Coral Reef Monitoring
Kapoho, Hawai'i
1995

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Abstract

Coral reef ecosystems, valued as a source of beauty, scientific importance, food, and diversity of life, are falling prey to the plundering of industrialized man. Around the world reefs are suffering, yet the true cause and resulting condition of health remain largely unknown. One of the only solutions lies in creating a worldwide coral reef monitoring program. This technique allows for normal fluctuations to be recorded, which can then act as a template for comparison if and when environmental conditions change, either naturally or anthropologically. This research contributed to the collection of data on the world's coral reefs by continuing a four year long monitoring program surveying coral bleaching, percent coral coverage, and fish and invertebrate abundance at Kapoho, Hawai'i. Analysis shows that there has been no significant change in coral bleaching or fish and invertebrate abundance over time. Significant difference was found between brightness of coral species, between abundance of fish in 1995, and coral coverage between years, and coral coverage (1994-1995) between transects. This study has succeeded in strengthening the standardization which will facilitate further studies of coral reef monitoring at Kapoho.

Introduction

Coral reefs rank among the most biologically productive of all marine ecosystems. And they have been compared to rainforests in their species richness and diversity (Brown & Ogden 1993). Corals are very delicate and extremely intolerant of environmental changes. Any imbalance in their environment such as disease, excessive ultraviolet radiation, pollution, sedimentation, or changes in salinity or temperature can cause corals to bleach (Brown & Ogden 1993). Coral bleaching can have a major impact on the health of the whole reef system. As corals are lost to bleaching so to is the environment that provides shelter and food to hundreds of species of fish and invertebrates. Unfortunately during the past ten years, acute and chronic bleaching of tropical reef corals has occurred with increasing frequency and scale (Gates *et al.*, 1992). And some reefs have suffered such high coral mortality that bioerosion now exceeds net carbonate production and threatens to reduce well-established reef structures to sediment (Glynn 1991).

An integral part in discovering more about the working of the reef system requires standardized, long-term monitoring to assess environmental change (Glynn 1991, 1993). Without being knowledgeable about the "normal" fluctuations of a particular reef system before an environmental change, there is little chance of being able to differentiate the natural variations over time from those changes resulting from an environmental incident, either human-caused or natural. Local monitoring of coral reefs is vital in obtaining this knowledge. Any change in the reef can be assessed and compared to other reefs around the world. If a network of sites that conducts cooperative observations were set up worldwide, then the extent of change in coral reefs can be determined globally. Right now, the Caribbean Coastal Marine Productivity Program is a cooperative research network of more that 20 Caribbean countries set up to monitor reef ecology in their waters (Brown & Ogden 1993). But as yet there is no international monitoring effort in the central and Western Pacific Ocean, an area that has a huge amount of reef systems. Project like Kapoho reef monitoring can help create interest in a cooperative monitoring effort that would oneday encompass the entire Hawai'ian Island chain.

For the past four years research has been done at the Coral Garden in Kapoho, Hawai'i to establish a baseline monitoring study by examining the degree of coral bleaching, and the diversity of coral, fish, and invertebrates in each year. This data can then be used to test the following hypotheses; H1) The overall percent cover of coral has changed from 1992-1995, including a change in the cover of the dominant species; H2) There has been a significant increase in instances of coral bleaching; and H3) The diversity and abundance of significant fish and invertebrates has changed in the past four years.

Materials and Methods

Data was collected from the coral garden at Kapoho, HI. every Thursday afternoon from two p.m. to four p.m. during the weeks of June 15 to July 18. Three 10 meter, permanent transects were haphazardly placed in 1991 allowing for temporal changes to be observed (Figure 1). To ascertain the diversity of fish, a strip transect was swam by two snorklers on either side, noting all species and numbers of fish in the water column within nine meters of each side of the transect (Figure 2). The fish transects were swam twice, once for incriptic species and once for cryptic species, and two three replications were done on each transect (Table 1). Diversity of invertebrates was then determined by using a square meter square, constructed of PVC pipe and broken into four equal sub-squares, placed along the right side of the transect with the lower left hand corner of the quadrat touching the meter mark on the transect. Ten quadrats per transects were recorded (Table 2,3,4). Each quadrat was inspected for species and abundance of invertebrate inhabitants. Coral cover and bleaching was measured by 1 meter square photoquadrats taken every meter along the transects, again with the lower left hand corner of the quadrat touching the meter marks on the transect. This process yielded 18-20 slides of coral cover per transect.

Int he lab, the slides from 1994 and 1995 were projected on to a 555mm by 365mm sheet of paper with 50 random marked points. The corresponding substrate under each point was recorded. This was then used to estimate the total percent coral cover and the coverage of individual species. Only slides from 1994 and 1995 were analyzed in this fashion. No photoquadrats were taken for 1992 and 1993 (Table 5). These data points were then used by a Sigmascan program to determine the exact percent coral coverage. The degree of coral bleaching was determined by scanning the slides into the computer and using Sigmascan to digitally analyzed the amount of coral that was bleached. To adjust the pixel intensity to account for different lighting in each slide, a total maximum value for the PVC was found to be 254. The maximum value of the PVC on each slide was subtracted from the total maximum value and then the result was added to each pixel value on that slide. For each species, a sample of coral was selected from a slide, then the brightness of that sample was calculated by Sigmascan. By comparing the averages of pixel intensities, a range of normal to bleached was determined for each coral. This method enabled the bleaching of an individual coral head in 1994 to be compared to its present state in 1995. This computerized system has standardized (Beiswenger & Larson 1994) the measurement of bleaching for this experiment to obtain more accurate assessments of coral cover variations and coral bleaching changes to reduce researcher bias in evaluation.

Statistical analysis was then run on the entire data using the Minitab statistical program.

Results

To test the first hypothesis; that the percent coral cover has not changed from 1992-1995, we first ran general linear model statistics on data gathered in 1994 and 1995. GLM was used because the sample sizes were different between years. From this test we found that the only significant difference was between transects. Years, and transects between years were not significantly different (Table 6). To compare changes in coral coverage between years only, we ran a One-way ANOVA of percent coral cover for 1992-1995, five values were found because the data from 1994 was entered as both as human estimated, and taken from photoquadrats (Table 7) (Blair *et al* 1992, Quelch *et al* 1993, Giorno *et al* 1994). From this test, we had a P value of 0.000, which rejected our first hypothesis. So there has been a significant change of coral cover since 1992.

To test our second hypothesis that there has not been an increase in coral bleaching in the past four years, we ran a three-way ANOVA, testing change in coral brightness between species, colonies, and years (Table 8). From this test we determined that the null hypothesis was accepted for all data sets except species. There was a significant difference in brightness between species. *Porites lobata* was shown to be the brightest, followed by *Porites varians*, and *Montipora verrucosa* was the darkest (Figure 3). But there was no significant difference in bleached coral between the years of 1994 and 1995.

Our third null hypothesis states the diversity and abundance of dominant fish and invertebrates has not changed in the past four years. We tested the hypothesis on the fish, we ran a one-way ANOVA on the top three species for each year. From the P-value seen on Table 9 we found that there has been no significant change in the abundance of dominant species of fish in the past four years. To determine the differences in abundance of fish for 1995 only, a one-way ANOVA was run for the top five most abundant fish observed (Table 10). The P-value shows there is a significant difference in abundance of fish for 1995. Statistical analysis of invertebrate data was not possible because individual quadrat data could not be obtained from the 1992-1994 studies. To find differences in abundance of invertebrates for 1995 only we compared the mean number of individuals per 10 meter square and found that *Echinometra mathaei* is the most abundant (Figure 4). To determine any change in invertebrate abundance, we graphed the two dominant species of 1995 and compared them to counts taken from 1992-1994. Figure 5 shows changes in *Echinometra mathaei* densities over the past four years. 1992 showed almost 180 mean number of individuals, while data from 1995 shows a marked decrease of mean number of individuals per 10 meter square. Changes in the population of *Spirobranchus giganteus* are shown to be relatively consistent for 1992, 1994, and 1995 (Figure 6).

Discussion

In figure 7, there is a noticeable decrease in the estimation of percent coral cover for the photoquadrats taken in 1994 and 1995, and the human estimated percent coral done in 1992-1994. Studies from 1992-1994 showed a significant decrease in coral coverage over three years, but the photoquadrat data from 1994 and 1995 showed no significant difference of coral cover between these two years. The fact that there is no significant difference between 1994 and 1995 helps validate the marked decrease in percent coral coverage between data taken by human estimation methods in 1994, and photoquadrat data for 1994. It is this teams opinion that the photoquadrat method is much more accurate in estimation the true percent coral cover, because there is almost no human bias possible.

Our analysis of coral bleaching found no significant difference of the amount of coral bleached among years and transects. This means that there is either, not a detectable bleaching problem at Kapoho, or that bleached coral species are able to recover or recolonize within one year. The lack of difference between transects could suggest that there is an overall effect of bleaching at the coral garden rather than isolated instances of bleaching. The only significant difference we found was between brightness levels of species. This can easily be explained by natural coloration of the individual coral species. *Porites lobata* was shown to be the brightest coral species, and lobe coral is normally light yellow color, and *Montipora verrucosa*, which is normally brown in color, was found to be the darkest species. These results verify the Sigmascan method of determining bleached coral as being reliable.

Figure 8 shows the most abundant fish species for 1995 was *Thallosoma duperrey*. The fact that this fish is more abundant than the other species, and has been for the past four years suggest that *Thallosoma duperrey* is an extremely adaptive species, and very hearty. Although there was shown to be no significant change in the abundance of the top three species over the past four years, figure 9, 10, and 11 show how the high standard error could have skewed the statistics and caused a type I error. More replicates of the fish transects would help to increase N and lower the standard error. The ranking of the top five species according to mean numbers of individuals per 10 meter square has changed every year, *T. duperrey* being the only constant. This could be caused by a yearly changed in researchers with individual biases.

Without statistical analysis, it is difficult to make assumptions about the invertebrate populations. However, from figure 5 we can see that there appears to be a significant decrease in the *E. mathaei* populations. The decline in *E. mathaei* populations of *Spirobranchus giganteus* have remained stable for 1992, 1994, and 1995. The big number of individuals found in 1993 is thought to be a mistake made by that years researchers (Figure 6). A comparison of invertebrate abundances for 1995, Figure 4, shows that E. mathaei remains the most abundant invertebrate at Kapoho, even though its numbers are decreasing. This indicates that the invertebrate populations as a whole may be decreasing.

The Kapoho reef monitoring survey is invaluable in increasing the general knowledge of reef ecology. However, standardization of methods must be upheld in order to use the data gathered in a more productive manner.

Literature Cited

Beiswenger, James & Christy Larson 1994
Percent Coral Cover and Bleaching Survey: Kapoho Summer 1994, unpublished

Blair, Kelley & Michelle Clapper 1992
Kapoho Tide Pool Survey 1992, unpublished

Brown, Barbara E. & John C. Ogden 1993
Coral Bleaching, Scientific American 268: 64-70

Gates, Ruth D., Garen Baghdasarian, & Leonard Muscatine 1992
Temperature Stress Causes Host Cell Detachment in Symbiotic *Cnidarians:* Implications for Coral Bleaching, Biological Bulletin 182: 324

Giorno, Frank., Ty Fuller, & Joe Raffaele 1994
Coral Reef Monitoring Kapoho Bay, Hawai'i, unpublished

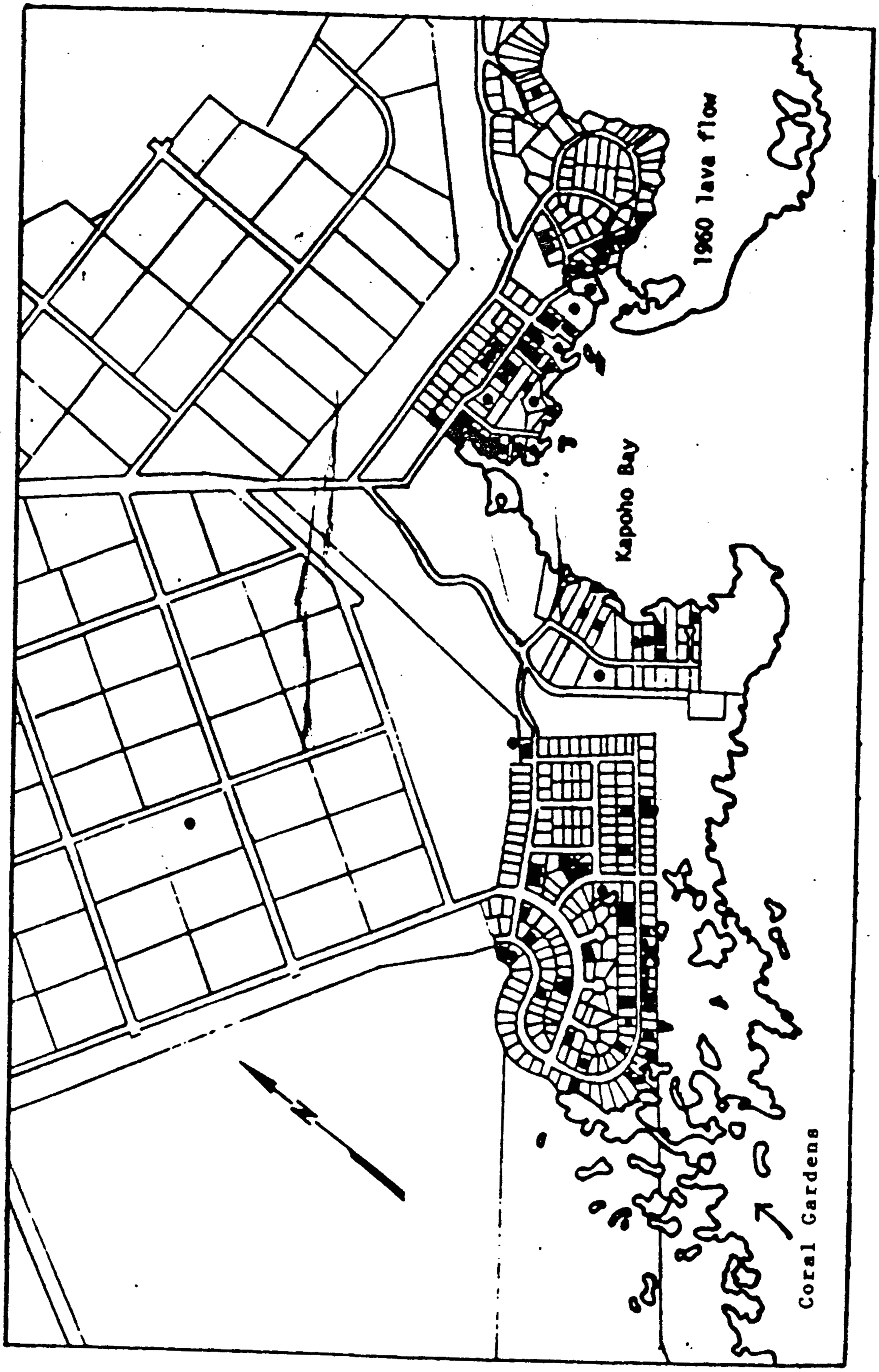
Glynn, Peter W. 1993
Coral Reef Bleaching: Ecological Perspectives, Coral Reefs 12: 1-17

Glynn, Peter W. 1991
Coral Reef Bleaching in the 1980's and Possible Connections with Global Warming, Trends in Ecology and Evolution 6: 175-180

Quelch, Cyndi., James Gawlowski, & Josh Derby 1993
Coral Reef Monitoring, Kapoho Bay, Hawai'i, unpublished

Appendix

Figure 1

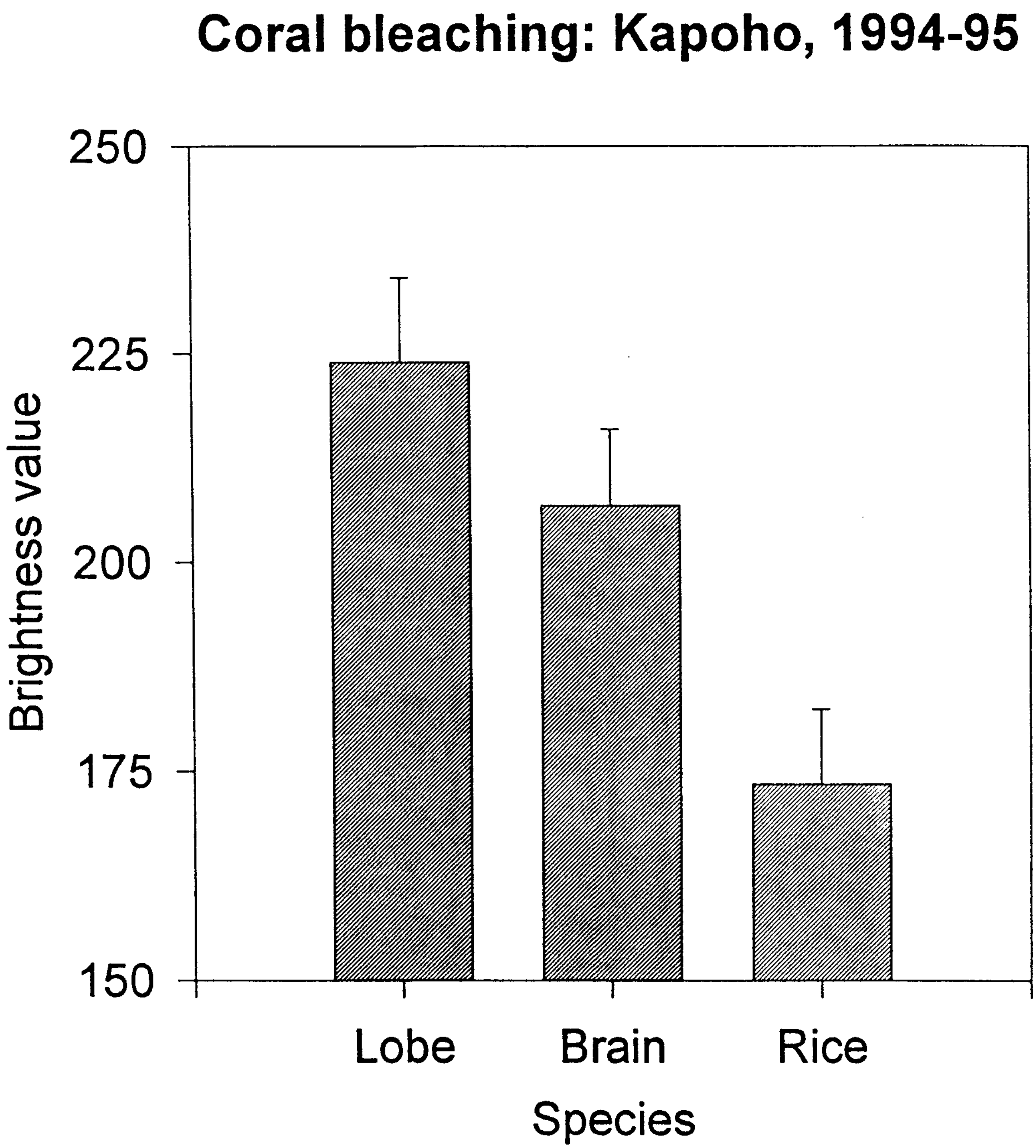


"CORAL GARDENS" KAPOHO, HAWAII

PERMANENT TRANSECT LINE 1

Z	Y	X	A	B	C
		10			
		9			
		8			
		7			
		6			
		5			
		4			
		3			
		2			
		1			

START OF TRANSECT


Coral bleaching: Kapoho, 1994-95
250
225
200
175
150
Brightness value
Lobe
Brain
Rice
Species

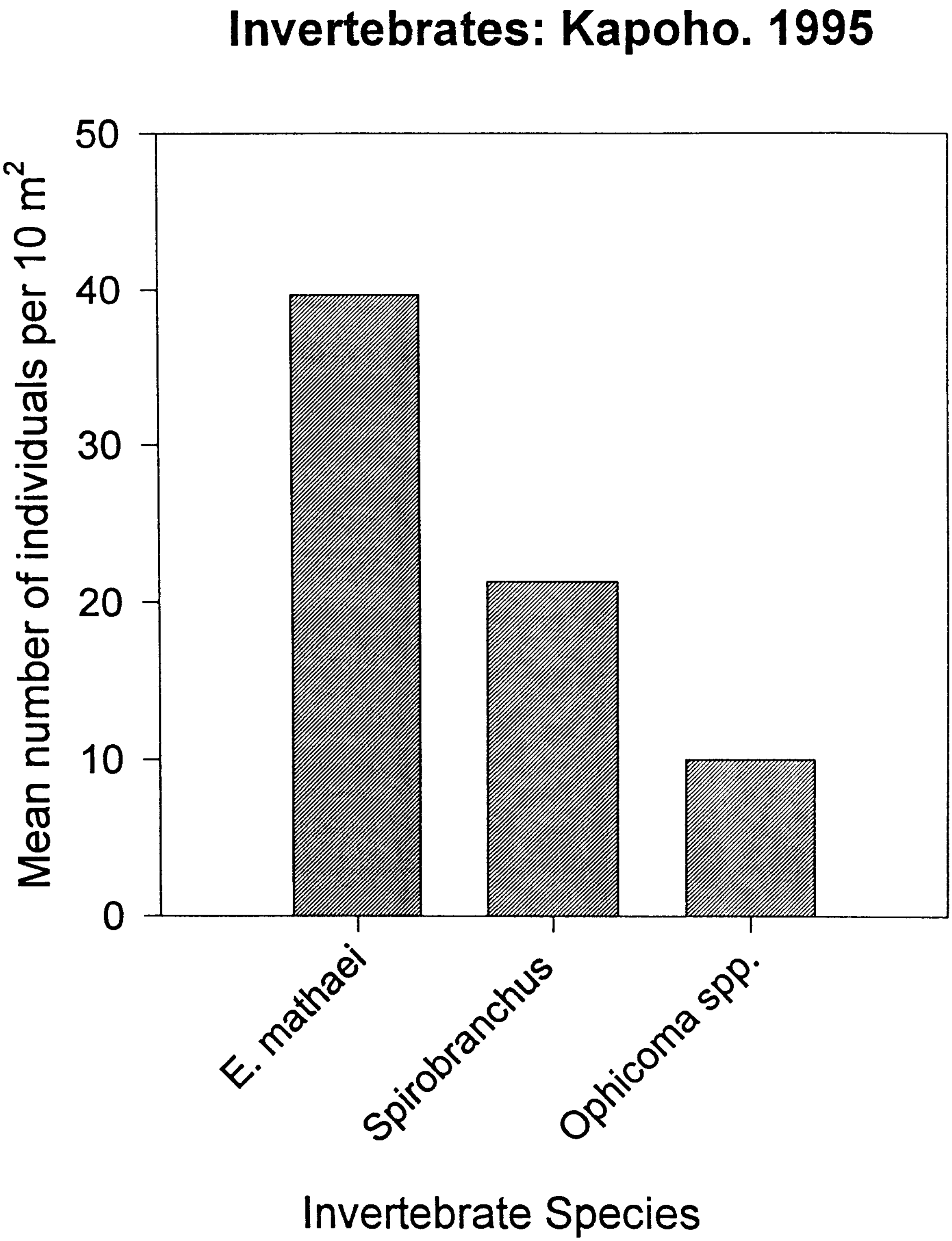
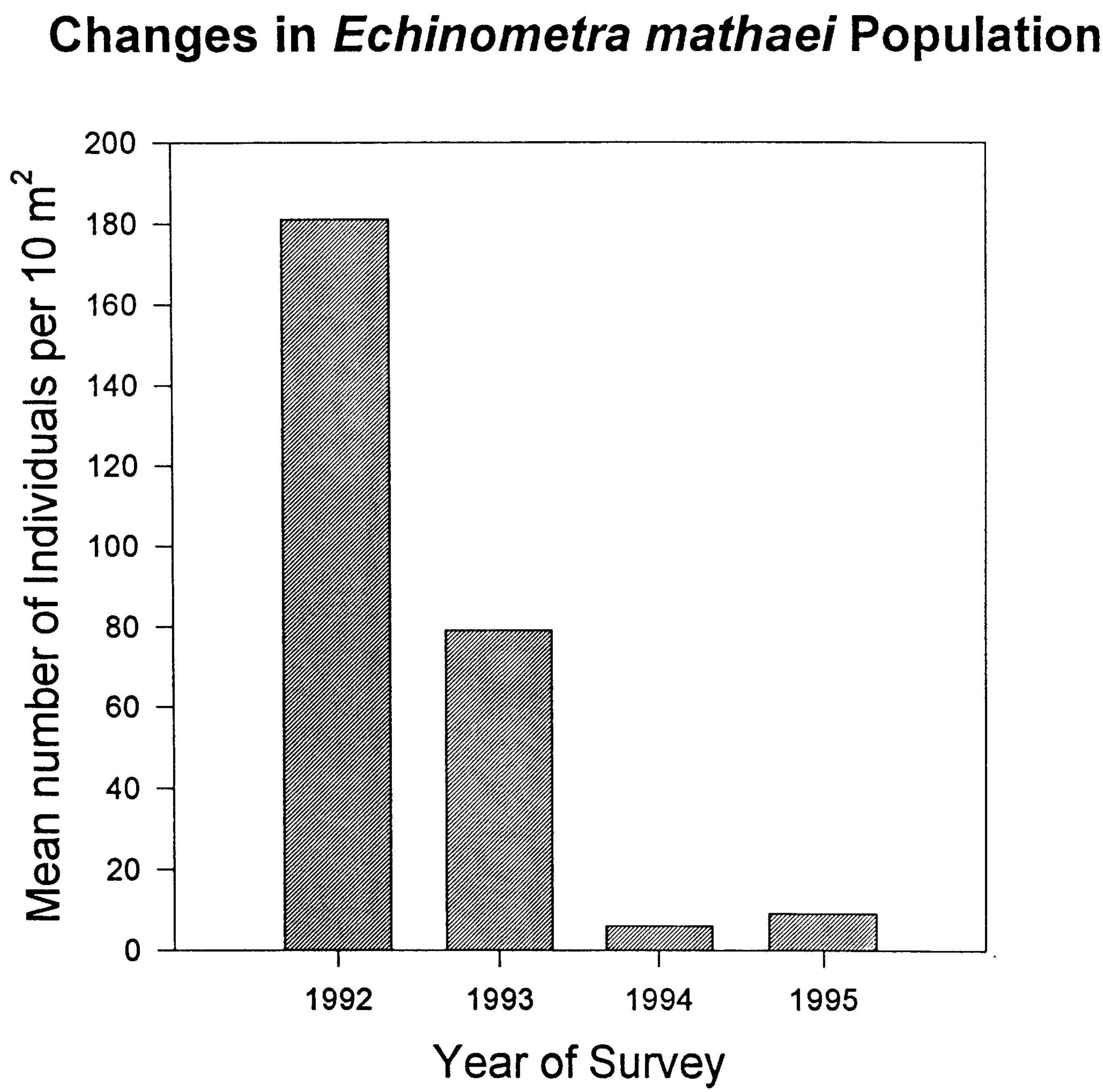
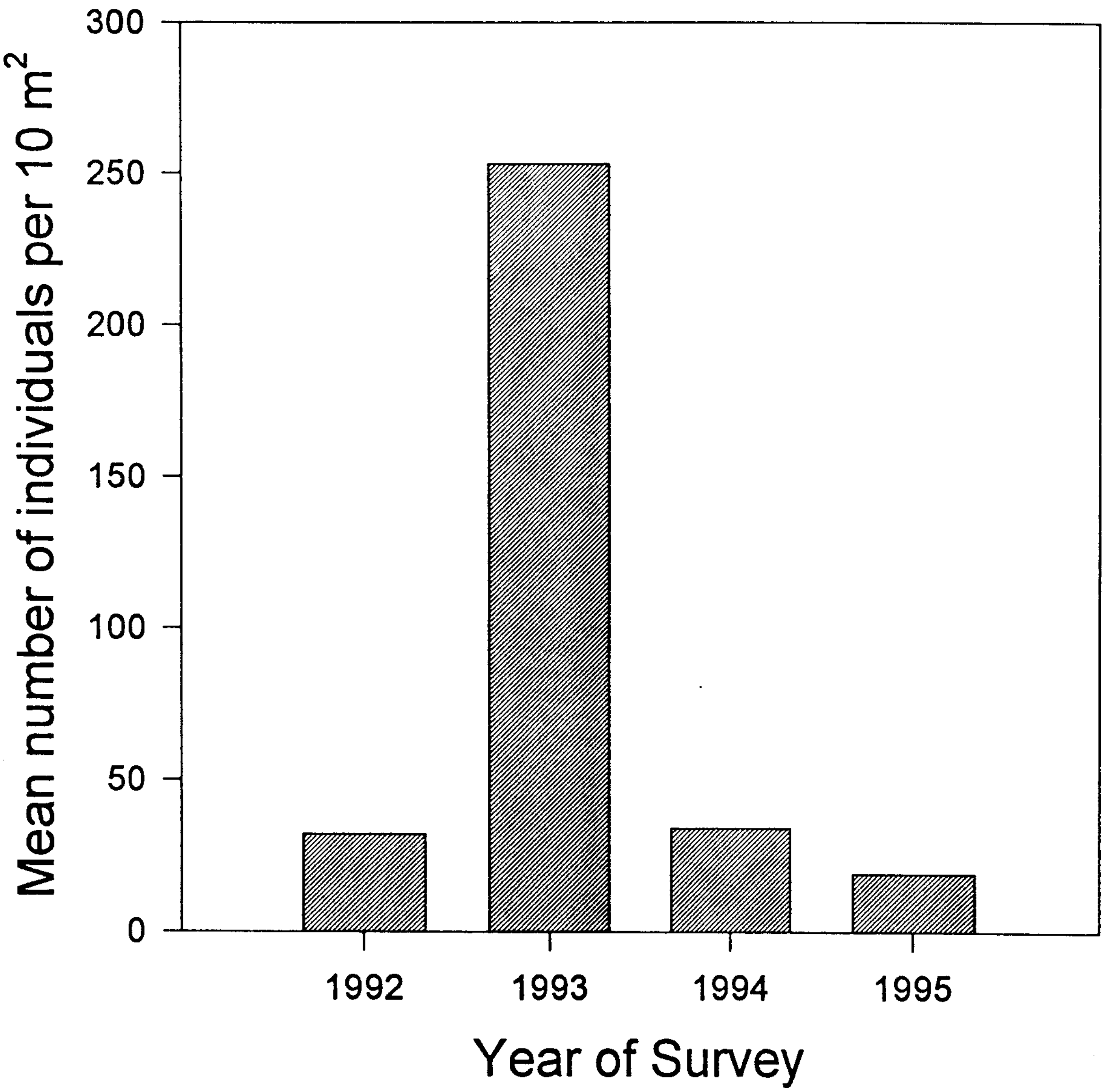

Invertebrates: Kapoho. 1995
Mean number of individuals per 10 m2
0
10
20
30
40
50
E. mathaei
Spirobranchus
Ophicoma spp.
Invertebrate Species

Figure 5


Changes in *Echinometra mathaei* Population
Mean number of Individuals per 10 m²
200
180
160
140
120
100
80
60
40
20
0
1992
1993
1994
1995
Year of Survey

Changes in *Spirobranchus giganteus* Population



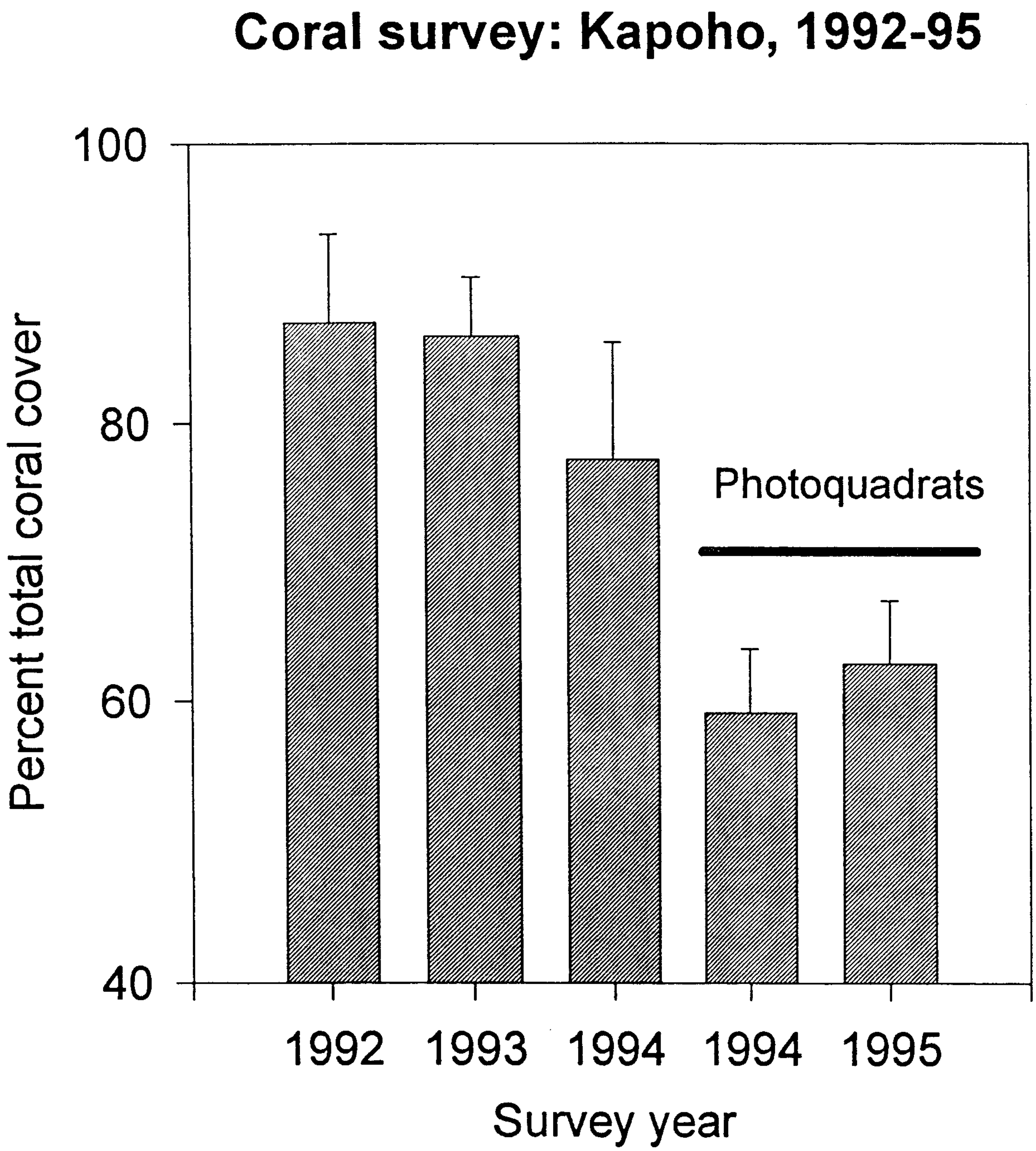
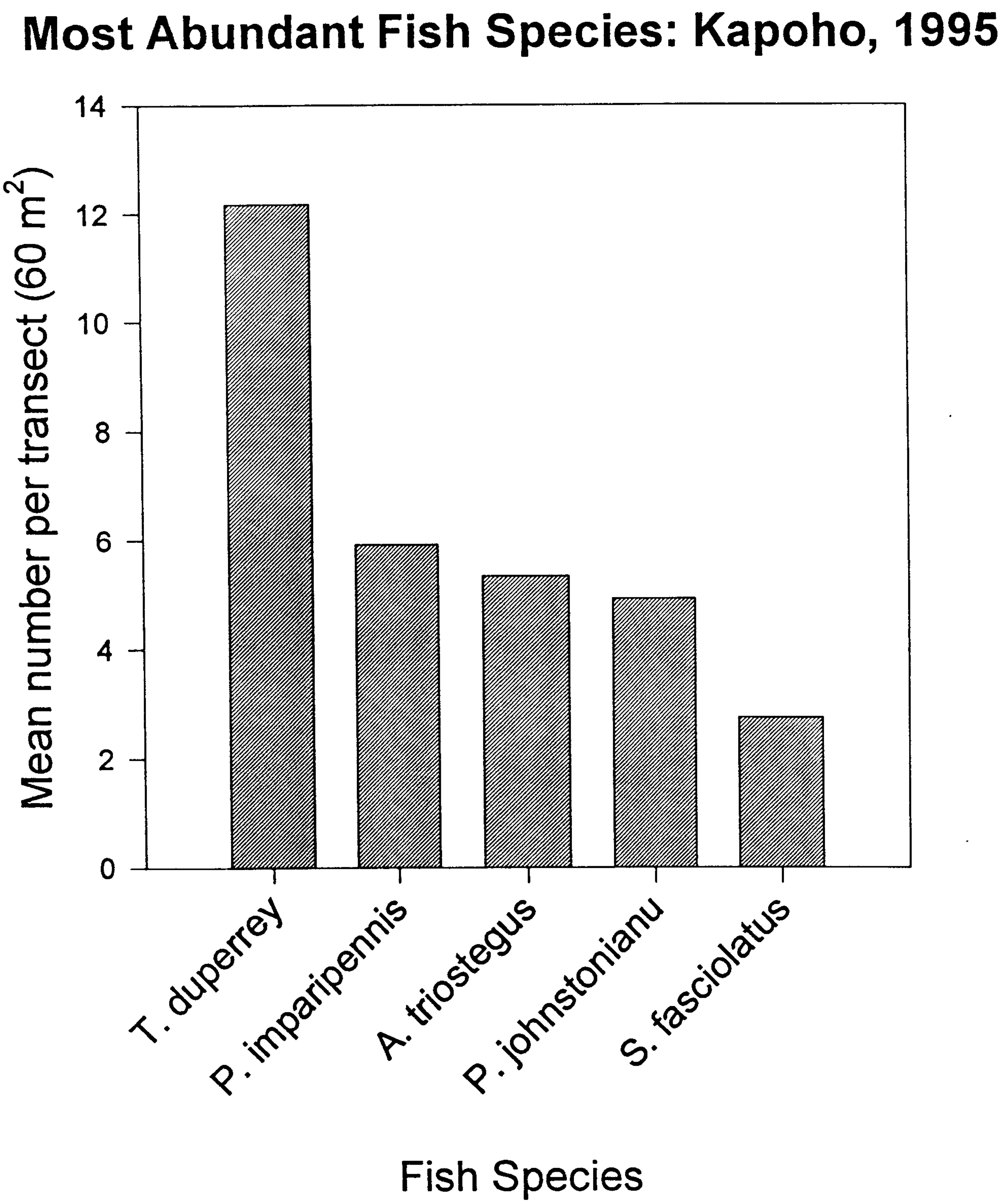
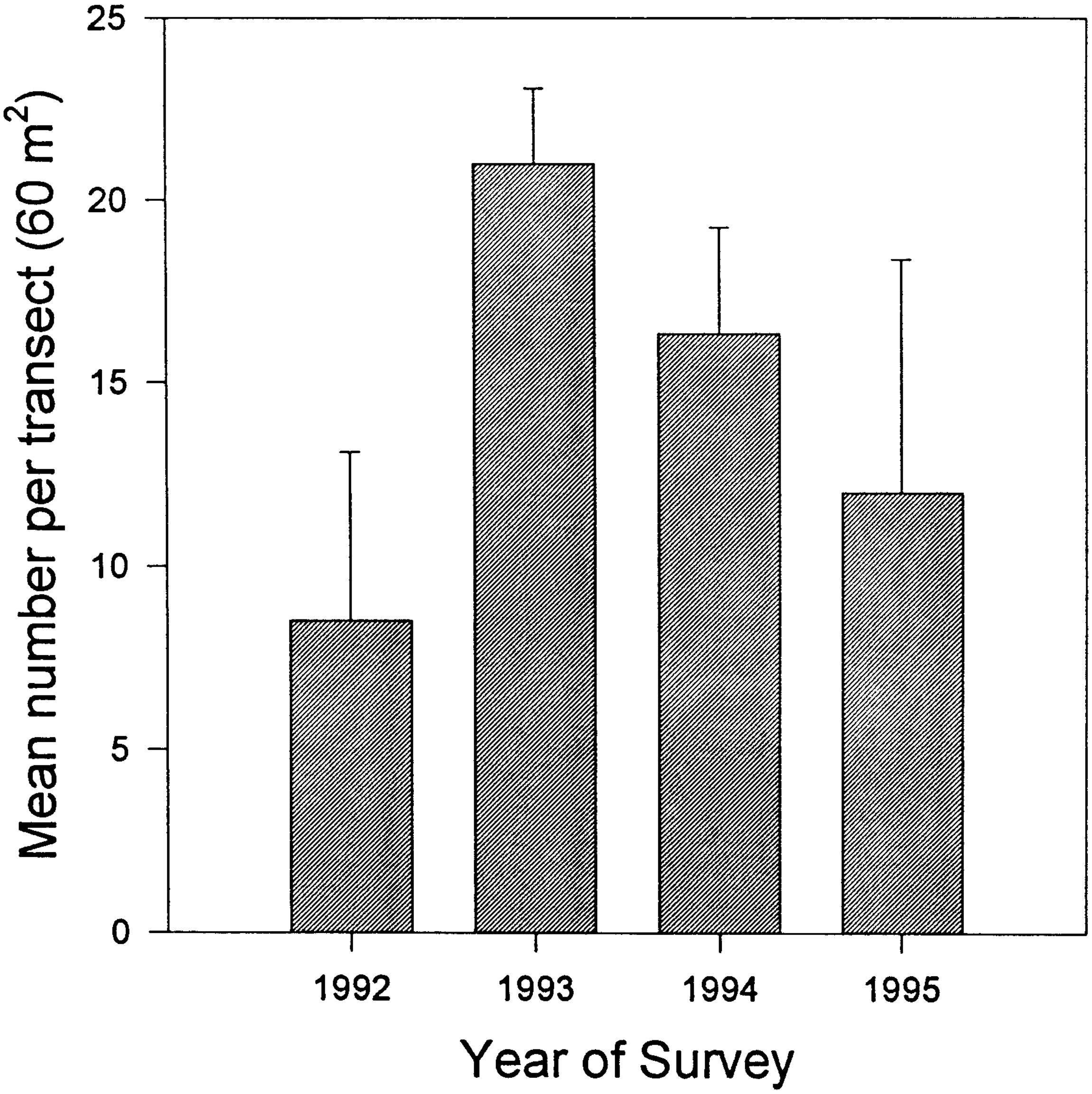

Coral survey: Kapoho, 1992-95
100
80
60
40
Percent total coral cover
Photoquadrats
1992
1993
1994
1994
1995
Survey year

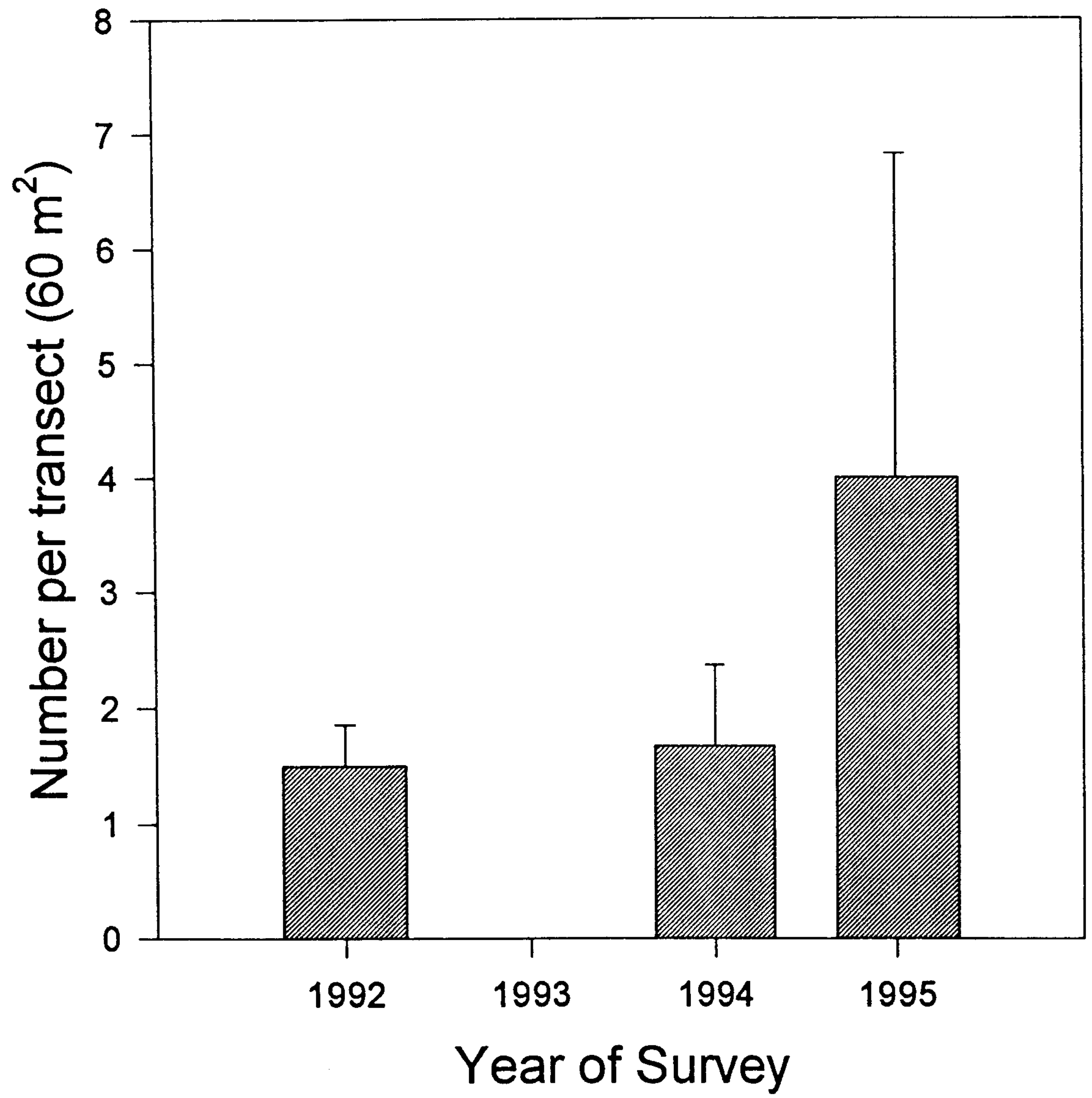
Figure 8


Most Abundant Fish Species: Kapoho, 1995
Mean number per transect (60 m2)
14
12
10
8
6
4
2
0
T. duperrey
P. imparipennis
A. triostegus
P. johnstonianu
S. fasciolatus
Fish Species

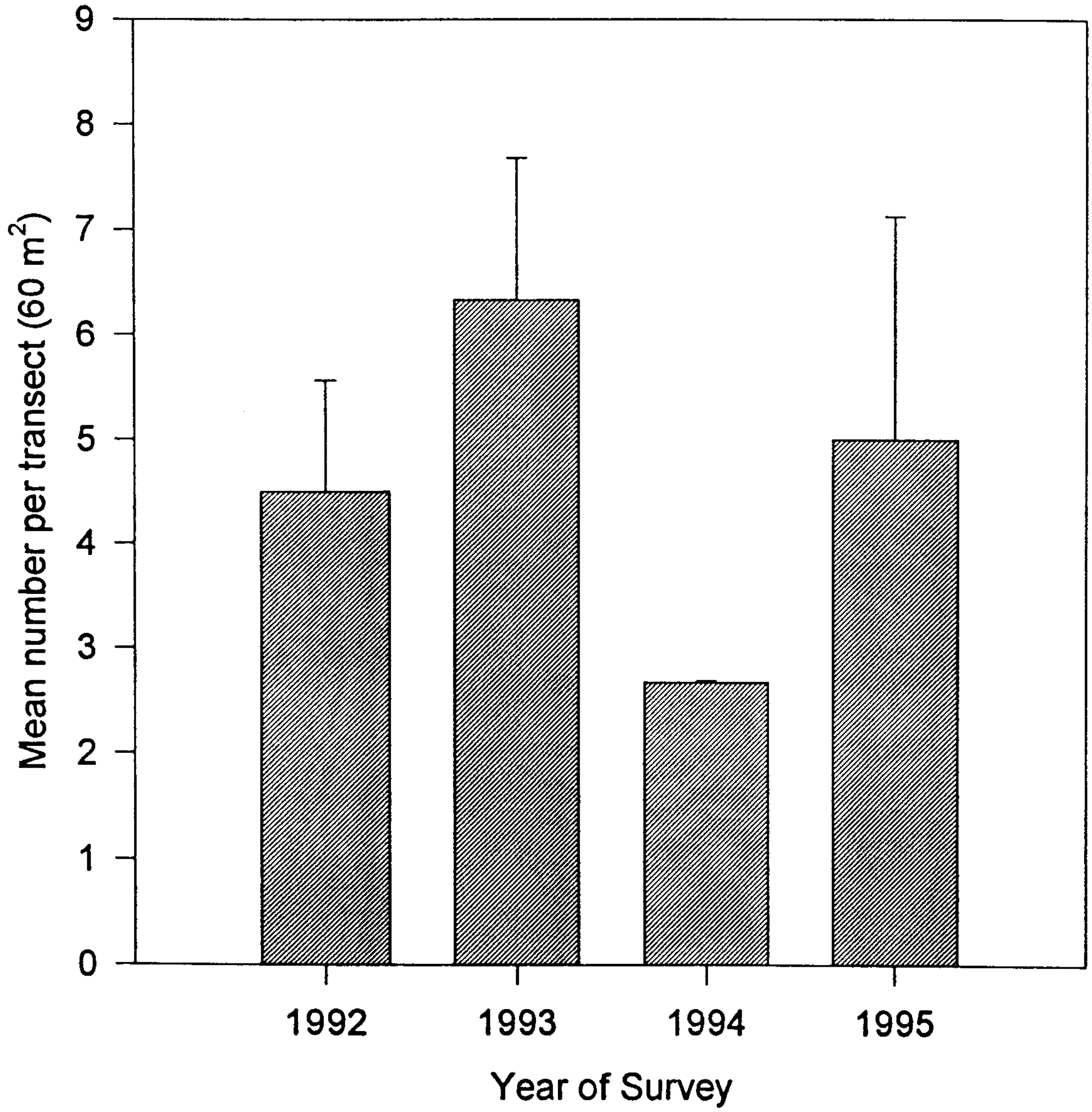
Change in *Thallosoma duperrey* Population



Changes in *Plectroglyphidodon imparipennis* Population



Changes in *Acanthurus triostegus* Population



Fish 1995	Kat 7-6 Transect 1	Kat 7-13 Transect1	Mean Transect 1	Kelly Transect 2	Kelly 7-13 Transect 2	Kat Transect2	Tom Transect 2	Mean Transect 2	Kelly Transect 3	Tom Transect 3	Mean Transect 3
Chaetodon auriga	0	0	0	0	0	0	0	0	0	0	0
Chaetodon quadrimaculatus	1	0	0.5	0	0	0	0	0	0	0	0
Chaetodon lunula	2	0	1	0	0	3	1	1	0	0	0
Chaetodon miliaris	0	0	0	0	0	0	0	0	0	0	0
Chaetodon ornatissimus	0	2	1	0	0	1	0	0.25	0	0	0
Chaetodon multicinctus	0	2	1	0	0	0	0	0	0	0	0
Forcipinger flavissimus	0	0	0	0	0	0	0	0	0	0	0
Abudefduf abdominalis	10	0	5	1	6	0	4	2.75	0	1	0.5
Plectroglyphidodon imparipennis	8	0	4	8	9	2	8	6.75	7	7	7
Plectroglyphidodon johnstonianus	6	3	4.5	7	11	2	7	6.75	4	3	3.5
Stegastes fasciolatus	4	2	3	10	0	4	4	4.5	8	0	4
Chromis hanui	0	0	0	2	0	0	2	1	2	0	1
Dascyllus albisella	0	0	0	0	0	0	0	0	1	0	0.5
Labroides phthirophagus	3	0	1.5	5	0	1	0	1.5	4	0	2
Coris gaimard	1	0	0.5	0	0	0	0	0	1	1	1
Coris flavovittata	0	0	0	0	0	10	0	2.5	0	0	0
Thallosoma ballieui	0	0	0	0	21	0	0	5.25	0	0	0
Thallosoma duperrey	21	3	12	14	2	11	19	11.5	16	10	13
Scarus sordidus	1	0	0.5	2	4	1	0	1.75	5	0	2.5
Scarus perspicillatus	0	0	0	0	3	0	0	0.75	2	0	1
Acanthurus triostegus	2	8	5	6	0	2	6	3.5	8	7	7.5
Acanthurus achilles	0	0	0	0	3	0	0	0.75	0	0	0
Acanthurus nigrofuscus	1	0	0.5	3	0	4	0	1.75	3	2	2.5
Acanthurus nigroris	0	0	0	0	0	0	0	0	0	0	0
Ctenochaetus strigosus (Kole)	3	0	1.5	0	1	3	3	1.75	0	0	0
Ctenochaetus hawaiiensis	0	0	0	0	1	0	0	0.25	0	0	0
Zebrasoma flavescens	1	1	1	0	0	0	0	0	0	0	0
Zanclus cornutus	0	0	0	0	0	0	0	0	0	0	0
Rhinecanthus rectangulus	0	0	0	0	0	0	0	0	0	0	0
Rhinecanthus aculeatus	0	0	0	0	0	0	0	0	0	0	0
Sufflamen bursa	0	0	0	0	0	0	0	0	0	0	0
Ostracion meleagris	5	0	2.5	2	0	0	4	1.5	2	1	1.5
Arothron meleagris	0	2	1	0	0	0	0	0	0	0	0
Gomphosus varius	0	0	0	0	0	0	0	0	3	1	2
Paracirrhites arcatus	0	0	0	0	0	0	0	0	0	0	0
Chromis vanderbilti	0	0	0	0	0	0	0	0	0	0	0
Canthigaster jactactor	0	0	0	0	0	0	0	0	0	0	0
Chaetodon fremblii	0	0	0	0	0	0	0	0	0	0	0
Scarus rubroviolateus	0	0	0	0	0	0	0	0	0	0	0
Gymnothorax spp.	0	0	0	0	0	0	1	0.25	0	0	0
Naso lituratus	0	0	0	0	0	0	0	0	0	0	0
Cephalopholis argus	0	0	0	0	0	0	0	0	0	0	0
Parupeneus bifasciatus	0	0	0	0	0	0	0	0	0	0	0
Centropyge potteri	0	0	0	0	0	0	0	0	0	0	0
Gnathosepis anjerensis	0	0	0	1	1	0	1	0.75	0	0	0
Cephalopholis argus	0	0	0	0	0	0	0	0	1	0	0.5
Chaetondon unimaculatus	0	0	0	0	0	0	0	0	1	0	0.5
Cirripectes vanderbilti	0	0	0	0	0	0	1	0.25	0	1	0.5

Table 1

Table 2

Transect 1 6-22-95	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5	Quadrat 6	Quadrat 7	Quadrat 8	Quadrat 9	Quadrat 10	Total
Conus spp.	0	0	0	0	0	0	0	0	0	0	0
Cypraea caputserpentis	0	0	0	0	0	0	0	0	0	0	0
Cypraea tigris	0	0	0	0	0	0	0	0	0	0	0
Drupa & Morula spp.	0	0	0	0	0	0	0	0	0	0	0
Hexabranchus sanguineus	0	0	0	0	0	0	0	0	0	0	0
Octopus spp.	0	0	0	0	0	0	0	0	0	0	0
Eurythoe complanata	0	0	0	0	0	0	0	0	0	0	0
Lanice conchilega	0	0	0	0	0	0	0	0	0	0	0
Spriobranchus giganteus	1	0	3	0	0	2	3	2	0	8	19
Sabellastarte sactijosephi	0	0	0	1	0	1	4	0	0	0	6
Carpilius maculatus	0	0	0	0	0	0	0	0	0	0	0
hermit crabs	0	0	0	0	1	0	1	0	0	0	2
Panulirus marginatus	0	0	0	0	0	0	0	0	0	0	0
Paribaccas antarcticus	0	0	0	0	0	0	0	0	0	0	0
Podophthamalus spp.	0	0	0	0	0	0	0	0	0	0	0
Stenopus hispidus	0	0	0	0	0	0	0	0	0	0	0
Acanthaster planci	0	0	0	0	0	0	0	0	0	0	0
Actinopyga mauritiana	1	1	0	0	0	0	0	0	0	0	2
Chondrocidaris gigantea	0	0	0	0	0	0	0	0	0	0	0
Colobocentrotus atratus	0	0	0	0	0	0	0	0	0	0	0
Culcita novaeguineae	0	0	0	0	0	0	0	0	0	0	0
Echinometra mathaei	1	0	2	1	2	1	0	0	1	1	9
Echinometra oblonga	0	0	0	1	1	0	0	0	0	0	2
Echinothrix calamaris	0	0	0	0	0	0	0	0	0	0	0
Echinothrix diadema	0	0	0	0	0	0	0	0	0	0	0
Heterocentrotus mammillatus	1	1	0	0	0	0	0	0	1	0	3
Holothuria atra	0	0	0	0	0	0	0	0	1	2	3
Linckia multifora	0	0	0	0	0	0	0	0	0	0	0
Ophicoma spp.	0	0	0	0	0	0	0	0	1	0	1
Ophiodesoma spectablis	0	0	0	0	0	0	0	1	0	0	1
Tripneustes gratilla	0	0	0	0	0	0	0	1	0	0	1

Table 3

Transect 2 6-22-95	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5	Quadrat 6	Quadrat 7	Quadrat 8	Quadrat 9	Quadrat 10	Total
Conus spp.	0	0	0	0	0	0	0	0	0	0	0
Cypraea caputserpentis	0	0	0	0	0	0	0	0	0	0	0
Cypraea tigris	0	0	0	0	0	0	0	0	0	0	0
Drupa & Morula spp.	0	0	0	0	0	0	0	0	0	0	0
Hexabranchus sanguineus	0	0	0	0	0	0	0	0	0	0	0
Octopus spp.	0	0	0	0	0	0	0	0	0	0	0
Eurythoe complanata	0	0	0	0	1	0	0	0	0	0	1
Lanice conchilega	0	0	0	0	0	0	0	0	0	0	0
Spriobranchus giganteus	3	0	9	4	12	2	4	3	4	0	41
Sabellastarte sactijosephi	0	0	0	0	0	0	0	0	0	0	0
Carpilius maculatus	0	0	0	0	0	0	0	0	0	0	0
hermit crabs	0	0	0	0	0	0	0	1	0	1	2
Panulirus marginatus	0	0	0	0	0	0	0	0	0	0	0
Paribaccas antarcticus	0	0	0	0	0	0	0	0	0	0	0
Podophthamalus spp.	0	0	0	0	0	0	0	0	0	0	0
Stenopus hispidus	0	0	0	0	0	0	0	0	0	0	0
Acanthaster planci	0	0	0	0	0	0	0	0	0	0	0
Actinopyga mauritiana	0	1	0	3	0	0	0	0	0	0	4
Chondrocidaris gigantea	0	0	0	0	0	0	0	0	0	0	0
Colobocentrotus atratus	0	0	0	0	0	0	0	0	0	0	0
Culcita novaeguineae	0	0	0	0	0	0	0	0	0	0	0
Echinometra mathaei	0	1	0	3	3	3	3	0	1	0	14
Echinometra oblonga	0	0	2	0	2	1	0	0	1	1	7
Echinothrix calamaris	0	0	0	0	0	0	0	0	0	0	0
Echinothrix diadema	0	0	0	0	0	0	0	0	0	0	0
Heterocentrotus mammillatus	0	0	1	0	0	0	0	0	0	0	1
Holothuria atra	0	0	0	0	0	0	0	0	0	0	0
Linckia multifora	0	0	0	0	0	0	0	0	0	0	0
Ophicoma spp.	0	0	2	1	1	1	3	0	1	0	9
Ophiodesoma spectablis	0	0	3	0	0	0	0	1	0	0	4
Tripneustes gratilla	0	0	0	0	0	0	0	0	0	0	0

Table 4

Transect 3 6-29-95	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5	Quadrat 6	Quadrat 7	Quadrat 8	Quadrat 9	Quadrat 10	**Total**
Conus spp.	1	0	0	3	0	0	0	0	0	1	5
Cypraea caputserpentis	1	0	0	0	0	2	0	0	0	0	3
Cypraea tigris	0	0	0	0	0	0	0	0	0	0	0
Drupa & Morula spp.	1	2	0	0	0	0	0	0	0	1	4
Hexabranchus sanguineus	0	0	0	0	0	0	0	0	0	0	0
Octopus spp.	0	0	0	0	0	0	0	0	0	0	0
Eurythoe complanata	0	0	0	0	0	0	0	0	0	0	0
Lanice conchilega	0	0	0	0	0	0	0	0	0	0	0
Spriobranchus giganteus	0	0	0	0	0	2	1	1	0	0	4
Sabellastarte sanctijosephi	0	0	0	0	1	0	0	0	0	0	1
Carpilius maculatus	0	0	0	0	0	0	0	0	0	0	0
hermit crabs	0	0	0	0	0	0	0	0	0	0	0
Panulirus marginatus	0	0	0	0	0	0	0	0	0	0	0
Paribaccas antarcticus	0	0	0	0	0	0	0	0	0	0	0
Podophthamalus spp.	0	0	0	0	0	0	0	0	0	0	0
Stenopus hispidus	0	0	0	0	0	0	0	0	0	0	0
Acanthaster planci	0	0	0	0	0	0	0	0	0	0	0
Actinopyga mauritiana	1	0	1	0	0	0	1	0	0	0	3
Chondrocidaris gigantea	0	0	0	0	0	0	0	0	0	0	0
Colobocentrotus atratus	0	0	0	0	0	0	0	0	0	0	0
Culcita novaeguineae	0	0	0	0	0	0	0	0	0	0	0
Echinometra mathaei	3	3	16	10	9	11	1	17	16	10	96
Echinometra oblonga	0	0	1	0	0	0	1	0	0	0	2
Echinothrix calamaris	0	0	0	0	0	0	0	0	0	0	0
Echinothrix diadema	0	0	0	0	0	0	0	0	0	0	0
Heterocentrotus mammillatus	0	0	0	0	0	0	0	0	0	0	0
Holothuria atra	0	0	0	0	0	0	0	0	0	0	0
Linckia multifora	0	0	0	0	0	0	0	0	0	0	0
Ophicoma spp.	1	0	11	5	0	1	1	0	0	1	20
Ophiodesoma spectablis	0	0	0	0	0	0	0	0	0	0	0
Tripneustes gratilla	0	0	0	0	0	0	0	0	0	0	0

Kapoho data

		B Blue rice	C Meandrin	E Lace	F Finger	L Lobe	O Ocellina	P M. patula	R Rice	V Brain	Total coral
1992	10A		0.063			0.188			0.438		0.688
	10X										0.000
	1A		0.063						0.188	0.750	1.000
	1X					0.438			0.375		0.813
	2A				0.063				0.125	0.813	1.000
	2X					0.563			0.438		1.000
	3A				0.125				0.188	0.688	1.000
	3X					0.188				0.813	1.000
	4A				0.875				0.125		1.000
	4X				0.375	0.063				0.563	1.000
	5A				0.250					0.750	1.000
	5X				0.875				0.125		1.000
	6A				0.063					0.938	1.000
	6X				0.563					0.438	1.000
	7A									1.000	1.000
	7X					0.625				0.375	1.000
	8A									1.000	1.000
	8X					0.563			0.313	0.125	1.000
	9A					0.063			0.375	0.313	0.750
	9X								0.125	0.063	0.188
1993	10A		0.150			0.150		0.150	0.100	0.100	0.650
	10X					0.400			0.300		0.700
	1A					0.300			0.600	0.100	1.000
	1X					0.050			0.450		0.500
	2A	0.050				0.200			0.600	0.150	1.000
	2X					0.200			0.250		0.450
	3A			0.030	0.100	0.100	0.020		0.560	0.100	0.900
	3X				0.100					0.700	0.800
	4A					0.150	0.020		0.480	0.250	0.900
	4X				0.500	0.250			0.250		1.000
	5A					0.400			0.400	0.200	1.000
	5X					0.500			0.500		1.000
	6A					0.500			0.100	0.400	1.000
	6X					0.250				0.750	1.000
	7A				0.150	0.700				0.150	1.000
	7X				0.150					0.850	1.000
	8A				0.050	0.900			0.050		1.000
	8X					0.050			0.050	0.900	1.000
	9A			0.050		0.150	0.020		0.380		0.600
	9X								0.500	0.250	0.750
1994	10A					0.075			0.175		0.250
	10X					0.089					0.089
	11A									0.639	0.639
	11X					0.652				0.109	0.761
	12A									1.000	1.000
	12X					0.546				0.030	0.576
	13A					0.029				0.800	0.829
	13X					0.167			0.028		0.194
	14A					0.054				0.838	0.892
	14X								0.478	0.217	0.696
	15A					0.037			0.259	0.630	0.926
	15X								0.087		0.087
	16A						0.028		0.556		0.583
	16X						0.022				0.022
	17A					0.196			0.436	0.043	0.674
	17X										0.000
	18A					0.341			0.390		0.732
	1X						0.024		0.881		0.906
	2A		0.045		0.046	0.114			0.250	0.023	0.477
	2X					0.578			0.378		0.956
	3A		0.091			0.364			0.023		0.477
	3X					0.521			0.167	0.042	0.729
	4A					0.095			0.310	0.167	0.571
	4X					0.188			0.688		0.875
	5A				0.025				0.250	0.250	0.525
	5X				0.047	0.233			0.140	0.256	0.674
	6A				0.024				0.357	0.286	0.667
	6X				0.111				0.089	0.511	0.711
	7A				0.026	0.077			0.128	0.308	0.538
	7X				0.233					0.465	0.698
	8A					0.132			0.237	0.263	0.632
	8X			0.049	0.439				0.024	0.122	0.634
	9A				0.020	0.082			0.265		0.367
	9X					0.711					0.711
1995	10A				0.075					0.775	0.850
	10X				0.050	0.100			0.025	0.450	0.625
	11A									0.976	0.976
	11X				0.455					0.364	0.818
	12A				0.024					0.762	0.786
	12X				0.114	0.159			0.045	0.295	0.614
	13A									0.850	0.850
	13X	0.303				0.333				0.152	0.788
	14A								0.194	0.806	1.000
	14X					0.048			0.643	0.143	0.833
	15A					0.049			0.512	0.317	0.878
	15X			0.024					0.122	0.024	0.171
	16A					0.023			0.477		0.500
	16X					0.022	0.022				0.044
	17A					0.133	0.067		0.400		0.600
	17X						0.044		0.022		0.067
	18A					0.295			0.614		0.909
	18X			0.023			0.023		0.045		0.091
	19A								0.585		0.585
	1A				0.081	0.027			0.351	0.162	0.622
	2A					0.371			0.200	0.029	0.600
	2X				0.024	0.571	0.024		0.333		0.952
	3A				0.065	0.217			0.261		0.543
	3X	0.024			0.405				0.333		0.762
	4A					0.079			0.421	0.237	0.737
	4X					0.279	0.023		0.488		0.791
	5A				0.026	0.053			0.184	0.395	0.658
	5X			0.073	0.098	0.024			0.024	0.317	0.537
	6A								0.432	0.432	0.865
	6X				0.093				0.047	0.581	0.721
	7A				0.167	0.048			0.405	0.167	0.786
	7X				0.125					0.525	0.650
	8A				0.213				0.213		0.426
	8X					0.343			0.143	0.171	0.657
	9A			0.025	0.025				0.050		0.100
	9X	0.025		0.025		0.075			0.050		0.175

```
Worksheet size: 100000 cells


MTB > Save  'I:\KAPOHO\CORAL95.MTW';
SUBC>    Replace.
Saving worksheet in file: I:\KAPOHO\CORAL95.MTW
MTB > anova coral=year|tran;
SUBC> means year|tran.
* ERROR * Unequal cell counts.

MTB > glm coral=year|tran;
SUBC> means year|tran.
```

General Linear Model

Factor	Levels	Values	
Year	2	1	2
Tran	2	1	2

Analysis of Variance for coral

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Year	1	0.03476	0.11501	0.11501	1.51	0.222
Tran	1	0.39491	0.38837	0.38837	5.10	0.026
Year*Tran	1	0.26682	0.26682	0.26682	3.51	0.064
Error	104	7.91217	7.91217	0.07608		
Total	107	8.60867				

Unusual Observations for coral

Obs.	coral	Fit	Stdev.Fit	Residual	St.Resid
33	0.02174	0.59107	0.04730	-0.56933	-2.10R
34	0.00000	0.59107	0.04730	-0.59107	-2.18R
87	0.04444	0.62683	0.04597	-0.58238	-2.14R
88	0.06667	0.62683	0.04597	-0.56016	-2.06R
95	0.95918	0.39714	0.06328	0.56205	2.09R

R denotes an obs. with a large st. resid.

Means for coral

Year		Mean	Stdev
1		0.5803	0.03950
2		0.5120	0.03911
Tran			
1		0.6090	0.03298
2		0.4834	0.04474
Year*Tran			
1	1	0.5911	0.04730
1	2	0.5696	0.06328
2	1	0.6268	0.04597
2	2	0.3971	0.06328

```
MTB >
```

```
Worksheet size: 100000 cells


MTB > RETR 'I:\KAPOHO\CORAL95B.MTW'.
Retrieving worksheet from file: I:\KAPOHO\CORAL95B.MTW
Worksheet was saved on  7/17/1995
MTB > Save  'I:\KAPOHO\CORAL95B.MTW';
SUBC>    Replace.
Saving worksheet in file: I:\KAPOHO\CORAL95B.MTW
* NOTE  * Existing file replaced.
MTB > Oneway 'coral' 'Year';
SUBC>   Tukey 5.
```

One-Way Analysis of Variance

```
Analysis of Variance on coral
Source       DF         SS          MS          F        p
Year          4     1.7881      0.4470       5.98    0.000
Error       122     9.1170      0.0747
Total       126    10.9051
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
 Level        N       Mean       StDev    -------+---------+---------+---------
     1       20     0.8719      0.2835                      (--------*--------)
     2       20     0.8625      0.1877                     (--------*---------)
     3       17     0.7741      0.3451               (---------*--------)
     4       34     0.5911      0.2708    (-----*-------)
     5       36     0.6268      0.2723       (-----*-----)
                                          -------+---------+---------+---------
Pooled StDev =      0.2734                     0.60      0.75       0.90

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00650

Critical value = 3.92

Intervals for (column level mean) - (row level mean)

                  1          2          3          4

     2     -0.2302
            0.2490

     3     -0.1522    -0.1616
            0.3477     0.3383

     4      0.0673     0.0579    -0.0420
            0.4943     0.4850     0.4081

     5      0.0337     0.0244    -0.0757    -0.2170
            0.4564     0.4470     0.3703     0.1455


MTB >
```

```
Worksheet size: 100000 cells

MTB > Save  'I:\KAPOHO\BLEACH95.MTW';
SUBC>    Replace.
Saving worksheet in file: I:\KAPOHO\BLEACH95.MTW
MTB > anova pixels=year|species|colony;
SUBC> means year|species|colony.
```

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values		
Year	fixed	2	1	2	
Species	fixed	3	1	2	3
Colony	fixed	3	1	2	3

Analysis of Variance for Pixels

Source	DF	SS	MS	F	P
Year	1	46986	46986	2.09	0.148
Species	2	331776	165888	7.39	0.001
Colony	2	66497	33249	1.48	0.228
Year*Species	2	901	451	0.02	0.980
Year*Colony	2	11111	5555	0.25	0.781
Species*Colony	4	156225	39056	1.74	0.139
Year*Species*Colony	4	20570	5142	0.23	0.922
Error	738	16567773	22450		
Total	755	17201838			

MEANS

Year	N	Pixels
1	378	209.26
2	378	193.49

Species	N	Pixels
1	252	223.94
2	252	173.47
3	252	206.71

Colony	N	Pixels
1	252	211.03
2	252	188.67
3	252	204.43

Year	Species	N	Pixels
1	1	126	232.32
1	2	126	179.84
1	3	126	215.62
2	1	126	215.57
2	2	126	167.10
2	3	126	197.80

Year	Colony	N	Pixels
1	1	126	219.26
1	2	126	191.69
1	3	126	216.82
2	1	126	202.79
2	2	126	185.65
2	3	126	192.03

Species	Colony	N	Pixels
1	1	84	239.85
1	2	84	204.12
1	3	84	227.87

Table 8 cont.

2	1	84	201.70
2	2	84	162.28
2	3	84	156.42
3	1	84	191.53
3	2	84	199.61
3	3	84	228.99

Year	Species	Colony	N	Pixels
1	1	1	42	243.69
1	1	2	42	205.65
1	1	3	42	247.61
1	2	1	42	217.22
1	2	2	42	163.30
1	2	3	42	159.00
1	3	1	42	196.87
1	3	2	42	206.14
1	3	3	42	243.85
2	1	1	42	236.00
2	1	2	42	202.60
2	1	3	42	208.12
2	2	1	42	186.19
2	2	2	42	161.27
2	2	3	42	153.84
2	3	1	42	186.19
2	3	2	42	193.08
2	3	3	42	214.14

MTB >

Worksheet size: 100000 cells

Table 9

MTB > Aovo c1 c2 c3 c4

One-Way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        p
Factor      3     214.9      71.6     0.90    0.494
Error       6     477.2      79.5
Total       9     692.1
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1992        2     8.500     9.192  (------------*------------)
1993        3    21.000     6.245              (---------*----------)
1994        3    16.333     8.737          (----------*---------)
1995        2    12.000    12.728     (------------*------------)
                                   ------+---------+---------+---------+
Pooled StDev =    8.918                  0        12        24        36
```

Worksheet size: 100000 cells

MTB > Aovo c1 c2 c3 c4

One-Way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        p
Factor      3     19.23      6.41     0.93    0.480
Error       6     41.17      6.86
Total       9     60.40
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
1992        2     1.500     0.707    (------------*------------)
1993        3     0.000     0.000  (----------*----------)
1994        3     1.667     2.082      (----------*---------)
1995        2     4.000     5.657          (------------*------------)
                                   -+---------+---------+---------+-----
Pooled StDev =    2.619          -3.5      -0.0       3.5       7.0
```

* NOTE * All values in column are identical.

Worksheet size: 100000 cells

MTB > Aovo C1 C2 C3 C4

One-Way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        p
Factor      3     20.57      6.86     0.74    0.567
Error       6     55.83      9.31
Total       9     76.40
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
1992        2     4.500     2.121     (--------------*--------------)
1993        3     6.333     4.041            (-----------*-----------)
1994        3     2.667     0.577  (------------*-----------)
1995        2     5.000     4.243     (--------------*--------------)
                                   -----+---------+---------+---------+-
```