to a range of 1,237 kg to 1,256 kg, worth between $158 million and $168 million (Joll 1995). Tahitian progress was even more dramatic. French Polynesia increased production from 407 kg in 1987, worth $20 million; to 2,094 kg in 1993, worth $77 million; to $135.3 million in 1994 (Coeroli 1995). The Cook Islands, a nearby nation, produced some $5 million in black pearls in 1994, and is quickly accelerating production (Kanekoa 1995).

Indonesia has near perfect conditions for culturing *P. maxima* among its 13,667 islands, spanning 3,200 miles. The area estimated to be suitable for pearl culture is 5,600 hectares (Winanto 1994). Indonesia's resources have not escaped the notice of both the Australians and Japanese, who have been aggressively establishing farms. Indeed, one farm, located in West Timor, has gone to the stock exchange in search of investors, and is now the world's only publicly traded producer of South Seas pearls (Henry 1995). Bo Torrey, editor of *Pearl World*, the pearl industry's most widely distributed publication, has called Indonesia the "Wild West... a new frontier where almost anything goes!" (Torrey 1995).

Because *P. margaritifera* and *P. maxima* are sizable oysters, they can take a large, 10 mm-plus nuclei to produce 12 mm-plus pearls. *Pinctada maxima* is the larger of the two. The shell can reach 30 cm in diameter, with a thickness of 3 cm, and weigh up to 5 kg. The booming French Polynesian and Australian pearl industries, and the expansion of South Seas pearl farming throughout the South Pacific, have dramatically increased the demand for the washboard *(Megalonaias nervosa)*, which has become "the foundation of the current mussel industry" (Thiel and Fritz 1993). The price has also skyrocketed since 1994. Today, live washboards can bring as much as $7 per pound. According to Robert Leasure, an American shell exporter, the price of large washboard has risen 40% to 50% in recent years (Leasure 1995). Indications are that the supply of large washboards — many are more than 25 years old — is definitely decreasing (Parrott 1995).

The Beadmakers

We have seen that Japan's monopoly of beadmaking was an important device to maintain control of the industry. North American mussel exporters considered getting into the nucleus-making business, but there was only one customer, Japan, "and Japan wouldn't buy them" (Cohen 1995). The expansion of pearl farming into the South Pacific, an increase in non-Japanese grafters, and the demand for large nuclei opened up an opportunity for Americans.

Today, there are five U.S. companies in the nuclei business: two manufacture beads in the U.S., one produces beads in China; and two cut shells into cubes for beadmakers in Australia and Tahiti (Table 3). In addition, there is 1 large Hong Kong manufacturer, 35 in Japan, and an unknown number in

Table 3. Some Bead/Cube Makers, November 1995.

Name	Principal	Location
American Shell	James Peach	China
Aquila International	Tim Parrott	Lexington, Kentucky
Australian Netmakers	George Ventouras	Australia
OctoCross	Paul Cross	Nevada City, California
Empire Shell Products	Charles Lawson	Garnavillo, Iowa
Fukui Shell Nucleus Factory	Arthur Wong	Hong Kong
South Pacific Nucleus	David McCullough	Costa Mesa, California

China (Wong 1995) (Table 3). The annual business is loosely estimated to be $250 million (Lawson 1995). Nuclei are separated into three grades: 1st — white, perfectly round; 2nd — round, but colored (streaks possible); and 3rd — not perfect, colored, pits possible. The Americans have concentrated on the 1st grade, and all are processing large washboards.

China

China represents, by far, the greatest competitive threat to Japan's pearl industry. Japan has, perhaps, 2,000 pearl farmers. China, on the other hand, has "tens of thousands" of farms producing pearls. According to noted pearl expert Fred Ward, "With temperatures from tropical to temperate, China will pose increasing competition to Japanese and South Seas producers. Already, Chinese success with freshwater and saltwater pearls has driven Japan to all but abandon domestic production of 4, 5, and 6 mm pearls" (Ward 1995).

Indeed, the Chinese pearl explosion has forced Japan to form trade agreements whereby Japanese technicians assist the Chinese in developing their skills in return for allowing Japanese firms to process and market Chinese pearls. Frequently, these pearls are then sold on the world market as "Product of Japan" (Ward 1995).

After initial successes with saltwater pearls in the 1920s, the Japanese turned to the culture of freshwater pearls in Lake Biwa. The Chinese had shown as far back as the 12th century that it was possible to trigger nacre production by cutting small slits into the mantle tissue inside both mussel shells, and inserting live mantle tissue from another mussel into those slits. By altering the shape of the tissue, the technician could create various odd shapes, including bars, crosses, and circles. By the 1950s, Biwa pearls of various brown and golden colors were sold in Japan as an alternative to more expensive saltwater pearls (Ward 1995).

However, rapidly increasing pollution from untreated sewage, herbicides, and pesticides during the late 1970s and early 1980s doomed Biwa pearls. The Chinese, realizing that the world preferred round pearls, studied the Japanese experience and refined techniques for producing a consistent crop of rounds. Chinese freshwaters, composed entirely of nacre, now rival the best of the naturals. Interestingly, Ward reports that the Chinese have reshaped tissue-produced, "reject" all-nacre pearls, and use these as nuclei in freshwater mussels. The result is a large, round, all-nacre pearl that is difficult to tell from a natural. By Ward's estimate, Chinese freshwater production now totals more than 300 tons annually (Ward 1995).

Grafters

Another blow to the Japanese pearl monopoly has been the proliferation of non-Japanese grafters. Although the Japanese are still considered to be the best in the business, there are Chinese and Tahitian grafters in French Polynesia, an American grafter and a New Zealander grafter in the Cook Islands, and Australian grafters in Australia (Fassler 1995). Now that secrets are out, the supply is likely to grow in coming years. It is important to note that these grafters are not obligated to purchase nuclei from Japanese makers, or for that matter, obligated to buy nuclei made from American shell.

The Internationalization of Pearling

A further indication of how the Japanese have lost their control of the pearl industry is the gradual formation of a "world pearl community" through meetings and organizations — some outside of Japan. Pearls '94, held in Hawaii in May 1994 and chaired by the author, brought together 645 pearl farmers, scientists, government officials, and equipment suppliers from 39 nations. The International Pearl Association was started at the same time. In November 1994, delegates from 17 countries were invited to Kobe to form the World Cultured Pearl Organization. International assistance groups, such as the U.S. Agency for International Development and the Australian Centre for International Agriculture Research, are funding pearl farming projects in various South Pacific nations (Fassler 1995).

We have seen, then, that Japan's position as the number one customer for American freshwater mussel shell has decreased in recent years due to a number of reasons, including declines in the domestic pearl industry because of pollution, the rise of the Chinese pearl industry, and the spread of grafting technology. The growth of the nuclei industry has resulted in as many as 15 species for export; an expansion in the number of musselers ("diggers"); the inclusion over time of states outside the Tennessee River area, stretching from Minnesota to Alabama; and an increasing concern for the future of the mussel resource.

Regulating the Resource

A significant event in the history of efforts to protect mussels was the formation of the Upper Mississippi River Conservation Committee (UMRCC) to "promote the preservation and wise utilization of the river's resources" (Thiel and Fritz 1993). Surveys of mussels in 1975 led to regulations that increased the harvest size, reduced the length of the harvest season, and encouraged better reporting of shells taken. According to Thiel and Fritz (1993), "Today size limits are the management tool used to regulate the industry."

Some states allow musseling, others have restricted musseling to the Mississippi River, and others have banned the activity altogether in an effort to prevent further habitat destruction and the spread of destructive nonindigenous species (Table 4). Peggy Baker, president of the largest shell exporting company (Tennessee Shell), feels that the states that have banned mussel harvesting are taking a "wait and see" attitude towards the resource. "Most states have indicated a study would be made as to proper management requirements and the state would reopen at such time as adequate information is obtained. There are various reasons for state closures — social, political, and so on. But the main reason has been lack of study and information available" (Baker 1995).

Habitat Destruction and the Spread of Nonindigenous Species

There are 281 species of the North American freshwater mussels in the families Margaritiferidae and Unionidae ("unios") (Williams et al. 1993). It is estimated that since the beginning of the century, at least 20 species have vanished from North America because of habitat reduction and alteration, pollution, and (to some extent) overharvesting (Sweaney and Latendresse 1982). An October 1995 *New York Times* article includes a quote from Dr. Arthur E. Bogan, a research associate in invertebrate zoology at the Carnegie Museum of Natural History in Pittsburgh: "Everybody talks about biodiversity in the tropical rain forests, but you don't have to go to the tropics to see a major extinction event." The entire family of mussels, states Bogan, is "poised on the brink of a major and widespread extinction" (Cushman 1995). The *Times* article points to the factors that have caused the destruction: dredging and gravel mining, siltation from streamside logging and agriculture, sewage discharge, and toxic wastes and polluted runoff (Cushman 1995).

A recent study by The Nature Conservancy found that the most imperiled North American species were those that "depend on aquatic systems for all or part of their life cycle." Freshwater mussels were listed as having the highest percentage of species at risk of extinction (67.1%). The decline was

Table 4. Status of mussel fishing in selected states, November 1995 (From Cohen 1995b).

State	Total Ban	Banned on	Permitted
Alabama			x
Arkansas			x
Indiana	x		
Illinois			Mississippi & Ohio rivers
Iowa		iw	
Kansas			x
Kentucky			x
Louisiana			x
Michigan	x		
Minnesota		iw	
Missouri		iw	borders
North Carolina	x		
North Dakota	x		
Ohio	x		
Oklahoma			x
South Carolina	x		
South Dakota	x		
Tennessee			Tennessee and Cumberland (part) rivers
Texas			x
Virginia	x		
West Virginia	x		
Wisconsin		iw	

iw = inland waters

Note: In states where musseling is generally permitted, there can be restrictions on certain areas, methods of harvesting, mussel size, etc.

attributed to "poor water quality and the long-term effect of dams and other water diversions" (The Nature Conservancy, quoted by Dicke 1996). Williams and other scientists offer an important reason for the mussels' imperiled status: "The decline of the freshwater mussels during the past century has involved a variety of threats, the single most important being the destruction of habitat. While habitat destruction continues, expansion of the distribution and populations of nonindigenous mollusks such as the Asian clam, *Corbicula fluminea*, and zebra mussel, *Dreissena polymorpha*, appear poised to decimate many of the remaining native mussel populations" (Williams et al. 1993). The zebra appears to be by far the greater threat.

The Zebra Mussel

Dreissena were first discovered in Lake St. Clair in 1985, thought to be introduced by cargo ships traveling from northern Europe to the Great Lakes. They spread quickly throughout most of the Great Lakes, and by late 1991 were reported in the Ohio, Illinois, and Tennessee rivers; by 1993, they were discovered as far south as the lower Mississippi in southern Louisiana (Williams et al. 1993). Where zebras lack size (most are no bigger than a thumbnail), they are strong in numbers, attaching themselves by thousands, if not millions, to any firm material in their paths, literally burying and suffocating other mussels. Zebras will survive in waters ranging from 32°F to 86°F and can thrive in salinities up to 7 ppt. They need calcium levels above 25 ppm, pH levels from 7.4 to 9.0, dissolved oxygen concentrations of 8-10 mg per liter, and water flow between 0.5 and 0.7 m per second (Bryant and Falk 1995).

The result of the zebra mussel's successful adaptation to its new home has been a substantial reduction in native mussel populations, coupled with severe fouling of water intake pipes of industrial plants and electrical generating stations. Biologists B.R. Griffin and C.M. Collins point to Europe's experience with the zebra mussel and state that "they will not successfully colonize the waters of more southerly states" (Griffin and Collins 1995). However, other biologists are not as optimistic. Margaret Dochoda, with the Great Lakes Fisheries Commission, has predicted that "within 20 years, the zebra mussel will likely have taken the entire East Coast of the United States" (in Nash 1991). Snyder et al. (1992) are even more negative: "Most authorities consider the spread of the zebra mussels across North America to be a certainty" (Snyder et al. 1992). In order to prevent this possibility and help prevent the further spread of zebra mussels, numerous states are enacting measures that will have a profound impact on their mussel resource and, consequently, the future of the nuclei and pearl industries.

The Crisis

Things have never looked better for the world pearl industry — or worse. The Japanese monopoly on the business, which many persons felt was holding back expansion, was showing signs of weakness heading into the late 1980s, and began to quickly erode in the early part of this decade. Today, according to Ward, "the Japanese are has-beens in the pearl trade. They had, and unfairly maintained, a world monopoly for nearly a century, and the impact of all the ill-will they earned by their one-sided trade practices and arrogance, their severe pollution problems, their greed (evidenced in short-culturing), their national economic woes, and their parallel destruction of their freshwater and saltwater pearl capabilities is unprecedented. The Japanese pearl trade is one of the great business failures in history" (Ward 1995). Added to their domestic problems, the Japanese have been forced to cope with the rise of China as a "pearl power" and the spread of farming to the South Pacific. Technology that was closely held since Mise, Nishikawa, and Mikimoto was suddenly available. Japanese pearl executives, not to be left behind, were venturing overseas, setting up farms and demonstrating a spirit of cooperation never seen before. Pollution in Japan was reducing the size of the domestic industry, but there were positive signs of expansion in Australia, French Polynesia, and Indonesia.

In the 1980s, the North American mussel supply, while the subject of increasing regulations, still looked strong. The shell exporting industry employed some 10,000 people (Cohen 1994), with an estimated value of $50 million. Mikimoto's most desired material for nuclei was destined to fuel the pearl expansion. Then along came the zebra mussel and the situation changed within a few years. The search for substitutes for the North American nuclei was on. The Japanese were the first to become alarmed. They had heard reports of the closing of major U.S. rivers and "explosions" in zebra mussel populations. They invited many of the leading mussel exporters (Peggy Baker, Lonnie Garner, Butch Ballenger, Nelson Cohen, James Peach, Robert Leasure) to a conference in Kobe in April 1992. According to Leasure, the question they posed was, "Can you maintain the present supply level for five years?" The answer they received from the exporters was, "We will not be able to supply only first-grade shells. Second and third grades also must be purchased. We have a disaster and it is happening now." When asked how long the present level of exports could be maintained, the Americans "all gave about the same outlook: three years" (Leasure 1995). The Japanese wanted 10,500 tons per year. By 1994, the quantity had dropped to 6,500.

Substitute nuclei were already on the Japanese pearlers' minds and ceramic beads were discussed at the conference. However, the cost would be higher than the shell and there was the important question of whether people would accept a man-made product inside of a pearl (Leasure 1995). The Americans were asked about the possible aquaculture of freshwater mussels. The exporters pointed to increased efforts by the U.S. Fish and Wildlife Service and the need to work closely with them. Several of the Japanese even offered to extend financial assistance.

No concrete plans were worked out, but the meeting did lead to the formation of the Shell Exporters of America (SEA), whose goals were to "help in the preservation of this resource . . . to assist the various state and federal agencies in their attempt to manage the freshwater shell . . . to eradicate the zebra mussel . . . to assure our customers overseas that they will have a reliable source of this raw material" (Cohen 1994). Long-time shell exporter, beadmaker, pearl farmer, and jeweler James Peach advised, "We must look for other sources because I believe the shell business in the United States will be in great jeopardy in the next five years" (Jewellery News Asia 1994).

The Search for the Substitute Nuclei

Since 1992, the world pearl community has been generally pessimistic about the future of the American mussel as a major source of material for pearl nuclei. A survey of farmers and nuclei distributors in six countries brought mixed reactions to the situation, with some predicting the end of the mussel supply in a few years, and others extending this to a decade or so. According to Ward (1995), "There is nothing scientifically unique that makes American shells acceptable. Over the next few years, we are going to see nuclei made from everything . . . mussel shells from several countries, from shells of other mollusks, from composites, from reconstituted natural and man-made materials formed into beads, and from materials that experimenters are trying right now." No one predicted that the present supply would be maintained; most saw drastic reductions ahead, and are actively searching for a substitute or substitutes. Substitutes range from completely man-made products, like ceramics, to a wide range of mollusks, some previously untried. Significantly, no respondent felt that the substitutes would be an improvement on North American shell. Country by country, these are the results:

Japan

Because of the high price of raw shells, the Japanese pearl farmer, long-time user of the 1st grade nucleus (sending the poorer grades overseas), is "using more second grade or little bit down grade to substitute the high cost of 1st grade nucleus" (Wong 1995). There is speculation that the Japanese are buying U.S. shell, then redirecting the poorer quality product to China to be made into beads because of labor problems in Japan and much cheaper labor costs in China (Lawson 1995a). There was also the opinion that the Japanese are now buying the better quality Chinese nuclei "at a fraction of the cost, "because they are still reasonably priced and very white for their thin coatings" (Ventouras 1995).

There seems to be little doubt that the Japanese have developed synthetic nuclei (Jewellery News Asia 1994) and that "at least 5-7 patents for synthetic nuclei have been applied for." Ventouras (1995) states, "this is not ideal, but it is an alternative." It appears, however, that Japan has yet to use this nuclei. Morimitsu Muramatsu, director of the Institute for Marine Biological Research of Tasaki Shinju Company, one of Japan's largest pearl companies, stated, "About synthetic nuclei . . . no need to discuss. We will never use it" (Muramatsu 1995). Andy Muller, a long-time and well-respected Swiss pearl dealer in Japan, could not confirm the use of synthetic nuclei in Japan (Muller 1995).

China

China's sudden burst onto the world's pearl stage as its leading producer has resulted in considerable interest and speculation regarding its industry. Solid information is difficult to come by because of secrecy and poor reporting of production. However, we do know that the freshwater mussels *Lamprotula leai* (Gray), *Lamprotula polystica* (Hence), and *Lamprotula rochechouarti* (Hence) are commonly used for nuclei, and they are often harvested in the area of Boyang Lake (Jiangxi Province) and Dong-ting Lake (Hunan Province) (Xu 1995). Also, there seems to be common agreement that these shells are small, producing beads, 6 mm or less, with poor quality material (Wong 1995) that has a tendency to fracture when drilled. The Chinese export some of this nuclei to Japan, and import American shell to China (Xu 1995).

James Peach has established a beadmaking operation in China, and there is some speculation that other American, Hong Kong, and Japanese companies have done the same to take advantage of the extremely inexpensive labor. Peach has had preliminary talks with scientists in China on the feasibility of translocating some American mussel species (Jewellery News Asia 1994). Of course, as noted above, the Chinese are producing pearls with no nucleus at all.

Australia

According to George Ventouras, owner of Australia's only nuclei producer, his country's pearl farms consume about 1.5 million nuclei annually. Sixty percent of this comes from the United States, with the rest coming from sources in Asia (possibly U.S. shell processed and shipped) (Ventouras 1995). There have been experiments using giant clam shell (*Tridacna squamosa*) and *P. maxima* shell, but Ventouras (1995) says, "The clam may work but the shell usually has inherent cracks in the structure and therefore may split when drilled" and "the *maxima* would be too expensive (more than the mussel)." Ventouras is not optimistic about the future of American shell in Australia: "We anticipate that the American mussel will last for the world market for at least the next 3-4 years. By this stage, an alternative will be required; we are already conducting tests. I figure this long because each year a greater number of manufacturers are substituting Asian shell for American, and no one can tell" (Ventouras 1995).

George Kailis, Managing Director of Australia's second largest pearl company, reported that his firm has been testing *P. maxima* and giant clam for nuclei material, but he prefers to use nuclei based on American shell. However, he pointed out that "In large scale trials with *Pinctada maxima,* those quality aspects that relate to colour do not appear to significantly affect final pearl quality. It should be noted, however, that the thick coating that a *P. maxima* shell forms around a nucleus in Australian production is in distinct contrast to the relatively thin layer that is prevalent in Akoya pearl production and where any off colours in the nuclei might show through" (Kailis 1995).

A study by Roberts and Rose (1989) on the use of giant clams concluded that they "may be a suitable alternative to those from Unionidae freshwater mussels," but they have reportedly backed off from this position. Although the clam would certainly be suitable for large bead production, a major problem would be the restriction on the harvest and export of naturally caught giant clam products among the signatories of the Convention on International Trade in Endangered Species (CITES) (Wong 1995).

Indicative of Australia's strong interest in threats to the American mussel, the government of Western Australia sent one of its leading scientists, Dr. Lindsay Joll, to a mussel conservation conference in St. Louis (October 16-18, 1995) to assess the future of the resource.

French Polynesia

Like Australia, French Polynesia is a major user of nuclei in the larger-sized 9 mm to 12 mm range, although some farmers have utilized 16 mm to 18 mm nuclei (at $135 each) to produce "giant" 20 mm pearls (Thompson 1995a). Because of the dark color of their pearls, many farmers can use the 2nd or 3rd grade nuclei. Japanese technicians use the best quality nuclei where they have the greatest involvement in the farming venture. They use lesser quality beads where they have less commitment to the farm (Thompson 1995a).

Estimates of the number of pieces used annually is 6 to 7 million, with a single farm accounting for 760,000 ("and he is not the largest!") (Ventouras 1995b). According to Martin Coeroli, director of GE "Perles de Tahiti," French Polynesia's pearl marketing agency, "Giant clam nuclei have been considered as not suitable for pearl seeding, as they split when the pearl is drilled. *Pinctata maxima* nuclei are suitable for seeding, but too expensive, and too rare to find" (Coeroli 1995).

Nevertheless, in October 1994, the Tahitian government launched an experiment to compare *P. maxima* nuclei, which they obtained from a manufacturer in the Philippines, with the nuclei from North American mussels. Results will be known in April 1996 (Seaman 1995). In regard to the *P. maxima* cost, it appears that it is not much more expensive than the 3rd grade nuclei, and cheaper than the 1st or 2nd. However, there have been problems obtaining adequate supplies from the Filipino company: "Farmers in Tahiti are generally afraid to risk the *P. maxima* nuclei because, if the results are negative, they've wasted several years. It appears that hundreds of *P. maxima* nuclei were spread around French Polynesia for farmers to try" (Seaman 1995). The largest distributor of nuclei in French Polynesia, Gnit Fa Chong of Etablissements Aming, confirmed that he still sells nuclei from American mussels — "100%" (Chong 1995).

India

India is destined to become an important pearl producer because of its numerous lakes and rivers, a long coastline, a history of pearling, and an impressive group of research scientists working to accelerate the industry. According to Dr. Narasimham of the Central Marine Fisheries Research Institute in Cochin, "Till this date, we are using shell bead nuclei made from the American mussel. Recently a Calcutta based company is making nuclei from the shell of the locally available gastropod *Xancus pyrum* and we have initiated studies to assess the suitability of these nuclei for pearl production in *P. fucata*" (Narasimham 1995).

On the freshwater side, a young biologist and entrepreneur, Ajai Kumar Sonkar, has successfully developed a nucleus by pulverizing certain species of freshwater mussels, and then mixing "some material." While he cannot make large nuclei because Indian oysters tend to be small, "any size nuclei can be prepared" (Sonkar 1995).

Vietnam

Next to China, Vietnam is reported to have the largest number of freshwater mussels that can be utilized for nuclei, although the mussels are small. The Vietnamese are producing nucleated pearls in the freshwater mussels *Hyriopsis cumingii* (Lea), *Cristaria bialata* (Lea), and *Anodonta jourdyi* (Morlet) (Thang 1994). Nuclei are manufactured from mussel shells from members of the genus *Lamprotula* (Kim et al. 1994).

Cook Islands

Reuben Tyler, a partner in the Cook Islands' largest pearl farm, said that his farm has used Vietnamese nuclei, with perhaps "50% bad," but because of the extremely low price, it was worthwhile looking through batches of nuclei and selecting the best. His farm uses as many as 60,000 nuclei annually (Tyler 1995). Dan Emery, an American grafter in the Cook Islands, told us that "everyone uses the 1st grade nuclei from Etablissements in Tahiti" (Emery 1995). Japanese grafters are still active in the Cook Islands, taking 33% of the value of the crop to perform the first graft. When a second graft in the same oyster is used (to produce an even larger pearl), they receive 50% of the crop's value (Thompson 1995).

The Reconstituted Nucleus

If *P. maxima*, the giant clam, and other mollusks cannot provide an adequate substitute, and if synthetics and other nonshell nuclei (ceramic, glass, et al.) have a difficult, if not impossible, task in gaining acceptance by the pearl consumer, what about a reconstituted nucleus, using shell? After all, it is a natural product made from freshwater shell. As previously discussed, Ajai Sonkar has constructed a reconstituted nucleus. Will others follow?

In about 1970, most American shell exporters considered a reconstituted nucleus; one exporter even approached a university for assistance. However, the right binder was not found, and the idea was dropped (Cohen 1995). There is speculation that roughly 5 or 6 years ago the Japanese approached the American firm Dow Chemical to develop a reconstituted nuclei. Also, there is speculation that Chinese beadmakers are already into large-scale production of reconstituted nuclei. In late September 1995, 400 to 500 tons of extremely poor-quality American mussel shell was exported overseas (Cohen 1995). To China? Japan? And for what purpose?

Nucleus Quality and Pearl Quality

We have noted that the shortage of American shell, and the availability of much cheaper shell from other nations, principally China, has led pearl producers to utilize lower-quality nuclei. An important question needs to be posed: Will these nuclei result in a lower-quality pearl? According to many beadmakers we have spoken to, the answer is "Yes!" The implication for future, quality-conscious buyers of pearl necklaces and rings is enormous. Unfortunately, few studies have been made to test the hypothesis, but preliminary indications seem to support the beadmakers.

George Ventouras, the Australian beadmaker, says the surface smoothness of the nuclei is all-important for the creation of a high-quality pearl: "The platelets of calcium carbonate, which are secreted by the oyster that forms the pearl, are microscopic, and as they are laid down will follow the contour of the surface of the nucleus. A nucleus with a surface that has pits, holes, or deep scratches due to low-quality processing techniques may result in a pearl with pin holes, hammering, marks, or defects" (Ventouras 1995). Ventouras feels that a pitted nucleus can trap polishing compounds that are acidic, which can have a detrimental effect on the oyster and nacre layers (Ventouras 1995). Also, he feels that improper grinding could lead to edges which "that will stick out" and lead to the rings on "circle pearls" (Ventouras 1995).

Ventouras' feelings are echoed by his American counterpart, Chuck Lawson, of Empire Shell Products. Lawson says, "Many of the problems that the pearl farmers are experiencing with regards to surface quality, that is, pitting, circling, etc., are a result of the condition of the nuclei surface. We have had a pearl peeler peel pearls which have shown surface imperfections in the nacre layers and have found that under each imperfection in the surface of the pearl there has been in most cases a corresponding imperfection in the nucleus layer directly below the imperfection" (Lawson 1995).

Lawson is calling for an independent study by a professional organization that he feels will prove that "the quality of the nucleus would dictate the quality of the pearl" (Lawson 1995).

In one of the few field experiments testing nuclei, Ajai Sonkar of India tested rough nuclei and smooth nuclei, expecting the adhesion to be greater on the rough material, which would result in more layers to cover the irritation, and, hence, a smoother pearl. But he discovered that "the pearl sac deposited around the surface of the pearl was as rough as the nuclei. On the smooth nuclei, the formation was smooth, although the grip on the rough nuclei was stronger" (Sonkar 1995). According to George Kailis, Broome Pearls Ltd. in Western Australia is researching the impact of nuclei on final pearl quality with tests on material from non-U.S. sources (Kailis 1995). The results may confirm what Ventouras, Lawson, and Sonkar have already pointed out.

Future Outlook

The American mussel survived the pearling era in the late 19th century and the pearl button era in the early 20th century. The latest era, the pearl nuclei era, is showing signs of coming to an end. If it were not for the zebra mussel and the Chinese, one might be able to predict another 20 years of life, but, as it is, these forces have probably cut this to a decade. With no viable solutions yet proposed for halting the zebra onslaught, the creature will continue to decimate native mussel populations. Aquaculture could provide some relief, but by the time a crop of mussels is ready for nuclei harvest, beadmakers will have turned to other sources of supply. One of the great advantages of American shells today is that they are raised for "free." As any experienced aquaculture businessman will tell you, when you have to consider paying for such things as leasing land, constructing and running a hatchery, and providing security, the "bottom line" may rule out further involvement in the venture. This is not to say that aquaculturing our native mussels should not be attempted. They have been one of this country's great historical and biological treasures, and there should be no lack of effort to save the remaining species from extinction. Federal and state governments most certainly need to play a major role.

State governments should give highest priority to completing mussel resource studies and work closely with the shell exporters to implement better management strategies. The SEA members present at the St. Louis conference (six out of nine companies were represented) have shown a strong desire to support mussel conservation efforts and reduce the harmful effects of dam construction, pollution, and dredging. The future of their industry is tied to the future of the mussel resource. Certain measures have been introduced in Congress, but the October 1995 *New York Times* article (noted previously, which is highly sympathetic to the plight of mussels) takes a dim view of their effectiveness, stating, "There is little of an emergency nature in recovery plans for the mussels or for their ecosystems." The author, John Cushman, quotes a draft recovery plan for certain species in Alabama: "'Recovery of the mussels to the point of being removed from the endangered species list is unlikely in the near future because of the extent of their decline, their apparent sensitivity to common pollutants and continued impacts upon their habitat'" (Cushman 1995).

The effect of the Chinese, with their massive production and no-shell-nuclei pearls, on mussels and the world pearl industry has also been profound. If Mikimoto and his cultured product made

Table 5. Cultured pearl industry: from mussel to market.

1. *Musseler,* who sells to
2. *Buyer,* or directly to
3. *Shell exporter,* who ships to
4. *Bead manufacturer,* who ships to
5. *Bead distributor,* or directly to
6. *Pearl farmer,* who harvests pearls and sends to
7. *Designer,* who creates a design for
8. *Manufacturer,* who makes a necklace, ring, etc., and sells to
9. *Wholesaler,* who sells to
10. *Retail jeweler,* who sells to
11. *Customer*

pearls affordable, the Chinese have made pearls downright cheap. And as people once resisted cultured pearls, but eventually accepted a shell nucleus center, it is likely that the world will accept a reconstituted nucleus. (It will take many years, I believe, before the consumer will tolerate ceramic, glass, metal, or the like). Does this mean that pearl quality will suffer as a result of the substitute nucleus? Yes, but, offsetting this, the low price will make pearls available even to school girls.

A major exception to this scenario will be the South Seas pearls, whose giant size will place them out of reach of nuclei from the inexpensive, lower-grade Chinese shells (unless the Chinese are able to construct a large bead out of reconstituted shell). By insisting on the best shell and paying more attention to overall nuclei quality, pearl farmers may succeed in producing even more magnificent specimens. The pressure on North America's washboard resource will continue, with high prices reflecting scarcity and increasing demand. *Pinctata maxima* and the giant clam may someday replace the washboard, but at a much greater cost. In short, South Seas pearls are likely to emerge as a luxury of the truly rich, much as, for 2,000 years, the natural gems adorned only the most affluent.

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