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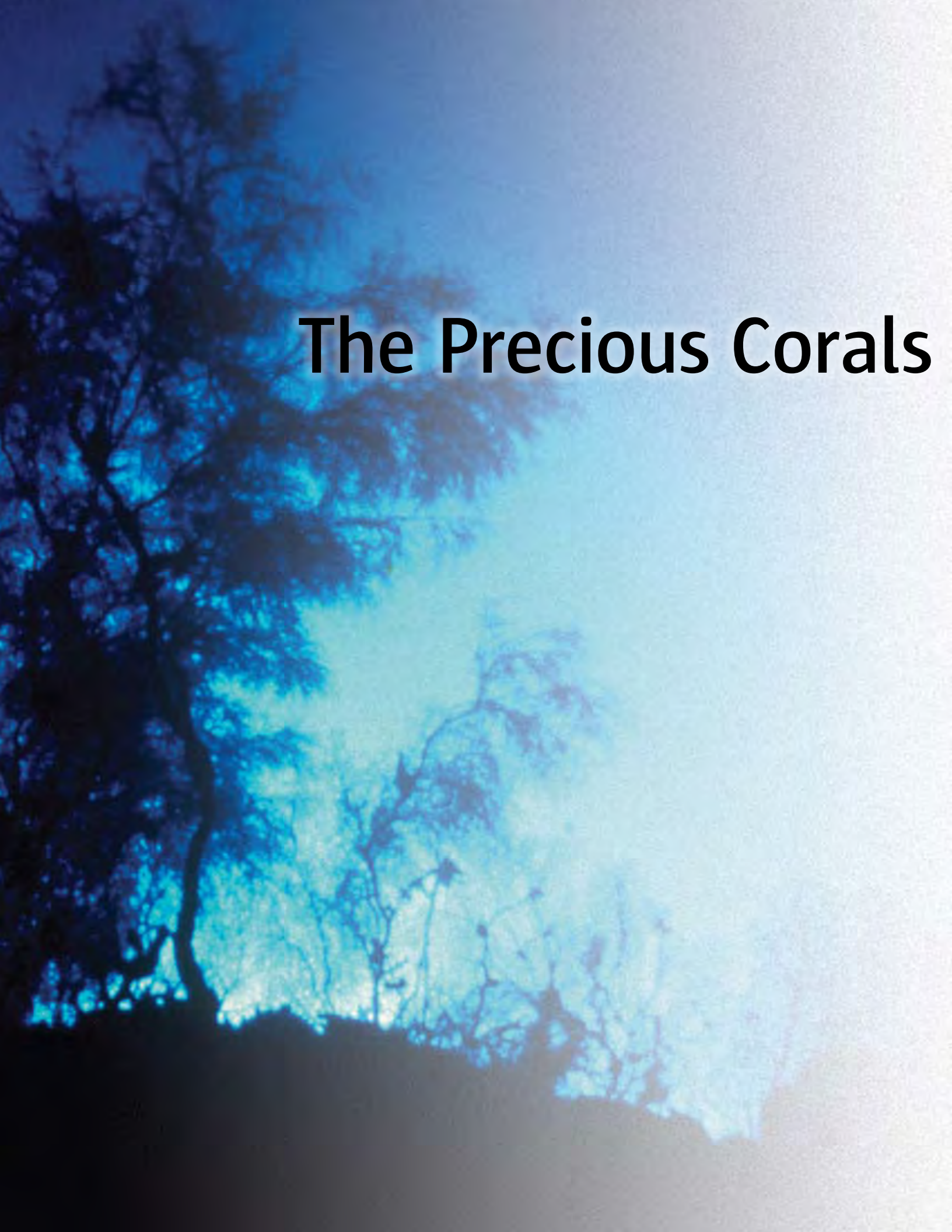
By Richard Grigg



The Precious Corals

Fishery Management Plan

of the Western Pacific Regional Fishery Management Council

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January 2010

Opposite: A large colony of black coral (*Antipathes griggi*) photographed at a depth of 200 feet off Lahaina, Maui, Hawaii. Photo courtesy of R. Grigg

Cover photo courtesy of D. Doubilet

I. Introduction and history of the precious corals fishery

Precious corals have been treasured as jewelry by mankind ever since the dawn of history. The earliest records of man's use of precious coral date back almost 25,000 years and consist of perforated and polished beads of red coral (*Corallium rubrum*) recovered from archaeological grave excavations in Germany (Tescione, 1965). Red coral is found in the Mediterranean Sea at depths of 10–600 m; therefore, early man must have collected it by way of shallow-water divers or possibly from storm deposits on Mediterranean beaches. Over the millennia, red coral artifacts have been found in Sumerian artwork (~5,000 Before Present), in Egyptian tombs, again buried with the dead, and more commonly in Greco-Roman jewelry and sculpture. Shortly after the birth of Christ, the Greeks invented a special device, a wooden cross with attached netting, to drag and entangle red coral from depths greater than humans could dive. This device, known as the Ingegno (also Saint Andrew's Cross), was used intermittently by various fishers in Mediterranean Seas up until the 20th century when it was almost completely replaced by divers equipped with SCUBA diving equipment (Tescione, 1965).

Precious corals were not discovered in the Pacific Ocean until 1803 in waters off Japan where beautiful red (*Corallium japonicum*) and pink (*C. elatius*) corals were discovered at depths ranging between 100 and 300 m. A fishery did not develop in Japan, however, until after the Meiji Reform in 1868, before which the absolute rule of the Emperors forbade free enterprise.

While precious coral fisheries developed in the far Western Pacific after 1868, little is known of their history for the next 100 years. Shortly after 1868, about 100 small boats began collecting red coral from Japanese coastal waters. Unfortunately, the method used was highly destructive tangle nets (mops), and the known grounds were quickly exhausted (Grigg, 1971). Annual production generally ranged under 10 tons. New grounds were discovered sporadically, but they too underwent rapid depletion. This boom and bust pattern characterized fishing efforts by the Japanese and Taiwanese coral fishermen until two decades after World War II.

In 1963 and again in 1965, Japanese coral draggers made two large discoveries, the first on the Oza Banks, 160 km south of Okinawa, and the second on the Milwaukee Banks in the Emperor Seamounts, 800 km northwest of Midway Island, at depths near 400 m (Grigg, 1971). Then in 1969, Taiwanese boats discovered even more, new and rich precious coral banks on other Emperor Seamounts. During this period in the 1960s almost 230 tons of pink coral (*C. secundum*) worth over $4 million were harvested collectively from these areas (Grigg, 1971).

As a result of the successful and profitable discoveries of precious coral in the Emperor Seamounts, two scientists from the University of Hawaii (UH), Ted Chamberlain and Vernon Brock, set out in 1969 to explore for similar resources in the main Hawaiian Islands. They were almost immediately successful just 9 km off the east coast of Oahu where they discovered the now famous Makapuu Bed at a depth of 400 m (Grigg, 1974). Chamberlain and Brock were again using dragging gear consisting of weighted salmon netting. Both recognized the destructive nature of the gear, and both realized that a selective method of harvest (**Figure 1**) would need to be developed before the new beds could be harvested in a sustainable manner. Chamberlain and Brock's discovery set in motion a new research program at the University of Hawaii that over the next 40 years would lead to many other major discoveries including development of a new management regime that ultimately became the first Fishery Management Plan (FMP) of the Western Pacific Regional Fishery Management Council (WPRFMC). Adding impetus to this program was another discovery of several species of shallow water black corals in Hawaii in 1958. Black corals are also utilized in the manufacture of jewelry and are, therefore, classified as

Figure 1. *Star II* submersible surfacing with precious corals collected from the Makapuu Bed in 1974. Photo courtesy of D. Doubilet

precious corals. The history of this discovery, as well as research and management of black corals, is covered in Section II.

A final and extremely important point is to distinguish between precious corals and shallow-water reef-building corals. They are NOT the same! Their ecologies are completely different, as are all management issues and policies. As a consequence, the WPRFMC has developed a separate and entirely different FMP for the management of shallow-water coral reef ecosystems.

II. History of the black coral fishery in Hawaii

In 1958, Jack Ackerman and Larry Windley discovered a large bed of commercial quality black coral at depths between 35–100 m off Lahaina, Maui (Grigg, 1965). Their discovery had been stimulated by the occasional collection of broken branches of black coral recovered from the entangled lines of Lahaina bottomfish fishermen. The Maui Bed (later officially defined as the Auau Channel Bed) contained two main species, *Antipathes griggi* and *A. grandis*. A third species, *A. ulex*, also known as fern coral, was present in the bed, but its skeleton turned out to contain streaks of brown color and was slightly less dense than the other two species. Other deeper water species of black coral had been discovered in Hawaii by the Challenger Expedition (1872–76) and the Albatross Expedition (1902), but all of these species were too small and too rare to be considered for anything other than their biological significance. Of the 150 species of black coral that are known worldwide (Grigg and Opresko, 1977), fewer than a half-dozen are large enough and with sufficient density and consistency to be suitable for cutting, carving and polishing into black coral jewelry.

Ackerman and Windley's discovery represented a major opportunity for the development of a new precious coral industry in Hawaii. Within one year, they had set up a small company in Lahaina, Maui, giving birth to a new firm called Maui Divers of Hawaii. Soon, a small number of divers (~10) were harvesting black corals in the Auau Channel off Lahaina, Maui. For the next 10 years, harvest rates would remain low, less than 3,000 kg/yr (Poh, 1971). The new cottage industry was economically profitable and gradually began to grow. By the mid-sixties, Maui Divers of Hawaii relocated to Oahu and about five other small companies started up on Maui or Oahu. Management and regulation of this fledging fishery was a responsibility of the State of Hawaii, Department of Fish and Game, although in those years virtually no oversight was exercised over the fishery.

The lack of management effort by the State of Hawaii was partially due to the fact that in the early 1960s almost nothing was known about the ecology and biology of black coral in Hawaii. This information gap was also the impetus for a new research project at the University of Hawaii entitled "Ecological studies of black coral in Hawaii." The study was conducted by Richard Grigg and eventually served as the subject of his master's thesis at the University of Hawaii, Department of Zoology, in 1964 (Grigg, 1965). The major results of this preliminary research showed that the larvae of *A. griggi* and *A. grandis* are both negatively phototaxic, thus explaining their settlement behavior at depths of low light intensity generally below zones of active growth of shallow-water reef corals. Reef corals contain algal pigments (zooxanthellae) that require sunlight for photosynthesis, whereas black corals are completely devoid of algal symbionts. The early research by Grigg also provided a preliminary list of habitat requirements of both species of black coral including a firm and rugose substratum for settlement and attachment as well as strong bottom currents for the active transport of detritus and micro-planktonic food particles and for sweeping the bottom clear of sediments. This early research would resume in 1970, when Grigg returned to the University of Hawaii where he was hired as an assistant marine biologist at the Hawaii Institute of Marine Biology on Coconut Island. In that year, Dr. Grigg teamed up with Dr. Garth Murphy in the Department of Oceanography to obtain a multi-year grant from the National Science Foundation to investigate the ecology of precious corals throughout the Hawaiian Archipelago. With continued funding later from the National Sea Grant College Program, this work continued virtually uninterrupted for the next 30 years. Over this time frame, the results provided the main foundation for the Precious Corals FMP produced by the WPRFMC.

III. Extended jurisdiction and the creation of Fishery Management Councils

In 1976, the US Congress passed an Act that extended US jurisdiction over fishery resources from 3 to 200 miles offshore, later to be called the US exclusive economic zone (EEZ). This Act, named the Fishery Conservation and Management Act (FCMA), was later called the Magnuson-Stevens Act (MSA). Although enacted in 1976, the FCMA became officially effective on March 1, 1977 (Grigg, 1976). In addition to extending US jurisdiction, a major outcome of the FCMA was the creation of eight Regional Fishery Management Councils that were given responsibility for conserving and managing fishery resources of the US EEZ. The WPRFMC was given jurisdiction and management authority for the State of Hawaii and all other US Pacific Islands including the Territories of American Samoa and Guam, the eight Pacific Remote Island Areas (PRIAs)—Wake Island, Johnson Island, Howland Island, Baker Island, Kingman Reef, Jarvis Island, Palmyra Atoll and Midway Atoll—and eventually the Commonwealth of the Northern Marianas (CNMI). One of the major tasks of the FCMA was the preparation and implementation of FMPs in accordance with the National Standards, which require achievement of sustainable optimum yield (OY) for all major fisheries in the region. At the outset, precious corals were identified by the WPRFMC as one of the major fishery resources in the region requiring an FMP.

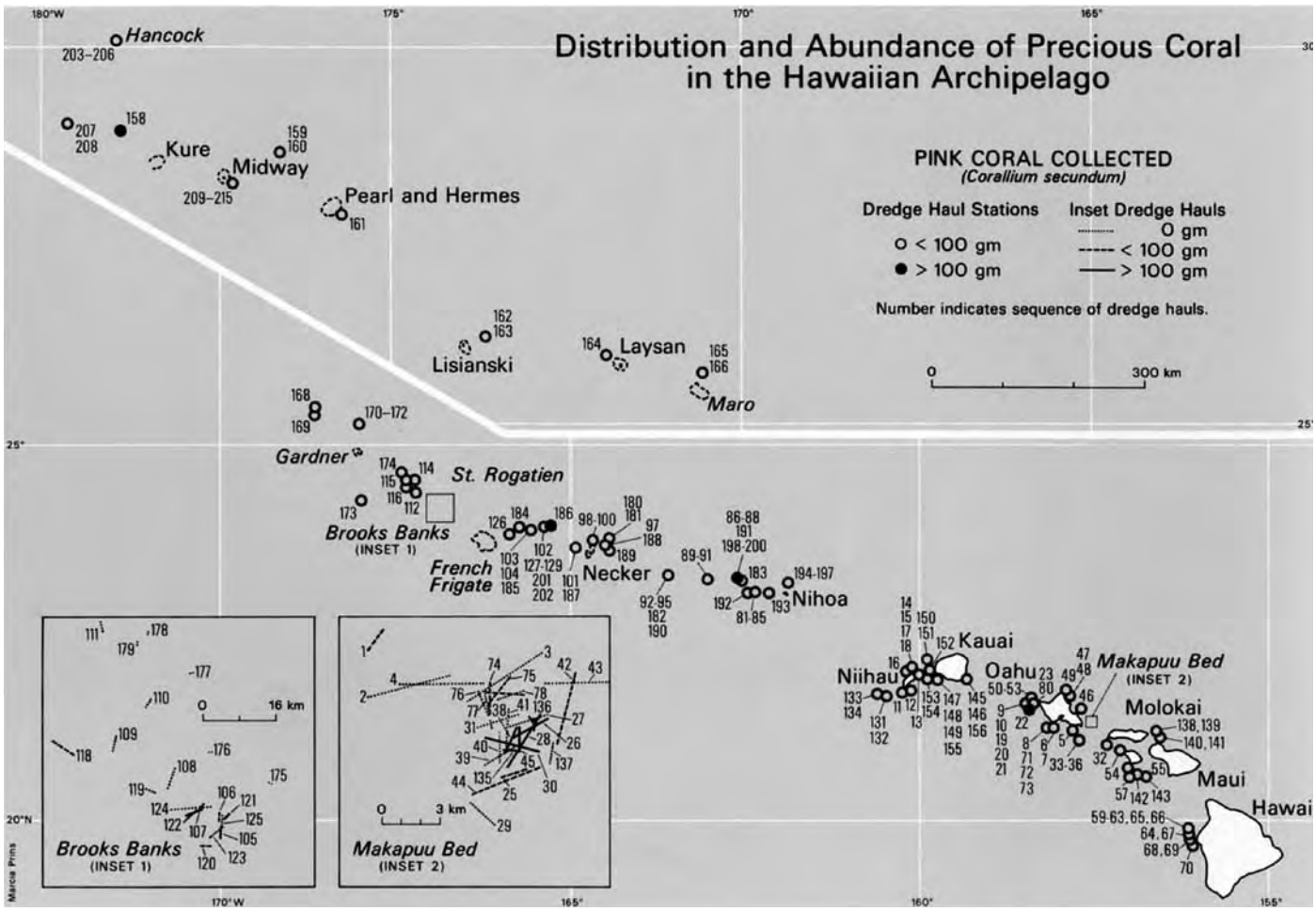

Figure 2. Distribution and abundance of deepwater precious corals in the Hawaiian Archipelago based on 215 dredge haul samples collected by the UH research program. Coral beds are highlighted. Solid lines in insets indicate high abundance of precious coral.

Prior to 1976, management of fishery resources in the US Pacific Islands was plagued by many problems including frequent incursions by foreign fishermen and lack of oversight and adequate enforcement by state and federal agencies. In the case of precious corals, Japanese and Taiwanese coral draggers were very active in the Emperor Seamounts beginning in 1965 continuing into the 1970s and even the 1980s, with sporadic reports of their entry into US waters within the 200-mile EEZ. In 1977, some of these incursions were still taking place inside US territorial limits. The most conspicuous of these events occurred in 1978 at Hancock Seamount just inside the US 200-mile EEZ. Photographs of two Japanese coral draggers, the *Hoku Maru* and the *Manpuku No. 18*, were taken by Robert Iverson of the US National Marine Fishery Service during a routine Coast Guard flight over the Northwestern Hawaiian Islands (NWHI) and its offshore waters. Other violations within the US EEZ in Hawaii were rumored to have taken place as far south as seamounts north of French Frigate Shoals where large amounts of precious corals were reportedly harvested. Unfortunately, there are no accurate records of these events and their exact locations and harvest amounts are unknown.

The large beds of precious coral discovered and exploited by Japanese and Taiwanese coral draggers and their known and suspected poaching in US waters during these years were among the major reasons the WPRFMC identified precious corals as a high priority fishery in need of immediate attention. By 1976, the black coral fishery in Hawaii had also grown and expanded beyond Maui to Kauai and occasionally the big island of Hawaii, and its need for management was another strong argument that led to the development of a Precious Corals FMP. Therefore, the WPRFMC began to work immediately on preparation of an FMP that would include both deepwater precious species as well as black corals. Before describing the Precious Corals FMP, however, it is important to first discuss the natural history of precious corals in general, as well as the results of the precious corals research program at the University of Hawaii up until 1976. Much of the policy and guidelines in the Precious Corals FMP was based on this early body of knowledge.

IV. Natural history of precious corals

In this section, it is again important to distinguish precious corals from shallow-water reef corals. Their taxonomies and ecologies are completely different, and their habitats rarely overlap.

In general, precious corals are deep-water corals living below the euphotic zone (zone of photosynthesis). All precious corals lack symbiotic algae, and none form reefs. Universally, precious corals form solitary colonies. In contrast, shallow-water reef corals live within the euphotic zone and almost all harbor symbiotic algae. And, more importantly, virtually all shallow-water reef corals form reefs, giving way to their name, reef-building (hermatypic) corals. In many places in the world, reef building corals are increasingly undergoing stress due to natural and anthropogenic factors such as pollution and global warming. Deepwater pre-cious corals, on the other hand, are rarely impacted by these type of anthropogenic stressors, except, of course, by destructive fishing methods such as tangle gear or even selective over-harvest. Successful management strategies for precious corals invariably require sustainable yield methods while reef corals are increasingly managed by precautionary principles such as no-take zones or marine protected areas (MPAs). Precious corals are considered fishery resources, whereas coral reefs are more often considered habitat to be protected as sanctuaries or refugia.

In general, most species of precious coral form solitary colonies living in deep water. Almost all are slow growing, have low rates of recruitment and natural mortality, and consequently are relatively long lived. In the far western Pacific, all species of commercially valuable precious corals are vulnerable to overexploitation 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. Unfortunately, this pattern of fishing has been employed by the Japanese and Taiwanese coral draggers who use destructive tangle gear. This practice has repeatedly led to a pattern of discovery and heavy exploitation followed by depletion. It is this history in the far western Pacific Ocean and the Emperor Seamounts that motivated research efforts in the Hawaiian Archipelago to develop methods of sustainable selective harvest.

V. Early research on precious corals in Hawaii

As mentioned in Section II, the first ecological research conducted on precious corals in Hawaii was on black corals in the early 1960s (Grigg, 1965). Basically this work described the habitat requirements and larval and feeding behavior of *A. griggi* and *A. grandis* in the black coral beds off Lahaina, Maui, in the Auau Channel. Also, as mentioned above, a very much larger and longer research program focused more on deepwater precious coral species began in 1970 at the University of Hawaii. The results of these programs relevant to the Precious Corals FMP are described below. It is also important to reiterate the importance of the very large discoveries of precious coral in the Emperor Seamounts and the discovery of the Makapuu Bed at 400 m depth. The immediate priorities were to complete the mapping and stock assessment of deepwater precious coral within the Hawaiian Archipelago and to develop sustainable and ecologically sound methods of harvest.

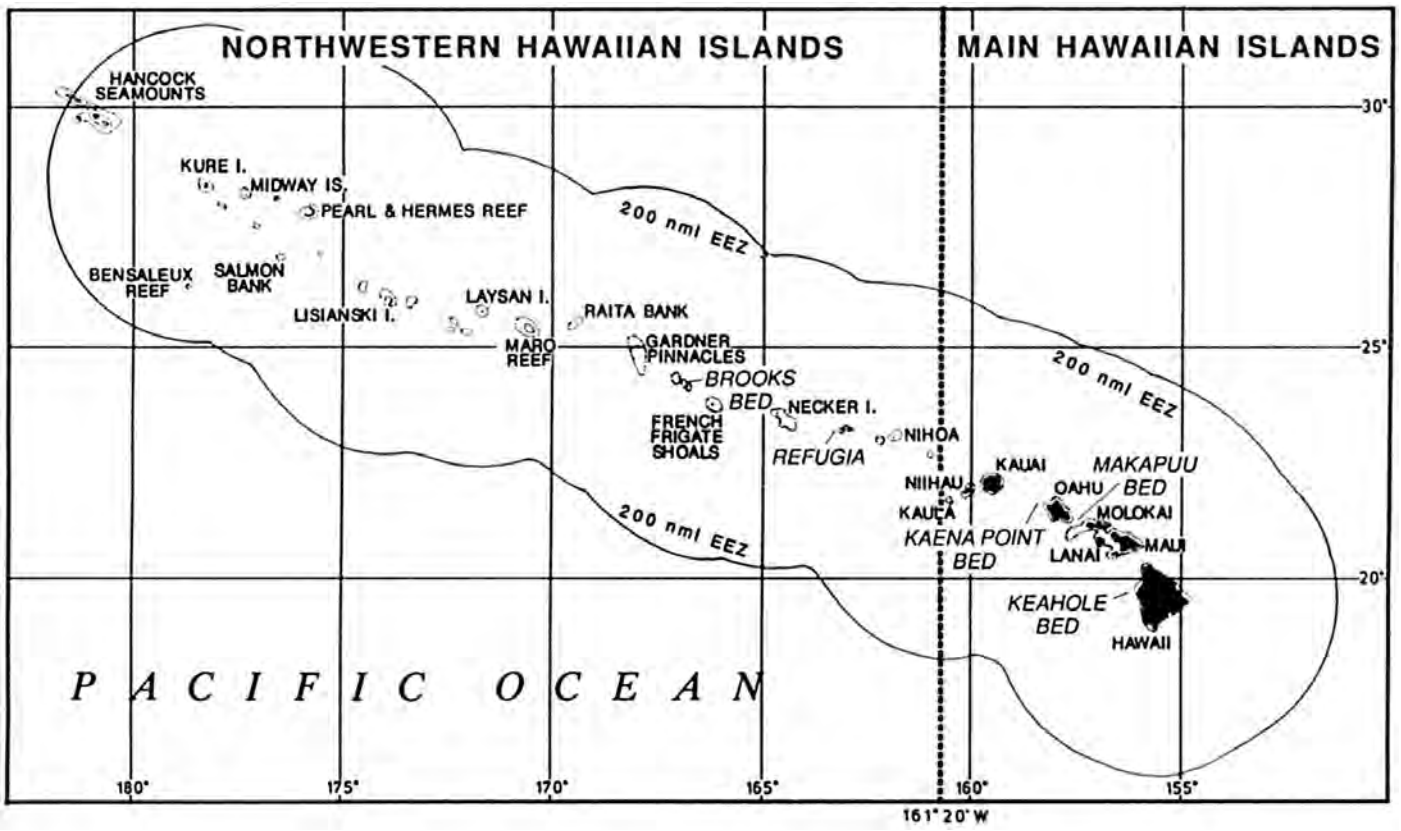

Figure 3. The Hawaiian Archipelago illustrating the major precious coral beds that exist in the main Hawaiian Islands and the NWHI.

With regard to stock assessment, initial exploration was limited to dredging with small tangle gear. A two-man submersible, the *Star II*, was acquired by the University of Hawaii in 1971, and this technology was first used to map the Makapuu Bed down to 425 m located about 9 km off Oahu in the Molokai Channel (**Figure 1**). During the first three years of the program, 16 cruises on the UH research vessel *Teritu* were conducted during which 215 dredge haul stations were sampled spanning the entire length of the Hawaiian Archipelago from the island of Hawaii to Hancock Seamount 180 miles northwest of Kure Atoll (**Figure 2**). During these expeditions, six precious coral beds were discovered and/or explored: from north to south 1) 180-Fathom Bank (Hancock Seamounts) north of Kure Atoll, 2) Brooks Bed, 3) Westpac Bed (later to become a Refugia) between Nihoa and Necker Islands, 4) Kaena Point Bed, 5) Makapuu Bed, and 6) Keahole Bed off the island of Hawaii (**Figure 3**). Of these, the Makapuu Bed was by far the largest bed covering at least 3.6 square km in area at depths of 350–425 m. The *Star II* submersible made 10 dives in 1971–72, all in the Makapuu Bed, to further map the extent of the resource (pink and gold corals) and to begin what would become a long-term study of their ecology.

A secondary topic of the 1970 program was the continuation of the earlier work on the black coral fishery but focused more broadly on stock assessment off all islands. This work led to the discovery of two more beds, one off Kauai and the other at several locations off the island of Hawaii. Ecological studies relevant to fishery management were also undertaken in these beds.

The ecological factors that were considered most important for fishery management were rates of growth, recruitment and natural mortality, and reproductive behavior and seasonality. Habitat requirements, depth zonation, and both larval and feeding behavior were also studied. A detailed description of the methods and results of this work can be found in the UH Sea Grant Technical Report 77-03 (Grigg, 1976). It should also be noted that the methods of study and questions asked were designed to satisfy the requirements of a fishery model that had been chosen to produce estimates of maximum sustainable yield (MSY) and OY. OY is defined as the yield that will produce a) the greatest bene-fit to the nation and b) MSY as modified by relevant economic, social and ecological factors.

Fortunately, as it turned out in 1976, one of the National Standards of the FCMA was to achieve OY on a sustainable basis from each fishery. The management model selected early on was the Beverton and Holt Model that produces estimates of MSY and OY (Grigg, 1976) Other approaches have been used elsewhere in the world to manage precious corals, such as rotation of beds, closed seasons, arbitrary size limits or weight quotas (Caddy, 1993), but none of these seemed appropriate for circumstances in the Hawaiian Islands where few beds exist, or at least were known to exist in the early 1970s.

For the purpose of this review, all of the results applicable to produce estimates of MSY and OY for pink, gold and black coral are given in **Table I**. The paper by Grigg in 1976 contains a complete description of all methods and results, as well as a description of the Beverton and Holt Model and how it was used to produce management guidelines for both the Preliminary Management Plan (PMP) and final FMP.

Table I. Management guidelines of precious corals in Hawaii (Grigg, 1976)

Species	Growth cm/yr	Mortality annual	Yield/ recruit	Age/MSY yrs	MSY Kg	OY Kg	Size inches
Black corals (*A. griggi* & *A. grandis*)							
Maui Bed	6.42	0.07	1050 gm	28	6174	5000	48
Kauai Bed					1543	1250	48
Gold (*Gerardia sp.*)							
						650	
Pink coral (*C. secundum*)							
Makapuu Bed	0.9	0.066	203	34	1072	1000	10
Conditional Beds	0.9	0.066	203	34	prorated		10
Exploratory Beds	0.9	0.066	203	34		1000	10

- The Preliminary Management Plan (PMP) for Precious Corals was completed in 1977 (US Department of Commerce, 1977). The management measures contained therein were considered preliminary and temporary; therefore, they are not discussed in detail here. Basically, the proposed action in the PMP prohibited foreign harvest in the US EEZ until surplus levels of precious coral had been determined. The PMP also contained estimates of OY for pink and gold corals in the Makapuu Bed. It also recommended the prohibition of coral dredging for commercial harvest of all species due to it destructive and wasteful nature.
- The OY size limit of 10 inches for *C. secundum* was lowered from 12 (MSY size limit) due to economic considerations. The OY for gold coral was first reported in the PMP. Bamboo corals, while allocated in the PMP, were never targeted for harvest by the fishery.

VI. FMP for precious corals in the Western Pacific Region

Preparation of a final FMP for precious corals was a lengthy and tedious process that was not fully complete until 1983 (Fishery Management Plan for Precious Coral Fisheries of the Western Pacific Region, 1983).

While highly technical and detailed, the basic elements of the initial plan were as follows:

First, four categories of management area were created: 1) Established Beds, 2) Conditional Beds, 3) Exploratory Areas, and 4) Refugia. Established Beds were defined as beds of known area in which OY had been determined. Only one Established Bed was defined for the region—the Makapuu Bed off Oahu, Hawaii. Conditional Beds are beds known to contain precious corals but in which the OY is prorated based on the area of the Conditional Bed relative to the area of the Makapuu Bed. Exploratory Areas include all other areas in the US EEZ that are not Established, Conditional or Refugia Beds. Second, weight quotas and size limits were set for Established and Conditional Beds (**Table 1**). The plan also provided for closures when weight quotas were reached except that a two-year weight quota of 2,000 kg for *C. secundum* was allowed to be harvested in one year or less in the Makapuu Bed, but that, once attained, the bed would be closed for the remainder of the two-year time period. All other quotas were based on one-year seasons. Third, the OY for Exploratory Beds was set at 1,000 kg basically to serve as an incentive for exploration rather than for commercial harvest. A more detailed description of the FMP can be found in Vol. 45, No. 189, of the *US Federal Register*, published on August 30, 1983.

One feature of all FMPs is that they are not fixed documents. Changes can be made in the form of various amendments. In the case of the Precious Corals FMP, three amendments were added during the first 15 years of operation. In the first amendment, the eight PRIAs were identified as a single Exploratory Area; the genus *Corallium* was expanded to include other species of the genus; and new Experimental Fishing Permits were created to stimulate exploration. In the second amendment, overfished was defined as occurring when harvesting had reduced the spawning biomass to 20 percent of its unfished condition. In the third amendment, a framework process was established to facilitate future changes.

Later amendments increased the minimum size of black corals from 36 inches to 48 inches for fishermen not exempted (grandfathered), prohibited the use of non-selective fishing gear to harvest precious coral so size limits could be met, designated the Auau Channel black coral bed as an Established Bed, set a two-year 5,000-kg quota for black corals in the Auau Channel, and created a five-year moratorium on the harvest of gold coral in the Western Pacific Region. The rationale for the gold coral moratorium was based on a new but preliminary study of its growth rate using radiometric methods. The results suggested a slower growth rate and greater longevity (Roark et al., 2006).

The above description of the Precious Corals FMP makes it clear that deepwater precious pink and gold corals were the resources of primary concern in the original plan. This is because all deepwater coral beds in the Hawaiian Archipelago exist outside of the 3-mile State limit and, therefore, fall under federal jurisdiction. In contrast, the majority of the black coral commercial beds in the Hawaiian Archipelago are found mainly within 3 miles of the coastline and their management falls under State jurisdiction. It is interesting, when one examines the history of each fishery, that the deepwater fishery for pink and gold coral has experienced a pattern of off and on activity, while the black coral fishery has operated continuously since inception in 1958, marking over 50 years of uninterrupted harvest activity. The total annual landings of each fishery over its entire history are tabulated in **Tables II** and **III**.

Over its entire history in Hawaii, the deepwater precious corals fishery has rarely had annual harvest levels that exceeded the estimates of OY for either pink or gold coral. Why the fishery has been so on and off then is not related to abundance of the resources or problems of supply. The problems lie mainly with economic factors. First, the cost of operation is very high due to the necessity to use submersible technology for selective harvest. Diving operations are also weather limited. For example, strong

Table II. Annual harvest of pink, gold and red coral in Hawaii (kg).

Year	Gear	*C. secundum*	*Gerardia sp.*	*C. regale*
1966–1969	Dredge[1]	1800	0	0
1970–1972	No harvest	0	0	0
1973	Submersible[2]	538	0	0
1974	Submersible[2]	2209	734	0
1975	Submersible[2]	1385	621	0
1976	Submersible[2]	400	363	0
1977	Submersible[2]	1421	329	0
1978	Submersible[2]	474	50	0
1979–1987	No harvest	0	0	0
1988	Dredge[3]	500	0	0
1989–1999	No harvest	0	0	0
1999–2001	Submersible[4]	1216	150	61
2002–2009	No harvest	0	0	0

1. United Fishing 2. Maui Divers of Hawaii 3. Vessel *Aukai* 4. American Divers

Table III. Annual harvest of black coral* in Hawaii (kg), except as noted.

Year	Maui Bed	Kauai Bed
1958–1968[1.]	3,000	0
1968–1972[2.]	4,000	2,000
1972–1980[3.]	8,000	4,000
1981[4.]	72	0
1982	430	0
1983	867	0
1984	1,422	0
1985	140	0
1986	425	0
1987	1,978	0
1988	234	0
1989	464	0
1990	395	0
1991	1,048	0
1992	1,090	0
1993	393	0
1994	1,979	0
1995	2,735	0
1996	2,211	0
1997[4.]	689	0
1999–2005[5.]	3,182	0

**Antipathes griggi* and *A. grandis*

1–3. Annual harvest based on interviews with divers

4. Annual harvest as reported to the State of Hawaii, Div. of Aquatic Resources, 1981–1997

5. Parrish, 2006

trade winds and rough seas limited American Divers to operate just 20 percent of the time each year it was in operation. Finally, the value of the resource itself can vary between $100 and $1,000/kg (Grigg, 2002) and has always been marginally sufficient to produce sustainable profits for the industry. During periods of no domestic harvest, the precious coral jewelry industry relied solely on imports from Taiwan, Japan and Italy.

The black coral fishery in Hawaii has enjoyed a more profitable and continuous history. Examination of **Table III** illustrates a highly variable catch record, but this is primarily an artifact of incomplete reporting to the Hawaii Division of Aquatic Resources, especially during the years 1981–1997. In spite of this problem, the landings do not appear to have exceeded estimates of OY (5,000 kg/yr for the Maui Bed) (**Table III**). In this regard, it is important to clarify that harvest of black coral has always been selective, favoring large colonies and discouraging the collection of undersize colonies. The research on black coral (Grigg, 1976) not only established estimates of OY but also recommended a size limit of 48 inches for both species of black coral (**Table I**).

In **Figure 4**, the age frequency of the black coral populations of Maui are shown in 1975 versus 1998. Clearly, recruitment over this time period has been nearly continuous, and the fishery itself can therefore be considered stable. That was in 1998. Unfortunately since that time, annual harvest has increased (Parrish, 2006; **Table III**). Also, in 2001 an alien species, *Carijoa riisei*, was discovered invading the deeper zones of the black coral bed off Maui at depths of 80-100 m, and it has been overgrowing portions of the substratum as well as many adult colonies of both species of black coral (Grigg, 2003, 2004; Kahng and Grigg, 2005). While this invasion is limited in scope and does not appear to be escalating (S. Kahng, personal communication), the growing demand on the resource by both increased harvest and overgrowth by *C. riisei* colonies suggests there is a need for more stringent guidelines such as a reduction in OY or a larger size limit (Grigg, 2004). Because of these developments, the WPRFMC in 2007 increased the minimum-size limit for black coral by removing a prior exemption allowing harvest of black coral with a minimum-size diameter of 3/4 inch. All harvest of black coral must now be done at a minimum 1-inch base diameter or 48-inch minimum height. In 2008, the WPRFMC established a quota for the Auau Channel Bed (also known as the Maui Bed) of 5,000 kg/2 years.

While management of the black coral fishery has been traditionally the responsibility of the State of Hawaii, the WPRFMC has also been active in the management of this fishery and sponsored a management workshop on black coral in cooperation with the State of Hawaii on April 18–19, 2006. Indeed, it was this workshop that led to the passage of the more stringent

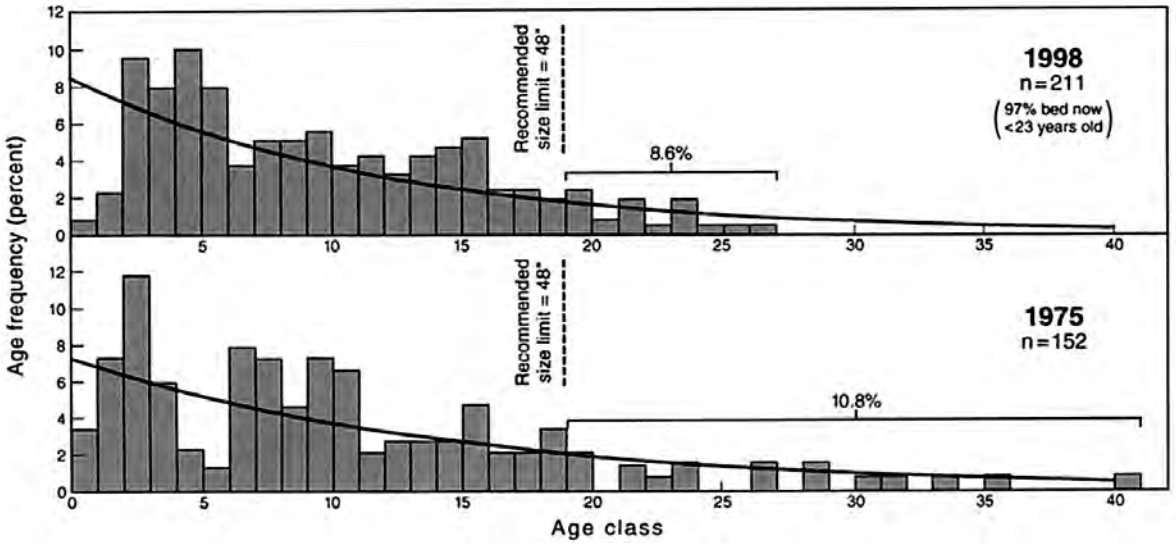

Figure 4. Age frequency distributions of black coral (*A. griggi*) in the Maui Bed in 1975 and 1998 (Grigg, 2001). Note that 97% of the bed in 1998 is entirely due to recruitment since 1975. In other words, recruitment has been sustainable over the entire time period of 23 years between 1975 and 1998.

management guidelines for the black coral fishery that are described above (WPRFMC, 2006).

VII. Summary and future prospects of the precious corals fishery in the Western Pacific Region

At the present time (2009) the deepwater precious coral fishery in Hawaii is dormant. Even though the NWHI have been closed due to classification as a marine national monument, adequate supplies still exist in known beds in the main Hawaiian Islands. The problem is not supply, but rather the high cost of operation versus the present value of target species. Unless prices of the raw material for pink, red and gold coral increase significantly, the outlook for the fishery over the short term will depend on the possible development of a low cost, remote controlled technology that would dramatically reduce the cost of harvest. This is an obvious opportunity for future research.

The future of Hawaii's precious corals industry, on the other hand, will depend on the cost and availability of foreign imports. Over the years, when the domestic deepwater precious coral fishery was inactive, the industry was sustained by this source of both raw and finished material.

The black coral fishery and industry continues to thrive. The State of Hawaii and the WPRFMC are now working together to improve management guidelines, and the fishermen are now accurately reporting annual harvest. The fishermen fully appreciate the need to carefully abide by the 48-inch size limit for black coral. They understand that the future of the industry, as well as their own future, depends on the continued sustainability of the resource. As it now stands, after 50 years of operation, the black coral fishery in Hawaii is one of the few fisheries in the world that has remained sustainable over this period of time.

Finally, it is important to assess the economic value of the precious coral fishery and industry to the nation. In spite of various logistical and economic limitations over the past 50 years, the precious coral industry in the State of Hawaii has grown to well over $50 million annually and employs more than 1,000 people. It is even more important to understand that, without the regulatory authority inherent in the FMP developed by the WPRFMC and the cooperation of the State of Hawaii, environmental concerns would have prevented significant development of the deepwater precious coral and black coral fisheries.

It is also important to recognize that the WPRFMC was a pioneer in developing rules and regulations to successfully manage precious coral resources. The Precious Corals FMP could, in fact, be used as a template for other precious coral fisheries in the world (Italy, France, Japan, and Taiwan) that are in urgent need of comparable management programs (Grigg, 1993, 1984 and 1982).

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The pink coral (*Corallium secundun*) is the most abundant deepwater precious coral in the Hawaiian Archipelago. Photo courtesy of D. Doubilet

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