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The John Brewer Reef Floating Hotel:
A Case-Study in Marine Environmental Monitoring

Proceedings of a GBRMPA Workshop reviewing the Environmental Monitoring Program, held in Townsville, Australia in December 1989

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SUMMARY

Although the John Brewer Reef Floating Hotel remained in operation for only one year from March 1988, its construction and installation triggered a major environmental assessment and monitoring program which was innovative in many ways. First, the hotel was the first of its kind in the world so the potential impacts were largely unknown and, second, there was increasing community pressure for comprehensive assessments of environmental impacts given the high conservation value placed on the Great Barrier Reef Marine Park - a World Heritage Area.

As a result, the environmental impact assessment and monitoring procedure which was implemented was probably the most complex that had been attempted for a project of that scale in Australia and proved, in many ways, to be a pilot for studies within the Great Barrier Reef Marine Park since then. The program involved many individuals and several institutions working in areas such as oceanography, water quality, biological monitoring and social impact studies, with the program coordinated by the Centre for Coastal Management at the University of New England - Northern Rivers (then known as the Northern Rivers College of Advanced Education) on behalf of the proponent.

The reports of the many separate studies which formed part of the environmental assessment and monitoring program existed only as unpublished reports to GBRMPA and the hotel developers. A workshop was held in Townsville in December 1989 to bring together the participants in the monitoring program, in order to draw on the experiences gained from the study and to apply this experience to the design of future monitoring programs. To follow on from the objectives of that workshop this document summarises the separate studies which constituted the monitoring program and presents them in a single report.

The components of the monitoring program and the conclusions of the studies were as follows:

a. Bommie cropping: Coral communities and limestone were removed from the tops of individual patch reefs in the lagoon of John Brewer Reef to allow for entry of the hotel and for a swing circle around the hotel. Some corals were transplanted away from the damaged patch reefs and survived well, but any fauna remaining on the reef tops and within approximately a 20 m radius was damaged or killed by the process. Organisational problems hampered the efficiency of the transplantation operations.

b. Biological monitoring: Surveys of the benthic fauna and fish populations adjacent to the hotel site and at control sites were completed before installation of the hotel, during its operation and after its removal. Few significant differences in the fauna attributable to the hotel were detected, apart from an aggregation of fish under the resort, probably as a result of feeding by charter boat and resort staff.

c. Water quality compliance assessment: A study of the wastewater treatment plant showed that there were numerous technical problems with the operation of the plant so that the effluent breached permit requirements on many occasions, particularly during the early phase. Monitoring of water quality in the lagoon showed no significant differences between hotel sites and control sites, indicating that any effluent discharged was rapidly dispersed and diluted.

d. Sediments compliance monitoring: The presence of the hotel had only a small impact on the sediments in the vicinity. The sediments near the hotel were coarser than those at the control site, probably due to increased turbulence resulting from the physical presence of the hotel structure increasing the winnowing of the sediments. Copper concentrations were also higher near the resort in the early part of the study, probably as a result of metallic litter dropped into the water during the establishment phase of the resort.

e. User surveys: The pattern of human usage of John Brewer Reef was examined before and after the installation of the hotel. User groups surveyed included boat owners, anglers, charter boat operators and researchers. There were no clear-cut results concerning the attitudes of users to the hotel. For most groups there were approximately equal numbers of positive and negative comments concerning the impact of the hotel on their use of the reef. A few users visited the reef specifically to visit the hotel and few people appeared to actively avoid the reef because of the hotel. There was a wide choice of alternative reef sites for users to visit.

f. Hypothesis testing: Several small projects were completed by post-graduate students or contractors. An examination of the effects of bird droppings on lagoonal water quality showed that no changes were detectable. A study of the effect of shading on fish predators demonstrated that fish aggregated under the hotel, but the role of light in the aggregations could not be determined. Noise from the resort could be detected underwater up to 1 km from the resort, but did not deter fish from aggregating under the hotel. A study of the dispersal of the brine plume showed that only minute increases in salinity of the lagoonal waters could be detected at a distance of 12 m from the discharge point.

At the workshop many suggestions were made concerning possible improvements to the design of the monitoring program with the benefit of hindsight. In particular, there was the view that the monitoring program should be more focused and more intense in particular significant areas. In some areas of the study a reduction in sampling intensity and hence cost could have been achieved without loss of vital information. Another major point was that the detail of the environmental impact study was not matched by detail and accuracy in the economic forecasts, and more attention needs to be paid to social aspects of similar developments in the future.

In summary, the commercial failure of this project did not occur at the expense of social or environmental quality, nor did the provision for social and environmental requirements contribute directly to project failure. Efforts by the project proponents during the design phase to minimise potential environmental impacts were largely successful. The outcome vindicates the emphasis given by management on environmental protection and reinforces the utility of the adaptive management approach used in this project.

CHAPTER 1: INTRODUCTION

Peter Saenger and Ian Dutton

The history of the John Brewer Reef Floating Hotel

The idea of a floating hotel evolved initially from the geography of the Great Barrier Reef (GBR) which lies, for the most part, some considerable distance and travelling time, off-shore. Its direction from mainland ports together with the most frequent prevailing wind conditions necessitates lengthy trips across a side-on swell. Tour operators believed that visitation could be significantly increased with shorter or faster trips, or through the provision of fixed off-shore accommodation. Several continental islands already had been developed to cater for tourists as well as two coral cays, and prevailing wisdom (i.e. Great Barrier Reef Consultative Committee; Australian Coral Reef Society; Buckley, 1983) was strongly opposed to further tourism developments on coral cays. Two options appeared to remain: build artificial islands or moor structures on or near reefs.

In 1981, a group of Townsville businessmen proposed an artificial island on the Great Barrier Reef, comprised of three partially sunken liners embedded in sand. This proposal was discarded because of potentially unacceptable environmental impacts and the costs of maintenance. The subsequent development of floating accommodation for the off-shore oil industry and the military (e.g. Falkland Islands) led a Townsville consortium to investigate the feasibility of locating a luxury version of that floating accommodation in the lagoon of John Brewer Reef, approximately 70 km north-east of Townsville (Figure 1).

Built by Consafe Engineering in Singapore, the floating hotel consisted of a five-storey self-contained floating building (Table 1.1), containing 140 double rooms and 34 luxury suites. Floating pontoons adjacent to the main structure served as walkways, and contained moorings, swimming pool and tennis courts.

Table 1.1. Project specifications of the floating hotel

Length	89.2 m
Width	27.6 m
Height from sea level	24.2 m
Draught	3.0 m
Freeboard	3.0 m
Ballast capacity	4000 t
Fuel oil capacity	200 t
Potable water supply	150 t/day
Generating capacity	2300 kW
Guest accommodation	356
Staff	98

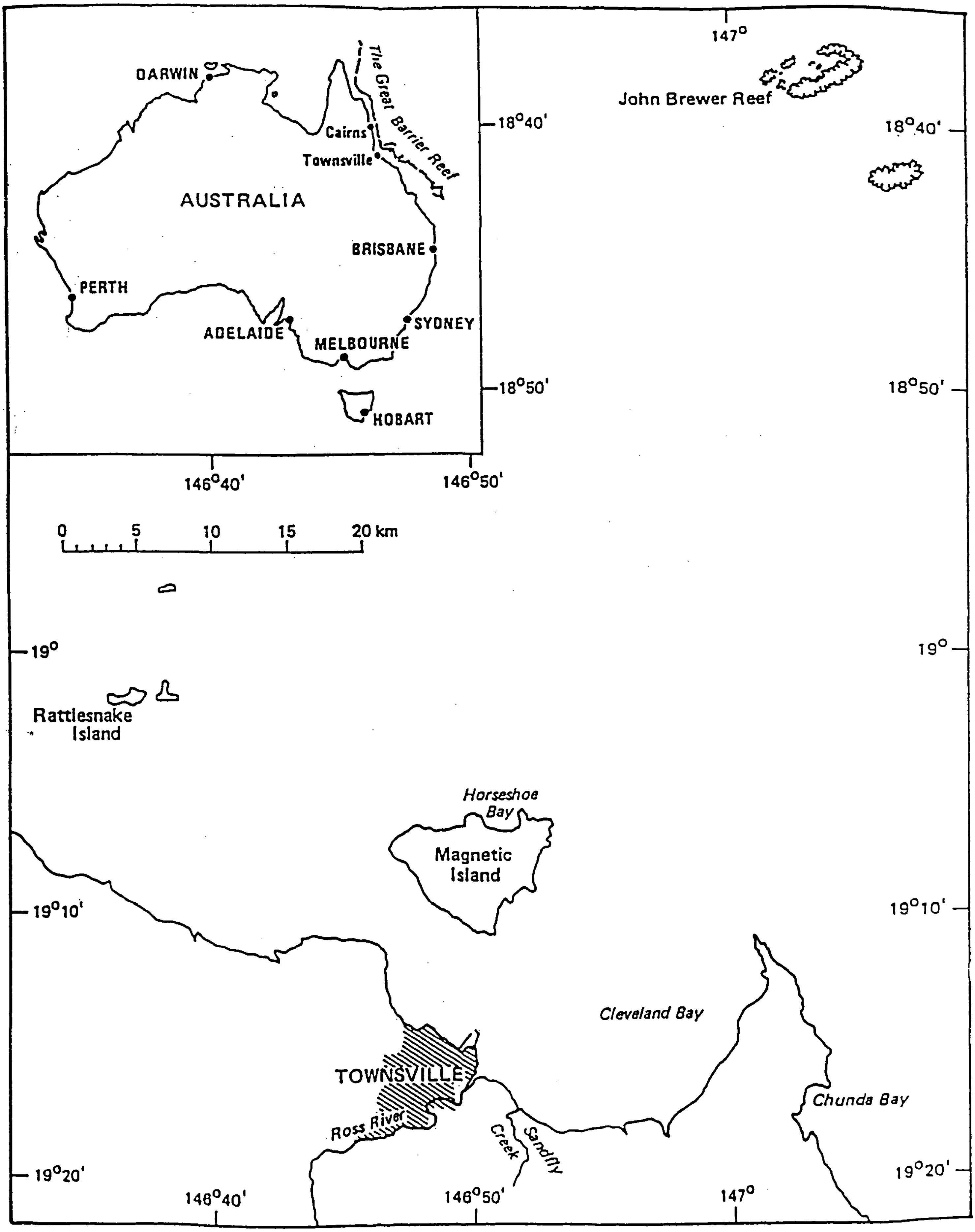


Figure 1. Location of John Brewer Reef

John Brewer Reef is an almost entirely closed, circular reef with a narrow opening 60 m wide on its northern side. The floating hotel was towed through this opening (after some obstructing coral bommies were cropped) and fixed in the lagoon using a single-point mooring system capable of withstanding a 100-year cyclone.

Water depth in the lagoon varies between 6-10 m at low water with a tidal range of up to 2.5 m. The volume of the John Brewer lagoon is approximately 7 x 10^7 m^3 at mid tide and has flushing rates in the order of 80% every five days (Parnell, 1986). Consequently, the lagoon is shallow but well flushed. During the design phase of the hotel attempts were made to minimise any impacts of the hotel on the environment. With the exception of a brine plume from the desalination plant, no liquid wastes were to enter lagoonal waters. All waste water was treated by a package plant on board to secondary standards followed by disinfection. The solids were subsequently incinerated while the treated wastewater was loaded onto a barge and discharged at sea in an area designated under the *Environment Protection (Sea Dumping) Act 1981.*

Gaseous wastes from the incinerator were emitted from a 24 m high stack which modelling had shown (Best, 1986) to have virtually no impact on ecological or aesthetic values of the lagoon. All solid wastes were either incinerated at high temperature or returned to the mainland. Additional controls on accidental emissions (e.g. a protocol designed for fuel transfer to and from the floating hotel) were also developed (Centre for Coastal Management (CCM), 1987).

The chronology of major events during the project is given in Table 1.2 and shows that the regulatory context in which the project developed changed continuously. First, federal sea dumping legislation commenced operation in 1984 followed by Queensland state legislation on this topic in 1986. State legislation covering off-shore structures was then introduced, followed by federal legislation. Each set of regulations required permits for a project which had developed to that point without such requirements.

A number of accidental, but often only indirectly related, events occurred during the life of the project which undermined public confidence in the project. The newly acquired high-speed catamaran ('Reeflink II'), designed to carry 400 passengers to the floating hotel, caught alight during a transfer to John Brewer Reef before it could service the hotel. Between the arrival of the hotel at John Brewer Reef and its official opening, the hotel was hit by a cyclone and although it suffered no mishap, some of the peripheral structures, such as the floating tennis court, were damaged, delaying the opening to paying guests. Fantasy Island, a totally unrelated floating platform independently installed at John Brewer Reef, sank during a storm two months after the hotel opened. Finally, a large, previously unidentified ammunition dump was found in the lagoon of John Brewer Reef, approximately 5 km from the hotel!

Table 1.2. Chronology of major events in the life of the floating hotel project -1981-1989

Oct. 1981	Great Barrier Reef awarded World Heritage listing.
Nov. 1981	Preliminary engineering assessment prepared for the 'Great Barrier Reef City' - a resort comprising three ocean cruise ships permanently placed on the sea bed of John Brewer Reef, together with an artificial sand cay and underwater walk tubes, with facilities for 3,000 guests.
Mar. 1983	The concept of a floating hotel first conceived by a group of Townsville businessmen.
Mar. 1985	Draft EIS for floating hotel completed and submitted for public review.
Dec. 1985	Conditional permit (G701) issued by GBRMPA. *Queensland Marine (Sea Dumping) Act* gazetted.
Apr. 1986	A ten-year contract for the marketing and operation of the resort awarded to Four Seasons Limited.
Jun. 1986	Construction of floating hotel commenced in Singapore.
Aug. 1986	*Off-Shore Facilities Act (Qld.)* gazetted.
Sep. 1986	Barrier Reef Holdings Limited listed on Australian and New Zealand stock exchanges.
May 1987	Baseline survey of lagoon biota carried out. Permit (G87/153) issued by GBRMPA for the cropping of bommies in the vicinity of the hotel site.
Jul. 1987	EM Program independently reviewed. Monitoring of bommie cropping operation in lagoon. Reeflink II burned off Magnetic Island.
Sep. 1987	Report on the success of coral transplanting received.
Oct. 1987	Zoning Plan for Central Section of GBRMP gazetted. *Sea Installation Act* was passed by the Federal Government to provide regulatory regime for sea installations in waters adjacent to Australia. Barrier Reef Holdings issued with an Exemption Certificate under this Act pending the issue of a full permit.
Dec. 1987	EM Program and EM Plan accepted by GBRMPA. Permit (G97/416) to operate the resort issued to Barrier Reef Holdings. Barrier Reef Holdings scholarships advertised nationally.
Jan. 1988	First water quality baseline surveys undertaken. Permit to discharge treated wastewater at sea granted under *Environment Protection (Sea Dumping) Act 1981.* Resort arrived from Singapore and installed in John Brewer Reef lagoon.
Feb. 1988	Cyclone 'Charlie' passed over resort.
Mar. 1988	Resort commenced operation.
May 1988	Fantasy Island sank in John Brewer Reef lagoon.
Jul. 1988	Barrier Reef Holdings announce $7.89 million loss for 87/88 financial year.
Sep. 1988	Resort put on the international market. Large old ammunition dump found in John Brewer Reef lagoon.
Apr. 1989	Barrier Reef Holdings became subsidiary of EIE Development Company Limited.
Aug. 1989	Overview report on EM Program covering May 1988-89 finalised. Floating hotel arrived in Ho Chi Minh City on the Mekong River, Vietnam.
Nov. 1989	Hotel officially opened to guests in Ho Chi Minh City.

After the company's takeover by Japanese interests (EIE), the floating hotel was moved to Vietnam to alleviate a shortage of quality hotel accommodation in Ho Chi Minh City - as evidenced by a >80% occupancy rate (Griffiths, pers. comm.).

Impact assessment, management and monitoring

Under the *Environment Protection (Impact of Proposals) Act 1974,* the Federal Minister for the Environment deemed that, as the project was likely to have significant environmental effects, an Environmental Impact Statement (EIS) was required and a draft EIS was submitted for public review in March 1985 (Det Norske Veritas and Coastal Ecosystems, 1985). Only six submissions were received in response to the draft EIS and the comments were incorporated into a final EIS. In December 1985, a conditional permit to install and operate the floating hotel was given by the appropriate federal agency, the Great Barrier Reef Marine Park Authority (GBRMPA).

Conditions of permission included (Dutton 1986):

- development of a resort management plan (CCM, 1987);
- development of an environmental monitoring program (CCM, 1988)
- classification of the facility and development of operational standards for matters such as public health and safety;
- insurance and environmental rehabilitation (bond) requirements;
- further research requirements (e.g. on brine plume modelling); and
- operational permission requirements (e.g. on bommie removal).

These requirements were the most comprehensive of any permit granted by GBRMPA to that time, and established a precedent for more elaborate environmental impact management regimes now used by GBRMPA for coastal and off-shore development projects (GBRMPA, 1991). In developing these requirements, the Authority also began to identify, for the first time, issues which were not capable of resolution under the planning and management regime developed to that time. As a consequence, a moratorium was placed on the further development of such facilities, to enable these permit provisions to be tested and further policy and planning studies to be completed (e.g. Cameron McNamara, 1985).

Program goal and objectives of the Environmental Monitoring Program (EMP)

The overall goal for this monitoring program was:

> **to provide information to management (both the resort operator and regulatory agencies) on the continuing environmental impact of the placement of the floating resort and associated operations.**

The three main elements (sub-programs) of the monitoring program were defined by establishing the information needs of the operator and regulatory agencies. They included:

a. Baseline survey and trend monitoring

The baseline survey was an integral component of the monitoring activity. It was intended to provide information on the environment at John Brewer Reef and other areas of the Great Barrier Reef Marine Park to be used by the resort operation prior to the commencement of such operations. This survey allowed identification of any changes in the environment subsequent to establishment of the resort.

Trend monitoring involved the systematic assessment over time and/or space of the general state ('health') of John Brewer Reef. Trend monitoring allowed changes in the reef to be detected. This monitoring included monitoring of coral cover, fish life, crown of thorns starfish densities, etc.

Contingency monitoring, i.e. programs to monitor accidental events, changes in operational procedures or unidentified impacts as these arise, is included within this sub-program.

Objectives for the baseline survey and trend monitoring program were:

- to establish sufficient reference data on the environmental conditions at John Brewer Reef prior to the placement of the floating resort to enable comparative analysis with data obtained subsequently in other monitoring sub-programs;

- to sample episodic events in order to provide reference data for any subsequent monitoring purposes;

- to assess the overall 'health' of those areas of John Brewer Reef and other marine areas affected by this project, including those coral bommies requiring cropping for the resort placement, through purposeful and repeated examination of the state or condition of selected parameters;
- to compile data on the relative usage of the Great Barrier Reef Marine Park which directly resulted from the resort's operations; and

- to provide advance warning of environmental changes caused by the project, or which may have had an influence on the continuing operation of the project.

b. Compliance assessment

This included monitoring of any permit conditions and standards established by regulatory agencies, for example, water quality determinations on the sewage system effluent, etc. The goal was to determine the extent to which environmental quality standards and objectives established in permit conditions for the project were met.

c. Hypothesis testing

This involved structured investigations into specific areas of concern identified in the EIS, including areas where it was agreed that there was some uncertainty in relation to the possible environmental effects of an aspect of the project. These investigations included assessment of the validity of some of the predictions made in the EIS, for example, effects of night lighting on fish, noise on fish, effects of seabird droppings on lagoon water quality, etc.

Objectives of the hypothesis testing were:

- to evaluate specific hypotheses regarding the predicted environmental effects of the resort; and
- to assess the effects of aspects of the project for which no prediction was made in the EIS, or about which some uncertainty existed.

The results obtained from each of these monitoring programs form the basis of this case-study, and are discussed in detail in the following sections.

CHAPTER 2: BOMMIE CROPPING OVERVIEW

David A. Fisk

Introduction

The floating hotel was towed to John Brewer Reef and moved into the lagoon in January 1988. The passage of the hotel and towing vessel into the lagoon would have been blocked by submerged bommies which were close to the surface (Figure 2). To facilitate the installation of the floating hotel, nine bommies (patch reefs) were cropped, i.e. the top of the bommies was removed so that the top of the bommies was deeper and the vessels could pass over their tops. The largest and shallowest of the bommies (Bommie #12) was approximately 50 m x 32 m in size, and required 4 m to be removed from the top, i.e. approximately 6400 cu.m. of material. The other bommies were smaller and required less material to be removed. The tops of the bommies contained variable amounts of living organisms which would be destroyed during the cropping process. A rapid survey of bommie #12 recorded the presence of at least 30 coral species, and over 80 colonies. Hard corals were predominantly pocilloporids and staghorn *Acropora* colonies.

The procedure followed for the bommie-cropping was as follows:

a. Large organisms were removed from the bommie and transplanted to another bommie away from the area. Corals were collected and placed in a metal cage which was towed submerged to the transplantation site. Coral were placed carefully in their correct orientation and were wedged into crevices but were not otherwise attached to the substrate;

b. A barge was positioned over the bommie and the reefal material was broken up with a pneumatic drill;

c. The broken material was transferred to a floating bin along-side the barge using a back-hoe crane; and

d. The material was dumped in a designated area several hundred metres away in the lagoon.

The objectives of this project were:

a. to survey the bommies and to determine whether any of the organisms were suitable for transplantation away from the area which was to be damaged;

b. to transplant some of the fauna to other bommies, and to determine the survival rates of the transplanted organisms; and

c. to monitor the general impact of the bommie cropping on nearby areas.

Methods

Surveys were done in May, July and August, 1987 and January 1988. The first stage of the project was a brief survey of the benthic fauna on the first and largest bommie to be cropped (described above), with particular attention to the hard corals. Many corals outside the immediate excavation area were tagged to determine their survival rate in situ, but many of these were eventually removed when it became clear that the drilling operation was going to have a major impact on any remaining organisms on the bommie.

At intervals of one to two months, the survival rates of the transplanted colonies were monitored. Observations also were made about the general effects of the operation.

Impacts of the bommie cropping

The removal of living corals from the bommie surfaces was incomplete at the time of the start of bommie cropping, and was done on a voluntary basis by the excavation contractors only at times when the weather was too rough for the excavation works. The excavation works resulted in the dislocation of large amounts of debris down the bommie sides, adjacent to areas which were heavily impacted by the operations. One month after the beginning of the operations, over 50% of the coral colonies, some soft corals, and Tridacnid clams had been transplanted away from the excavation site. They appeared to have been handled carefully and subsequent mortality of transplanted organisms was low.

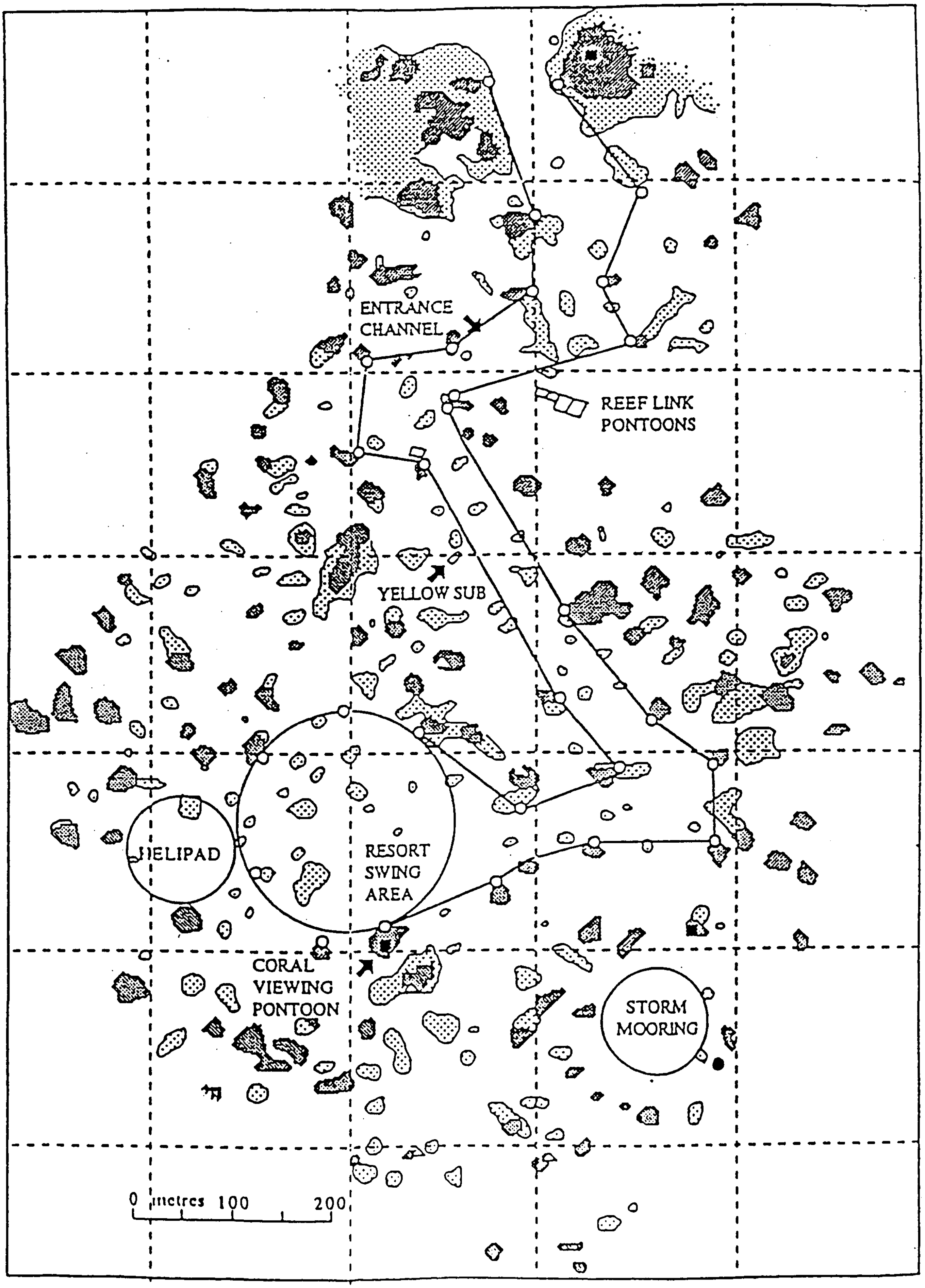


Figure 2 Map of John Brewer Reef showing the passage of the hotel and the towing vessel into the lagoon

The drilling operation ran into several technical problems which slowed operations greatly, and was limited by weather conditions in which work could not proceed. The initial plan of supporting the drilling barge with steel studs was unsuccessful for excavations and as well, the studs moved, damaging organisms which had not been removed from the bommie tops.

The use of stakes and cable ties to stabilise the barge was more successful. The drill operations either killed any remaining organisms directly or severely affected nearby organisms to a distance of about 3 m, probably as a result of fine sediment plumes generated by the excavation activities. Most individuals of a common reef-top sponge apparently died as a result of the drilling operations.

The removal of material from the bommie created several sources of sedimentation: one source was heavy sediments which rolled down the side of the bommie to a distance of up to 30 m from the base of the bommie, producing a thick sediment layer which covered the slope in less than two hours after the commencement of operations; the second source was from fine sediments discharged from the excavating bin holding mostly solid fragments broken from the bommie. This plume of fine sediment extended up to 150 m in the direction of the prevailing currents, and sank slowly as it moved away.

Any organisms remaining on the bommie within about 20 m of the operations showed clear reactions to the presence of the sediment. Soft and hard corals reacted by producing copious mucus, and some were covered in medium-sized sand grains.

Survival of transplanted corals

Corals and clams were transplanted over a two to three month period from May 1987. On 18 July 1987, the transplanted corals were surveyed using SCUBA. Of 318 colonies transplanted, only 1.6% (five colonies) had died. These corals represented approximately 24 species, but most (77%) were pocilloporids. One of the 16 transplanted clams had died, and two were over-turned.

A rapid snorkel survey around the site on 27 August 1987 showed that the transplanted corals continued to appear to be in good health, and with only a few corals dislodged. On 14 January 1988, the transplants were inspected again using snorkel. Survivorship appeared to be high, and the tips of the arborescent corals damaged during transplantation were re-growing. Most of the corals were in the correct orientation, indicating that the initial efforts by the transplanters to wedge the corals into position seemed to be effective. Larger fragments appeared to have survived better than smaller fragments and this is supported by other results (Harriott and Fisk, 1988). Some of the larger colonies showed partial mortality of some of the lower parts of their skeletons. This is common for transplants, but there was no sign of recent partial mortality. Of the transplanted clams, all appear to have survived and only one was not in the correct orientation.

Conclusions

In an area where construction activity is likely to physically disrupt large areas, or result in the discharge of large amounts of sediment, it is advisable to remove as many organisms as possible from the construction site. Transplantation of corals and clams at John Brewer Reef was successful with high survival rates over at least six months. The corals were wedged into place, but not otherwise attached. This was successful in the short term, but long term survival rates in adverse weather conditions may be improved by a better attachment method.
There were organisational problems with the John Brewer Reef bommie cropping program. Transplantation was not complete at the time of commencement of the destructive phase, and methods for the removal of the material had to be modified as the need arose. These changing methods meant that potential impacts of the process could not be predicted with any certainty. Flexibility in the management response was required, e.g. in removing organisms from the sides of the bommies when it became clear that these areas would be extensively damaged.

Following the success of the coral transplantation, the hotel management was interested in transplanting a wider variety of organisms onto one of the cropped bommies close to the hotel to improve the snorkelling amenity of the hotel guests. This technique of accelerated regeneration is feasible for the relatively small areas involved and quite likely could have included organisms removed from the same bommies prior to the cropping exercise. Unfortunately, financial difficulties intervened before the project could be started. The concept of removal of organisms from an area to be physically impacted, their storage, and subsequent use to regenerate the damaged area is one which may have relevance in a variety of situations.

CHAPTER 3: BIOLOGICAL MONITORING

Mark McCormick and Howard Choat

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

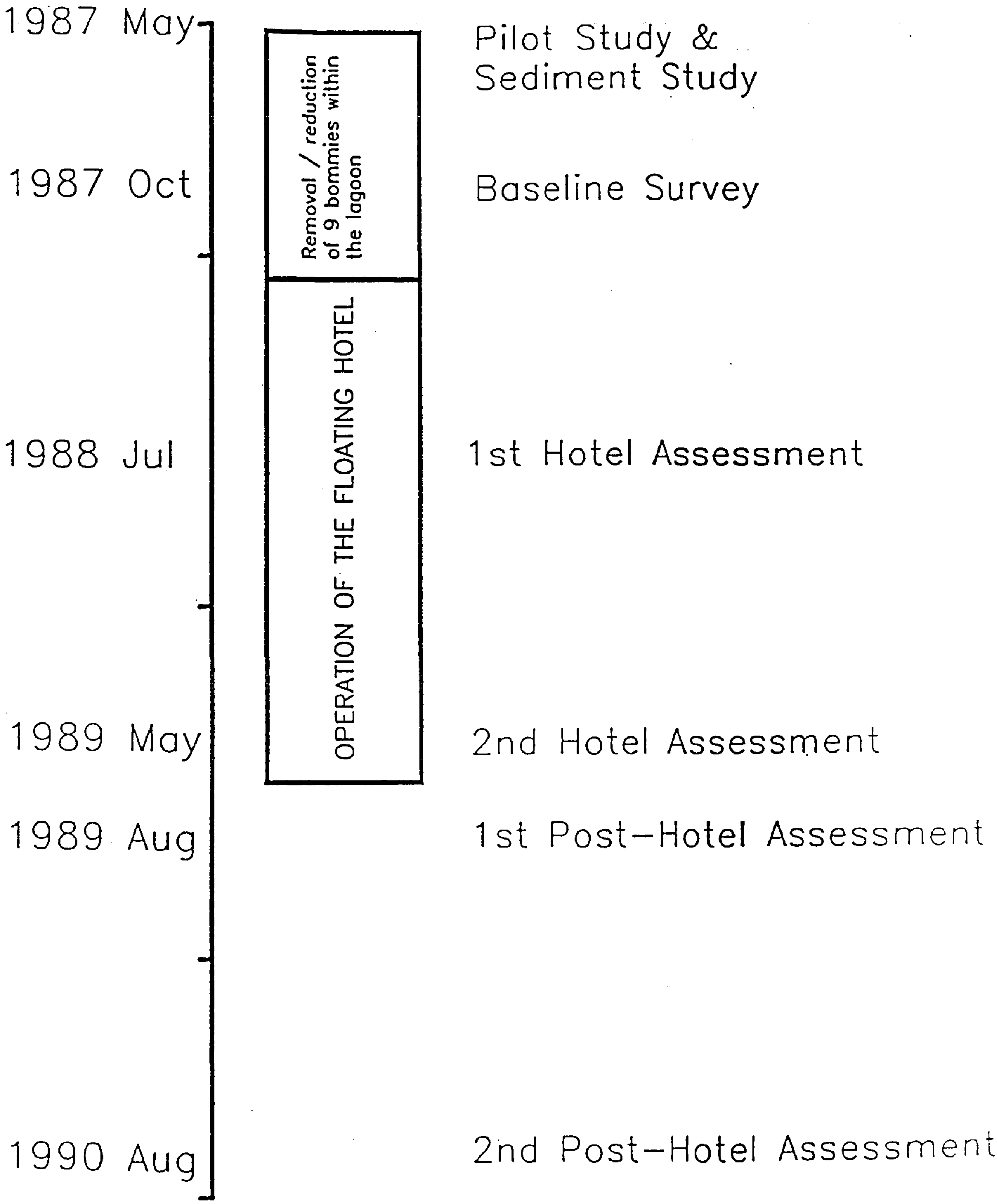
c. fish surveys: impacts attributable to the hotel potentially might have resulted in either a decline or an increase in fish numbers, which are another major element of coral reef fauna.

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



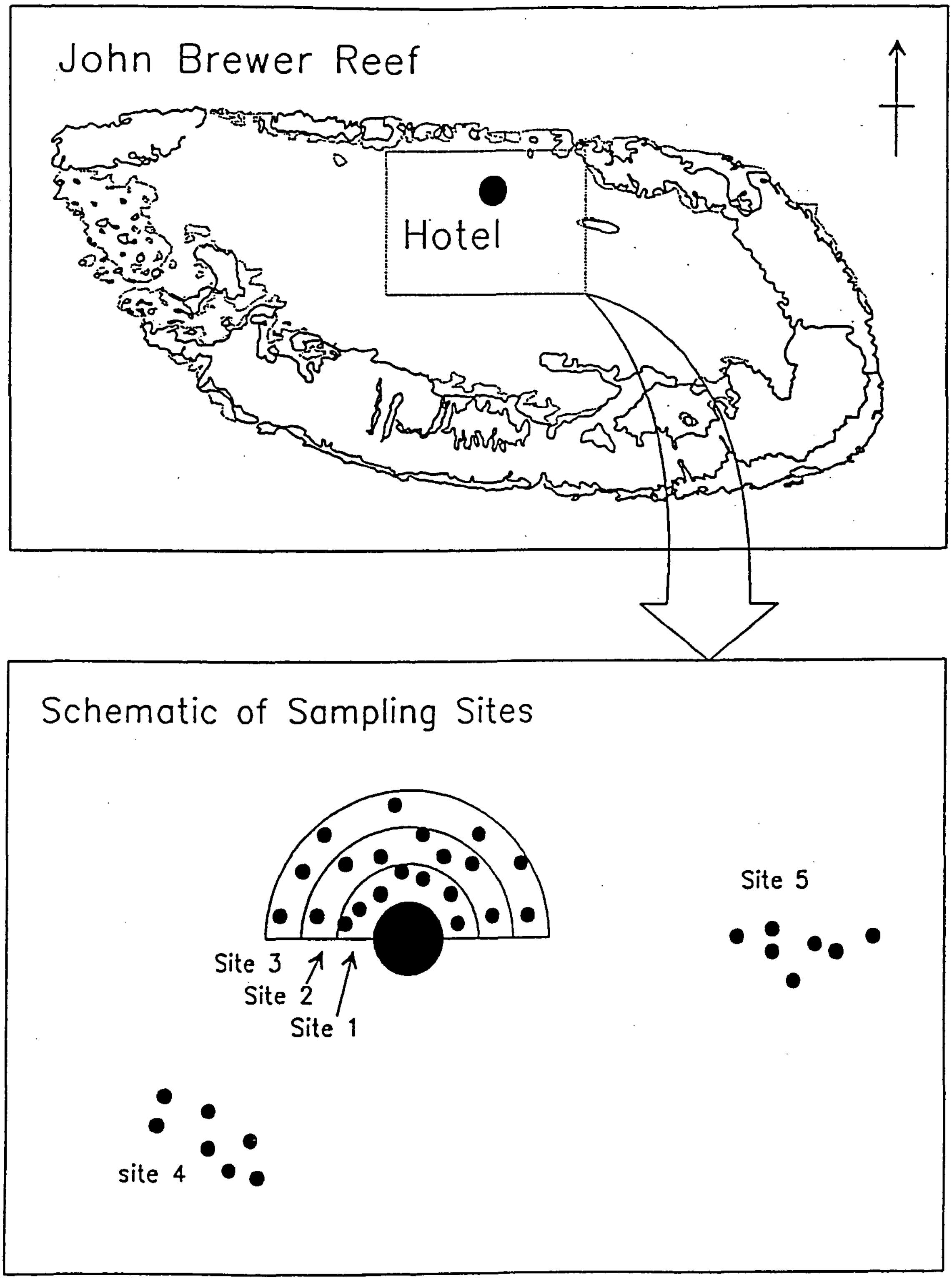


Figure 3.1. Map of John Brewer Reef, showing the schematic position of the five sampling sites radiating from the hotel swing circle, bommies are represented by the small black circles

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

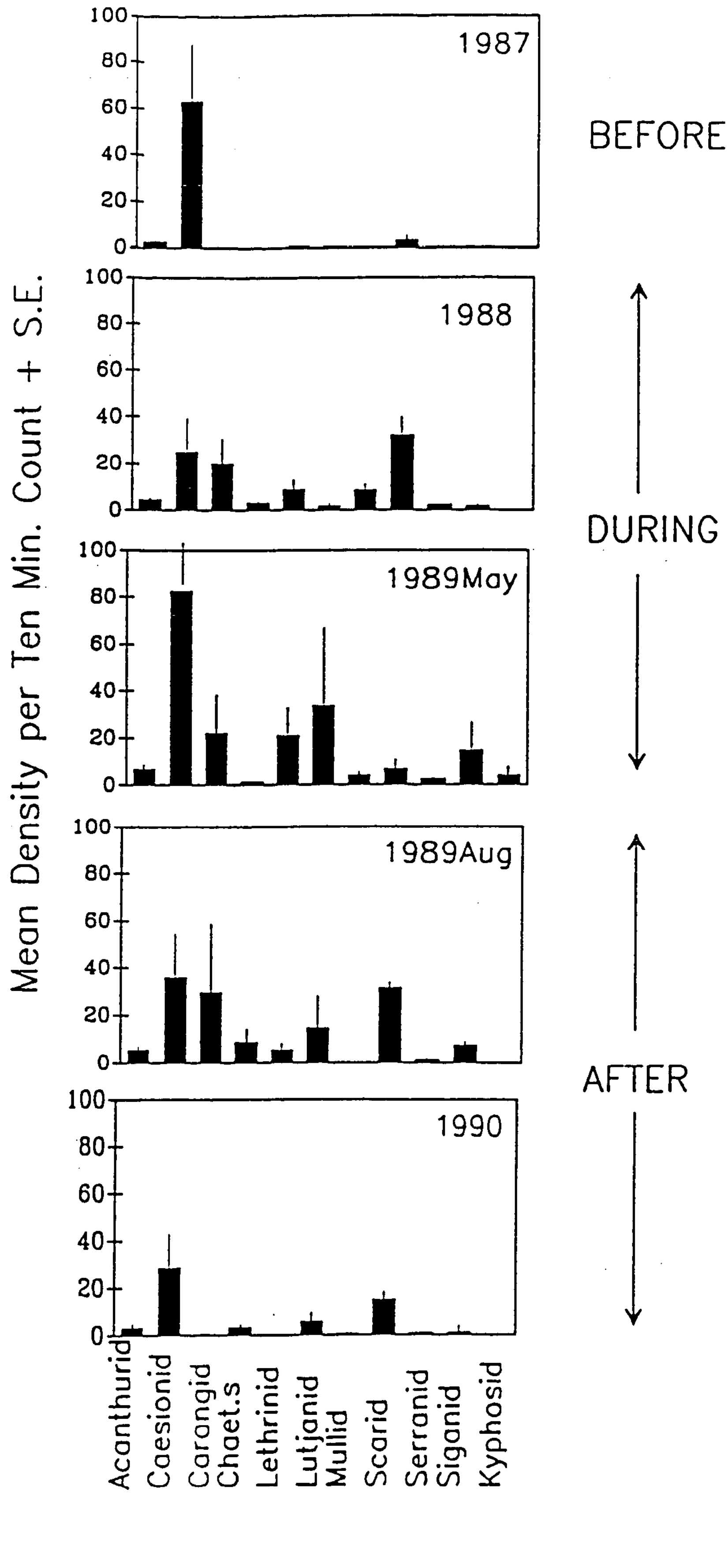


Figure 3.2. Comparison of densities of large mobile families of reef fish within the swing circle over four years. Mean densities per ten-minute swim are plotted and standard errors (n = 6)

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.

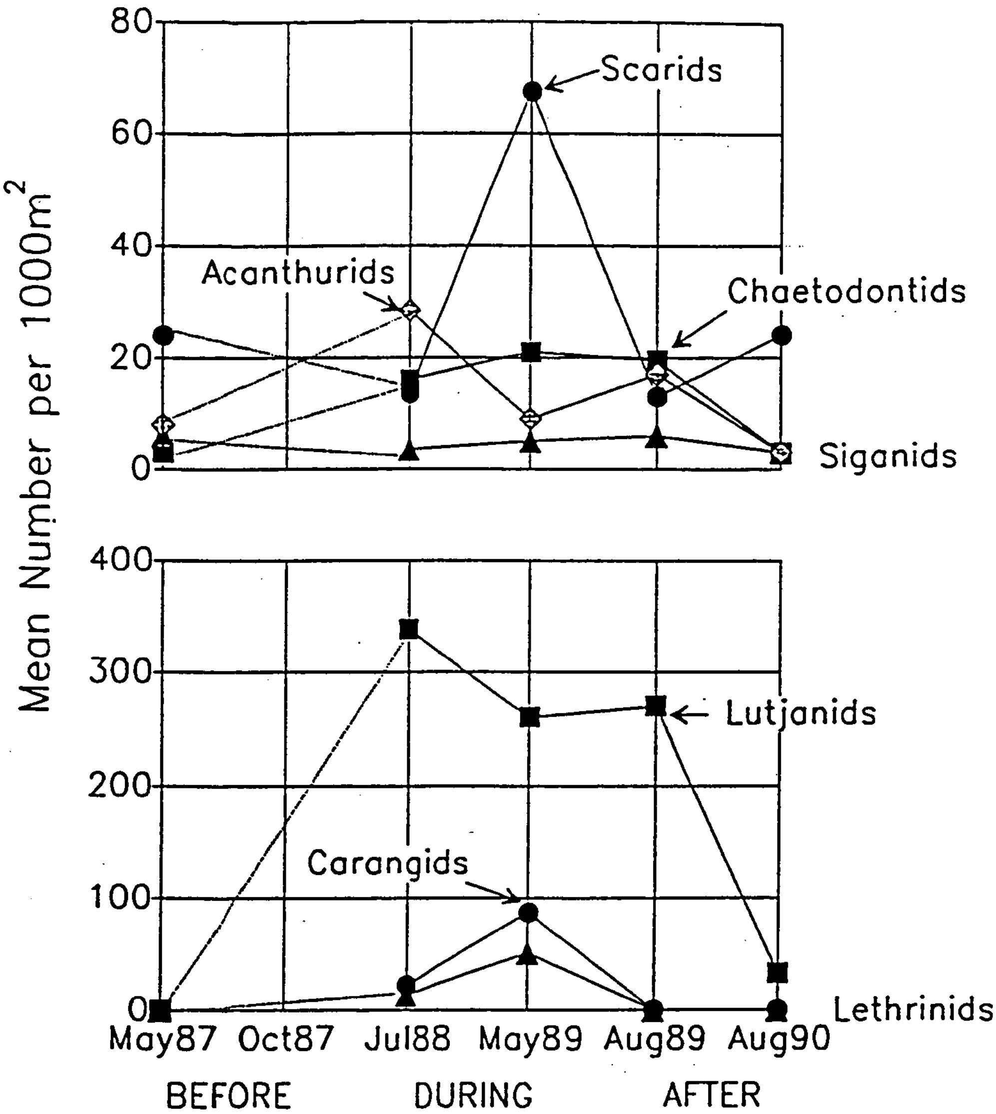


Figure 3.3. Comparison of the mean densities of large mobile fish on the bommie under the hotel (cropped in June 87 - February 88) over the monitoring period, May 1987 estimates are from the pilot study (McCormick, 1989)

CHAPTER 4: WATER QUALITY: COMPLIANCE ASSESSMENT

Graham Jones

Introduction

Probably the single most important indirect effect of tourist developments in the coral reef environment is that of a decline in local water quality (Saenger and Dutton, 1989). Sewage discharges, particularly if inappropriately sited or inadequately treated, are the most common sources of adverse effects on the biota (see review by Pastorok and Bilyard, 1985). Kaneohe Bay, Hawaii has been the site of the most detailed study of the effects of urban runoff and sewage on a coral reef ecosystem (Banner, 1974). In this bay, there was a drastic decline in the coral cover (particularly of *Porites compressa*) with heavy overgrowth by algae, such as *Dictyosphaeria cavernosa*. Immediately after resiting the sewage outfalls, some recovery was evident (Smith, 1977) and six years later the coral and macroalgal cover had returned to pre-discharge levels (Maragos et al, 1985).

In the Caribbean, where less than 10% of the sewage generated is treated, bacterial levels regularly exceed international standards for recreational contact waters (Barnes, 1973; Ward and Singh, 1987). In addition, the mat-forming alga *Cladophora prolifera* presently covers huge areas of in-shore waters although 25 years ago it was not reported (Bach and Josselyn, 1978; 1979; Lapointe and O'Connell, 1989). This alga, with a highly active alkaline phosphatase system and, thus, a high capacity to recycle organic phosphorus, can grow well in oligotrophic waters doubling its biomass every 100 days. However, with Nitrogen and/or Phosphorus enrichment, the biomass doubling time of this species is reduced to 14 days, allowing extensive mats to form which cause anoxia and a reduction in infaunal and epifaunal species diversity on decomposition (Lapointe and O'Connell, 1989).

Quite apart from the eutrophication effects described above, phosphate enrichment of coral reef waters may directly inhibit hard coral growth through phosphate inhibition of calcium carbonate deposition (Simkiss, 1964), an essential process of healthy coral growth.

As a condition of the GBRMPA permit and the permit under the *Environmental Protection (Sea Dumping) Act 1981*, the floating hotel resort was obliged to comply with set limits pertaining to water quality of the sewage plant effluent, the lagoonal water quality and the organic loads in the lagoonal sediments as defined in the environmental monitoring program (CCM, 1988). The results of the programs examining water quality are presented here.

Two sewage plants with a capacity of 15 cu.m. /hr treated all sewage and wastewater generated by the resort. Wastewaters were collected in a tank and treatment was started when levels reached a minimum treatment level. There were four stages of treatment:

a. Separation of sludge and wastewater. Initial plans were to incinerate sludge on-site, however, because of the mooring direction, soot from the incinerator fell back onto the boat, and the process consumed a lot of fuel. The sludge therefore was transferred by barge to the mainland for disposal;

b. Oxidation. Wastewater was treated by mixing oxygen and chlorine in the treatment plant. Throughout the life of the project there were major problems with low oxygen levels;

c. Disinfection. After oxidation with chlorine and oxygen, the wastewater passed through a whirl container where the action of the chlorine killed bacteria; and

d. Filtration and U.V. sterilization. Wastewater was filtered and treated by U.V. sterilizers, once they were functional in July 1988, at which point chlorination was no longer used.

Treated water was pumped on board a service barge and released at a designated location about 5 km from the resort.

Water quality monitoring objectives

The main objectives of the monitoring program for water quality of the sewage treatment plant effluent were:

a. to obtain water quality data on the treated effluent of sufficient reliability to satisfy the permit requirements of the GBRMPA and the requirements of the Sea Dumping permit (essentially this meant that treated wastewater should have a biological oxygen demand (BOD) of 20 mg/L; a non-filtrable residue (NFR) of 30 mg/L, an *E. coli* bacteria reading of no more than 200 organisms/100 ml of effluent, and a residual chlorine level of 2 mg/L); and

b. to provide sufficient data on effluent quality to enable the performance of the sewage treatment plant to be critically evaluated.

In addition to the program targeting the wastewater effluent, there was a second program concerned with general water quality in the vicinity of the resort. The objectives for the program monitoring lagoonal water quality were:

a. to obtain water quality data from John Brewer Reef lagoon, in the vicinity of the resort and its operation of sufficient reliability to satisfy the permit requirements of the GBRMPA; and

b. to provide sufficient data on water quality in the lagoon to enable the effect of the various resort-related activities to be critically evaluated.

In effect this meant measuring a number of water quality parameters, pre-resort, during the resort's operation, and post-resort. At the present time, no guideline values exist for estimating the water quality of reef waters.

Methods

Water quality monitoring for the Compliance Assessment Program was carried out from January to December 1988, and in July 1989. The first period covers the pre-resort and resort surveys and the latter was a post-resort survey.

Sewage effluent samples were tested every two weeks up until April 1988, and monthly thereafter. Samples were obtained from the terminal end of the transfer pipe at regular intervals during the transfer of the effluent to the barge and combined to produce a composite sample of the treated effluent. Mid-stream samples were taken in duplicate and were stored on ice until analysis.

All samples were collected in airtight sterile acid-rinsed bottles. Standard techniques (Standard Methods, 1981) were used for measurement of each of the parameters.

The following parameters were measured for the effluent samples, either on-site or in the laboratory:

five-day BOD	*E. coli* concentrations
non-filtrable residue	pH and dissolved oxygen
free chlorine residue	total phosphorus
total organic carbon (TOC)	ammonia-nitrogen
salinity	total nitrogen

For the lagoonal water sampling, samples were obtained from two fixed sites within the lagoon at monthly intervals. These sites were the resort station (R) and control station (C) (Figure 4). Lagoonal water quality was monitored during three periods, pre-resort (January 1988), during resort operations (July and December 1988), and after the resort was removed (July 1989). During these three periods, sampling was carried out over 24-hour periods to determine daily and tidal variation in each of the parameters measured.

All samples were analysed on-site or, alternatively, stored on ice and analysed as soon as they reached the laboratory.

The following parameters were measured:

dissolved inorganic nitrogen	salinity
ammonia	temperature
dissolved inorganic phosphate	dissolved oxygen
silica	free chlorine residue
chloroplyll *a*	*E. coli* bacteria
total organic carbon	BOD
dissolved organic carbon	

Results and conclusions

Wastewater treatment

Monitoring of the wastewater treatment plant showed that a number of technical problems existed and that during the commissioning phase (January to April 1988), the quality of the effluent did not reach the manufacturers specifications nor conform to the Sea Dumping permit requirements. Mean levels of BOD, suspended solids, *E. coli* and free residual chlorine for January - March 1988 were 57 mg/L, 70 mg/L, too numerous to count, and 0 respectively. Mean nutrient concentrations and TOCs for this period did not pose a problem: respective means were: 23 mg/L total Nitrogen; 5 mg/L total Phosphorus and 21 mg/L TOC.

The technical problems during commissioning included inadequate chlorination, poor UV disinfection, corrosion in holding tanks, the unexpected effects of flocculants in the wastewater, and the build-up of sludge in the holding tanks due to the incomplete operation of the resort's incinerator. By April, many of these technical problems had been overcome and good free chlorine levels and no *E. coli* were present in the effluent samples. Better operating procedures and the installation of an improved UV unit were undoubtedly responsible for improved disinfection. However, levels of BOD remained high and this was ascribed to:

a. the apparently high BODs of the flocculants from the desalination plant;

b. washings from the desalination plant which appeared to be contributing chemical oxygen demand (COD) to the effluent, and

c. build-up of iron in the holding tanks which exerted a high COD.

Based on the trends shown, it would seem that the following concentrations could be expected in the wastewater effluent without major operating changes:

Total Phosphorus	5-6 mg/L
Total Nitrogen	30-40 mg/L
Total Organic Carbon	30 mg/L
Suspended Solids	70-90 mg/L
BOD	50-70 mg/L
E. coli	nil N/100 mL

While these concentrations did not pose a significant problem for open ocean discharge, particularly with good initial dispersion, they were in breach of the Sea Dumping permit. Particular attention should be paid to the effects of the flocculants from the desalination plant on the BODs and total N levels in the wastewater.

Other aspects of the operating procedures that needed to be examined further included:

a. the diversion of effluent from the black water tank to the grey water tank when the oil and grease content exceeds 15 ppm;

b. the build-up of iron in the holding tanks from corrosion or the use of potassium permanganate; and

c. better aeration in the holding tanks and the adjustment of the pH to 8.0-8.5 to lessen sulphide generation.

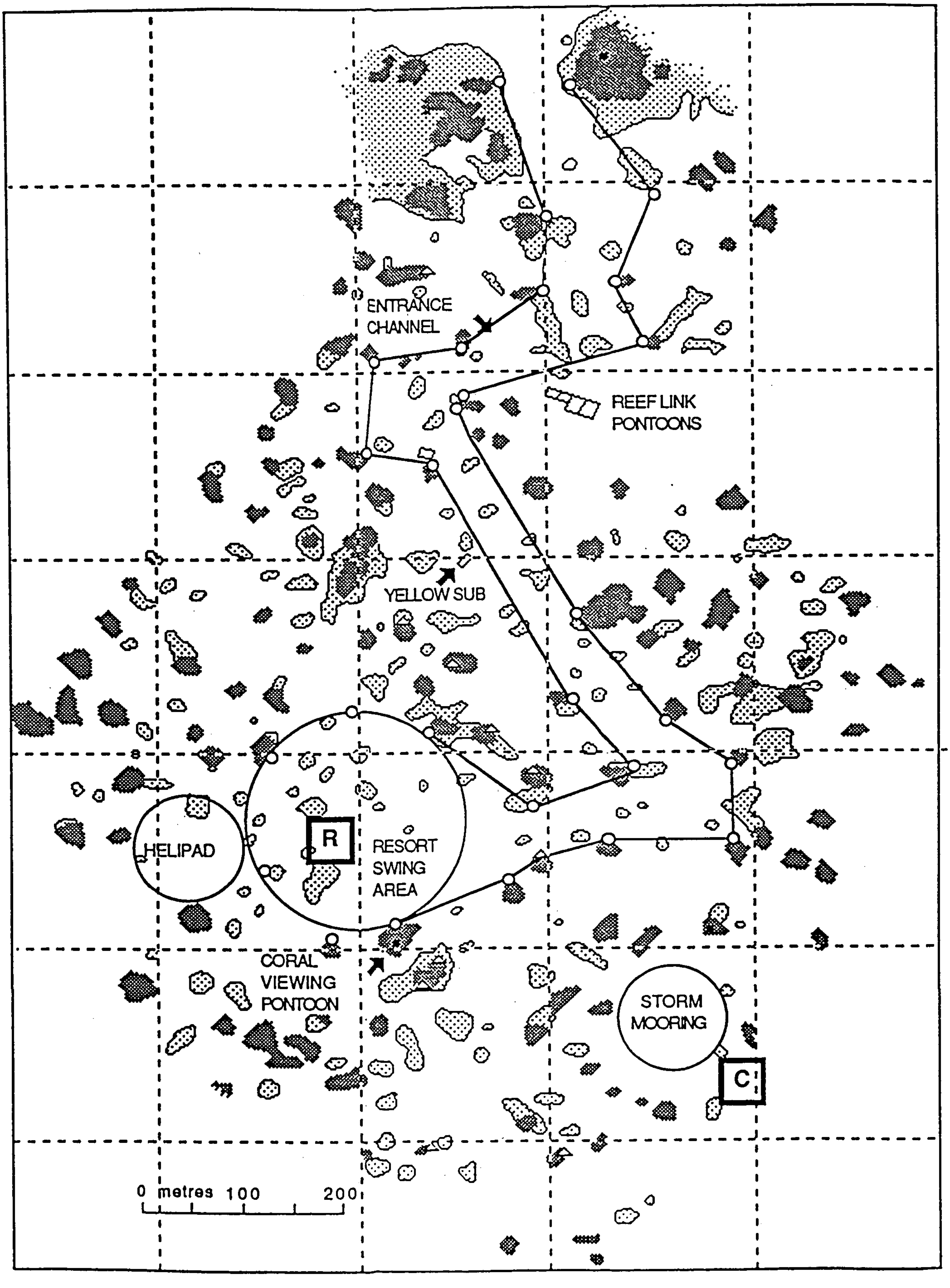


Figure 4. Resort swing circle (R) and control (C) sampling sites

The problem of the free residual chlorine concentration was a vexed one. The Sea Dumping permit required a free chlorine residual of 2 mg/L. Whether such a level was achievable without massive slug-dosing is questionable. Its desirability can certainly be questioned while adequate disinfection is being attained with UV irradiation.

A comparison of BOD and COD showed that there was no difference between the two, indicating that BOD for the sewage plant was very low (< 10 mg/L), while the value for COD was a result of the high levels of iron and sulphides present in the effluent. Overall efficiency of the operations ranged from 62% to 72%. The total amount of treated wastewater discharged at sea in 1988 was approximately 8052 tons, less than 0.07% of the wastewater discharged into Cleveland Bay from the population of the Townsville district. This is an extremely small quantity being discharged into an open sea environment with very great dilution factors.

Barnes (1973), in his analysis of Caribbean sewage effects, showed that with the increased use of package treatment plants, sewage effects can be minimised. However, a number of factors relating to the operation of package plants means that such systems do not operate to their full potential. These factors need to be considered in day-to-day management planning for tourist developments. They include:

a. fluctuating loads during peak and slack tourist seasons caused problems of overload at certain times, and an inadequate load to maintain the microbial populations within the plant at other times;

b. package plants often were operated by inexperienced personnel rather than by sanitary engineers, as a result of which, package plants were poorly maintained, and subject to frequent mechanical failure; and

c. virtually no monitoring of package plant function was undertaken.

Lagoonal water quality

The results of the lagoon monitoring indicated that there were no significant differences in any of the parameters between the resort and control sites (Table 4.1). One anomalous finding was the silica concentrations, which had increased significantly at both the resort and control sites during December 1988; but as no significant difference occurred between the resort and control sites, the increase must be due to a regional phenomenon such as an algal (silicoflagellate or diatom) bloom, rather than any effect due to the resort.

Only two effluents, the brine plume and some seawater coolant water, entered the lagoon from the hotel. Analysis of coolant seawater for nutrients established that this was not significantly different from lagoon water close to the resort. Sampling of the brine plume in April 1988 showed that this effluent contained appreciable levels of suspended solids (23 x seawater) and elevated levels of nutrients: phosphate (5 x seawater), nitrate (2.4 x seawater), silica (21 x seawater) and ammonia (60 x seawater).

On another occasion (30 June 1988), only silica was significantly higher than seawater (x 6). When these values were compared with concentrations measured in the swing circle station, it appeared that the brine plume did not significantly affect nutrient water quality in the vicinity of the resort. On one occasion (April, 1988), 15 MPN/100 mL *E. coli* were detected at the resort site and this was attributed to a visiting trawler.

The less intense monthly monitoring supports these findings and leads to the conclusion that prior to the placement of the resort, the lagoonal waters at John Brewer Reef were not significantly affected by human bacteria such as faecal coliforms and *E. coli.* Levels of organic matter in the lagoonal waters were low and comparable to other reef waters and no significant contamination of phosphorus and nitrogenous organic compounds was evident.

Monitoring results since the placement of the resort to December 1988 have shown that the activities of the resort have not significantly affected water quality parameters measured as part of this project, and the post-resort monitoring was consistent with this pattern.

Table 4.1. Mean water quality and nutrient data for John Brewer Reef (a) Pre-Resort, (b) Resort and (c) Post Resort

Mean Water Quality Data

	Temp (°C)	pH	O_2 (mg/L)	Susp Sed (mg/L)	Turbidity ((NTU)	BOD (mg/L)	TOC (mg/L)	DOC (mg/L)
(a) Pre-Resort (January 1988)								
Control Station	27.70 (11)	-	7.30 (4)	3.78 (20)	0.40 (11)	1.8 (10)	-	1.48 (9)
Swing Circle	27.55 (11)	-	7.48 (4)	3.62 (20)	0.35 (11)	1.8 (10)	-	1.68 (9)
(b) Resort (Febuary-December 1988)								
Control Station	25.92 (26)	8.25 (34)	7.77 (34)	2.64 (43)	0.26 (34)	0.54 (10)	0.98 (12)	0.68 (4)
Swing Circle	25.92 (32)	8.33 (34)	8.33 (43)	2.59 (42)	0.34 (34)	0.39 (6)	0.70 (12)	0.64 (4)
(c) Post-Resort (August 1988)								
Resort Station	20.80 (11)	-	8.72 (11)	3.06 (17)	-	-	-	-

Mean Nutrient Data

(a) Pre-Resort	PO_4 µM	NO_3 µM	NH_3 µM	Si µM	Chl *a* µg
(a) Pre-Resort					
Control Station	0.25 (21)	0.23 (21)	-	1.03 (21)	0.44 (22)
Swing Circle	0.29 (21)	0.48 (21)	-	0.99 (21)	0.30 (22)
(b) Resort	0.22 (39)	0.27 (39)	0.19 (36)	2.95 (21)	0.52 (43)
Swing Circle	0.24 (38)	0.26 (38)	0.19 (36)	2.97 (21)	0.58 (43)
(c) Post-Resort					
Swing Circle	0.12 (21)	0.28 (21)	-	0.93 (21)	0.16 (8)

Effect of *Trichodesmium* on water quality

Anomalous effects on nutrient water quality were found at John Brewer Reef during the presence of *Trichodesmium*, a blue-green algae which blooms prolifically in the Great Barrier Reef lagoon (Jones et al, 1982). This organism was present in the lagoon on 14 - 15 January 1988 and November - December 1988. During these occasions significant changes ($P < 0.001$) in dissolved phosphate, nitrate, ammonia, silica, chloroplyll *a*, pH and suspended sediment occurred (Jones, 1992). Suspended sediments and dissolved inorganic phosphate levels exceeded or were close to recent water quality tolerance levels derived for corals (Hawker and Connell, 1989).

Monitoring program design

The following recommendations were made for modification to an on-going program of routine water quality monitoring, had it continued.

a. Effluent disposal

- Operating procedures for the wastewater treatment plant should be examined with a view of improving the effluent standards; this includes reduction of sulphide generation and minimisation of corrosion of iron in the holding tank.

- Studies on the effect of flocculants on the BOD and total Nitrogen levels of the effluent should be investigated. The types of detergents and cleaning agents used should be critically examined to remove from use any that are phosphate-based.

- Delete the free chlorine requirement of 2 mg/L on the basis that UV disinfection is effective, and preferable to chlorination.

- Sludge, wastewater, and brine wastes should be returned to the mainland.

- Any effluent entering the lagoon should be monitored.

- Trace metals, oil and grease, and total Nitrogen and Phosphorus should be made every three months.

- The efficiency of the wastewater plant should be monitored every three months by the appropriate government agency.

b. Lagoonal water quality

- Comprehensive 24 hour monitoring should be carried out every three months. Visits should be intensive rather than cursory monthly visits.

- Specific activities should be labelled for critical examination.

- Any effluent entering the lagoon should be monitored for metals, nutrients and organics.

- In any reef water quality monitoring program specific attention should be given to assessing whether *Trichodesmium* is present since it has been established that this organism significantly affects water quality in the Great Barrier Reef Lagoon. Failure to take account of this organism can be detrimental to the developer.

An inherent problem with any monitoring program is that comparisons between 'impact' and 'control' sites provide data which can be criticised on statistical grounds. Claims are often made for random-block compartments distributed around 'impact' and 'control' sites. For seawater studies, such claims are not valid. Apart from being costly exercises, seawater is usually homogenous with most constituents lying within very narrow tolerance levels. A simple and inexpensive way is to correlate data for impact and control sites (Jones, 1991). Any deviations away from a significant correlation then can be investigated in detail.

CHAPTER 5: SEDIMENTS: COMPLIANCE MONITORING

David McConchie

Introduction

In addition to the compliance monitoring of water quality for the sewage discharge and lagoonal waters, part of the monitoring was designed to determine whether the hotel resulted in any detectable changes in the sediments in the vicinity of the hotel. The objectives of this study were:

a. to obtain lagoonal sediment data of sufficient reliability to satisfy the permit requirements of GBRMPA;

b. to provide a means of accurately monitoring any changes in indicative sediment parameters including organic loading and nutrient status; and

c. to assess the significance of any observed changes in terms of the likely effects on the biota of the sediments.

Methods

Samples were obtained from a number of sites within the lagoon in the vicinity of the resort and at control sites. These sites corresponded to the treatment and control sites established for the biological monitoring program.

Samples were collected monthly from January to December 1988, and were obtained by hand-held corers. The sediments in the cores were analysed for:

sediment mineralogy and texture;
total organic matter;
total-Nitrogen; and
total-Phosphorus.

In addition, both sediments and sediment-inhabiting biota were analysed for heavy metals (including cadmium, zinc, copper and lead) and hydrocarbons. Standard analytical techniques were used for these parameters.

In August 1989, Graham Jones collected and analysed an additional sediment sample at the same time that he collected water samples, for a post-resort survey.

Conclusions

Of the various physical and chemical parameters measured in this project, only sediment composition, sediment texture, and copper concentrations showed any significant differences between samples collected near the resort and from control sites. The difference in sediment composition reflects the presence of small quantities of 'litter' near the resort. The biological impact of such litter was likely to be small.

Sediment textures near the resort were initially similar to those at the control site, but sediment near the resort became coarser and more poorly sorted, probably because the disruption of natural current flow across the lagoon by the resort caused locally increased turbulence and winnowing of nearby sediment. This was a localised effect and of little environmental consequence in the context of the lagoon as a whole. The increased turbulence and winnowing near the resort may have meant that any liquid or fine particulate matter added to lagoon waters as a consequence of the resort was diluted and dispersed more rapidly than initially anticipated.

Copper concentrations near the resort were initially slightly higher than at the control site but during the study period, the difference in copper concentrations at the resort and the control site generally decreased to the point where, by the end of the study, the difference between the two sites was not significant. Anomalously elevated copper and zinc concentrations detected in one sample from near the resort were attributed to traces of metallic litter found in the sample.

In the post-resort analysis by Graham Jones, copper and lead concentrations did not differ between control and resort sites, and copper concentrations were lower than the values reported during this study, but zinc concentrations were significantly higher at the Swing Circle site than at the control site.

Overall, the data obtained during this study indicate that the resort had a negligible impact on the lagoonal sediments nearby. In view of the absence of significant changes in lagoonal water quality, this conclusion is not unexpected.

Consequently, it was recommended that, had the monitoring program continued, the frequency of monitoring should be scaled down to about once every three months.

Monitoring of lagoonal sediment quality would consist of the following:

a. sediment mineralogy should be determined by X-ray diffraction and microscope examination once every year and should be supplemented by three monthly inspections for 'litter' carried out by a diver and the yearly sampling should include one sample from the control site and three from near the resort;

b. determinations of sediment texture should be continued to monitor the turbulence induced changes caused by the resort and this monitoring should involve the collection and examination of one sample from the control site and three samples from near the resort once every three months;

c. determinations of nutrient element and organic carbon concentrations by chemical means should be replaced by three monthly inspections and documentation by divers of the extent of algal growth on the sediment surface near the resort; and

d. determination of heavy metal loads should be limited to measurement of the copper, lead and zinc concentrations and should involve one sample from the control site and three samples from near the resort collected once every three months.

CHAPTER 6: USER SURVEYS

Ian Dutton and Peter Valentine

Introduction

To understand the impact of the John Brewer Reef floating hotel on the environment it was necessary to understand both patterns of human usage of the reef prior to the hotel construction, and how those usage patterns were likely to be modified once the hotel was installed. The project had two stages. Stage 1 was undertaken between May and July 1988 and reported on a 'baseline' survey of reef use and user attitudes for John Brewer Reef and other areas to be directly affected by the hotel operations. Stage 2 was completed in 1989 and examined changes in use of the reef and surrounding areas as a result of the resort operations. Stage 3 was planned to be a study of issues arising as a consequence of the resorts operations but did not proceed because of the hotel's closure and removal.

The objectives of the surveys were:

a. to determine the nature, extent, frequency, duration and other characteristics of use of John Brewer Reef and other areas to be affected by resort operations prior to the commencement of the resort operation; and

b. to assess changes in these use patterns and characteristics following commencement of operations to enable further investigation of reasons for changes, should such investigation be deemed necessary.

Methods

Stage 1: Description of previous use (Baseline)

This stage involved determining the patterns of use of John Brewer Reef and other areas (e.g. adjacent reefs to be used for fishing operations emanating from the resort). Use patterns and characteristics were determined according to the following methods for the various user groups:

User Group	Measurement Technique
a. Day Trippers	Observation of use and interview with operator(s)
b. Private Boat Owners	Interview with sample drawn from DH&M records and review of surveillance data
c. Amateur Fishing Clubs	Interview with sample drawn from records and review of surveillance data
d. Commercial Fishermen	Review of surveillance data and interview of sample of skippers/crew drawn from surveillance records
e. Charter Boat Operators	Review of Surveillance data and interview of sample (includes Dive Operators) of operators
f. Scientific Researchers	Interview of selected researchers (to include all major institutions)

Apart from the descriptive information obtained during this stage, users were asked to outline their concerns in relation to the resort, in particular to indicate how they perceived the resort might affect their use of areas involved.

Stage 2: Survey after 12 months

Data was collected using similar techniques to those used in the first surveys, i.e. the observational/anecdotal method and direct survey methods. Because commercial day trips ceased shortly after the opening of the hotel this user category was removed from the questionnaire sample, leaving the remaining five user groups.

For each group, samples were selected as follows:

Private boat owners: questionnaires were sent to 133 boat owners who had responded to the earlier survey and to a random selection of 422 boat owners from the district.

Amateur fishing clubs: the ten clubs surveyed in the first sample were re-surveyed. and club members were interviewed by phone.

Commercial fishermen: representatives of the Queensland Commercial Fishermen's Organisation and mackerel fishermen were interviewed personally.

Charter boat operators: the sample was 24 charter boat operators who participated in the first survey and one new operator. All were sent a questionnaire or contacted by phone.

Scientists/researchers: of the 23 active researchers at John Brewer Reef (compared with 19 prior to the placement of the hotel), 20 were contacted and questioned.

Conclusions

Stage 1 surveys

The major users of John Brewer Reef in 1987 (in descending order of participant numbers) were day trippers, charter boat passengers and private boat owners. Other users included commercial fishermen, amateur fishing clubs and scientific researchers. However, the latter groups comprised only a small proportion of total visitation.

The baseline survey found that most users believed that the resort would have beneficial or neutral impacts on their use of John Brewer and other reefs. For example, among private boat owners, 58% indicated that they thought the resort would not change their use or experience at John Brewer, 30% indicated that their use of John Brewer would increase as a result of the resort and 12% believed that their use or experience at John Brewer would decrease due to the resort.

Among charter boat operators, similar trends were found with 54% stating that their visits would increase, 29% expected no change and 12% thought that their use would decrease. The few users who indicated concern about the potential impact of the resort on their use, cited reasons including adverse effects on fishing, aesthetically unappealing, loss of remoteness, adverse effect on reef or more restriction on reef access.

Stage 2 surveys

The response rate to questionnaires for the private boat owners was 39%. Of these, 17% did not visit the reef in 1988 and 34% visited the inner reefs and islands only. Fishing was the primary reason to visit the reef for 70% of boat owners. Of 20 reefs nominated in the Townsville region, John Brewer Reef was visited by the greatest number of boats (37 boats for 97 visits), and the primary purpose of the visits was fishing (44%), followed by swimming (24%), and snorkelling or scuba diving (24%). The presence of the floating hotel at John Brewer Reef was nominated as major attractant by many respondents.

Approximately half of the boat owners surveyed reported that the floating hotel did not affect either the frequency or the quality of their use of John Brewer Reef. Where frequency of visits was changed, 61% reported an increase in visitation and 39% a decrease. Two of the 37 responses voiced strongly negative values about the appearance of the hotel. Other comments concerned the advantages of the hotel as a navigation aid, complaints about being unable to fish in the area, and concerns about the feeding of fishes from the resort.

Amateur fishing clubs made a total of 87 weekend club trips to the reef in 1988. None of the visits were to John Brewer Reef. Comment again was made on the use of the hotel as a navigational aid.

The two representatives for commercial fishermen were interviewed. Both reported little apparent impact from the hotel. Trawlers continued to anchor there and used the facilities of the hotel. Mackerel fishermen who had frequented John Brewer Reef in the past continued to do so, although in general it was not considered to be a good location for mackerel fishing and had not been so for five or six years.

Of the 25 charter boat operators contacted, responses are available from 15. Five take day-trips, five make two-day trips and the others have trips of variable length. A total of approximately 1400 trips were reported, of which 87% were to the reef. The operators are approximately equally divided between predominantly fishing or diving trips. John Brewer Reef was the second most frequently visited site (behind the Palm Islands), with 398 visits, and all but one of these were two days or less. Visitation rate was higher than in 1987 (346 visits), partly because of work associated with the hotel. Of the eight operators who reported visiting John Brewer Reef in 1988, five said that the hotel had changed the way that they used the reef and three said that it had not. Comments made by this group on the hotel include its use in navigation, a convenient point for passenger pick-up, and increase in the fish population due to the hotel, and as an interesting feature for the tourists.

Of the 20 researchers interviewed, most visited four times or less, and stayed from one to ten days. The hotel served as a focus for ten of the research scientists. Scientists from Australian Institute of Marine Science operated independently of the resort and reported little change in their use of the reef as a result of the hotel. For other scientists, the majority reported a change in their use of the reef; reasons included increased ease of transportation, provision of funding for research, studies on the impacts of the hotel. There was one negative comment on the debris produced by the hotel and its placement. With the removal of the floating hotel, along with the cessation of the Reef Link operation, there is now decreased opportunities for travel to the reef and research effort there may decline.

In summary, there were no clear cut results regarding the effects of the floating hotel on users. In the sampled populations, there was a slight increase in the number of users in the charter boat, private boat and researcher categories, but the major decline in day-trips as a result of the Reef Link closure. A few users chose to visit the reef specifically to see the hotel (novelty value), and others were economically dependent on the hotel (some charter boat operators and researchers) but there is little evidence that people actively avoided the hotel. Because of the variety of reef destinations, John Brewer Reef was never a particularly popular reef.

The proportion of responses commenting on negative aspects of the floating hotel were relatively small, and a high proportion of comments reflected other management issues such as a decline in fishing and the crown-of-thorns starfish. For most groups, there were reportedly approximately equal numbers of positive and negative impacts. Most of the perceived impacts were the same as those identified in the EIS for the project.

A category of user was deliberately excluded from the survey design: i.e. the hotel guests. Some mechanism for incorporating information on guests' attitudes into this survey, or directly to GBRMPA would have been desirable. Given that the hotel represents a potential 'threat' to John Brewer Reef, it is clear that more emphasis should have been placed on factors affecting the likely financial success of the venture. As hindsight has so clearly revealed, the earlier market assessment was flawed. More detailed information on guest experience would have been useful in assessing future applications for off-shore resorts.

Major recommendations of this study included:

a. methodological problems in social survey research require greater attention, and should be funded as part of GBRMPA's research activities;

b. a wider range of research methods should be tested before future attitudinal monitoring studies are conducted;

c. GBRMPA should give greater priority to strategic and regional reef use data, both collection and updating; and

d. existing information collection, storage and retrieval systems should be reviewed and improved, on the basis of the difficulty in extracting such information for the present study.

CHAPTER 7: HYPOTHESIS TESTING

Peter Saenger

Introduction

Some specific issues arose during the EIS process which were amenable to relatively short-term studies. It was recommended that some of these projects be conducted as post-graduate research studies. Barrier Reef Holdings offered logistical and financial support to carry out the projects.

Two other studies were not suitable as post-graduate projects. The actual dispersal of the brine plume was monitored on a contractual basis during the operations of the floating hotel, while a study on the effects of increased recreational fishing on fish stocks of John Brewer and adjacent reefs was intended to be carried out by a log-book scheme which did not eventuate due to the closure of the hotel.

The effects of bird droppings on lagoonal water quality

The floating hotel and associated structures provided additional roosting areas for a number of birds which, in turn, might have led to the localised enrichment of lagoon waters by their droppings, particularly in respect of phosphates and nitrates. On sand cays in the Great Barrier Reef, bird droppings may lead to enriched nutrient groundwater outflows which, in turn, may lead to narrow zones of enhanced algal growth (particularly of the green alga *Enteromorpha flexuosa*).

The objectives of this project were:

a. to assess the level of bird usage and droppings on surfaces of the floating hotel and associated structures;

b. to determine the level of nutrient leaching from such surfaces;

c. to assess the likelihood and level of enrichment of lagoonal waters around the floating hotel and associated structures as a result of leaching of bird droppings; and

d. to determine the effect of any such enrichment on the growth of fouling and other associated organisms around such structures.

It was found (M. Howland, unpubl. report) that the presence of the resort and associated structures led to a slight increase (approximately 5%) in the number of birds although the data in Figure 7.1 suggests this may have been due to seasonal variation. A longer time span would be required to identify real trends in bird numbers. Seabirds were generally limited to the pontoons situated around the resort.

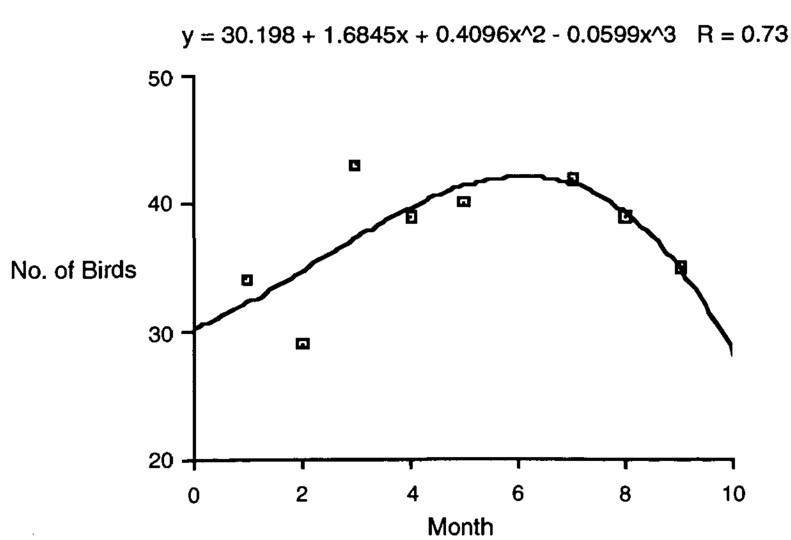


Figure 7.1. Average bird numbers from June 1988 - February 1989

Wastes produced by these birds equated to around 240 kg of faecal material entering the lagoonal waters or accumulating on roosting surfaces annually. The average nutrient (Nitrogen and Phosphorus) concentrations of this material are 13% Nitrogen and 2.8% Phosphorus (by weight) respectively. Given the volume of the John Brewer lagoon to be approximately 7 x 10^7 m^3 at mid tide and flushing rates in the order of 80% every five days (Parnell, 1986), the calculated average nutrient increase in the lagoonal waters were around 1.2 x 10^{-6} ppb Phosphorus and 5 x 10^{-6} ppb Nitrogen respectively, which was far below the natural variability of these parameters and below any detectable limit either analytically or biologically.

The accumulation of bird droppings on pontoon surfaces necessitated regular cleaning (usually by pressure hose) for aesthetic and health reasons. To ensure the best possible dilution and removal of the faecal material (washed directly into the lagoon), cleaning during ebbing spring tides was recommended.

Seabirds were noted only to frequent pontoons which were not regularly used by the resort, hence the regular use of these pontoons (as was done with the watersports pontoons) with the possible repositioning nearer the resort itself may have alleviated potential problems. The exception to this was the helipad which often had up to 200 terns roosting there despite regular usage, leading to the danger of collisions between helicopters and birds. Resort staff found a workable bird deterrent by the use of small plastic cachets containing mothballs placed around the pontoons. This method appeared both cheap and effective.

On the basis of this study, it would appear that the positioning of the resort within the lagoon at John Brewer Reef had no adverse effects on water quality by increasing bird usage of the area. Some minor operational problems existed, but these were overcome by the use of bird deterrents and sensible cleaning practices.

The effects of light and shading on pelagic organisms

Lights under the water or shining directly onto the water surface can attract fish and squid. Planktivorous fish such as antherinids and clupeids are not noticeably affected but when schools of these species aggregate, other species such as garfish (hemirhamphids), longtoms (belonids) and squid usually appear, either as a direct result of the light or in response to the schools of baitfish. Such artificial aggregations of fish as a result of lighting and the subsequent arrival of predators, can alter the predator-prey relationship that exists between these groups of species.

The objectives of the study were:

a. to assess the extent to which the prey and predator species may be affected by lighting, particularly in relation to their attraction to light;

b. to assess the extent to which prey species may be affected by lighting, particularly in relation to increased predation; and

c. to compare the composition of such light-induced aggregations with similar aggregations in the absence of light.

The study compared the fish community structure under the resort and from five control patch reefs, between June and November 1988 (K. Weaver, unpubl. report). Data were analysed at the family level using multi-variate techniques. The resort appeared to act as an aggregation device for many species, with species richness greater under the resort than in equivalent sized control sites. In addition, a number of species were present at the resort but not at control sites.

A major factor appeared to be the substrate type under the resort, which provided additional habitat favourable to territorial fish. The differences between the sites were considered to be attributable to differences in the nature of the substrate, rather than to any differences in lighting caused by shading by the resort structure.

The effects of underwater noise on fish populations

The EIS identified underwater noise and vibrations as having a potential to affect a number of reefal organisms, particularly fish.

The objectives of this section of the study were:

a. to assess the effect of constant and periodic underwater noise and vibration on reefal organisms, particularly fish;

b. to determine the extent to which these organisms can accommodate such noise levels; and

c. to determine the extent to which any noise-induced avoidance behaviour is counteracted by regular feeding activities.

Recordings of underwater noise were made at 50 sites within the sphere of influence of the resort-generated noise, and up to 1 km from the reef (R. McCauley, unpubl. report). No assessment of the effect of noise on fish numbers was possible as the fact that fish were attracted by daily fish-feeding (generally associated with propeller noise) seemed to counteract any tendency towards their possible avoidance of noise.

Dispersal of the brine plume

Performance characteristics of the desalination plant indicated that the salt concentrations in the left-over brine would be increased from approximately 3.5% to 4.7% (van Woesik et al, 1989). With constant operation, this resulted in a 225 m^3/day discharge of 4.7% brine solution. In addition to increased salt levels, the brine effluent would contain organic flocculants and anti-scalants at low concentrations. It was predicted that the brine plume was not likely to extend for more than a few metres from the point of discharge (Parnell, 1986) and the teleost fish were likely to avoid this particular area. The extent and dispersion characteristics of the brine plume were established on the basis of fluorescent dye studies in March and April 1989.

The objectives of this section of the study were:

a. to validate the actual extent and dispersion characteristics of the brine plume; and

b. to investigate the possible effects of its constituents (e.g. high salt concentration, flocculants and anti-scalants) on a range of selected organisms.

The results of the study indicated that only small increases in salinity were initially detected within 12 m of the outfall, and dispersion and advection of the brine was relatively rapid. An advection axis of approximately 320 degrees was observed during the prevailing SE winds, and above ambient salinities were very small along the advection axis. Increases in salinity above ambient of more than 0.001 ppt were unlikely for extended periods and there was no evidence that the brine solution accumulated on or near the floor of the lagoon.

The first coral community to be under the influence of the brine was a small aggregation of corals, rising from the bottom of the sandy lagoon to approximately low water level approximately 100 m east of the resort. The above ambient salinities were very low and, on the basis of experimental studies, these concentrations are not stressful to corals.

CHAPTER 8: REVIEW OF THE WORKSHOP

Claudia Baldwin

Introduction

In December 1989, a workshop was held at the offices of GBRMPA in Townsville for the purpose of reviewing the status and conclusions of the monitoring program for the John Brewer Reef floating hotel. The aims of the workshop were:

a. to collect together, for the first time, the participants in the environmental monitoring program and the management agency for an exchange of information and opinions.

b. in an informal atmosphere, to evaluate the good points of, and any omissions from, the environmental monitoring program; and

c. to discuss the rationale of the program design as a potential basis for future monitoring programs.

The workshop program and list of participants are included as appendices.

Conclusions

The conclusions based on the written reports are included in each separate chapter. Only the informal discussions at the workshop are presented here.

Bommie cropping

The transplantation of organisms away from the bommies being cropped did not occur in a formal or organised fashion, but rather on an ad-hoc basis by the drilling contractors. This could have been better organised, and finished before the excavation activity started. In future, to minimise impact everything within 30 m of the site of activity should be moved, in the case of an operation similar to that at John Brewer Reef. To improve the information gained from the program, more time should have been allowed for detailed tagging and follow-up surveys to monitor survival of the transplanted corals.

The excavation method was designed to be low-key, with the intention that this would minimise the impacts. Instead, the process was so slow that there were months of low-level sedimentation. Perhaps the controlled use of explosives might have been more satisfactory in the long-term.

Environmental Monitoring Program design

A common impression expressed in the workshop was that the scope of the program was too ambitious. This was reflected in the cost. It may have been more desirable to have a more focused program with greater depth in some specific areas.

Total costs of the program were approximately:

Full year of monitoring	$150,000
EMP and RMP design	$ 40,000
Review of EMP	$ 10,000
Ongoing monitoring	$ 60,000

There were limitations with the hydrodynamic data produced for the EIS stage of the program. Longer term studies showed that there was a reversal of the flow twice per day in light winds. The data had been used as a basis for sampling design for some of the studies.

Biological monitoring

There were some statistical difficulties with the monitoring design, and it was agreed that a narrower and more intense program may have been preferable. Some of the difficulties arose from comparing a single impact site with several controls. Multiple impact sites would be preferable. If more hydrodynamic data had been available prior to the design phase, the program could have been better designed to take current movements etc. into account.

Overall conclusions were that the removal of the bommie tops did not take away anything biologically unique, although there was some discussion concerning the value of the 'uniqueness' of a particular community type as a determinant of its value when lost. Many of the statistical difficulties were the result of the fact that the communities demonstrated considerable variability, both spatial and temporal within each of the sites, as much as between sites. The increase in rubble on the cropped bommies resulted in a change in the habitat type and an increase in the abundance of small fish. There was no pattern in change of sedimentation evident from sediment trap studies. The use of photographic surveys was begun but not continued when it was concluded that they were not cost-effective.

Water quality

There was no monitoring of chemicals used in the process of production of drinking water by reverse osmosis, e.g. potassium permanganate. Tests for trace metals, oil and grease also were recommended. Lack of responsibility for the operation of the treatment plants was a problem, and some problems would have been alleviated by duplicating the treatment plants in case of failure of one plant. One factor in lagoonal water quality was the discharge of untreated wastes from trawlers routinely anchored in the lagoon.

Sediments

Because the major input into the system was waste blown or thrown off the hotel into the water, it may be possible to modify the design of off-shore structures to catch some of the debris before it falls into the water. The observation that the hotel modified water movement in the vicinity and resulted in a shift in the sediment grain size might similarly apply in other environments, although it was not a problem in this study. Measurement of nutrients in the sediments was of little use compared with water quality measurement. It was suggested that the monitoring of algal growth rate on fouling panels might be an effective biological indicator of excess nutrients in the water, with the results integrated over a longer time period than single water samples.

User surveys

The results of the user surveys may have been affected by the fact that the surveys coincided with the installation and removal of the hotel. The most noticeable result of the study was the paucity of general information on human use of the reef. Information sources were patchy with respect to availability and usefulness of the surveys. It was clear that there were discrepancies between the public's attitude and behaviour, with behaviour providing a more accurate indicator of use.

A major discussion point of the workshop was the need for better evaluation of the economic feasibility of such a project. Initial evaluations supposedly were based on American data. Fortunately there was minimal environmental impact by the hotel -- however there was the risk that impacts could have been incurred without sufficient research on its likely economic success.

Hypothesis testing

Fish feeding became a feature of the hotel operations, although this was not to be allowed according to the original Resort Management Plan (CCM, 1988). There were some faults with the generator so that it could be heard 23 m from the resort. The overall conclusion was that the studies funded under this section of the program represented an over-kill and, in retrospect, were unnecessary.

Summary of environmental impact and recommendations for future monitoring

One major problem was the failure for the duration of the hotel to appoint an on-site environmental coordinator. The primary impacts were from the bommie cropping, an increase in fish populations close to the resort, a change in sediment size under the hotel and a small increase in copper in the sediments. There were no other detectable differences attributable to the hotel.

The sewage system never operated to the manufacturers specifications, and was not operated efficiently. Staff dedicated to the efficient operation of the waste water treatment plants is necessary. Occupancy was, on average, only 20% during the year of the hotel's operations. If occupancy had been higher, the plant may have operated more efficiently. However there is the possibility that more problems may have occurred, and the barge may have been required to remove effluent daily. Dual systems for both small and large loads may be required in the future. Other than the occasional sighting by Coastwatch, there was no monitoring of sea-dumping.
There were impacts on the aesthetics of the area as a result of the dumping of waste material and the production of rubble, in particular from the bommie cropping. The bommies may have been more

efficiently handled with explosives, with less impact, but public perception may have presented a problem. It still would be valuable to monitor the changes in the cropped bommies over time.

There was a minor spill of oil during the operation of the hotel. While this event received considerable publicity in the media, the amount spilled was trivial and had no detectable environmental impact. It was more detrimental to the image of the hotel.

It was suggested that if an environmental audit is done, it should include an economic analysis of the development, and cost-effectiveness of the impact assessment and monitoring program, with respect to the public, government and the developer.

It was concluded that GBRMPA received considerable benefits as a result of the information collected during the study. These included acquiring:

- greater skill in impact assessment and monitoring program design;
- useful experience regarding coral transplantation, recovery and coral substrate removal;
- knowledge of fish behaviour; and
- experience in a variety of monitoring techniques.

It was clear that information on users' attitudes to the reef needs to be expanded. Major work is needed on impact monitoring design and analysis. The design work initiated as a result of this program was continued and expanded for projects in later years.

CHAPTER 9: IMPLICATIONS FOR MANAGEMENT: A RETROSPECTIVE ANALYSIS

Peter Saenger and Ian Dutton

Introduction

The floating hotel project on the Great Barrier Reef (GBR) illustrated a unique combination of engineering, environmental and entrepreneurial approaches to tourism development in a coral reef environment. With a rapid burgeoning in demand for off-shore tourism facilities (Driml, 1988), limited options for facility development and a comprehensive, but changing regulatory system, the floating hotel project faced many challenges.

While the particular engineering design, socio-economic and administrative circumstances of the floating hotel project were unusual, the lessons provided by this project represent a valuable complement to international experience with EIA of off-shore development (Beanland and Duinker, 1984) and validation of the general management approach to such developments proposed by Kelleher and Dutton (1985).

While the project proved commercially unviable, it met all requirements from the perspective of regulatory authorities and the public interest. As the monitoring studies revealed, predictions made about the minor nature of biophysical impacts were validated. Furthermore, the wide range of matters addressed in operational planning and contingency provisions for extreme, unforeseen and accidental events proved adequate to limit environmental impacts.

The success of these provisions is due largely to two factors. Firstly, the fundamental concept of a removable structure gave operators and managers flexibility which is unparalleled in most tourism operations (O'Brien, 1988). Additionally, and perhaps of greater importance with respect to future proposals of this type, was the deliberate (albeit at times asynchronous) juxtaposition of logistical operations (such as design and commercial management) with environmental management requirements. This iterative approach to tourism development is all too rare, partly because it requires considerable design flexibility throughout the project life cycle and partly because regulatory frameworks are not usually as comprehensive as those established in the GBR Region.

Two key aspects of the environmental management process, however, are worthy of further comment. First, on the nature of monitoring programs and, second, on the administration of such programs.

Monitoring design

An inherent problem with any monitoring program is that comparisons between 'impact' and 'control' sites provide data which can be criticized on statistical grounds - other factors between two such areas are not constant. For valid statistical comparisons, random-block compartments distributed between and around 'impact' and 'control' sites should be compared. However, the comparison of random-block compartments is logistically difficult and costly on the scale of this type of project, and may not be entirely suitable for water quality assessment (see report by Jones, this volume).

This difficulty was partially overcome by using replicated sets of 'control' sites at varying distances from the supposed source of impact. For other components of the monitoring program, the use of 'before' and 'after' data from identical sites has reduced the statistical difficulties. These measures have considerable merit, and the present monitoring program revealed the value of such an approach.

However, had a source of impact, unforeseen during the monitoring planning phase and located away from the supposed source of impact become apparent, a large segment of the monitoring effort may not be relevant to, or useful in, assessing the overall impact of such a project. This has not happened in this case, but for the design of further monitoring studies on GBR projects, the possibility of unforeseen impacts arising away from the supposed point source(s) of impact, should be considered.

Monitoring program administration

Many aspects of the administration of the present monitoring program were not helpful to the overall program (Saenger, 1989). These included late reports by consultants (perhaps because of slow payment), excessive claims for confidentiality, lack of on-site support and delay in appointment of a reference person (such as an environmental officer, as originally planned) through whom all consultant reports could be channelled. Many of these difficulties arose because an organization (in this case the resort owner) without personnel qualified to conduct such a monitoring study, was given the responsibility for the program. This difficulty has now been overcome by the development of a monitoring policy by GBRMPA, under which the management agency assumes responsibility for program design and management (with funding provided by the proponent/operator).

While the sensitivity concerning confidentiality by the resort owner was understandable, the moratorium that was placed on floating resorts (with the consequential benefits of commercial exclusivity for the present resort), the resort had a responsibility to make public the findings of the monitoring program. (Clearly, this does not include details of a commercial nature.) Quite apart from the benefit the resort might gain from such public disclosures, the monitoring program clearly indicated that the resort had nothing to hide. This obligation was even stronger (though perhaps less sensitive and urgent) once the resort was removed from the reef.

A further aspect of the project administration which caused difficulties was the lack of agreed protocols for the conduct of some studies and/or delays in receipt of approval/feedback on project findings and proposals for changes to project methodology.

While such difficulties were surmountable, they demonstrated the notion that successful tourism projects should be characterised by a partnership approach, in which all involved recognise and respect their particular role requirements (Saenger and Dutton, 1989).

Implications for similar projects

Although the floating hotel project was developed in unique geographic and administrative circumstances (and in a World Heritage area), the following general principles which underpinned the design and management of the project are potentially applicable to any off-shore tourism development. For convenience, these principles are stated as a set of evaluative questions.

a. Can the environmental impact of such projects be adequately predicted?

This question has been partially addressed in the above discussion. While the scope of the impacts of the floating hotel at John Brewer Reef was found to have been adequate and within predicted limits, this project was fortunate in having both a capacity to service the rigorous requirements of regulatory authorities (environmental management costs were about 3.5% of the total project budget) and in being located in an area which has been relatively well studied. As a consequence, the extent to which the approach used for this project is transferable to other coral reef situations is questionable, although the notion of employing an iterative approach to design and management is transferable and may serve to overcome limits on knowledge and management resources.

b. Was there an adequate nexus between impact assessment and environmental management?

This is a common criticism of EIA studies (Beanlands and Duinker, 1984) and commonly occurs when project management is apportioned between different sets of parties. In the case of the floating hotel, the major 'players' were limited in number, and the over-riding control of a single management agency (GBRMPA), coupled with scientific input from a core group (Centre for Coastal Management) over the entire life of the project considerably simplified co-ordination of impact assessment and management. For other projects of this type, similar, simple project management arrangements are highly desirable, and have already been proposed in various studies using the form of a lead agency system.

c. What were the major limitations of the approach to project development?

The main reasons for the failure of the project were largely commercial ones. The project failed to attract a viable client base, suggesting either inadequate market research, poor choice of location, inappropriate facilities, competing attractions, or a combination of these factors. While these are inherent in any commercial venture, they emphasize the risky nature of new types of tourism development and further justify the conservative approach of the management agency (which required sureties in the event of failure). Such sureties have now gained wider acceptance (e.g. O'Brien, 1988) as an important basis for environmental protection.

d. With the relocation of the floating hotel, did any irreversible effects remain?

While the single most important effect of tourist developments in the coral reef environment in general is that of a decline in local water quality, to date, it appears from the results of the monitoring program, that such effects have been avoided at John Brewer Reef. In fact, the most notable 'after effect' was that with the removal of the floating hotel, fish aggregations which had been formed as a result of daily feeding, had to be protected from overfishing at the site for a 12 month period. This was achieved by the declaration of a 'no fishing' zone over the site under Queensland fisheries legislation.

Conclusion

The growing emphasis (e.g. Dutton et al, 1990) on sustainability of resource use poses many challenges for managers of complex natural systems such as coral reefs. As Barbier, (1987) observed, sustainability implies a commitment to the use of multiple objective criteria (economic, social and environmental) in decision-making. Such criteria are implicit in the objectives of GBRMPA and were reasonably well demonstrated at the project level in the case of the floating hotel. As was shown during this project, however, it is extremely difficult for all factors to be given adequate attention, with commercial factors in this case ultimately resulting in project failure.

It is notable, however, that unlike many other natural resource management examples, commercial failure did not occur at the expense of social or environmental quality, nor did the provision for social and environmental requirements contribute directly to project failure.

This outcome vindicates the emphasis given by management to environmental protection, but makes the simple extrapolation of this experience to other coral reefs problematical. Nonetheless, many of the lessons from this project are potentially transferable to tourism management elsewhere, and ancillary project outcomes (e.g. increased knowledge of impacts of structures, waste management technology, etc.) reinforce the utility of the adaptive management approach used in this project.

APPENDIX

Appendix A

Workshop program

Four Seasons Floating Hotel Environmental Monitoring Program
John Brewer Reef

5 December 1989

Conference Room, GBRMPA
Townsville

Chair:	Dr Wendy Craik
9.00	Introduction - From Environmental Impact Statement to Environmental Monitoring Program - Ms Claudia Baldwin
9.15	Bommie Cropping Overview - lessons learned - Mr David Fisk
9.30	Environmental Monitoring Program - overview - Dr Peter Saenger, Centre for Coastal Management, University of New England - Northern Rivers
10.00	Biological Assessment - Professor Howard Choat, Marine Biology Department, James Cook University - presented by Dr Peter Saenger
10.30	MORNING TEA
10.45	Compliance Assessment - Dr Graham Jones, Department of Chemistry and Biochemistry, James Cook University
11.15	Compliance Assessment/Sediments - Dr David McConchie, Centre for Coastal Management, University of New England - Northern Rivers
11.45	User Survey - Mr Ian Dutton, Centre for Coastal Management, University of New England - Northern Rivers
12.15	Hypothesis Testing - Dr Peter Saenger
12.40	LUNCH
2.00	Summary of the Environmental Impacts - Dr Peter Saenger
2.15	Present Commitment to Future Monitoring; Discussion on Future Monitoring - Ms Claudia Baldwin
2.30	Critical Review: (i) Prediction vs reality (ii) The Process (iii) Environmental Monitoring Program - Dr Wendy Craik
3.30	AFTERNOON TEA
3.45	Discussion continued
4.30	Finish

Appendix B

Workshop participants

Janice Morrisey, Great Barrier Reef Aquarium
Vicki Harriott, Great Barrier Reef Aquarium
Dave Fisk, Reef Research and Information Services
Jamie Oliver, James Cook University of North Queensland
Jon Brodie, James Cook University of North Queensland
Robert van Woesik, James Cook University of North Queensland
Lea Scherl, James Cook University of North Queensland
Ian Dight, James Cook University of North Queensland
Eric Gustavson, Qld Department of Environment and Heritage, Environment Division
Peter Saenger, Centre for Coastal Management, UNE - Northern Rivers
David McConchie, Centre for Coastal Management, UNE - Northern Rivers
Ian Dutton, Centre for Coastal Management, UNE - Northern Rivers
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Appendix C

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