FISHERY MANAGEMENT PLAN

for the

PRECIOUS CORAL FISHERIES (and ASSOCIATED NON-PRECIOUS CORALS)

of the

WESTERN PACIFIC REGION

PREPARED BY

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TABLE OF CONTENTS

Tables

Figures

Page

Executive Summary

The Fishery Conservation and Management Act of 1976 (Public Law 94-265) provides for United States exclusive management authority over the fishery resources and fisheries within a Fishery Conservation Zone (FCZ) extending from the seaward boundary of the territorial sea (3 miles from shore) to a distance of 200 nautical miles from shore. The responsibility for developing management plans for the fisheries in the FCZ is vested by the Act in eight Regional Fishery Management Councils. The Western Pacific Fishery Management Council is responsible for the fisheries off the coasts of Hawaii, Guam and American Samoa. The Council may also recommend measures to be implemented in the FCZ beyond the area of concern in the Northern Mariana Islands. Implementation and enforcement of any regulations pertinent to fishery management within the FCZ are the responsibility of the Secretary of Commerce. This Precious Corals Fishery Management Plan has been developed by the Western Pacific Fishery Management Council and will be submitted to the Secretary of Commerce for approval and implementation. The major objectives of the Plan are to obtain Optimum Yields of precious corals in the FCZ and maximize the benefits of the precious coral fisheries to the nation. Precious corals are known or believed to occur in the FCZ seaward of Hawaii, American Samoa, Guam, the Commonwealth of the Northern Mariana Islands and off other United States island possessions in the central and western Pacific Ocean.

In the Management Plan, precious coral beds are treated as separate management units. The beds are classified as Established, Conditional or Exploratory. Established Beds are those which have a history of harvest and for which firm Optimum Yields have been determined on the basis of scientific data. Conditional Beds are those for which locations and approximate area are known and for which estimates of Optimum Yield can

be derived by analogy with Established Beds but which require additional data for determination of firm Optimum Yields. Exploratory Areas comprise all other area in the FCZ of the Western Pacific Region. Only one coral bed has been studied adequately enough to be classified as Established. It is off Makapuu, Oahu, Hawaii. Five other peds are classified as Conditional, all of them off the Hawaiian Islands (See Figures 1 and2).

Management measures are prescribed for commercial harvest from all three bed categories, otherwise referred to as permit areas. There is no recreational fishery. The prescribed measures are summarized as follows: 1) Optimum Yields have been determined for pink (Corallium secundum), gold (Gerardia sp.) and babboo (Lepidisis olapa) coral populations in the Makapuu Bed. These Optimum Yields are based on estimates of Maximum Sustained Yield (MSY). Rounded estimates of MSY for the three species in the Makapuu Bed are 1,000 kg/year for pink coral, 300 kg/year for gold coral and 250 kg/year for bamboo coral. Optimum Yields have been set at double these values for twice the time, i.e. for 2 years. The adjustment to 2 year periods is proposed because of socio-economic considerations; 2) Optimum Yields for Conditional Beds are determined by their areas in relation to the area of the Makapuu Bed, assuming the same MSY per unit area, and reducing the OY to 20% of the MSY if non-selective harvesting methods are used; 3) U.S. harvesting and processing capacity and expected annual harvest and processing levels from the Makapuu Bed and all Conditional Beds are equal to the levels proposed for Optimum Yield, and therefore no surplus exists in these areas which can be allocated to foreign fisherman or to joint venture operations. Domentic processing capacity is sufficient to process expected domestic harvest; 4) Until the definitive Optimum Yields of

beds in Exploratory Areas can be determined, an initial Optimum Yield and Total Allowable Level of Foreign Fishing (TALFF) for each of those Areas (Hawaii, Samoa, Guma, and the Northern Marianas and other U.S. island possessions) is set at 1,000 kg total of all species, of which 500 kg are to be set aside as a reserve for potential domentic fishing and 500 kg are available as TALFF; 5) Other species of precious corals and associated non-precious corals which are known or are believed to occur in the FCZ are included in the plan. No specific conservation and Management measures are proposed at this time and Optimum Yields have not been determined. This plan may be amended to manage these species as more data become available and as the need arises; 6) A prohibition on the use of dredging techniques is recommended for all permit areas where selective harvesting methods are current practice and for the FCZ seaward of the main Hawaiian Islands; 7) A quota for dredging is provided in all other permit areas under specified conditions; 8) Taking of precious coral in the FCZ incidental to other fisheries is allowed for both domestic and foreign fishermen, subject to reporting requirements and return of the coral to the sea; 9) A recommendation is made to provide for closing certain coral beds to commercial or exploratory fishing as refugia or preserves, and to designate as the first such preserve the WesPac Bed, situated between Nihoa and Necker Islands, off the Northwestern Hawaiian Islands. Other refugia may be designated by amendment to this plan; 10) Permits are required for domestic and foreign fishermen, subject to extensive reporting requirements and conditions which embody the above provisions. Vessels may be required to carry observers. The proposed management measures are designed to maximize overall benefits to the nation and are consistent with the National Standards of the FCMA.

I. INTRODUCTION

This is a Fishery Management Plan (FMP) for the precious coral and associated non-precious coral fisheries within the United States Fishery Conservation Zone of the central and western Pacific region. It has been prepared by the Western Pacific Regional Fishery Management Council under the authority of the Fishery Conservation and Management Act of 1976 (FCMA) (P.L. 94-265).

The FCMA provides for the conservation and management of fishery resources of the United States by establishing a Fishery Conservation Zone of 200 nautical miles, within which the United States has exclusive management authority over all fishery resources except highly migratory species which are defined as tuna. The Act calls for the preparation and implementation of Fishery Management Plans, through which the objectives of a national fishery management program may be accomplished.

The Fishery Management Plans provide the basis for the determination of annual harvest predicated on scientific information and involving the needs of the States, the fishing industry, recreation groups, consumers, environmental organizations and other interested parties. In essence, the allowable catch of any fishery resource will be based on the Optimum Yield from that resource.

The fishery management unit in this case comprises a number of discrete populations or beds of precious corals and associated non-precious corals within the FCZ off the shores of U.S. islands in the central and western tropical and subtropical Pacific. At present only one such bed is the object of consistent exploitation by a domestic fishery. Others are or may have been subject to poorly documented harvesting by foreign fishermen, while others have been located by exploratory surveys but are not yet under exploitation.

There are undoubtedly other precious coral beds in the region which will eventually be prospected and exploited, and it is prudent to make some preliminary provision for their conservation, in view of the ease with which this resource can be depleted.

In this FMP, precious coral beds which have a history of exploitation and for which a Maximum Sustainable Yield (MSY) can be estimated based on scientific data, are designated Established Beds. Others for which only the locations and approximate area are known are called Conditional Beds, while those which are yet to be located are referred to as Exploratory Areas. (See Section IV.F.2, for fuller definition of these categories.) Under this plan, five portions of the FCZ - the portions around Hawaii, Guam, American Samoa, U.S. Possessions and the Northern Mariana Islands - are designated Exploratory Areas for purposes of setting quotas for identification of and harvests from Exploratory Beds.

The major objective of the Plan is to achieve the optimum yield of precious corals which occur within the Fishery Conservation Zone (FCZ) of the United States in the Central and Western Pacific Ocean. The term optimum yield is defined in the Act as that amount of "fish" which will provide the greatest overall benefit to the Nation, and which is prescribed as such on the basis of the maximum sustained yield (MSY) as modified by any relevant economic, social or ecological factor. Species of precious corals which are considered in this document include the precious pink coral, *Corallium secundum*, the gold coral, *Gerardia* (formerly *Parazoanthus*) sp., and the bamboo coral, *Lepidisis Olapa*. (formally Keratoisis nuda Other species of precious coral and other corals on the continental shelf or in the FCZ are also included in the plan although no specific Conservation and Management Measures are limited at this time to a permit and data collection requirements. Further management measures for these corals will be included in the plan sequentially on an as needed basis.

Areas considered in this document include the Hawaiian Islands, American Samoa, Guam, the Commonwealth of the Northern Marianas and other U.S. island possessions in the Central and Western Pacific Ocean.*

Included in the management plan are estimates of optimum yield for species of greatest commercial importance and recommendations for measures that are deemed necessary in order to achieve optimum yield.

II. Description of the Fishery

A. Stocks

Within the FCZ of the United States in the Pacific (Figures 1-4) the only fishery for precious corals is in the Hawaiian Islands. The fishery is based on two groups of species, one in deep water near 400 meters and another in much shallower between 40 and about 80 meters. Both fisheries are entirely commercial, i.e. non-recreational. At the present time the bulk of the catch of deep species consists of pink (*Corallium secundum*) and gold coral (*Gerardia* sp., = *Parazoanthus* sp.). A third species, bamboo coral (*Lepidisis olapa*) co-occurs with pink and gold coral and is considered to be of immediate economic potential. Other potential species of precious coral including the shallow water black corals are listed in Table I.

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*Pending amendment of the Fishery Conservation and Management Act, the Western Pacific Fishery Management Council has no statutory authority to prescribe management measures for fisheries in the Fishery Conservation Zone off the Northern Marianas or minor United States Pacific island possessions. References to management measures for precious coral fishing in those areas in this Plan are in the nature of recommendations which may be implemented by the Secretary of Commerce by actions pursuant to Sec. 201 (g) or Sec. 304 (c) of the Act.

immediate economic potential.

The shallow water fishery consists of three species of black coral *Antipathes dichotoma, Antipathes grandis* and *Antipathes ulex.* About 90% of the catch consists of the first species, 9% the second and 1% the third. Approximately 85% of all black corals harvested in the state of Hawaii are taken within the Territorial Sea.

The FMP contains specific management measures for Corallium secundu Gerardia sp. and Lepidisis olapa. Measures for black corals are currently being developed jointly by the State of Hawaii and the WPRFMC, and will be added to the plan on a sequential basis. As it appears likely that other species of precious coral and other corals in the FCZ will be subject to harvest, additional measures for these species will also be added to the plan on a sequential basis.

C. secundum and the bamboo coral *Lepidisis olapa* belong to the Order Gorgonacea in the Subclass Octocorallia of the class Anthozoa in the Phylum Coelenterata. *Gerardia* sp. and *Antipathes* spp. belong to separate Orders, Zoanthidea and Antipatharia, in the Subclass Hexacorallia, also in the class Anthozoa and the Phylum Coelenterata.

Precious corals are known to exist in Hawaii, Samoa, Guam and the Commonwealth of the Northern Marianas and other U.S. possessions, but little is known of their distribution and abundance. What little knowledge is available of the distribution and abundance of precious corals in the Western Pacific can be summarized as follows:

American Samoa — One or more species of black coral of commercial quantity and quality are known to exist at depths of 40 meters and deeper, but these stocks are within the jurisdiction of American Samoa.

Table I Actual and potential precious corals in the Western Pacfic.

Scientific name	Common name	harvest status
Corallium secundum	Pink coral	harvested
Corallium regale	Pink coral	not harvested
Corallium lacuense	Pink coral	not harvested
Gerardia sp.	Gold coral	harvested
Callogorgia gilberti	Gold coral	not harvested
Narella sp.	Gold coral	not harvested
Calyptrophora sp.	Gold coral	not harvested
*Lepidisis olapa**	Bamboo coral	not harvested
Acanella sp.	Bamboo coral	not harvested
Antipathes dichotoma	Black coral	harvested
Antipathes grandis	Black coral	harvested
Antipathes ulex	Black coral	harvested

*previously known as Keratoisis nuda

The only information available on deeper water precious corals comes from reports by fishermen. Pink coral has been reported off Cape Taputapu, but there are no data on quantity, quality and depth (Ian Swan, personal communication). Unidentified precious corals have also been reported off Fanuatapu Island at a depth of 90 m (possibly bamboo coral) and on the sides of an uncharted seamount three-fourths of a mile off the northwest tip of Falealupo at a depth of about 300 meters (Bill Travis, personal communication).

Guam and the Commonwealth of the Northern Marianas — No commercially important quantities of precious coral have been found on U.S. surveys in the Nothern Marianas (Grigg and Eldredge 1975). However, Japanese fishermen (personal communication) claim to have taken some *Corallium* off Rota, Saipan and north of Pagan Island.

Other U.S. island possessions — Japanese fishermen report that in 1975 alone, a harvest of 100 metric tons of red corals (*Corallium* spp.) was taken from grounds within 200 miles of Midway, Wake, Yap and Saipan (EIS/PMP Precious Corals, DOC, 1977). However, the magnitude of this estimate (approximately the world production in 1970) casts some doubt on its validity. On the other hand, none of the deep precious coral beds off Wake or Yap have been surveyed by U.S. scientists and only the most preliminary U.S. data are available for the Saipan and Midway areas.

Hawaii — Beds of pink, gold and/or bamboo coral have been found at six locations off the Hawaiian Archipelago (Grigg 1974) (Figures 1 & 2). These are as follows:

Description	Lat. N.	Long. W.	Area in km^2
1. Off Ke-ahole Point, Hawaii	19°46.0'	156°06.0'	0.24
2. Off Makapuu, Oahu (Fig. 5)	21°18.0'	157°35.5'	3.60
3. Off Kaena Point, Oahu	21°35.4'	158°22.9'	0.24
4. WesPac Bed, between Nihoa and Necker Islands	23°18'	162°35'	0.8
5. Brooks Bank	24°06.0'	166°48.0'	1.6
6. 180 Fathom Bank, north of Kure Is.	28°50.2'	178°53.4'	0.8

With the exception of the Makapuu Bed and those beds (if any) harvested by Japanese fishermen, all other precious coral beds within the U.S. fishery conservation zone are believed to be in an unexploited or "virgin" state. The Makapuu Bed has been harvested off and on since 1966 (see Table II, page 10). The area and the pre-fishery standing crop of pink coral in the bed are estimated to be 4.5 km^2 and 43,500 kg, respectively. Over a 10-year period only about 16% of the original standing crop of pink coral has been harvested; this averages 1.6% per year, and is below estimates of MSY (see section III-F). However, in three of four years the estimate of MSY has been exceeded (see Table II). Of the other five areas, WesPac Bed, Brooks Bank and 180 Fathom Bank are considered to hold the most promise for domestic harvesters. There are undoubtedly many other undiscovered beds, especially off the Northwestern Hawaiian Islands, where few surveys have been conducted. The large yields (see following section) are reported to have been taken by foreign fishermen from the Milwaukee Banks (Lat. 32.5°N, Long. 173.0°E), which are outside the U.S. Fishery Conservation Zone, are indications of the potential in the Northwestern Hawaiian Isalnds. Because of the sessile habit of precious corals and the large distances which separate the known beds, it is a reasonable assumption to treat each bed as a separate management unit, even though nothing is known of the relationship between stock and recruitment.

There are no known Indian or native Hawaiian traditional uses or rights associated with precious corals. If any rights or ceremonial values are identified, this plan can be amended as necessary.

B. History of Exploitation

Although a precious coral fishery has existed in the Mediterranean Sea since about 3000 B.C., precious coral was not discovered in the Pacific until the early 19th century off Japan. Historically, the primary method of fishing in both the Mediterranean Sea and off Japan has been dredging. Initially little fishing occurred off Japan until 1868, the year of the Meiji Reform. Prior to 1868, coral was confiscated from fishermen by the Shoguns, therefore little incentive existed for commercial fishing. After 1868, however, this custom was abolished and the fishermen were allowed to market coral products freely. Shortly after 1868, about 100 boats began harvesting coral, soon exhausting local grounds near Japan. Subsequent catch and effort depended on the discovery of new grounds and has been extremely variable up to the present time. The pattern of the coral fishery in Japan has been one of exploration, discovery, exploitation and depletion. In spite of the obvious need to control fishing effort, there has been no effective management of the fishery.

The extremely variable nature of the fishery is demonstrated by data for catch and effort collected in Taiwan between the years 1925 and 1940 (Anon. 1956) (Figure 6 and 7). These data show that catch and effort correlate fairly well and indicate the boom or bust nature of the fishery.

Until recent years, the precious coral fishery in the Pacific was centered off Japan, Okinawa and Taiwan (Grigg, 1971). Depletion of the beds in these areas, however, led to wide ranging exploratory efforts primarily on the part of Japanese fishermen. In 1965, Japanese coral fishermen discovered a very large bed of pink coral contiguous with the Hawaiian Archipelago on the Milwaukee Banks about 500 miles northwest of Midway Island. Milwaukee Banks including Kinmei Seamount have an area slightly greater than 300 km^2. Little data are available concerning the amount of pink coral Japanese fishermen harvested from Milwaukee Banks. However in 1969 alone, they reportedly took about 113,000 kg (H. Ozawa*, personal communication, 1970).

Prompted by the discovery of pink coral on the Milwaukee Banks, U.S. scientists in 1966 discovered a commercial bed of *Corallium secundum* between 350 and 450 m depth in the Molokai Channel off Makapuu Oahu. Shortl thereafter, a small group of fishermen began dredging this Makapuu bed on a limited scale. This activity continued on and off for about 3 years until high costs of operation and bad weather led to its discontinuation. About 1,800 kg (4,000 lb) were harvested during this period. After an abortive attempt in 1969 at harvesting with a remote T.V. camera assembly by a Seattle firm (Jacobsen Brothers), research at the University of Hawaii by the Sea Grant Program led to the development of a selective harvesting system utilizing a submersible. Maui Divers of Hawaii, Ltd. incorporated this system and began harvesting the Makapuu Bed in 1973. Total annual landings of pink and gold coral from the Makapuu Bed between 1966 and 1977 are given in Table II.[1]

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*H. Ozawa was the Managing Director of the All Nippon Coral Fishery Union in 1970.

TABLE II

Annual harvest of pink and gold coral from the Makapuu Bed[1].

Harvest (kg)

Year	Gear	Pink	Gold	Knockdown*
1966-69	Dredge	1,800	0	2700
1970-72	----------No harvesting----------			
1973	Submersible	538	0	
1974	"	2,209	734	
1975	"	1,385	621	
1976	"	400	363	
1977	"	1,421	329	
1978 (Jan-June)	"	474	50	

*During 1966 to 1969 when dredges were used in the Makapuu Bed the amount of coral dislodged from the bottom and not recovered must also be considered. Simulated harvesting trials in shallow water indicate that tangle dredges are about 40% efficient for one drag. Therefore for every kilogram harvested, 1.5 kg is assumed to have been knocked down and lost.

1. In 1977, 2.7 kg of pink coral and 106 kg of gold coral were harvested from the Kea-hole Point Bed off the island of Hawaii.

In the past, there has been no documented foreign harvest of precious coral within the U.S. conservation zone. However, in 1975 Japanese vessels reportedly harvested about 100 MT of precious corals within 200 miles of Midway, Wake, Yap and Saipan Islands (EIS/PMP Precious Corals, DOC, 1977). However, because the world landings in 1970 were only about 85 MT (H. Ozawa, personal communication), this report is somewhat doubtful. In 1976 and 1977, Taiwanese dredgers were reportedly operating on the Milwaukee Banks and may also have harvested precious corals within the U.S. Fishery Conservation Zone. On June 8, 1977, the U.S. Coast Guard reported entry of a Taiwanese coral fishing vessel, C/B Hai Tien No. 2, to Midway Island, which informed the Coast Guard that about 30 other vessels would soon be dredging in the Milwaukee Banks area. The Milwaukee Banks are approximately 280 miles northwest of the U.S. 200 mile limit. Japanese and Taiwanese vessels are presently allowed to fish on seamounts west of 180° longitude and north of 28° latitude in the FCZ for pelagic armorheads and alfonsins. Some incidental catch of precious corals may result from this activity, but retention of the incidentally caught coral is prohibited. Catches must be reported.

II.C.1 Vessels and Gear

Historically, both in the Mediterranean Sea and in the far western Pacific, the primary method used to harvest precious coral has been dredging with tangle nets. Over the long history of the fishery, gear design has varied, but it has always centered around the basic idea of a dredge (weighted tangles) (Figure 8). The weights serve to keep the dredge on the bottom as well as dislodge the coral while the nets entangle it.

Off Hawaii the first attempt to selectively harvest precious coral was by the Jacobsen Brothers in 1969 using a remotely controlled manipulator guided by a television camera. This technology proved to be uneconomical but was the first step which led to the development of a successful system of selective harvest utilizing a manned submersible. Remotely controlled vehicles for the harvest of precious coral are currently being developed by separate companies in Hawaii and Taiwan.

The vessels utilized in the coral fishery differ largely as a function of the method of collection. Foreign dredge haulers range between 40 and 100 feet in length and employ crews which vary between 3 and 20 men. Typically, the dredges are lowered and raised by line haulers which are located amidships and operated over the side of the vessel. Dredging usually is accomplished without power. The ship is simply allowed to drift positioned at right angles to the current. Japanese fishermen usually deploy from 4 to 8 dredges simultaneously. Some larger vessels are able to handle up to 16 lines at once. Given good weather, Japanese coral fishermen continue dredging 24 hours a day, rotating the crew. The same grounds are often redredged.

In 1975, about 90 Japanese vessels (of which 26 were specialized) were engaged in harvesting precious corals off Midway, Wake, Yap and Saipan (Akira Matsura*, personal communication). Most likely the entire Japanese coral fleet is considerably larger. In Taiwan, about 30 coral dredgers operate seasonally (summer) out of the Peng-hu (Pescadores) Islands.

The vessels employed by the domestic fishery off Hawaii include a two-man submersible, a towing barge (the LRT) and a 70-foot surface support and towing vessel.

The submersible, Star II, is launched and recovered from the LRT below the surface at a depth of about 60 feet. Three SCUBA divers are required for this operation. The coral harvesting gear on Star II consists of a coral cutter, wire basket and hydraulic claw (Figure 9). Coral which is harvested selectively is packed in the basket. Maximum payload is about 200 pounds, but the average is about 60 pounds.

II.C.2 Evaluation of Gear Performance and Efficiency

Off Hawaii in 1972, experimental trials using dredging and selective harvesting methods were conducted in the Makapuu Bed. The dredge consisted of a concrete-filled cylinder (80 lbs.) with 6-foot hanks of nylon netting attached to eyebolts (Figure 8). The selective method was Star II. Data were compared in order to evaluate the ecological and economic efficiency of both techniques (Grigg, Bartko and Brancart, 1973). The results favored the selective method. However, this was in part due to the method of dredging employed. Only one dredge was used in the test whereas Japanese fishermen may drag up to 16 dredges simultaneously.

The size frequency distribution of coral collected with the submersible was characterized by larger pieces of higher quality than fragm collected by dredging (Figure 10). On the average, one day of effort with the submersible produced a catch about 10 times the value of an equal day's effort dredging with one coral net. However, if 10 nets were deployed simultaneously, the value of the coral produced should be about the same. Hence the major advantage of utilizing a submersible was not gross production but rather selectivity.

The advantages and disadvantages of the two methods are outlined in Table III.

There are several advantages of a submersible over a dredge. First, the use of a submersible permits selective harvest; immature colonies can be avoided and other benthic species are not disturbed. Second, the capacity for selectivity allows the use of a size limit as a management tool. The advantage of this is that the maximum sustained yield at an optimum size is theoretically about twice what it is if no size limit is imposed (dredging) (see Section III-F). This is because dredging leads to growth-overfishing, that is young colonies are harvested before reaching their maximum potential for growth. Thirdly, with a submersible, nearly all the coral dislodged from the bottom is brought to the surface. Dredges, on the other hand, only recover about 40% of what is initially "knocked down".[1] Dredges, of course, can be dragged repeatedly over the same area. Hence overall recovery with a dredge could be significantly greater than 40%. For example, three replicate hauls should theoretically collect 78% of the coral, four hauls, 87% recovery. Catch per unit effort, of course, would be progressively less and at some point, depending on costs, the operation would cease to be profitable. Exactly where this point lies no doubt varies with the quality and quantity of coral in each bed. A fourth advantage of a submersible over dredging is that a larger percentage of high quality coral may be collected.

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[1] The estimate of efficiency for tangle nets is based on simulated trails in shallow waters in Kaneohe Bay, Hawaii. Recovery of planted coral on the bottom for the five trails was 35, 39, 44, 40, 42 percent producing an average recovery of 40%.

TABLE III

Advantages and disadvantages of two coral-harvesting systems

Submersible	Dredging
Advantages	
. Permits selective harvesting, i.e. little or no damage to other components of the ecosystem	. Relatively inexpensive, low capital and operating costs
. Permits the use of a size limit as an aid to conservation, however breakage makes enforcement difficult	. May be more productive per 24 hour day, if multiple dredges employed
. Practically no waste	. Able to harvest continuously
. Larger percentage of high quality coral	. Major equipment readily adaptable for other uses
Disadvantages	
. High capital and operating costs	. Nonselective harvesting, immature colonies unprotected
. Requires preparation, maintenance and repairs of expensive, specialized equipment	. Ecologically more destructive, other species and habitats disturbed
. Need for support vessels	. More wasteful, some coral dislodged from the bottom may not be recovered
. Shutdown idles high capital investment	. Larger percentage of lower-valued coral
. May have limited depth capability and not fully utilize the resource	

Advantages of dredging over a submersible include the following. First, dredging is considerably less costly than operating a submersible. In some cases, dredging may also be actually more economical since more than one dredge can be employed and because the operation may be continuous on a 24 hour basis. The equipment is also readily adaptable to other fishing technologies, which may have economic advantages in areas where diversified fishing is profitable. A submersible requires several support vessels and service and maintenance, both quite costly. A major breakdown of a submersible system or a closed season would both result in idling a significant amount of capital investment. Also, dredges have no depth limits per se while submersibles do. In Hawaii, Star II has an operational depth limit of 1200 feet (365 m) which curtails full utilization of precious corals (see Table IV). Finally, in the event that distant or deeper coral beds are discovered, selective harvesting may be economically prohibitive or simply not possible, in which case dredging may be the only feasible alternative. Exploration for beds might also be best accomplished by dredging techniques.

Depending on desired goals and varying circumstances, such as the abundance of the resource, either system might be a more "efficient" or desirable alternative. It may be more profitable for industry to utilize a submersible so as to more fully utilize the resource, or if quotas are not overly restrictive, dredging may offer clearcut economic advantages.

Hence, the benefits of selective harvest vis-a-vis dredging must be considered on a case by case basis. Clearly there are economic and social tradeoffs which may not be the same for all locations in the Pacific.

II.D.1 Global Economics of the Precious Coral Industry

Worldwide, the precious coral jewelry industry is valued at about $500 million/year (retail sales). This arises from a world production of raw coral worth between $5 - $10 million (H. Ozawa, personal communication). In 1976, about 95% of the world's production was harvested from the Pacific Ocean. Most of this coral is sold to international buyers through a system of closed auctions in Japan that are operated by coral fishing associations. World jewelry production today is dominated by Japanese and Italian manufacturers.

In Hawaii most precious coral sold in the market place is purchased by local retailers who buy polished but unset "stones" from markets in the Orient. These stones are mounted in Hawaii in order to save import taxes on finished jewelry. A survey in 1971 showed at least 15 manufacturers producing jewelry and 150 to 100 retail outlets (Poh, 1971). Since then, there has been little or no increase in the number of major manufacturers. however, the number of retail outlets has increased by a factor of about two or three.

Retail sales in 1978 in Hawaii for both imported and locally produced coral jewelry were about $20 million (Clifford Slater, personal communication). This total represents a sevenfold increase since 1969 (see Thompson, 1975). This is based on pink, black and gold coral sales. Of the pink coral, about 80% is imported from the orient in a polished but uncut state. Almost 100% of the black and gold coral sales are of locally harvested coral.

II.D.2 Domestic Commercial Harvest

The domestic fishery for pink and gold coral in Hawaii is carried out by one submersible, two support craft, and about 12 personnel. The annual harvest capacity of the fishery is at least 3000 kg of pink and gold coral combined. The actual annual harvest in the 1974-77 period averaged less than 2000 kg (Table II).

Estimates of the ex-vessel value of raw pink and gold coral are given in Table IV. Also, for purposes of management analysis, an estimate of the ex-vessel price may be determined from: the price of imported polished-unset coral, the retail price differential between pink and gold coral jewelry, the relative value of the coral gem in a jewelry setting, and the costs of production at the harvesting and processing stages. The total ex-vessel value of pink and gold coral for 1977 was $262,000 (Table IV).

Table IV — Estimated ex-vessel value of pink and gold raw precious coral harvested in Hawaii, by year, 1975-77.

Year	Pink	per/kg	Gold	per/kg	Total
1975	$190,000	$137	$71,000	$114	$261,000
1976	94,000	136	42,000	114	136,000
1977*	215,000	150	47,000	147	262,000

*Projection based on the actual in the first three quarters of the year.

The value of raw coral is determined by color, size and condition (living or dead and solid versus wormy). For pink coral, the most valuable pieces are light pink or "angelskin." Lighter pink or darker red shades are lower priced. For gold coral, the most valuable shades are dark golden-brown. No dollar value can be estimated for bamboo coral at this time.

II.D.3 Domestic Commercial Processing

The processed commercial product relevant to the Fishery Management Plan is polished-unset precious coral. The primary supply of this product is imports to Hawaii. The domestic harvest of precious coral from the Makapuu bed and other potential exploitable beds provides the domestic industry with the raw material to produce an alternate source of polished-unset precious coral. About 35 jobs are directly related to processing raw coral harvested locally.

Value added at the processing stage of producing polished-unset coral from landed raw coral is approximately 100%. That is, $100 of value is added to every $100 of raw coral processed to produce $200 worth of polished-unset precious coral. These estimates are based on the cost of imported polished-unset coral and average costs of different stages of production reported confidentially from industry sources.

The estimated value of pink and gold polished-unset coral produced in 1976 was about $423,000. This included some raw coral from previous years' inventories. In the same year the coral jewelry manufacturers imported polished-unset coral at a cost of about $1,538,000 (see Table IV).

Table V — Value of polished-unset precious coral imports to Hawaii; percent of total coral imports, by country of orgin and year, 1973-76.

	1973		1974		1975		1976	
Country	$	%	$	%	$	%	$	%
Hong Kong	59,192	11.3	66,770	13.2	17,633	3.3	64,226	
Japan	241,862	46.4	226,109	44.7	153,929	28.4	277,592	18.
Philippines	0		0		73,450	13.6	42,005	2.
Taiwan	220,496	42.3	203,354	40.8	247,167	45.7	1,130,382	73.
Others	264	0.05	7,020	1.4	49,025	9.1	23,442	1.
TOTAL	521,814	100.0	506,253	100.0	541,204	100.0	1,537,737	100.

Source — Hawaii Custom District, Report Number IA-253, 1973-76.

II.E. Employment

While the number of people directly employed in the harvesting (12) and processing (35) of locally produced precious coral in Hawaii is not great, about 800 persons are engaged to some extent in the precious coral business there. Most jobs are in wholesale and retail sales.

II.F. State and Federal Tax Revenues and Multiplier Effects

Considering the excise tax on all retail precious coral products sold in Hawaii, revenues to the State (4%) amounted to about $800,000 in 1978 (Clifford Slater, Personal communication). About 20% of this can be attributed to local production of pink and gold coral in 1978. If wholesale taxes, State and Federal income taxes and operational taxes associated with the entire industry are taken into account, State and Federal tax revenues combined are about 2.5 million annually. About $500,000 of this is based on local production.

If a multiplier effect of two (Anderson et al., 1975) is used to show the impact of the total retail sales of the industry based on local production (4 million) on the economy of the State, a figure of about $8 million annually is produced. Eight million dollars is about one tenth of one percent of the Gross State Product of $6.6 billion (Bank of Hawaii, 1976). If the total industry is considered with the same multiplier, the value is 40 million or 0.6 percent of the Gross State Product in 1976.

The relevance of economic data for the total precious coral trade of Hawaii to the management of the domestic pink coral fishery has been questioned, in view of the small contribution of domestically harvested coral to the overall business.