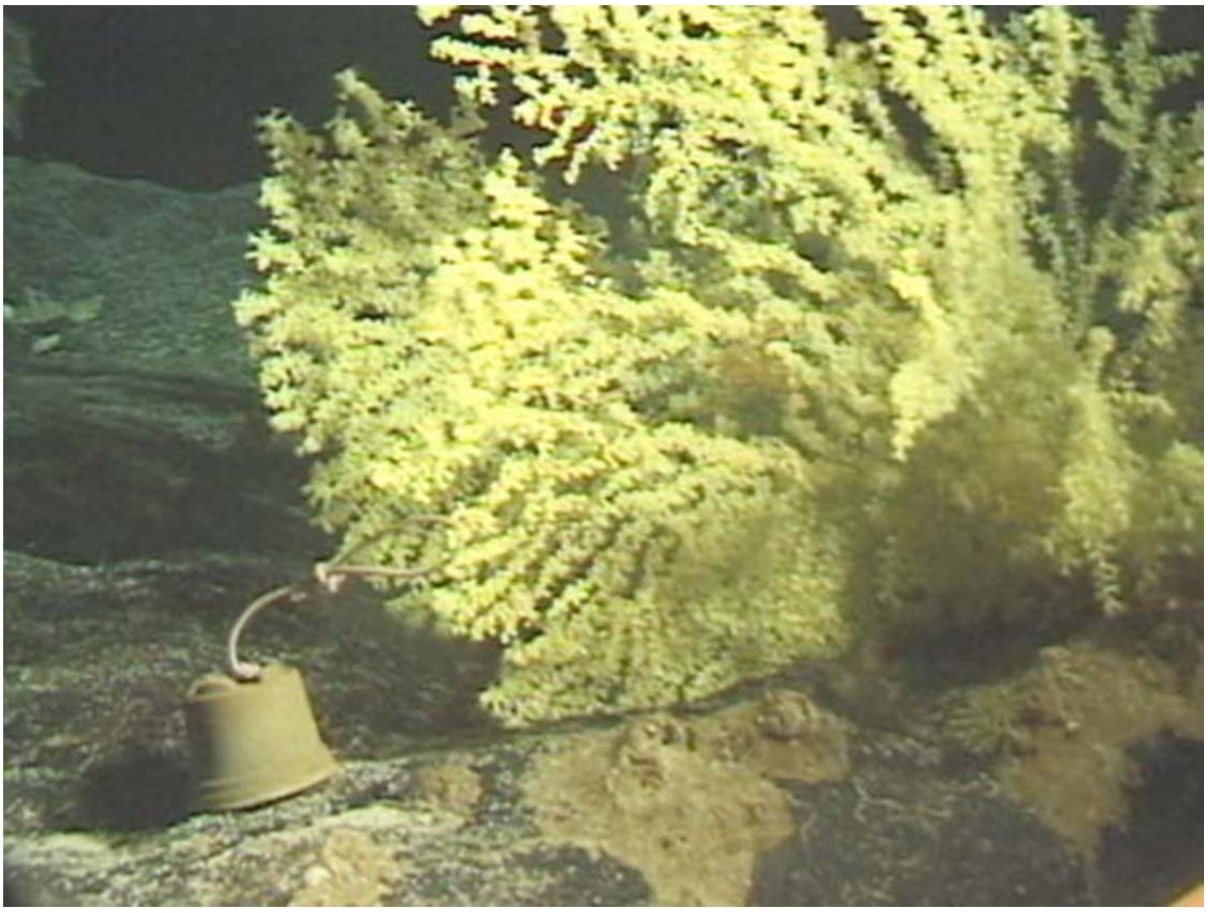
WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL

# Management Options for the Western Pacific Gold Coral Fishery



*(image from: http://docs.lib.noaa.gov/OEDV/NWHI_2003/image/gold_coral_600.jpg)*

Prepared by Council Staff
for the 111th SSC and 155th Council Meetings

September 25, 2012

Western Pacific Regional Fishery Management Council
1164 Bishop St. Suite 1400
Honolulu, Hawaii 96813

**Executive Summary**

Past research on gold coral indicated that the linear growth rate of gold coral is approximately 6.6 centimeters per year, suggesting a relatively young age for large trees. These estimates were based on the assumption that growth rings are laid down annually as in other precious corals such as black coral and pink coral (*Corallium rubrum* and *C. secundum*). Recent research done on the aging of gold corals using radiometric dating on three samples collected from the Makapuu Bed and off of the island of Hawaii found that gold coral may grow at a much slower rate of 14-40 micrometers per year aging those samples at 450-2,740 years old (Roark et al. 2006). Research conducted on *Gerardia* species in the Atlantic have estimated the age of large gold coral trees to be 1,800 years old (Druffel et al. 1995).

As a result of this discrepancy between growth estimates, the Council recommended to place a five-year moratorium on the harvest of gold corals in the Western Pacific region. The moratorium took effect September 12, 2008 and will expire on September 11, 2013. During the moratorium, Parrish and Roarke (2009) marked and measured 48 gold coral colonies at six different sites across the Hawaiian Archipelago and found no discernible growth. They estimated gold coral growth was slower than estimates produced through previous linear measurements. While this one study does provide additional information, studies looking at the gold coral growth over a period longer than 1-9 years may need to be done to confirm these results. Therefore, the need continues to provide time for the gold coral estimates to be reassessed, as well as incorporate this information into a better assessment of the stocks and the development of a proper Annual Catch Limit (ACL).

The action being proposed to the Council is to recommend an option to ensure the sustainability of the gold coral fishery in the Western Pacific region. Options ranging from no action (letting the moratorium lapse) to a permanent closure are being considered.

**Table 1: Options for gold coral**

| Option | Description |
|---|---|
| 1 | No Action-Moratorium to expire on September 11, 2013; Harvest of Gold Coral to resume |
| 2 | Extend Moratorium-extend the moratorium an additional five years to provide time for science and management to assess the gold coral status and develop an appropriate ACL for the fishery prior to reopening in 2018 |
| 3 | Prohibit the take of gold coral-institute a permanent ban on gold coral harvest in the Western Pacific Region |

# Table of Contents



## List of Tables



## Table of Figures

## Introduction and Background

Past research on gold coral indicated that the linear growth rate of gold coral is approximately 6.6 centimeters per year, suggesting a relatively young age for large trees. These estimates were based on the assumption that growth rings are laid down annually as in other precious corals such as black coral and pink coral (*Corallium rubrum* and *C. secundum*). Recent research done on the aging of gold corals using radiometric dating on three samples collected from the Makapuu Bed and off of the island of Hawaii found that gold coral may grow at a much slower rate of 14-40 micrometers per year aging those samples at 450-2,740 years old (Roark et al. 2006). Research conducted on *Gerardia* species in the Atlantic have estimated the age of large gold coral trees to be 1,800 years old (Druffel et al. 1995).

The Western Pacific Region's gold coral fishery is currently dormant, although research on gold coral remains active. Recent research has called into question current assumptions about the correlation between linear and axial growth rates of gold coral. Based on recommendations from fishery scientists, the Council recommended, and NMFS implemented, a five-year moratorium on the harvest of gold coral in the Western Pacific region. The moratorium is set to expire in 2013 and some research has been done to look at linear growth estimates of gold coral in Hawaii. Along with that, Annual Catch Limits (ACLs) have been developed for all management unit species in the Western Pacific region, with no ACL developed for gold coral due to the moratorium.

## Historical Management Overview

The Fishery Management Plan (FMP) for the Precious Corals Fisheries of the Western Pacific Region was implemented in September 1983 (48 FR 39229). It established the plan's management unit species and management area, and it also classified several known beds (See Tables 2 and 3 and Figure 1).

Amendment 1 to the FMP became effective July 21, 1988 (50 FR 27519) and applied the management measures of the FMP to the Pacific Remote Island Areas (Palmyra and Johnston Atolls, and Wake, Kingman, Jarvis, Baker, and Howland Islands) by incorporating them into a single Exploratory Permit Area, expanded the Management Unit Species (MUS) to include all species of the genus *Corallium* (See Table 3), and outlined provisions for the issuance of experimental fishing permits designed to stimulate the domestic fishery.

Amendment 2 to the FMP became effective January 22, 1991 (56 FR 3072, January 28, 1991) and defined overfishing for Established beds.

Amendment 3 to the FMP became effective November 18, 1998 (63 FR 55809, October 19, 1998) and established a framework procedure for adjusting management measures in the fishery.

Framework Measure 1 to the FMP became effective April 17, 2002 (67 FR 11941, March 18, 2002) and revised the definitions of "live coral" and "dead coral," suspended the harvest of gold coral at Makapuu Bed, applied minimum size restrictions only to live precious corals, prohibited the harvest of black coral with a stem diameter of less than one inch or a height of less than 48

inches (with certain exceptions), prohibited the use of non-selective fishing gear to harvest precious corals, and applied the minimum size restrictions for pink coral to all permit areas. The framework measure included additional proposed measures that would have applied only to the NWHI, but they were not approved because they were determined to be inconsistent with the management regime of the NWHI Coral Reef Ecosystem Reserve (see below).

Amendment 4 addressed new requirements under the 1996 Sustainable Fisheries Act (SFA). Portions of the amendment that were immediately approved included designations of essential fish habitat, definitions of overfishing and descriptions of bycatch and of some fishing communities. Those provisions became effective on February 3, 1999 (64 FR 19067, April 19, 1999). Remaining portions that were approved on August 5, 2003 (68 FR 46112) were provisions regarding Hawaii fishing communities.

**Table 2: Current Western Pacific Region Precious Coral Beds and Harvest Quotas for Gold Coral**

| Name of Bed | Type of Bed | Harvest Quota | Quota Duration |
|---|---|---|---|
| Makapuu Bed (MHI) | Established | Gold 0 kg | 2 years |
| Keahole Point (MHI) | Conditional | Gold 20 kg | 1 year |
| Kaena Point (MHI) | Conditional | Gold 20 kg | 1 year |
| Brooks Bank (NWHI) | Conditional | Gold 133 kg | 1 year |
| 180 Fathom Bank (NWHI) | Conditional | Gold 67 kg | 1 year |
| Westpac Bed (NWHI) | Refugium | Zero (0 kg) | N/A |
| Other EEZ waters around Hawaii, American Samoa, Guam, CNMI, PRIA | Exploratory | 1,000 kg per area, all species combined (except black corals) | 1 year |

Note: “Established Beds” are areas for which a MSY can be estimated based on bed-specific scientific data; “Conditional Beds” are those areas for which MSY estimates have been made based on their size relative to similar Established Beds; all other EEZ waters of the Western Pacific Region are termed “Exploratory Areas,” and are managed under area quotas. “Refugia” are beds with no harvest allowed.

Of relevance to the management of the NWHI precious corals fishery is the Northwestern

Hawaiian Islands Coral Reef Ecosystem Reserve, established December 4, 2000 through Executive Order (EO) 13178 (65 FR 76903, December 7, 2000), as modified by EO 13196 on January 18, 2001 (66 FR 7395, January 23, 2001). The Reserve is managed by the Department of Commerce under the National Marine Sanctuaries Act. On June 15, 2006, President George W. Bush signed Presidential Proclamation No. 8031 establishing the Northwestern Hawaiian Islands Marine National Monument (NWHI monument). The proclamation set apart and reserved the Northwestern Hawaiian Islands for the purpose of protecting the historic objects, landmarks, prehistoric structures and other objects of historic or scientific interest that are situated upon lands owned and controlled by the federal Government of the United States. Proclamation No. 8031 directs the Secretary of Commerce and the Secretary of the Interior (the Secretaries) to prohibit access into the NWHI monument unless authorized, and limit or regulate virtually all activities in the area through a permit and zoning system among other measures. Precious coral harvest is prohibited within the NWHI monument.

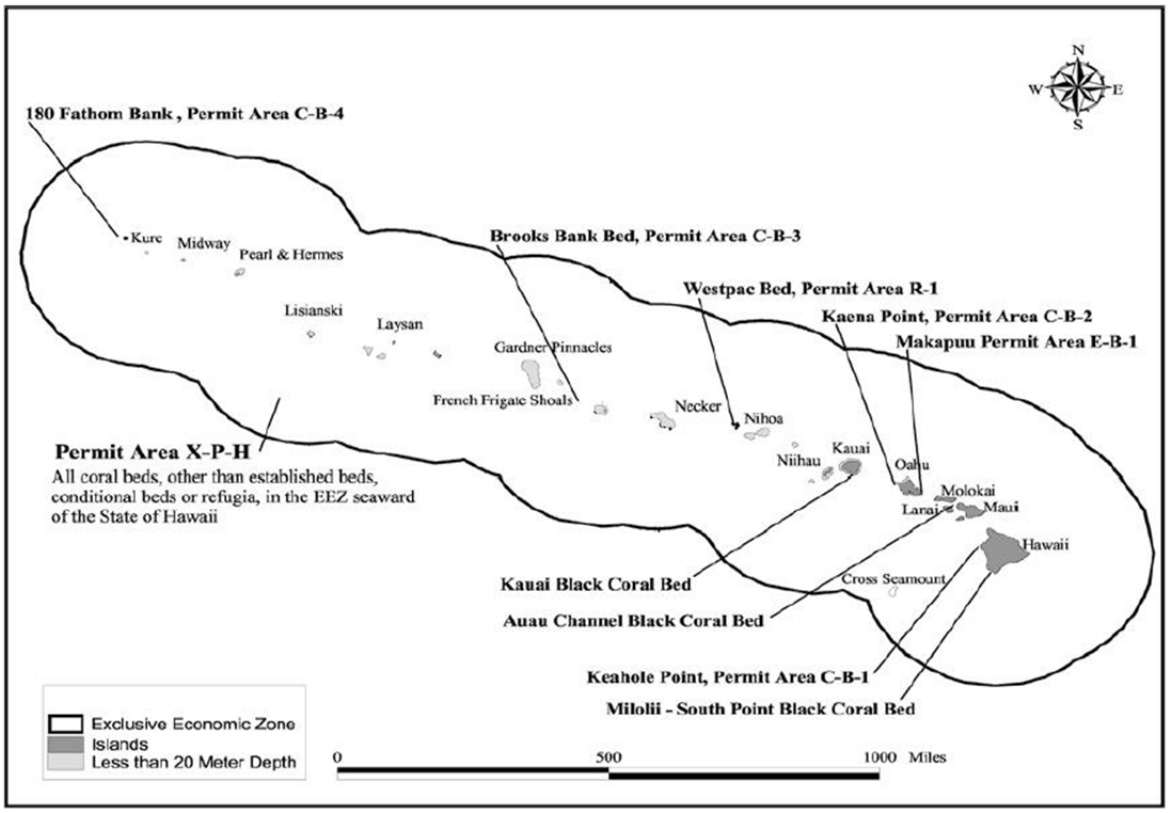



**Figure 1: Map of Hawaii Precious Coral Beds**

Amendment 5 to the FMP was prepared and transmitted to NMFS for approval in parallel with the FMP for Coral Reef Ecosystems of the Western Pacific Region. This amendment prohibits the harvest of Precious Coral Management Unit Species in the no-take marine protected areas established under the Coral Reef Ecosystems FMP. The Coral Reef Ecosystems establishes such areas around Rose Atoll in American Samoa, Kingman Reef, Jarvis Island, Howland Island, and Baker Island. No-take areas were also proposed for the NWHI, but all measures proposed in the Coral Reef Ecosystems FMP that would have applied to the waters around the NWHI (including

Midway) were disapproved because of possible conflict and duplication with the management regime of the NWHI Coral Reef Ecosystem Reserve. Accordingly, NMFS issued a Record of Decision on June 14, 2002 that partially approved the Coral Reef Ecosystems FMP and Amendment 5 to the Precious Corals FMP. A final rule implementing the Coral Reef Ecosystem FMP (including Amendment 5 to the Precious Corals FMP) was published on February 24, 2004 (69 FR 8336).

Amendment 6 included the federal waters around the Commonwealth of the Northern Mariana Islands (CNMI) within the FMP's management area and became effective September 12, 2006 (71 FR 53605).

A Regulatory Amendment to the FMP, which became effective on November 14, 2007, eliminated an exemption that allowed the harvest of black corals that have a minimum base diameter of ¾ of an inch to those fishermen that reported harvest to the State of Hawaii prior to April 17, 2002 (72 FR 58289). Black corals may only be harvested at a minimum base diameter of 1 inch or minimum height of 48 inches.

**Table 3: Precious Corals Management Unit Species**

| Common name | Scientific name |
|---|---|
| Pink coral (also known as red coral) | *Corallium secundum* |
| Pink coral (also known as red coral) | **Corallium regale* |
| Pink coral (also known as red coral) | *Corallium laauense* |
| Gold coral | *Gerardia* spp. |
| Gold coral | *Callogorgia gilberti* |
| Gold coral | *Narella* spp. |
| Gold coral | *Calyptrophora* spp. |
| Bamboo coral | *Lepidisis olapa* |
| Bamboo coral | *Acanella* spp. |
| Black coral | *Antipathes dichotoma* |
| Black coral | *Antipathes grandis* |
| Black coral | *Antipathes ulex* |

* *Corallium regale* has been recently identified by taxonomic experts as *Corallium laauense*

Amendment 7 became effective September 12, 2008 (73 FR 47098, August 13, 2008) and designated the Au'au Channel bed as an established bed with a harvest quota for black coral of 5,000 kg every two years for Federal and state waters combined. It also implemented a five year gold harvest moratorium for the entire region while research on life history is done.

**Purpose and Need**

Past research has revealed that the current growth rate estimates in the FEP may be overly generous. Radiocarbon dating of three gold coral samples from Hawaii has estimated that gold coral has an axial growth rate of 14-40 micrometers per year (Roark et al. 2006), which is similar to results from radiocarbon dating of gold corals in the Atlantic (Druffel et al. 1995). Currently, the FEP gold coral management is based on a gold coral growth rate of approximately 6.6 cm/yr

from numerous gold coral samples. On September 12, 2008, a moratorium was placed on the harvesting of gold corals to provide scientists time to reassess the current gold coral estimates to determine if they are adequate to prevent overfishing.

Since the amendment was put into place, only one study has been conducted to look at the current gold coral estimates. Parrish and Roarke (2009) marked and measured 48 gold coral colonies at six different sites across the Hawaiian Archipelago and found no discernible growth. They estimated gold coral growth was slower than estimates produced through previous linear measurements. While this one study does provide additional information, studies looking at the gold coral growth over a period longer than 1-9 years may need to be done to confirm these results. Therefore, the need continues to provide time for the gold coral estimates to be reassessed, as well as incorporate this information into a better assessment of the stocks and the development of a proper Annual Catch Limit (ACL).

The purpose of this action is to establish a moratorium for gold coral harvest as to prevent the renewal of a fishery under regulations that may not be sufficient to prevent overfishing. Parrish and Roarke (2009) provided additional impetus to merit the existing moratorium and an extension of the moratorium would provide the Council and NMFS with more time to prepare an ACL for the fishery that was appropriate given the science on gold coral growth.

**Description of the Options**

The following options are under consideration:

**Option 1: No action**

Option 1 would allow the moratorium on the harvest of gold coral to expire on September 11, 2013. Harvest of gold coral would be allowed and restricted to an Annual Catch Limit yet to be determined.

**Option 2: Extend moratorium**

Option 2 would extend the moratorium on the harvest of gold coral in the Western Pacific an additional five years (until 2018). The extension of the moratorium would provide time for any additional research to inform the gold coral growth estimates, as well as provide time for the development of an ACL for gold coral based upon a re-assessment of the stock utilizing any new information available.

**Option 3: Prohibit the take of gold coral**

Option 3 would implement an indefinite ban on the taking of gold coral in the Western Pacific region. An ACL would not be developed, and gold coral would continue to be a part of the Management Unit Species.

**Affected Environment**

**Life History**

In general, western Pacific precious corals share several ecological characteristics: they lack

symbiotic algae in tissues (they are ahermatypic) and most are found in deep water below the euphotic zone; they are suspension feeders (they require external water motion to bring them food); and many are fan shaped to maximize contact surfaces with particles or microplankton in the water column. Because precious corals are suspension feeders, most species thrive in areas swept by strong to moderate currents (Grigg 1993). Although precious corals are known to grow on a variety of hard substrate, they are most abundant on substrates of shell sandstone, limestone, or basaltic rock with a limestone veneer.

All precious corals are slow growing and are characterized by low rates of mortality and recruitment. Natural populations are relatively stable, and a wide range of age classes is generally present. This life history pattern (longevity and many year classes) has two important consequences with respect to exploitation. First, the response of the population to exploitation is drawn out over many years. Second, because of the great longevity of individuals and the associated slow rates of turnover in the populations, a long period of reduced fishing effort is required to restore the ability of the stock to produce at the MSY if a stock has been over exploited for several years.

Because of the great depths at which they live, precious corals should be insulated from some short-term drastic changes in the physical environment. For the same reason, man-made pollution may not affect their environment, except in the unlikely event that large quantities of heavy material, such as waste from manganese nodule refining, were dumped directly on a bed. Little is known about the potential long-term effects of changes in environmental conditions, such as water temperature or current velocity, on the reproduction, growth, or other life activities of the precious corals.

Precious corals MUS are taxonomically classified as members of the phylum Cnidaria, which includes all of the corals, hydroids, jellyfish and sea anemones. Its members are characterized by the presence of:

- a sac-like body with only one opening for the gut;
- only two tissue layers, an outer protective layer of epidermis and an inner digestive layer, the gastrodermis, lining the gut cavity;
- an intermediate layer called the “mesoglea” or “middle jelly” consisting mostly of protein fibers and generally lacking cells; and
- explosive, stinging devices called nematocysts used in either prey capture or defense.

Within the Cnidaria, precious corals are placed in the class Anthozoa, which includes the corals, soft corals and sea anemones, all characterized by having a relatively complicated gut, compared with other cnidarians. Living tissues are composed of polyps, each with a mouth surrounded by tentacles. Some species are composed of a single polyp while others are colonies of many polyps.

Within the Anthozoa, precious corals are members of three orders in two subclasses: 1) subclass Octocorallia (or Alcyonaria), order Gorgonacea, and 2) subclass Hexacorallia (or Zoantharia), orders Zoanthidae and Antipathidae.

Members of the subclass Octocorallia are characterized by their eight tentacles. All octocorals are

colonial, with each colony consisting of numerous polyps growing out of, and constituting the body of, the animal. These are all connected by a complicated system of internal tubing running through the colonial mesoglea. Octocoral MUS include the pink corals of the genus *Corallium* and the bamboo corals of the genera *Lepidisis* and *Acanella*.

Other anthozoans have their tentacles in multiples of six and are thus termed the Hexacorallia, or hexacorals. Hexacoral MUS include gold corals of the order Zoanthidea and black corals of the order Antipathidae.

Adult pink, bamboo and gold corals are found in deep water (100-1500 m) on solid substrate where bottom currents are strong. This is in contrast to black corals which also typically occur on solid substrate, but generally at depths between 30 and 110m.

Gold coral (*Gerardia* sp.) are Zoantharian corals that belong to the family Parazoanthus. Many are parasitic species that commonly overgrow other gorgonian corals. *Gerardia* seems to prefer overgrowing the bamboo corals (*Acanella* spp.). In fact, this association may be almost obligate as few colonies of *Gerardia* have been found without an *Acanella* base within the holdfast of the gold coral colony. In Hawaii, *Gerardia* sp. is found at depths between about 350 and 450 meters and prefers steep drop-offs. Typically it settles at the very top of drop-offs within this depth range where the current appears to be enhanced. *Gerardia* is also bioluminescent and can serve as habitat for bottomfish, sometimes including arrowtooth eels (*Meadia abyssalis)*. In the NWHI, monk seals have been observed, using radio telemetry, to dive in areas where red and gold coral occur (Parrish et al. 2002), prompting a hypothesis that monk seals forage among precious corals because they provide structural relief for various fish assemblages the seals' prey on. In 2000, the National Undersea Research Laboratory conducted a study using manned and unmanned submersibles in known beds of the Western Pacific region (Parrish et al 2002). The objective of the study was to see if gold coral provided habitat for deep-water fish. Results of the study found that gold coral did not seem to aggregate a significant fish assemblage. At the Cross Seamount, the study found arrowtooth eels in areas adjacent to the coral beds, but without the presence of gold corals. Although greater fish numerical density occurred in areas with gold coral, when the known effects of bottom relief and depth are accounted for, the relationship with gold coral loses statistical significance (Parrish 2006).

Past studies estimated the linear growth rate of gold coral was approximately 6.6 centimeters per year, suggesting a relatively young age for large trees (Grigg 2002). These estimates are based on the assumption that growth rings are laid down annually as in other precious corals such as black coral and pink coral (*Corallium rubrum* and *C. secundum*). Recent research done on the aging of gold corals using radiometric dating on three samples collected from the Makapuu Bed and off of the island of Hawaii found that gold coral may grow at a much slower rate of 14-40 micrometers per year aging those samples at 450-2,740 years old (Roark et al. 2006). Research conducted on *Gerardia* species in the Atlantic have estimated the age of large gold coral trees to be 1,800 years old (Druffel et al. 1995).

***Current research since the establishment of the moratorium***

In 2009, a study published by Parrish and Roarke quantified the growth of gold coral colonies that

were measured and marked across the Hawaiian Archipelago between one and nine years prior. The study was used to determine growth in relation to published estimates of growth using stem ring counts and radiocarbon analyses. The 48 colonies at six different sites measured showed no growth, signifying the slow growth of gold coral. Parrish and Roarke (2009) estimated that it "would take decades for the colonies marked in the field to grow enough to be detected by [our] current measurement technique."

**Distribution**

Precious corals are known to exist in the EEZ around Hawaii and likely exist in the EEZ around American Samoa, Guam, CNMI and the PRIA, but virtually nothing is known of their distribution and abundance in these areas outside of Hawaii. In America Samoa, there are three known areas with pink coral: near Upolu and Falealupo, and at Tupuola Bank (Carleton and Philipson 1987). In the Northern Mariana Islands, Japanese fishermen have reported pink coral north of Pagen Island and near Rota and Saipan. Since these areas remain unsurveyed, no information is available regarding the abundance of coral present.

To date, beds of pink, gold and/or bamboo corals have been found in eight locations in the EEZ around Hawaii. This number includes two recently discovered beds, one near French Frigate Shoals in the NWHI, and a second on Cross Seamount, approximately 150 nm south of Oahu. The species composition and density of the corals in these beds varies considerably (Parrish in Press).The approximate areas of six of these eight beds have been determined. These beds are small; only two of them have an area greater than 1 $km^2$, and the largest is 3.6 $km^2$ in size. The Keahole Point Bed off Hawaii's Kona coast, however, has been estimated to be 4 times larger than originally thought (Grigg 2002).

There are undocumented and unconfirmed reports that precious corals have been observed or exploited in widely scattered locations in the Western Pacific Region: off American Samoa, Guam, the Northern Mariana Islands, and Wake Island, but no details are available. In some cases attempts at scientific surveys in areas referred to in such reports have failed to turn up any evidence of precious corals. Undocumented reports of large past commercial production by Japanese vessels on the Milwaukee Banks, some 500 miles beyond the northwestern extreme of the NWHI, and the large physical area of those banks, lead to conjecture that at some locations precious corals may occur in much larger aggregations than have as yet been demonstrated by scientific surveys. Asian coral fishers, who have roamed the western and central Pacific for decades, undoubtedly have undocumented and unorganized information on precious corals beds which has yet to be revealed to U.S. researchers and or resource managers. In general, the available information on precious corals occurrence and distribution is fragmentary and very incomplete, and there is a high probability that further surveying and prospecting will reveal significant additional precious corals resources in areas under U.S. jurisdiction. The beds described below are shown on Figure 1.

<u>Makapuu Established Bed</u>

Within the EEZ, the Makapuu Bed has experienced the greatest level of legal exploitation and scientific research and thus is the source of much of the available information about the region's precious corals. Density of occurrence estimates for precious corals colonies in their habitat, based on observations made at the Makapuu Bed, reveal a fairly dense habit of growth. This bed was

surveyed in the 1970s, and again in 1997.

In 1971, densities of commercial species were determined in an unexploited section of the bed, and the size frequency distribution of pink coral was determined (Grigg 1976). The average density of pink coral in the Makapuu Bed was 0.022 colonies per square meter. Extrapolation of this figure to the entire bed (3.6 million $m^2$) results in a standing crop of 79,200 colonies. The 95% confidence limits of the standing crop are 47,200 to 111,700 colonies. Conversion of standing crop colonies to biomass produced an estimate of 43,500 kg for *C. secundum* in the Makapuu Bed.

The estimates of density for gold coral (*Gerardia* sp.) and bamboo coral (*Lepidisis olapa*) in the Makapuu Bed were 0.003 colonies/$m^2$ and 0.01 colonies/$m^2$ respectively. However, the distributional patterns of both of these species were found to be very patchy, much more so than *C. secundum*, and the area where they occurred was only about half that for pink coral, or 1.8 million $m^2$. The corresponding estimates of unfished abundance for gold and bamboo colonies are 5,400 and 18,000 colonies respectively. Data for the mean weight of colonies in the populations of gold and bamboo coral in the Makapuu Bed are lacking, but rough estimates were 2.2 kg for gold coral and 0.6 kg for bamboo coral. Multiplying mean weights by densities leads to rough estimates of standing crop of about 11,800 kg for *Gerardia* sp. and 10,800 kg for *Lepidisis* sp. (Grigg 1976)

An analysis of growth rings in the cross sections of pink coral branches suggests that colony height increases about 0.9 cm/year, at least to an age of about 30 years (Grigg 1976). The largest colonies of pink coral found at Makapuu were rarely more than 60 cm in height. Gold coral colonies were seen to reach a height of about 250 cm, while *Lepidisis olapa* (bamboo coral) was observed at about 300 cm.

The natural mortality rate for pink coral was calculated by first converting the size-frequency distribution of the unfished stock to an age-frequency distribution and then determining the rate of diminution in progressively older age classes (Grigg 1976). The best estimate of the annual instantaneous mortality rate of *C. secundum* in the Makapuu Bed is 0.066. This is equivalent to an annual survival rate of about 93% in the absence of fishing. Mortality rates for gold and bamboo coral are not available because their growth rates and age structures are unknown.

Pink corals reach sexual maturity at a height of about 12 cm (13 years). However, the data are not very precise (Grigg 1976). The reproductive cycle is annual with spawning taking place during June and July. The relationship between parent stock and recruitment in pink coral is unknown. However, because pink coral is long-lived, and the population is composed of many year classes, the standing stock should be relatively stable even with moderate year-to-year fluctuations in recruitment. An estimate of steady state recruitment of the unexploited Makapuu stock was obtained by multiplying the virgin stock size (79,200 colonies) by the best estimate of instantaneous mortality (0.066). Given steady state, the instantaneous rate of recruitment should equal the instantaneous rate of natural mortality. This gives an estimate of recruitment for the Makapuu Bed of 5,277 colonies.

Biomass per recruit as a function of age was calculated in the absence of fishing using a cohort production model (Wetherall and Yong 1977). In this model, the cohort gains weight until an age

is reached where growth gains are overtaken by natural mortality losses. This is the "critical age" at which the cohort reaches its maximum biomass in the absence of fishing. For pink coral the maximum biomass per recruit, attained by a cohort at age 31.4 years, is 237 gm.

Under the FMP, the MSYs for precious corals are calculated using a Beverton and Holt cohort production model (Beverton and Holt 1957) where data are available for *Corallium secundum*, and the Gulland Model (MSY = 0.4 MBo, where M=natural mortality and Bo is virgin biomass) for *Gerardia* and *Lepidisis* (Gulland 1970). According to the FMP, the estimated MSY for pink coral at Makapuu Bed is 1,000 kg/yr, and the estimated area of the Makapuu Bed is 3.6 $km^2$.
If fishing removes all colonies of a cohort at once, then the yield per recruit is identical to the biomass per recruit at the harvest age. Therefore, the maximum yield per recruit is achieved by harvesting all survivors in a cohort of pink coral exactly at the critical age of 31.4 years, and in this case the maximum yield per recruit is 237 gm. In practice this would require an infinite instantaneous fishing mortality rate exactly at 31.4 years. Since this is not feasible, the 237 gm/recruit is a theoretical upper limit to the harvest that may actually be obtained. More realistic figures of yield per recruit are obtained by considering a fishery that applies a steady finite fishing mortality rate to all ages in a cohort above a specified minimum harvest age. With a minimum harvest age of 30 years, the maximum yield per recruit is essentially equal to the upper limit of 237 gm, whereas with a minimum harvest age of zero years the greatest yield per recruit possible is only 119 gm. Hence, if non-selective measures are employed, the highest yield per recruit that can be expected is only half the maximum yield per recruit theoretically possible under selective harvesting. As long as recruitment is constant or independent of stock size, a fishing policy that maximizes the yield per recruit will also maximize the total yield on a sustained basis. In other words, it will also produce the maximum sustainable yield.

Amendment 4 to the FMP designated the Makapuu Bed as a habitat area of particular concern[6] for the precious corals fishery because of the ecological function it provides, the rarity of the habitat type and its sensitivity to human-induced environmental degradation. The potential commercial importance of the Makapuu Bed and the amount of scientific information that has been collected at the bed during the past three decades were also considered.

Between 1973 and 1978, a manned submersible was used to harvest 5,953 kg of pink coral and 2,097 kg of gold coral from the Makapuu Bed. In August 1997, the Hawaii Underwater Research Laboratory (University of Hawaii) and NOAA used a manned submersible to assess the extent to which the precious corals at the Makapuu Bed had recovered since the bed was last harvested over 20 years before (Grigg 1997). During this survey, the number of transects made on the Makapuu Bed was limited, and only a small portion of the bed was surveyed. However, based on the limited data obtained, it was concluded that this bed may be at least 15% larger than was suggested by previous data. The survey also showed that the recovery of pink coral has increased from 74% of the virgin biomass in 1978, to 90% in 1997. This finding supports the supposition that recruitment

[6]Habitat areas of particular concern are sub-areas of essential fish habitat that are particularly important to the long-term productivity of populations of one or more managed species, or are particularly vulnerable to degradation.

of pink coral is unaffected by harvesting and independent of the density of the standing stock. However, the assessment found that gold coral stocks at the Makapuu Bed may have experienced little or no recruitment. During the 1997 survey only two or three colonies of gold coral were observed. The number of transects of the Makapuu Bed made during this assessment were too limited to determine if the stock of gold coral was in an overfished condition, but the data collected suggest that the level of recruitment of gold coral at the Makapuu Bed has been low. It is uncertain, however, if the current scarcity of gold coral colonies at the bed was caused by the 1973-1978 harvests. There has been no gold coral harvest at the Makapuu Bed since, and the fishery remains dormant.

Brooks Bank Conditional Bed

The original harvest quota listed in the FMP for pink coral at Brooks Bank was 444 kg/yr.[7] This figure was calculated using the following formula provided in the FMP for setting the quota for Conditional Beds for which site specific data are unavailable.

$$\frac{\text{MSY for Makapuu Bed}}{\text{Area of Makapuu Bed}} = \frac{\text{MSY for Conditional Bed}}{\text{Area of Conditional Bed}}$$

This bed was surveyed only once, in September 1998. On this survey, 2.1 km-long transects were conducted at a depth of 350-505 m. Red coral (*C. laauense*) was observed to be very abundant, with thousands of colonies present. Colonies occurred in 1-5 $m^2$ patches, and were located at depths of 430-517 m. These colonies were up to 50 cm in height and averaged 1 cm in diameter. Extrapolation of these data suggests that a conservative standing crop of 8,000 kg of *C. laauense* exists at this bed (Grigg 1998b). *C. regale* has been recently identified by taxanomic experts as *C. laauense*. If it is assumed that this species of precious coral has the same natural mortality rate as *C. secundum* at the Makapuu Bed (6.6%), an estimate of the MSY can be derived from the formula provided by Gulland (1970): MSY = 0.4MB, where M is the natural mortality rate and B is the standing crop biomass. Rounding down, it is estimated that 200 kg of *C. laauense* could be harvested annually on a sustainable basis, based on these data and assumptions. Pink coral (*C. secundum*) was observed to be moderately abundant on the east side of the bank at depths of 363-427 m, but colonies were generally small (less than 20 cm in height). Gold coral was abundant with 250 large colonies found between 392-467 m. It was estimated that there was a standing stock of 2,000 kg of live gold coral, with an equal amount observed dead. Observations of finfish in the area were rare, and there was no evidence of predation by sea urchins at this bed.

Westpac Refugium Bed

This bed was also surveyed in 1998, using 3.2 km-long transects at depths of 360-500 m. No red

[7] The final rule implementing the FMP published on 20 August 1983 lists the harvest quota for pink coral at Brooks Bank as 17 kg. This is a typographical error.

coral was observed, however, pink coral was abundant, with thousands of colonies in 0.3-1.0 $m^2$ patches. Gold coral was rare, with only two colonies observed. Finfish (mostly Polymixia) were abundant, and there was high predation by Eucidarid sea urchins, with 50% of colonies showing signs of predation.

Keahole Point Conditional Bed

The Keahole Point Bed has been a Conditional Bed since the original FMP. Keahole Point Bed is located in the federal waters off the Kona coast of the Big Island of Hawaii. Based on its radius, published in federal regulations, its area is 2.69 $km^2$, but recent surveying and harvesting by industry has estimated that the bed could be four times as large (Grigg 2002). Red and pink corals are found in patches, with colonies occurring intermittently and in occasional dense patches for 30 km along the 400 m depth contour.

Scientific dives in the same area occurring a few months after industry dives found no evidence of harvesting (i.e., recently sheared stumps). This led the scientists to believe that commercial divers may have been in a different area of an even larger bed. Data are still being assessed to better define the location, size and total coral stock of this bed.

French Frigate Shoals-Gold Pinnacles Exploratory Bed

The 1998 survey also located a previously unknown bed near French Frigate Shoals, which has been named the FFS-Gold Pinnacles Bed. No red coral (*C. laauense)* was found along 2.9 km-long transects at depths of 360-575 m, and pink coral *(C. secundum*) abundance was low. Observed pink coral was generally small, averaging less than 12 cm in height (Grigg 1998b). Both live and dead gold coral were found in abundance, and 300 colonies were observed in scattered patches at depths of 365-406 m. Extrapolation of the transect data suggests that the gold coral standing crop at the FFS-Gold Pinnacles Bed is 3,000 kg.

Cross Seamount Exploratory Bed

The most recently discovered beds of precious corals were found by marine scientists examining fossil coral reefs 150 nm south of Oahu. Precious coral colonies were discovered on three of four basaltic outcroppings surveyed on Cross seamount. An estimated 324 kg of harvestable gold and 35 kg of harvestable red coral occurs at Cross Seamount. Colonies showed a normal size distribution of gold coral trees, with the largest trees three meters across (Grigg 2002). Much dead gold coral was seen on the ocean floor, and some pink coral colonies were seen growing off the dead gold coral.

**MSY Estimation**

According to the FMP, if recruitment is constant or independent of stock size, then the maximum sustainable yield (MSY) can be determined from controlling the fishing mortality rate (F) to maximize the yield per recruit (MYPR), i.e., MSY=MYPR (g/recruit) x R (recruits/yr). MYPR is a function of area of the bed, average colony density and natural mortality. If a stock-recruitment relationship exists, recruitment is reduced as a function of reduced stock size, and MSY will also be reduced. The assumption of constant recruitment appears to be reasonable based on the robust recovery and verification of annual growth rings from a previous survey (Grigg and Opresko 1977).

Alternatively, the Gulland (1969) method to estimate MSY is especially useful for gold and bamboo coral, where information on population dynamics is lacking. MSY is 40% of the natural mortality rate times virgin stock biomass (estimated from the product of area of the bed, average colony density and weighted average weight of a virgin colony: MSY = 0.4 x M x B). The mortality rate for pink coral (M=0.066) is used as a proxy for other species. However, with recent research on gold corals using radio-carbon dating methods to determine population dynamics, this assumption is being questioned.

The MSY for pink, gold and bamboo corals from the six beds in the Hawaii EEZ is about 3,000 kg/yr. It is likely that, at least while the fishery develops, the MHI will be the area most heavily fished. The harvest quota for the Makapuu Bed is 2,000 kg for a 2 year period. A recent resurvey, which used a newer technology enabling deeper dives, found the Makapuu Bed to be about 15% larger than previously estimated (Grigg 1997). MSY for conditional beds has been extrapolated, based on size, by comparison with that of the established beds. Amendment 2 set harvest quotas at 1,000 kg/yr each for American Samoa, Guam, CNMI and the PRIA (exploratory areas). No quotas have been determined for species of black corals.

The 1997 resurvey, by NOAA's Hawaii Underwater Research Laboratory, used a manned submersible to assess the extent to which the precious corals at the Makapuu Bed had recovered since the bed was last harvested over 20 years ago (Grigg 1997). The number of transects of the Makapuu Bed made during the assessment was limited, and only a small area of the bed was surveyed. Based on the data obtained, it was concluded that the precious corals bed may be at least 15 percent larger than was indicated by previous surveys. The survey also showed that the recovery of pink coral has increased from 74 percent of the virgin biomass in 1978 to 90 percent in 1997. This finding supports the supposition that recruitment of pink coral is unaffected by harvesting and independent of the density of the standing stock. However, the assessment found that gold coral at the Makapuu Bed may have experienced little or no recruitment. During the survey only two or three colonies of gold coral were observed. The number of transects of the Makapuu Bed made during this assessment was too limited to determine if the stock of gold coral was in an overfished condition, but the data collected suggest that the level of recruitment of gold coral at the Makapuu Bed has been low. However, it is uncertain if the current scarcity of gold coral colonies at the bed was caused by earlier harvests. At present, there is still insufficient information on the biology of gold coral to quantify the impacts of harvesting on the recruitment of these coral species.

In 2000, the harvest quota for gold coral at the Makapuu Bed was suspended by the Council until additional information becomes available on the impact of harvesting on subsequent recruitment of gold coral at the Makapuu Bed. The benefits of this management measure cannot be quantified due to the poor understanding of the biology and population dynamics of gold coral. Suspending the quota for gold coral at Makapuu Bed is a precautionary measure expected to increase the probability that a recovery in the number of gold coral colonies at the Makapuu Bed eventually occurs.

Scientific surveys have also identified a significant new bed at Cross Seamount. In addition, the

Keahole Point Bed was found to be four times larger than its previously known size. The Kaena Point Bed, conversely, was found to be smaller than anticipated (R. Grigg pers. comm. 2000. Univ. HI).

**Non-target species**

Little to no catches of non-target species occurs in the Western Pacific Region's precious coral fisheries. Prior to 1976, foreign fisheries utilized non-selective dredges and tangle nets. However, the FEPs requires the use of selective gear to harvest corals from any precious corals permit area. Selective gear means any that can discriminate or differentiate between type, size, quality, or characteristics of living or dead corals. Black coral are hand harvested with SCUBA gear, and deep-water species of precious corals have been harvested using manned submersibles or remotely-operated vehicles (ROVs). The use of manned submersibles is a highly selective method of harvest. Minimal bycatch is also expected with the use of ROVs, although the ROV tether may damage precious corals if not carefully tended.

**Gold Coral Fishery**

Most of the fishery participation has been for black corals in the Auau Channel off Maui, as currently, it is the only fishery harvesting precious corals management unit species in the EEZ (with the majority of harvest occurring in State of Hawaii waters). In 2001, American Marines Services Group received federal permits to harvest deep-water precious corals at the Makapuu Bed and in the Hawaii Exploratory Area. The company did not renew its permit, and the harvest levels from its operation can not be reported here because of data confidentiality requirements. In 2007, less than 3 fishermen have applied for and received federal permits to fish for precious corals in Hawaii. No precious corals harvester has received a federal permit to fish in EEZ waters surrounding American Samoa, Guam, CNMI or the PRIA since the implementation of the FMP in 1980.

In 1988, the domestic fishing vessel *Kilauea* used a tangle net dredge to harvest beds at Hancock Seamount. The owners of the *Kilauea* received a federal Experimental Fishing Permit that allowed them to collect an amount of precious corals in excess of the harvest quotas that had been established by the Council in 1980. However, their catch consisted mostly of dead or low quality pink coral, and the operation was soon discontinued (Grigg 1993). The only other domestic harvests on non-black precious corals since the inception of the FMP have been from the Makapuu Bed. The harvest levels of this operation cannot be reported here due to data confidentiality policies. The operation did not renew its permit and is no longer participating in the fishery.

<u>Participation</u>

There are currently no permitted operations for gold corals in the Western Pacific Region.

<u>Markets</u>

The worldwide glut of *Corallium* produced during the boom years of the early 1980s caused the market value of pink coral to fall even below breakeven prices for Taiwanese and Japanese coral fishermen (Grigg 1993). Consequently, many fishermen dropped out of the fishery and the worldwide supply of deep-water precious corals has dwindled. For the past 20 years Hawaii

businesses engaged in the manufacture of deep-water precious corals jewelry have relied on local stockpiles of gold coral and imports of pink coral from foreign suppliers. Prices for precious corals have gradually increased, and specimens of the highest quality pink coral currently sell for $5,000/lb in international auctions. However, changes in the jewelry industry during the past decade may have diminished the demand for precious corals. Products such as black pearls have captured a substantial share of the market formerly held by precious corals (C. Marsh pers. comm. 2000 Maui Divers of Hawaii, Inc., Honolulu). The precious corals jewelry industry in Hawaii has been estimated to be worth up to $70 million statewide (WPRFMC 2006).

**Protected Species Concerns**

Protected species are considered to include those species listed as endangered or threatened under the Endangered Species Act (ESA), all marine mammals and all seabirds.

In a 1996 Biological Opinion, NMFS determined that the precious corals fishery did not jeopardize the continued existence of the listed cetaceans that occur in the Western Pacific Regions. Due to the required use of selective harvesting gear and the nature of recent fishery operations, interactions between listed cetaceans and precious coral fisheries operations are not expected.

There have been no reported or observed interactions between monk seals and precious corals fisheries in the Western Pacific Region. Fishery operations are conducted using hand held tools or submersibles that would not cause a hooking or entanglement.

There have been no reported or observed interactions between sea turtles and precious corals fisheries in the Western Pacific Region. Fishery operations are conducted using hand held tools or submersibles that would not cause a hooking or entanglement.

There have been no reported or observed interactions between seabirds and precious corals fisheries in the Western Pacific Region. Fishery operations are conducted using hand held tools or submersibles that would not cause a hooking or entanglement.

**Essential Fish Habitat**

The MSA identifies essential fish habitat (EFH) as those waters and substrate necessary to fish for spawning, breeding, feeding, and growth to maturity. This includes the marine and aquatic areas and their chemical and biological properties that are utilized by the organism. Substrate includes sediment, hard bottom, and other structural relief underlying the water column along with their associated biological communities.

NMFS produced guidelines to assist in the implementation of the EFH requirements of the MSA. These guidelines state that the quality of the available data should be rated using a four level system as follows:

- Level 1: All that is known is the occurrence of a species based on distribution data for all or part of the geographic range of the species.

- Level 2: Data on habitat related densities or relative abundance of the species where available.
- Level 3: Data on growth, reproduction, or survival rates within habitats where available.
- Level 4: Data on production rates by habitat.

At present there are not enough data on relative productivity of various habitats for precious corals within the region to develop EFH designations based on Level 2, 3 or 4 data.
The designation by the Council of EFH for precious corals (Table 4) was based on the best available scientific information, which was obtained through an iterative process consisting of a series of public meetings, and through scientific, industry, and FMP panel meetings. In addition, the Council worked in close cooperation with scientists from the NMFS Southwest Fisheries Science Center, PIFSC, PIRO, and the NMFS Southwest Region Office (WPRFMC 1998). Careful judgment was used in determining the extent of EFH that should be designated to ensure that sufficient habitat in good condition is available to maintain a sustainable fishery and the managed species contribution to a healthy ecosystem. Because there are large gaps in scientific knowledge about life histories and habitat requirements of many of the managed species in the Western Pacific Region, the Council adopted a precautionary approach to ensure that enough habitat is protected to sustain the managed species. Under this precautionary approach, the Council designated the six previously known beds as EFH for precious corals. The FFS-Gold Pinnacles Bed was undiscovered at the time of the designations. Additionally, three black coral beds in the MHI are designated as EFH: - a bed between Milolii and South Point off the Island of Hawaii, a bed in the Auau Channel between Maui and Lanai; and a bed off the southern coast of Kauai.

The Council also designated HAPC based on the following criteria: ecological function of the habitat, sensitivity to anthropogenic degradation, development activities and stresses, or habitat rarity. Three of the six beds in the Hawaiian Archipelago are designated as HAPC - Makapuu, Westpac, and Brooks Bank. These three were designated as HAPC because of the ecological function they provide, the rarity of the habitat type, and their possible importance as monk seal foraging habitat. An additional area, the Auau Channel, was designated as HAPC for black coral because of its ecological function, the rarity of the habitat type, and its sensitivity to human-induced environmental degradation.

**Table 4: Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) for all Western Pacific FMPs**

| FMP | EFH (Juveniles and Adults) | EFH (Eggs and Larvae) | HAPC |
|---|---|---|---|
| Precious Corals | Keahole Point, Makapuu, Kaena Point, Westpac, Brooks Bank, 180 Fathom Bank deep water precious corals beds and Milolii, Auau Channel and S. Kauai black coral beds | Not applicable | Makapuu, Westpac, and Brooks Bank deep water precious corals beds and the Auau Channel black coral bed |

Note: All areas are bounded by the shoreline and the outer boundary of the EEZ, unless otherwise indicated.

The above table describes EFH and HAPC for precious corals in the Western Pacific Region. In order to refine EFH and HAPC designations additional research is needed to identify and evaluate actual and potential adverse effects on EFH, including, but not limited to direct physical alteration, impaired habitat quality/functions, and cumulative impacts from fishing. The continuation of the current precious corals fishing management regime would not adversely affect EFH or HAPC for any managed species, as it is not likely to lead to substantial physical, chemical or biological alterations to the habitat, or result in loss of, or injury to, these species or their prey.

**Analysis of the Options**

**Option 1-No action**

Target Species

Under this Option, a potential risk of overfishing gold coral would remain as new scientific information regarding the growth rates of gold coral has brought the sustainability of the region's existing quotas under question. Under this option, any future harvests of gold coral would continue to be regulated through the existing quotas and prohibition on the use of non-selective gear. An ACL for gold coral would also be developed based upon available assessments of the species. New growth estimates would be available as part of this assessment and wound contribute towards the development of the ACL as well.

Non-Target Species

A variety of invertebrates and fish are known to utilize the same habitat as precious corals. However, there is no evidence that these species or others significantly depend on precious corals for shelter or food. In addition, under the existing FEPs only selective gear can be used to harvest precious corals, thereby virtually eliminating the potential for catches of non-target species or degradation of their habitat. For these reasons, this option would have minimal impacts on non-target species or their habitat.

Protected Species

*Cetaceans*

There have been no reported or observed interactions between marine mammals and the precious corals fishery in the region. The potential impacts on the Hawaiian monk seal are discussed below. There could be some impact on marine mammals from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be extremely rare and therefore constitute a low-level risk to marine mammals. The gold coral fishery is currently dormant, participants are required to use selective gears the areas fished are not known to provide habitat to Cetaceans. Under this option, this extremely low-level risk to marine mammals would remain.

*Hawaiian Monk Seal*

As described above, monk seals have been observed diving to depths where gold corals and other

deep-water organisms occur (> 100 m) however there is no evidence that monk seal foraging is dependent upon gold corals. There could be some impact from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be rare therefore constitute a very low-level risk to monk seals. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Hawaiian Monk Seals. Under this option, this extremely low-level risk to monk seals would remain.

*Sea Turtles*
There have been no reported or observed interactions between sea turtles and precious corals fisheries in the region. There could be some impact on sea turtles from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be rare therefore constitute a very low-level risk to sea turtles. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Sea Turtles. Under this option, this extremely low-level risk to sea turtles would remain.

*Seabirds*
The precious corals fishery relies on selective harvesting gear (hand harvest and submersibles) which is not likely to result in any interactions with seabirds, and no such interactions have been observed or reported. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Seabirds. Consequently, this option is not expected to impact any seabird species that occur in the region.

Essential Fish Habitat
Under NMFS' guidelines (Table 4), impacts of an action must consider the EFH and HAPC of all managed species in the region. Therefore, the impact of the precious corals fishery under this option must also consider EFH and HAPC of species managed under the respective Pelagics, Bottomfish, Crustaceans, and Coral Reef Ecosystem FMPs. EFH or HAPC in the Western Pacific Region fall under two categories: either the water column above the ocean bottom, or the ocean bottom itself. Water column EFH and HAPC have been designated for pelagic, bottomfish and crustacean MUS. Precious corals fishing activities do not directly impact the water column.

Indirect impacts to water column EFH or HAPC potentially could occur through pollutant discharges from precious corals fishing vessels. The day-to-day operations of a fishing vessel can produce a number of waste products, including oil, sewage and garbage that if handled improperly, could affect marine habitat (WPRFMC 1998). However, vessels potentially engaging in the precious corals fishery are generally sophisticated motherships that must be able to support submersible operations. The crews on these large ships are highly-trained and tend to be drawn from high-tech marine industries rather than from traditional fisheries. It could be expected that regulatory awareness and the capacity to implement pollution mitigation measures would be greater for these operations than for many other types of fishing operations.

Areas of ocean bottom have been designated EFH and HAPC for precious corals, crustaceans bottomfish, and coral reef ecosystem MUS. Allowing only selective gear for the harvest of

precious corals minimizes adverse impacts on benthic habitat and other living components of the ecosystem. A variety of invertebrates and fish are known to utilize the same habitat as precious corals. These species of fish include *onaga* (*Etelis coruscans*), *kāhala* (*Seriola dumerallii*) and the shrimp *Heterocarpus ensifer*. However, there is no evidence that these species depend on the coral for shelter or food.

Anchor damage can occur to coral reefs and other types of bottom habitat from vessels attempting to maintain position over productive fishing areas. Due to the depths where precious corals are found, vessels do not routinely anchor while fishing for precious corals.

The accidental grounding of fishing boats can also adversely affect coral reefs and other types of bottom habitat. The impact of a vessel striking the bottom could physically destroy coral colonies in the immediate area, and the possible subsequent break-up of the vessel and release of fuel and oil can result in pollution of habitat and mortality of marine life. Since the harvest of precious corals occurs in deep waters, the likelihood of accidental grounding is unlikely.

Under this option, the continuation of the current precious corals fishing management regime would not adversely affect EFH or HAPC for any managed species, as it is not likely to lead to substantial physical, chemical or biological alterations to the habitat, or result in loss of, or injury to, these species or their prey.

Commercial, Recreational and Charter Fishing Sectors

The impact of this option on the commercial precious corals fishery is uncertain. Renewed harvests of gold coral measures may be unsustainable and could ultimately lead to fishery closures while the resources were rebuilt.

The charter and recreational fishing sectors would not be affected by under this option, as these sectors are not involved in the harvest of precious corals in the Western Pacific Region.

Regional Economy

The short-term impact of this option on the region's economy is uncertain because of the dormant and undeveloped status of the fishery. In the long-term, this option could have a positive impact on the regional economy by preserving opportunities for the future development of a sustainable and profitable gold coral fishery.

Fishing Community

No fishing communities as defined by the MSA would be affected by this option as there are no communities substantially dependent on the harvest of precious corals to meet social and economic needs. As noted above the region's deep-water fishery is dormant.

Environmental Justice

This option would not result in a significant and disproportionate adverse impact on members of minority or low-income populations. If overfishing were to occur, all participants in the gold coral fishing community would be equally affected.

Climate Change

There are no anticipated impacts from global climate change on the outcome of this option. Due to the great depths at which they live, precious corals will likely be insulated from short term changes in the physical environment. The lack of vessels in the fishery and gold coral fishing operations do not have significant impacts on local or global climate change.

**Option 2-Extend moratorium**

Target Species

As compared to the no action option, under this option the potential risk of overfishing gold corals would be removed for five years while further research into their growth rates is conducted. This would ensure that harvests of gold coral are sustainable and that overfishing does not occur. The moratorium would also provide a buffer against harvest whilst scientists and managers develop additional assessments based upon new growth estimates. ACLs will also have more time to be developed based upon these assessments.

Non-Target Species

A variety of invertebrates and fish are known to utilize the same habitat as precious corals. However, there is no evidence that these species or others significantly depend on precious corals for shelter or food. In addition, under the existing FEP only selective gear can be used to harvest precious corals, thereby virtually eliminating the potential for catches of non-target species or degradation of their habitat. For these reasons, this option would have minimal impacts on non-target species or their habitat.

Protected Species

*Cetaceans*

There have been no reported or observed interactions between marine mammals and the precious corals fishery in the region. The potential impacts on the Hawaiian monk seal are discussed below. There could be some impact on marine mammals from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be extremely rare and therefore constitute a low-level risk to marine mammals. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Cetaceans. Under this option, this extremely low-level risk to marine mammals would remain for activities directed at non-gold corals during the five year moratorium and for activities directed at all precious corals after the moratorium.

*Hawaiian Monk Seal*

As described above, monk seals have been observed diving to depths where gold corals and other deep-water organisms occur (> 100 m) however there is no evidence that monk seal foraging is dependent upon gold corals. There could be some impact from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be rare therefore constitute a very low-level risk to monk seals. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Hawaiian Monk Seals. Under this option, this extremely low-level risk to monk seals would remain for activities directed at non-gold corals during the five year moratorium and for activities directed at all precious corals after the moratorium.

*Sea Turtles*
There have been no reported or observed interactions between sea turtles and precious corals fisheries in the region. There could be some impact on sea turtles from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be rare therefore constitute a very low-level risk to sea turtles. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Sea Turtles. Under this option, this extremely low-level risk to sea turtles would remain for activities directed at non-gold corals during the five year moratorium and for activities directed at all precious corals after the moratorium.

*Seabirds*
The precious corals fishery relies on selective harvesting gear (hand harvest and submersibles) which is not likely to result in any interactions with seabirds, and no such interactions have been observed or reported. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Seabirds. Consequently, this option is not expected to impact any seabird species that occur in the region.

Essential Fish Habitat
As compared to the no action option, this option would not be anticipated to have any additional impacts to EFH or HAPC as it would not lead to changes in fishing operations or increased fishing effort.

Commercial, Recreational and Charter Fishing Sectors
As compared to the no action option, in the short-term this option would adversely impact potential commercial harvesters of gold coral as it would prohibit all harvests of gold coral in the Western Pacific Region for five years. In the long-term, it would result in better specified gold coral quotas/ACLs and thus maintain a sustainable fishery. Currently, there are no commercial permits issued for gold coral in the Western Pacific and no commercial fishery has existed in the recent past. The charter and recreational fishing sectors would not be affected under this option, as these sectors are not involved in the harvest of precious corals in the Western Pacific Region.

Regional Economy
In the short-term this option could have an adverse impact on the region's economy by prohibiting the harvest of gold coral for five years. In the long-term, this option would have a positive impact on the regional economy by preserving opportunities for the future development of a sustainable and profitable gold coral fishery.

Fishing Community
No fishing communities as defined by the MSA would be affected by this option as there are no communities substantially dependent on the harvest of precious corals to meet social and economic needs. As noted above the region's deep-water fishery is dormant. In the long-term, fishing communities that engage in future harvests of gold corals would be positively impacted as that fishery would be a sustainable one.

Environmental Justice

This option would not result in a significant and disproportionate adverse impact on members of minority or low-income populations. If overfishing were to occur, all participants in the gold coral fishing community would be equally affected.

Climate Change

There are no anticipated impacts from global climate change on the outcome of this option. Due to the great depths at which they live, precious corals will likely be insulated from short term changes in the physical environment. The lack of vessels in the fishery and gold coral fishing operations do not have significant impacts on local or global climate change.

**Option 3-Prohibit the take of gold coral**

Target Species

As compared to the no action option, under this option the potential risk of overfishing gold corals would be removed permanently.

Non-Target Species

A variety of invertebrates and fish are known to utilize the same habitat as precious corals. However, there is no evidence that these species or others significantly depend on precious corals for shelter or food. In addition, under the existing FMP only selective gear can be used to harvest precious corals, thereby virtually eliminating the potential for catches of non-target species or degradation of their habitat. For these reasons, this option would have minimal impacts on non-target species or their habitat.

Protected Species

*Cetaceans*

There have been no reported or observed interactions between marine mammals and the precious corals fishery in the region. The potential impacts on the Hawaiian monk seal are discussed below. There could be some impact on marine mammals from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be extremely rare and therefore constitute a low-level risk to marine mammals. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Cetaceans. Under this option, this extremely low-level risk to marine mammals would remain for activities directed at non-gold corals during the five year moratorium and for activities directed at all precious corals after the moratorium.

*Hawaiian Monk Seal*

As described above, monk seals have been observed diving to depths where gold corals and other deep-water organisms occur (> 100 m) however there is no evidence that monk seal foraging is dependent upon gold corals. There could be some impact from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be rare therefore constitute a very low-level risk to monk seals. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are

not known to provide habitat to Hawaiian Monk Seals. Under this option, this extremely low-level risk to monk seals would remain for activities directed at non-gold corals during the five year moratorium and for activities directed at all precious corals after the moratorium.

*Sea Turtles*
There have been no reported or observed interactions between sea turtles and precious corals fisheries in the region. There could be some impact on sea turtles from routine fishing vessel operations (e.g., behavioral or physiological reactions to noise, collisions, or releases of pollutants), however such impacts would be rare therefore constitute a very low-level risk to sea turtles. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Sea Turtles. Under this option, this extremely low-level risk to sea turtles would remain for activities directed at non-gold corals during the five year moratorium and for activities directed at all precious corals after the moratorium.

*Seabirds*
The precious corals fishery relies on selective harvesting gear (hand harvest and submersibles) which is not likely to result in any interactions with seabirds, and no such interactions have been observed or reported. The gold coral fishery is currently dormant, participants are required to use selective gears and the areas fished are not known to provide habitat to Seabirds. Consequently, this option is not expected to impact any seabird species that occur in the region.

Essential Fish Habitat
As compared to the no action option, this option would not be anticipated to have any additional impacts to EFH or HAPC as it would not lead to changes in fishing operations or increased fishing effort.

Commercial, Recreational and Charter Fishing Sectors
This option would have a large impact on fishing, as it would prohibit this activity. Currently, there are no commercial permits issued for gold coral in the Western Pacific and no commercial fishery has existed in the recent past. The charter and recreational fishing sectors are also not involved in the harvest of precious corals in the Western Pacific Region. While there may not be a fishery currently, this prohibits the development of any future fishery.

Regional Economy
This option could have an adverse impact on the region's economy by prohibiting the harvest of gold coral and removes opportunities for the future development of a sustainable and profitable gold coral fishery.

Fishing Community
No fishing communities as defined by the MSA would be affected by this option as there are no communities substantially dependent on the harvest of precious corals to meet social and economic needs. As noted above the region's deep-water fishery is dormant, but this option would not allow fishing communities to engage in future harvests of gold corals.

Environmental Justice

This option would not result in a significant and disproportionate adverse impact on members of minority or low-income populations. If overfishing were to occur, all participants in the gold coral fishing community would be equally affected.

Climate Change

There are no anticipated impacts from global climate change on the outcome of this option. Due to the great depths at which they live, precious corals will likely be insulated from short term changes in the physical environment. The lack of vessels in the fishery and gold coral fishing operations do not have significant impacts on local or global climate change.

**Literature Cited**


Beverton, R. and S. Holt. 1957. "On the dynamics of exploited fish populations. *Fish Invest. Minist. Agric. Fish. Food* (G.B.), Ser II 19:1-553.

Carleton, C. and Philipson, P. 1987. "Report on a study of the marketing and processing of precious coral products in Taiwan, Japan and Hawaii." South Pacific Forum Fisheries Agency Report No. 87/13.

Druffel, E. R. M., Griffin, S., Witter, A., Nelson, E., Southon, J., Kashgarian, M., Vogel, J. 1995. "Gerardia: Bristlecone pine of the deep sea?" *Geochimica et Cosmochimica Acta.* 59(23):5031-5036.

Grigg, R. W. 1976. Fishery management of precious and stony corals in Hawaii. UNIHI-SEAGRANT-TR77-03. 48 pp.

Grigg, R. 1993. "Precious coral fisheries of Hawaii and the U.S. Pacific Islands." *Marine Fisheries Review 55*(2):50-60.

Grigg, R. 1997. "Resurvey of the Makapuu precious coral bed - August 21-22, 1997." Unpublished report.

Grigg, R. 1998a. "Status of the black coral fishery in Hawaii - 1998." Report prepared under contract with Office of Scientific Authority, U.S. Fish and Wildlife Service.

Grigg, R. 1998b. "NWHI precious coral expedition - September 1998." Unpub. Rept.

Grigg, R. 2002. "Precious Corals in Hawaii: Discovery of a new bed and revised management measures for existing beds." *Marine Fisheries Review 64(1): 13-20.*

Grigg, R. and D. Opresko. 1977. "Order Antipatharia: black corals." Reef and Shore Fauna of Hawaii, B.P. Bishop Mus. Spec. Pub. 64(1):242-261.

Gulland, J. 1969. *Manual of methods for fish stock assessment. Pt. 1. Fish population analysis*. FAO Man. Fish. Sci. 4.

Gulland, J. 1970. "The fish resources of the ocean." FAO Tech. Paper 97, Food and Agriculture Organization, Rome.

Parrish, F. K. Abernathy, G. J. Marshall and B.M. Buhleier. 2002. "Hawaiian monk seals (*Monachus schauinslandi*) foraging in deep-water coral beds." *Marine Mammal Science* 18(1): 244-258.

Parrish, F. 2006. Precious Corals and Subphotic Fish Assemblages. *Atoll Research Bulletin* 543:(425-438)

Parrish F. In Press. Density and Habitat of three deep-sea corals in the lower Hawaiian chain. Bulletin of Marine Science.

Parrish, F. and Roarke, E.B. 2009. "Growth validation of gold coral *Gerardia* sp. In the Hawaiian Archipelago." *Marine Ecology Progress Series* 397: 163-172.

Roark, B. E., T. P. Guilderson, R. B. Dunbar and B. L. Ingram. 2006. "Radiocarbon-based ages and growth rates of Hawaiian deep-sea corals." *Marine Ecology Progress Series* 327:1-14

Wetherall, J. A. and M. Y. Yong. 1977. Computer simulation of pink coral population dynamics and analyses of harvest policies. Part 1: Preliminary Studies. Southwest Fisheries Center Admin. Rept. 21 H, 1977 (computer printout).

WPRFMC. 1998. "Magnuson-Stevens Act definitions and required provisions. Amendment 6 to the Bottomfish and Seamount Groundfish Fishery Management Plan, Amendment 8 to the Pelagic Fishery Management Plan, Amendment 10 to the Crustaceans Fishery Management Plan, Amendment 4 to the Precious Corals Fishery Management Plan." Western Pacific Regional Fishery Management Council. Honolulu, HI.

WPRFMC. 2006. 2006 Black Coral Science and Management Workshop. Honolulu, HI.