A Quantitative Survey of *Fungia scutaria* In Kaneohe Bay

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Aug. 3, 2001

INTRODUCTION

Fungia scutaria, a free-living solitary coral in the family of Fungiidae, can be found in the shallow reefs of Kaneohe Bay, Oahu, of the Hawaiian Islands. Commonly referred to as "mushroom coral", it has a disk-like morphology [Fig. 1], and its juveniles are often found attached to the dead coralla or reef substrate by a stalk, having an appearance similar to a mushroom. Adult *Fungia* range in diameter from 5 to 20 centimeters, and in Kaneohe Bay, are commonly found under ledges or amongst the coral heads of *Porities compressa*. They have an oral side covered with tentacles [Fig. 2] and a rough aboral side (Gulko, 1998). The abundance of this coral has been suggested to have suffered a marked decrease from 1965 to 1975 due to eutrophication, land use changes, and sedimentation in Kaneohe Bay (Maragos 1977). Although the mushroom coral is thought to have made a comeback in the last decade, there has been no quantitative analysis thus far as to their abundance, size class distribution, or population density in Kaneohe Bay. In this study, quantitative data were collected on *Fungia scutaria* at 42 sites in Kaneohe bay by snorkeling surveys.

In the early 1900's , Kaneohe Bay was described as a "coral garden" hosting a variety of flourishing corals. Researcher Charles Edmonson (1928), cited by Smith, *et al.* (1973), remarked that "within the protected waters of the Bay, Hawaiian reef corals were one of the best exhibitions of living corals to be seen." Several decades ago, *Fungia scutaria* was observed to be abundant in Kaneohe Bay (Bosch, 1967). It was found in large numbers in the shallow reef patches scattered throughout the bay, as well as on some fringing reefs. Since then, several anthropogenic factors including sewage pollution, changes in land use and dredging have led to a decline in the health and abundance of coral communities in the bay (Smith *et al.*, 1973)..

Between 1963 and 1978 Kaneohe Bay suffered a period of eutrophication as sewage was being released into the bay. In 1963, secondarily treated sewage was dumped into the south lagoon from the newly constructed Kaneohe municipal sewage treatment plant. By 1971, the sewage outfall reached a level of over 11,000 m^3 per day (Smith *et al.*, 1973). The resultant eutrophication in the bay led to diminished light in the water column due to a higher density of phytoplankton growth, thus making it difficult for light-dependent corals to survive (Maragos, 1972). In addition, the increased nutrient loading led to algal blooms, and the opportunistic algal species *Dictyosphaeria cavernosa* and *Kappaphycus striatum* began to outcompete and smother the existing corals (Smith *et al.*, 1973).

Coral reef communities in the south lagoon were also severely impacted by dredging, which occurred extensively during construction of the Marine Corps base in 1938. An estimated 7.6 million cubic meters of reef material was destroyed upon removal (Smith *et al.*, 1973).

Kaneohe Bay has additionally suffered from sedimentation due to changes in land use patterns. Heavy rainstorms in cleared areas produced erosion, increased sediment loading and excessive runoff (Bosch, 1967). In 1965 Kaneohe Bay corals suffered a freshwater kill due to flooding from torrential rains. In conjunction with low tides, the freshwater runoff devastated the coral communities inhabiting shallow reef slopes and tops. Three years later, the corals were only beginning a slow recovery (Banner, 1968).

All the aforementioned disturbances have had a cumulative, drastic negative impact on the health of many coral species in Kanoehe Bay including *Fungia scutaria*. Over the years, due to ameliorating measures such as the diversion of the sewage outfall, some of the coral communities have witnessed a slow recovery (Evans, *et al.*, 1986) .There has been conjecture that *Fungia scutaria* has made a comeback, but it is hard to tell due to the lack of any solid evidence. Although two qualitative surveys for *Fungia* were conducted in the years of 1963 and 1968, (Bosch, 1967 and Maragos, 1972) there are no comprehensive quantitative data that exist to assess the current abundance and health of *Fungia*. The Bosch study (1967) included *Fungia* distribution throughout Kaneohe Bay; however, in his figure depicting *Fungia* populations, [Fig. 3], the scale of "rare/none", "few", "common" and "abundant" was never quantified by specific numerical data. Maragos (1972) also did a qualitative distribution study on the presence and absence of *Fungia* in the bay. [Fig 4] The new data gathered from the current quantitative study will help to assess the present status of *Fungia scutaria* in Kaneohe bay based on population numbers, size classes, and number of dead corals.

METHODS and MATERIALS

The *Fungia scutaria* study was implemented in Kaneohe Bay from the Hawaii Institute of Marine Biology (HIMB) on Coconut Island, Oahu. The dates of the survey were from January 2000 to May 2000. The study was carried out by the author, and graduate student Amy Lacks, who was in charge of the study as it was part of her Master's thesis research. The data were collected by snorkel survey, where each diver snorkeled on different areas of the same reef patch, which was demarcated on a navigational map of Kaneohe Bay showing over 40 numbered patch reefs [Fig. 5]. A small motor boat (Boston Whaler) was the primary means of transportation from the laboratory at Coconut Island to the study sites.

The data were gathered from 42 sites in the entire bay of Kaneohe, which was divided into regions: North, Mid, and South Bay, in order to better evaluate the data collected [Fig. 6]. At each study site located on the map, *Fungia scutaria* was surveyed for 30 minutes by each diver, with one diver swimming in one direction along the reef, and the other diver swimming in the opposite direction so as not to overlap any data. Every survey was counted as one hour of swimming, since each snorkeler swam for thirty minutes at each designated patch reef. Surveys concentrated on the area of reef most hospitable to *Fungia scutaria*, that being the seaward-facing margin of the patch reef, as found in prior studies (Bosch 1967, Maragos 1972). Marginal areas not conducive to the habitation of Fungia, such as the shallow rubble and sandy areas, were not surveyed. Quantitative data were gathered at each site for number of living corals and size class distributions defined as: extra-small(<5 cm in length), small (<9 cm), medium (9-12 cm) and large (>12 cm). Observations were taken on the aggregation pattern of the colonies (grouped in clumps or solitary) and the phenotypes represented in each group (color, tentacles, similarity, dissimilarity). Dead corals were also counted and observations were made on overall health of reefs and abundance of overgrowing algae such as *Dictyosphaeria cavernosa* and *Kappophycus striatum*.

The data on coral ecosystem health was based on the surveyor's subjective assessment of live coral, reef structure, fish assemblage, and abundance of the aforementioned algae. The coral health classification scale ranged from "good" to "ok" to "poor". A reef in "good" health was considered to have a generally high percentage of live coral cover, low percentage of overgrowing algae, and a large population of fish assembling in the reef structure. A reef classified as "ok", had approximately half of its coral population alive and half dead; a medium percentage of deleterious algal growth, and a medium sized population of fish when compared to other reefs surveyed. Finally, reefs classified as "poor" had very little live coral cover, abundant populations of deleterious algae smothering the reefs, and a smaller population of fish.

DATA and RESULTS

The raw data gathered from the 42 sampling sites consisted of information on number of live corals, size classes (XS, S, M, L), aggregation, number of dead corals, and reef condition [Table 1].

One aspect of the raw data studied in further detail was the average live coral count according to the location of survey. The average number of live *Fungia* surveyed per hour is plotted against Kaneohe Bay region [Fig. 7] in order to assess where the greatest number of live corals exists. From the data, it was concluded that, per average, the most abundant *Fungia* were found in the North Bay, and the least in the South and Mid Bay. According to the statistical analysis of Amy Lacks, the large gap witnessed between the higher number of live corals in the North Bay versus the lower numbers in Mid and South Bay is slightly decreased upon calculation of the standard deviation. However, the probability that the North Bay *Fungia* populations could be considered similar in number grouping to those of the Mid and South Bay is less than .0005 percent (Lacks, 2000). Thus, it is highly probable that a definitively larger population of mushroom corals exists in the North Bay, and similarly smaller populations occur in the Mid and South Bay.

From a theoretical point of view, it would make sense that the North Bay would contain a higher number of live corals since the South Bay suffered such a great *Fungia* population decline during the era of urbanization and population growth in Kaneohe. Bosch's research (1967) indicated that *Fungia scutaria* naturally prefer to inhabit calmer waters, such as the south and middle parts of Kaneohe since the north bay has too much wave motion; however, all the disturbances in the mid and south bays may have led to a shift in habitat preference. It could be a combination of many factors explaining the data collected, yet it is impossible to say for sure. The data correlated by Amy Lacks in the form of a map showing *Fungia* abundance categories for all patch reef surveys [Fig. 6] confirms the aforementioned observation that there is a greater abundance of living mushroom corals in the North Bay. The map shows that the

North Bay reflects abundance categories of "abundant" and "common" whereas the Mid and South Bays have over half their sites recorded as "few" with only one "abundant". This analysis is based on a scale of: "abundant"= 250-400 corals counted per site; "common"= 100-250 corals counted per site; "few"=10-99 corals; and "rare/none" = less than 10 corals.

It is interesting to compare these data with Bosch's abundance data from 1963. Although his scale is not quantified, he shows in his distribution map [Fig. 3], that *Fungia scutaria* was abundant throughout all regions of the Bay. Only the area near the sewage outfall was recorded to have rare or no corals. Bosch (1967) does add, in another table, that two locales he considers to be "abundant" have a population density of 19.1 and 36.2 corals per meter squared. This is a very large number when compared to Lacks' scale of abundant being 250-400 mushroom corals counted per site in one hour of swimming.

Other aspects explored in this study are the size class distribution, number of dead corals, and reef health. The number of live corals was plotted against size class distribution (consisting of XS, S, M and L), [Fig. 8]. The data show that the greatest number of *Fungia scutaria* is in the small size class, followed by medium size corals and finally the large and extra small size corals roughly equivalent in number. The data for the extra small corals may be deceiving because in the field, it is difficult to spot and count all the extra small size corals. They are tiny and often grow attached to the aboral surfaces of mushroom corals, which are normally facing down towards the reef and out of view (Krupp *et al.*, 1992). Thus, it can be noted that many of the *Fungia* in this extra small size class may have been overlooked.

The number of dead corals was plotted against Kaneohe Bay region [Fig. 9]. This graph had greater abundance of dead *Fungia* in the mid bay, with the south and north bay having a lesser number of dead *Fungia* by an average of about 25. This is not a significantly large number, and in addition, it is not always easy to find dead mushroom corals in the field since they are often buried in sediment. Therefore, the overall data on dead corals can be considered inconclusive.

Reef Health was plotted against Kaneohe Bay region [Fig. 10] with the ranges of health, from good to ok to poor, being represented as percentages. It appears that the percentage of reef in good health was greatest in the North bay, followed by the South and lowest in the Mid bay. The overall trend depicted in the graph shows the Mid bay having the worst condition of reef health, with a high percentage of poor reefs and a low percentage of good reefs. The South bay has the highest percentage of OK reefs whereas the North bay has the highest percentage of good reefs and the lowest percent of poor reefs. Although this data cannot be relied upon too heavily due to its basis in purely subjective observation, it can be helpful in seeing an overall trend.

Finally, the average number of live *Fungia* was plotted against reef health to determine whether there was any correlation between the health of a reef and the number of live corals found there. [Fig. 11] The results showed a clear trend of the average number of live corals surveyed decreasing with declining reef health. As the health of the reef deteriorated from good to poor, the average number of live corals was observed to drop.

CONCLUSION

The data gathered in this study was the first quantitative data to be accumulated on abundance, size classes, and population density of *Fungia scutaria* in Kaneohe Bay. It can serve as a baseline for future comparison of *Fungia* abundance and distribution in the bay. Although it is difficult to pinpoint with accuracy the demise of the mushroom coral over the decades (and its possible comeback) due to lack of quantitative data, it can be seen from the current data that the population numbers are rarely abundant. In the past, according to Bosch's qualitative map, (Bosch 1967) *Fungia* were once recorded as abundant and common in the Mid bay and in parts of the South bay. Bosch considered "abundant", in one study, to be from 19.1 to 36.2 corals per meter squared. The population numbers of mushroom corals today do not even come close. In the current study, the highest population of mushroom corals found, those classified as "abundant" by Amy Lacks (2000), were only 250-400 corals counted per site in one hour snorkeling.

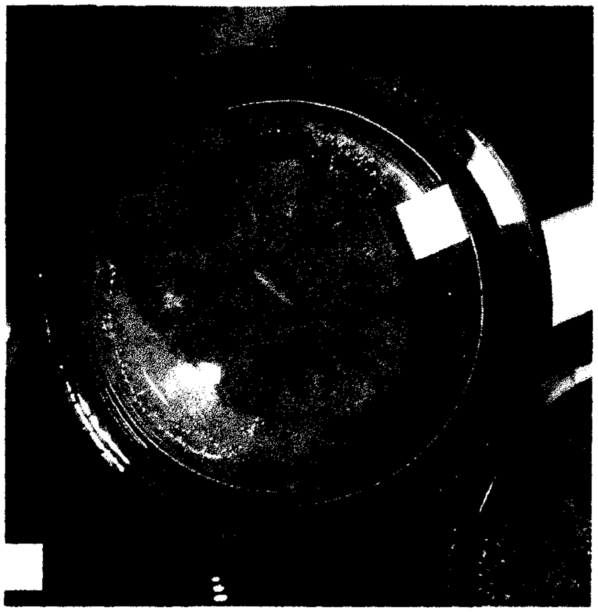
According to the trends observed from the present data, the greatest number of *Fungia* are found in the North bay, and the least in the Mid and South bays. Reef health is consistently found to be better in the North bay and poorer in the Mid and South Bays. This shows a decline as compared to previous data from Bosch's study. It also shows a shift in the habitat of the mushroom corals since they previously inhabited the Mid and South bays more abundantly than the North Bay. Naturally, the Mid and South bays have calmer waters more conducive to the habitation of *Fungia* than the areas of the North bay which receive greater wave action. This correlates to the history of change in land use patterns, dredging and sewage pollutants which flowed into the South bay. It can be concluded that these anthropogenic factors led to the death of many mushroom corals in the South and Mid bays, and the population kept its foothold in the North bay where the reef was not as damaged. For the future, it is important to preserve the overall reef health in the bay in order to foster the comeback of Kaneohe's corals. The data generated by this study will enable future researchers a means to quantify any improvements.

Personal Statement

The current Marine Option Project I completed with the help of Amy Lacks, project leader, and Dr. Dave Krupp, advisor, gave me an opportunity to do hands on fieldwork gathering scientific data. At the time, I had been in the midst of taking Dave's Coral Biology 200 class, and working on Amy's project really gave me deeper understanding of the true coral reef habitat in the field. I was able to spend several hours a week looking at corals and learning to identify several aspects of not only *Fungia scutaria*, but other flora and fauna as well. I learned about the specific habitat preferences of the mushroom coral and how to differentiate morphologies and size classes. I was able to point out several species of corals and algae by the end of our study. In addition, I began to develop a sense of reef health by looking at so many patch reefs in different conditions. I also learned how to operate a Boston Whaler and I got to spend some time out at Coconut Island and become inspired by all the different research projects that were occurring in the various labs there.

Finally, although it was a little grueling after letting so many months go by, I learned how to force all my scattered ideas into a paper and analyze what I had learned. By doing this project, I learned a bit about the process that goes into the research and the write-up of a scientific study. This was possible because I was able to collect data in the field with Amy and then witness the outcome of our efforts in our data collected and in her completed Master's Thesis. It was all very interesting and most importantly, it was fun!

Figure 1. Adult *Fungia scutaria*
This live adult specimen of Fungia was collected from Kaneohe Bay



0 cm 20 cm

Figure 2. Adult *Fungia scutaria* with tentacles extended
This live adult specimen of Fungia was collected from Kaneohe Bay, and is currently spawning

0 cm 20 cm

Figure 3. <u>*Fungia scutaria* distribution throughout Kaneohe Bay (Bosch, 1967).</u>

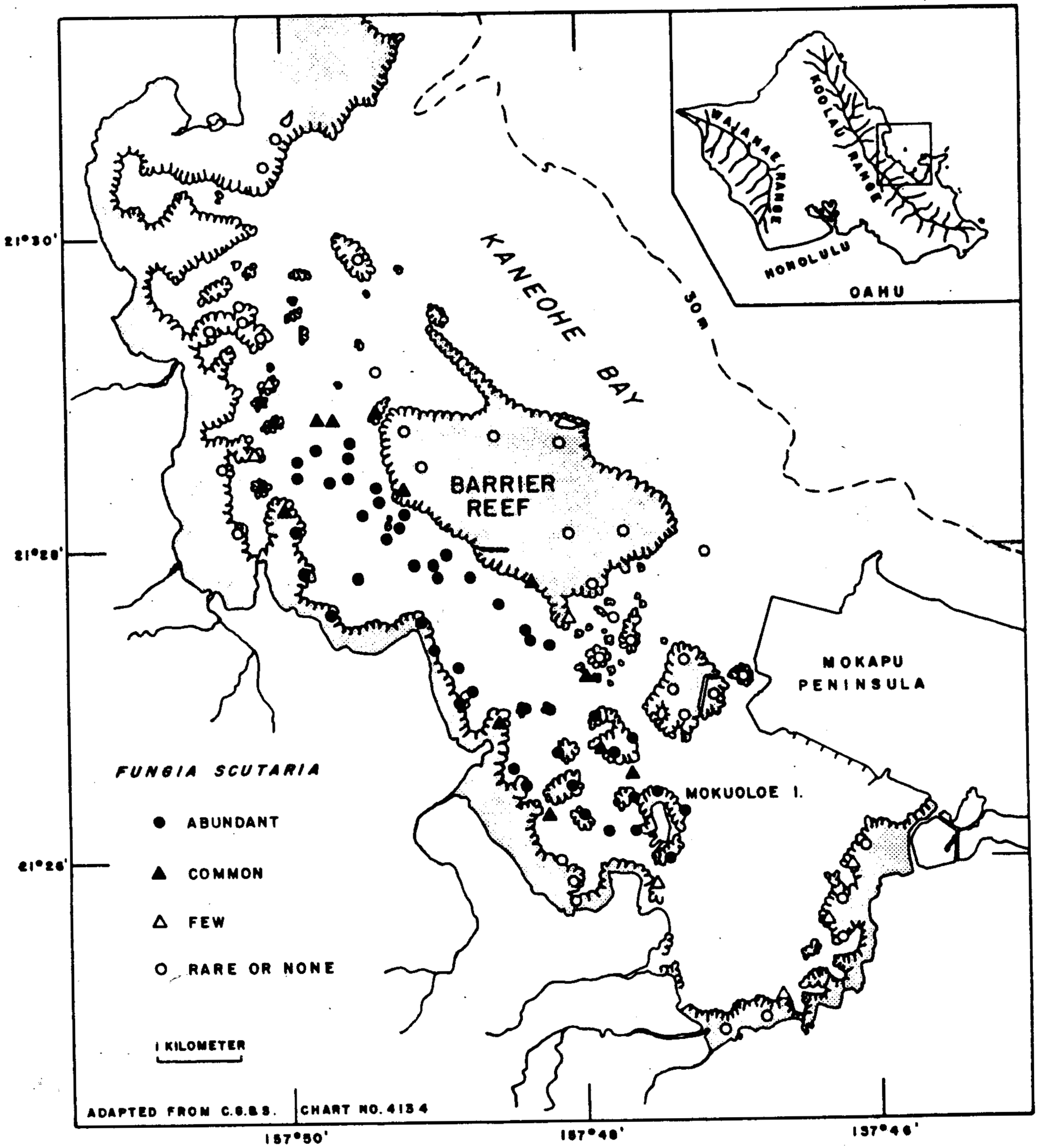


Figure 4. Presence and absence of *Fungia* in Kaneohe Bay (Maragos, 1972)
● = presence of *Fungia scutaria* ○ = absence of *Fungia scutaria*

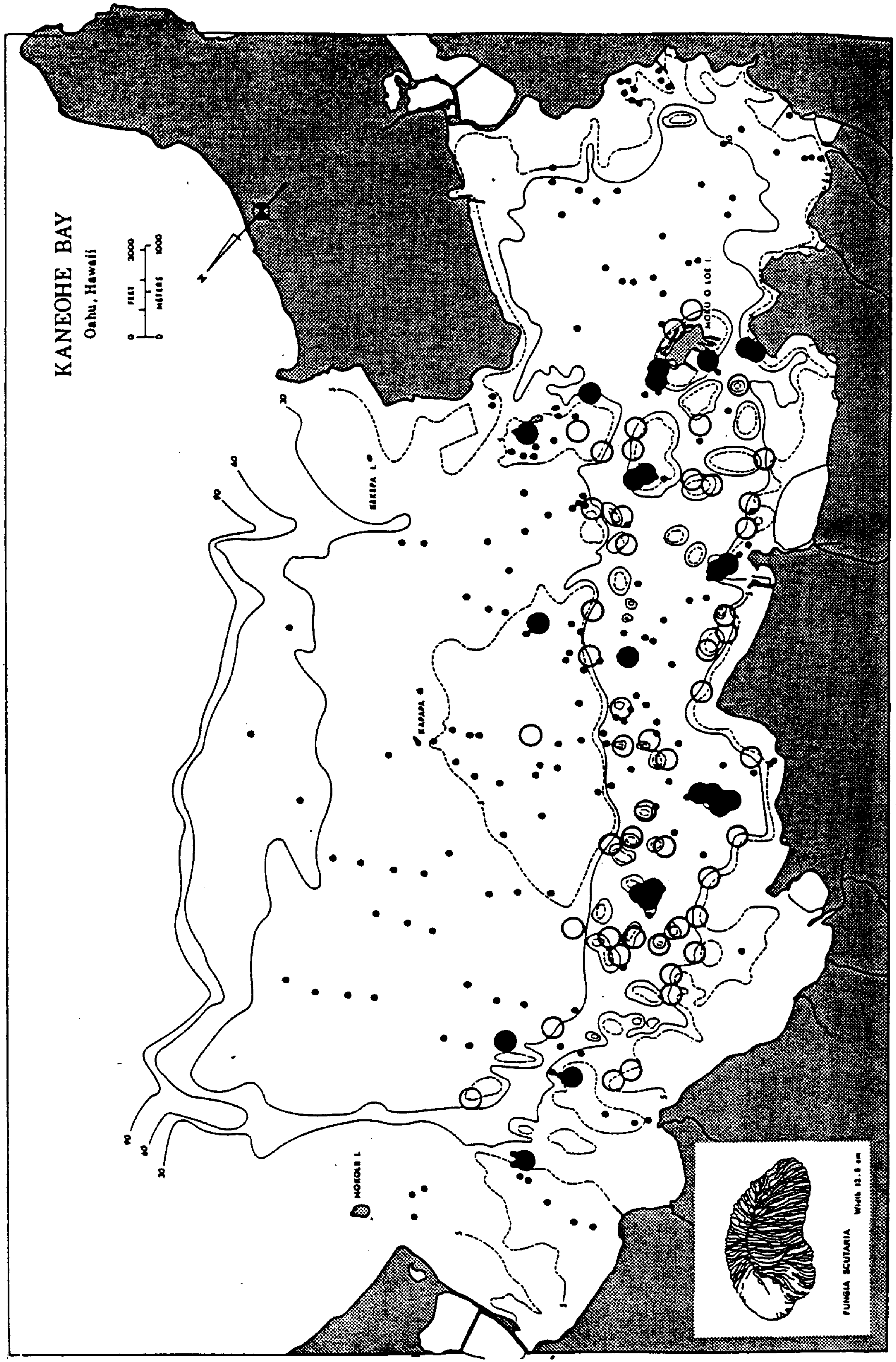


Figure 5. Navigational map of Kaneohe Bay, *patch reefs numbered* (Lacks, 2000).

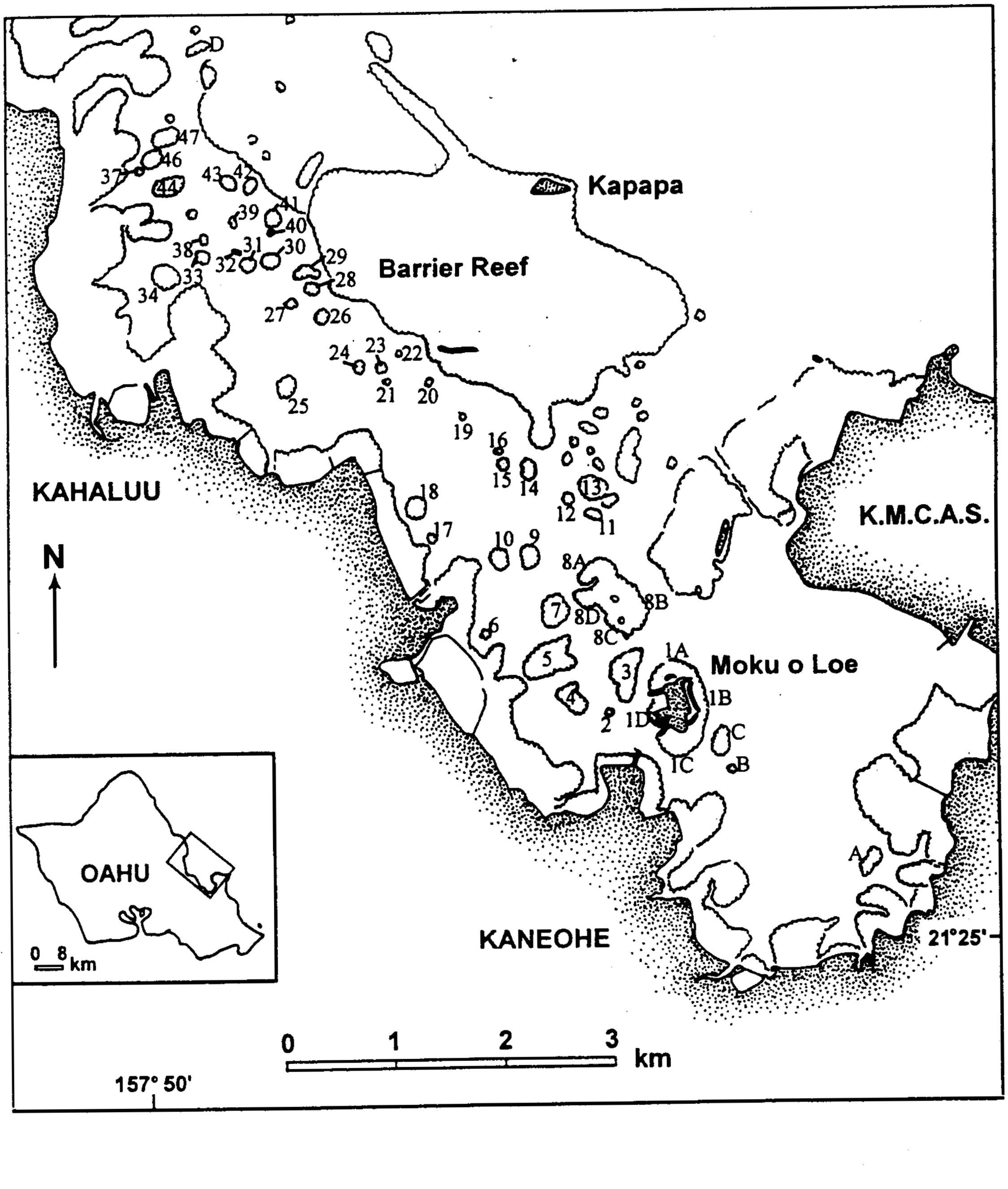


Figure 6. Map of Kaneohe Bay divided into regions and showing abundance categories on reefs surveyed. (Lacks, 2000)

Abundance Categories defined:

- ● Abundant = 250-400 *Fungia* counted per site
- ▲ Common = 100-250 *Fungia* counted per site
- ■ Few = 10-99 *Fungia* counted per site
- □ Rare or None = less than 10 *Fungia* counted per site

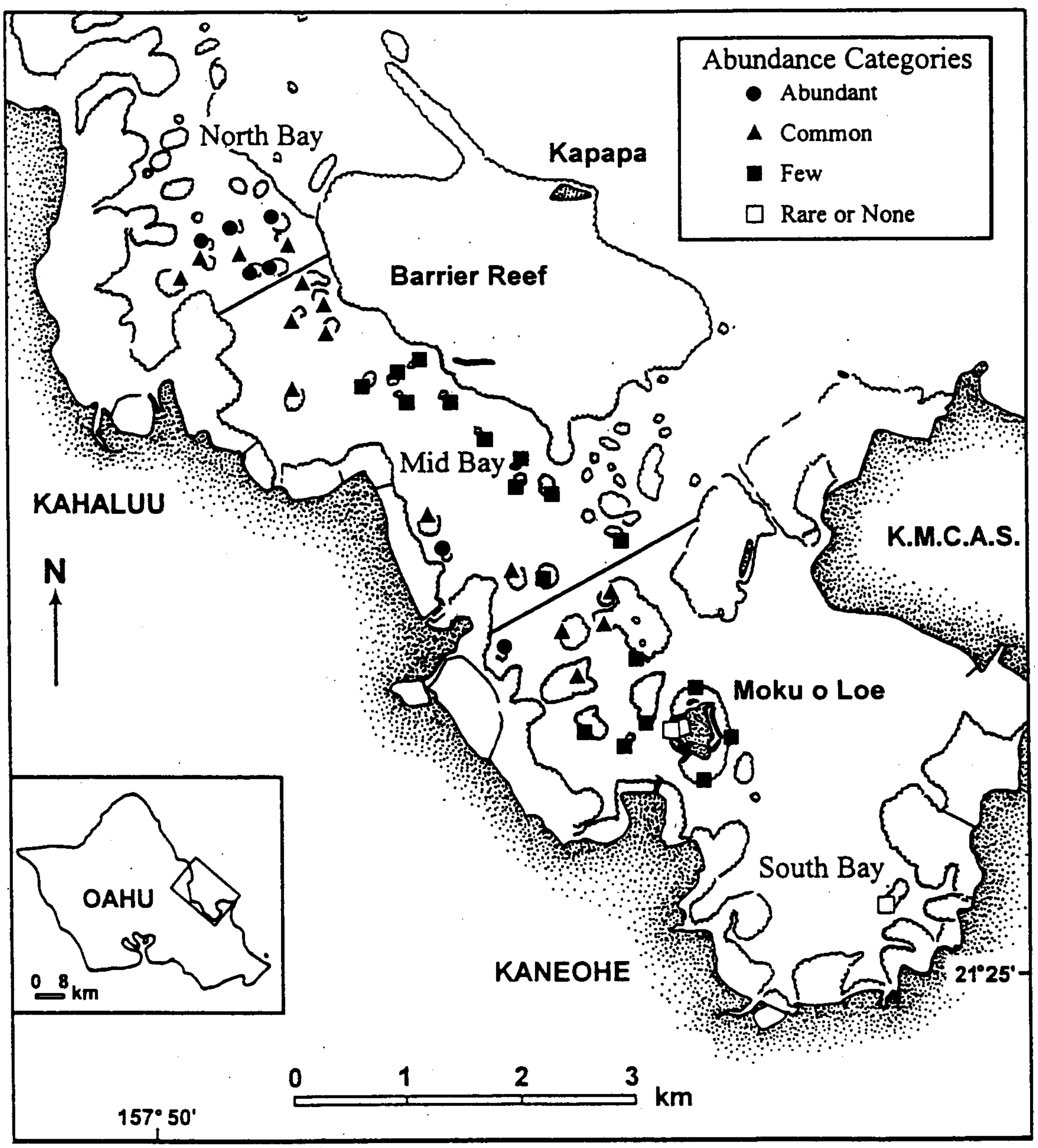


Figure 7. Sampling effort of live *Fungia scutaria* vs. Kaneohe Bay region
Sampling effort is classified as the average number of live *Fungia* surveyed at patch reef by snorkeler per hour swimming.

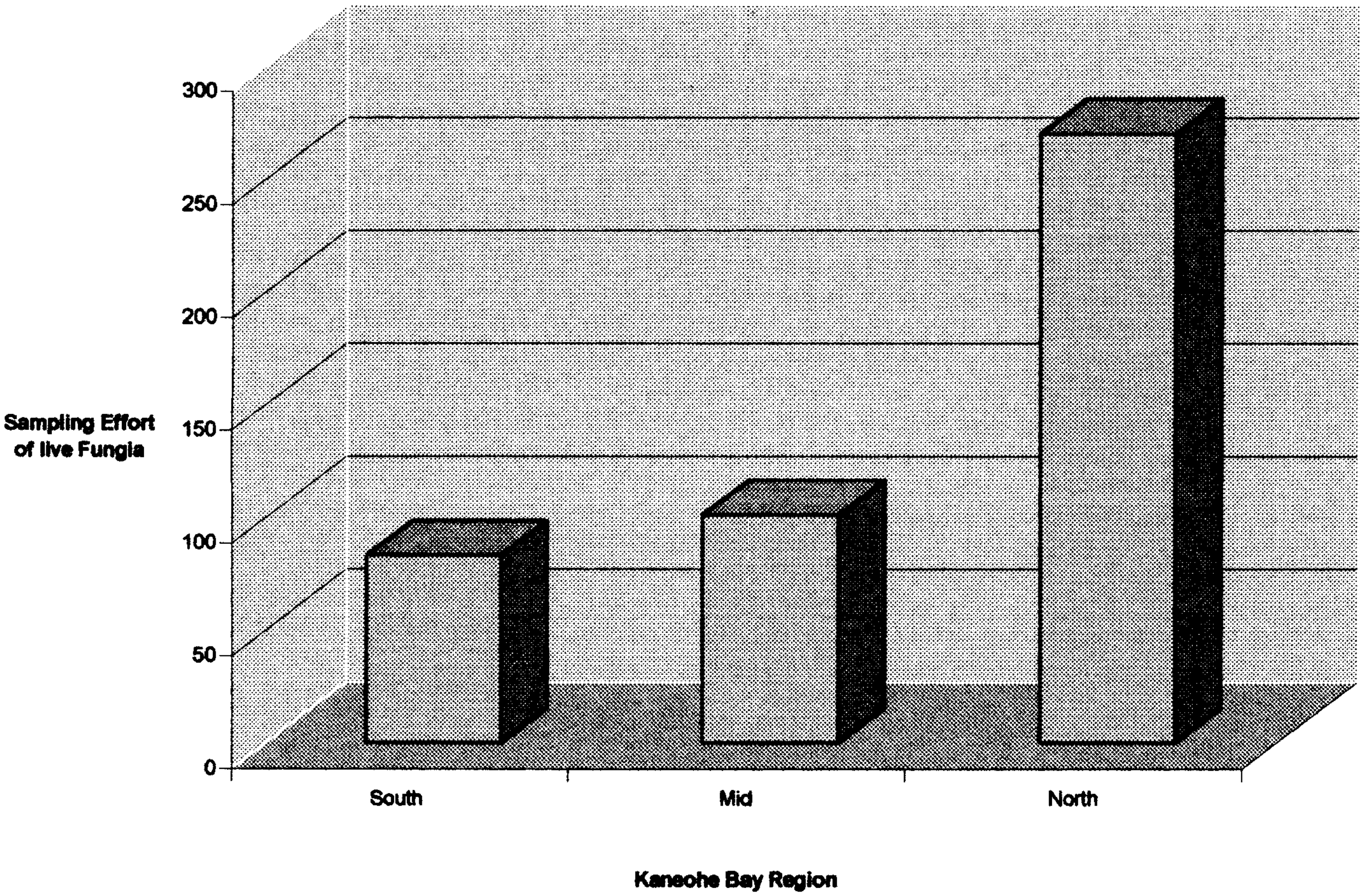


Figure 8. <u>Size class distribution of *Fungia Scutaria* in Kaneohe Bay</u>

<u>Size classes defined</u>:

XS = extra small, <5 cm in length
S = small, <9 cm in length
M = medium, 9-12 cm in length
L = large, >12 cm in length

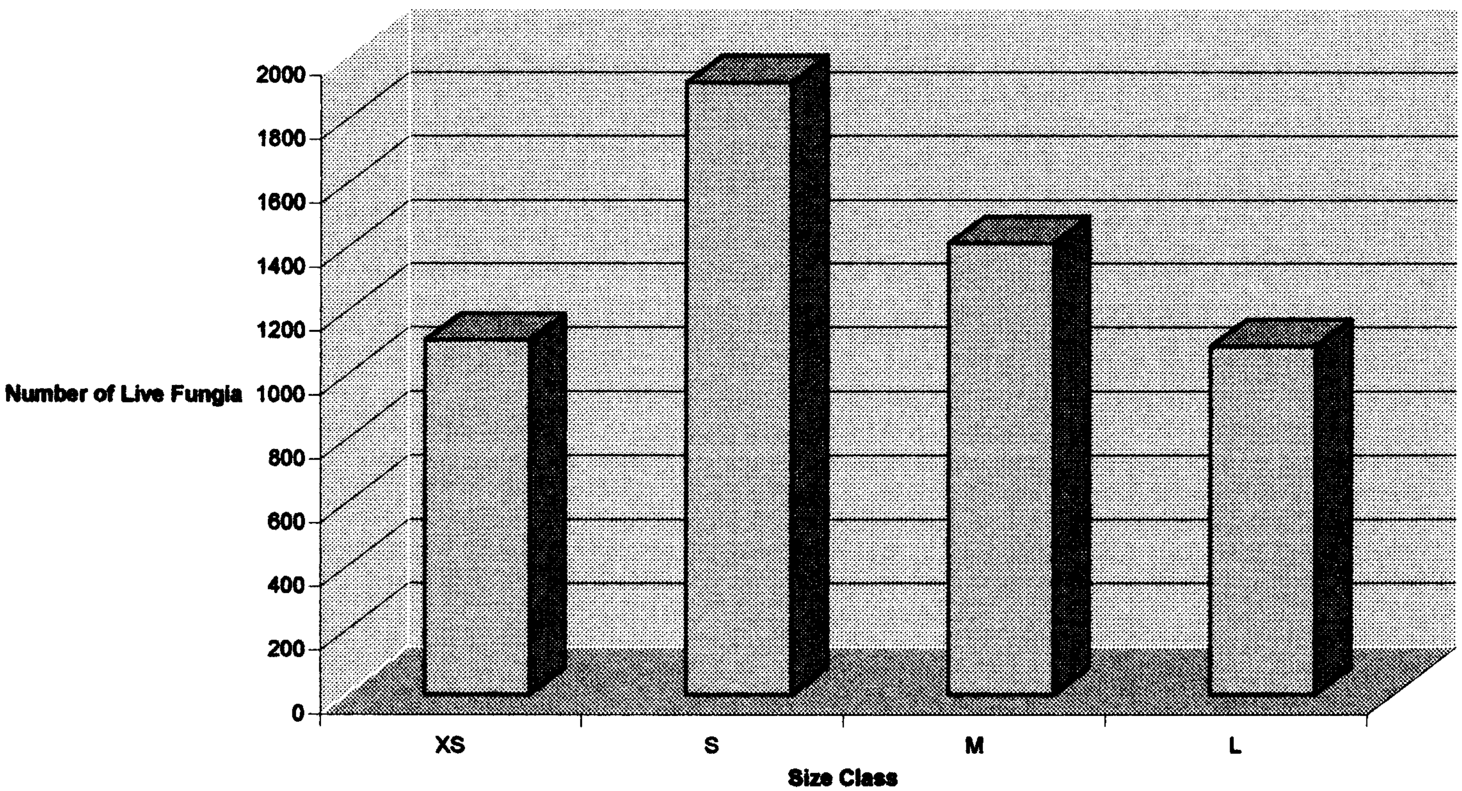


Figure 9. Average number of dead *Fungia scutaria* surveyed per hour vs. Kaneohe Bay region

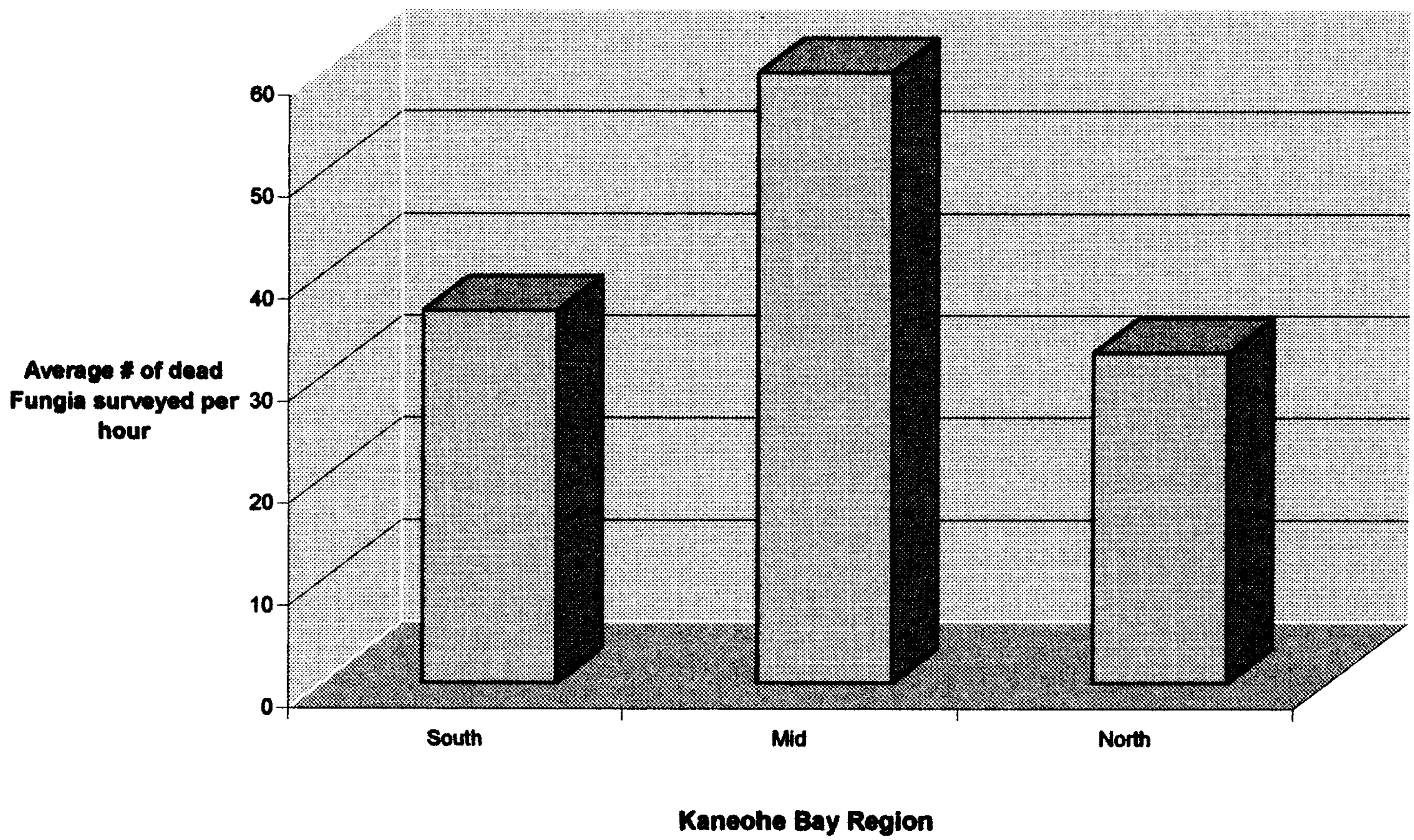


Figure 10. Reef health vs. Kaneohe Bay region

The following figure represents the survey of reef health throughout the three regions of Kaneohe Bay: the South Bay, Mid Bay, and North Bay. Reef Health has been classified as "good", "ok", and "poor" and has been represented in the chart as follows:

- ▨ = percentage of reef in good condition
- ▨ = percentage of reef in ok condition
- ☐ = percentage of reef in poor condition

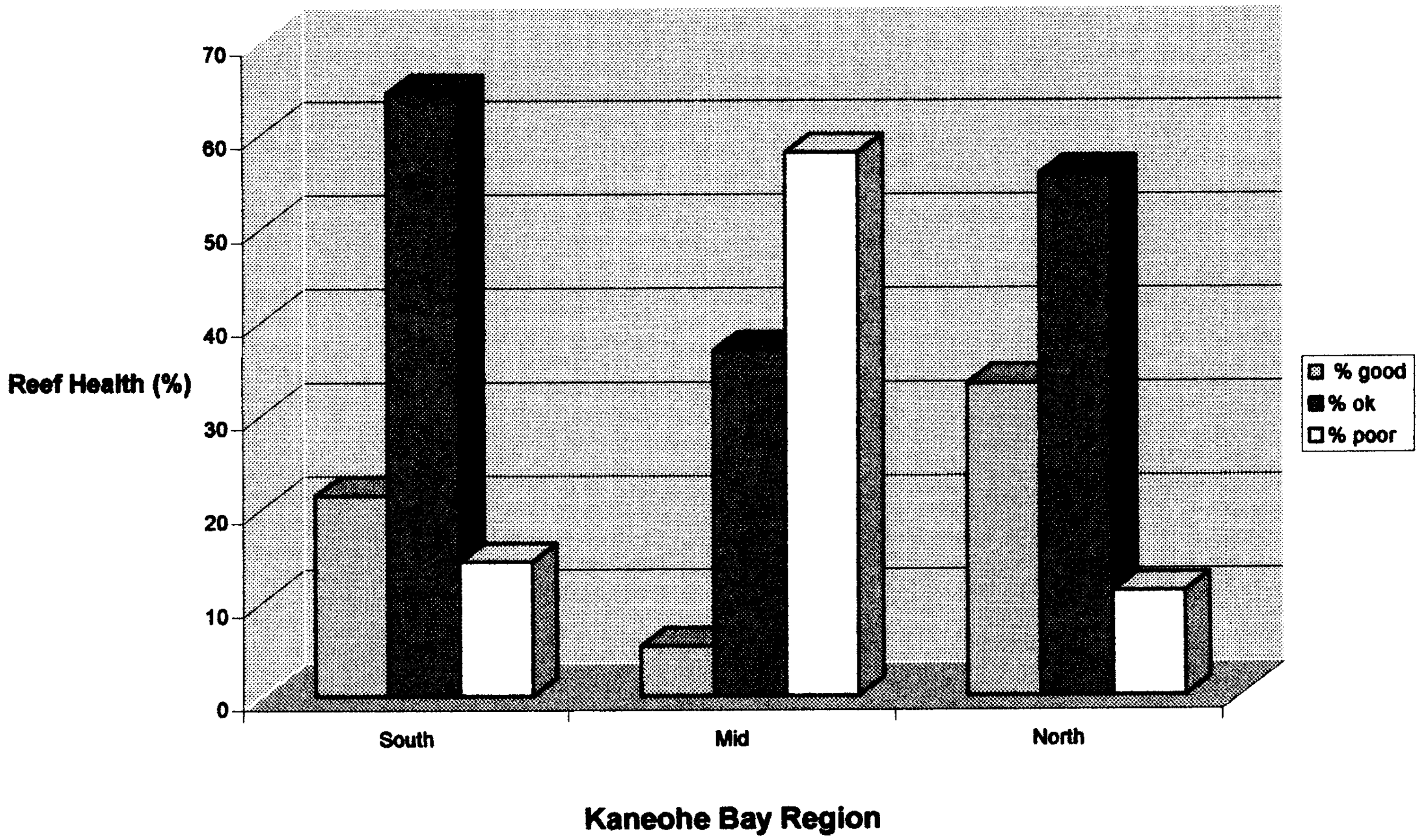
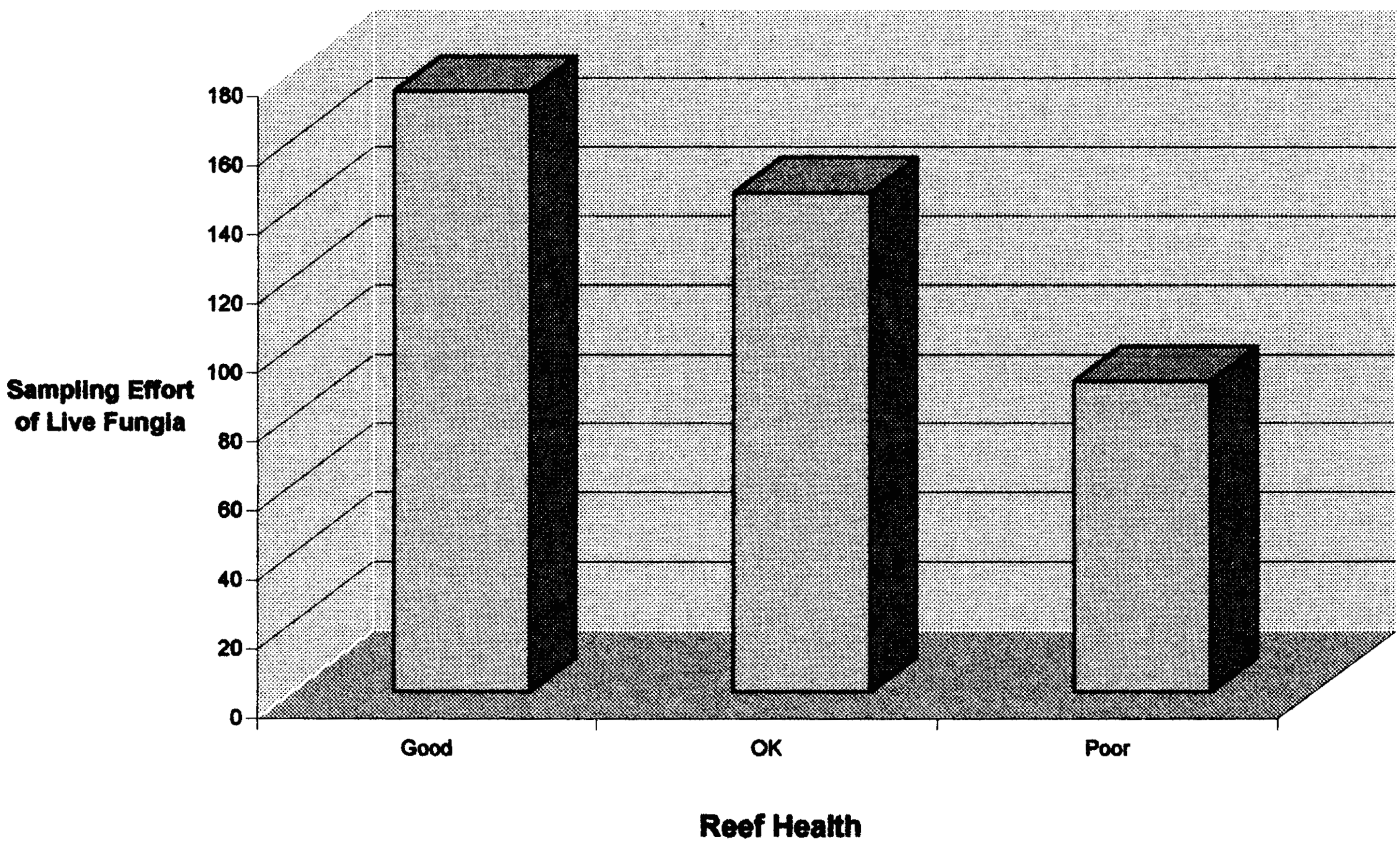


Figure 11. <u>Sampling effort of *Fungia scutaria* vs. reef health</u>

Sampling effort is classified as the average number of live *Fungia* surveyed at patch reef by snorkeler per hour swimming. Reef health is classified from "good" to "ok" to "poor".



APPENDIX

Table 1. *Fungia scutaria* abundance and distribution: raw data

Raw data were taken from 42 patch reefs in Kaneohe Bay and placed under "Location" heading. Three bay regions are demarcated as North, Mid, and South bays. Reef health is classified into three categories, "good" health, "ok" health, and "poor" health. Data collected on *Fungia scutaria* consisted of: total number of live and dead *Fungia* counted per 1 hour snorkeling; size class distribution of XS, S, M, and L; aggregation (clumped, and clumped with same phenotype); and habitat (under crevices).

Location	Total Live	XS	S	M	L	Crevices	Clumped	Clmp same	Dead	Reef Health	Bay Region
Reef A	0	*	*	*	*	*	*	*	0	ok	South
Coco N (1A)	63	3	31	23	6	55	51	51	2	ok	South
Coco E (1B)	32	0	10	14	8	22	22	22	84	ok	South
Coco S (1C)	31	2	12	6	11	22	16	16	10	good	South
Coco W (1D)	8	0	4	1	3	8	6	2	1	ok	South
Chekr N (8A)	176	31	60	35	50	53	79	50	43	ok	South
Chekr S (8C)	44	14	16	7	7	19	22	20	164	ok	South
Chekr W (8D)	100	26	44	24	6	37	61	61	24	ok	South
Reef 2	48	7	12	14	15	32	35	35	16	poor	South
Reef 3	33	15	10	2	6	26	25	22	22	good	South
Reef 4	51	18	13	15	5	21	32	32	16	poor	South
Reef 5	119	65	32	18	4	95	87	85	14	ok	South
Reef 6	326	31	98	128	69	167	246	198	45	good	South
Reef 7	132	20	27	22	63	19	73	73	68	ok	South
Reef 9	98	15	29	24	30	19	58	55	105	poor	Mid
Reef 10	147	15	48	43	41	62	82	82	60	poor	Mid
Reef 11	28	2	11	9	6	9	14	14	261	ok	Mid
Reef 14	44	6	13	7	18	6	27	27	146	poor	Mid
Reef 15	36	7	9	6	14	12	18	18	38	poor	Mid
Reef 16	53	0	13	8	32	2	26	26	203	poor	Mid
Reef 17	366	14	164	124	64	143	293	269	43	poor	Mid
Reef 18	175	35	67	55	18	115	129	126	12	ok	Mid
Reef 19	24	2	7	7	8	2	18	18	29	poor	Mid
Reef 20	23	3	10	5	5	4	6	6	28	poor	Mid
Reef 21	14	1	3	4	6	0	0	0	40	poor	Mid
Reef 22	59	21	9	8	13	33	34	34	15	poor	Mid
Reef 23	46	19	14	10	3	31	29	29	6	ok	Mid
Reef 24	93	21	32	23	17	29	49	47	25	poor	Mid
Reef 25	181	48	65	44	24	112	132	116	15	ok	Mid
Reef 26	122	43	35	25	19	25	70	65	31	ok	Mid
Reef 27	146	52	48	32	14	68	87	87	49	ok	Mid
Reef 28	141	63	60	15	3	68	87	87	13	ok	Mid
Reef 29	124	47	61	14	2	61	74	74	16	good	Mid
Reef 30	397	52	196	104	45	228	289	271	25	ok	North
Reef 31	303	130	95	48	30	243	234	224	82	ok	North
Reef 32	162	33	83	41	15	138	144	139	7	ok	North
Reef 33	127	5	56	34	32	115	100	95	15	good	North
Reef 34	204	47	65	59	33	147	168	160	16	poor	North
Reef 38	286	85	86	66	49	181	213	199	29	ok	North
Reef 39	358	46	102	97	112	202	299	288	41	good	North
Reef 40	218	29	49	68	72	139	167	157	27	good	North
Reef 41	374	26	116	122	110	215	298	249	49	ok	North

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