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PEARL FARMING IN THE TUAMOTUS: ATOLL DEVELOPMENT AND ITS CONSEQUENCES

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The black-lipped pearl oyster *(Pinctada margaritifera),* naturally abundant in the remote atolls of the Tuamotu Archipelago, became almost extinct following a century of overexploitation. Surviving stocks now provide the basis for an innovative pearl-farming industry, attracting investors and return migrants from Tahiti. There are now concerns that intense exploitation will result in deelining profitability and perturbation of lagoon ecosystems. Disputes are also increasing over the relative rights of local communities, external entrepreneurs, and the Tahitian administration. As pearl farming is one of the few viable development opportunities on Pacific atolls, the potentially problematic consequences need to be carefully addressed by governments and development agencies.

THE BOOMING GROWTH of the black-pearl-farming industry seems out of place in the sun-drenched, windblown, and storm-prone atolls of the Tuamotu Archipelago, French Polynesia. Work sheds and platforms line lagoon shores, while lagoon interiors brim with millions of cultivated oysters suspended by miles of rope, buoys, and inflated plastic drums. Cargo boats are constantly working their way through narrow reef passes unloading construction materials, aluminum boats, outboard engines, scuba equipment, and other supplies. Small airplanes arrive weekly on formerly remote atolls, serving the needs of visitors, investors, returning migrants, and well-to-do pearl farmers.

Cultured production of the black pearl, high-priced on the international market, was pioneered in the Tuamotus based in part on techniques previously developed in Japan and Australia for white pearls.[1] Over the past few decades, pearl farming has become a highly successful industry, and it is currently a vital element in French Polynesia's drive for self-reliance. Following

the French initiative black-pearl-farming ventures have also been launched in the Cook Islands, and trials are under way in other Pacific islands. The potential importance of this industry was recently underscored by an international conference on pearls held in Honolulu, attracting some five hundred participants from around the world (Fassler 1994:325-354).

This newly emerging industry is particularly worthy of academic scrutiny because it is one of the few successful development efforts on coral atolls (see Connell 1986:41-58). Raised only a few feet above sea level, with virtually no soil and limited groundwater supplies, and highly vulnerable to hurricanes and tsunamis, atoll communities rely largely on copra, external aid, and (to a variable extent) subsistence gardening and fisheries. Pearl farming provides a remarkable example of transition between a rudimentary gathering industry (mother-of-pearl diving) and a highly sophisticated aquacultural technology. This article, based on written sources and personal fieldwork, describes how, when, and through whom the transition was accomplished.

This article also documents the unanticipated cascade of socioeconomic, political, and ecological changes that followed the introduction of pearl farming. The new industry has served as an economic magnet, attracting a rapid influx of migrants from Tahiti. Dense farming of pearl oysters has raised concerns about oversupply and has been related to epidemic mortality in mollusc populations. Competition over pearl farming has also resulted in a struggle among native islanders, alien entrepreneurs, and the Tahitian administration over the control and allocation of lagoon space.

Biology and Ecology in Brief

Aspects of the biology and ecology of the black-lipped pearl oyster *(Pinctada margaritifera)* have been discussed in several reviews (Ranson 1962:43-69; Intes 1982:36-38). The species is found throughout the Pacific Islands, as well as in the Indian Ocean, the Persian Gulf, and the Red Sea. The oyster generally reaches a diameter of fifteen centimeters and is easily recognized through the iridescent nacre ("mother-of-pearl") that layers the shell internally. When stimulated by a foreign body (such as a parasite), the intrusion is sealed off, creating a pearl. Perfectly rounded natural pearls are highly valued, but they are generally extremely rare.

The pearl oyster becomes sexually mature at about the age of two years, often followed by a sex reversal from male to female. Millions of eggs are released by a single oyster, but there is extremely high mortality owing to vagaries of current flow and predation. Eggs that survive and become fertilized float with the plankton. When large enough, they settle to the bottom and attach to a hard substrate, such as dead coral, with a muscular foot.

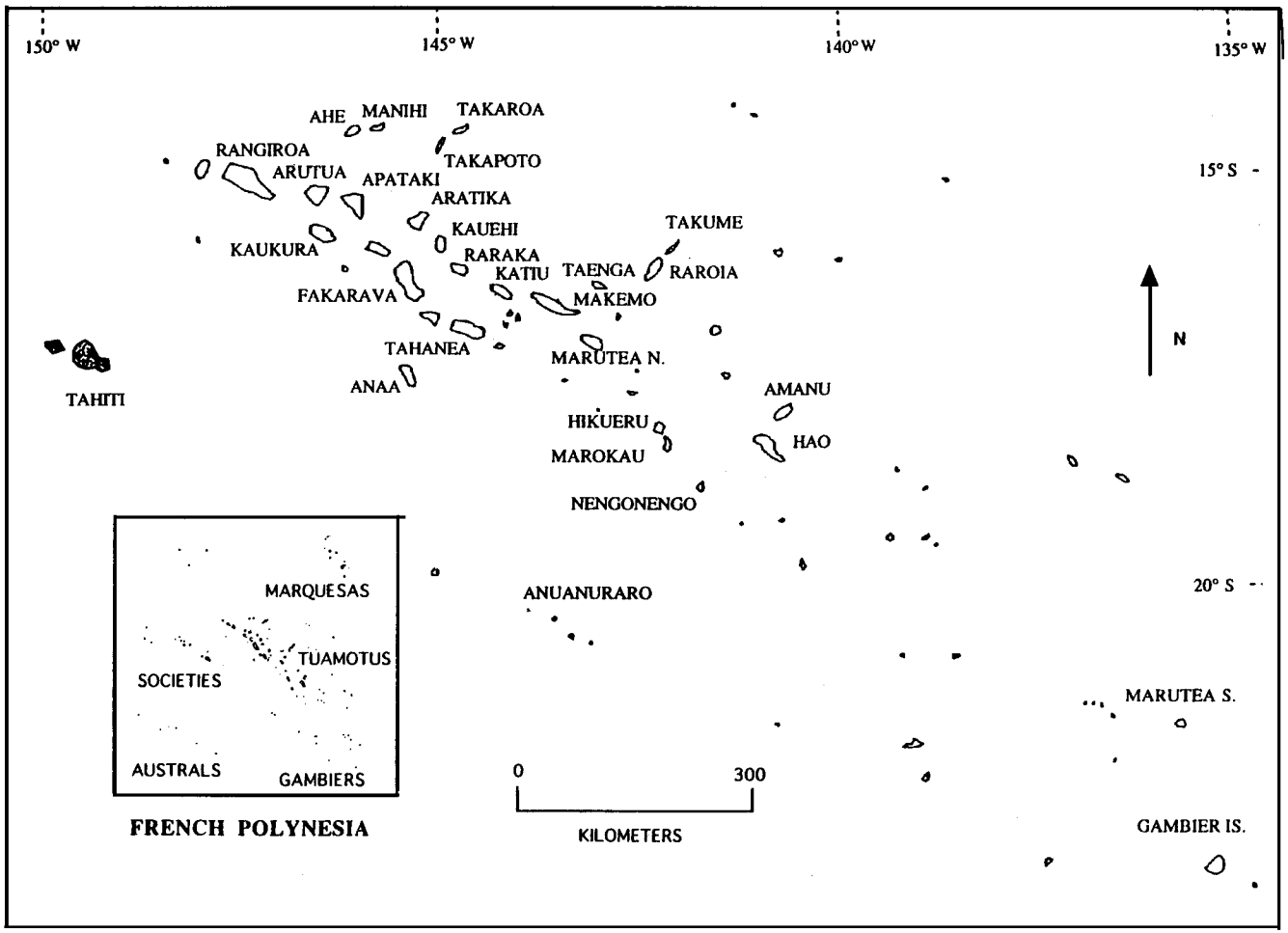

FIGURE 1. **The Tuamotu Archipelago.**

Then sessile, the growing pearl oyster is a filter feeder, ingesting planktonic food and organic detritus. It may live for ten years or more.

Reproductive losses and sessile habits of the adult individual constrain dispersal and limit population size. The abundance of pearl oysters varies greatly. Abundant patch reefs, adequate current flow, and narrow passes favor oyster growth and reproduction. Lagoon size is also a significant factor. In the Tuamotus, the largest oyster populations generally occur in lagoons with an area ranging between forty and a hundred square kilometers. Over millions of years, genetically distinct populations of pearl oysters have evolved on individual islands in the Tuamotus and other groups.

The Mother-of-Pearl Industry

The Tuamotuan mother-of-pearl industry was launched in the early nineteenth century by traders from Europe, South America, and Australia (Kunz and Stevenson 1908:189-198; JPS 1954:117-120). Though pearls were occasionally found, shells were the principal object of commerce, marketed in Europe for high-quality buttons and inlay work. Typically, a trader contracted an interpreter and a native diving team, sailed to a propitious atoll, and set out to work in isolated and rugged conditions. The lagoon floor was scanned with a glass box, divers descended quickly on a weighted line, and oysters were hauled to the surface. Sustained lack of oxygen sometimes led to motor and sensory dysfunction (Herve 1933:1401-1431).

Atolls with deep ocean passes were preferred because ships could set anchor in protected lagoons. When accessible stocks of pearl oysters became exhausted, the ship would move to another atoll. The permission of the atoll residents was not always secured, and altercations were frequent. On several occasions trading ships were pillaged by the islanders and their crews threatened with death (Beechey 1831:280-283; FitzRoy 1839:530-535; Moerenhout 1837:335-369). In 1842 the French Protectorate had become established in Tahiti and began regulating the mother-of-pearl diving industry.

Colonial regulations were based on recommendations from French oyster biologists who visited Tahiti intermittently. On a yearly basis, certain lagoons would be opened to diving, others would be opened only in certain portions, and still others would be closed until stocks began to regenerate. Minimum-size limits were placed on the oysters, depending on the size at maturity, and diving was restricted to certain seasons. Natural reserves were set aside in several lagoons. Underwater diving machines (“scaphanders”) were licensed in several lagoons, particularly those thought to be dangerous or inaccessible to free divers (*JOEFO,* 28 August 1890:301-303).

But management of the diving industry on remote atolls proved more illusory than real. Traders carrying undersized shells could easily evade government scrutiny and could bypass Papeete altogether. Native islanders claimed traditional rights to their lagoons and resented external intervention. The use of diving machines by entrepreneurs from Tahiti was strongly resisted by the Tuamotuans owing to the potential for overexploitation. Objections were particularly strident when the administration announced a Tuamotuan settlement plan for French oyster farmers (*PVCG, Pièces annexes* 1, 1888:123-138).

By the turn of the century, conditions in the diving industry had become less rugged and, in some cases, positively enjoyable. The opening of a dive season on one of the oyster-rich atolls has been described as "Rabelaisian" (Baruch 1936:45-47). Schooners and boats packed with divers and their families, dogs, pigs, chickens, canoes, and other goods would arrive day and night. Within days, an atoll that had barely held a hundred people would receive thousands. A tiny village suddenly became a huge agglomeration of traders, divers, and other workers. Wine, rum, and champagne flowed in unlimited quantities. There would be traveling theaters and shops that were stocked with trade goods as well as any store in Papeete.

After several weeks to several months, pearl oysters would become increasingly rare, and the divers would move on to another atoll. Some thirty-five atolls formed part of this vast archipelagic circuit (Figure 2),[2] about a third of which would be opened for diving for a several-month interval (data tabulated in SP n.d.). The divers and their families were funded by advances from Chinese-Tahitian entrepreneurs, covering the expenses of transport, housing, and subsistence. These entrepreneurs also ran the local shops, frequently at high markup values. Unless a pearl of exceptional value was found, the diver would not save very much from his several months of work and would often wind up in long-term debt to the entrepreneurs (Herve 1933:1413-1414).

Intensive exploitation by divers in underwater gear during World War II was apparently the last straw for natural stocks. By the 1950s, production of pearl shells had begun a dramatic decline in virtually all atolls (Ranson 1962: 56-57). In lagoon after lagoon, the Tuamotuan pearl oyster stocks reached the point of extinction, until only a handful of lagoons still contained stocks worth exploiting. With the help of French administrative aid, overseas biologists and technicians, and local entrepreneurs, a new industry was developed based on the capture of postlarval oysters ("spat collection"), rearing to maturity ("oyster culture"), and induction of pearl formation ("pearl culture").

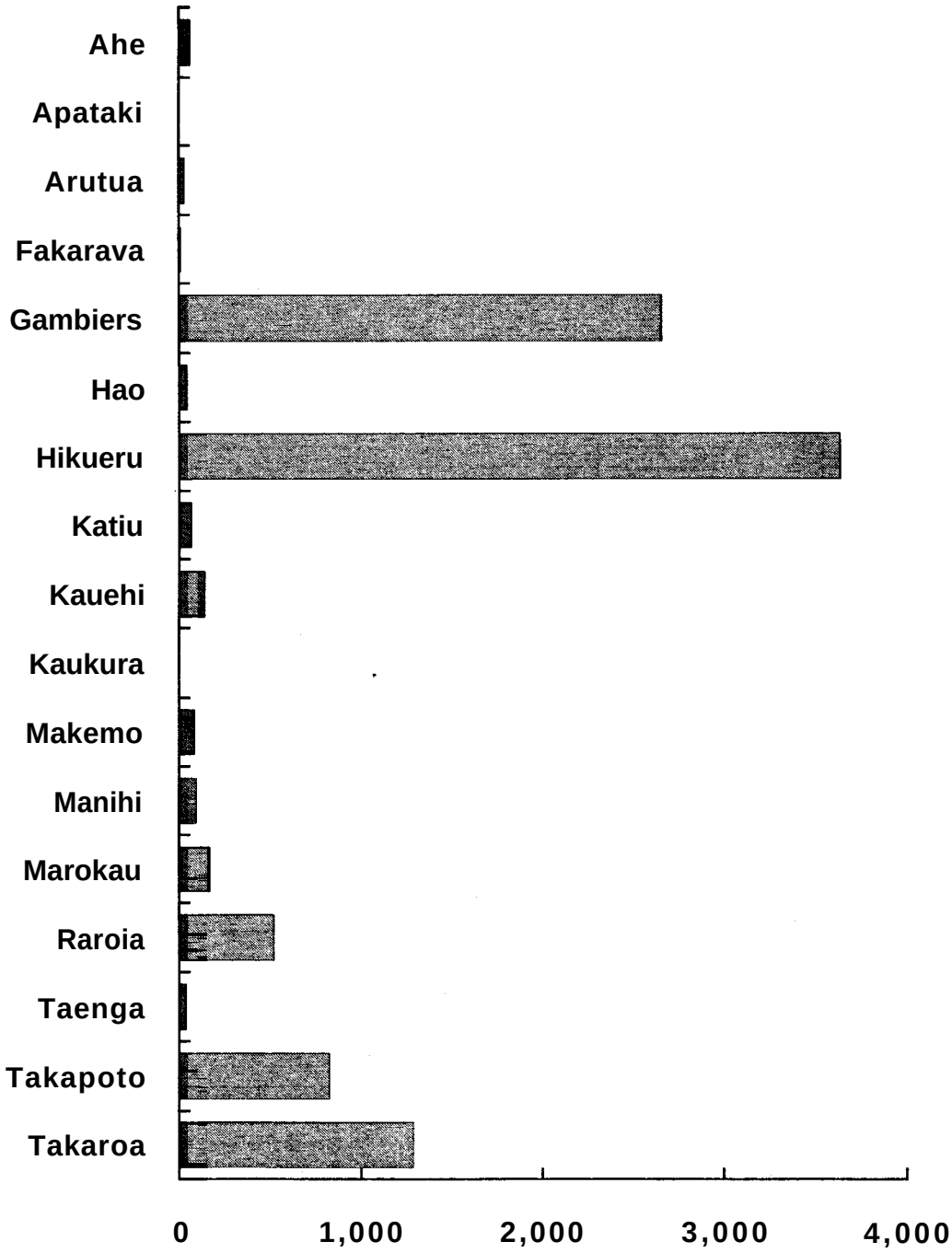

FIGURE 2. **Shell production (tons), 1946-1969.**

Spat Collection

The introduction of spat collection in the Tuamotus is credited to the pioneering efforts of Gilbert Ranson, a French oyster biologist. Ranson was called to Tahiti in the 1950s by the colonial administration when it became apparent that oyster catches were declining precipitously. Ranson con-

ducted surveys in the most promising lagoons, recording water temperatures and salinities, collecting plankton, and studying the growth of the pearl oyster at various depths, the nature and conditions of the bottom, and the direction of the currents. Ranson also conducted studies on pearl oyster biology and reproduction (1962:43-69).

Ranson found that only a minute fraction of the eggs produced by mature pearl oysters manage to become successfully fertilized, to evade being consumed by predators, to keep from being swept out into the ocean, and to find a suitable substrate. Fortuitously, he had learned of a tremendous enrichment of the natural pearl oyster stocks following hurricanes, which swept a large amount of debris onto the lagoon floors. Divers reported that trees on the bottom of certain lagoons had been covered by as many oysters as they had formerly had leaves. This suggested that artificial substrate might be utilized as well (Ranson 1962:65-66).

Ranson chose to experiment on Hikueru, an atoll that had long been a mecca for the diving industry (1962:7). He suspended thousands of bundles of local hardwoods beneath the lagoon surface, hoping to induce settling of spat (postlarval oysters). Ranson's efforts were successful, and Hikueru became the center of a trial pearl-farming project by the administration. In this early stage, however, relatively few oysters were needed, and these could be gathered by divers from the lagoon floor without necessarily endangering the natural stocks.

Ultimately, spat collection did replace diving. As pearl culture expanded, natural stocks were not sufficient. A simplified, efficient means of spat collection was devised using inexpensive, synthetic materials that required less maintenance and yielded oysters that could be easily collected at maturity. By the mid-1970s spat collection became the principal source of juvenile ("seed") oysters for pearl farming. Spat collection relieved the pressure on natural oyster stocks and produced oysters that were better suited for pearl farming (Coeroli and Mizuno 1985:551-556).

In 1970, Hikueru's lagoon had experienced an algae bloom, resulting in high mortality rates of pearl oysters. Takapoto, also rich in pearl oyster stocks, took its place as the center of experimental efforts in spat collection and pearl farming. By 1980, practically every household on Takapoto had spat collection stations scattered across the lagoon. Much of the yield was ultimately transshipped to pearl farmers on oyster-poor atolls. In general, native farmers did the diving and the spat collection, while the French and Chinese-Tahitians dominated in pearl culture.

Spat collectors are now manufactured primarily from opaque black polyethylene film sheets (see Coeroli, de Gaillende, and Landret 1984:45-67). The sheets are cut into narrow lengths and woven into twisted, flowerlike strips yielding abundant protected surface for spat fixation. The strips are

suspended at the lagoon surface with a series of floats and weights. These spat collection "stations" are set in a deep part of the lagoon at the change of seasons (April or October) when pearl oyster spatfall is highest relative to that of competing mollusc species. The stations are left to settle several meters below the lagoon surface, protecting the oysters from wave action.

Since spat collection is dependent on the abundance of natural oysters as well as the variable conditions of lagoon bathymetry and current flow, attempts have been made to produce spat through the more controlled conditions of on-land hatchery culture. Hatchery trials in Japan and Australia have met with serious setbacks, apparently because the protracted larval stage has precise, and not yet fully understood, physiological and nutritional requirements (Sims 1988:15). Other problems relate to difficulty with spawning induction and large numbers of abnormal larvae.

A pilot hatchery effort was launched by the Tahitian Institute for Aquaculture Development (EVAAM) on Rangiroa Atoll in 1987 (Cabral 1992). In sterile, well-oxygenated tanks of salt water, supplemented by nutrient unicellular algae, mature female oysters were induced to spawn through exposure to thermal and chemical shock. Fertilized eggs successfully developed into larvae, collected on substrate, and were nurtured in breeding tanks. When large enough, the oysters were transferred to lagoons. By 1990, fifty thousand spat were being produced through hatchery culture. Although mortality rates have been high, success has reportedly been achieved (the status of hatchery work in other regions is reported in Fassler 1994: 325-354).

Regulation of spat collection has proved difficult for the administration in Tahiti. To promote spat collection, concessions were authorized by the administration without fees. But following the disease problems, the administration decided to cut down on the number of spat collectors. To accomplish this, a fee was charged for every meter occupied, a fifty-meter maximum length was placed on all stations, and the number of stations was limited to three per individual (SMA 1987:1-3). These limits are seldom observed in practice.

It is also difficult to force islanders to keep within authorized concession locations (MM 1988:4). The stations are usually situated "chaotically" in the middle of the lagoons, and the islanders themselves have difficulty remembering where they were deployed and frequently move them to new, unauthorized locations. Some stations are deployed by islanders who do not reside on the atoll and only come once a year to deploy new stations or sell old ones. Consequently, in the long intervals between administrative surveys, it is difficult for anyone to keep track of what is going on in the center of the lagoons.

Oyster Culture ("Grow-Out")

Within half a year, young oysters have typically grown to six centimeters, large enough to be removed from the stations, cleaned from fouling algae, and transferred for rearing closer to the shore. The live oysters are pierced through the border of their shells and attached on floating lines (Coeroli, de Gaillende, and Landret 1984:60-62). An alternate method is to place the oysters in mesh pockets or wooden boxes. Some farmers do not move their oysters near shore, leaving them attached to the spat collection stations for direct use or sale to pearl farmers. These oysters are sold for lower prices, since they still require sorting, cleaning, and preparation for grafting.

During the first decade of pearl farming, oyster culture took place on fixed, metallic tubular platforms raised several meters above the lagoon bottom. These platforms were later suspected to be detrimental to the oysters because of heavy-metal leaching, detritus buildup, and crowding-related malnutrition. Accordingly, it was recommended that the farmers switch to floating, synthetic lines, similar (but more sturdy) to those employed in spat collection (EVAAM 1986:95-97). The growing oysters soon become quite heavy and are supported by large plastic drums filled with compressed air.

Transshipment of oysters between atolls is hazardous, as the oysters will die if they remain out of oxygenated salt water for more than half an hour. The preferred means of transport is by small plane, usually making numerous trips back and forth between an oyster-rich atoll and a neighbor. The less expensive but more risky means of transport is by boat, typically a twenty-four-hour journey or more to one of the neighboring atolls. The oysters are kept in large drums and periodically replenished with fresh sea water. In either case, mortality is to be expected. Most worrisome, however, is the potential for spread of infectious oyster disease (SMA 1987:4).

Pearl Culture

Pearl culture was first developed in Japan in the early twentieth century (Calm 1949:8-12). With the demise of the mother-of-pearl industry in French Polynesia, Japanese technicians were contracted by the administration to apply their methods to Tuamotuan pearl oysters. The first experiments, conducted in the early sixties, were successful, but the effort stalled for several years for lack of an international market for these pearls. Having developed a market for the white pearl, Japanese pearl dealers (generally also producers or closely allied with producers) were not eager to promote a competing product.

In the mid-1960s, following a request for investments by the Tahitian administration, a French jeweler began an experimental pearl farm on Manihi, in the Western Tuamotus. By the mid-1970s, other private investors from Tahiti had launched pearl-farming enterprises in other atolls and had established links to the American market. Eventually, the Japanese dealers also became interested in marketing the black pearl, providing a major stimulus for Tuamotuan pearl farming. By the early 1980s, the black pearl auction in Papeete had become an annual event that was well attended internationally (Salomon and Roudnitska 1986:123-150).

The details of pearl induction are still a trade secret, but the basic technique is as follows: A live pearl oyster is opened slightly. An incision is made through the mantle and a round nucleus (made from a thick mollusc shell) is implanted into the gonad of the oyster together with nacre-producing mantle tissue from a donor oyster. The oyster is then returned to the lagoon, and concentric rings of nacre are gradually secreted around the nucleus. Within a year or two, a coating of nacre will have sufficient thickness, color, and luster for the pearl to be profitably marketed (Grand et al. 1984:192-193).

The grafting operation (also called "seeding") is performed by experienced Japanese technicians and, more recently, by a few native islanders, who are accommodated by client farmers and are the most highly paid individuals in the industry. The technician may be paid a daily salary of around CFP 25,000 (approximately US$250)[3] or, alternatively, a percentage of the harvest (usually 50 percent). The graft takes place in a small hut, usually constructed on pilings in the nearshore lagoon. Meanwhile, workers are continuously busy selecting and cleaning donor and host oysters, and moving the oysters between the technician and a holding platform.

A few large-scale pearl farmers hire their own grafters and laborers from Tahiti, paying for transport and other necessities. Most pearl farmers in the Tuamotus run small-scale family operations, generally grafting fewer than five thousand oysters annually. The rest of the year is spent taking care of the oysters and the spat collection stations. Small-scale pearl farmers are eligible for support by a government cooperative (Groupement d'Intérêt Economique Poe Rava Nui), which arranges bank loans, provides technical advice and assistance with supplies, contracts Japanese grafters, and arranges for marketing during the annual pearl auction (Cabral 1989:57-66).

Experience shows that one hundred grafted oysters will yield five gem-quality pearls, fifteen "salable" pearls, twenty "unsalable" pearls, and the remaining sixty oysters will yield nothing at all. The small number of harvested pearls relates to graft rejection and oyster mortality. The expenses are considerable and do not yield any revenues for five or six years. According to one estimate (Fassler 1991:48), US$35-45 is invested for each harvested

oyster (including the cost of the oyster, nucleus, implant, other labor, equipment, transport, and buildings). This investment seems excessive since pearls have been wholesaling for approximately US$100, which (at a 20 percent success rate) would mean a considerable loss to the producer.

As with spat collection, pearl-farming concessions are allocated by the administration in Tahiti. These concessions are easier to monitor than the spat collection stations, since pearl farms are situated closer to land and the concession location can be specified clearly in relation to known reference points on land. Concession fees are proportionate to the lagoon surface area occupied and are charged on a sliding scale (lower for the large-scale farmers). Since increasing the depth or the amount of production does not result in a higher fee, crowding of farmed oysters has unwittingly been encouraged.

Marketing

World production of pearls is estimated to be in the vicinity of one hundred tons annually, over 90 percent produced in Japan. Japan is also the world's largest importer of pearls (close to twenty tons in 1989), predominantly white pearls cultured in China and Southeast Asia. Annual black pearl production is relatively small (less than a ton), but it is several times more valuable than white pearls. Although black pearls are produced almost entirely in the Pacific Islands (French Polynesia and the Cook Islands), the Japanese have played a major role in this industry as well through their skilled overseas grafting technicians and their domination of the import-export market.

Pearls produced in the Tuamotus by large-scale farmers are sold in batches through private arrangements with black pearl wholesalers (in Japan, Switzerland, and the United States). Small-scale farmers associated with the government cooperative must market their pearls exclusively through the annual auction in Tahiti, to which the major international buyers are invited. The first export, of 6 kilograms of black pearls, took place in 1976 and was worth US$80,000. By 1983, 139 kilograms of pearls were exported, worth over US$4 million, becoming the top export earner of French Polynesia. Sales continued to increase in the following years (Figure 3), reaching 600 kilograms in 1990, worth US$37 million (McElroy 1990:4-6; SMA 1990:74; Sims 1992b:20).

Concern has been raised that increasing production of black pearls in French Polynesia and other Pacific islands (Cook Island production in 1989 was 26 kilograms, worth US$350,000) will ultimately lower the sale price of the black pearl (McElroy 1990:7). Prices per pearl have dropped by 15 percent between 1986 and 1991 (see Figure 3), but this may be related to slug-

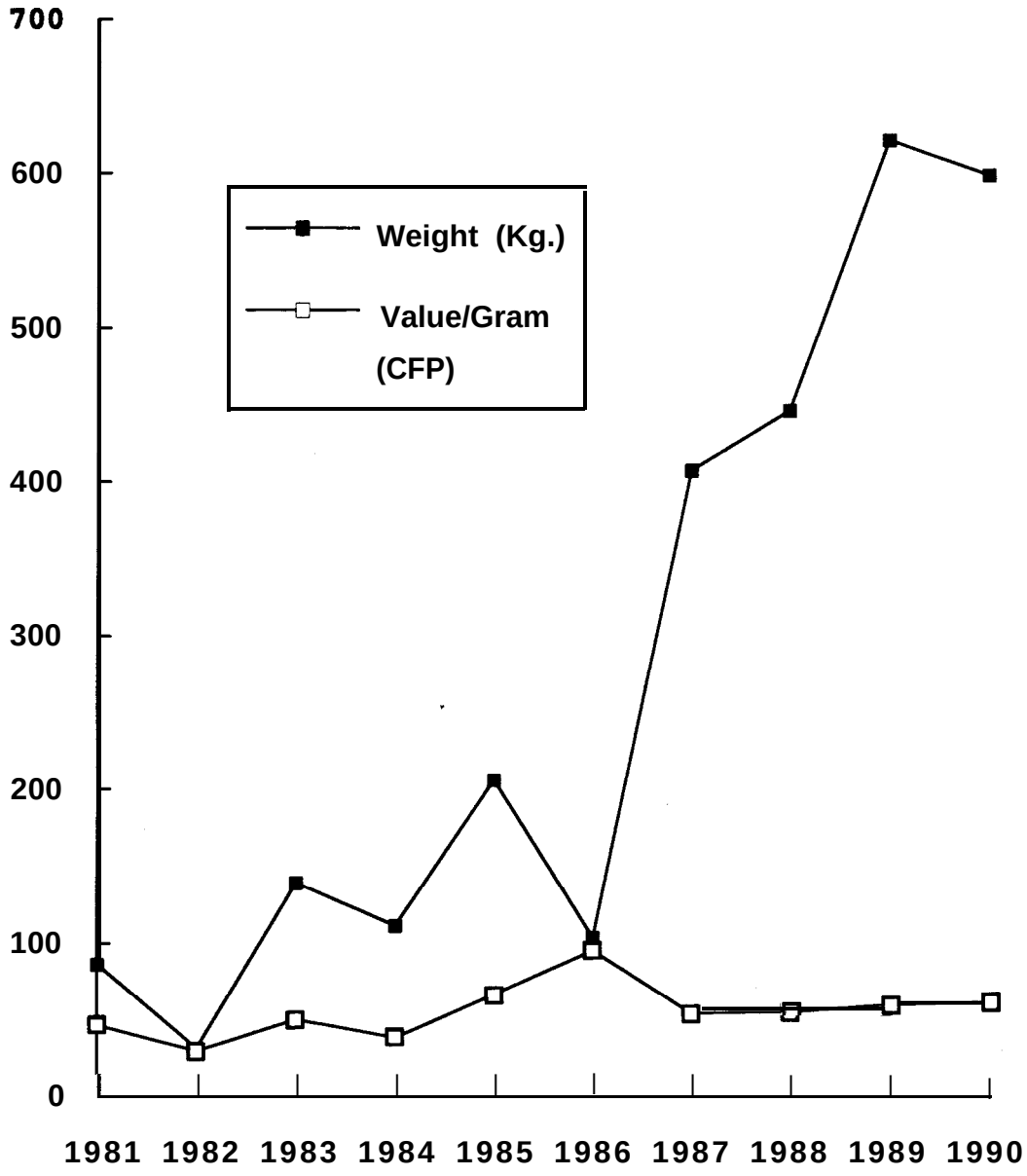

FIGURE 3. **Pearl exports, French Polynesia, 1981-1990.**

gish demand and global recession rather than oversupply. Fluctuating exchange rates over the past decade make it even more difficult to evaluate changes in sale prices. Proposed value-boosting steps have included freezing or slowing production and a concerted South Pacific trade policy to prevent price competition (Coeroli 1992:9).

Boom Growth in the Western Tuamotus

The takeoff of the Tuamotuan pearl-farming industry is attributable to several factors. Foremost among these was the success of pioneering efforts by

the administration and individual entrepreneurs in adapting spat collection and grafting technology to local oyster stocks and lagoon conditions. A major incentive was provided by grants and low-interest loans for pearl-farming development. Additional aid was allocated to help return migrants to their home atolls, assisting with transport, housing, and employment. The declining economic situation in Papeete also provided a "push" factor (Pollock 1978:133-135; Connell 1986:53-54).

An experimental pearl-farming station was built by the administration on Takapoto (Robineau 1977:19-21). Extension agents provided instruction to the population, and Takapoto rapidly became a center for supplying oysters to pearl farms on neighboring atolls. Pearl-farming cooperatives were established, employing the services of Japanese grafting specialists. An airport was built linking Takapoto and Tahiti. By 1974, migrants in Tahiti began to return to Takapoto, encouraged by the new prospects. By the mid-seventies, a long-standing trend of out-migration to Papeete had been reversed (Pollock 1978:133-135).

With the assistance of the Tahitian administration and local banks, pearl-farming cooperatives were established on several atolls in the Western Tuamotus by the late 1970s. However, spat collection was still producing meager harvests, and the majority of oysters (for pearl culture) had to be obtained through diving. The cooperatives soon became plagued with problems of financial mismanagement, treating loans like outright subsidies (Cabral 1989:63). Capital was hard to obtain for independent small-scale pearl farmers. Consequently, until the mid-1980s, the pearl industry remained moribund.

A breakthrough occurred following the series of hurricanes that ravaged the Tuamotus in 1982 and 1983. Debris deposited on the lagoon floor provided a natural substrate for oyster larvae, resulting in dramatic spat collection increases (EVAAM 1987:5). In lagoons where spat collection was most successful, juvenile oysters could be harvested after only six months, yielding a severalfold return on the initial investment. Spat collection provided an immediate source of capital and enabled islanders to acquire the seed oyster stocks, experience, and contacts necessary for pearl-culture operations.

For Tuamotuan migrants in Tahiti, many of whom had been left unemployed when the French nuclear-testing program had completed a massive program of construction work, the developing pearl-farming industry provided a welcome opportunity to return to the atolls. Many of these migrants had not seen their home atolls since childhood; some had even been born overseas (generally in Tahiti or New Caledonia). Between 1983 and 1988 (dates of successive government censuses), annual population increases of 3 percent or more were occurring on several pearl-farming atolls in the

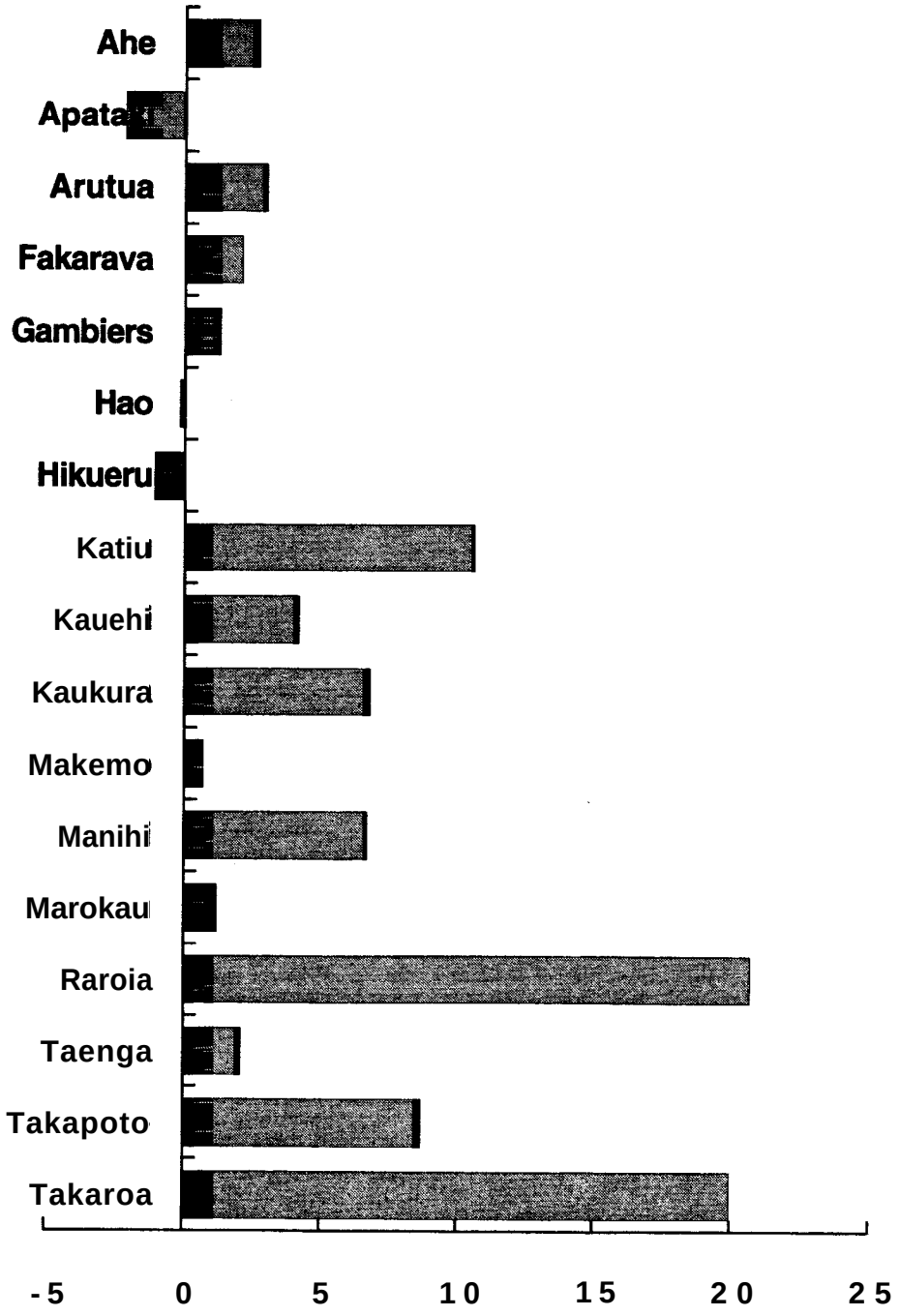

FIGURE 4. **Annual population growth rate (percentage), 1983-1988.**

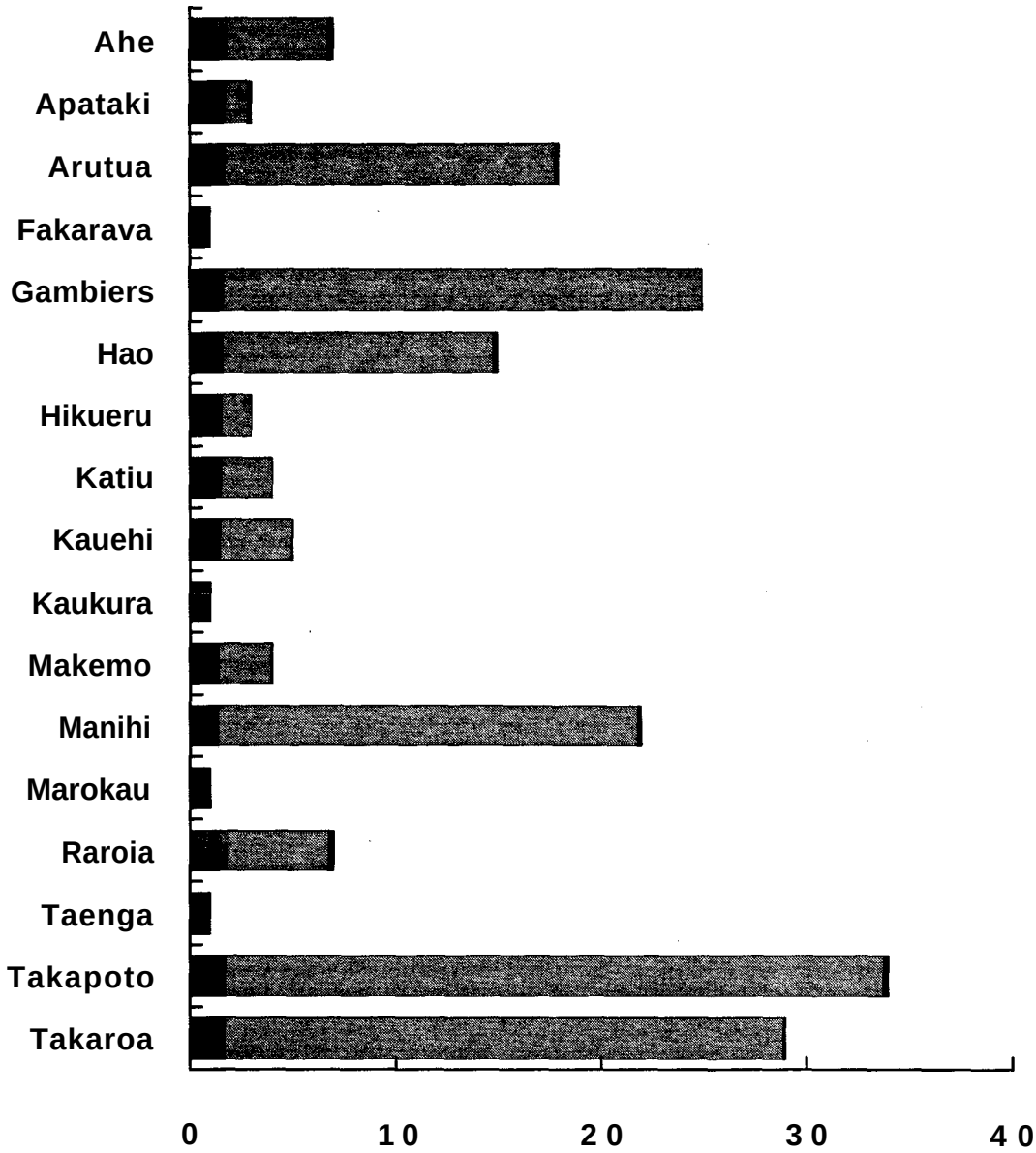

FIGURE 5. **Number of pearl-farming concessions, 1988.**

Western and Central Tuamotus (ITSTAT 1988:45; SMA 1988:22-23), reversing several decades of out-migration and population decline (compare Figures 4 and 5).

Growth rates were highest on Takaroa, which had become the center of the pearl-farming industry. They were also high on Takapoto and Manihi, the original sites of pearl-farming experimentation. These are atolls with midsized lagoons, with substrate and hydrological conditions apparently well-suited for natural pearl oyster stocks, yielding highly productive spat collection. The population change was negative for Hikueru, where natural

pearl oyster stocks had been devastated by an algal bloom during the late 1960s. Population also declined on Hao, site of a French military base, owing to the scaling down of military activities over recent years. There is no evident explanation for the population decline in Apataki, a pearl-farming atoll relatively close to Tahiti.

Pearl export statistics during the 1980s (see Figure 3) provide an indication of the dramatic increase in production. Between 1981 and 1990, exports had increased sevenfold. Detailed breakdown by atoll and by producer is not available (Table 1 provides a rough estimate based on the number of licensed grafting technicians), but it is reported that some fifteen large-scale pearl farms, run by entrepreneurs based in Tahiti, are responsible for over 80 percent of all production (SMA 1990:32; SMA n.d.:1). The remainder of the pearls are produced by small-scale pearl farmers, mostly

TABLE 1. **Estimated Pearl Production, 1990**

Proprietor	Grafters	Atoll(s)	Annual Pearl Production[a]
Total	55		385,000
R. Wan	17	Marutea S., Gambier, Nengonengo, Anuanuraro	119,000
Br. Rosenthal	6	Manihi	42,000
A. Breaud	5	,,	35,000
J. M. Domby	2	,,	14,000
M. Lys	2	,,	14,000
R. Bouche	2	,,	14,000
A. Giau	1	,,	7,000
P. Yu	4	Takaroa	28,000
J. P. Fourcade	2	Aratika	14,000
J. C. Girard	2	Takapoto	14,000
E. J. Den Breejen	1	,,	7,000
Y. Tchen Pan	2	Hikueru	14,000
L. Bellais	2	?	14,000
T. Martin	1	?	7,000
GIE[b]	5	Apataki, Arutua, Hao, Hikueru, Katiu, Kaukura, Makemo, Gambier, Manihi, Marutea N., Raraka, Raroia, Taenga, Tahanea, Takapoto, Takaroa, Takume	35,000
EVAAM (research)	1	Rangiroa	7,000

[a] Based on an estimate of 7,000 pearls per grafting technician.
[b] Groupement d'Intérêt Economique (cooperative).

native Tuamotuans affiliated with the government cooperative, with an annual production generally reaching a few hundred pearls per farmer.

Oyster Mortality

In July 1985, massive mortality suddenly struck Takapoto's pearl oysters. Annual mortality reached as high as 30 to 90 percent (normally it is only about 10 percent). The problems began in farms near the village islet, but within a few months the entire lagoon was affected by high rates of oyster mortality. Regulations were immediately promulgated banning the transport of oysters from Takapoto, depriving the population of its major source of income (transshipment of oysters to private farms on other atolls). But it was apparently too late. By 1986, high mortality rates were also reported on five other atolls (EVAAM 1987:3).

The highest increase in mortality rate occurred with adult oysters. During the height of the disease, oyster mortality increased twofold in pregraft oysters and up to fivefold in postgraft oysters, but natural oysters and related molluscs were affected as well. The pearl retention rate plummeted and many farms became financially endangered. In September, several government-supported research institutions organized a coordinated effort to study the problem and sent researchers shuttling back and forth to Takapoto and neighboring atolls.

Initial histological findings indicated no infectious agent in the affected oysters. However, abnormalities in cellular lysosomes indicated stress. One line of evidence suggested that mortality is related to heavy-metal toxins from decomposing pearl-farm platforms. Alternatively, the problem was linked to detritus buildup underneath farmed oysters. A third theory was that an excess of oysters had been produced following the deposit of debris by the hurricanes of 1983. When the suspended nutrients settled, the lagoon reverted to a lower equilibrium and the "excess" oyster population could no longer be supported ecologically (Grizel 1986:14-15; EVAAM 1986:104-119).

Although the mortality was still not fully understood, remedial measures were taken by both the administration and local pearl farmers. Takapoto was quarantined and its neighbor atoll, Takaroa, not yet affected by the epidemic, became the new center for spat collection and transshipment (close to a million oysters were reportedly sent to neighboring atolls in 1990). Exploitation of natural stocks was phased out completely. The pearl farmers removed their oysters from metal platforms to low-density longline systems. The measures were at least partially successful. By 1987, mortality rates had dropped significantly on several affected atolls (EVAAM 1987:6).

Conflict over Lagoon Control and Allocation

By the mid-1980s, French and Chinese-Tahitian entrepreneurs based in Tahiti had established large-scale pearl farms on several atolls in the Tuamotus (see Table 1). Some of these entrepreneurs had been granted lagoon concessions by the Tahitian administration; others had not. In any case, frustration mounted as newly returning migrants, and in some cases long-term resident islanders, found their concession applications delayed or refused owing to lagoon overcrowding. On several atolls, "associations of protection" were formed to resist and ward off alien entrepreneurs. Resistance has been especially evident on Takaroa.

The conflict was brought to territorywide attention by the media in 1990, when members of Takaroa's association of protection massed at the village quay seized several tons of buoys, rope, construction materials, petroleum, and other goods intended for alien pearl farmers, locking them up in the community storehouse (*DT,* 10 October 1990:13; *DT,* 14 October 1992:13). The situation was temporarily defused through a high-level visit by Gaston Flosse (president of French Polynesia), who promised to cover the expenses of reshipping the seized goods to Tahiti. In the ensuing months, the association president was arraigned on criminal and civil charges, and the goods were reshipped to the atoll. The situation remains highly volatile.

At the heart of the problem is the thorny issue of native land and lagoon rights. Current protest by Tuamotuans against administrative allocation of pearl-farming concessions is linked with claims to adjacent land. In native views, lagoon concessions should be allocated to legitimate claimants of adjacent land parcels in proportion to the land area claimed. In practice, the administration grants concessions to aliens without formal rights to adjacent land. Even where formal land rights are claimed by aliens, the allocated concessions often extend way beyond the boundaries of the adjacent land parcel, interfering with potential lagoon rights of neighboring landholders.

A second argument is that the government has no business being in charge of Tuamotuan lagoon concessions in the first place. The Tahitian administration took over reef and lagoon rights from the colonial government, but colonial lagoon claims rest on an 1890 decree that (arguably) violates previous agreements guaranteeing existing native property rights. Consequently, the view of some islanders is that authorizating lagoon concessions should be handled exclusively by local communities, not by a distant administration in Tahiti.

A discussion of the historical, political, and legal aspects of land and lagoon tenure is beyond the scope of this article and is considered in detail elsewhere (Rapaport n.d.). Briefly, the institution of the French legal system

and tenure laws in the nineteenth century, requiring privatization of land titles and government expropriation of lagoons, facilitated the alienation of highly valued land and lagoon space. In the Tuamotus, land was generally preserved under native control by failure to comply with official title and transaction procedures. Even land that had been privatized reverted to a state of collective ownership after the death of the title holders, making subsequent market transactions onerous and prohibitive.

Lagoons, however, had been declared part of the public domain by the colonial administration. Atoll populations continued to utilize their lagoon resources for the mother-of-pearl diving industry, subject to periodic lagoon closures, quotas, and licensing by the French. Control of the public domain was transferred to the territorial administration in Tahiti under the *loi cadre* (statute) of 1957. Under the autonomous Tahitian administration all citizens, regardless of ethnicity, could apply for lagoon concessions. Not surprisingly, wealthy entrepreneurs from Tahiti have increasingly gained access to large sectors of Tuamotuan lagoon space.

Conclusion

A previous article in this journal aptly summarized the difficult situation of remote and resource-poor atoll communities of the South Pacific (Connell 1986:41-58). On rural islands, lack of economic opportunity has led to outmigration, increasing external dependence, and “dying” communities. Conversely, urban islands (such as Majuro and Tarawa) face severe crowding, pollution, and unemployment. Against this seemingly hopeless backdrop, it was suggested that government support of infrastructure, pearl farming, and return migration to outer islands in the Tuamotus was apparently successful and might serve as a model for development efforts in other Pacific atolls (Connell 1986:57).

Overton considers the above issues for the Pacific Islands in general. Export crops, still “the cornerstone of development in most places” (Overton 1993:50), face unstable or contracting markets, while imported food has increasingly replaced subsistence production. Lacking economic opportunities, rural popuations have left for urban centers, placing severe strains on land and water resources and exacerbating problems of housing and employment. Overton cautions that agricultural success alone does not provide the overall solution and may lead to accumulation, dispossession, environmental degradation, and conflict over land and lagoon resources.

The situation today indicates that development efforts in outer islands of the Tuamotus have indeed borne fruit. Following initiatives by the Tahitian administration and risk-taking entrepreneurs, innovative aquacultural tech-

niques have been introduced and a highly successful pearl-farming industry has been established. Surviving natural oyster stocks on lagoon floors constitute an ecologically precarious base of the new farming industry. Floating collectors provide a substrate for the attachment of spat. The collected oysters are then grown to maturity and induced to produce pearls of high value on the international market.

It is now evident, however, that the Tuamotuan pearl-farming initiative has led to unanticipated consequences, potentially endangering the future viability of the industry. The pearl boom has attracted a wave of migrants from Tahiti, approaching population growth rates of up to 20 percent annually in some atolls. Many of the new pearl farmers are native Tuamotuans returning to their home islands, but there are also alien entrepreneurs from Tahiti, some of whom occupy large sectors of lagoon space. Intense oyster farming has been related to epidemic oyster mortality, concerns about oversupply, and conflict over the allocation of Tuamotuan lagoon concessions to entrepreneurs from Tahiti.

Similar consequences have begun to occur elsewhere in the emerging Pacific Island pearl industry (see Sims 1988:7 for comparable developments in Japan and Australia). On Manihiki, in the Cook Islands, pearl farming has been successfully established, attracting migration and investment from the main island, Rarotonga. However, pearl-farming activities have been linked with an outbreak of oyster disease (not yet fully explained). Pearl farming has also led to conflict over lagoon allocation and control. A law passed in 1982 granted island councils control over lagoon resource management, but "veto power" was reserved by the central government, which has become embroiled in disputes between local farmers, a Tahitian entrepreneur, and the island council (Sims 1992a:11-12; Dashwood 1992:29-30).

Development planners elsewhere considering expansion into the pearl-farming industry may benefit from the Tuamotuan experience.. To begin with, the distribution and abundance of natural pearl oyster stocks, potential competitors, lagoon morphology, and available nutrition should be evaluated. Experimental trials can be undertaken. If the initial results are promising, existing laws, traditions, and precedents concerning lagoon tenure bear careful investigation. A potentially rapid and chaotic influx of migrants needs to be anticipated and planned for. Above all, the needs and wishes of long-term inhabitants should be taken into account before any intervention.

NOTES

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cooperation, and generosity extended by the community and pearl farmers of Takaroa, representatives of administrative agencies and research institutions in Tahiti, and colleagues and friends in both Hawai'i and Tahiti. I also gratefully acknowledge the informative critique offered by two anonymous reviewers.

1. Pearl farming also occurs in the Gambier Islands (including Marutea Sud), which are administratively linked with the Tuamotu Archipelago. Pearl-farming trials have also occurred in the neighbor islands of Tahiti but have not yet reached productive importance. Some data from the Gambiers have been included here, but this article is primarily focused on the Tuamotus. The ground-breaking work on pearl culture in Japan and more recent successes in Australia, Southeast Asia, China, India, and the Cook Islands (George 1978; Fassler 1991:34-52; Doumenge 1992:1-52) are beyond the scope of this article.

2. Data have been aggregated for Raroia (includes neighbor atoll Takume) and the Gambier Islands (includes Marutea Sud).

3. Exchange rates have fluctuated considerably The dollar appreciated against the French Polynesian franc in the mid-1980s (the dollar attained a high of 164 francs in 1986) but depreciated toward the end of the decade (dropping to 102 francs in 1990).

ABBREVIATIONS

DT	*La Dépêche de Tahiti*
EVAAM	Etablissement Pour la Valorisation des Activités Aquacoles et Maritimes
ITSTAT	Institut Territorial de la Statistique
JOEFO	*Journal Officiel des Etablissements Français de l'Océanie*
MM	Ministère de la Mer
PVCG	*Procès-Verbaux des Séances du Conseil Général*
SMA	Service de la Mer et de l'Aquaculture
SP	Service de la Pêche

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