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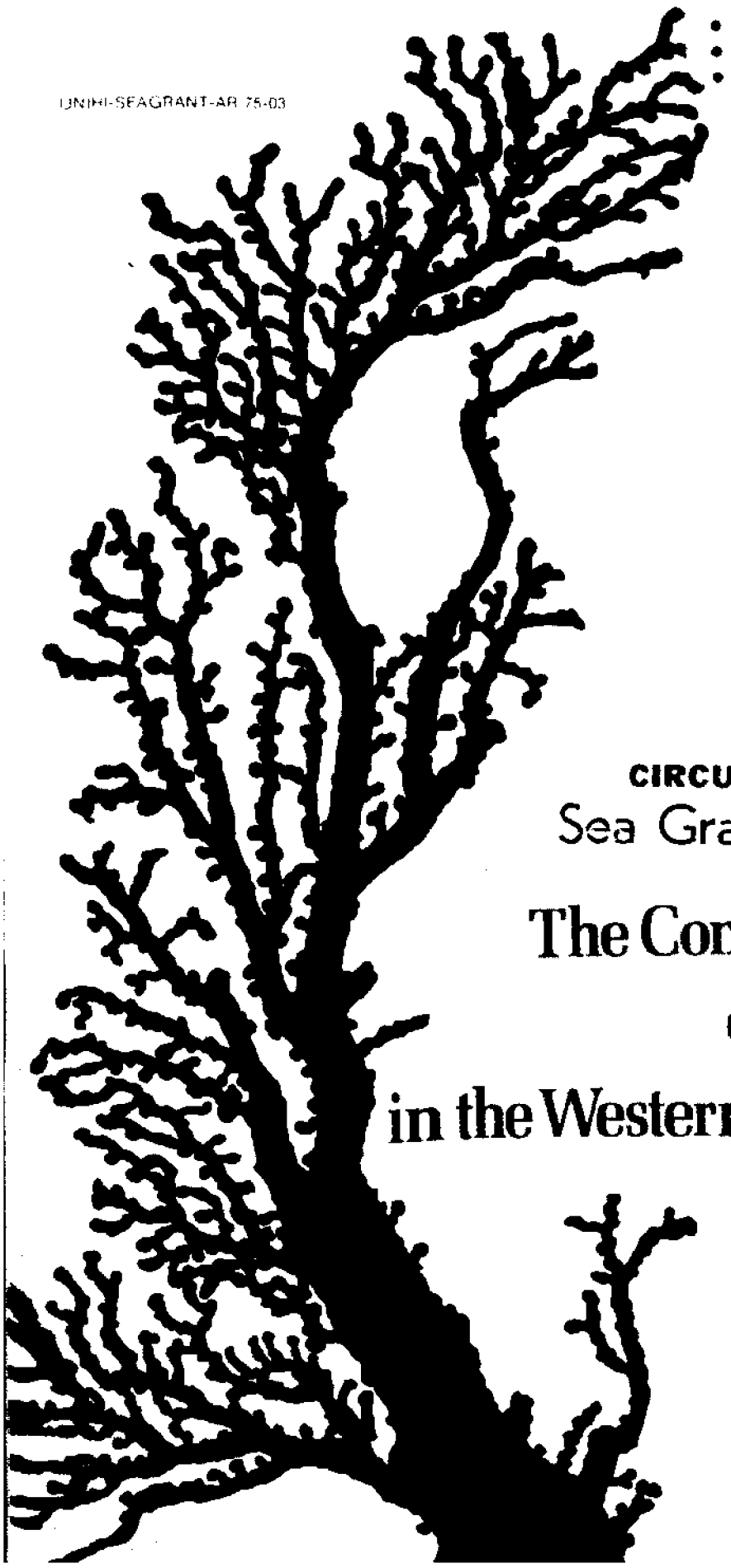

The Commercial Potential of Precious Corals in the Western Caroline Islands, Micronesia

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THE COMMERCIAL POTENTIAL OF PRECIOUS CORALS IN THE WESTERN CAROLINE ISLANDS, MICRONESIA

by

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ABSTRACT

Diving surveys and reconnaissance in Palau have revealed the existence of species of precious coral which have commercial potential. Quantities of black coral Antipathes dichotoma *sufficient to support a small local industry were found both inside and outside the barrier reef. Although specimens outside the reef are larger and more heavily branched, the depth distribution is considerably deeper than it is inside the reef. This, in combination with the constant threat of sharks outside the barrier reefs, makes the resources inside the reef a more practical source of raw material. In Palau, the maximum sustained yield of black coral is estimated to be about 1400 lb per year. Because the abundance of this resource is limited and because growth rates are very slow, precautions should be taken to prevent the creation of an export market.*

Precious pink corals also exist in Palau. Samples of Corallium elatius *believed to have been collected between Peleliu and Angaur were confiscated from a Japanese fishing vessel and were found to be of high quality. Further surveys for* Corallium *are recommended. Other species of commercial importance in Palau include several scleraxonians in the family Melitodidae and a fern black coral similar to the Hawaiian species* Antipathes ulex. *The melitodids lack the luster and hardness of* Corallium *and therefore are less valuable; however, they are also valued as decorative displays. The fern black coral, when polished, is similar to the true gold coral of Hawaii.*

Before a precious coral industry is developed in Micronesia, it is strongly recommended that control measures aimed at resource conservation be adopted. Also, certain unusually rich areas should be "set aside" as marine preserves in which the taking of any corals should be disallowed. This recommendation is of particular significance to the growing tourist and recreation industry in Micronesia since it has an enormously greater economic potential than the precious coral industry.

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INTRODUCTION

Man's use of precious coral for jewelry and artifacts dates back thousands of years. Prior to the nineteenth century, the only known sources of precious coral were the Mediterranean and Red Seas. Hickson (1924) has described the early trade in both red and black coral. In 1801, red and pink coral (*Corallium*, order Gorgonacea) were discovered in the Pacific by the Japanese; however, a coral fishery was not established in the Pacific until the Meiji Reform in 1868. Since that time, Japanese coral fishermen have been dredging *Corallium* from depths of between 90 and 400 m in areas bordering the western Pacific. The known distribution of commercial grade *Corallium* in the Pacific can be roughly approximated by constructing an arc which connects Hawaii, the Milwaukee Banks (32°N x 173°E, northwest of Hawaii), Tokyo, and the South China Sea (Grigg, 1970; Takahashi, 1942). Currently, the red and pink coral industry in the Pacific has an ex-vessel value of about $10 million annually. At the retail level, this would amount to about $300 million.

Black corals (*Antipathes* spp., order Antipatharia) are known to exist in widely scattered areas throughout the Pacific at depths generally below 30 to 40 m. However, very little is known about their quality and quantity outside of Hawaii where a large black coral industry has existed since 1958. In 1974, retail sales in Hawaii amounted to about $2.5 million. In Palau, a very small black coral industry, which more accurately may be described as a one-man operation, has been operational for several years. Although the craftsmanship is crude, the raw material does appear to have good potential. There is no existing literature on the distribution or abundance of black corals in the Trust Territory.

Other types of precious corals (gold and bamboo) also exist in Hawaii, but as with the black corals, knowledge of their distribution, abundance, and value elsewhere in the Pacific is virtually nonexistent. The gold corals include members in the following genera: *Parazoanthus* (family Zoanthidae) and *Callogorgia* and *Primnoa* (family Primnoidae). The bamboo corals belong to the family Isididae in the genera *Keratoisis* and *Acanella*. With the exception of *Parazoanthus* (subclass Zoantharia), all of the gold and bamboo corals are gorgonian corals.

In 1970, a research grant was awarded to the University of Hawaii by Sea Grant to investigate the ecology of precious corals in Hawaii. Although the primary thrust of this project was aimed at establishing an independent coral industry in Hawaii, one of its goals was to transfer the experience gained in Hawaii to Guam and the Trust Territory of the Pacific Islands. This report is primarily an evaluation of black coral resources of Palau in the Western Caroline Islands. A related report* presenting the results of an exploratory survey for precious

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**The Commercial Potential of Precious Coral in the Northern Mariana Islands* by Richard W. Grigg and Lucius G. Eldredge. All requests should be directed to: The University of Guam, Marine Laboratory, P.O. Box EK, Agana, Guam 96910.

corals in the Mariana Islands and containing the data of a survey designed primarily to locate pink coral (*Corallium*) between Guam and Saipan will be published by the University of Guam. The overall program was jointly sponsored by Sea Grant through the University of Hawaii, the University of Guam, and the Trust Territory of the Pacific Islands.

METHODS

In order to describe the distribution and abundance of black corals in Palau at depths ranging between 3 and 75 m, SCUBA dives were made in as many varied geographic locations as possible both within the lagoon and outside the barrier reef. Fourteen stations representing the widest possible variety of habitats within diving depth limits were selected for survey (Figure 1). Station data are presented in Table 1. Seven stations were located inside the barrier reef including a channel reef, a patch reef, a reef surrounding a rock island, a reef within a pass between two rock islands, a reef flat behind a barrier reef, and two sunken ships in the lagoon. Stations outside the barrier reef were steep, often vertical slopes on both the east and west sides of the island.

Samples were collected in all areas where black corals were present and records of depth and colony size were made. The total standing crop of the black coral, *Antipathes dichotoma*, was estimated by extrapolations based on the population density, average colony size, and the length of reef judged to be suitable habitat in terms of known ecological requirements.

Collections of black coral were also taken at several locations within Palau Lagoon where Japanese warships had been sunk during World War II (Figure 2). Assuming that the largest colonies present on these ships settled soon after the ships sank (May 30, 1944), measurements of their size provide minimum estimates of growth rate. Measurements of height and basal diameter of the largest colonies present were made at the same depth (24 to 34 m) on two ships of the same age. Measurements were taken in November 1973.

All samples of black corals collected in Palau were shipped to Honolulu and Los Angeles, California where their gem potential was appraised by Maui Divers of Hawaii and the Gemnological Institute of America (GIA), respectively. All field work was completed by June of 1974.

RESULTS

Distribution and Ecology

Commercial grade black coral of the species *Antipathes dichotoma* was found both inside and outside the lagoon. However, between the two

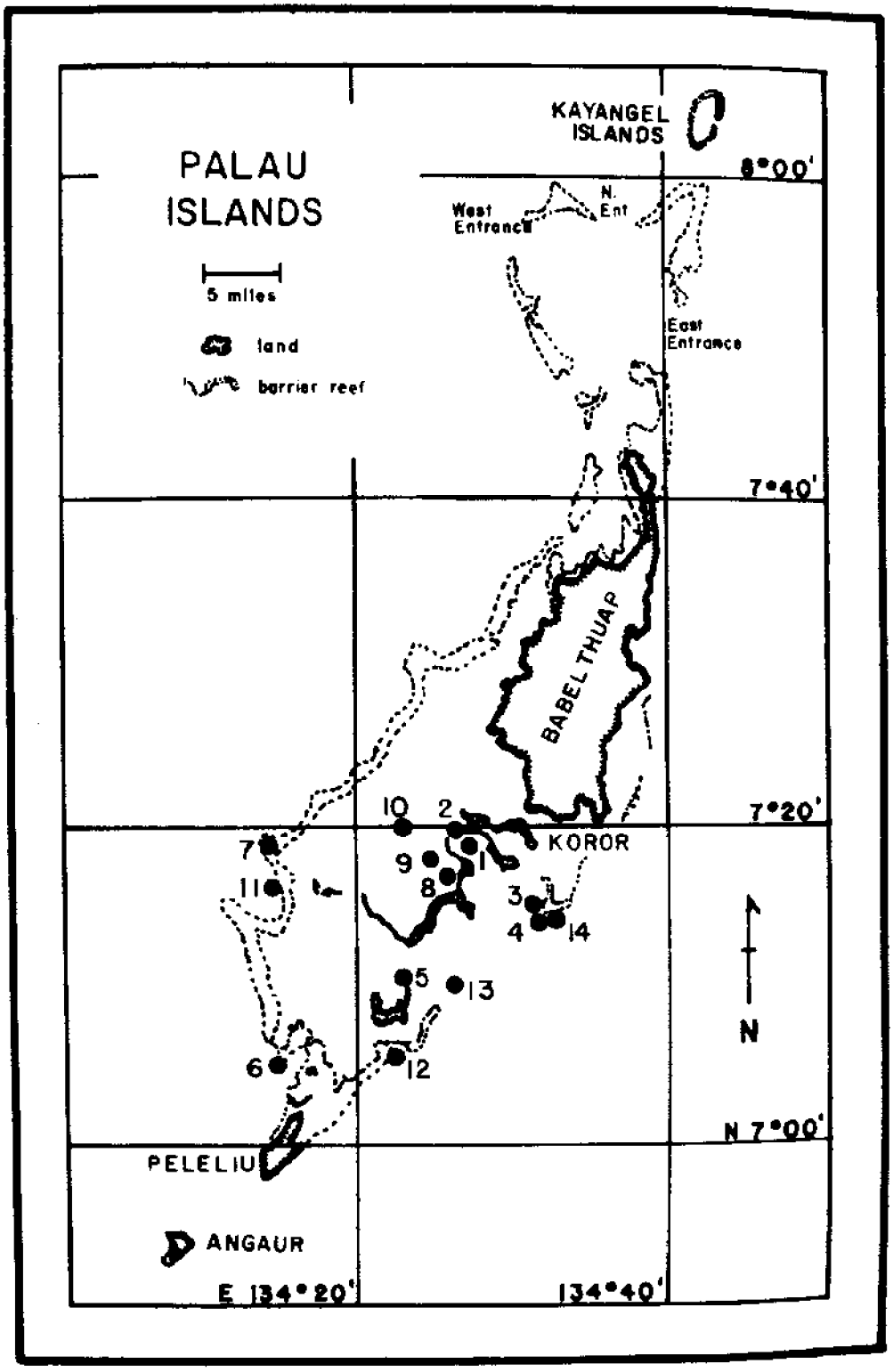

Figure 1. Map of Palau showing the location of the 14 diving stations.

TABLE 1. STATION DATA AND OBSERVATIONS IN PALAU

Station	Date	Location	Latitude/ Longitude	Depth (m)	Observations
1	11-1-73	Channel reef edge, 0.6 miles SE of Malakal (inside barrier reef)	7°19.00'N 134°27.85E	12-21	Channel reef slope about 45°; limestone and coral substratum; current moderate--about 0.25 cm/sec. *A. dichotoma* present--about 0.25 colonies per meter of reef; average basal diameter 1.57 cm.
2	11-1-73	West Malakal Pass (inside barrier reef)	7°20.00'N 134°26.88'E	20-39	Current moderate--about 0.15 cm/sec. Sunken Japanese ship, the *Amatau*, depth 39 m; *A dichotoma* present between 20 and 36 m; largest colonies --2.75 m, average height of largest colonies--1.93 m; average basal diameter of largest colonies--2.12 cm.
3	11-1-73	East drop-off on lee of Augulpelu Reef (outside barrier reef)	7°15.58'N 134°31.63'E	10-70	Drop-off inside of reef; no *Antipathes*; current weak--about 5 cm/sec; many scleractinians and gorgonians.
4	11-2-73	East drop-off at southern tip of Augulpelu Reef (outside barrier reef)	7°15.26'N 134°31.72'E	20-58	Drop-off outside the reef; large colonies of *A. dichotoma* up to 3 m in length and 6.35 cm in diameter and abundant at depths below 50 m; current moderate--about 20 cm/sec.
5	11-1-73	Rock Island pass near the Sar Passage (inside barrier reef)	7°11.82'N 134°23.07'E	5.5-33.5	Drop-off between two rock islands; current strong--up to 1.0 m/sec; *A. dichotoma* abundant at depths between 6 and 22 m; 0.20 colony per meter of reef length; average of largest colonies: height--1.44 m, basal diameter ---1.84 cm.
6	11-2-73	Off Bairakaseru Island (Ngemelis drop-off) (outside barrier reef)	7°05.60'N 134°15.00'E	10-75	Vertical drop-off outside the reef; current moderate; *A. dichotoma* abundant at depths below 35 m; very large colonies up to 3 m in length 6.0 cm in basal diameter, about 1 colony per meter of reef length, about 2.0 kg/m of reef length.
7	11-2-73	Reef flat behind barrier reef	7°19.25'N 134°14.50'E	3	Shallow fringing reef; coral and patches of sand; current moderate to strong; no *Antipathes*.
8	11-3-73	Urukthapel Bay (inside barrier reef)	7°17.70'N 134°25.75'E	18-25	Sunken Japanese ship; current weak--about 5 cm/sec; *A. dichotoma* present; average largest colonies--1.34 m height, 0.74 cm basal diameter; heavily encrusted with invertebrates.
9	11-3-73	Rock Island, west of Urukthapel Bay (inside barrier reef)	7°18.50'N 134°25.00'E	6-27	Gently sloping (30°) sand drop-off with scattered reef building corals; no *Antipathes*; current weak.
10	11-4-73	Patch reef west of Malakal Pass (inside barrier reef)	7°20.00'N 134°23.50'E	15-30	Gently sloping (20°) sand drop-off with reef building corals abundant; shallower than 20 m; no *Antipathes*.
11	7-3-74	West of Aulong Island (outside barrier reef)	7°16.5'N 134°15.0'E	10-70	*Antipathes* absent; outer slope vertical; gorgonians abundant; current weak--5 cm/sec; thermocline 55 m.
12	7-4-74	Off Ngeregong Island (outside barrier reef)	7°6.5'N 134°22.6'E	15-70	*Antipathes* absent; outer slope about 45°; gorgonians abundant; current 10 to 15 cm/sec.
13	7-4-74	Outside of Kreis Reef (outside barrier reef)	7°11.2'N 134°28.0'E	30-60	*Antipathes* absent; outer slope about 45°; gorgonians abundant; current weak--5 cm/sec.
14	6-30-74	Eastern exposed side of Augulpelu Reef (outside barrier reef)	7°15.3'N 134°32.4'E	15-75	*Antipathes dichotoma* present but rare; slope vertical beyond 30 m; current 15 cm/sec; gorgonians abundant; thermocline 65 m.

Figure 2. Collection of a colony of black coral (*A. dichotoma*) from the deck of a sunken Japanese ship, the *Amatsu*, at a depth of 25 m.

areas, there are rather major differences in growth form, abundance, and depth zonation (see Table 2). Inside the lagoon, *A. dichotoma* is considerably smaller and more sparsely branched and occurs shallower. The average basal diameter of the largest colonies measured at stations inside the lagoon ranged between 0.74 and 2.12 cm compared with 3.00 and 6.35 cm for colonies outside. Similar contrasts for the ranges of average heights of the largest colonies and population densities inside and outside the lagoon were as follows: for height, 1.34 to 1.93 m inside compared with 3 m outside and for density, 0.20 to 0.25 colonies/length reef (m) inside compared with 1.0 colonies/length reef (m) outside. The ratio of basal diameter to height of a colony is also a useful way to express the differences in growth form of colonies found inside and outside the lagoon. Typically, the basal diameter ratio for colonies outside the lagoon (0.015) is about 2.5 times the ratio for colonies inside (0.006), illustrating that more robust and heavily branched colonies occur outside the reef.

TABLE 2. SIZE AND DEPTH ZONATION OF *A. DICHOTOMA* FOUND AT STATIONS INSIDE AND OUTSIDE PALAU LAGOON

	Inside the Lagoon	Outside the Lagoon
Range of average basal diameter of largest colonies	0.74 - 2.12 cm	3.00 - 6.35 cm
Range of average height of largest colonies	1.34 - 1.93 m	up to 3 m
Density, colonies per length reef	0.20 - 0.25 m	1.0 m
Depth range	6 - 36 m	35 - 75 m

The cause for the differences in growth form of *A. dichotoma* between stations may be related to differences in current speed. For example, if the sizes of the largest colonies that have colonized on the two sunken Japanese vessels (stations 2 and 8) are compared and these should be of comparable age, at station 2 (West Malakal Pass) the height of the largest colonies are about twice (2.75 m compared with 1.34 m) the height of colonies found at station 8 (Urukthapel Bay). Station 2 is located near a pass while station 8 near the center of a large bay; therefore, currents can be expected to be much stronger at the former station. Estimates of the current at both stations on the days of the survey were 15 cm/sec and 5 cm/sec, respectively.

If the largest colonies now present on the ships settled soon after the ships sank (May 30, 1944) and if the pattern of growth is linear, the growth rate (obtained by dividing the average height of the largest of

colonies on the ship in West Malakal Pass by 29.5 years) is 9.32 cm (increase in height) per year. Using the same method, the growth rate for colonies on the ship in Urukthapel Bay was found to be 4.52 cm per year, about half the rate of growth of colonies in the West Malakal Pass. Differences in the growth rate may be related to differences in currents at the two stations. Interestingly enough, measurements of growth of *A. dichotoma* in Hawaii at a 52-m depth off Lahaina, Maui where currents are relatively strong (often greater than 50 cm/sec or 1 knot), give an average rate of linear increase in height of 6.37 cm per year, intermediate between the estimates in Palau.

Another factor which limits the size of black coral colonies is the probability of mortality caused by encrustation by other benthic invertebrates. Inside the lagoon, the number of larvae of all other benthic invertebrates is much greater than outside the lagoon where the water mass is more pelagic in character. Observations inside the lagoon indicate that mortality of *A. dichotoma* caused by encrustation is much more prevalent than outside the lagoon. Thus, absence of large colonies inside the lagoon may in part be due to a high rate of mortality there caused by encrustation.

Differences in depth zonation of *A. dichotoma* inside and outside the lagoon appear to be caused by differences in turbidity which affects the amount of light that reaches a particular depth. Studies of black coral species in Hawaii indicate that their larvae are negatively phototactic (Grigg, 1965). The water mass inside the lagoon is almost always more turbid than the water mass which bathes the outer reefs. This may account for the rather striking difference in depth zonation of *A. dichotoma* inside (6 to 36 m) versus outside (35 to over 75 m) the barrier reef.

Abundance

Inside the barrier reef, *A. dichotoma* is found only in areas where strong currents prevail such as within passes between rock islands and along reef drop-offs where flow due to tidal currents is strong. The difference between high and low tides in Palau is about 2.5 m. Currents are strongest between tidal extremes. The density in areas where tidal flow is strong is about 0.25 colonies per meter length of reef. Average colonies weigh about 1.0 kg. An estimate of the total standing crop of *A. dichotoma* inside the barrier reef can be obtained by multiplying these figures by the cumulative length of reef that can be considered as suitable habitat (about 15 km). This calculation produces a figure of 3,750 kg (about 8,000 lb). Most of the area considered to be suitable habitat lies within the rock islands south of Malakal Harbor. This area is extremely accessible to divers throughout the year.

Outside the barrier reef, a similar procedure was followed to estimate total standing crop. Observations at seven stations outside the barrier reef showed that *A. dichotoma* was present only in areas exposed to strong currents. For example, at Augulpelu Reef *A. dichotoma*

was abundant only at station 4, while at station 3 it was absent and at station 14, quite rare. Station 4 (see Figure 1) is situated at the southern tip of Augulpelu Reef and is exposed to strong east-to west-flowing currents. Stations 3 and 14 are located off straight reef drop-offs and appear to be less exposed to strong currents. *A. dichotoma* was absent at stations 11, 12, and 13 which, like stations 3 and 14, are not directly exposed to strong currents. Currents observed at stations 3, 11, 12, 13, and 14 did not exceed 15 cm/sec.

The largest colonies and the greatest density of *A. dichotoma* were found off Ngemelis drop-off (station 6). Several colonies were collected at this station and were later analyzed for gem quality by Maui Divers and the GIA. Larger colonies measured 3 m in length and often up to 6.0 cm in diameter at the base. The average population density of *A. dichotoma* at Ngemelis is about one colony per meter of reef length. Average colonies weighed about 2 kg.

Following the same procedure for estimating total standing crop as inside the barrier reef, the total reef length on the outside reef (4.5 km) judged to be suitable habitat was summed and multiplied by the figures for density and colony weight at Ngemelis, giving a total of 9,000 kg or almost 20,000 lb. Dives at stations 3, 4, 6, 11, 12, 13, and 14 showed that little of the outer barrier reef is suitable habitat. Only those areas at the mouth of major passes, such as the North, West, and East Entrances north of the island of Babelthuap and exposed points between the passes that lie between the major islands such as Angaur and Peleliu, were considered to be characterized by strong enough currents to support significant populations of *A. dichotoma* . Most of this area is situated north of Babelthuap or near the Kayangel Islands, all of which are relatively inaccessible to major population centers. All of these areas are also heavily infested with sharks.

Even if the estimates of the total standing crop of *A. dichotoma* outside the barrier reef were added to those inside the barrier reef, the total standing crop in Palau would still be only about 12,750 kg (28,000 lb). To put this figure in perspective, the amount of black coral processed annually in Hawaii is about 9,000 kg (almost 20,000 lb). It is clear that if an unregulated fishery were allowed to export black coral out of Palau that, in all likelihood, the resource would be rapidly depleted.

Estimates of natural mortality and average longevity of *A. dichotoma* in Hawaii indicate that natural recovery (recruitment and growth) annually amounts to about 10 percent of the standing crop. Assuming harvesting will pre-empt about half of natural mortality, about 5 percent of the standing crop can be harvested annually without depleting the population. If this value is used for Palau, only about 190 kg (400 lb) inside the barrier reef and 450 kg (1,000 lb) outside the barrier reef should be harvested annually. This amount of coral is sufficient to support a small industry within the Trust Territory but certainly is not large enough to support potential export demands.

The conclusions reached in this study in regard to the potential supply of black coral in Palau are generally supported by observations

made by a team of black coral divers from Hawaii including Jack Ackerman, Chris Johnson, Robert Cary, and Dale McGowan, who conducted an independent survey of black coral in Palau in the spring of 1974. Although they concluded that the black coral in Palau is too small and sparsely distributed to support a large industry, they did find scattered colonies at a number of locations that were up to 2 m in height and 2 cm in diameter. The results of their survey are summarized in Table 3.

TABLE 3. SURVEY OF BLACK CORAL IN PALAU*

Date	Location	Depth (m)	Observations
4-24-74	Augulpelu Reef	43-59	Scattered colonies 1 m in height and 2 cm in diameter
4-25-74	Ngemelis Reef	49-61	Scattered colonies 2 m in height and 2 cm in diameter
4-26-74	Ngemelis to Putyaur	52-59	Colonies 1 m in height and 1.25 cm average diameter
4-26-74	Ngurumkaal Channel	59	Colonies sparse and small
4-27-74	Shephan Reef	49-52	No black coral observed
4-27-74	Towacelmid Channel	40	Scattered colonies 1 m in height and 1.25 cm in diameter
4-27-74	Ngirikul Island	21	Sparse 1.25-cm diameter stock maximum
4-28-74	Ngchelobel Island	30	Sparse 1.25-cm diameter stock
4-29-74	Augulpelu Reef	55-61	No black coral sighted

*Conducted by Jack Ackerman, Chris Johnson, Robert Cary, and Dale McGowan

In contrast to the large colonies observed and collected at Augulpelu Reef and Ngemelis drop-off during the survey reported on here, it is surprising that the Ackerman group did not sight larger colonies. In any event, the very fact that a very small black coral enterprise already exists in Palau illustrates the industrial potential. If 640 kg of black coral were harvested annually, this would require the employment of several divers and about 20 jewelry fabricators. At the retail level, annual gross sales from this amount of coral would be about $140,000.

OTHER SPECIES OF COMMERCIAL POTENTIAL

The most valuable precious corals belong to the deep water family Corallidae. Takahashi (1942) reported that *Corallium* of good quality was discovered off the southern coast of Peleliu before World War II. He stated that there were problems associated with collecting but did not elaborate. In late October of 1973, a Japanese coral fishing vessel was seen inside of 12 miles off the coast of Palau and appeared to be dredging for coral. Authorities quickly confiscated the vessel and found a map and samples of freshly caught *Corallium*. Markings on the map indicated that the coral was collected between the islands of Peleliu and Angaur at approximately 6°57.00'N by 134°13.5'E at a depth of between 200 and 300 m. Examination of the coral revealed two species, one of high quality and one of average quality. These were tentatively identified as *C. elatius* and *C. konojoi*, respectively.

Several shallow water gorgonians in Palau appear to have a limited potential for jewelry and artifacts. Two scleraxonia of the family Melitodidae (identified as *Melitodes albitincta* and *Mopsella* sp. by Frederick M. Bayer) possess rigid calcarious skeletons hard enough and large enough to be fabricated into jewelry. Unfortunately, both are slightly porous and do not "take" a high polish and therefore are not as valuable as *Corallium* for fine jewelry. Nevertheless, they are currently used in Palau (by Obak, a jewelry manufacturer) for pendants and other artifacts. Both are red and have a rather attractive, primitive appearance. They are also used for making replicas of the famous Yapize stone money.

There is another species of black coral in Palau which resembles the fern black coral *Antipathes ulex* in Hawaii. This species has a hard skeleton (between 2 and 3 on the Mohs scale) and when polished has a high luster. The predominant color is black but numerous streaks of gold give it a very attractive pattern. Unfortunately, this species is too rare to be of much commercial significance.

CONCLUSIONS AND RECOMMENDATIONS

1. There is sufficient black coral of commercial quality in Palau in the Trust Territory of the Pacific Islands to support a small local precious coral industry (about $140,000 annually at the retail level). Because the abundance of the resource is limited and because growth rates are very slow, precautions should be taken to prevent the development of an export market. If this were to occur without control of the rate of harvest, a large fraction of the black coral resource would probably be depleted rapidly. A law prohibiting the exportation of black coral out of the Trust Territory should be passed. Also if the industry develops in Palau, the amount of black coral harvested annually should be controlled. About 640 kg (1400 lb) is recommended. If the Trust Territory does not become politically split, it would probably be more economical to centralize the manufacture and sales of black coral in Guam or Saipan.

2. A more thorough assessment of the black coral resource of other islands in all districts is recommended. For example, it is known to occur in Truk although the exact quantity is unknown. If black coral resources in other districts besides Palau were utilized, obviously a larger industry centrally located in Guam or Saipan could be supported.

3. In Palau, the distribution, abundance, and growth form of *A. dichotoma* inside the barrier reefs are different from outside. Inside the barrier reefs, *A. dichotoma* is smaller and more sparsely branched. Also it is shallower and less densely populated. Strong current appears to favor growth and settlement. Estimates of the growth rate of colonies growing on Japanese ships sunk in 1944 vary between 4.5 and 9.3 cm per year.

4. It is clear that the commercial value of *A. dichotoma* outside the barrier reef in Palau is higher than it is inside, primarily due to differences in size. However, harvesting black coral outside the barrier reefs is considerably more hazardous than it is inside. Divers must not only go much deeper and thereby risk bends, narcosis, and embolism, but they also are exposed to more and larger sharks outside the lagoon. For these reasons, the resources inside the lagoon would be a more practical source of material when and if a fishery is developed in Palau.

5. A training program to teach local divers the art of harvesting black coral and to teach artisans to fabricate jewelry should be established. A joint program with the jewelry industry located in Hawaii might best accomplish this.

6. An economic study of the potential market demand in the Trust Territory should be conducted.

7. Ecological studies of the growth, natural history, and impact of harvesting black coral should be concomitant with the development of an industry.

8. Certain areas in Palau which are characterized by particularly diverse and lush biota should be designated as marine preserves in which black coral harvesting should be disallowed. The area known as the Ngemelis drop-off is known internationally by divers as one of the most spectacularly beautiful reefs in the world. It is recommended that the District of Palau establish this area as its first marine preserve. This recommendation is of particular significance to the growing tourist and recreation industry in Palau since it has much greater economic potential than the precious coral industry.

9. Further exploration for *Corallium* should be conducted in Palau within the passes between the major islands at depths between 100 and 400 m.

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