2006 Black Coral Science and Management Workshop Report

April 18-19, 2006
Honolulu, Hawaii

Sponsored by:

Western Pacific Regional Fishery Management Council

Hawai'i DAR Division of Aquatic Resources

Cover Page: Diver utilizing SCUBA to harvest black coral circa 1970's
(photo by Rick Grigg)

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Prepared by the
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Executive Summary

A two day workshop (April 18-19, 2006) on the Hawaiian black coral fishery was hosted by the Western Pacific Fishery Management Council and the State of Hawaii's Division of Aquatic Resources. Frank Parrish served as facilitator for this workshop which was held to bring the mix of scientists, fishers, managers, industry and enforcement together to review the state of knowledge on Hawaiian black coral and identify objectives for the future.

The workshop was spurred by recent concerns about recruitment of black corals and infestation by *Carijoa* which have prompted increasing minimum size limits. The State of Hawaii is also showing interest in a wider range of options for management of the fishery.

The first day was dedicated to review the available science and this began with a historical overview of the fishery from Richard Grigg which was then followed with the findings of recent black coral surveys conducted by State aquatic biologist Tony Montgomery. Two scientists were flown in to present their black coral research. One was Brendan Roark from Stanford University who used radiometric methods to estimate the age of Hawaiian black coral trees and the other was Ken Grange from New Zealand who had conducted 7 years of manipulative black coral research in the fiords of the south island. Other data reviewed included available information on the harvest location and the catch of Hawaiian black coral. Sam Kahng from the University of Hawaii made a presentation that detailed the state of knowledge on *Carijoa risei* and made an appraisal of the risk to the Hawaiian black coral stock.

The second day had more of a management focus and began with Jerry Tanaka from Maui Divers Jewelry presenting on the current state of the Hawaiian black coral industry. This was followed by an overview of CITES (convention on international trade of endangered species) regulations and its relevance to the black coral trade presented by US Fish and Wildlife Service inspector Tony Palermo. A large portion of the workshop was spent in open discussion, much of centered on the insight contributed by the participating black coral divers. In total four black coral divers attended including Robin Lee, Henry Ah Sam, Calvin Wada and Mitchell Major. Gaps in knowledge were identified and research needs were prioritized.

Future research objectives identified included studies on growth, reproduction, recruitment, mortality, fishing, and invasive species. Research and management strategies discussed included area based management and replanting projects. Joint projects between researchers and black coral divers were discussed as a way to leverage resources. Included in this report are summaries of presentations given at the workshop, as well as recommendations for research and management of black coral resources.

Agenda

Black Coral Science and Management Workshop

April 18-19, 2006

0800a-0400p	**Day 1 – Science**
0800a	Introduction- Frank Parrish
0815a	Hawaii Black Coral Fishery History and Historical data – Rick Grigg Background and overview of the size frequency data
0900a	Recent State Surveys – Tony Montgomery Synthesis of early data size frequency data with current data.
0945-1000a	*Coffee Break*
1000a	Radiometric aging of Auau black coral – Brendan Roark
1045a	Growth of tagged Black corals in New Zealand – Ken Grange
1130a	Findings from tagged Hawaiian colonies – T. Montgomery
1200n-0100p	*Lunch*
0100p	Impacts of Carijoa on the Hawaii black coral stock and habitat – Sam Kahng
0145p	Spatial distribution of fishing/survey effort – T. Montgomery
0215p	Fishery landings - F. Parrish
0230p	Open discussion – Identification of trends in data
0400p	*Meeting adjourned*

0800a-0400p **Day 2 – Management objectives**

0800a	Maui Divers overview/challenges of the precious coral industry- Jerry Tanaka
0830a	Interpretation of deep sea coral CITES regulations by enforcement – Tony Palermo
0900a	Federal black coral responsibilities – Joshua DeMello
0930a	State Draft Regulations – T. Montgomery
1000 – 1015a	*Coffee Break*
1015a	Recommendation discussion topics
1100a	Resolve base diameter versus height issues.
1200-0100p	*Lunch*
0100p	Merits of changing size limits
0200p	Merits of establishing an MPA/or biological reference area
0230p	Better growth, reproduction and recruitment data
0300p	Merits of improved reporting
0330p	Write Draft recommendations of workshop
0400p	*Meeting Adjourned*

Presentations

Science and Research

History of the black coral fishery in Hawaii – 2006

Richard W. Grigg
University of Hawaii

Two species of commercially valuable black coral, *Antipathes dichotoma* and *A. grandis*, were discovered in 1958 off Lahaina, Maui by Jack Ackerman and Larry Windley (Grigg, 1993). Subsequent development of the resource by these two pioneer divers led to the formation of a small black coral cottage industry based on the manufacture of black coral jewelry. This operation steadily grew over the years to later become Maui Divers of Hawaii, Ltd. Today, Maui Divers is the largest black coral jewelry manufacturer in the State of Hawaii, generating approximately 70 million dollars in annual sales at the retail level. Approximately a dozen other smaller firms also manufacture and currently sell black coral jewelry in Hawaii.

Until recently, the black coral fishery has been well managed since its inception. Research carried out at the University of Hawaii for over four decades (1962-2004) with primary support from the National Sea Grant Program and the Hawaii Undersea Research Laboratory led to a management plan prepared by the Western Pacific Regional Fisheries Management Council (WestPac). Estimates of maximum sustained yield (MSY) were calculated for black coral beds off Maui and Kauai and a size limit of 48 inches (height) was recommended for both species. These guidelines were part of the Federal Precious Coral Fishery Management Plan

(FMP) published in 1981, representing the first FMP published by WestPac.

The black coral fishery in Hawaii continued to operate on a sustainable basis for over 40 years (Grigg, 2001). Results of a survey of the bed off Maui in 1998 showed that rates of recruitment and growth were near steady state, and appeared to account for the long-term stability of the fishery.

Unfortunately, two recent changes in harvesting pressure and the introduction of an alien pest species Carijoa riisei, appear to threaten the future stability of the fishery. Although harvesting rates have remained below estimates of MSY, they have increased somewhat in the last 10 years (Tony Montgomery, Personal Communication, DLNR). Also, *Carijoa riisei* has been discovered overgrowing large areas of the substratum, as well as, many adult colonies of both species of black coral at depths of 70-100 meters in the Au'au Channel, off Maui. This invasion may be contributing to a decrease in recruitment in recent years (Grigg, 2004). Taken together, these changes suggest a need for more stringent regulations including strict adherence to the 48 inch size limit, a possible reduction in the MSY and perhaps the creation of marine protected areas (MPA's) within the Au'au Channel bed.

In response to these developments, the Precious Coral Planning Team of WestPac is presently considering a number of new management guidelines, as well as, several new research initiatives designed to monitor recruitment, evaluate restoration (transplantation) and possible closure of certain selected areas to all black coral harvesting in the Maui Bed.

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Photos by Rick Grigg

Draft report on the current status of black coral in the Auau Channel

Tony Montgomery
Aquatic Biologist
Division of Aquatic Resources
Department of Land and Natural Resources

Introduction

This report analyzes data collected in 2004 and draws conclusions about the current status of the black coral population in the Auau Channel located between Maui and Lanai. DAR conducted a series of surveys in the fall of 2004. The main focus of this document is to compare current data with historical data on the Auau Channel black coral population. This approach is aimed at giving insight into any potential changes that have occurred in the population.

Historical Data – 1975, 1998, 2001, and 2005

Historical data from the black coral population in the Auau Channel has been collected (1975, 1998, and 2001) and published by Grigg (Grigg, 1976; Grigg, 2001, and Grigg, 2004). This represents the majority of data from the Auau Channel population. Grigg's studies concentrated on using age frequency distributions created by measuring the height of individual colonies (by divers in 1975 and 1998 and by submersible in 2001) and converting the height into estimated age. Grigg used age frequency distributions to calculate the slopes of linear regressions of log-transformed abundance data versus age to determine an estimate of mortality rate.

Grigg's 1998 surveys provided data that appear to show the fishery was sustainable. Grigg concluded, when comparing the 1975 data to the 1998 data, that the larger, older colonies had been reduced in the population but that recruitment and overall mortality had been relatively stable since the 1975 survey. It was suggested that the fishery was sustainable due to voluntary compliance by fisherman to a suggested harvest size of 48 inches (1.2 meters) height (estimated 19 years old), and because there was an unfished deeper population of black coral (Grigg, 2001) which provided a breeding stock reservoir. Figure 1 shows the age distributions for Grigg's datasets.

Grigg's 2001 surveys showed further changes in the population structure since 1998, including a continued decline in the larger, older age classes and a recent decrease in the proportion of corals in age classes under 5. The population structure was dominated by intermediate age classes. The continued decline in larger, older ages was attributed to fishing. However, the cause of the decline in younger age classes was attributed to some combination of: (1) harvesting; and (2) overgrowth of black coral by the invasive soft coral, *Carijoa riisei*, in the deeper (unfished) population. Grigg uggested the future sustainability of the fishery might be in jeopardy unless more restrictive regulations are put in place (Grigg, 2004).

Although the results of Grigg's 2001 survey (Grigg, 2004) show dramatic differences with earlier populations, there is reason to suspect differences in survey methodology between 2001 and previous surveys could account, at least in part, for the apparent low level of recruitment evident in Grigg's 2001 surveys. Since there is a call to action to increase regulations, the Division of Aquatic Resources needed to gather more data to verify the current status of the population.

Most recently, Kahng and Grigg (2005) reported on the impact *Carijoa riisei* has had on black coral in the Auau Channel. They reported the greatest impact to colonies deeper than 80 meters and greater than 75 cm in height, which represents the estimated size of maturity. They also report an increase in black coral colony infestation between 2001 and 2004 (~65% and 90% respectively). This may indicate that the entire (or almost entire) mature population below 80 meters may be lost with time. This could effectively remove the breeding stock reservoir proposed by Grigg.

Current Data

Methodology

In order to directly compare newly collected age frequency distribution data with historical age frequency distribution data, the same methods employed by Grigg in 1975 and 1998 were used by DAR in the 2004 surveys. The height of all black coral colonies was taken by measuring colonies with a 1.2-meter rod and recorded on an underwater data sheet. The height was defined as the longest continuous branch of the colony regardless of the direction of growth. The height was then converted into age by dividing the height by the reported species-specific growth rate (Antipathes dichotoma = 6.42 cm/year and A. grandis = 6.12 cm/year). The current dataset (2004) contains 1421 samples (both species combined) from depths of 30 to 65 meters; however, samples from depths of 45 to 55 meters were pooled to generate the data in Figure 2 in order to make a better comparison with historical data (which were collected in the 45 to 55 meter isobath).

Following the approach of Grigg (1976, 2001), changes in regression slopes through time are used to indicate changes in mortality rate and therefore to assess whether there is support or not for the idea that population structure has changed through time.

This analysis will address the following questions:

1) Have there been changes in the age structure across all ages?
2) Are there differences in post-harvest age structure (>14 years)?
3) Are there differences in pre-harvest age structure (<14 years)?
4) Has recruitment in younger ages classes diminished?

Age structure across all ages:

Visual (qualitative) analysis of the age frequency distributions (Figure 2) suggests two changes in the population: (1) a continuing decline in the proportion of larger, older colonies - those above about age 19 and (2) fewer corals in age classes less than 9 years in the 2004 dataset. These analyses are only qualitative, so there is a need for more quantitative analysis to verify these qualitative observations.

Figure 3 shows the regression of the 1975, 1998, and 2004 data and suggests that there have been changes in the population. However, it is difficult to determine what changes have taken place, as a presumption of a common mortality rate across all age classes is simplistic particularly for a harvested population. It seems logical to break the data into pre-harvest and post-harvest age groups and separately estimate mortality within those ranges. The current minimum size for harvesting is ¾" base diameter (~ 14 years); therefore, the following analysis is for 'pre-harvest' age classes (<14 years old) and 'post-harvest' age classes (>14 years old).

Post-harvest age structure:

If the post-harvest age classes have declined in comparison to historical populations, a higher mortality rate across the post-harvest age range would be expected. Figure 4 shows a trend of increasing mortality rate as the post-harvest mortality rate increased from 1975 to 1998 and then again in 2004. Since there were no observed colonies infested with *Carijoa riisei*, an increasing mortality rate suggests that the harvestable age classes are increasing being affected by fishing. The mortality rate between 1975 and 1998 only increased slightly: from 17.3% to 19.7%, but by 2004 the mortality rate of harvestable age classes had increased to 30.9%.

Pre-harvest age structure:

Age frequency distribution in pre-harvest age classes is worth examining as it may show changes in relative recruitment. An assumption of the regression technique used to calculate IRM is that recruitment is constant among years and declines in age class frequencies as age increases are a reflection of real mortality rates. If that assumption is violated more than mildly, the calculated mortality rate will not be realistic. As a corollary of that, an unrealistic mortality rate may indicate the steady state recruitment assumption has been violated.

The regression analysis of pre-harvest age classes in the 1975, 1998 and 2004 datasets suggests there was minimal if any change in the recruitment between 1975 and 1998 (same conclusion as in Grigg, 2001). However, the estimated mortality for 2004 was almost 0 (a flat slope). An assumption of zero mortality is not realistic based on historical datasets, especially in young age classes; a more likely explanation would be that recruitment into the early age classes has decreased during the period between about 1998 and 2004. The regression is shown in Figure 6. This suggests variability in age class abundance for the 2004 regression. The short period of low recruitment in 1975 (ages 3 to 5) may contribute to its lower r^2 value. It is difficult to know how significant this apparent period of low recruitment – 1998 to 2004 – is, since low numbers of corals in age classes 3 to 5 in the 1975 dataset indicates that a few years of low recruitment is not unprecedented. Nevertheless an apparently sustained period of low recruitment is a matter of some concern.

Grigg (2004) suggested the age frequency distribution measured in 2001 showed signs of diminished recruitment in age classes under 5. Age distribution data collected in 2004 suggests diminished recruitment in age classes under 9 (somewhere between 5 to 9 years). If each of these datasets were back calculated to the time period of possible recruitment slow down, they both tend to suggest a similar timing of the onset of low recruitment (mid-late 1990s). It therefore seems reasonable to assume that a wide-scale slow down in recruitment occurred in the mid-late 1990s.

Colonies-counted per unit of time:

Another way to analyze changes in the population is to calculate the number of measured individuals per unit of time or area. Area-surveyed was not measured on these or previous surveys, but survey time was closely watched and close to fully utilized (due to safety reasons for calculating decompression). Number of colonies recorded per unit of survey time may therefore be a useful indicator of coral density in various age class categories (<9, 9-14, 14-19, and >19).

Analyzing this data (Figure 6) for age classes under 9 suggests that there are fewer individuals under age 9 in 2004 as in previous years (1975 and 1998). Also, note that the number of individuals in age classes 9 to 14 is approximately the same in all survey periods. Age classes 9 to 14 would be expected to remain similar over time as they are not subjected to harvesting pressure and are older than the age classes seemingly affected by diminished recruitment (in other words, they provide a sort of test of this analytical approach). Age classes 14 to 19 seem to be approximately equally abundant in all survey periods too. However, the age classes above age 19 have clearly decreased since 1975 and 1998.

Figure 6 shows that in 2004 there were fewer colonies under age 9, almost the same number of individuals between ages 9 to 14 and 14 to 19, and fewer colonies over age 19 when compared to previous surveys. This is not an exact method to estimate the population structure changes, but does coincide with the regression analysis. This analysis is valuable as the different analytical approaches suggest similar changes in population structures.

Conclusions

1) Age structure for all ages has changed between 1975 and 2004 as shown by an increased mortality rate (from 10.2% to 15.9%).

2) Post-harvest age structure has significantly changed with an increase in mortality rate (particularly between 1998 and 2004) and fewer large colonies. The cause is believed to be from fishing pressure (1975=17.3%, 1998=19.7%, and 2004=30.9%).

3) Pre-harvest age structure has also changed by having fewer recruit and juveniles in the populations presumably indicating a drop in recruitment. The cause of this is unknown but may be a combination of fishing, Carijoa infestation and natural slow down in recruitment.

4) Analysis using colonies counted per minute of dive time support the conclusions made for changes in the population structure for pre and post-harvest sages.

5) Analysis of the 2004 surveys seems to support Grigg's conclusion of diminished recruitment. The reduction of older age classes is most likely due to harvesting, as surveys detected very little Carijoa (and zero deaths were attributed to Carijoa). However, the cause of diminished recruitment is much more uncertain. We do not have a sound understanding of the reproductive input supplied by the deeper population of black coral (the portion being mostly effected by Carijoa), and we do know that harvesting has

impacted the larger colonies in depths that Carijoa has not impacted directly. The most likely cause of diminished recruitment is a combination of Carijoa impacts and harvesting, but also recognizing the possibility that natural fluctuation in recruitment may be a factor. We may never know the cause, but it seems like the phenomenon is real.

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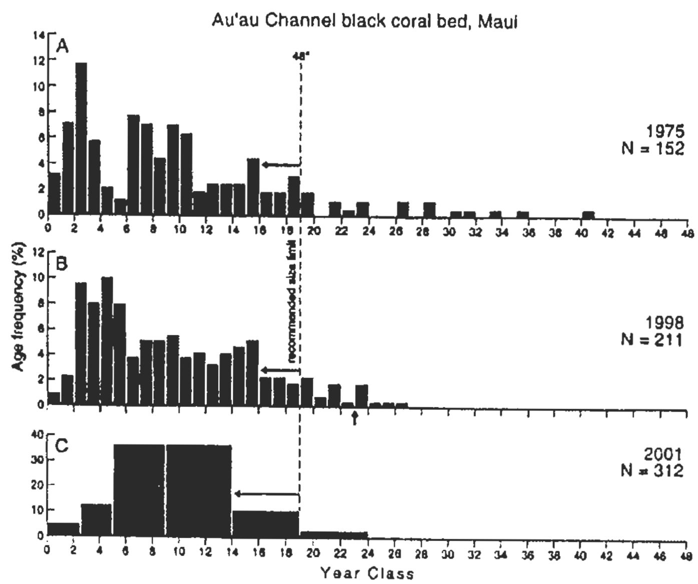


Figure 1.

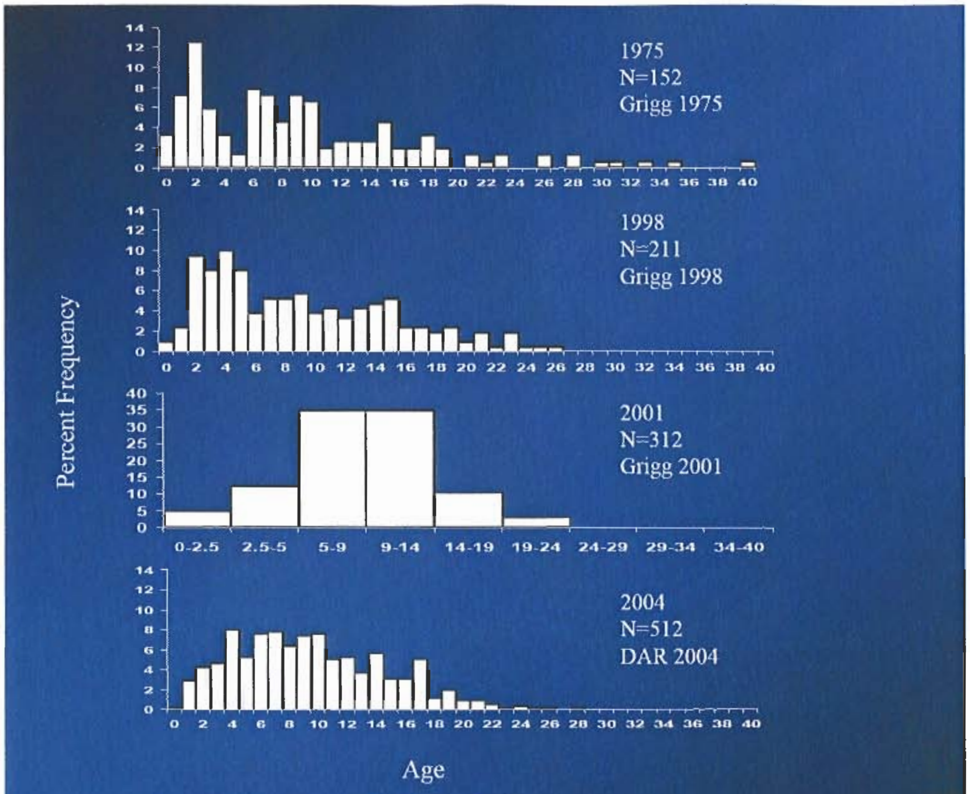
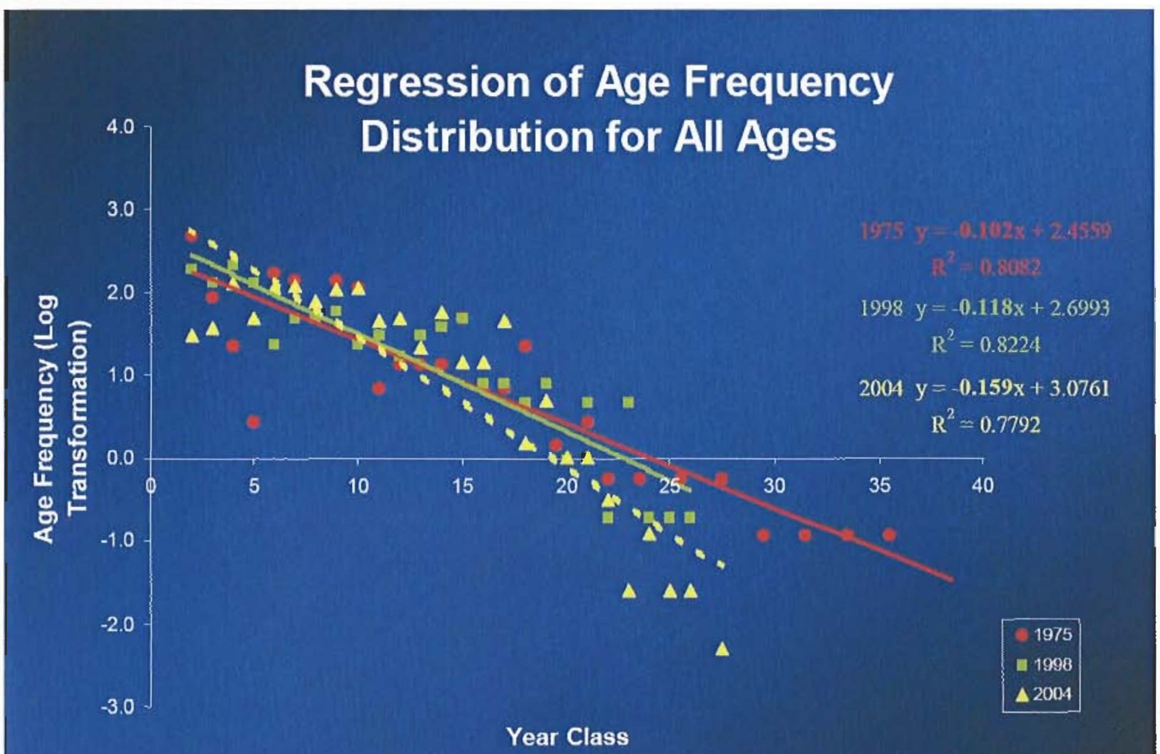


Figure 2.



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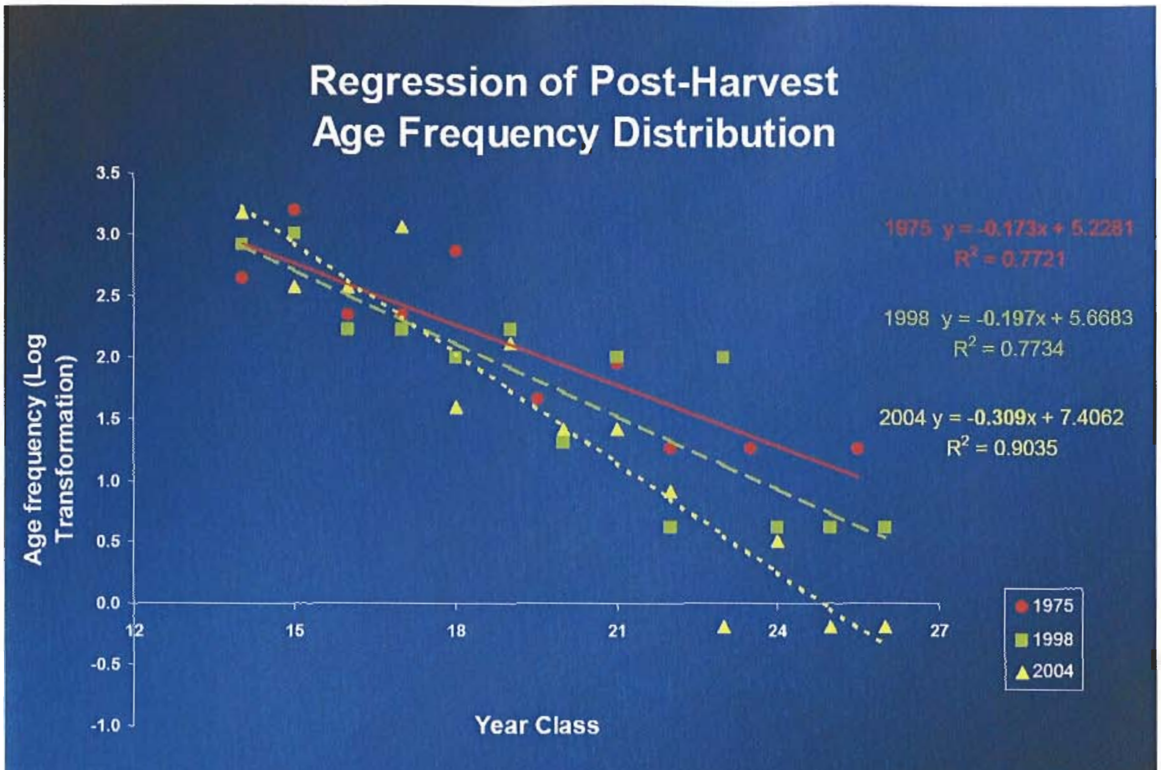

Figure 4.

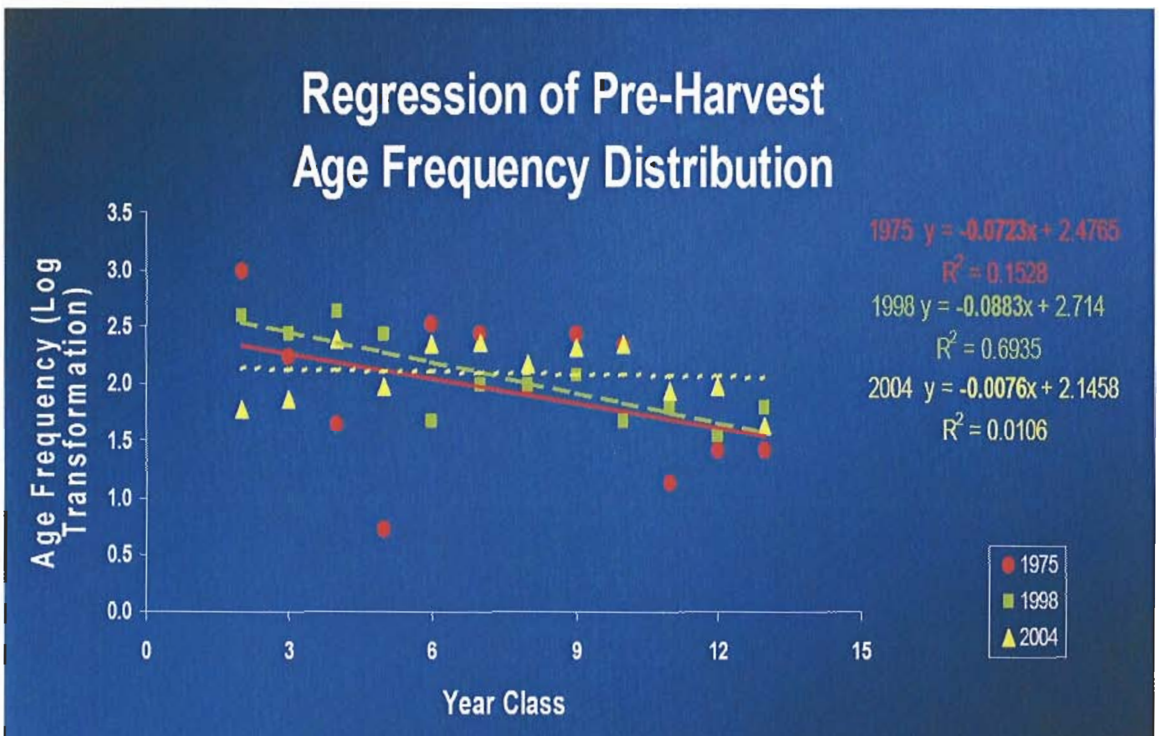

Figure 5.

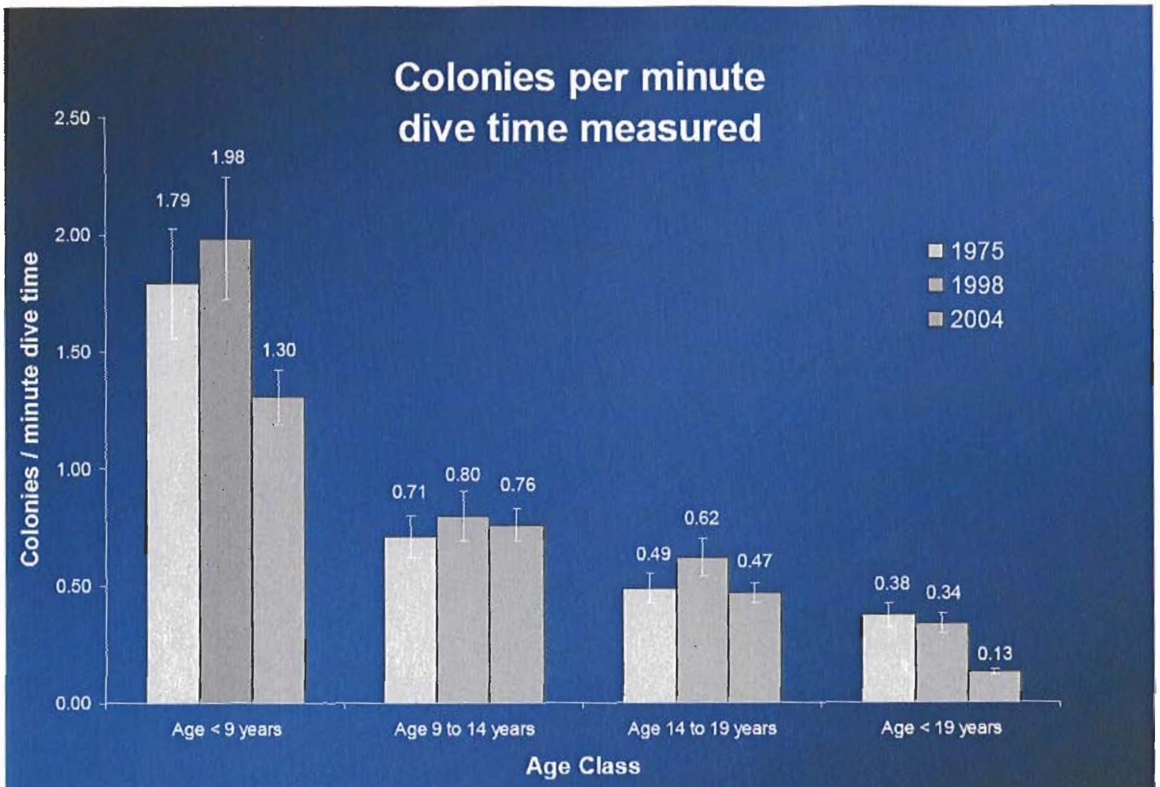
Colonies per minute
dive time measured
Colonies / minute dive time
2.50
2.00
1.50
1.00
0.50
0.00
1.79
1.98
1.30
0.71
0.80
0.76
0.49
0.62
0.47
0.38
0.34
0.13
1975
1998
2004
Age < 9 years
Age 9 to 14 years
Age 14 to 19 years
Age < 19 years
Age Class

Figure 6.

Radiocarbon dating of the black corals *Antipathes dichotoma* and *Leiopathes glaberrima*

E. Brendan Roark[1*], Thomas P. Guilderson[2,3], Robert B. Dunbar[1]

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The ages and growth rates of the black corals, *Antipathes dichotoma,* collected at 50 m, were significantly different from the age and growth rate of a "deep-water" black coral, *Leiopathes glaberrima,* collected at 450 ± 40 m. Only the *L. glaberrima* is known to have been alive at the time of collection. Radiocarbon measurements done on radial transect (0.5-0.6 mm intervals) across one of the *A. dichotoma* specimens (BC3) shows decreasing bomb carbon values over the outer 4.5 mm, after which the $\Delta^{14}C$ values did not change (Fig. 1). The date (1957) that the increase in bomb carbon began can be determined by comparison to a surface coral $\Delta^{14}C$ time-series (Guilderson and Schrag, unpublished data; Fig. 2). While all the *A. dichotoma* samples were alive at the time of collection, the exact year in which they were collected is unknown, thus the year of collection ("death") must also be estimated from the surface coral $\Delta^{14}C$ time-series. In the case of sample BC3, the outermost value (106.5 ± 4.3 ‰) is equivalent to an age of ~1965 or ~1992 in the surface coral $\Delta^{14}C$ time-series (Fig. 2). A linear interpolation between the increase in bomb ^{14}C at 4.5 mm and the outermost edge (1957 - 1992 = 35 years) gives a growth rate of 130 μm y^{-1} which, if assumed to be constant over the entire growth of the specimen, suggests that the sample is ~105 years old. Alternatively, a growth rate of 560 μm y^{-1} and an age of 25 years is calculated if the coral died in 1965.

Inner and outer $\Delta^{14}C$ measurements on two other *Antipathes dichotoma* samples (BC1 and BC2) collected at 50 m were all above –50 ‰ and thus incorporated bomb ^{14}C. Comparing these bomb ^{14}C values to the surface coral $\Delta^{14}C$ time-series the shortest and longest lifespan (growth rate) possible for BC1 is ~ 15-32 years (390-180 μm y^{-1}) and the lifespan (growth rate) of BC2 is ~12-29 years (1,140-470 μm y^{-1}) (Fig. 2).

Using tagged colonies of *Antipathes dichotoma*, a liner growth rate of 6.42 cm y^{-1} was measured over a 3.5 year time span (Grigg 1976). In the same study, the height of *A. dichotoma* was also correlated to the assumed annual growth rings (Grigg 1976). Using the linear growth rate on samples whose height was known, we estimate the age of sample BC1 to be ~12 years old and sample BC2 to be 20 years old. Using the linear relationship between height and growth rings y^{-1}, BC1 and BC2 were estimated to be 15 and 25 years old, respectively. These results are in agreement with the younger and thus faster radial growth estimates using bomb ^{14}C.

The $\Delta^{14}C$ values along the radial transect of the *Leiopathes glaberrima* collected at ~450 m (BC5) decreased gradually from a pre-bomb $\Delta^{14}C$ value of -69.2 ± 4.1 ‰ at the outer edge to a value of -280.7 ± 2.9 ‰ (2600 ± 35 ^{14}C years) at the center (Fig. 1). To convert the ^{14}C age to a calendar age, a reservoir age correction must be applied. The reservoir age is a result of the depletion in the radiocarbon content of surface waters brought about by the mixing of surface waters equilibrated with the atmosphere with older water from subsurface depths. This makes surface waters appear older than the atmosphere. Typically, the "reservoir age" is calculated by assuming a global average value of 404 ^{14}C years and adding a regional reservoir correction (or ΔR value). Using a ΔR of –28 ± 4 ^{14}C years (Druffel et al. 2001), a calibrated age of 2320 ± 15 cal yr. BP at the center was calculated for the central portion of the sample using the CALIB 5.0 (Stuiver & Reimer 1993) program and the marine04 calibration dataset (Hughen et al. 2004). Since the present is defined as 1950 in the calibrated age it is also necessary to add 47 years (1997-1950=47) to the calibrated age. With a life span of ~2377 years and a growth rate of ~5 μm y^{-1}, this organism is extremely long-lived and slow growing. However, the growth rate is not constant, with faster growth occurring when the sample was younger (Fig. 1).

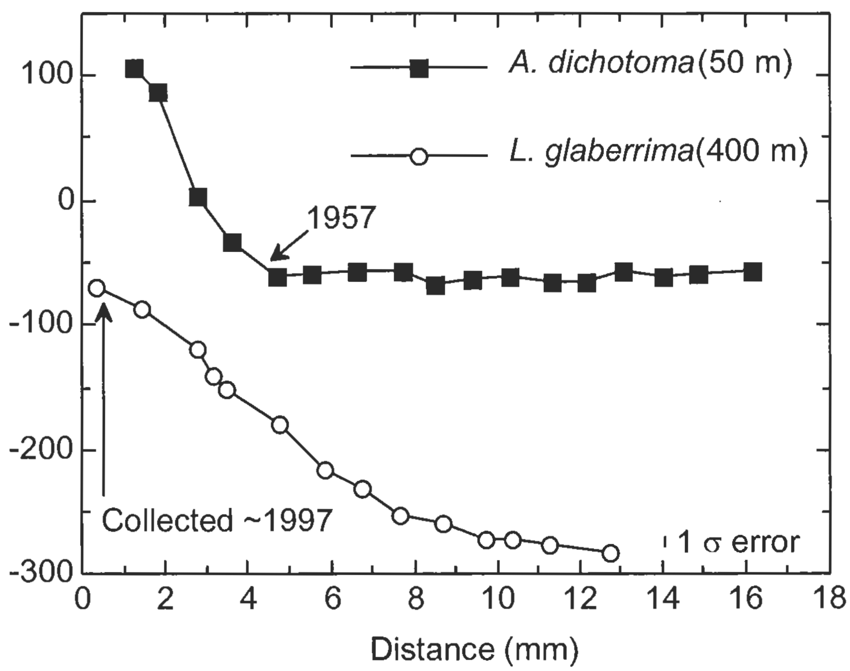

Figure 1: $\Delta^{14}C$ radial transect across a *Antipathes dichotoma* (sample BC#3, closed squares) collected at 50 m and a *Leiopathes glaberrima* (sample BC#5, open circles) collected at 400 m. $\Delta^{14}C$ values > -50 ‰ are indicative of bomb ^{14}C and can be used to set an initial time marker of 1957 for sample BC#3.

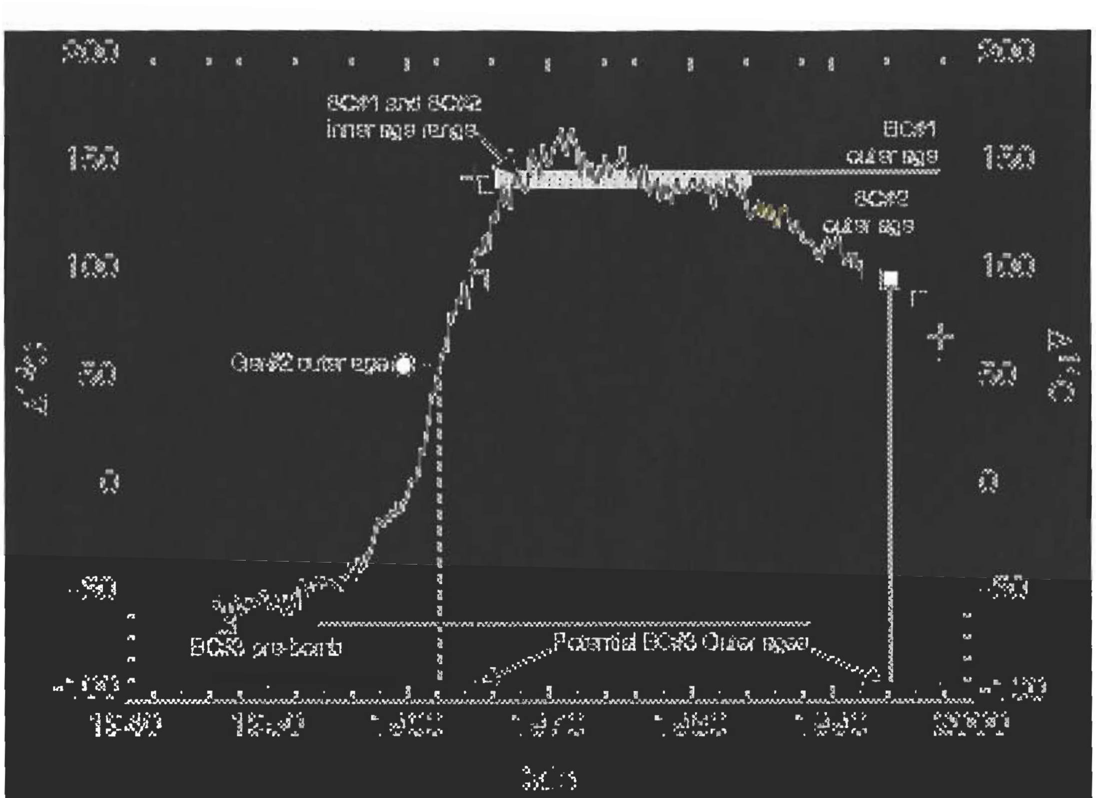

Figure 2: $\Delta^{14}C$ time-series in a surface coral (solid line) from the island of Hawaii (Guilderson and Schrag, unpublished data).

Inner and outer $\Delta^{14}C$ values of *Antipathes dichotoma* (BC#1, BC#2, and BC#3) and the outer value of a *Gerardia* sp. sample (GER#2) are plotted so that calendar dates may be estimated. Where the DSC $\Delta^{14}C$ value is equal to the surface coral $\Delta^{14}C$ value an age can be estimate. Uncertainties in this method exist when the surface water ^{14}C is not changing quickly, resulting in large age estimate (e.g. inner BC#1 and BC#2 age range) and where one $\Delta^{14}C$ value can be associated with two time markers (e.g. outer BC#3 age). The pre-bomb $\Delta^{14}C$ values of BC#3 where assigned an age of 1957 (see figure 5). The outer age (1962) of GER#2 was used to determine the age and growth rate of the sample in figure 7.

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Ecology, growth rates, and population structure of New Zealand black corals

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Nelson, New Zealand

The fiords of south-western New Zealand, through a unique set of environmental conditions, are more like habitats found on deep reefs or the continental shelf. These habitats support a variety of unusual species associations, including a large population of black coral, *Antipathes fiordensis*, which occurs as shallow as 6 m. This accessible population has provided an unparalleled opportunity to understand the ecology and biology of these black corals. Although a different species to those harvested in Hawaii, it is hoped that some of the basic biology of the NZ species, such as growth rates, reproductive biology, and population structure could be relevant to sustainable management of the Hawaiian species.

Growth rates

Growth rates have been estimated using a variety of methods, including:

- X-radiography to show the growth rings;
- Monitoring of tagged colonies for 7 years;
- Monitoring recruitment and mortality at various sites and colony size;
- Autoradiography to mark individual growth rings.

X-radiography, assuming the growth rings were annual, provided growth rates of less than 30 mm/yr, with constant growth for at least 120 rings (years). The growth rates of tagged colonies did not differ significantly among sites or size classes, and gave a mean growth rate of 24 mm/yr, with considerable variability among individual colonies. Labelling living branches using ^{14}C proteins and subsequent autoradiography to measure the growth since incubation provided growth-rate estimates of 16 mm/yr. Autoradiography also showed that not all growth rings are laid down annually, but their periodicity across a colony (or branch) roughly equates to annual deposition.

Growth rates in the New Zealand species is, therefore, less than half that recorded for Hawaiian species.

Recruitment and mortality

Recruitment and mortality were estimated by marking off an area of rock-wall in which every colony was tagged and mapped and examined every 6 months for 7 years. Sizes were measured, any mortalities recorded, and any new recruits also tagged and mapped.

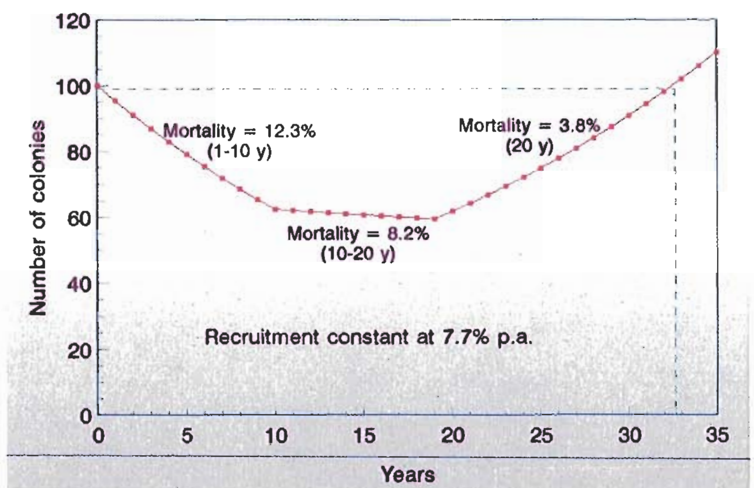
Recruitment was highly variable among years, with no recruitment recorded within the area on 4 of the 7 years. Mean recruitment was 7.7% per annum over the 7 years.

There was a significant difference in mortality of different size classes of colonies:

- Only 50% of new recruits survived their first year, with only 30% surviving their second year;
- On average, 0-10 year-old colonies suffered 12.3% mortality;
- 10-20 year-old colonies, 8.2% mortality; and
- Colonies over 20 years old had low (3.8%) mortality.

Population structure

The population is dominated by colonies less than 300 mm tall, although colonies over 2 m tall are not uncommon. Given the range of growth-rate estimates, most of the population (those < 300 mm) will be 10-18 years old, while the largest colonies would be over 150 years old. Given the high mortality in young colonies, and the low, but variable, recruitment, a simple model indicates that assuming an initial population of 100 colonies, each recruit, on average, must survive for over 30 years for the population to remain stable.



Reproduction

Antipathes fiordensis has separate male and female colonies, with a sex ratio close to 1:1. The difference between sexes is apparent only during mid to late summer, when the male polyps appear milky white and the female polyps orange. Spawning occurs in late summer, potentially associated with a full moon. Colonies become sexually mature and first spawn at around 1 m in height. Sexual maturity therefore corresponds to a colony age of approximately 30-60 years, and full reproductive output is not reached until a colony height of > 2.5 m, or 80-160 years old.

Summary

For *Antipathes fiordensis*:

- Growth rates are slow (16-30 mm/yr) or 2-4 times slower than Hawaiian species.
- Most of the population is comprised of small colonies than may be sexually immature.
- Recruitment is variable.
- Mortality is high for the first 10 years.

On average, each new recruit must survive for over 30 years to maintain the population, yet reproduction does not occur until the colonies are over 50 years old.
The population is therefore maintained by the relatively few very large, old, colonies that have low mortality and high reproductive output. Despite the large population in the New Zealand fiords, it is unlikely that it could sustain a commercial harvest.

The New Zealand results emphasise the role of large, old, black coral colonies in maintaining the population. Any process that reduces recruitment or reproductive output of these large colonies may have serious consequences for the population. The relevance of this is obvious with the current potential effects of the invasive *Carijoa* in Hawaii, and leads support for a no-take protected area to maintain a portion of the reproductive population.

Black coral growth (2006)

Tony Montgomery
Aquatic Biologist
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Department of Land and Natural Resources
State of Hawaii

In 2003 and 2004, 39 black coral colonies were tagged on Oahu (9 total) and Maui (30 total). These colonies were measured using height as an indicator for growth. During this time period, some colonies did not show any liner growth in height, while others showed significant growth (Table 1).

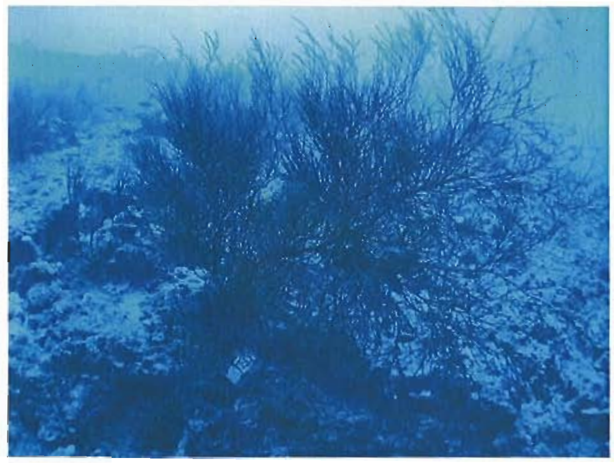


Photo by Tony Montgomery

Table 1

Site	Oahu	Maui – Stone Walls	Maui - Pinnacle	Maui – Grigg 1976
N	9	20	10	16
Time monitored	31 months	12 months	12 months	42 months
Growth rate (cm/year)	4.78 – 5.52	4.0 – 11.6	7.56	6.42
Size range (cm)	12-59	53-138	26-100	30-125
Portion not showing growth	11%	45%	0%	0% (not verified)

Conclusions:

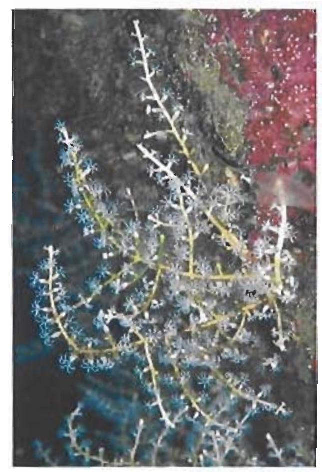
1) Colonies tagged similar in size to Grigg 1976.
2) Growth rates ranged from 5.12 to 8.35 cm/year averaging approximately 6.74 cm/year.
3) Given the timeframe of this study, these growth rates do not vary significantly from Grigg 1976 -- 6.42 cm/year compared to 6.74 cm/year.
4) Growth seems highly variable; however, this isn't a surprise.
5) Although environmental factors may affect growth, these average growth rates may have a resemblance of the population as a whole. However, more time and work is required to monitor growth.

The ecological impact of an alien octocoral on Hawaii's deep reef community

Sam Kahng
University of Hawaii

Introduction

Commonly called snowflake coral, *Carijoa riisei* (Duchassaing & Michelotti, 1860) is an azooxanthellate, skiophilous (shade-loving), shallow-water octocoral (Order Alcyonacea, Family Clavulariidae) originally described from the tropical Western Atlantic and Caribbean [1]. Since its initial discovery on the island of Oahu in 1966 (J. Earle, pers. comm.), *C. riisei* has spread throughout the main Hawaiian Islands [2-4]. *C. riisei* grows quickly and is a passive filter feeder commonly found within the fouling community in harbors [1, 5]. In Hawaii, it was previously thought to be a relatively benign introduction occupying underutilized habitat [4]. However, recent research demonstrates this is no longer the case. In 2001, a survey of the deep reef in the Au'au Channel using the Hawaii Undersea Research Laboratory (HURL) *Pisces V* submersible and *RCV-125* remotely operated vehicle (ROV) showed that a significant number of dead black coral colonies were overgrown with *C. riisei* below 70 meters [6, 7]. As a result of this discovery, a research program at the University of Hawaii was launched to assess *C. riisei's* ecological impact on Hawaii's coral reef ecosystem and investigate the reasons for its ecological success.



Biogeography of *Carijoa riisei*

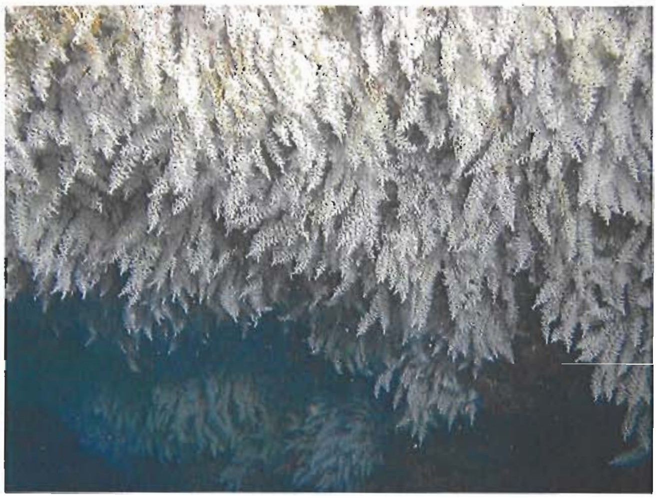
The distribution of *C. riisei* in the Caribbean/Atlantic is widespread [1]. In the Indo-Pacific, the biogeography of *C. riisei* as a species is unclear but the genus *Carijoa* is widespread. The taxonomy of *Carijoa* and many other genera of Indo-Pacific alcyonacean octocorals are unresolved to the species level [8]. Populations of *Carijoa* are known from tropical locations in the Indian Ocean, Red Sea, Persian Gulf, western Pacific, and the far eastern Pacific [4, 8-10] (P. Alderslade, H. Benayahu, G. Paulay, J. Sanchez, pers. comm.). Based on morphology, most specimens appear indistinguishable from *C. riisei* in Hawaii. Without a proper historical baseline of comparison for many of these locations, it is not known whether these populations are *C. riisei*, whether they are native, and/or whether they represent modern biological invasions.

Dispersal history in Hawaii

Based on the chronology of initial reports by location, it appears that *C. riisei* quickly spread to all sides of Oahu by the late 1970's and to Maui and Big Island during the 1980's. Recent surveys suggest that *C. riisei* has only recently colonized Kauai and is in an early stage of population growth there. *C. riisei* has yet to be reported from any of the Northwest Hawaiian Islands [4]. Both hull fouling and ship ballast water have been implicated as likely vectors of transport of *C. riisei* to Hawaii [11]. *C. riisei's* abundance in almost every major boat harbor in

Hawaii (except Nawiliwili Harbor in Kauai) suggests that maritime vectors may have also contributed to its inter-island dispersal.

Genetic analysis of mtDNA markers indicates that *C. riisei* in Hawaii was not introduced from the Caribbean/Atlantic but was probably introduced multiple times from locations in the Indo-Pacific. An Indo-Pacific origin is supported by the association of *C. riisei* with a specialized nudibranch predator (*Phyllodesmium poindimiei*) exclusive to the Indo-Pacific (B. Rudman, pers. comm.). The mtDNA haplotype frequency distribution within Hawaii suggests that the local population is not in genetic equilibrium. This status is consistent with an unusually slow rate of mutation in the mtDNA of cnidarians [12] and/or modern introductions to multiple locations within Hawaii. Evidence also suggests that there may be more than one species of *Carijoa* present in Hawaii.



Impact on the deep reef

Prior to 1983, *C. riisei* was unknown to the Au'au Channel. Now it is a common sight under ledges and large coral heads above 60 meters were it appears to be restricted to the shade. Below 60-70 meters, light attenuates to less than 10-15% of surface intensity and *C. riisei* proliferates on exposed substrata, scleractinian plate corals (*Leptoseris* spp.), and black coral colonies. *C. riisei* is not observed below 120 meters which coincides with the seasonal thermocline where temperatures quickly drop 3-4 degrees.

In 2001-2004, surveys of the Au'au Channel showed that over 50% of black coral colonies were overgrown with *C. riisei* on the deep reef below 70 meters with large colonies being differentially affected [13]. In most cases black coral colonies were completely smothered by a thick carpet of *C. riisei*. No previous large scale mortality of black coral colonies has been observed from any causal factor other than harvesting through 40 years of continuous black coral research and commercial fishing activity [14].

Hawaiian black corals, *Antipathes dichotoma* and *A. grandis*, are commercially valuable species used for the manufacture of precious coral jewelry [15]. Black coral is the official gemstone for the state of Hawaii and supports a multi-million dollar state-wide industry [7] which has been successfully managed since 1958 [14]. In Hawaii, the commercial species of black coral occur at depths between 30-120 meters and is selectively harvested above 75 meters by SCUBA divers [15]. The unharvested population below this depth has historically been considered a de facto reserve of large, highly fecund colonies and a source of larvae seeding the shallower depths. With the biological invasion of *C. riisei*, this resevoir now faces size selective mortality similar to that caused by harvesting.

Management implications

While *C. riisei* overgrowth on black corals is widespread in the Au'au Channel, it has yet to be observed in Kauai – home to the second largest black coral population in Hawaii [14]. In 2004, deep water surveys off southern Kauai recorded dense black coral forests but no evidence of *C. riisei* on the deep reef. Since its discovery on Kauai in 2002 [16], *C. riisei* has only been found at a few shallow-water sites there suggesting that eradication may be feasible if prompt and decisive management action is taken.

In the Au'au Channel, the biological invasion of *C. riisei* is dramatically altering the community structure on the deep reef. While it is unclear to what extent *C. riisei* will ultimately proliferate, evidence suggests that the invasion has yet to peak and the impact on the black coral population will worsen. Given the depth and off-shore location of the benthic habitat in the Au'au Channel, the success of the *C. riisei* invasion on the deep reef appears to be independent of habitat alteration and anthropogenic disturbance – a feature that differentiates this biological invasion from many others [17-20]. As a biological invasion of a coral reef ecosystem, the potential scale and severity of *C. riisei's* impact may be unprecedented with ecological implications throughout the Hawaii Archipelago and possibly elsewhere.

Acknowledgements

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Map of black coral activities in the Auau Channel

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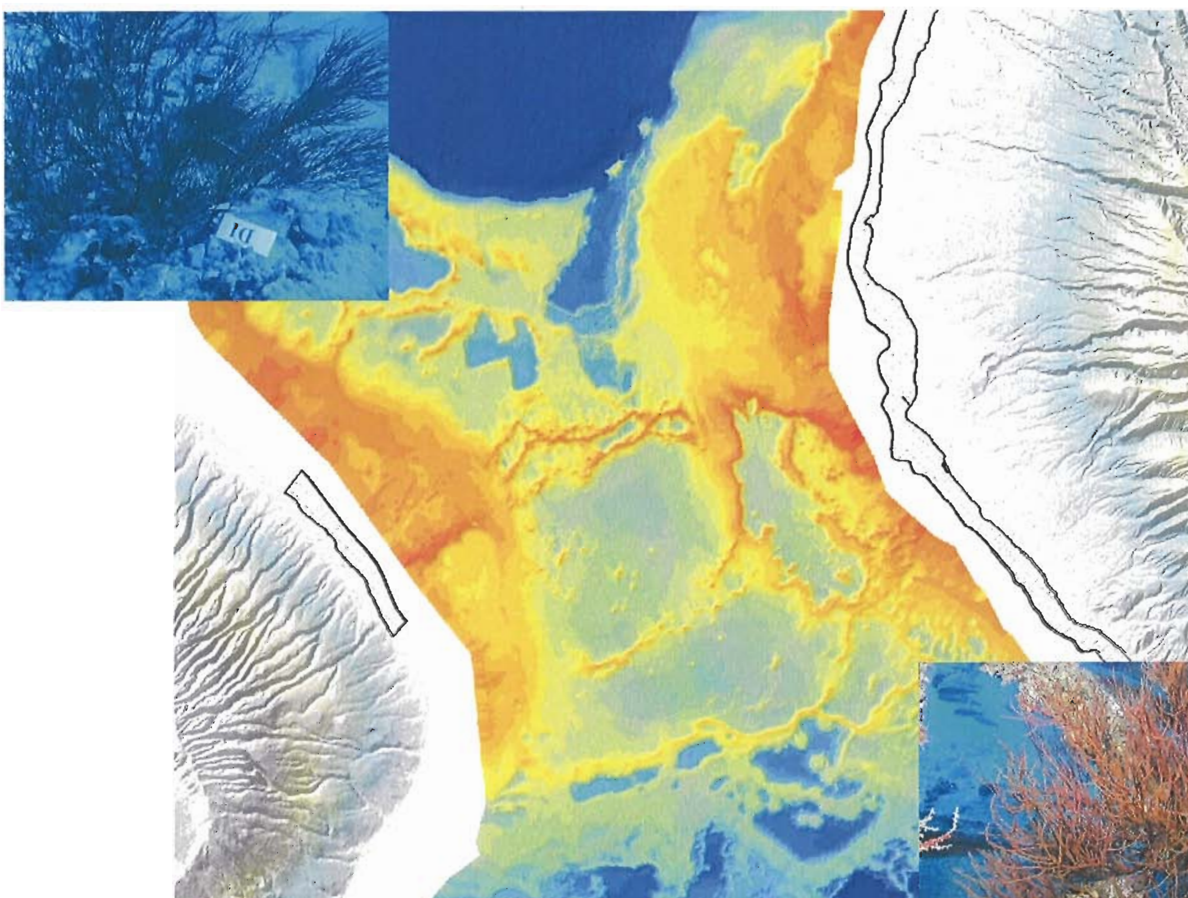
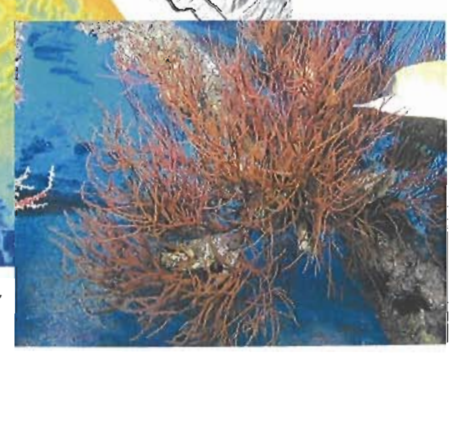
State of Hawaii

During the 2006 black coral workshop, locations of most research and coral harvesting activities over the last five years were plotted on a single map. The data were provided by the University of Hawaii (Richard Grigg and Sam Kahng), NOAA (Frank Parrish and Ray Boland), Department of Land and Natural Resources (Tony Montgomery), and the coral fishermen (Robin Lee). The overlap of plotted positions indicated scientists and coral harvesters were looking at the same areas. This data is extremely valuable by displaying a simple overview of all activities and help tease out areas that may need more exploration and research. The positions of the activities were intentionally left off the base map presented below.





Photos and Map by Tony Montgomery

Black coral fishery landings 1985-2005

Frank Parrish
National Marine Fisheries Service, Pacific Islands Fisheries Science Center

Fishery landings for the black coral fishery from 1985 to 2005 were aggregated across multiple fishers using seven year bins to meet confidentiality requirements for catch reporting. A seven year period was the smallest bin size that could be used and still have data pooled for three or more fishers. An overall increase in black coral landings is clear throughout the last two decades of monitoring. Landings in the last 7 years comprised 58% of the total catch since 1985 (Fig 1). Based on the interviews with the coral divers most of the catch comes from the Auau Channel. The average annual catch reported for the period 1999-2005 more than doubled the catch for the seven year period prior (Fig 2). This increase has been attributed to a growing coral demand from the buyer (Grigg 2004) and improved efficiency in fishing due to detailed bathymetric maps and adoption of GPS positioning (Robin Lee; pers. comm.).

MSY for black coral in the Auau coral bed has been estimated at 5000 kg or 11,023 lbs/yr (Grigg 1976). The fact that the coral harvesters have exceeded this target level at least once, requires some reflection by management. Furthermore, the MSY for the Auau coral bed was set two decades prior to the infestation of *Carijoa riisei* (Kahng and Grigg 2005). In 2001 the bed was resurveyed and the standing biomass was estimated to be 25% lower than stock measurements made in 1976 (Grigg 2004). Given the decrease in black coral biomass, the infestation of *Carijoa riisei,* and the recent demand for the resources by industry Grigg (2004) stated the need for more stringent regulations, including larger size limits, a 25-50% reduction in MSY and a reassessment of the economics of the fishery. Grigg made these recommendations unaware of the full extent of the increased harvesting conducted in the last seven year period.

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Kahng S, Grigg R 2005. Impact of an alien octocoral, *Carijoa riisei*, on black corals in Hawaii. Coral Reefs 24(4): 556-562

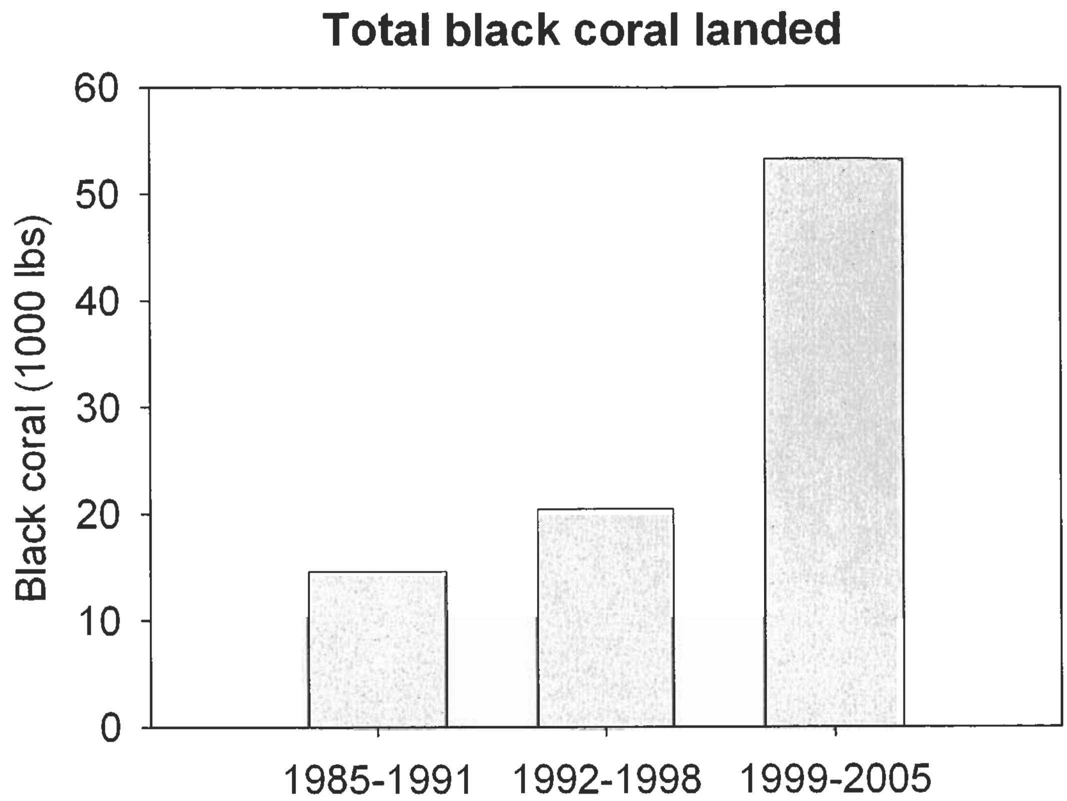

Figure 1.

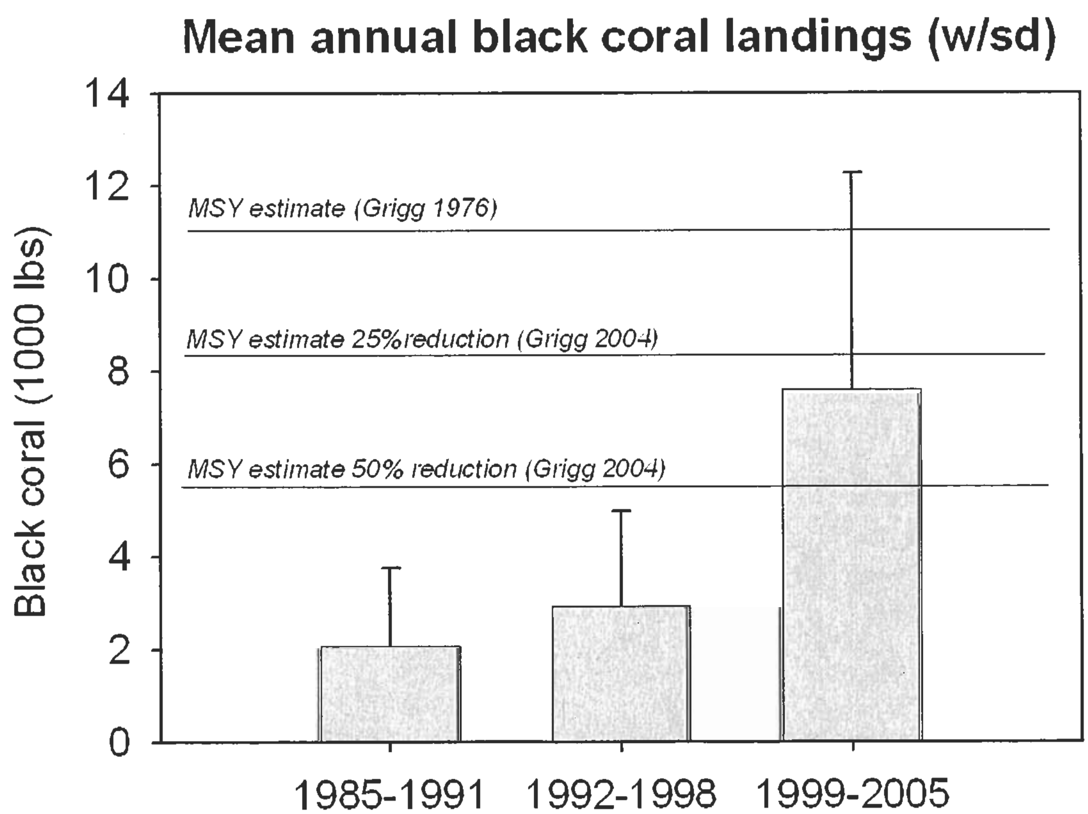

Figure 2.

History and overview of black coral in the jewelry industry

Jerry Tanaka
Maui Divers Jewelry

In the waters off of Lahaina, Maui, a new coral bed was found in 1958. One year later after this discovery of coral, Maui Divers Jewelry was founded and black coral jewelry became the initial staple of its business. As the jewelry market changed and trends moved on, Maui Divers Jewelry began to diverse its product offering, yet still remained committed with its black coral jewelry designs. Black coral also eventually became the official Hawaii State gemstone and Maui Divers has grown to be the largest jewelry manufacturer in the state.

Black coral usage has been consistent with the economics and external trends of our society. Maui Divers allows demand to drive its harvesting and purchasing needs. Natural cycles help with the preservation of coral beds. To ensure the future of Hawaiian black coral, Maui Divers strictly adheres to state regulations that prohibit the harvesting of immature colonies. Only certified and licensed divers, who abide by all rules and responsibly respect the coral, are used as suppliers. Maui Divers also continues to jointly work with scientists and divers to ensure the fisheries community is taking the proper steps for current health and future of the coral beds.

Lastly, Maui Divers has experienced challenges with CITES permits and the Fish and Wildlife Services. For example, Fish and Wildlife seized merchandise that was shipped out correctly with the proper documentation and was returned by the vendor at a later date. This difficulty causes great delays, waste in material and labor, and increased costs to get the merchandise back. Maui Divers recommends a level of understanding and compromise on relevant cases for future merchandise (that clearly matches the export documentation included with the shipment) to be returned without similar challenges.

CITES regulations for black corals

Source: www.cites.org

The Convention of International Trade in Endangered Species of wild fauna and flora (CITES) was drafted in 1963 through a resolution adopted in 1963 at a meeting of The World Conservation Union (IUCTN) and agreed upon in 1973, then was finally created on July 1, 1975. CITES is an agreement between governments that was created to ensure that international trade in specimens of wild animals and plants does not threaten their survival.

CITES is a voluntary agreement in which individual governments implement at the national level. The United States of America became the first party to ratify CITES on January 14, 1974, and was part of a nine-country contingent that entered into the agreement on January 1, 1975. In the United States, the US Fish and Wildlife Service (USFWS) is responsible for managing CITES and its

Under CITES, species subject to international trade are listed in three appendices, according to the degree of protection they need. Appendix I species are those threatened with extinction and are only permitted in exceptional circumstances. Appendix II species include those that are not necessarily threatened with extinction but in which trade must be controlled. Appendix III species are those protected in at least one country and needs assistance from other countries in controlling the trade.

On June 6, 1981, all species of black coral were listed in the CITES Appendix II list. This means that the commercial trade of black coral is permitted but controlled. The black coral trade also requires an export/re-export permit from the USFWS.

Photo by Anthony Palermo

Western Pacific black coral regulations

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An Introduction to the Council

The Western Pacific Regional Fishery Management Council (Council) is one of eight regional fishery management councils created by Congress in 1976 through the Fishery Conservation and Management Act (which was later renamed the Magnuson-Stevens Fishery Conservation and Management Act). The Council is responsible for the management of fisheries in the U.S. Exclusive Economic Zone (EEZ, generally 3 to 200 miles offshore) in the Western Pacific. This region includes the Territory of American Samoa, Territory of Guam, State of Hawaii, the Commonwealth of the Northern Mariana Islands and U.S. Pacific island possessions, an area of nearly 1.5 million square miles.

The Council's task is to protect fishery resources while maintaining opportunities for domestic fishing at sustainable levels. It is a unique "bottom-up" approach to government, where stakeholders provide recommendations to the National Marine Fisheries Service (NMFS) on management of their resources. The Council is comprised of 16 members and has five Fishery Management Plans for the Western Pacific region.

A Plan for Precious Corals

A 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, as well as classifying several known beds. These regulations, along with subsequent amendments, are codified in the Code of Federal Regulations (CFR) under Title 50, Part 665, Subpart F: Precious Coral Fisheries. These regulations provide protection in the Western Pacific region for all precious corals Management Unit Species (MUS), including:

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

The Precious Corals FMP also provides regulations on permits, prohibitions, seasons, quotas, closures, size restrictions, area restrictions, and gear restrictions for the harvest of the precious corals MUS. Nearly all of the fishery is centered in Hawaii, although precious corals are found in other areas under the Council's jurisdiction. The black coral fishery, the only one of its kind in the United States, is situated in Hawaii also. Figure 1 provides a graphic of the precious coral beds in Hawaii.

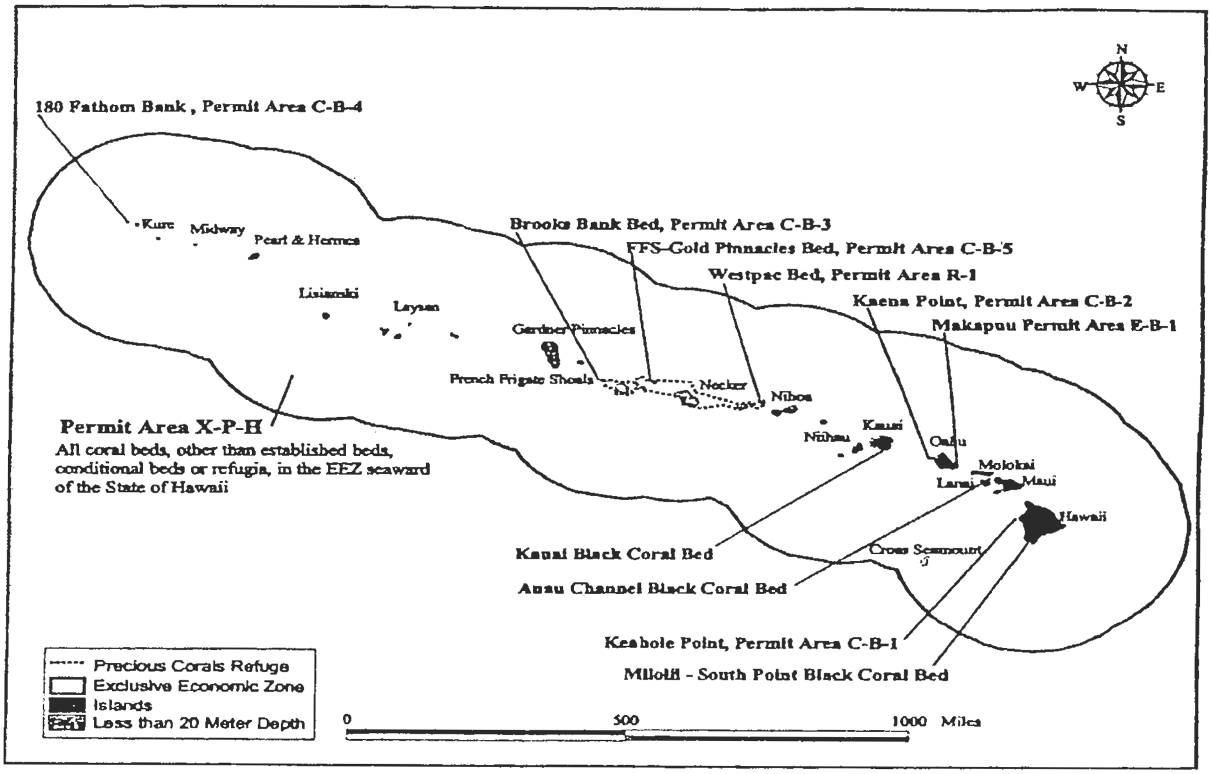

Figure 1: A Map of the Hawaii Precious Coral Beds

The Black Coral Fishery and its Regulations

There are two known major beds of black coral in the Western Pacific Region (the Au'au Channel Bed and the Kauai Bed), and several minor beds. Most of these are located in Hawaii's state waters. However, the largest (the Auau Channel Bed) extends into the EEZ, and thus the Council and Hawaii share jurisdiction over this bed.

Since 1980, virtually all of the black coral harvested around the Hawaiian Islands has been taken from the Au'au Channel Bed. Most of this harvest has been confined to State waters. Although a substantial part of this bed is located in the EEZ, the Hawaii Department of Land and Natural Resources estimates that about 85% of the black coral harvested is collected within three miles of the shoreline (DLNR 1979), perhaps because gear constraints have restricted divers for black coral to relatively shallow waters (75 m or less) (Grigg 1998a).

The commercial harvest of black coral has occurred in the waters around Hawaii for more than three decades. Significant commercial harvest of black coral has occurred in the Auau Channel Bed and in the Kauai Bed. By 1976, Grigg had determined the area coverage of these beds to be 1.7 km^2 and 0.4 km^2 respectively, and MSYs (calculated using a Beverton and Holt yield production model) for the two beds were estimated to be 6,174 kg/yr and 1,480 kg/yr (Grigg 1976).

These values were adjusted downwards by about 20% to recommended MSYs of 5,000 kg/yr and 1,250 kg/yr, respectively. These values correspond to a minimum size limit of 1.2 m (48 inches) for both species and thus allow smaller but fewer colonies to be harvested, which is consistent with economic considerations (optimum yield) and traditional fishing practices (Grigg 1998a).

Black coral regulations initiated by the Council have been put into place to provide the fishery with an opportunity to harvest black coral, but at the same time provide the resource with the protection it needs to keep the fishery sustainable. A permit system is in place, and black coral fishermen must obtain a permit if they harvest black corals in the EEZ. The fishery is mainly regulated on size. Black coral fishermen are prohibited to harvest black coral that has not attained either a minimum stem diameter of 1 inch or a minimum height of 48 inches. While there are quotas for other MUS, there are none for black corals. Table 1 lists a summary of the Precious Coral FMP regulations in 50 CFR 665, Subpart F as it applies to black coral fishing.

Table 1: A summary of black coral regulations by section

CFR Section	Summary of Black Coral Regulations
Section 665.81-Permits	Federal permit and reporting required for harvest of black corals in EEZ
Section 665.82-Prohibitions	It is prohibited to take black corals: a. Without a permit b. With non-selective gear c. In restricted areas (i.e. refugia) d. Where a quota is attained
Section 665.83-Seasons	The black coral harvesting season is from July 1 – June 30
Section 665.84-Quotas	There are no quotas on the harvest of black corals
Section 665.85-Closures	The Wespac Bed is closed to any black coral harvest
Section 665.86-Size Restrictions	Except as exempted, live black coral harvested from any precious coral permit area must have attained either a minimum stem diameter of 1 inch (2.54 cm), or a minimum height of 48 inches (122 cm). An exemption permitting hand-harvesting of live black coral that has attained a minimum base diameter of 3/4 inches (1.91 cm), measured on the widest portion of the skeleton at a location just above the holdfast, may be given to any person who reported a landing of black coral to the State of Hawaii within 5 years before April 17, 2002.

Section 665.87-Area Restrictions	No Fishing in the Refugia (Wespac Bed)
Section 665.88-Gear Restrictions	Only selective gear may be used to harvest coral from any precious coral permit area.

Future plans for black corals and the FMP

In November 2006, at its 129th Meeting, the Council recommended that the National Marine Fisheries Service (NMFS) remove the exemption allowing the harvest, by those exempted, of black corals at a smaller minimum base diameter than the current regulations. This exemption will be removed in the near future, and all harvest of black corals in federal waters will be done at a minimum height of 48 inches or a minimum base diameter of 1 inch.

At the same meeting, the Council recommended moving towards an ecosystem-approach to fisheries management by beginning the process of converting its existing FMPs to Fishery Ecosystem Plans (FEPs). These new FEPs will be place-based, and arranged according to archipelagos and island groups and replace the older species-based FMPs. The change from species-based FMPs to place-based FEPs will allow the Council to make fishery management decisions based on information about the ecosystem and surrounding area and not just fisheries information. The first step will consolidate the existing regulations from each FMP and consolidate them into each archipelagic area. This means that the black coral regulations in the Precious Corals FMP will be put into each archipelagic FEP. Future steps to this process will include amendments to the FEPs and incorporating ecosystem indicators and principles into the plan and management actions.

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State of Hawaii black coral regulations

Hawaii Administrative Rules
Title 13-Department of Land and Natural Resources
Subtitle 4-Fisheries
Part V Protected Marine Fisheries Resources
Chapter 91-Pink, Gold, and Black Corals

Current Regulations

Under Hawaii Administrative Rules (HAR 13-91), "No person shall take, destroy or possess any black coral with a base diameter of less than ¾ inches from State marine waters." According to HAR 13-91, "black coral" includes the three species of coral *Antipathes dichotoma, Antipathes grandis,* and *Antipathes ulex* in their raw state. This regulation went into effect on July 23, 1999.

Also, in section 13-91-5, it should be noted that the taking of pink, gold, or black coral and the piece of rock attached to the coral shall not be considered a violation of the prohibition on live rock collecting.

In section 13-91-6 of the HAR, a control date is set at July 23, 1999 (the effective date of the section), that would be used if the State of Hawaii intends to limit participation in the Hawaiian Islands commercial precious coral fishery. This is a prior notice to the public in case a limited entry program is established in the future.

Future plans for black coral management

The Division of Aquatic Resources is now considering options for the future of black coral management. The options being considered include an increase in minimum size as well as area based management, limited entry, and/or limited take. These options are only under consideration and may be phased in the regulations gradually. However, during the course of the workshop, fishers felt that certain areas closed to black coral harvesting may be a useful tool and will be further considered as a management option.

Discussion, Issues, and Objectives

Following the presentations, potential black coral science and management issues were discussed and prioritized. The status of each issue was then looked at and current knowledge on the issue was identified. From this, the group was able to identify needs and gaps in the knowledge and generate objectives to fill in these gaps. Management objectives were also identified.

The workshop participants were able to compile these issues into future priorities and needs for the black coral industry to continue in Hawaii (Tables 1 and 2). Future research objectives identified included studies on growth, reproduction, recruitment, mortality, fishing, and invasive species. Research and management strategies discussed included area based management and replanting projects. Joint projects between researchers and black coral divers were discussed as a way to leverage resources. The issues will be provided to the Western Pacific Regional Fishery Management Council, its Scientific and Statistical Committee, its Precious Corals Plan Team and other advisory bodies.

Table 1: Research Issues and Objectives
* Note: Data and status from New Zealand black corals is represented in *italics*.

Issue	**Status**	**Research objectives**
Growth	Grigg baseline data avg = 6.42 cm/yr (1972-76) (3-yr tagging) Montgomery tagging avg = 6.74 cm/yr (2005) (1-yr tagging) Roark radiometric ages consistent (2006) with Grigg and Montgomery tagging data (3 samples)	Local area effects of current/flow on growth-oceanographic proxies Long-term monitoring of growth through tagging Collect known age colonies and mark for radiometric verification Is growth rate constant?
Reproduction	Hawaii black coral-*A. dichotoma* -separate sexes -Reproductive age 10-12 yrs (~70 cm) *NZ black coral- separate sexes* *-Reproductive age 30 yrs (~1 m height)* *-Synchronous broadcast spawning* *-Asexually produced colonies far reaching*	Minimum age of reproduction Size related fercundity Depth/light/location effects on reproduction Identify seasonal cycles/time of spawning
Recruitment	Data suggests possible recent lower recruitment in Auau Channel population *NZ example-A 7-year monitoring study showed no recruitment in 4 of the 7 years and the population remained stable.*	Fishery-independent survey every 3-5 yrs Establish research study sites for monitoring (potential for density dependence and life mortality) Early growth rates for recruitment Black coral settlement work
Mortality	Greater mortality evident on colonies >14 years (post-harvest size) for 2004 survey versus 1975 and 1998 surveys. Age-specific mortality; Detected fewer colonies >19 yrs	Fishery-independent survey every 3-5 yrs Establish research study sites for monitoring Increase the number of tagged colonies for monitoring
Fishing	Overall increase, (The last 7 years comprised 58% of the total landings over the last 25 yrs of the fishery). Attributed to technological advances and increased experience in fishing.	Improve the resolution of catch data (e.g. report number of colonies and catch locations).

Issue	Status	Research objectives
Carijoa riisei	Carijoa riisei shares similar habitat requirements as black coral and can out-compete black coral >70 m. At sites surveyed, 50-60% of black coral deeper than 70m is over grown/dead Surveys of black coral at Kauai have identified two confirmed locations of Carijoa riisei. Carijoa riisei seen on black coral transect survey in Kalohi Channel at Maui. A survey of Carijoa riisei on black corals on the Big Island (2002) showed no Carijoa riisei.	Continue time series in the Keyhole area of the Auau Channel Survey other deep basins in northern Auau for impacts of Carijoa riisei GIS analysis to project percent stock loss >70m in Auau Channel Increase surveys in other areas of the MHI
Geography	Kauai black corals closer to shore and shallower. Black corals on Maui represents the primary beds (Auau Channel, Kalohi Channel) with optimal habitat. Big Island black corals found deeper; South Point aggregation not commercially viable (A. grandis).	Conduct a GIS analysis of suitable black coral habitat Repeat Auau Channel black coral surveys in (listed in order of priority): -Kauai -Maui (Kalohi Channel) -Big Island -Niihau and the Northwestern Hawaiian Islands

Table 2: Management Issues and Objectives

Topic	Management Issue	Management objectives
Carijoa riisei	Enforcement issues with identification of live/dead black corals resulting from Carijoa riisei infestation. Eradication of Carijoa riisei on Kauai.	Time sensitive nature of Carijoa riisei growth highlighted for possible eradication on Kauai. Eradication of Carijoa riisei from identified pockets at Kauai and Niihau.
Size Limits	Federal size limits being changed, State of Hawaii size limits to change to be consistent with Federal regulations, and may go beyond with further protection.	Support State's change.
MPA/Biological Reference Area	Close an area to black coral harvest for protection and to create a scientific study area (a place near Lahaina where black coral can exist without harvesting; i.e. the redwoods near San Francisco). Lahaina roads solution basin an example of a proposed area for fishery-independent research on recruitment and mortality, stock enhancement, eco-tourism and protection.	Create a closed area and issue permits to allow certain activities in this area.
Area-based Management	Close selected areas to black coral harvest (i.e. Oahu, N. Kauai, Big Island, etc.)	Consider and explore the idea of area-based management and closing off areas (instead of closing off all areas and opening up select areas)
Reporting Requirements	Divers faced with filling out Federal logbook forms *and* State of Hawaii commercial catch report.	Look at having one form replace the other. PIFSC work with PIRO to revise PC reporting form before the expiration date (Nov 30, 2006).
Transplanting	Creating projects for stock enhancement of black corals through transplanting. Use closed area for black coral transplanting	Identify funding opportunities for cooperative research First funding opportunity is State of Hawaii Disaster Relief Program
Base vs Height	Unable to measure base diameter reliably through fishery-independent surveys.	Low priority-refine height/base relationship. Use height in science/research.

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WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL

The Western Pacific Regional Fishery Management Council is the policy-making organization for the management of fisheries in the exclusive economic zone (EEZ, generally 3 to 200 miles offshore) around the Territory of American Samoa, Territory of Guam, State of Hawaii, the Commonwealth of the Northern Mariana Islands and US Pacific island possessions an area of nearly 1.5 million square miles.

The main task of the Council is to protect fishery resources while maintaining opportunities for domestic fishing at sustainable levels of effort and yield. To accomplish this, the Council monitors fisheries within its region and prepares and modifies fishery management plans as needed. The regulations are enforced jointly by the National Marine Fisheries Service, US Coast Guard and deputized state and territorial agents. The Council encourages cooperative fishery management among the island and distant-water fishing nations throughout the Pacific.

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Hawai`i DAR
Division of Aquatic Resources

The Division of Aquatic Resources (DAR) is a division of the State of Hawaii Department of Land and Natural Resources. The mission of the DAR is to manage, conserve and restore the state's unique aquatic resources and ecosystems for present and future generations. The DAR manages the State of Hawaii's aquatic resources and ecosystems through programs in commercial fisheries and resource enhancement; aquatic resources protection, habitat enhancement and education; and recreational fisheries. Major program areas include projects to manage or enhance fisheries for long-term sustainability of the resources, protect and restore the aquatic environment, protecting native and resident aquatic species and their habitat, and providing facilities and opportunities for recreational fishing.

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