Precious Coral Fisheries of Hawaii and the U.S. Pacific Islands

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Introduction

Precious corals have been used by humans for the fabrication of coral jewelry since antiquity (Grigg, 1989). Along with amber, precious coral may have also been used as a source of currency for trade by paleolithic man (Tescione, 1968). As a renewable resource in the sea, precious corals are thought to be the slowest growing organisms of any known fishery past or present. Pink and red coral fisheries exist in the Mediterranean Sea and the Pacific Ocean. Black corals are distributed world-wide and small fisheries for black coral exist in all oceans. Hence, precious corals represent a unique and interesting case history of a fishery which is very old and quite widespread and one which renews itself very slowly. In this paper, these aspects of the fishery are considered but only as they relate to the modern history and management of precious coral fisheries in Hawaii and the Western Pacific during the past 35 years. Over this period in this area, two different precious coral fisheries have been developed; one in relatively shallow water between 30–100 m for several species of black coral, and the other, for pink, gold, and bamboo corals at depths of 400–1500 m. A brief history of both fisheries is presented including a description of their ecology and management of target species. Future research needs for both fisheries are described and future prospects of the precious coral industry are considered.

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ABSTRACT — The precious coral fishery in Hawaii and the Western Pacific consists of one industry but two distinct and separate fisheries. The first is the harvest of black coral by scuba divers from depths of 30–100 m. The second is a fishery for pink and gold coral at depths between 400 and 1500 m and employs either a human-operated submersible that permits selective harvest or tangle net dredges which are nonselective. The modern history of these fisheries date from 1958 until the present. In this paper the ecology, life history, and management of the dominant species that make up these fisheries are reviewed. Research needs of the fisheries and the economic and future prospects of the precious coral industry are also described. At the present, the precious coral jewelry industry in Hawaii (all species) is valued at about $25 million at the retail level.

Taxonomy

Briefly, all species of precious coral in the Western Pacific belong to one of three Orders within the Class Anthozoa, Phylum Coelenterata. The pink and bamboo corals, *Corallium* spp. and *Lepidisis olapa*, are in the Order Gorgonacea. The Hawaiian gold coral, *Gerardia* sp., is in the Order Zoanthidae and the black corals, *Antipathes dichotoma*, *A. grandis, A. ulex,* and *Cirrhipathes anguina*, are all in the Order Antipathidae. Gorgonians are octocorals while the Hawaiian gold and black corals are hexocorals.

History of the Precious Coral Fishery in Hawaii and the Western Pacific

Commercial beds of black coral were discovered in Hawaii in 1958 by Jack Ackerman and Larry Windley (Stewart, 1962a; Grigg, 1965). This discovery was located 4.8 km due west of Lahaina, Maui, at a depth of 30–75 m along a drop-off known as "stone wall" on the Lahaina Roads Reef. What Ackerman and Windley had discovered were populations of two species of exceedingly large black corals, *Antipathes dichotoma* and *Antipathes grandis* (Fig. 1). Subsequent research has shown that 12 additional species exist in Hawaiian waters but most of these occur at depths below 100 m, and none are large enough or are of sufficient quality to be of commerical value for coral jewelry (Grigg and Opresko, 1977).

The discovery of black coral in Hawaii in 1958 led to the establishment of a small cottage industry that produced curios and black coral jewelry in Lahaina, Maui (Stewart, 1962b). In 1960, John Stewart and Jack Ackerman started a company known as Maui Divers. Over the next ten years, Maui Divers grew steadily under the direction of Clifford Slater, and was joined by about a dozen other small companies. By 1969 the industry collectively was producing about $2 million gross retail sales; part of these sales included imports of pink coral jewelry from Taiwan and Japan.

In 1965, Japanese coral fishermen discovered a huge bed of commercial pink coral at about 400-m depth on the Milwaukee Banks in the Emperor Seamount Chain north of Midway Island near the northwesternmost end of the Hawaiian Archipelago. In terms of significance to the United States, only about 10% of the entire area (the so-called Midway Grounds) exist within the U.S. economic zone (EEZ). Nevertheless, as a result of this discovery, interest in precious coral resources dramatically increased in Hawaii. This stimulated new exploration in the high

Figure 1.—Jack Ackerman and Larry Windley display a large colony of *Antipathes dichotoma* collected from a depth of 65 m off Lahaina, Maui. The colony is dead and encrusted with numerous sponges and other invertebrates. Even so, the skeleton is still of commercial quality for the manufacture of coral jewelry.

Hawaiian Islands and in 1966, Vernon Brock and Ted Chamberlain of the University of Hawaii discovered a small bed of pink coral *Corallium secundum*, near 400 m depth off Makapuu, Oahu (Fig. 2). In the following three years, a small group of fishermen dredged the Makapuu Bed for pink coral on a small scale using tangle nets (Fig. 3).

In 1970 a long-term research program on precious corals began at the University of Hawaii and this led to the development of a selective harvesting system utilizing a manned submersible (Grigg et al., 1973; Figure 4). In 1973, Maui Divers of Hawaii incorporated this system and began a commerical operation of selective harvest for pink, gold, and bamboo coral which lasted until 1978. The gold coral (*Gerardia* sp.) and bamboo coral (*Lepidisis olapa*) (Muzik, 1978) coexist within the same depth zone and habitat with *Corallium secundum*. The Maui Divers operation lasted 6 years but was discontinued in 1978 because of high operating costs. The annual harvest of pink and gold coral from the Makapuu Bed during this period is given in Table 1. Since this time, the industry in Hawaii has relied on stockpiles of gold coral and exports of pink and red corals (*Corallium* spp.) mostly from Taiwan and Japan. The only other attempt to harvest pink corals domestically within the Western Pacific EEZ was in 1988, when crew members of the vessel *Kilauea* used nonselective tangle nets at Hancock Seamount. Their catch was only 450 kg of *Corallium secundum* and most of the colonies harvested were dead and of low quality.

Because Hawaii's precious coral industry continues to be dependent on sources of raw material outside the US EEZ, it is important to analyze trends in the supply of *Corallium* spp. Pacific-wide. From the time of the major discovery of *Corallium secundum* on the Milwaukee Banks in 1965 to the present, the annual supply of both pink and red corals has been extremely erratic. The harvest of shallow water *Corallium* by Japanese and Taiwanese coral fishermen first peaked in 1969 when production Pacific-wide reached 150 metric tons. Following this boom year, production fell precipitously and remained low for the next five years

Table 1.—Annual harvest of pink and gold coral from the Makapuu Bed (kg).

Year	Gear	*Corallium secundum*	*Gerardia* sp.
1966–69	Dredge	1800	0
1970–72	No harvest	0	0
1973	Submersible	538	0
1974	Submersible	2209	734
1975	Submersible	1385	621
1976	Submersible	400	363
1977	Submersible	1421	329
1978 (Jan–June)	Submersible	474	50
1979–92	no harvest	0	0

Figure 2.—*Corallium secundum* (center) at a depth of 390 m in the Makapuu coral bed. The substratum consists of a hard fossilized limestone. It is swept by strong bottom currents which prevent the buildup of sediments. The measuring rod is marked at 10 cm intervals.

Figure 3.—A = Coral tangle dredges consisting of stones with attached netting.

(Grigg, 1984). Accurate statistics for these years are not available. Then in 1978, a deep-water undescribed species of *Corallium* (sp. nov.) was discovered by a Japanese fishermen at depths between 900 and 1500 m on the Emperor Seamounts. While the color of this species is spotty (sometimes called Scotch), varing between pink and white, it was extremely abundant, and like the 1965 discovery, it produced a "coral rush." In the peak year of 1981, over 100 coral boats from Japan and Taiwan fished the Midway Grounds and production neared almost 300 metric tons (t) Pacific-wide (Table 2). Unfortunately, this intensive fishing effort led to a gradual depletion of the resource, illustrating the well established pattern for all precious coral fisheries: exploration, discovery, exploitation, and depletion (Grigg, 1989).

By 1991, production Pacific-wide stood at an all time low of 2,930 kg (Table 2) and prices of raw material were at unprecedented highs. According to the American Institute in Taiwan, coral production in Taiwan fell to

Table 2.—Total foreign yield (kg) of precious coral (*Corallium* spp.) in the Pacific during the years 1979–91.

Year	Japan			Taiwan (All areas combined)	Total
	Midway grounds	Western Pacific	Submersible		
1979	76,988	14,516	0	123,000	214,504[1]
1980	74,228	10,227	0	154,000	238,455[1]
1981	30,484	5,381	775	254,000	290,640[2]
1982	52,166	3,000	551	69,200	123,917[2]
1983	51,087	2,947	306	109,000[3]	163,493[2]
1984	33,164	3,315	634	157,000[3]	194,113[2]
1985	9,322	2,366	816	214,000[3]	226,504[2]
1986	1,650	1,268	1,261	141,000[3]	146,179[2]
1987	585	1,986	425	106,000[3]	108,977[2]
1988	217	1,605	1,082	50,000[5]	52,094[2]
1989	1,961	1,057	938	5,400[6]	9,156
1990	0		(2,172[4])	1,000[6]	3,172
1991	0		(1,390[4])	~1,000[6]	~2,930

[1] Grigg, 1984.
[2] All Japan Coral Fishing Association.
[3] Coordination Council for North American Affairs, Taipei, Taiwan, D. K. P. Liu.
[4] D. M. Ancona, Embassy of the United States, Tokyo, Japan. Western Pacific and submersible catch combined.
[5] Taiwan Fisheries Bureau, Sing-Hwa Hu. Personal commun. 1989. Taipei.
[6] Personal Communication, Vanila Lin, Taipei, Taiwan. 1990.
[7] American Institute in Taiwan, M. J. Matthews. Personal commun. 1992 Taipei.

Figure 3.—B = Japanese coral fishing boat showing line haulers, tangle net dredges, and rollers on side of vessel.

1 t in 1990 but exports drawn from previous year stockpiles were 63 t of coral products. As stockpiles of the resource are gradually reduced worldwide, new production will depend on the discovery of new precious coral beds. This boom and bust cycle of harvest and supply dramatically illustrates the need for management of the fishery. Management has been hampered by the multinational character of the fishery and because many precious coral beds exist in international waters.

In contrast to the pink and red coral fishery in the Pacific, the black coral fishery in Hawaii is relatively stable. While demand has fluctuated considerably over the years since its discovery in 1958, the supply of black coral has never failed to meet demand. In the early years of the industry during the 1960's and early 70's, as much as 10,000 kg were harvested annually from the black coral beds off Maui and Kauai. During the late 70's and early 80's the demand for black coral was greatly reduced, being replaced by a higher consumer interest in pink and gold coral. However, since about 1986, demand for black coral has been steadily increasing. Consumption by one company, Maui Divers of Hawaii, Ltd., illustrates this trend (Table 3).

Table 3.—Consumption of Hawaiian black coral by Maui Divers of Hawaii, Ltd., 1982–92.

Year	Weight (all species combined), kg
1982	78
1983	70
1984	257
1985	278
1986	463
1987	934
1988	432
1989	824
1990	1295
1991	1740
1992 (Jan–July)	1238

Production by Maui Divers of Hawaii accounts for more than 50% of all locally produced black coral jewelry in the State of Hawaii. Today, considerably less black coral is used for fabrication than during the 60's and 70's because the jewelry items produced are smaller and of higher quality and because modern cutting procedures are much more efficient than in the past. In November of 1987, black coral was named the State "Gem" and this has increased consumer interest considerably.

Over the years, the stability of the industry has been aided by the availability of inexpensive black coral from the Philippines and Tonga (Harper, 1988). These sources have filled the demand for low quality but high volume jewelry products. Also black coral resources in Hawaii have been well managed by local fishermen who voluntarily do not harvest colonies below

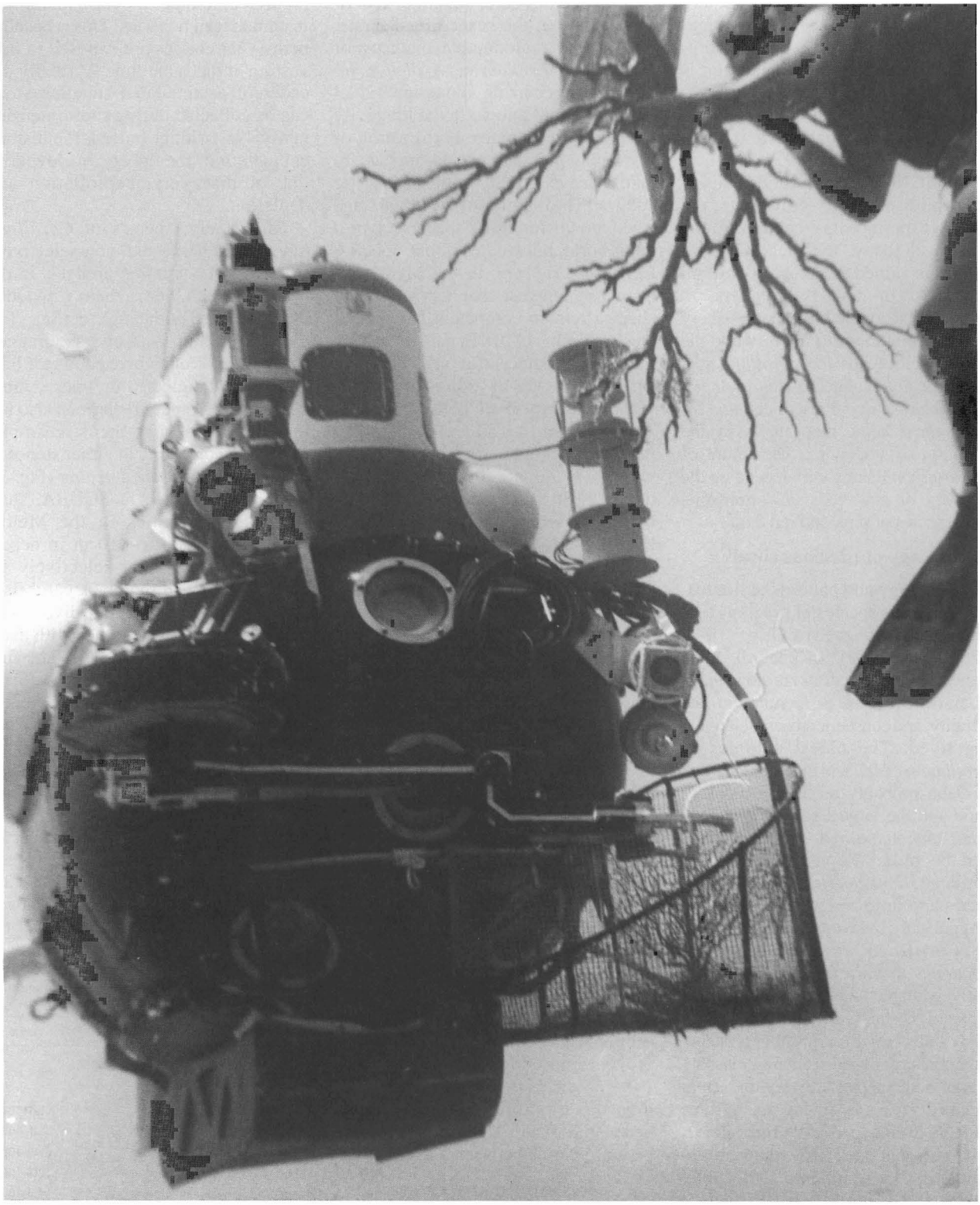

Figure 4.—As the Maui Divers *Star II* submersible approaches the surface, a subtender using scuba collects gold coral, *Gerardia* sp., from the basket.

48 inches (1.2 m) in height. This size limit has been adopted by the Western Pacific Regional Fisheries Management Council and has been recommended to the State of Hawaii and is based on the growth rate and reproductive pattern of *Antipathes dichotoma* and calculations of maximum sustained yield (Grigg, 1976).

Overall, the precious coral industry in Hawaii has steadily grown over the past 34 years since its inception. At the retail level today, the precious coral industry is valued at about $25 million and consists of about 100 retailers.

A small but stable black coral fishery in Hawaii continues to thrive while the fishery Pacific-wide for *Corallium* spp. has drastically declined owing to depletion of the resource. Present demand for *Corallium* is being met largely by the utilization of stockpiles. The future of the *Corallium* fishery will depend on the discovery of new beds of commercial grade species of pink and red coral.

Ecology of precious corals

The ecology and patterns of life history of various species of precious corals have been reviewed by Grigg (1974, 1976, 1984, 1989). In general, most species of precious corals are slow growing, have low rates of recruitment and mortality, and consequently are relatively long lived. The oldest colonies of *Corallium secundum* in the Makapuu Bed off Oahu probably reach an age of 75 years, and the largest colonies of *Antipathes dichotoma* and *A. grandis* may even be older. Populations of both *Corallium secundum* and both black coral species appear to be recruitment limited (Grigg, 1988). In favorable environments for *Corallium secundum* and *A. dichotoma* in Hawaii, populations are relatively stable suggesting that recruitment and mortality are approximately in steady state. However, in suboptimal environments, the age frequency distributions of both species are very uneven or truncated probably owing to episodic mortality events (personal observation).

Mortality is most often the result of smothering by sediments and by bioerosion of the substrata which leads to toppling of colonies. Fragmentation and reattachment (asexual reproduction) appears to rarely occur. Most species of precious coral are uni-sexual or dioecious, i.e. the sexes are separate. The age of reproductive maturity of *Corallium secundum* and *A. dichotoma* is similar, occurring about age 12–13 which is about one-sixth the longevity of the oldest colonies. Fertilization of Hawaiian precious corals appears to take place externally within the water column. The duration of the larval stage is unknown for most species of precious coral, but studies of one species, *Corallium rubrum*, in the Mediterranean Sea suggest that larvae of this species remain competent for several weeks (Vighi, 1970). In general, settlement is most successful on clean swept surfaces exposed to strong bottom currents. The larvae of both species of *Antipathes* in Hawaii are known to be negatively phototactic which explains why they are not found at shallow depths (< 30 m) and are most abundant beneath overhangs and on other dimly lit surfaces (Grigg, 1965).

The ecological requirements of all species of precious coral in the western Pacific can be briefly summarized as follows. All species require a firm (rocky) substratum free of sediment and most thrive in areas swept by moderate to strong currents. All species lack symbiotic algae in their tissues (ahermatypic) and most are found in deep water below the euphotic zone (Table 4). All species are filter feeders and many are fan-shaped, a growth form which maximizes contact of feeding surfaces with particles or microplankton entrained in the water column. Light and temperature appear to influence larvae more than adults. The lower depth limit of *A. dichotoma* and *A. grandis* coincides with the top of the thermocline in the high Hawaiian islands. Larvae may avoid settling deeper where lower temperature may prevent reproduction (Grigg, 1977, 1984). Species of *Corallium* exist below the euphotic zone at depths between 350 and 1,500 m where temperature varies between 14° and 3°C.

Resource management

The life history attributes of all species of precious corals in the western Pacific make these living resources highly vulnerable to over-exploitation in unmanaged fisheries. This is because many year classes are exposed to harvesting at the same time. Virtually decades of accumulated standing stock can be collected during short intensive periods of fishing. Indeed, the historical pattern of the fishery worldwide is one of discovery, exploitation and depletion.

Historically, species of *Corallium* have been harvested non-selectively using various types of dredges. In the Meditteranean Sea a heavy wooden cross outfitted with tangle netting (The Cross of Saint Andrew) is dragged across the bottom where corals are broken and entangled in the mesh. Japanese and Taiwanese fishermen also use tangle gear although theirs is simpler in design, consisting of either stones or iron bars with attached netting (Fig. 3). Since the inception of SCUBA, shallow water colonies in the Meditteranean Sea (up to 110 m in depth) have been harvested selectively by divers. In Hawaii the black coral fishery also employs SCUBA divers who selectively harvest colonies with axes, hammers, and saws (Fig. 4). The first selective harvest of *Corallium* in which a submersible was used by Maui Divers of Hawaii in 1973. This was accomplished with the use of a sophisticated cutter, claw, and basket assembly that was attached to the submersible (Fig. 5, Grigg et al., 1973). Since 1983 an unmanned submersible (robot) has been used in Japan to harvest selective species of precious coral in traditional seas (Table 2).

Precious coral resources in Hawaii and the Western Pacific fall under the

Table 4.—Depth zonation of all species of precious coral in the western Pacific.

Species and common name	Depth range (m)
Corallium secundum, Angle skin coral	350 –475
Corallium sp. nov., Midway deepsea coral	1000–1500
Gerardia sp., Hawaiian gold coral	300–400
Lepidisis olapa, bamboo coral	350–400
Antipathes dichotoma, black coral	30–100
Antipathes grandis, pine black coral	45–100
Antipathes ulex, fern black coral	40–100
Antipathes anguina, wire black coral	20–60

Figure 5.—A black coral diver in Hawaii approaches a small colony of *Antipathes dichotoma* at a depth of 50 m off Lahaina, Maui.

management authority of the State of Hawaii and the U.S. Federal government. The State has clear jurisdiction over resources out to three miles but also claims authority over inter-island waters. Hence the State has declared jurisdiction over the Makapuu Coral Bed situated 9 km (6 miles) off Makapuu in the channel between Oahu and Molokai. Federal jurisdiction extends from 3 miles outside the State of Hawaii, Guam, and American Samoa to 200 miles, and from the shoreline of all U.S. possessions in the Western Pacific (Johnson Atoll, Kingman Reef, and Palmyra, Wake, Jarvis, Howland and Baker islands) to 200 miles. This area is defined as the U.S. Exclusive Economic Zone (EEZ).

Presently black corals in Hawaiian waters are managed by the State of Hawaii. Fishermen are required to have commercial fishing licenses and report their catch monthly to the Hawaii Division of Aquatic Resources. A state regulation has been drafted which sets a minimum size of 48 inches in colony height and 3/4" in basal diameter for the harvest of *A. dichotoma* and *A. grandis*. At the present time, black coral divers in Hawaii comply voluntarily with this draft regulation.

Precious coral resources within the U.S. EEZ (Fig. 6) are managed by the Western Pacific Regional Fishery Management Council (WESTPAC), under a Fishery Management Plan (FMP) for precious coral (Dep. of Commerce, 1980). The FMP, finalized in September 1983, allows for domestic and foreign fishing by regular or experimental permits and requires logbooks of the permittees. Specific regulations contained in the FMP are as follows:

The FMP and regulations outline and classify the known beds of precious corals within the Western Pacific Region, and designate harvesting method and the amount of corals that can be harvested. There are four bed classifications: 1) Established Beds, 2) Conditional Beds, 3) Refugia Beds, and 4) Exploratory Permit Areas. Established beds are ones with a history of harvest, and optimum yields have been established on the basis of biological stock assessment techniques, and selective harvesting gear (submersibles or remote control harvester vehicles) is required. Makapu'u is the only designated Established Bed. Conditional beds are ones for which yields have been estimated on the basis of bed size relative to established beds with the assumption that ecological conditions at established beds are representative of conditions at all other beds. Four beds are designated as conditional beds: Kea-hole Point, Kaena Point, Brooks Banks, and 180 Fathom Bank. Nonselective harvesting is permitted only in the two conditional beds in the Northwest Hawaiian Islands (Brooks and the 180 Fathom Banks). A refugia bed is one set aside to serve as a baseline study area and possibly reproductive reserve. No harvesting of any kind is permitted in Refugia. Presently, the WESTPAC bed, between Nihoa and Necker Islands, is the only designated Refugia. Exploratory permit areas are unexplored portions of the EEZ in which coral beds are almost certain to exist, but no beds have yet been lo-

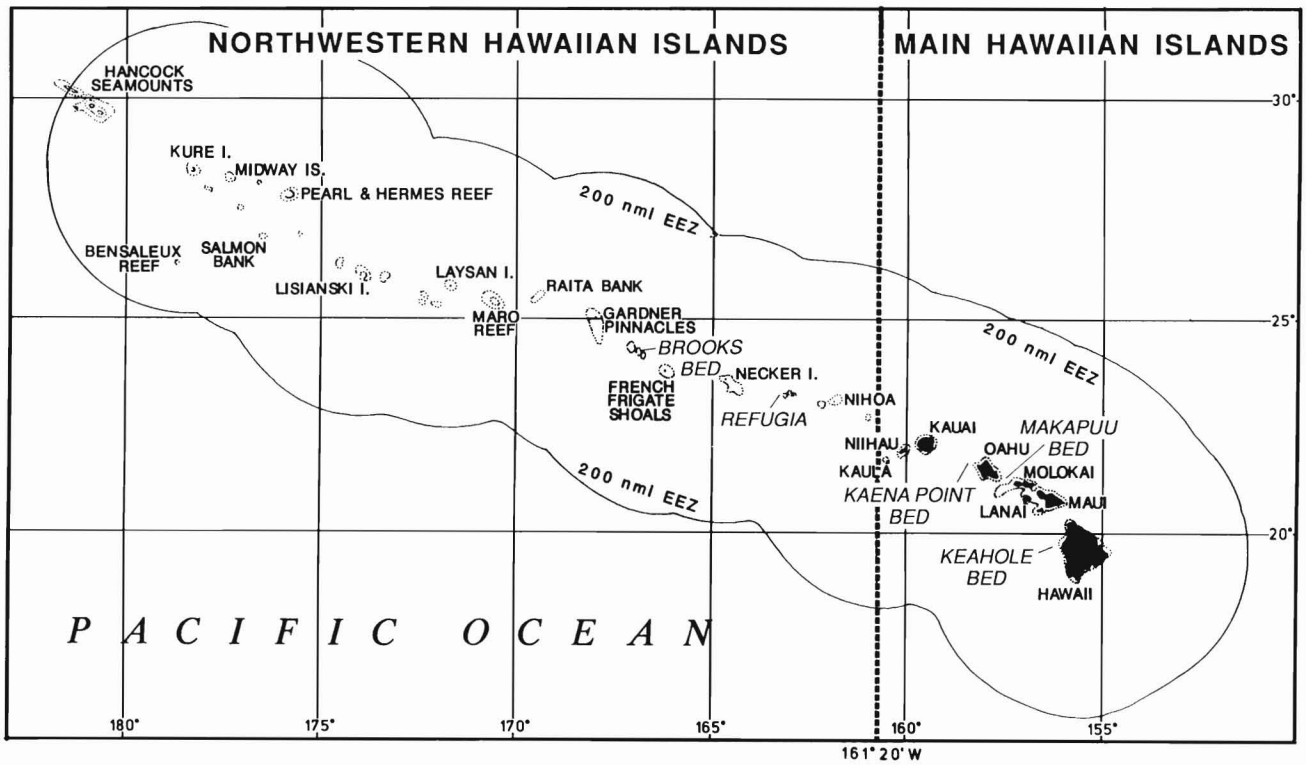

Figure 6.—Map of the EEZ in the southern half of the Hawaiian Archipelago showing the location of five precious coral beds.

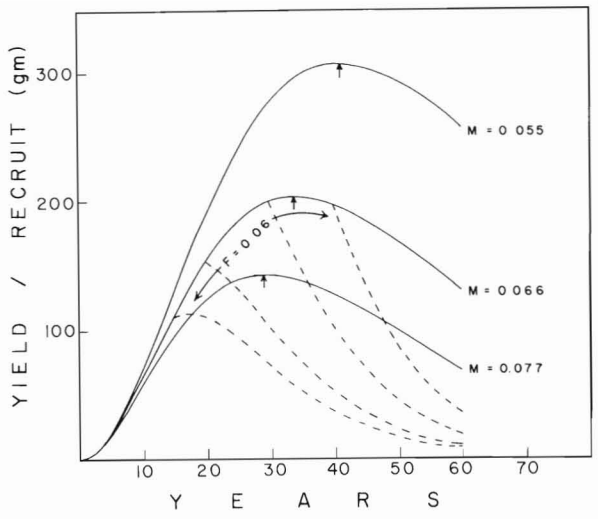

Figure 7.—The Beverton and Holt yield-per-recruit model was used to estimate MSY (vertical arrows) for *Corallium secundum* in the Makapuu coral bed at 3 different values of natural mortality. Dashed lines indicate yield curves produced by applying a fishing mortality of 0.06 at four different ages.

cated. There are four exploratory permit areas; one surrounding the Hawaiian Islands, another that encompasses Guam and the Commonwealth of the Northern Marianas, a third that encircles American Samoa, and a fourth, which was created by Amendment 1 to the FMP, which includes the EEZ's of all the remaining U.S. Pacific Island possessions. Either selective or nonselective harvest gear is permitted in exploratory permit areas except in the Hawaii exploratory area around the Main Hawaiian Islands.

Specific weight quotas and size limits have been determined based on estimates of maximum sustainable yields and optimum yields. For example, the established bed at Makapu'u has a 2-year harvest quota for selective gear only: 2,000 kg for *C. secundum*, 600 kg for *Gerardia* sp. and 500 kg for *L. olapa*. Only colonies of *C. secundum* taller than 10 inches can be harvested. Quotas of 1,000 kg of all species of precious coral combined, exist for each of the EEZ exploratory areas. Foreign fishing is allowed in exploratory areas, if the quotas are not taken by domestic fishermen. Maximum sustainable yields were calculated by using the Beverton and Holt cohort production model (Beverton and Holt, 1957) for *Corallium secundum* (Fig. 2, 7) and the Gulland Model (MSY = 0.4 *M Bo*) where *m* = natural mortality and *Bo* is the virgin biomass, for *Gerardia* and *Lepidisis*.

Having described the management measures established to conserve precious coral resources in Hawaii and the Western Pacific, it is important to evaluate their effectiveness over the history of the fishery. For pink corals, management efforts have been successful for the domestic fishery; however, poaching by foreign fishing has frequently occurred within the U.S. EEZ and is difficult to control.

Considering the domestic coral fisheries first, the cumulative harvest of *Corallium* from the Makapu'u bed between 1966 and 1978 was about 32% of the standing stock. The average annual harvest was 685 kg, somewhat less than the best estimate of MSY, near 1,000 kg. Surveys of the Makapu'u bed in 1983 and again in 1985 showed substantial recovery at rates in close agreement with model predictions in the FMP (Grigg, 1988). For black coral, the combined MSY for beds off Maui and Kauai is 6,250 kg/yr (Grigg, 1976). Harvest levels of black coral above MSY occurred only in the earliest years of the fishery (Table 3) and supply has always been unable to meet demand. Only the most accessible black coral beds off Lahaina, Maui, have been depleted.

Foreign poaching has been a serious problem in the past. During the 1980's, Japanese and Taiwanese coral vessels continuously violated the EEZ near the Hancock Seamounts. In 1985, about 20 Taiwanese coral draggers reportedly poached about 100 tons of *Corallium* from seamounts within the EEZ north of Gardner Pinnacles and Laysan Island. Absence of poaching since that time could indicate that the resources in these areas have been economically exhausted. A research program is currently planned to resurvey the Hancock Seamounts in 1994 with the University of Hawaii research submersible *Pisces V*, in order to assess the present condition of precious coral resources in this area.

Research Needs and Future Prospects

The most pressing need of the precious coral fishery (and industry) is stock assessment; first in order to describe the status of the stocks within established grounds, and second, to discover new areas. Without substantial efforts to explore and discover new grounds, the precious coral fishery will undoubtedly continue to decline. The problem will become increasingly more serious as existing stockpiles accumulated during the early 1980's are gradually exhausted.

The most promising exploratory areas appear to be in southern oceans. Channel waters around Madagascar and Tasmania (Grigg and Brown, 1991) are particularly promising areas and scattered occurrences of large colonies of *Corallium* spp. have been reported (exact locations are well guarded secrets). Considerable exploration has been conducted in the tropical Pacific by CCOP-SOPAC (Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas), and *Corallium* spp. have been recorded from many localities (Cook Islands, Fiji, Kiribati, Solomon Islands, Tonga, Vanuatu, and W. Samoa), but unfortunately not in commercial quality or abundance

(Harper, 1988). Most exploratory dredging by CCOP-SOPAC, however, has been at depths between 200 and 500 m, and virtually nothing is known about the potential of deeper water resources (such as *Corallium* sp. nov. which occurs at a 1,000–1,500 m depth by the Emperor Seamounts).

Another important research question concerns recovery rates (recruitment and growth) in areas which have been heavily harvested. A proposal to assess the stocks on the Hancock Seamounts using the *Pisces V* submersible has been accepted by the Hawaii Undersea Research Laboratory at the University of Hawaii and is presently scheduled for the summer of 1995. The whole area of population dynamics of precious corals is in need of further research.

The mariculture of precious corals is an exciting new area of research. A new laboratory for the biological, economic, and technical research of precious corals has recently been established in Kochi, Japan, in order to attempt the culture of precious coral (Sadao Kosuge, Director of the Institute of Malacology, Tokyo. Personal commun. 1992). To date, colonies of *Corallium japonicum* have been maintained alive in culture for over one year but growth rates are very slow and colonies have not been induced to reproduce. However, the research is still in a very early stage.

While a complete analysis of the economics of the precious coral fishery is beyond the scope of this paper, it is important to mention that this is another area in need of future research. The worldwide glut of *Corallium* precious coral produced during the boom years of the early 1980's caused prices to fall sometimes even below breakeven costs for Taiwanese and Japanese coral fishermen and many vessels dropped out of the fishery during this time. The future supply of *Corallium* to the Hawaiian industry will probably continue to depend on exports from these countries; therefore, what happens to the Japanese and Taiwanese fleet is important. Exploration is very expensive and there appears to be little Japanese or Taiwanese interest in wide ranging fishing expeditions at the present time. For this reason, the future of the industry can only be described at this juncture as uncertain. Prices will undoubtedly continue to climb. The raw material for Midway deep-sea coral is still (1990) reasonable at about $150/kg but prices for high quality pink and red *Corallium* peaked in 1990 at $3,069/kg and $16,103/kg, respectively (D. Ancona, U.S. Embassy, Tokyo. Personal commun. 1991). The future of the industry would appear to depend on either successful future exploration or a breakthrough in the mariculture of precious corals.

As for the future of the black coral fishery, at least in Hawaii, it appears to be secure in terms of both supply and demand for the resource. The management of other species of precious coral in Hawaii and the Western Pacific will continue to be covered by the existing FMP of WESTPAC. Regarding the control of foreign fishing in international waters, it is in the best interest of the United States, Japan, and Taiwan to enter into an international treaty for the purpose of conservation of precious corals. However, before this can be achieved, an impetus for such implementation must be initiated by one or all three countries. Based on the principle of common heritage embodied in the International Law of Sea (LOS) convention, and on articles of the LOS Treaty which urge agreements between member countries on measures to conserve living resources within and beyond EEZ's, the Western Pacific Fishery Council has requested that the U.S. State Department enter into multilateral arrangements with Japan and Taiwan for jointly managing the precious coral fisheries in the Pacific.

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