Precious Corals in Hawaii: Discovery of a New Bed and Revised Management Measures for Existing Beds

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Introduction and History of Hawaii's Precious Coral Fishery

Precious corals, *Corallium* spp., were first discovered in the Hawaiian Islands in 1900 on one of the *Albatross* expeditions (Bayer, 1956); however, it wasn't until the middle 1960's that commercial quantities were found and exploited. In 1965, Japanese fishermen discovered a huge bed of *Corallium secundum* at depths of 400 m on the Milwaukee Banks (Koko Seamount), about 750 km northwest of Midway Island (Grigg, 1974). In the following year, Vernon Brock and Theodore Chamberlain, of the University of Hawaii, discovered a small bed of *Corallium secundum* off Makapuu, Oahu in the main Hawaiian Islands, again at depths near 400 m (Grigg, 1974, 1993) (Fig. 1). The former discovery by the Japanese fueled a coral rush to the Emperor Seamounts that lasted about 20 years. During the peak years of this fishery, over 100 coral boats from Japan and Taiwan harvested up to 200,000 kg of *Corallium* annually from these seamounts (Grigg, 1974, 1982). Also during the peak years, a second undescribed species of *Corallium* was found in rich abundance at depths of 1,000–1,500 m. On the world market, both of these species are known as "Midway coral."

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ABSTRACT—The fishery for deepwater precious corals in the Hawaiian Islands has experienced an on-and-off history for almost 40 years. In spite of this, research, driven primarily by the precious coral jewelry industry, remains active. In this paper, the results of deepwater surveys in 2000 and 2001 are reported. In summary, a new bed on the summit of Cross Seamount is described and revised estimates of MSY's for pink coral, Corallium secundum*; red coral,* Corallium regale*; and gold coral,* Gerardia *sp., in the two known beds off Makapuu, Oahu, and Keahole Point, Hawaii, in the main Hawaiian Islands, are presented. The population dynamics of each species is described, as well as their ecological limits on Hawaii's deep reefs, island shelves, and seamounts. The local supply of precious coral in the main Hawaiian Islands is sufficient to support the local industry, but cost/benefits of selective harvest requirements and weather constraints limit profitability of the fishery.*

In 1966, a much smaller fishery was also initiated in the main Hawaiian Islands, in response to the discovery of *C. secundum* off Makapuu, Oahu, in the Molokai Channel (Fig.1). Between 1966 and 1969, about 2,000 kg of *C. secundum* was harvested in the Makapuu Bed by domestic vessels utilizing tangle net dredges (dredges consisting of heavy stones or iron bars with attached netting) (Poh, 1971).

Although the quantity of precious coral harvested in the Makapuu Bed was not great, it was sufficient to stimulate a long-term Sea Grant research program at the University of Hawaii. In the early 1970's, this program developed and deployed technology that permitted selective harvest by a manned submersible (Thompson, 1975). This technology was first utilized commercially by Maui Divers of Hawaii.[1] Maui Divers maintained a precious coral harvesting operation in the Makapuu Bed between 1972 and 1979. During this time, a Federal Fishery Management Plan (FMP) was written by the Western Pacific Regional Fisheries Management Council (USDOC, 1980).

[1]Mention of trade names and commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Finalized in 1983, the FMP allowed for selective harvest of up to 2,000 kg/2-year period of *C. secundum,* and, inter-alia, established a 10-inch minimum size limit. Both Federal and state permits were required to harvest the coral. The FMP also permitted harvest of two other species of precious coral from the Makapuu Bed; 600 kg of gold coral (*Gerardia* sp.) and 600 kg of bamboo coral (*Lepidisis olapa*). Both species were discovered in the Makapuu Bed by early Sea Grant research in 1970 (Grigg, 1974).

The Maui Divers operation on the Makapuu Bed flourished for about seven years but was discontinued in 1979 mainly due to increasing costs. A diving accident during the launch of the Star II submersible in the summer of 1975, which resulted in the death of two Maui Divers employees, also contributed to the closure.

For the next 20 years, the precious coral industry in Hawaii relied on imports of *Corallium* species of pink and red coral from Taiwan and Japan. During this time, the only precious corals harvested locally were the black corals, *Antipathes dichotoma* and *Antipathes grandis*. Both species are harvested by scuba divers at depths of 40–75 m in the main Hawaiian Islands. Grigg (2001) recently reviewed the history and management of the black coral fishery since its beginning in 1958.

In 1999, the precious coral fishery for deepwater red, pink, and gold corals in Hawaii was revived. The need to re-establish a local source of pink, red, and gold coral and the availability of a new and more cost-effective technology prompted American Deepwater Engineering (ADE), a U.S. corporation, to apply for and receive two permits to harvest deepwater precious corals utilizing two one-man submersibles (Deepworker-2000). The first permit was for the Makapuu Bed and allowed for selective harvest of up to 2,000 kg/2 years of *C. secundum*. The second permit was an Exploratory Area Permit (EAP) that permitted harvest in exploratory areas and allowed selective harvest of up to 1,000 kg of all species of deepwater precious coral combined.

During the 1999–2000 season, ADE, operating under both permits, harvested 1,216 kg of *C. secundum* from the Makapuu Bed, and 150 kg of *Gerardia* sp. and 61 kg of *C. regale* from exploratory areas off Kailua, Kona. The average prices obtained at auction for these three species were $187/kg for *C. secundum*, $400/kg for *Gerardia*, and $880/kg for *C. regale*, respectively.

Despite the Deepworker-2000 technology, operational costs remained high, in part because safety concerns required that two submersibles be operated in tandem. Diving was also limited by weather conditions to a sea state less than 5 and channel winds less than 20 kns. Diving operations were limited to just 20% of the time in each year. As experienced earlier by Maui Divers of Hawaii in the 1970's, profits were reduced by logistic constraints, ultimately producing a marginal return on investment.

Then in late 2000, President William J. Clinton issued Executive Order 13196 to establish a Coral Reef Ecosystem Reserve in the Northwestern Hawaiian Islands (NWHI). This effectively eliminated the entire NWHI (84 million acres) as potential grounds for deepwater precious coral exploration and harvest because two-thirds of the deepwater habitat for precious corals in the State of Hawaii is found in the NWHI. Given this reduction in potential supply and the marginal profits from harvest in 1999–2000, the Board of Directors of ADE elected to suspend precious coral operations at the end of 2001.

In spite of the on-and-off history of the deepwater precious coral fishery in Hawaii, research dealing with the ecology and management of the major species continued over the years and remains active. In recent years, attention has been focused on 1) evaluating impacts of past fishing activities on target stocks in the Makapuu and Keahole Point Beds, 2) assessing harvesting impacts on associated species, e.g. monk seals (Parrish et al., 2002), 3) refining estimates of MSY in known beds, and 4) exploration for new beds and estimating MSY's of species of precious coral that are found there. In this paper, recent progress is reported regarding objectives one, three, and four.

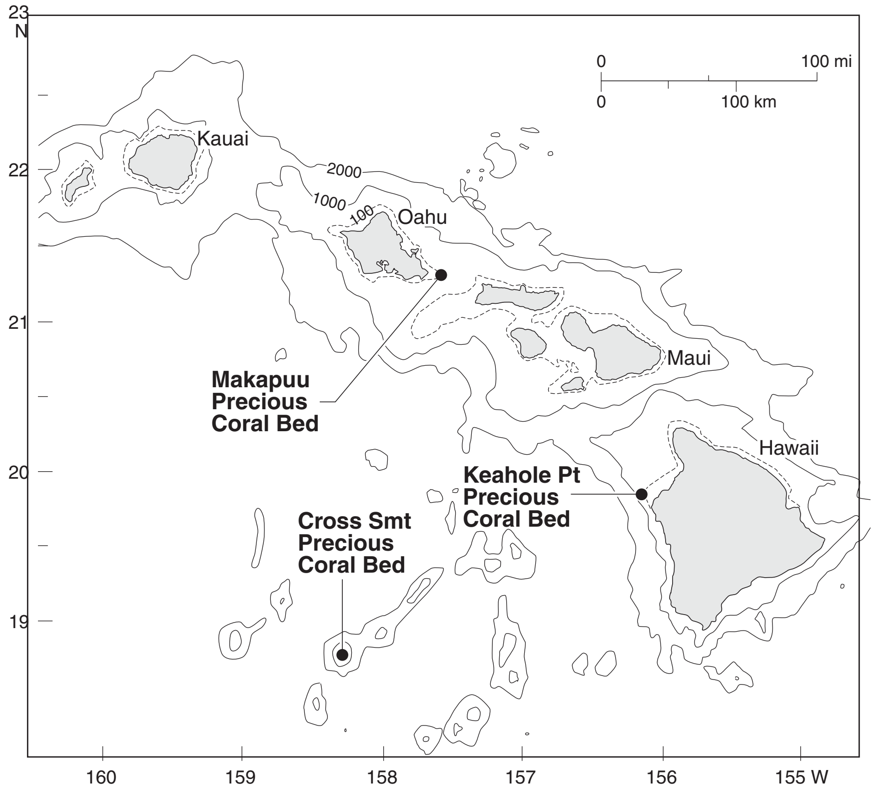

Figure 1.—The main Hawaiian Islands and location of the three known precious coral beds.

Table 1.—Precious coral research dives in 2000–01.

Location	Date	Technology	Dive no.	Depth (m)	Area surveyed (m^2)
Makapuu	10 Nov 01	Pisces IV	PIV-035	396–426	18,500
	11 Nov 01	Pisces IV	PIV-036	390–430	26,000
	10 Nov 01	ROV	RCV-120	315–485	17,000
	11 Nov 01	ROV	RCV-121	331–468	8,000
Cross Smt.	16 Nov 00	Pisces IV	PIV-014	336–458	27,000
	06 Nov 01	Pisces IV	PIV-032	354–421	13,000
	07 Nov 01	Pisces IV	PIV-033	343–445	31,500
	07 Nov 01	ROV	RCV-119	378–485	1,250
Keahole Pt.	19 Nov 00	Pisces IV	PIV-016	360–485	16,000
	05 Nov 01	Pisces IV	PIV-031	380–452	24,500

Methods

Deepwater precious corals in the main Hawaiian Islands are found at depths of 380 to 475 m. Data collection therefore requires remote controlled vehicles (RCV's) and/or submersible technology. Data in this paper was collected during seven dives in the Pisces IV submersible and three deployments of the University of Hawaii Undersea Laboratory's RCV-150 during 2000–01 (Table 1).

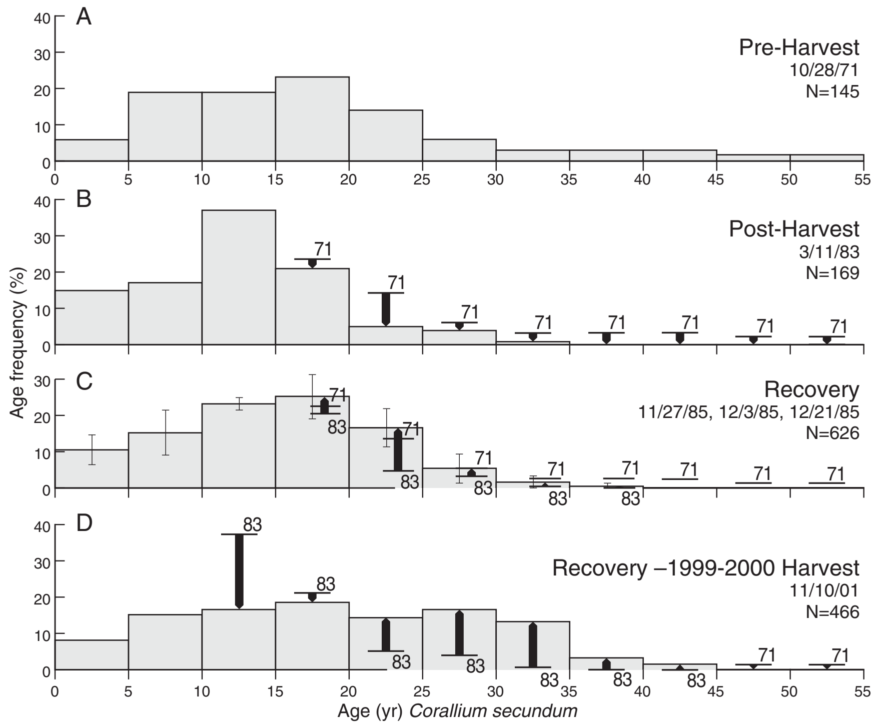

Figure 2.—Age structure (frequency distribution) of pink coral in the Makapuu Bed, Oahu, in 1971, 1983, 1985, and 2001. Arrow bars indicate relative decrease or increase in age frequency since reference year.

Pisces dives and RCV tracks were recorded in real time by the mothership R/V *Kaimikai-o-Kanoloa (KOK)* utilizing a combination of GPS and radar. Tracking of the submersible was accomplished with an ORE Trackpoint II acoustic navigation system. The RCV-150 is controlled from the ship by way of a tethered cable with a depth limit of 900 m. Video-audio tapes were recorded in the submersible using two external video cameras during the entirety of all dives. In the case of the ROV transects, video records were recorded in the ship's tracking room. Video-tapes recorded in the submersible are back-up to visual observations made by science observers in the submersible. Visual records include estimates of abundance, density, condition (percent of coral alive, incidence of disease, evidence of predation, etc.), and size frequency of precious corals. Estimates of density were based on the average number of colonies counted per 100 m^2 in 25 different sections of each bed. Linear tracking eliminated the problem of pseudo-replication. Evidence of recent past harvesting was based on observations of fallen and broken coral colonies in a localized pattern.

Colony size was measured with the aid of two laser lights projected in parallel (calibrated 15 cm apart) on benthic or coral surfaces. Other observations included type substratum, bottom steepness, depth, temperature, salinity, and current speed and direction. In situ collections are also possible during submersible dives using a robotic arm, claw, and basket assembly mounted on the submersible. A Sea Beam 210 multibeam sonar system on the *KOK* was used for precision bathymetric mapping.

Size-frequency distributions of coral colonies were converted to age-frequency distributions simply by dividing colony heights by estimates of linear growth rates for given species (Grigg, 1976). Recruitment and mortality, as well as impacts due to harvesting were estimated by interpreting changes in the age-frequency distributions of *Corallium* or *Gerardia* over time in the same area (Fig. 2). Revisions of MSY were calculated by pro-rating existing estimates by increases in bed area, or by application of the Gulland method, where MSY = $B \times m \times 0.4$ (Gulland, 1974), where B = biomass and m = mortality. Biomass estimates for *Corallium secundum* were obtained utilizing the equation $Y = 0.8x^{2.27}$ (Grigg, 1976) for converting length to weight, where Y = colony weight in grams, and x = colony height in cm. Biomass estimates for *Gerardia* sp. and *C. regale* were based on estimates of mean weight of legal size colonies measured on dive transects (4 feet for *Gerardia* and 10 inches for *C. secundum* and *C. regale*, (USDOC, 1980).

Age, for both species of *Corallium* and *Gerardia,* was determined by the relation between growth rings (assumed to be annual) and colony diameter and height (Fig. 3). Mortality was calculated as the best fit least squares regression of age class frequency plotted against age for *Gerardia* sp. (Fig. 4) and *Corallium* spp. (Grigg, 1976).

In the case of this study of *Gerardia*, growth ring counts judged to be annual produced a growth rate approximately 100 times greater than that estimated for a colony of *Gerardia* of similar size (3.1 cm basal diameter) collected at 620 m off Little Bahama Bank in the Caribbean Sea (Druffel et al., 1995). Growth bands (or laminations) counted in the Caribbean *Gerardia* were also assumed to be annual in periodicity, but, in that case, counts produced a colony age of 1,350–2,700 years. Carbon dating of the trunk of the same colony produced an age of 1800 years ± 300 years. The Druffel et al. (1995) estimate of growth and age cannot be correct for Hawaiian colonies of *Gerardia* because it would produce a wholly unnatural age-frequency distribution lacking in recruitment for many recent decades (Fig. 4). Missing recruitment for this many years is highly improbable, especially given our recent observations of moderately high recruitment in the Makapuu Bed (see below). More likely, the assumptions made in the Druffel et al. study (1995) are probably incorrect. Their growth bands more likely represent growth over several days. Their carbon dates may be skewed by colonies feeding on old particulate carbon. Or,

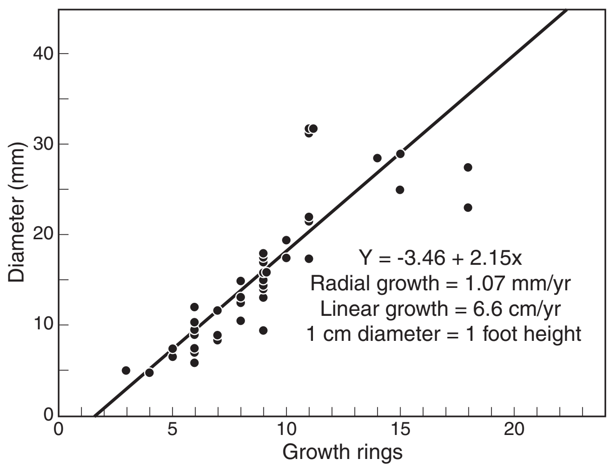

Figure 3.—Relationship between growth rings (assumed to be annual) and colony diameter for *Gerardia* sp. A radial growth rate of 1.07 mm/yr was found to be equivalent to a linear rate (annual increase in height) of 6.6 cm/yr. The linear rate was used to convert size frequency to age frequency in Figure 4.

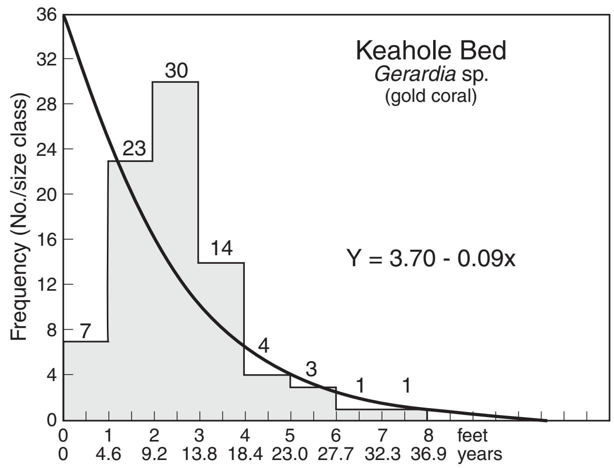

Figure 4.—Age frequency of gold coral in the Keahole Bed, Hawaii showing mortality rate beginning at larval settlement (recruitment to the bed).

isotopic exchange between the skeleton and seawater may have occurred. It is not likely that the growth rate of *Gerardia* growing at similar depths in the Pacific and the Atlantic would differ by two orders of magnitude. Clearly, more research on the ecology of *Gerardia* is needed before this discrepancy can be rectified.

Results and Discussion

Estimates of both the bed area and MSY were revised upward for the Makapuu and Keahole Point Beds based on the data produced by Pisces IV dives and ROV data collected in 2000–01. A new, large bed of *Gerardia* sp. and *C. regale* was also discovered on the summit of Cross Seamount. Patterns of distribution and abundance of both species on Cross Seamount are described and preliminary estimates of MSY are given.

Makapuu Bed

The November, 2001 surveys of the Makapuu Precious Coral Bed, consisting of two Pisces IV dives and two ROV/RCV-150 transects, produced several new and surprising results. Transect lines covering 11 linear km crossed and defined the edges of the bed at all boundaries to the north, south, east, and west (Fig. 1, 5). The area of the bed (4.3 km^2) was found to be 20% larger than previously estimated (Grigg, 1976). Also, the mean density of *C. secundum* was found to be 0.30 colonies/m^2 ± 0.03 SD in 2001 vs 0.022 colonies/m^2 ± 0.03 SD in 1971. The product of these differences (1.2 × 1.3) produces an overall abundance of about 1.5 times greater than that originally used to estimate MSY (Grigg, 1976), thus yielding an MSY ~50% greater than originally calculated, e.g. ~1,500 kg/yr. The surveys in the early 1970's were all within the same boundaries outlined in Figure 5.

Another positive result, from a management standpoint, was an increase in the percent of older year classes of *C. secundum* in 2001 compared to surveys in 1971 and 1983 and 1985 (Fig. 2). Year class groups of 20–25, 25–30, 30–35, 35–40, and 40–45 years, all increased in relative abundance over the same year classes in 1983, showing substantial recovery from the harvest years in the 1970's. Even though all year class groups in 2001 had not fully recruited (e.g. year classes 45–50 and 50–55 were still under-represented), the middle size colonies in 2001 were relatively more abundant and present in greater density compared to 1971 (Fig. 2), making the overall biomass in the bed 45% greater in 2001 than 1971. In terms of biomass, recovery in 2001 exceeded 100%. This result is due to the greater percent of older and larger colonies in the age-frequency distribution of the population.

The relative increase in older, larger colonies of *C. secundum* raises the question as to how this might have come about. Examination of the age structure in 1983 shows a strong year class group between years 10 and 15. This would have taken place when *C. secundum* recruited from larval settlement in the early 1970's at a time when submersible harvest began. The act of harvesting colonies may have triggered the release of larvae, or, alternatively, and perhaps more likely, the harvest (removal) of large coral colonies from the population may have caused their natural predators, such as *Eucidarid* sea urchins, to disperse, thereby lessening mortality especially to young colonies. In other words, *C. secundum*, may have increased in abundance due to increased survival of recruits in the 1970's due to reduced predatory pressure. During the 2001 survey, only 5% of all colonies measured (466) showed any signs of predation (broken branches or the presence of the grazing sea urchin, *Steriocidaris* sp.). The strong year class

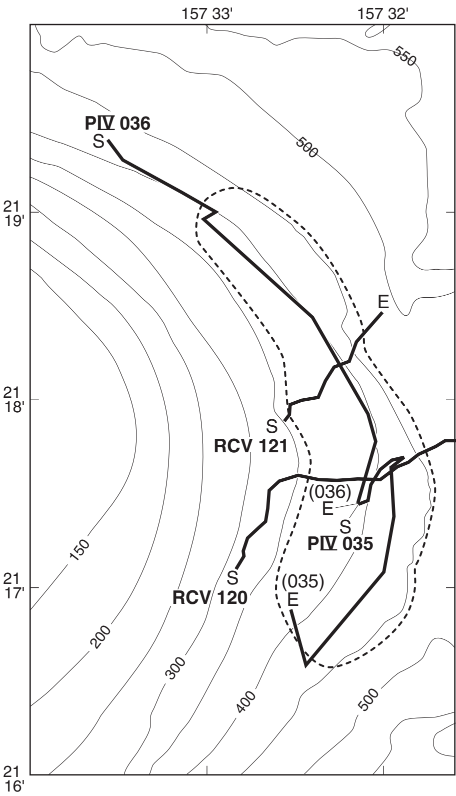

Figure 5.—The Makapuu Coral Bed showing the location of 2000–01 submersible dives and ROV transects.

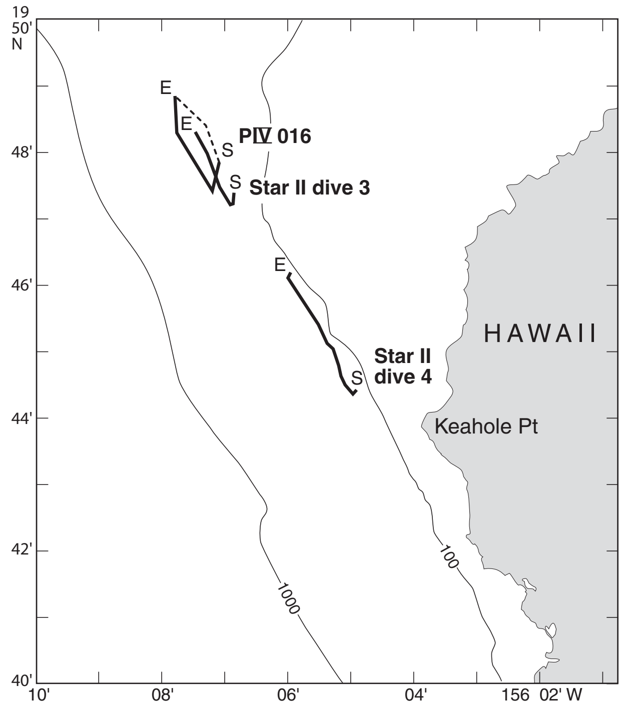

Figure 6.—Precious coral bed off Keahole Point, Hawaii. Bed is circumscribed by track of dive PIV 016 and dashed line. Track of PIV 031 all within prescribed area of the bed.

group in 1983 may have resulted from reduced mortality.

Another positive result regarding the management of gold coral, *Gerardia* sp., was a relative increase in recruitment of young colonies in the Makapuu Bed in 2001 compared to Pisces V surveys in 1997. On dives PIV-035 and PIV-036 in 2001, 14 colonies of *Gerardia* less than 30 cm high were counted, compared to only 3 in this size range in 1997. A similar area of bottom habitat was surveyed in both of these dive series. The low recruitment of *Gerardia* in the 1997 surveys in the Makapuu Bed, prompted the Western Pacific Regional Fishery Management Council to set the harvest quota of 600 kg/2 years for *Gerardia* to zero in 1999.[2]

A final observation made during the RCV-150 transects was a huge increase in abundance of crinoids attached to colonies of *C. secundum* during hours of darkness. Virtually no crinoids were observed from the submersible during 15 hrs of observation during daylight hours, whereas, at night during the ROV transects, literally thousands of individuals were observed out in the open, clinging to branches of *C. secundum*. Some colonies supported 2–4 crinoids. Clearly, crinoid behavior during daylight hours is extraordinarily cryptic even at depths where sunlight is virtually absent.

Keahole Point Bed

The precious coral bed off Keahole Point on the Kona Coast of Hawaii (Fig. 6) was found to be 4.0 times larger (0.96 km^2) during the 2000–01 surveys than previously charted by the Star II submersible in 1975 when the bed was first discovered (USDOC, 1980). This is often the case when new surveys explore bottom area beyond the limits of area initially covered. The 2000–01 Pisces IV dives logged 16.4 hrs bottom time and covered 4 times the distance of the original Star II transect, suggesting that a longer survey would result in charting even more bed area. Therefore, the estimate of bed area is considered conservative, as are estimates of MSY given below.

The depth ranges encountered for both species were 380–410 m for *Gerardia* and 388–450 for *C. regale*. Depth boundaries were relatively sharp; however, within the bed, the abundance pattern of both species was found to be quite patchy. Nevertheless, sharp depth limits produced accurate vertical boundaries for the bed. Aggregations of *Gerardia* were particularly common along or near the tops of drop-offs while colonies of *C. regale* were aggregated more to each other than to obvious variables of the substratum. No species of fish appeared to be associated with either species of

[2]Framework Adjustments to the Precious Coral Fishery Management Plan, 9-7-99)

precious coral although bottom fishes were generally more abundant inside vs. outside the bed, probably a consequence of sharing ecological factors in common (bottom steepness, substratum rugosity, depth, current, etc.).

During the course of Dives PIV-016 and PIV-031, 83 colonies of *Gerardia* sp. (Fig. 6) and 302 colonies of *C. regale* were measured (height). Applying Gullands' equation (MSY = $B \times m \times 0.4$) and inserting estimates of B and m for *Gerardia* (Fig. 4), and *C. regale,* produced estimates of MSY of 209 and 90 kg, respectively. These values apply to a bed area of 0.96 km^2 and would be greater if the bed area was found to be larger. If dollar values (based on the ADE auctions in 2001) are applied to both species, the collective value of annual yield (if realized) would be about $162,000 (Table 2).

Table 2.—MSY values (kg) and dollar values ($k) of precious coral stocks in Hawaii.

	Pink Coral		Red Coral		Gold Coral		Total	
Bed	Amt. (kg)	Value ($k)	Amt. (kg)	Value ($k)	Amt. (kg)	Value ($k)	Amt. (kg)	Value ($k)
Makapuu	1,500	280	—0—		—0—		1,500	280
Keahole	—0—		90	79	209	83	299	162
Cross	—0—		35	31	324	130	359	161
Totals	1,500	$280	125	$110	533	$213	2,158	$603

Cross Seamount Bed

Cross Seamount is located 250 km due south of Honolulu, Oahu, and 220 km west of the Kona Coast, Hawaii. The seamount is not part of the Hawaiian Island chain per se. Rather, it is believed to have originated during the Cretaceous Era at a location about 10 degrees south of the equator (Wessel and Keating, 1994). The present location of Cross Seamount on the Hawaiian superswell south of Oahu, is a result of plate motion (Rotondo, 1980).

Precious corals were first observed on the summit of Cross Seamount during an expedition there in 1986 to assess the resource potential of ferromanganese crusts and potential environmental impacts of crust mining (Grigg et al., 1987). Submersible dives in Pisces V in the following two years substantiated this discovery, but it wasn't until the 2000–01 dive series in the Pisces IV, that the resource was fully mapped.

A total of three Pisces IV dives and one ROV/RCV-150 transect were completed during the 2000–01 dive series (Table 1). A composite high precision (10 m contour) bathymetric map of the entire summit of Cross Seamount using Seabeam was also produced during the survey (Fig. 7). Video transects of all dives and in situ observations helped to interpret Seabeam bathymetry.

The summit of Cross Seamount is star-shaped in outline and about 6 km in diameter. The geomorphology and the depth of the seamount indicated that it is a guyot. Average summit depth is about 400 m; however, scattered over the summit are numerous outcrops in the form of steep-sided volcanic pinnacles and ridges, producing up to 10–15 m of relief. The largest and shoalest of these, is an oblong bathylithic dome about 1 km northeast of the summit center-point. Its diameter and depth are 0.3×0.5 km and 335 m, respectively. The dome is composed of smooth but fractured basalt. In at least two places on the flanks and at the base of the dome, thin veneers of limestone were found. Samples collected in situ show it to be highly indurated fossiliferous coral, presumably killed when Cross Seamount drowned during the Cretaceous Era (Malahoff[3]).

The dome itself is unique on the seamount because of its shape and smooth contour. All of the other pinnacles and ridges on the seamount contain more vertical relief and are more highly eroded. Sea caves, probably produced by wave erosion when the guyot drowned, are common, particularly at the bases of the pinnacles and ridges, strongly suggesting the summit itself is a product of wave truncation. A thicker veneer of limestone reef may have protected the bathylithic dome from wave erosion at the time of drowning. The flat-ground on the guyot floor consists of large sand pockets alternating with low wave-worn basalt outcrops.

The extant biology surrounding the dome of Cross Seamount is also unique. As opposed to the volcanic pinnacles and ridges where colonies of *Gerardia* and *C. regale* were abundant, none were observed on the summit dome. Even more unusual was a school of six or eight extremely large Cooke spiny sharks, *Echinorhinus cookei* and six-gill sharks, *Hexanchus griseus*, all about 3 m long, that were observed on all three P-IV dives, swimming back and forth, milling over the summit. Both of these species are extremely primitive fishes, having evolved during the Mesozoic Era (Tinker, 1978). For this reason, we named the summit of Cross Seamount, "Jurassic Park."

Colonies of the precious coral *Gerardia* sp. and *C. regale* were consistently present and moderately abundant on all of the volcanic pinnacles and ridges surveyed. *Corallium secundum* was also observed but it was not abundant. Depth ranges for *Gerardia* and *C. regale* were 380–430 m and 370–445 m, respectively. During the three Pisces IV dives, which consisted of 22.5 hrs bottom time, about 7.0 km of bottom was traversed. Of 25 pinnacles and 3.3 km of ridge-line at depths suitable for *Gerardia* and *C. regale,* identified on the Seabeam map (Fig. 7), 8 pinnacles and 0.75 km of ridge were surveyed, on which counts of both species were recorded.

This area represents about 25% of the suitable habitat for both species on the guyot summit. Over this area, a total of 562 colonies of legal size (4.0 ft) *Gerardia* and 625 colonies of legal size (10 in) *C. regale* were counted. If these figures are extrapolated over the entire suitable habitat on the summit, about 2,250 legal colonies of *Gerardia* and 2,500 legal colonies of *C. regale* would result. Converting these counts to biomass and applying Gulland's equation for MSY, would give an MSY of 324 kg for *Gerardia* and 35 kg for *C. regale* coral. These estimates must be considered very approximate since

[3]Malahoff, Alex, University of Hawaii, Honolulu. Personal commun. 1987.

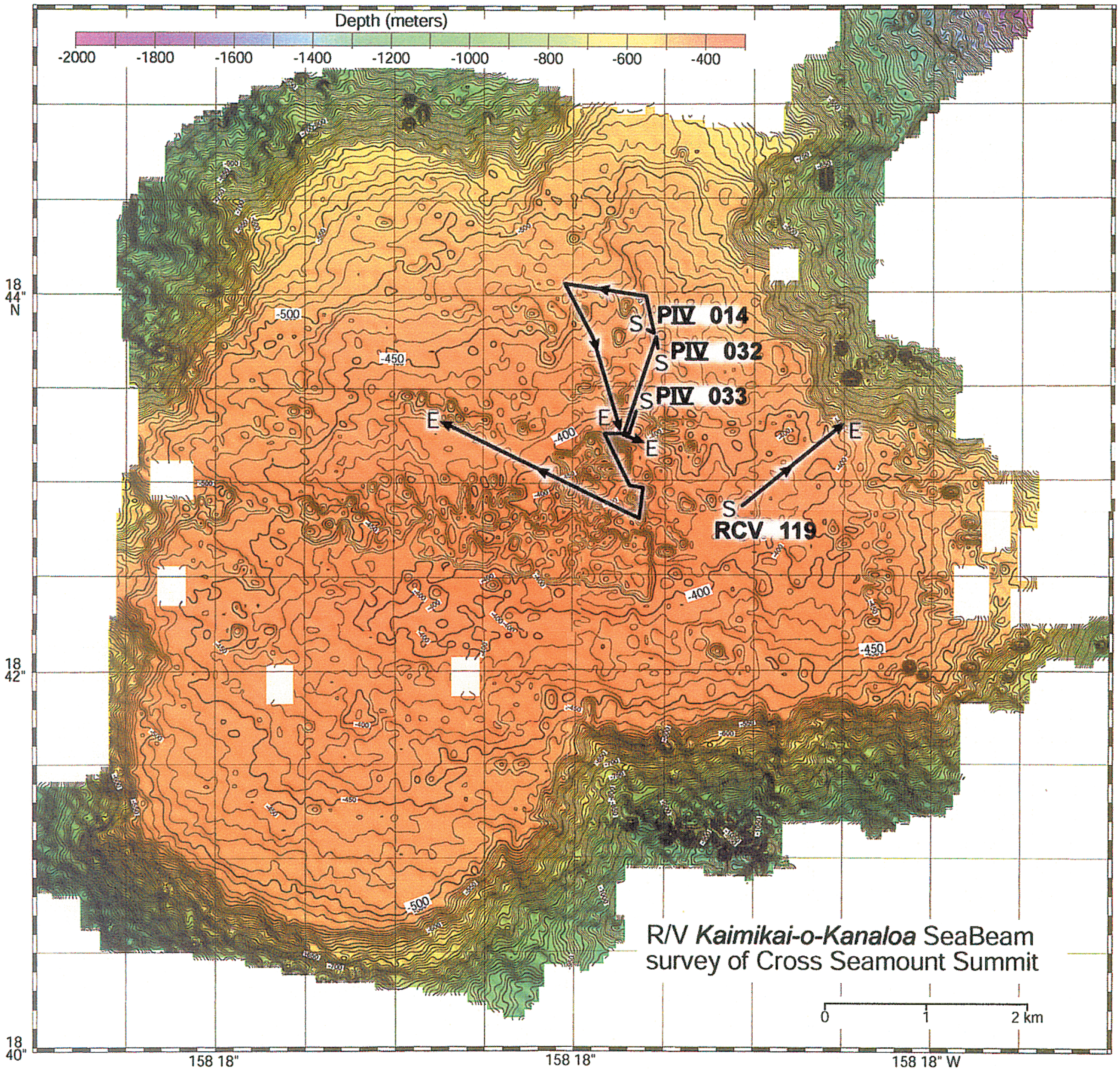

Figure 7.—Summit of Cross Seamount showing detailed bathymetry and suitable habitat of *Gerardia* sp. and *Corallium regale*. Contour interval is 10 m. The habitat of both species consists of all vertical outcroppings more than 2 m in relief on the summit of the seamount at depths shallower than 475 m.

only a small area of the summit was surveyed visually. However, the map bathymetry by which suitable habitat area was estimated appears to have good precision.

In the case of gold coral, a large number of dead colonies lying on the bottom could also be harvested. When colonies of *Gerardia* die and topple, their skeletons accumulate on the seafloor where they slowly decay. The amount available, that is still useable (slight or no decay) for the manufacture of jewelry, was judged to be at least as great as the MSY. Presumably the harvest of dead *Gerardia* would not produce negative environmental impact. Should both live and dead fractions of the gold coral be harvested, about 650 kg could be taken (at least in the first year) valued at about $250,000. Adding the value of the MSY for *C. regale* increases the total of raw coral for Cross Seamount to almost $290,000.

Conclusions and Future Prospects

The 2000–01 Pisces IV dive series to study precious coral in the main Hawaiian Islands increased the area of the two known beds off Makapuu, Oahu, and Keahole Point, Hawaii, and resulted in the mapping of a new bed at Cross Seamount. Estimates of MSY and potential dollar value of all three species of pink, red, and gold coral in each bed are given in Table 2.

The maximum sustained annual yield for all three species of precious coral in the main Hawaiian Islands is about 2 tons valued at about $600,000 for unprocessed raw coral. Given the demand expressed at the last auction held by American Deepwater Engineering in 2001 in Honolulu when 1,427 kg of all three species were sold, this supply is more than adequate to meet the needs of the small precious coral industry in Hawaii.

A serious problem that continues to plague the industry is the cost vs. benefit of harvesting the resource. The depths where deepwater precious corals are found, the surface weather where beds exist, and the legal requirement for selective harvest, all require that submersible or ROV technology be utilized. Harvesting costs are more or less fixed. The only way the supply side (harvesting) of the industry can survive is for prices of raw coral to increase, and/or for demand to increase. However, because the price structure is set by world market forces and supply is available from foreign sources, these changes are not likely to occur at least in the short term. The deepwater precious coral fishery in Hawaii may, therefore, remain dormant until market forces change. The same economics do not apply to the black coral fishery in Hawaii. A balance between supply and demand for black coral now exists and the fishery continues to be well managed by Federal and state agencies (Grigg, 2001).

In spite of economic uncertainties, scientific research dealing with precious coral species continues to produce new and important findings (Grigg, 2001; Parrish et al., 2002; Grigg et al., 2002). The deep reef where Hawaii's precious corals are found is essentially a mare incognitum, where almost every submersible dive produces new biological discoveries. The geology of the deep shelves, seamounts, and guyots, around Hawaii are also poorly studied. The presence of drowned fossil reefs in this environment hold clues to the sea-level history as well as the subsidence or uplift history of individual islands and submerged volcanoes. Citing one example, the drowning of the fossil coral reef that now veneers the summit of Cross Seamount may indicate that sea-level change in the Cretaceous Era may not have been much different than the last 20,000 years (The Holocene Transgression), when one-third of all atolls in the Pacific Ocean drowned (Menard, 1986).

Acknowledgments

The author would like to thank the Captain and the crew of the *Kaimi-o-Kamaloa* as well as the Hawaii Undersea Research Laboratory crew, in particular the pilots of the submersible, Terry Kirby and Chuck Hathoway, and the tracking engineer, Dan Gleason. I am also grateful to Frank Parrish of the Honolulu Laboratory of the National Marine Fisheries Service for procuring and sharing ship time in the *Pisces IV* submersible. Both the National Sea Grant College Program and the Western Pacific Regional Fisheries Management Council provided funding for the study. I also would like to acknowledge and thank Nancy Hulbrit of the University of Hawaii, HIG Publications, for preparing the figures.

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