CHAPTER 3: BIOLOGICAL MONITORING

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Introduction

A major part of any environmental impact assessment is an examination of the possible and actual effects of an activity on the biota of the area. The potential impacts of the floating hotel on the reef biota can be divided into two types: **predictable** (resulting from on-going activities such as hypersaline water from the desalination plant, generator noise, effects of fish feeding) and **unpredictable** (potential pollution spillage, unknown effects of a large reef structure). While some individual studies addressed the former impacts (Chapter 7), a large scale biological monitoring program was necessary to assess impacts from unpredictable sources.

Prior to the establishment of the hotel, a baseline survey documented the status of the biological macrofauna and established a survey protocol for detecting changes which may have been due to the presence or operation of the hotel. Two subsequent surveys occurred during the hotel's operations and a further two after its removal (Table 3.1).

The monitoring program had three main aims:

a. to establish sufficient reference data on the environmental conditions at John Brewer Reef to allow comparisons with data collected after the hotel was operational;

b. to document environmental changes due to the establishment and operation of the hotel, against the background of natural fluctuations; and

c. to determine whether the presence of the hotel caused any lasting impacts after its removal.

The major components of the program were:

a. reconnaissance surveys: following a review of the literature and consultation with scientists who have worked at the reef, a field program was used to identify sites suitable for monitoring purposes;

b. survey of corals and other benthic organisms: corals are one of the primary benthic reef organisms so data was collected on the composition and spatial extent of benthic communities on coral bommies; and

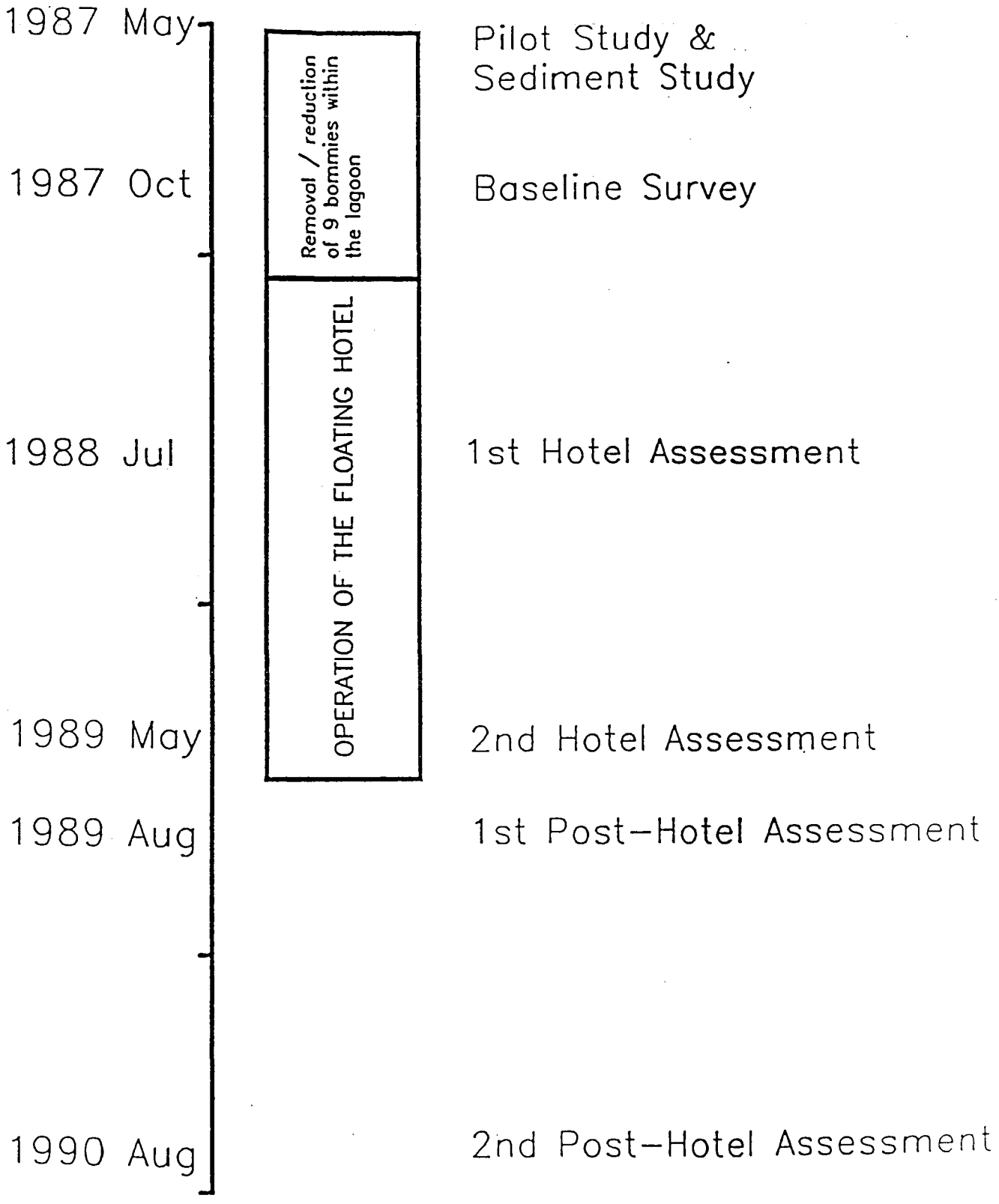
c. fish surveys: impacts attributable to the hotel potentially might have resulted in either a decline or an increase in fish numbers, which are another major element of coral reef fauna.

Methods

The hotel and associated structures were considered to be a point impact within the lagoon, with its potential effects radiating out from this point source. Sampling therefore was designed to detect a gradient of change with increasing distance from the hotel.

Sampling within the lagoon was conducted at five sites, consisting of three contiguous sites and two controls at a greater distance from the hotel (Figure 3.1). The contiguous sites were arranged in three concentric hemispheres of influence extending out from the swing circle and down-current (which predominantly flows S.E. - N.W., being a combination of tidal flushing and wind stress). Bommies within each of the five sites were sampled for sessile and fish fauna (five and seven bommies respectively). This enabled comparisons of assemblages between control and impact sites, among the five sampling zones, and the identification of gradients of change in the abundance of organisms with distance from the floating hotel. Bommies were selected to be of similar size and height above the sand. Control sites were selected so that they were close enough to the treatment area to be affected by the same natural environmental fluctuations, but away from areas allocated for use as tourist dive areas.

Table 3.1. A timeline indicating when differing surveys were conducted



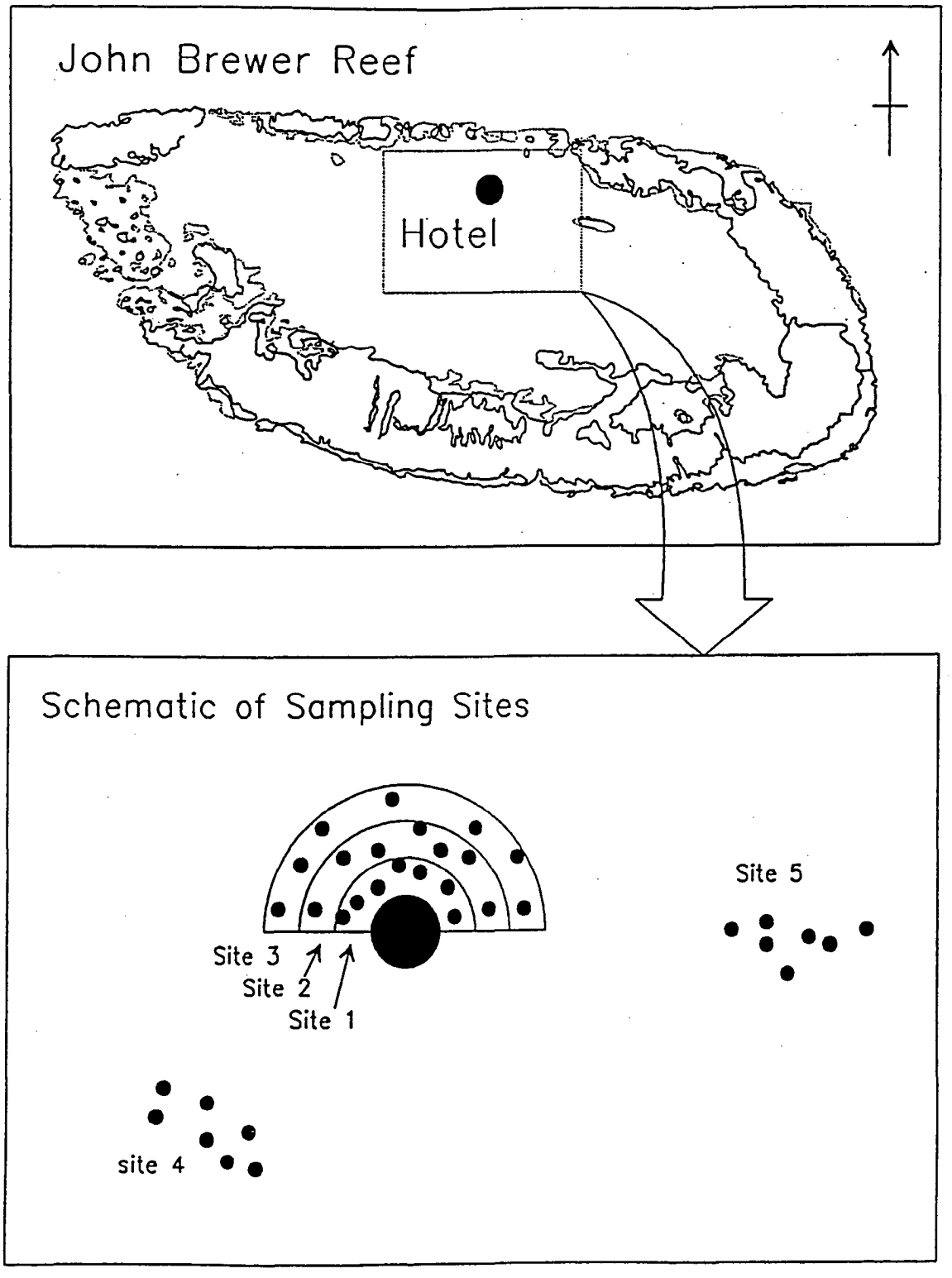


Figure 3.1. Map of John Brewer Reef, showing the schematic position of the five sampling sites radiating from the hotel swing circle, bommies are represented by the small black circles

Reconnaissance survey

Control sites were identified from aerial photographs and ground checking of possible sites. These sites were positioned away from activities associated with the resort (e.g. diving areas, proposed pontoons). Control and treatment sites were mapped, and bommies identified with small, numbered sub-surface buoys.

Coral and other sessile fauna survey

The benthic organisms on the lagoonal bommies were sampled by 20 m line-intercept-transects. Three transects were laid at each of the five bommies within each of the five sites. These transects were laid randomly under the constraint that they were at the 2.5 m depth contour, for it is at this depth that the pilot study found that most corals occurred. Organisms were generally identified to genus, and in the case of many hard corals, to species level.

Fish surveys

a. Large reef fish: For all five surveys, large or schooling reef and sandflat-associated fishes were counted using 50 x 20 m strip transects. When sampling bommies within the lagoon, transects were laid along the base of the bommies so that they were counted 10 m up and over the bommie, and 10 m into the adjacent sandflat. One transect was counted on each of the seven bommies per site.

b. Small reef fish: Small bommie-associated reef fish were counted using 20 x 5 m strip transects, and identified to species. One transect was counted on each of the seven bommies per site.

Fish within 20 x 5 m and 50 x 20 m strip-transects were counted over the rubble bommie under the hotel complex to compare with data from the main five-site survey. A further two 50 x 20 m transects were swum over a bommie 70 m north of the hotel which had been cropped during the clearance of the hotel swing circle.

During the five surveys, six ten-minute timed counts were swum over the sand flat within the hotel swing circle. During these counts, only the adults of large, mobile fish species were recorded.

Data collected during the biological monitoring program were analysed in two main ways: pattern analysis techniques which serve to simplify complex relationships between many species using ordination or cluster analysis; and hypothesis testing for differences in abundance of taxa with increasing distance from the hotel site using analysis of variance or multivariate analysis of variance.

Conclusions

Benthic flora and fauna

It was concluded from the baseline survey that the biota of John Brewer Reef lagoon was typical of mid-shelf lagoons although the fauna and flora of the lagoon were in the early stages of recovery from a severe crown-of-thorns starfish feeding event which ended in mid-1985. The hard corals were diverse and, at that time, small in size and dominated by corals of the fast growing family Pocilloporidae and by species of *Acropora.*

The benthic substratum was dominated by macroalgae throughout the survey period, with turfing algae comprising up to 71% of the cover on the surveyed bommies, and *Halimeda* and other macroalgae comprising up to 22% of cover. Hard corals accounted for between 6% and 9% of the cover (Table 3.2).

Complex changes in the benthic community were found at all temporal and spatial scales examined. These changes were due largely to changes in cover of the algal taxa. There was a general trend for turfing algae and *Halimeda* to increase in abundance over the survey period, and for soft corals to decrease (Table 3.2). These changes occurred, however, to varying degrees across the whole lagoonal area surveyed and were not attributable to the resort. Analyses showed no outstanding changes at specific bommies within sites, or at sites extending away from the resort. It seems likely that these changes represent patchiness in the natural processes and environmental factors regulating benthic reef communities. For *Padina* and *Halimeda*, these changes probably represent seasonal fluctuations in abundance. Hard coral cover increased over the study period, consistent with regrowth of corals after crown-of-thorns starfish predation. Overall, there was no evidence of an adverse effect of the hotel on the benthic fauna.

Fish surveys

Fish assemblages differed between sites with the assemblages at the site closest to the hotel most closely resembling the two most distant sites. Differences between sites were largely driven by the relative abundance of the damselfishes *Pomocentrus wardi* and *P. chrysurus*. In general, there was little change in the fish species composition during the time period of the study, and no gradient of change was detected extending away from the resort.

The establishment and subsequent removal of the hotel had a direct influence on the fish fauna within the 226 m diameter swing circle. Prior to the establishment of the hotel, the fish fauna was numerically dominated by fusiliers, and a few other species of large mobile reef fishes were present. The hotel and associated pontoons attracted a large number of predatory (e.g. lethrinids, lutjanids), grazing (e.g. scarids, siganids), and scavenging (e.g. mullids) reef fish. These were found to disperse from the swing circle in the months following the hotel's removal in July 1989 (Figure 3.2). The parrotfishes and surgeonfishes, which had been seen to graze on the swards of algae under the hotel, were found to disperse into other parts of the swing circle a month after the hotel's removal and a year later were found to occur in similar abundances to that of the baseline survey. Aggregations of drummer (*Kyphosus* sp.) and fusiliers were similarly found to have dispersed after removal of the hotel.

Table 3.2. Second post-hotel survey, mean percentage cover of the major coral and other sessile taxa sampled over five surveys, by line intercept transects in the John Brewer Reef lagoon. (* denotes that these values are zero due to the non-identification of some recruit hard corals)

	BEFORE	DURING		AFTER	
Category	**October 87**	**July 88**	**May 89**	**August 89**	**August 90**
Hard corals	6.3	5.15	6.96	11.38	9.09
Soft Corals	1.74	1.12	0.74	0.70	0.84
Sponge	0.93	1.35	0.77	0.66	0.45
Halimeda	9.36	16.72	17.57	18.88	7.64
Padina	1.49	0.01	0.00	0.00	0.00
Turfing Algae	35.69	41.82	51.52	49.85	70.98
Macroalgae	0.72	0.99	0.42	0.11	0.22
Coralline	1.25	0.00	2.96	2.88	0.22
Sand-rubble	32.38	27.92	17.68	13.22	9.61

HARD CORALS					
Category	**October 87**	**July 88**	**May 89**	**August 89**	**August 90**
Acropora	0.89	0.00 *	0.77	0.75	1.47
Montipora	0.83	0.55	1.96	2.24	2.14
Agariciidae	0.07	0.00 *	0.05	0.04	0.07
Caryophylliidae	0.03	0.00	0.00	0.00	0.00
Dendrophylliidae	0.11	0.00 *	0.03	1.21	0.56
Faviidae	0.94	0.77	0.80	0.80	1.45
Fungiidae	0.15	0.06	0.03	2.95	0.06
Merulinidae	0.01	0.02	0.02	0.05	0.02
Milleporidae	0.00	0.00	0.01	0.03	0.05
Mussidae	0.20	0.42	0.01	0.09	0.05
Oculinidae	0.16	0.03	0.34	0.10	0.05
Pocilloporidae	1.93	1.35	1.44	1.49	1.69
Poritidae	0.61	1.90	1.14	1.57	1.26
Siderastreidae	0.14	0.02	0.10	0.06	0.19

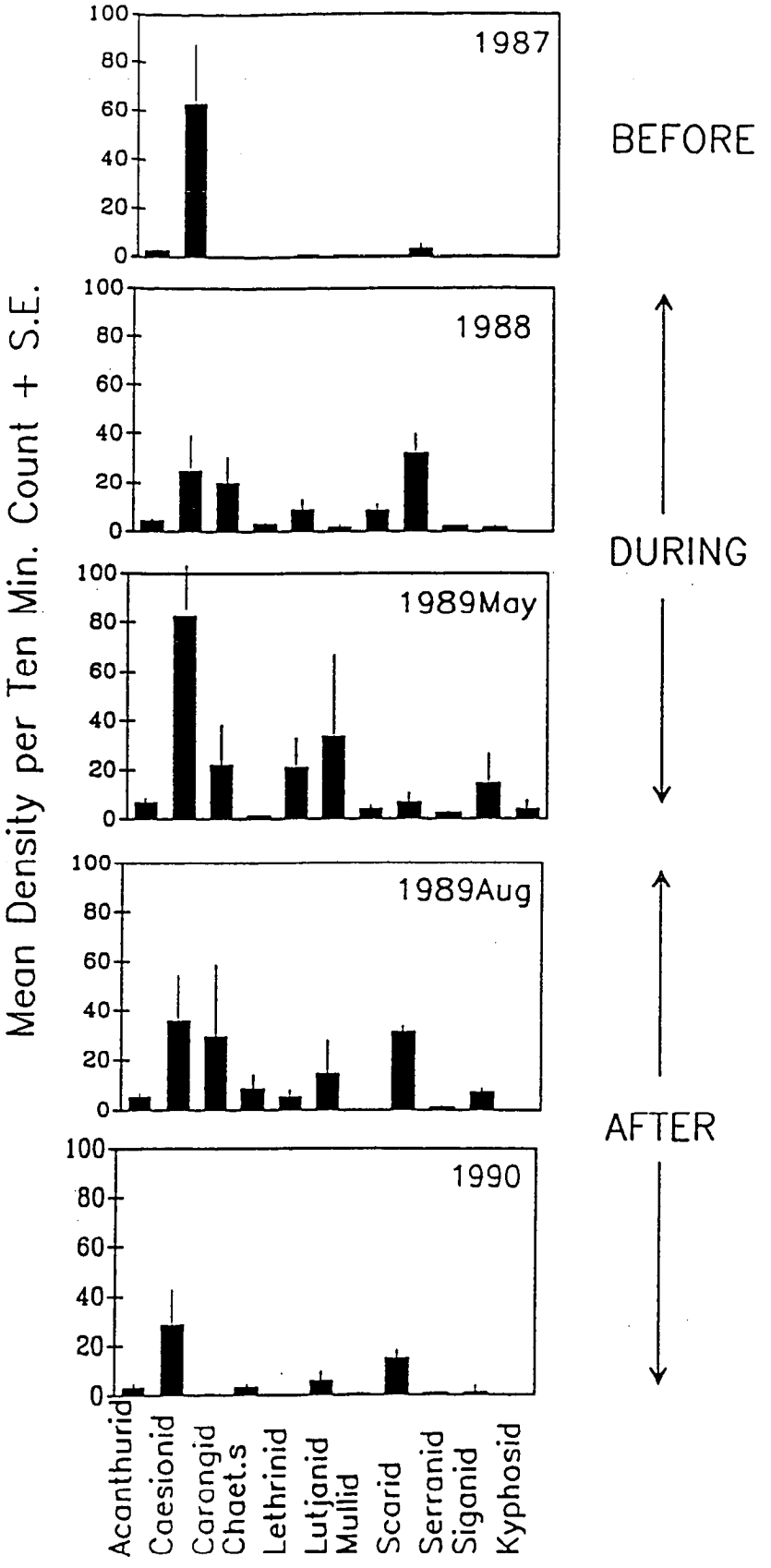


Figure 3.2. Comparison of densities of large mobile families of reef fish within the swing circle over four years. Mean densities per ten-minute swim are plotted and standard errors (n = 6)

The most striking changes were in the high numbers of large predatory lethrinids and carangids, forming large schools under the resort and the occurrence of large numbers of juvenile reef fish on the rubble from the bommie cropping operation (Figure 3.3). The aggregation of large predatory fishes, together with the high recruitment of fishes directly under the resort was not considered to be detrimental, but probably reflects effects from the resort. These changes were likely results of (i) regular feeding by charter boat and resort staff; (ii) the shading effect of the resort structure; and (iii) the provision of a unique coral rubble habitat around the resort.

A large amount of construction waste was left under the resort complex and within the swing circle, and deposits of litter directly under the catamaran docking area. Some of the construction wastes have also been implicated in elevating some heavy metal concentrations in the sediments. Consequently, it was recommended that the removal of the construction wastes and a weekly removal of litter should form part of the responsibility of the resort operator.

Findings suggested that the resort had only a localised effect on the biota of the reef, apart from an aggregation of reef fish under the resort complex. Many of the trends in the benthic community over the five surveys are attributable to recovery from the major crown-of-thorns starfish feeding episode which ended in mid-1985. These included: (i) the percentage of hard coral cover increased slightly, from both the growth of fragments and newly settled coral colonies; (ii) the percent cover of soft corals decreased from 1.7 to 0.7%; and (iii) the cover of algae (turf, filamentous and *Halimeda*) increased.

Outside the resort swing circle, the densities of the majority of fish species showed increases in abundance over the survey period while the benthos and some fish species showed significant fluctuations which were not directly related to the presence of the resort.

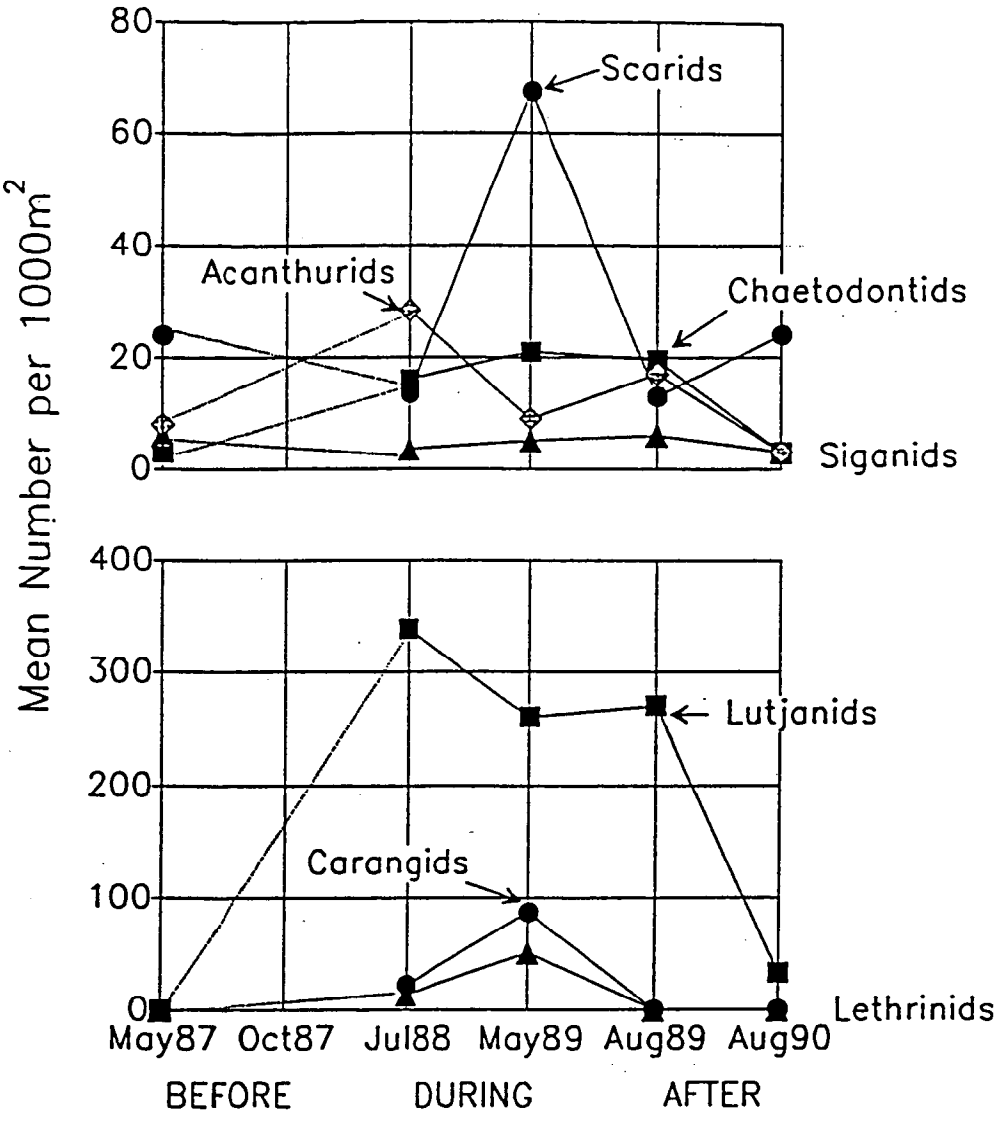


Figure 3.3. Comparison of the mean densities of large mobile fish on the bommie under the hotel (cropped in June 87 - February 88) over the monitoring period, May 1987 estimates are from the pilot study (McCormick, 1989)