

EAST KALIMANTAN CORAL REEF CONSERVATION PROJECT



- 1998 summary report prepared on behalf of -

TANJUNG BARA DIVE CLUB & PT KALTIM PRIMA COAL

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October 1998



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CONTENTS	PAGE
EXECUTIVE SUMMARY	III
ACKNOWLEDGEMENTS	V
ABBREVIATIONS	VI
FIGURES, TABLES AND APPENDICES	VII
1. INTRODUCTION	1
2. PROJECT BACKGROUND	2
2.1 Indonesia	2
2.2 East Kalimantan (Borneo)	3
2.2.1 Threats to the marine environment of East Kalimantan	4
3. EAST KALIMANTAN CORAL REEF CONSERVATION PROJECT	6
3.1 Participating organisations	8
3.1.1 Pt. Kaltim Prima Coal	8
3.1.2 Tanjung Bara Dive Club (TBDC)	10
3.1.3 Coral Cay Conservation Ltd (CCC)	10
4. METHODS	12
4.1 Baseline coral reef assessments	12
4.1.1 Baseline coral reef surveys	16
4.2 Taxonomy	17
4.3 Monitoring programme	17
4.3.1 Permanent transect monitoring	17
4.3.1.1 Permanent transect data analysis	19
4.3.2 Water quality monitoring	20
4.3.3 Sedimentation study	21
4.4 Socio-economic assessments	21
4.5 Training and conservation education	21
4.5.1 Science training programme	21
4.5.2 Dive training programme	23
4.5.3 Conservation education programmes	23
5. RESULTS	26
5.1 Baseline coral reef assessments	26
5.1.1 Topographical mapping	26
5.1.2 Baseline survey data analysis	26
5.1.3 Oceanographic data	32

5.1.4	Anthropogenic impacts	35
5.2	Taxonomy	35
5.3	Monitoring programme	37
5.3.1	Permanent transect monitoring	37
5.3.2	Water quality monitoring	41
5.3.3	Sedimentation study	42
5.4	Socio- economic assessments	42
5.5	Training and conservation education	45
5.5.1	Science training programme	45
5.5.2	Dive training programme	45
5.5.3	Conservation education programmes	46
6.	DISCUSSION	49
6.1	Coral reef assessments	49
6.2	Monitoring programme	52
6.2.1	Permanent transect monitoring	52
6.2.2	Water quality monitoring	52
6.2.3	Sedimentation study	54
6.3	Socio- economic assessments	54
6.4	Training and conservation education	54
7.	CONCLUSIONS	55
7.1	Coral reef assessment	55
7.2	Monitoring programme	55
7.3	Socio- economic assessments	56
7.4	Training and conservation education	56
8.	RECOMMENDATIONS	58
9.	REFERENCES	61

EXECUTIVE SUMMARY

The coastline of Kalimantan (Borneo, Indonesia) extends for over 8,000 km and contains some of the richest and most diverse coral reef systems in the world. These reefs provide an important source of food and revenue for local communities (per capita fish consumption in East Kalimantan is higher than in any other part of Indonesia). However, 80% of coral reefs in Southeast Asia are now under serious threat from over-exploitation and other anthropogenic activities, including those of East Kalimantan.

Between January and April 1998, members of the Tanjung Bara Dive Club (part of Pt. Kaltim Prima Coal) and Coral Cay Conservation volunteers initiated the East Kalimantan Coral Reef Conservation Project (EKCRC Project). The aim of the EKCRC Project was to obtain baseline survey and monitoring data from coastal coral reefs within the vicinity of Sangatta and providing training and conservation education opportunities for Indonesian counterparts and local school children.

Three coral reef areas (South Marker Reef, North Marker Reef and Bengalon Reef) were surveyed in detail to produce topographical maps, describe benthic community classes and identify gross anthropogenic impacts. Rapid ecological assessments were carried out on three other reefs within the EKCRC Project area (Sangatta Reef, Miang Besar and Rita's Reef). The data from all six reefs were used to establish a GIS-compatible database for the area. Analysis of the data discriminated at least eight separate major benthic classes and showed that the reefs within the project area were physically and biologically diverse (particularly Bengalon Reef) and in relatively good health compared with other Southeast Asian reefs.

The most significant anthropogenic impacts observed were related to the installation of navigational cardinal marks nine years previously. Destructive fishing methods (e.g. cyanide and fish bombing) are known to be used in the area and patchy areas of coral damage observed on Rita's Reef were attributed to fish bombing. Most fishing activity was observed at Sangatta Reef and Miang Besar, probably because of their proximity to fishing communities, and it is likely that these reefs have suffered to some extent from over-fishing.

Permanent monitoring sites were established on four reefs (Sangatta Reef, South Marker Reef, North Marker Reef and Bengalon Reef) to provide quantitative baseline data on benthic communities and water quality for future comparison. A validation exercise was conducted to assess the accuracy and consistency of benthic monitoring data gathered by volunteer divers over a one month period. This exercise revealed a similarity coefficient of less than 50%, suggesting that refinements in the training programme offered to the divers are required in order to improve the validity of data gathered by volunteer divers for detailed benthic monitoring purposes. However, the benthic monitoring data gathered during the EKCRC Project does provide a valuable baseline data set from which gross temporal changes within these benthic communities can now be monitored.

A range of oceanographic and water quality data was gathered during the course of baseline surveys and monitoring surveys. The water column was found to be homogeneous over the

depth ranges monitored and analysis of water samples did not reveal any obvious evidence of anthropogenic impacts. Turbidity levels within the water column were higher than expected and may have been related to elevated levels of plankton. A programme to monitor sedimentation levels within the project area was established and data from samples collected are currently being analysed.

Thirty project counterpart personnel were provided with entry-level and advanced SCUBA training certifications, and 24 counterparts were given training in marine ecology and survey techniques. The EKCRC Project also supported conservation education opportunities within the local community, including the organisation of field courses for 40 local school children and production of the KPC-sponsored educational wall chart entitled *Gugus karang dan hutan hujan Indonesia*, to help enhance environmental awareness within schools and communities.

The success of the EKCRC Project was the result of a unique partnership forged between Pt. Kaltim Prima Coal and Coral Cay Conservation, each complimenting the other in terms of providing appropriate resources and technical skills to establish a cost-effective method of helping protect natural resources in East Kalimantan. Of primary significance in this partnership is Pt. Kaltim Prima Coal's continuing commitment to supporting conservation initiatives in East Kalimantan.

It is recommended that Pt. Kaltim Prima Coal and Coral Cay Conservation should continue and expand upon the activities initiated during the course of the EKCRC Project with the aim of establishing recommendations for a Coastal Zone Management Plan which integrates lowland rain forests, mangrove forests and coastal marine resources, using a biosphere approach to encompass the neighbouring Kutai National Park. Key supporting activities should include the strengthening of conservation education opportunities within local schools and communities and provision of further skills training programmes to establish an Indonesian-led team of volunteer SCUBA divers capable of carrying out long-term monitoring programmes.

ACKNOWLEDGEMENTS

The success of the EKCRC Project would not have been possible without the financial and logistical support provided by Pt. Kaltim Prima Coal and the Tanjung Bara Dive Club. We would like to offer our special thanks to Irawan I. Poerwo (General Manager, Operations Support Division) for his support and encouragement.

We would also like to offer our sincerest thanks and gratitude to the following:

Leon Allen

Kel Bendeich

Ira Kamelia

Dan Michaelson

Inez Nastiti

Nadia Natoka

Raymond Nirwan

Patrick O'Neill

David Pearce

Potrodjojo Soeprapto

Warwick Steward

Thomas Tjahjono

Hartina Widychrisanti

The staff of the Tanjung Bara Aquatic Club

The staff and pupils of Swarga Bara Junior High School

The staff and pupils of Tanjung Bara International School

The staff of the KPC Environmental Department

TNT

Finally, we would like to thank the following Coral Cay Conservation team members:

STAFF

Bill Bradley - Expedition Leader

Maria Beger - Science Officer

Nigel Dunkley - SCUBA Instructor

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Deborah Ashford

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Tony Pates

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Will Postlethwaite

Philip Rance

Andrew Stirling

Katherine Stronach

Neil Tasker

Tony Watt

Leighton Williams

ABBREVIATIONS

CCC	Coral Cay Conservation Ltd.
CCC-TS	CCC Transect Survey
CCC-CS	CCC Contour Survey
CZM	Coastal Zone Management
CZMP	Coastal Zone Management Plan
EKCRC Project	East Kalimantan Coral Reef Conservation Project
GIS	Geographical Information System
GPS	Global Positioning System
IUCN	World Conservation Union
KPC	PT Kaltim Prima Coal
LIT	Line Intercept Transect
PADI	Professional Association of Diving Instructors
PRIMER	Plymouth Routines in Multivariate Ecological Research
SCUBA	Self Contained Underwater Breathing Apparatus
SIMPER	Similarity Percentage
SMB	Surface Marker Buoy
TBAC	Tanjung Bara Aquatic Club
TBDC	Tanjung Bara Dive Club
UNEP	United Nations Environment Programme

FIGURES

- Figure 1.** Map of Indonesia.
- Figure 2.** Map of the national areas and major settlements in Borneo.
- Figure 3.** Map showing KPC mine area and the EKCRC Project base at the Tanjung Bara Aquatic Club.
- Figure 4.** Map of the EKCRC Project area.
- Figure 5.** Mr Dan Michaelsen (Manager, KPC Environmental Department) and EKCRC Project volunteers inspecting KPC's rainforest tree nursery.
- Figure 6.** Schematic diagram of a baseline survey dive team showing the positions and data gathering responsibilities of all four divers.
- Figure 7.** A typical CCC survey team.
- Figure 8.** Schematic diagram (aerial aspect) of an example of a reef area mapped by divers during a sub-transect survey.
- Figure 9.** Plan of permanent transects at the monitoring sites.
- Figure 10.** Volunteer surveyor using the LIT protocol.
- Figure 11.** Science training week at TBAC.
- Figure 12.** Students from YPP Swarga Bara conducting project fieldwork.
- Figure 13.** Topographical map of South Marker Reef showing positions of survey transects.
- Figure 14.** Topographical map of North Marker Reef showing positions of survey transects.
- Figure 15.** Topographical map of Bengalon Reef showing positions of survey transects.
- Figure 16.** Dendrogram from cluster analysis of baseline survey data.
- Figure 17.** Summary of oceanographic data from 116 surveys during the EKCRC Project.
- Figure 18.** Summary of oceanographic data from 116 surveys during the EKCRC Project.
- Figure 19.** Summary of anthropogenic impact data from 116 surveys during the EKCRC Project.
- Figure 20.** Summary of line intercept transect data from the EKCRC project.
- Figure 21.** Summary of line intercept transect data from the EKCRC project.
- Figure 22.** Profiles of key water quality parameters within the EKCRC Project area.
- Figure 23.** EKCRC Project volunteers undergoing PADI SCUBA training.
- Figure 24.** YPP Swarga Bara conservation education course.
- Figure 25.** Four to six year-old pupils from Tanjung Bara International School during their parents reception show illustrating their field visit to the mangrove boardwalk.

TABLES

- Table 1.** Main aims, objectives and anticipated outputs of the EKCRC Project.
- Table 2.** Ordinal scale assigned to life forms and target species during baseline surveys.
- Table 3.** Methods used to assess the water quality parameters measured during the EKCRC Project.
- Table 4.** CCC science training programme schedule.
- Table 5.** Teaching and activity timetable of the coral reef ecology course provided for pupils at YPP Swarga Bara.
- Table 6.** Numbers of surveys conducted by the EKCRC Project team.
- Table 7.** Major characteristics of the eight benthic classes discriminated during the EKCRC Project.
- Table 8.** Consistency, measured using the Bray-Curtis Similarity Coefficient, between March and April values of each benthic category when recorded on any of the LIT survey transects.
- Table 9.** Mean values of water quality parameters measured during the EKCRC Project compared with published values.
- Table 10.** A summary of TBDC volunteers and Indonesian counterparts who undertook SCUBA diving and science training courses during the EKCRC Project.
- Table 11.** Pupils from YPP Swarga Bara who attended the coral reef ecology course and their assigned projects.

APPENDICES

- Appendix 1.** Examples of Coral Cay Conservation publicity material.
- Appendix 2.** CCC recording forms used by volunteer divers during the EKCRC Project.
- Appendix 3.** Codes used for life forms, genera, species and substratum during Line Intercept Transect surveys.
- Appendix 4.** Median abundances of the substratum categories, biological life forms and species found in each of the eight major benthic classes identified during the EKCRC Project.
- Appendix 5.** Species lists of marine invertebrates and fish identified during the EKCRC Project.
- Appendix 6.** Line Intercept Transect data.
- Appendix 7.** Results and methods used for water quality study during the EKCRC Project.
- Appendix 8.** Details of project work undertaken by students from Swarga Bara High School and two examples of submitted project reports.
- Appendix 9.** CCC Code of Safe Diving Practise for use by volunteer SCUBA divers undertaking marine research activities.

1. INTRODUCTION

Indonesia lies within a region which has been described as the “largest ecological system on earth” (Sheppard *et al.*, 1992). Recent evidence⁽¹⁾ shows that more than two-thirds of the earth's biological resources are found within just 17 “mega-diverse” countries, including Indonesia. Amongst these countries, Indonesia is ranked amongst the top six in terms of endemism and species diversity.

The tropical forests and coral reefs of Indonesia are amongst the most biodiverse in the world and are of vital importance both ecologically and economically. However, because of rapid economic and population growth, Indonesia's forests are now under serious threat from logging and agricultural development. Similarly, the countries' coral reef ecosystems are being adversely affected by a range of anthropogenic activities including over-fishing, destructive fishing, sedimentation, eutrophication and pollution, which has resulted in extensive loss of coral reefs and inducement of coral diseases. Such impacts represent substantial long- and short-term threats to the ecological balance and health of reef ecosystems which, if left unchecked, will ultimately lead to increased poverty amongst coastal communities relying on fishing and marine-based tourism.

Effective coastal zone management, including conservation of coral reefs, requires a holistic and multi-sectorial approach which is often a highly technical and costly process and one which many developing countries cannot adequately afford. With appropriate training, non-scientifically trained, self-financing volunteer divers have been shown to be able to provide useful data for coastal zone management at little or no cost to the host country. This technique has been pioneered and successfully applied by Coral Cay Conservation (CCC), a British non-profit organisation.

Pt. Kaltim Prima Coal (KPC), a coal mining company with operations in East Kalimantan (Borneo), supports local programmes to aid forest conservation, rehabilitation and conservation education initiatives. In 1998 these initiatives were expanded to cover the local marine environment through a collaborative project between KPC's Tanjung Bara Dive Club (TBDC) and CCC.

Between January and April 1998, the TBDC / CCC-initiated East Kalimantan Coral Reef Conservation (EKCRC) Project utilised TBDC members and CCC volunteers to survey, map and monitor the biodiversity and health of coral reefs adjacent to the KPC mine area in East Kalimantan and provide training and conservation education opportunities for local communities.

This report documents the results of the EKCRC Project and offers recommendations for future work.

⁽¹⁾ Conservation International website (<http://www.conservation.org/>)

2. PROJECT BACKGROUND

2.1 Indonesia

Indonesia (Figure 1) is the world's largest archipelagic state with approximately 81,000 km of coastline and over 17,500 islands covering an area of approximately 5.085 million km² (Sloan and Sugandhy, 1993; The Economist Intelligence Unit Ltd, 1996). The archipelago is part of the most species rich region on earth: in addition to extensive terrestrial resources, the marine coastal environment comprises nearly 80% of the country and exhibits high physical, chemical and biological diversity.

The marine resources of Indonesia include extensive coral reef formations which are amongst the most complex and highly productive shallow water tropical marine ecosystems in the world. Coral reefs have been identified as one of the "essential life-support systems" necessary for food production, health and other aspects of human survival and sustainable development (IUCN, 1980). There is a great diversity of reef systems throughout all of the Indonesian islands, comprising fringing reefs, barrier reefs, offshore patch reefs, oceanic high islands with barrier reefs, faro atolls and true atolls (Tomascik *et al.*, 1995). The coral reefs of Indonesia are so diverse that they are thought to be the point from which other Asia-Pacific reefs were colonised (Gray, 1997).

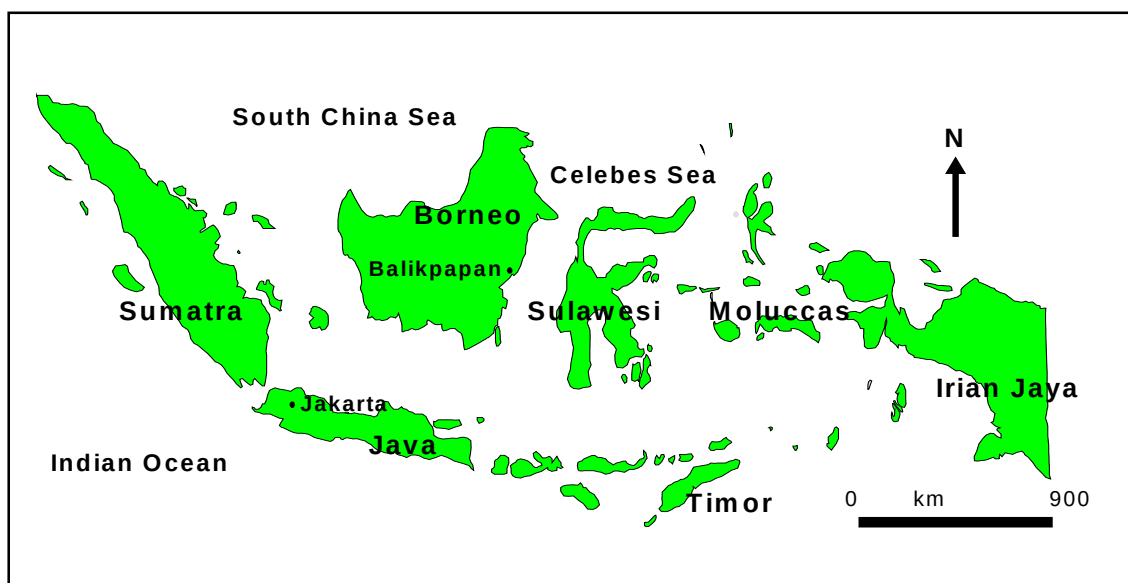


Figure 1. Map of Indonesia.

2.2 East Kalimantan (Borneo)

Borneo, the third largest island in the world, is divided into three national areas: the Malaysian area comprising of Sabah and Sarawak; Brunei, an independent Sultanate; and the Indonesian area, Kalimantan (Figure 2).

To the north-west, Borneo borders the South China Sea and to the south the Java Sea. At the eastern side it is separated from Sulawesi by a deep oceanic channel, the Makassar Strait. Analysis of sediments in the Makassar Strait prove that Borneo and Sulawesi have been separated for as long as 25 million years (Audley-Charles, 1987), which is reflected in the differences in flora and fauna found between Borneo and Sulawesi. The Wallace Line (named after the 19th century British naturalist, Sir Alfred Wallace), indicating the biogeographical divide between Southeast Asia and Australasia, runs through the Makassar Strait. It appears that Borneo's species are more closely related to those found on Sumatra and the Asian mainland than to those of the Antipodes or Eastern Indonesia (MacKinnon *et al.*, 1997).

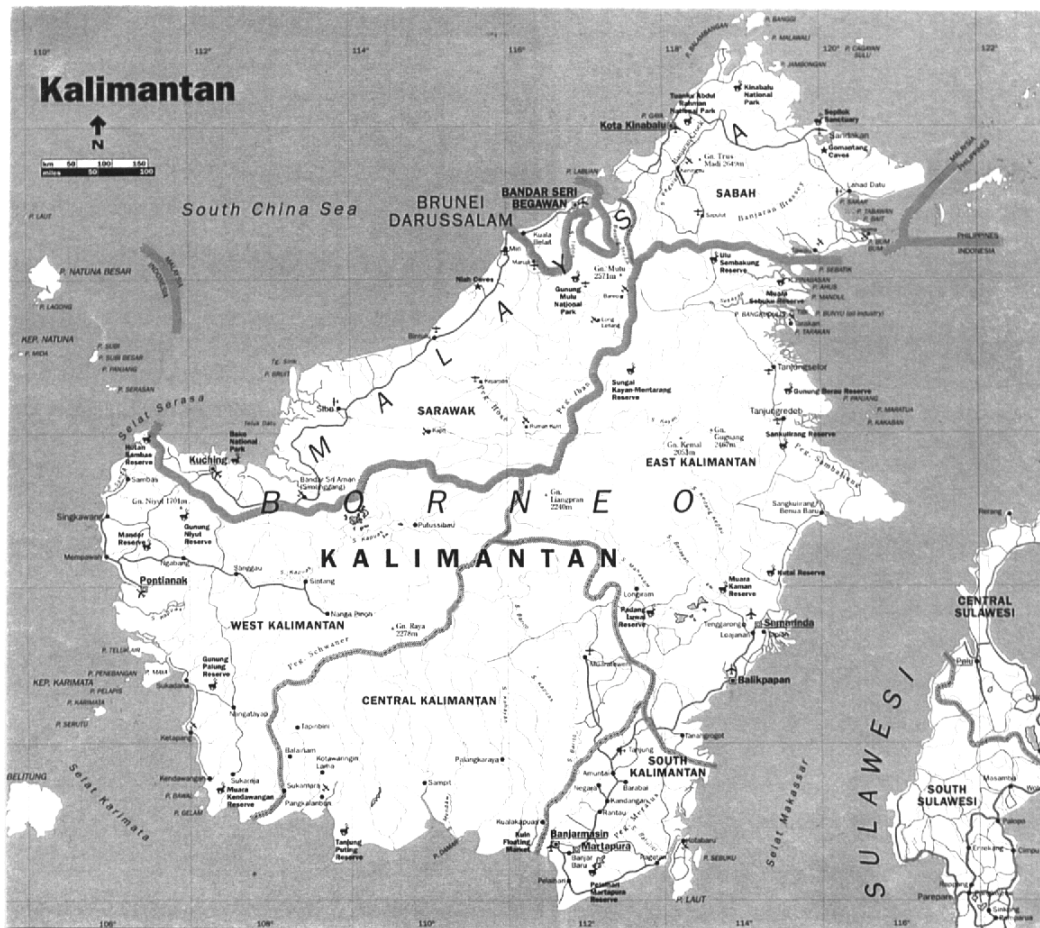


Figure 2. Map of the national areas and major settlements in Borneo. (Modified after MacKinnon *et al.*, 1997).

Kalimantan represents 73% of Borneo's land mass but with a population of 9.1 million supports just 5% of the total Indonesian human population (MacKinnon *et al.*, 1997). Kalimantan receives little revenue from its agriculture and plantations but is relatively wealthy because of its rich reserves of coal, natural gas, oil and native forests.

Whilst Kalimantan's economy is dependant on its historically rich geological structure, it also has a wealth of valuable marine resources. The coastline of Kalimantan extends 8,054 km from the Sambas Peninsula in the west to the island of Nunakan on the Sabah border, much of which is bordered by a dense belt of mangrove forest. It is also characterised by numerous large estuaries creating large areas of turbid water which are unsuitable for coral reef development. All of the three main coral reef formations (fringing, barrier and atolls) are found along the East Kalimantan coastline.

2.2.1 Threats to the marine environment of East Kalimantan

Over 80% of reefs in Southeast Asia, including those in Kalimantan, are at risk because of anthropogenic impacts (Bryant *et al.*, 1998). The main threats to coral reefs in Kalimantan are:

- **Deforestation and mangrove depletion**

Intensive logging and widespread forest fires (particularly those that occurred in 1983 and 1998) have resulted in significant loss of jungle vegetation and threaten the terrestrial integrity of East Kalimantan. There is concern that the recent forest fires, which were caused by a combination of severe drought and slash and burn agriculture, may have caused localised destruction of fringing coral reefs through sedimentation as a result of erosion of exposed soils and acidification caused by ash being washed from land.

Some areas of mangroves along the coasts of East Kalimantan have been converted to “*tampak*”, ponds used for the cultivation of milkfish and prawns. This has been particularly dramatic south of Samarinda (MacKinnon *et al.*, 1997). Besides being an important ecosystem, mangroves are also a vital nursery ground and refuge for coral reef associated organisms and the depletion of mangrove habitats therefore has a profound effect on the recruitment of coral reef species, including commercially important fish species.

- **Mineral extraction**

Kalimantan has rich mineral resources and coal, oil, gas, gold, and copper mining are major industries in the area. Mining in coastal areas may cause increased sediment runoff and consequent coral smothering in adjacent seas, and inputs from acid mine drainage and other pollutants can seriously affect coastal ecosystems.

- **Over-fishing**

About half of the daily dietary protein intake of Indonesians is derived from seafood (The Economist Intelligence Unit Ltd., 1996), placing a high demand on fish stocks within the coral reef system. Per capita fish consumption in East Kalimantan is higher than in any

other part of Indonesia (Birowo, 1979). A high percentage of coastal fisheries of East Kalimantan are small-scale reef fisheries but important pelagic fisheries are found in the south (MacKinnon *et al.*, 1997).

- ***Destructive fishing***

Destructive fishing, characterised by the use of explosives and cyanide, is prevalent throughout Southeast Asia, including East Kalimantan. Cyanide fishing may also be a major threat to the area with the increase in the live grouper fishery (Tomascik *et al.*, 1995). Potassium cyanide, used to stun target fish, also causes widespread damage to the benthic community and smaller fish species.

3. EAST KALIMANTAN CORAL REEF CONSERVATION PROJECT

The second largest coal mine in the world is located in East Kalimantan, operated by Pt. Kaltim Prima Coal (KPC), a company which has strict environmental policies and a high level of involvement with local environmental activities (Section 3.1). KPC employees have established the Tanjung Bara Dive Club (TBDC) which organises weekly diving to local reefs adjacent to the KPC mine area (Figure 3). Knowledge gained through the TBDC suggested that these reefs are biologically diverse and relatively healthy. This was confirmed during a rapid ecological assessment undertaken by Coral Cay Conservation (CCC) in 1997, although the assessment revealed clear evidence of anthropogenic disturbance attributed to destructive fishing methods and possibly over-fishing (Raines, 1997).

Following the results of the assessment made by CCC in 1997, TBDC members in association with KPC's Environmental Department and CCC, developed a programme of surveys, training and conservation education to assess the status of local reefs adjacent to the KPC mine site in East Kalimantan and improve environmental awareness amongst neighbouring communities. Entitled the *East Kalimantan Coral Reef Conservation Project* (EKCRC Project), the primary aims of the project were to harness the skills and resources of the participating organisations to provide baseline and monitoring data, training opportunities and environmental awareness programmes to facilitate an integrated approach to coral reef conservation in East Kalimantan (Table 1).

Table 1. Main aims, objectives and anticipated outputs of the EKCRC Project.

AIM	OBJECTIVE	ANTICIPATED OUTPUTS
➡ Resource assessment.	❶ Undertake a scientific survey of target coral reefs. ❷ Conduct preliminary human impact assessment studies. ❸ Establish a baseline database. ❹ Provide management tools and recommendations.	📄 Initial baseline database. 📄 Topographical maps. 📄 Description of reef habitat types. 📄 Documentation of anthropogenic impacts. 📄 Preliminary management recommendations.
➡ Environmental monitoring.	❶ Establish and validate a monitoring programme within the project area.	📄 Identification of permanent monitoring sites. 📄 Validation of monitoring protocol. 📄 Baseline data set.
➡ Training and conservation education.	❶ Provide scientific and SCUBA training for TBDC/ CCC volunteers and local counterparts. ❷ Heighten awareness of marine resources, their use and protection. ❸ Develop a sense of community stewardship in effectively monitoring and managing the coastal zone.	📄 Trained project members. 📄 Educational wall chart. 📄 Awareness amongst local school children and fisherfolk.



Figure 3. Map showing KPC mine area and the EKCRC Project base at the Tanjung Bara Aquatic Club (labelled as “Aquatic”). Source: KPC (1998).

Between 29 January and 24 April 1998, 24 international CCC volunteers (split equally between two six week phases) joined members of the TBDC and other KPC staff to carry out the aims of the EKCRC Project under the guidance of experienced CCC staff. The EKCRC Project team was based at the Tanjung Bara Aquatic Club (TBAC) located approximately 200 km north of Balikpapan near the former fishing village of Sangatta (Figure 3).

The EKCRC Project survey area encompassed six major reefs which are routinely dived by members of the TBDC (Figure 4). These reefs lie approximately 6 to 12 km offshore and are situated along an oceanic ridge parallel to the coastline. The reefs are marked by permanent shipping markers (cardinal marks) located in the shallowest zone or at the most northern point of each reef.

3.1 Participating organisations

3.1.1 Pt. Kaltim Prima Coal (KPC)



KPC is jointly owned by Rio Tinto, a world leader in mining and processing the earth's mineral resources, and British Petroleum. KPC's mine in East Kalimantan is the second largest in the world, with approximately 200 expatriate and 2800 local employees and local contractors (Michaelsen, pers. comm.). KPC's aim is to meet the global need for high quality coal whilst making a market contribution to economic development and employment in Indonesia. KPC works closely with their Indonesian hosts, respecting laws and customs, minimising adverse impacts and ensuring the transfer of benefits and enhancement of opportunities.

The company has strict environmental policies and a high level of involvement with local environmental activities. A high percentage of the mine pits are reclaimed and reforested through an extensive and pioneering forest restoration programme (Figure 5). KPC is a leading member of the "Friends of Kutai National Park" initiative which aims to support the management and protection of primary forests within the nearby Kutai National Park.

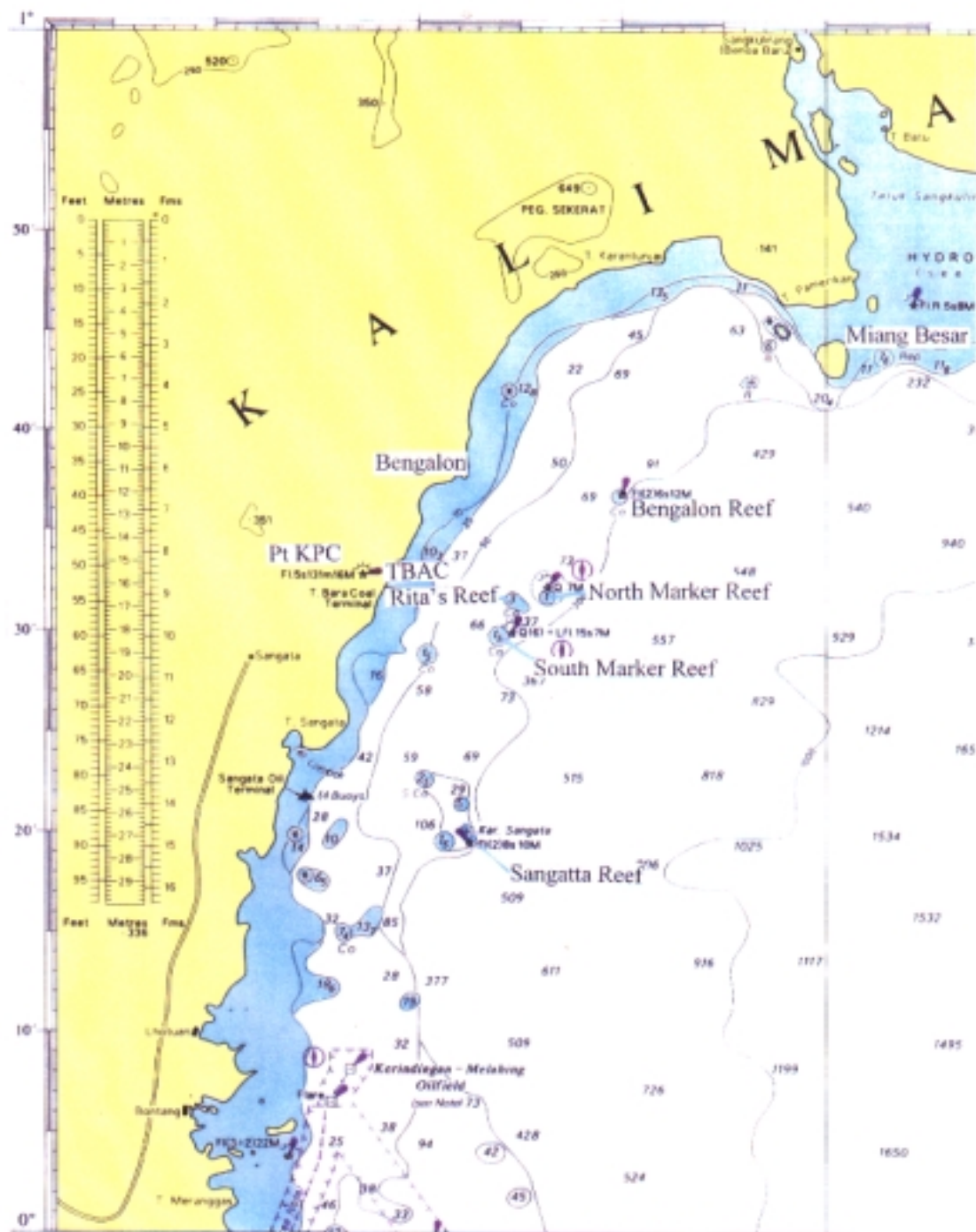


Figure 4. Map of the EKCRC Project area (modified from Admiralty Chart 3022).



Figure 5. Mr Dan Michaelson (Manager, KPC Environmental Department) and EKCRC Project volunteers inspecting KPC's rainforest tree nursery (Photo: Raines, 1998).

3.1.2 Tanjung Bara Dive Club (TBDC)

TBDC is a recreational club which organises SCUBA diving for KPC employees and guests. TBDC has a membership of approximately 50 divers and is well equipped with dive boats, tanks, compressors and SCUBA gear. Diving trips are organised on a weekly basis and TBDC members take an active role in improving knowledge of local reef systems and participation in coastal zone management initiatives (Pearce, pers. comm.).

3.1.3 Coral Cay Conservation Ltd (CCC)

Mission Statement: *Providing resources to help sustain livelihoods and alleviate poverty through the protection, restoration and management of coral reefs and tropical forests.*



Founded in 1986, CCC is an award-winning international organisation dedicated to providing resources to protect livelihoods and alleviate poverty through the protection and sustainable use of coral reefs and tropical forests in collaboration with government and non-

government organisations within the target host country (Appendix 1). CCC does not charge the host country for the services it provides and is primarily self-financed through a unique volunteer participatory scheme whereby international volunteers are given the opportunity to join a phase of each project in return for a financial contribution towards the project costs. Finances generated from the volunteer programme allow CCC to provide a range of services, including data acquisition, assimilation and syntheses, conservation education, technical skills training and capacity building programmes. CCC is associated with the Coral Cay Conservation Trust, the only British-based charity dedicated to protecting coral reefs.

Upon arrival at a project site, volunteers undergo a United Nations-reviewed training programme in marine life identification and underwater survey techniques, under the guidance of qualified project scientists, prior to assisting in the acquisition of data. This data is then assimilated into a Geographic Information System (GIS) database and used for the synthesis of resource maps for subsequent coastal zone management initiatives. Data derived from CCC volunteers has been used to establish eight marine reserves and wildlife sanctuaries in the Caribbean and Asia-Pacific, including the recent designation of the Belize Barrier Reef as a World Heritage Site.

4 METHODS

4.1 Baseline coral reef assessments

The principle aims of the baseline surveys carried out within the EKCRC Project area were to:

- map and describe the topography and habitat types of the reefs;
- collect basic oceanographic data;
- assess the extent of anthropogenic disturbance to the reefs.

In order to achieve these aims, the EKCRC Project utilised the standard baseline survey techniques developed by CCC for the rapid and accurate assessment of biological and physical characteristics of reefal communities by trained volunteer divers (Harborne *et al.*, 1996). CCC's techniques have been shown to generate precise and consistent data appropriate for baseline mapping. All surveys are co-ordinated by a qualified Science Officer to ensure accurate and efficient data collection. The standard CCC survey protocols are as follows:

- **CCC transect surveys (CCC-TS)**

The CCC Transect Survey method (CCC-TS) utilises a series of plot-less transects, perpendicular to the reef, starting at a depth of 28 m and terminating at the reef crest (or in the case of the EKCRC Project, terminating at a navigational cardinal mark located on each reef) to map zonation across a reef profile. Benthic and fish surveys are focused on a pre-selected number of species and standardised life forms that are either abundant, easily identifiable or ecologically or commercially important.

- **CCC contour surveys (CCC-CS)**

The CCC Contour Survey method (CCC-CS) is carried out along depth contours using CCC-TS protocols to record benthic and fish species. CCC-CS surveys are useful in mapping habitat and topographic changes at a given depth to compliment CCC-TS data. During the EKCRC Project surveys were carried out along the 15 m depth contour.

During the course of each survey, certain oceanographic data (e.g. salinity, temperature, vertical turbidity, current strength and direction, and wind strength and direction) and observations on obvious anthropogenic impacts and activities (e.g. presence and activity of boats) are recorded at depth by the divers and from the surface support vessel.

Since most transects require two or more dives to complete, CCC-TS and CCC-CS transect surveys are usually divided up into sections (or “sub-transects”) with surveys of each sub-transect being carried out by a team of four trained divers divided into two buddy pairs (A and B) as shown in Figures 6 and 7. At the start point of each sub-transect, Buddy Pair B remains stationary with Diver 3 holding one end of a 10 m length of rope, whilst Buddy Pair A swims away from them, navigating up or along the reef slope in a pre-determined direction until the 10 m line connecting Diver 1 and 3 becomes taught. Buddy Pair A then remains stationary whilst Buddy Pair B swim towards them. process is

repeated until the end of the planned dive profile, when a surface marker buoy (SMB) carried by Diver 2 is deployed to mark the end of that sub-transect. The SMB acts as the start point for the next survey team and this process is repeated until the entire transect is completed.

Normally during CCC surveys, the positions of the SMB at the start and end of each dive is fixed using a Global Positioning System (GPS). During the EKCRC Project, SMB positions were fixed either by GPS or by taking a bearing towards the cardinal marks, the precise positions of which are known from previous surveys undertaken by the KPC Survey Department.

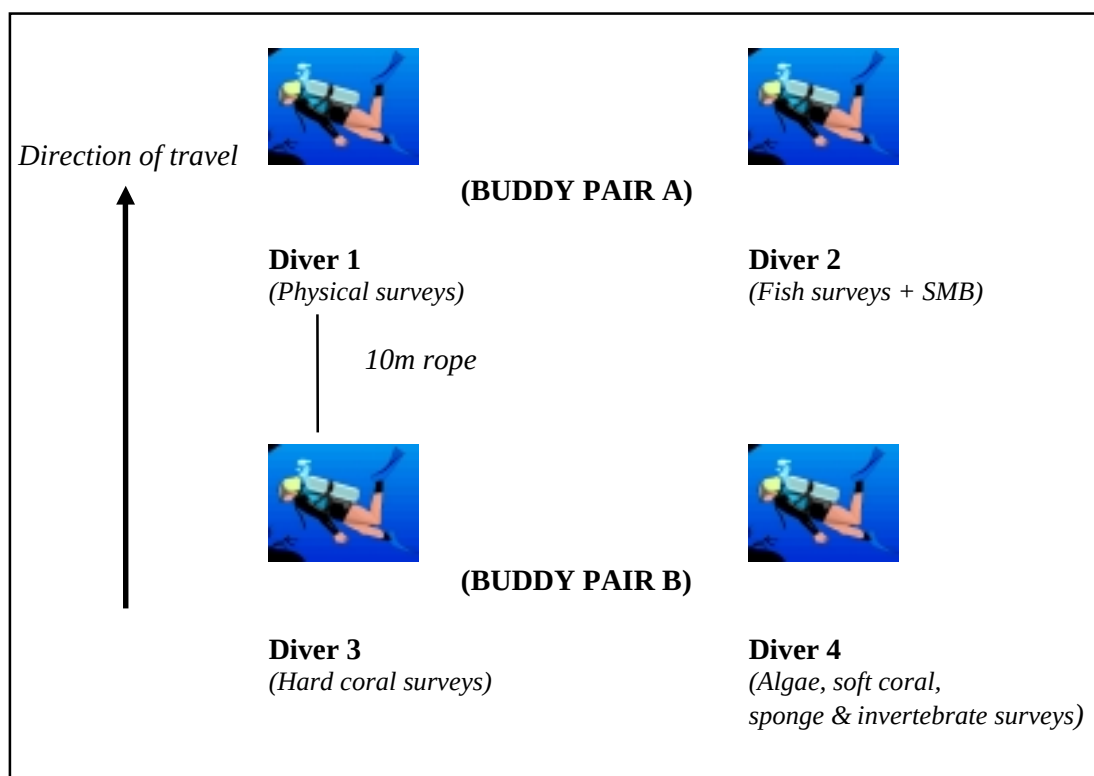


Figure 6. Schematic diagram of a baseline survey dive team showing the positions and data gathering responsibilities of all four divers. Details of the role of each diver are given in the text.

Diver 1 is responsible for leading the dive, taking a depth reading at the end of each 10m interval, and documenting signs of anthropogenic impact such as broken coral or fishing nets. Diver 1 also assesses the current direction and strength and takes a temperature reading at the start of the sub-transect along with a water sample for subsequent salinity measurements. Diver 1 also describes the substratum along the sub-transect by recording the presence of five substrate categories (dead coral, bedrock, rubble, sand and mud).

Fish are recorded by Diver 2 at a family level but additional important target species are also identified. Stony corals are recorded by Diver 3 by identifying the life forms described by English *et al.* (1997) along with additional target coral species. Sponges and octocorals are

are recorded in various life form categories by Diver 4. Diver 4 also identifies the marine flora which is classified into three groups (green, red and brown algae) with selected target species recorded (Appendix 2).



Figure 7. A typical CCC survey team (Photo: Coral Cay Conservation, 1998).

Diver 3 surveys an area of approximately 1 metre to each side of the transect line whilst Divers 1, 2 and 4 survey an area of approximately 2.5 metres to either side of the line.

During the course of each sub-transect survey, divers may traverse two or more apparently discrete habitat types, based upon obvious gross geomorphological or biological differences (e.g. dense coral reef, sand or rubble; Figure 8). The data gathered by each diver from each habitat type are recorded separately for subsequent analysis.

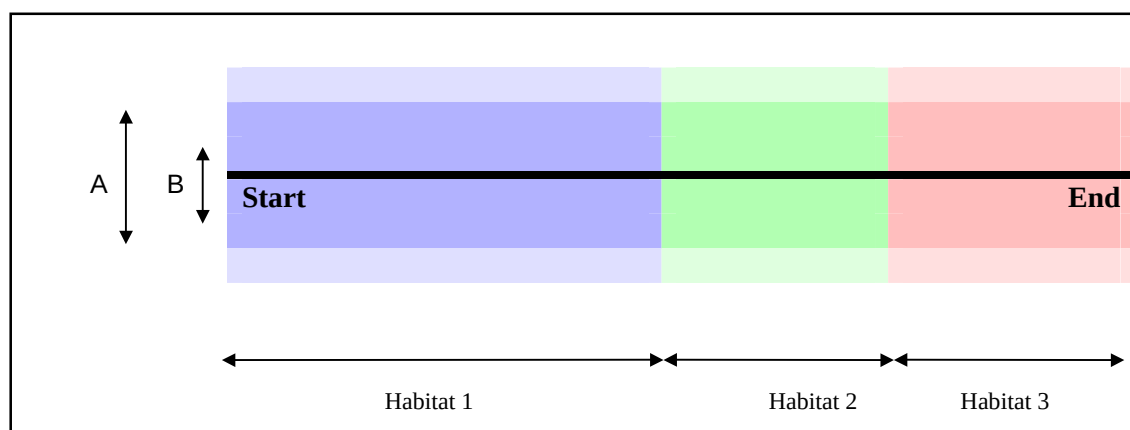


Figure 8. Schematic diagram (aerial aspect) of an example of a reef area mapped by divers during a sub-transect survey. Solid line represents imaginary sub-transect line. Dashed lines and shaded areas represent areas surveyed (A = 5 m wide swathe surveyed by Divers 1, 2 and 4; B = 2 m wide swathe surveyed by Diver 3). Benthic data from habitats 1, 2 and 3 (e.g. reef, sand and rubble) are recorded separately.

Each species, life form or substratum category within each habitat type encountered is assigned an abundance rating from the ordinal scale shown in Table 2.

Table 2. Ordinal scale assigned to life forms and target species during baseline surveys.

ABUNDANCE RATING	CORAL AND ALGAE	FISH AND INVERTEBRATES (NUMBER OF INDIVIDUALS)
0	None	0
1	Rare	1-5
2	Occasional	6-20
3	Frequent	21-50
4	Abundant	51-250
5	Dominant	250+

During the course of each dive, data on surface water temperature and salinity, vertical turbidity, wind strength and direction, and boating activity are collected by the Boat Marshall on board the surface support vessel. Wind strength is estimated using the Beaufort Scale and the vertical turbidity measured using a secchi disk. The Boat Marshall also records the numbers and activities (classed as fishing, diving, commercial or pleasure) of any boats observed during the course of the survey dive.

Data collected from each sub-transect survey during the course of the EKCRC Project were transferred to recording forms adapted from those routinely used by CCC for data recording (Appendix 2), prior to incorporation into CCC's GIS-compatible database stationed at the TBAC. Oceanographic and geo-referencing data obtained during the course of each survey dive were transferred onto a single Boat Form along with observations on human activity within the survey area. Physical data gathered by Diver 1 were transferred onto a single Physical Form whilst data gathered by Divers 2, 3 and 4

were transferred onto a Biological Form, with one Biological Form being completed for each discrete habitat encountered during the course of the sub-transect survey.

Geo-referencing and bathymetric data collected during the course of baseline coral reef assessment surveys were used to produce topographic base maps of selected reefs.

4.1.1 Baseline survey data analysis

In order to describe the reefal habitats within the project area, benthic and substratum data were analysed using multivariate techniques within PRIMER (Plymouth Routines in Multivariate Ecological Research) software. The data from each Biological Form (which represents a “snap-shot” of the benthic community from either part or all of a habitat type distinguished by the survey team) are referred to as a Site Record. Multivariate analysis can be used to separate each Site Record into different groups, each representing a distinct benthic class. Firstly, the similarity between benthic assemblages at each Site Record was measured quantitatively using the Bray-Curtis Similarity coefficient (Equation 1; Bray and Curtis, 1957). This coefficient has been shown to be a particularly robust measure of ecological distance (Faith *et al.*, 1987).

Equation 1:

$$\text{Bray - Curtis Similarity, } S_{jk} = \left[1 - \frac{\sum_{i=1}^p |x_{ij} - x_{ik}|}{\sum_{i=1}^p (x_{ij} + x_{jk})} \right]$$

Where X_{ij} is the abundance of the i th species in the j th sample and where there are p species overall.

Agglomerative hierarchical cluster analysis with group-average sorting was then used to classify field data. Cluster analysis produces a dendrogram grouping Site Records together based on biological and physical similarities. Site Records that group together are assumed to constitute a distinct benthic class.

Characteristic species or substrata of each class were determined using Similarity Percentage (SIMPER) analysis (Clarke 1993). To identify characteristic features, SIMPER calculates the average Bray-Curtis similarity between all pairs of intra-group samples (e.g. between all Site Records of the first cluster). Since the Bray-Curtis similarity is the algebraic sum of contributions from each species, the average similarity between Site Records of the first cluster can be expressed in terms of the average contribution from each species.

The standard deviation provides a measure of how consistently a given species contributes to the similarity between Site Records. A good characteristic species contributes heavily to intra-habitat similarity and has a small standard deviation. The univariate summary statistics of median abundance, frequency of occurrence of each species, life form and substratum category were also used to aid description of each habitat type.

4.2 Taxonomy

During baseline surveys a list of the fish and invertebrate species observed was compiled to assess biodiversity within the project area. Fish were identified from Kuitert (1992), Lieske and Myers (1994), Allen and Steene (1994) and Muller (1994) and the invertebrates from Gosliner *et al.* (1996). Both lists were collated by the project Science Officer to ensure reliable species level identification. Compilation of a list of coral species was not undertaken during the course of the EKCRC Project.

4.3 Monitoring programme

The principle aims of the monitoring programme were to:

- establish permanent monitoring sites within the EKCRC Project area;
- test the accuracy of monitoring data gathered by volunteer divers;
- assess water quality on target reefs;
- determine anthropogenic influences on water quality;
- provide recommendations for future monitoring programmes.

4.3.1 Permanent transect monitoring

Monitoring sites were installed on four reefs within the project area, namely: Sangatta Reef, South Marker Reef, North Marker Reef and Bengalon Reef (Figure 9). Each monitoring site was comprised of two sets of permanent transects and two sets of sediment traps. A set of permanent transects consisted of three replicate transects located along 20 m and 5 m depth contours, giving a total of 48 transects (i.e. 12 at each of the four reef sites). One set of replicates was placed directly east of the navigational cardinal mark located on each reef and the other set directly to the west of the same mark, thereby allowing easy relocation of transects by distance and bearing from the cardinal mark. The start position for surveys of each transect were standardised by positioning a submerged marker buoy to the left end of each transect, orientated by the divers facing the cardinal mark when at the transect location.

The permanent transects comprised of three five inch nails per transect marked with orange rope. Each of the three replicate transects were given an identification code (A, B or C), transect A being positioned to the left, B in the centre and C to the right hand side, when observed by divers orientated at the survey site facing the cardinal mark. The transects were also denoted by the number of floats attached to them.

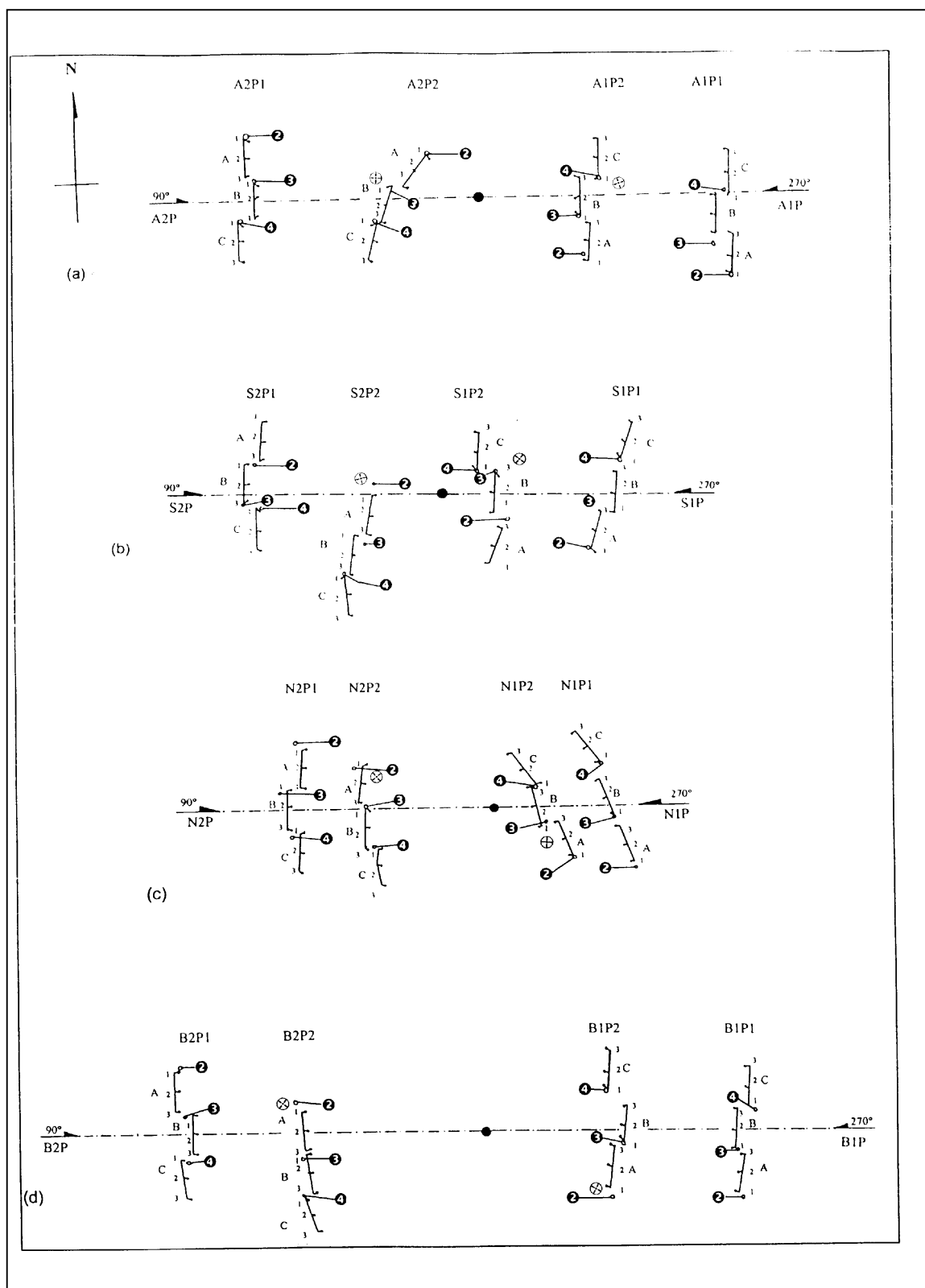


Figure 9. Plan of permanent transects at the monitoring sites.

(a) Sangatta Reef (b) South Marker Reef (c) North Marker Reef (d) Bengalon Reef.

☞ - sediment traps. ②, ③, ④ - number of marker floats attached. ● - cardinal mark.

All 48 transects were surveyed in March and 36 re-surveyed in April 1998 (Bengalon Reef was not re-surveyed), using a Line Intercept Transect (LIT) protocol based on that recommended by English *et al.* (1997). This technique, which provides quantitative data on the benthic cover of the reef, is simple to use and well documented and is therefore potentially suitable for use by volunteer divers. Furthermore, since the LIT protocol is widely used, data collected by this method during the EKCRC Project could be readily compared with data from other reef areas.

For the LIT surveys, one end of a 10 m measuring tape was attached to the nail marking the start point of the survey transect and the other end attached to the third nail marking the end of the transect. The tape was positioned along the depth contour using the central nail. Divers commenced surveys along the measuring tape from the start point of the transect, recording the organism type and position along the tape at each point where the tape intercepted a sessile benthic organism (Figure 10). The position of each organism was determined by recording the point furthest from the start point of the transect where the colony ended. Organisms and substratum were recorded into benthic categories modified from English *et al.* (1997) (Appendix 3).



Figure 10. Volunteer surveyor using the LIT protocol (Photo: Bradley, 1998).

4.3.1.1 Permanent transect data analysis

The percentage cover of each benthic category was calculated as follows:

$$\text{Percent cover} = \frac{\text{Total length of category}}{\text{Length of transect}} \times 100$$

Initial analysis of the percent cover information focused on assessing the consistency, and hence reliability, of the data. Based upon the assumption that changes in the composition of the benthic community between March and April would be negligible over such a short time-scale, the degree of consistency between temporal data sets from repeat surveys of each transect was assessed using Bray-Curtis similarity coefficients (Section 4.1.1) to compare data sets. Subsequent analysis then described the current status of the reefs as a baseline for future comparison.

4.3.2 Water quality monitoring

Physical parameters such as water temperature, vertical turbidity and salinity were routinely collected during the course of each survey dive (Section 4.1). To compliment these data, a water quality monitoring programme was established with the primary aim of obtaining information on possible impacts caused by forest fires in the region, changes in environmental conditions caused by the El Niño climatic phenomenon, and sedimentation, sewage or chemical inputs which may be derived from mining operations or local villages.

Water samples were collected at the location of each permanent monitoring transect (Section 4.3.1) on at least three separate occasions. One litre water samples collected at depths of 28 m, 15 m and 0 m (surface water) were analysed at the KPC water quality monitoring laboratory for the parameters shown in Table 3 and Appendix 6.3.

Table 3. Methods used to assess the water quality parameters measured during the EKCRC Project. Further details of protocols are given in Appendix 6.3.

PARAMETER	UNITS	METHOD	DETECTABLE LIMITS / SENSITIVITY
Dissolved O ₂	mg/l	Probe	±0.01
Salinity	g/l	Probe	±0.5
Total Carbon (TC)	mg/l	Gas detector	±0.1
Total Inorganic Carbon (TIC)	mg/l	Gas detector	±0.1
Total Organic Carbon (TOC)	mg/l	Gas detector	±0.1
pH-value	pH	Probe	±0.01
Conductivity	µS/cm	Probe	±1
NO ₃ and PO ₄	mg/l	Spectrophotometer	±0.001
SO ₄	mg/l	Spectrophotometer	±1
Bicarbonate (Alkalinity)	mg/l	Titration	±1
Water hardness	mg/l	Probe	±1
Total Dissolved Solids (TDS)	mg/l	Spectrophotometer	±1
Total Suspended Solids (TSS)	mg/l	Spectrophotometer	±1
Mg, K, Na, Ca	mg/l	Spectrophotometer	±1
Fe	mg/l	Spectrophotometer	>0.01
Co, Pb, Ni	mg/l	Spectrophotometer	>0.001
As, Cd	mg/l	Spectrophotometer	>0.0001
Hg	mg/l	Spectrophotometer	>0.00005

4.3.3 Sedimentation study

A sedimentation study was conducted to assess the degree of settling of suspended solids in the water column with particular reference to terrigenous outflows from the Sangatta River. Eight sets of sediment traps were positioned at Sangatta Reef, South Marker Reef, North Marker Reef and Bengalon Reef at a depth of 5 m along the central transect of each of the permanent monitoring transects (Figure 9). Each trap was constructed from three removable PVC collection tubes attached to a central stake (English *et al.*, 1997).

Collection tubes were removed every four weeks for analysis and replaced with empty traps. The contents of each sediment tube were analysed for total dry weight and particle size analysis at the KPC laboratory. Samples were filtered through a 60 µm filter and dried in an oven at 60° Celsius for 12 hours. The weight of the dried sediments were recorded as dry weight. After burning the dried sample in an oven at 600° Celsius the remaining dry inorganic weight was determined.

4.4 Socio-economic assessments

Visits to local fish markets and consultations with fisherfolk living in the village of Sangatta were made in order to carry out a rapid assessment of fish catches and fishing methods used, and to seek local views and opinions on environmental issues.

4.5 Training and conservation education

The principle aims of the training and conservation education programmes were to:

- provide scientific and SCUBA training for project personnel;
- provide conservation education opportunities for local schools and communities;
- produce conservation education training materials.

4.5.1 Science training programme

• CCC volunteers

Prior to assisting with data acquisition, CCC volunteers were required to undertake an intensive eight day training course in marine life identification and survey techniques (Table 4; Figure 11). The training programme included assessments of volunteers identification skills and their competence at undertaking reef surveys. Assessments were in the form of written tests to determine the level of competence of each volunteer in marine life identification. Only volunteers who passed the assessments satisfactorily (score of greater than 80%) were permitted to participate in data gathering.

• **TBDC volunteers**

Twenty-four members of the TBDC were provided training in coral reef ecology and marine life identification. Owing to employment obligations, training for TBDC members was scheduled on a part-time basis throughout the duration of the EKCRC Project.

Table 4. CCC science training programme schedule.

DAY		AM	PM	EVENING
1		-	Lecture 1. Introduction	
		-	Familiarisation snorkel and buoyancy checks.	-
2		Lecture 2. Introduction to coral biology and reefs. Identification of hard coral life forms.	Lecture 3. Identification of target hard coral species.	Knowledge review & coral identification slide show.
		Snorkel and dive to 12 m - reef orientation	6m dive - reef orientation.	-
3		Lecture 4. Identification of hard coral species. Morphotypic variation.	Lecture 5. Knowledge review of coral identification.	Knowledge review.
		18 m dive - coral ID.	15 m dive - coral ID	-
4		Lecture 6. Introduction to fish and fish identification. Major families and species.	Lecture 7. Further reef fish Identification.	Knowledge review
		24 m dive - fish ID	18 m dive - fish ID	-
5		Lecture 8. Invertebrate identification and soft coral growth forms.	Lecture 9. Marine plants and algae identification.	Study of algal reference collection.
		24 m dive - invertebrate ID	18 m dive (or snorkel) - algal ID.	-
6		Lecture 10. Overview and practice of survey methods (beach dry-run). Completion of boat forms.	Lecture 11. Physical and biological forms. Concept of ordinal scale and separate habitat types.	Coral knowledge test.
		18 m dive - practical survey technique.	15 m dive - practise survey and form completion.	-
7		-	-	-
		24 m dive - general identification.	15 m dive - coral ID trail.	-
8		-	-	Fish knowledge test.
		General identification snorkel / snorkel trail.	General identification snorkel.	-



Figure 11. Science training week at TBAC (Photo: Raines, 1998).

4.5.2 Dive training programme

TBDC members, Indonesian counterparts from the local communities and employees from various KPC departments were provided entry level and advanced PADI SCUBA training courses, ranging from PADI Open Water Diver to Rescue Diver certifications.

4.5.3 Conservation education programmes

- ***YPP Swarga Bara (Swarga Bara Junior High School)***

The EKCRC Project provided a coral reef ecology course for 20 pupils (14 to 15 year age group) from YPP Swarga Bara. Given in Bahasa Indonesia, the course incorporated the basics of reef, mangrove and fisheries ecology and coastal zone management over a period of two weeks (Table 5). The course included snorkel training at the local swimming pool and snorkelling field trips to Bengalon Reef and South Marker Reef.

Table 5. Teaching and activity timetable of the coral reef ecology course provided for pupils at YPP Swarga Bara.

	WEEK 1	WEEK 2
MONDAY	 Lecture: Introduction: CCC - resources and facilities. Introduction of project topics: mangroves, coral reef ecology, fish ecology, symbiosis, threats to coral reefs, human impacts and interactions.  Lecture: Why do we want to protect reefs? How do we look at reefs? How do we look at mangroves?	 Revision: Project work; discussion; questions.  Lecture: Diversity: Why do we need healthy reefs? Why kill animals?  Lecture: Fisheries management.
TUESDAY	 Revision: What are coral reefs?  Slide show: Hard corals.  Lecture: Coastal habitats and zonation (rain forest, mangroves, coral reefs), human impacts and threats	 Activity: Supervised project work; questions and answers session.
WEDNESDAY	 Revision: Reef zonation; human impacts on the reef.  Homework: Write a short essay on mangrove ecology.	 Activity: Snorkelling and supervised project work at Bengalon Reef.  Homework: Project work.
THURSDAY	 Revision: Mangrove ecology; coral reef zonation.  Activity: Walk through mangroves and inter-tidal zone.  Lecture: Fish biology, adaptations and living strategies (shoaling, camouflage, butterfly fish patterns, wrasse sex reversal).	 Open day: Supervised work on projects. Question and answer session.  Homework: Complete and submit project.
FRIDAY	 Revision: Homework review.  Lecture: Life on the reef; reef fish; symbiosis. Allocate project topics.  Activity: Snorkelling practice in pool.  Homework: Write a short essay on your project topic and make a plan for your practical work.	 Activity: Snorkelling at South Marker Reef.  Presentation: Present projects.  Debriefing: What did we achieve in these two weeks and how can we carry on?

Students were divided into pairs and each pair asked to choose a topic for a field project on either reef or mangrove ecology from a list of suggestions compiled by the students with the help of CCC volunteers. Each pair of students were assigned a Project Supervisor (a CCC volunteer) to assist them prepare a work proposal for their chosen project and to oversee their practical work (Figure 12). The students presented the results of their project work at the end of the field course.



Figure 12. Students from YPP Swarga Bara conducting project fieldwork. (Photo: Beger, 1998).

- ***Tanjung Bara International School***

An introductory presentation about coral reefs was arranged for 50 pupils at the Tanjung Bara International School. Two classes were also taken on a visit to a boardwalk through the mangroves accompanied by the project Science Officer, school teachers and CCC volunteers. This interactive exercise was designed to heighten awareness of the value of mangroves and the inter-tidal zone as an integral part of the coastal environment.

- ***Educational wall chart***

An educational wall chart entitled “*Gugus karang dan hutan hujan Indonesia*” (*Indonesian Reefs and Rainforest*), is currently being prepared for distribution to local schools and communities. Funded by KPC, the wall chart focuses on both terrestrial and coral reef ecosystems and is aimed at improving conservation awareness.

5 RESULTS

5.1 Baseline coral reef assessments

During the course of the EKCRC Project, 116 survey dives were undertaken to complete 36 survey transects using the CCC-TS and CCC-CS protocols to map and describe six reef sites (Table 6). Surveys generated 135 completed Biological Forms and approximately 10,000 species records (in terms of abundance and location).

Table 6. Numbers of surveys conducted by the EKCRC Project team.

REEF	CCC-TS		CCC-CS
	Number of transects completed	Number of sub-transects (dives)	Number of sub-transects (dives)
Sangatta	2	4	0
South Marker	12	27	11
North Marker	8	19	17
Bengalon	8	19	9
Miang Besar	4	6	0
Rita's	2	4	0
TOTAL	36	79	37

5.1.1 Topographical mapping

Geo-referencing and bathymetrical data gathered during the course of the surveys were used to create topographical maps of South Marker Reef, North Marker Reef and Bengalon Reef (Figures 13-15). Insufficient data were gathered to produce similar maps for Sangatta Reef, Rita's Reef and Miang Besar.

5.1.2 Baseline survey data analysis

The dendrogram (Figure 16) resulting from cluster analysis of the baseline survey data discriminated eight major benthic classes, each with a minimum of six Site Records. Using the characteristics of the benthic classes defined by SIMPER and univariate analysis (Table 7) these eight benthic classes were labelled as:

BC1: Sand and Sparse Algae	BC5: Non- <i>Acropora</i> Coral Dominated
BC2: Rubble and Dead Coral	BC6: Coral and Sponge Dominated
BC3: Sand and Foliose Coral	BC7: Dense Foliose Corals
BC4: Branching Coral	BC8: Medium-dense Foliose Corals

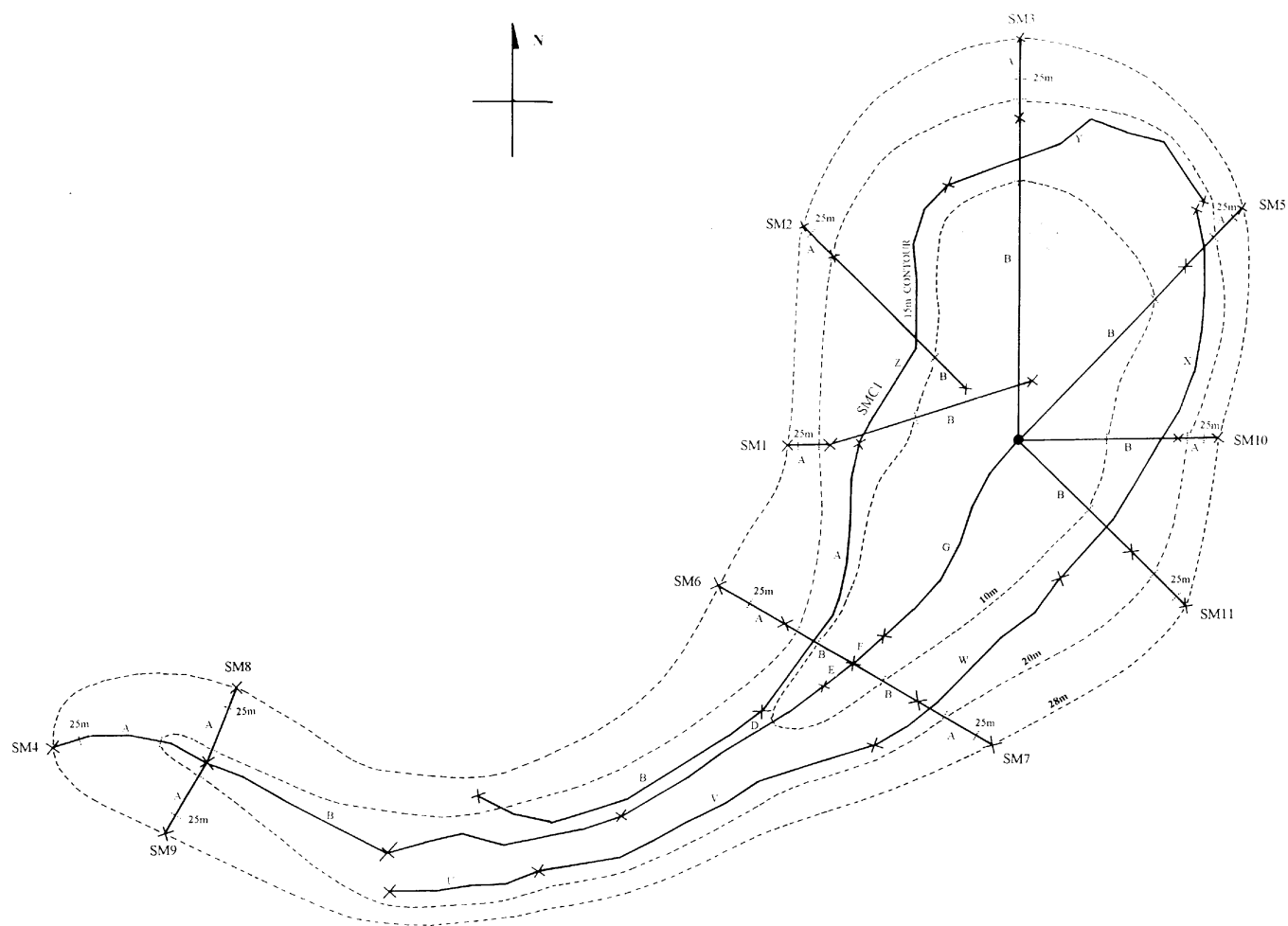


Figure 13. Topographical map of South Marker Reef showing positions of survey transects (N1-8) (X - start and end points of each sub-transect; ● - position of cardinal mark).

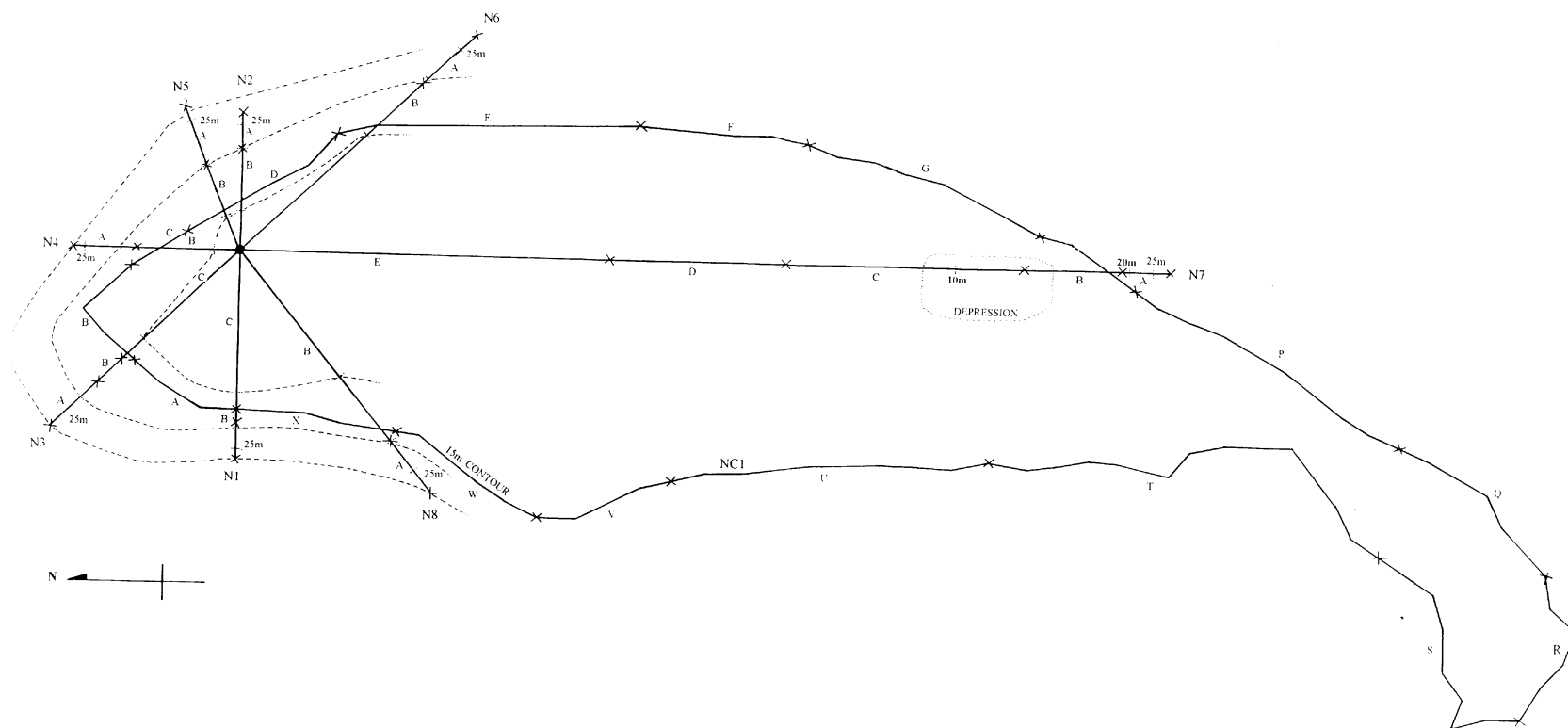


Figure 14. Topographical map of North Marker Reef showing positions of survey transects (SM1-11) (X - start and end points of each sub-transect; ● - position of cardinal mark).

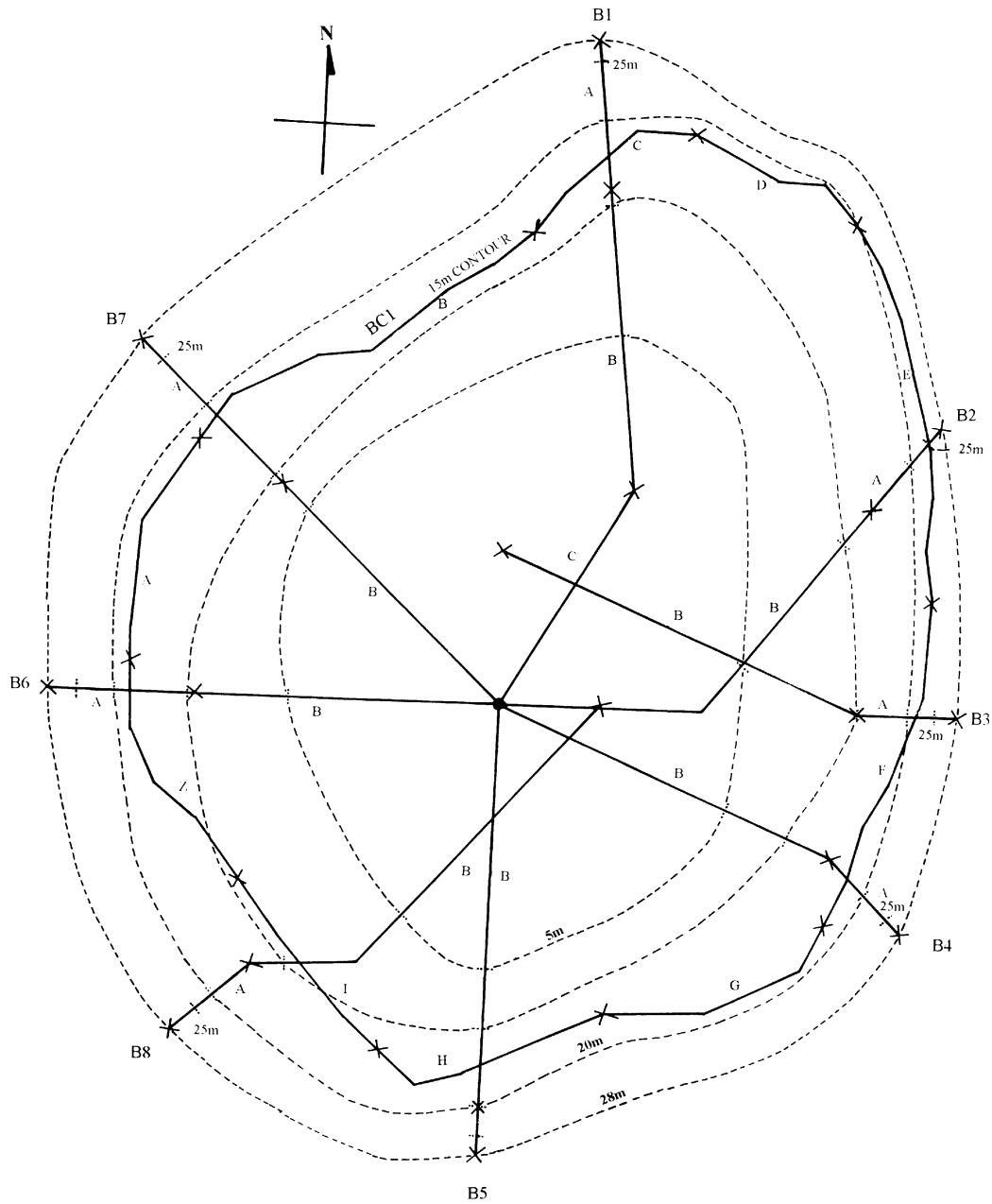


Figure 15. Topographical map of Bengalon Reef showing positions of survey transects (B1-8) (X - start and end points of each sub-transect; ● - position of cardinal mark).

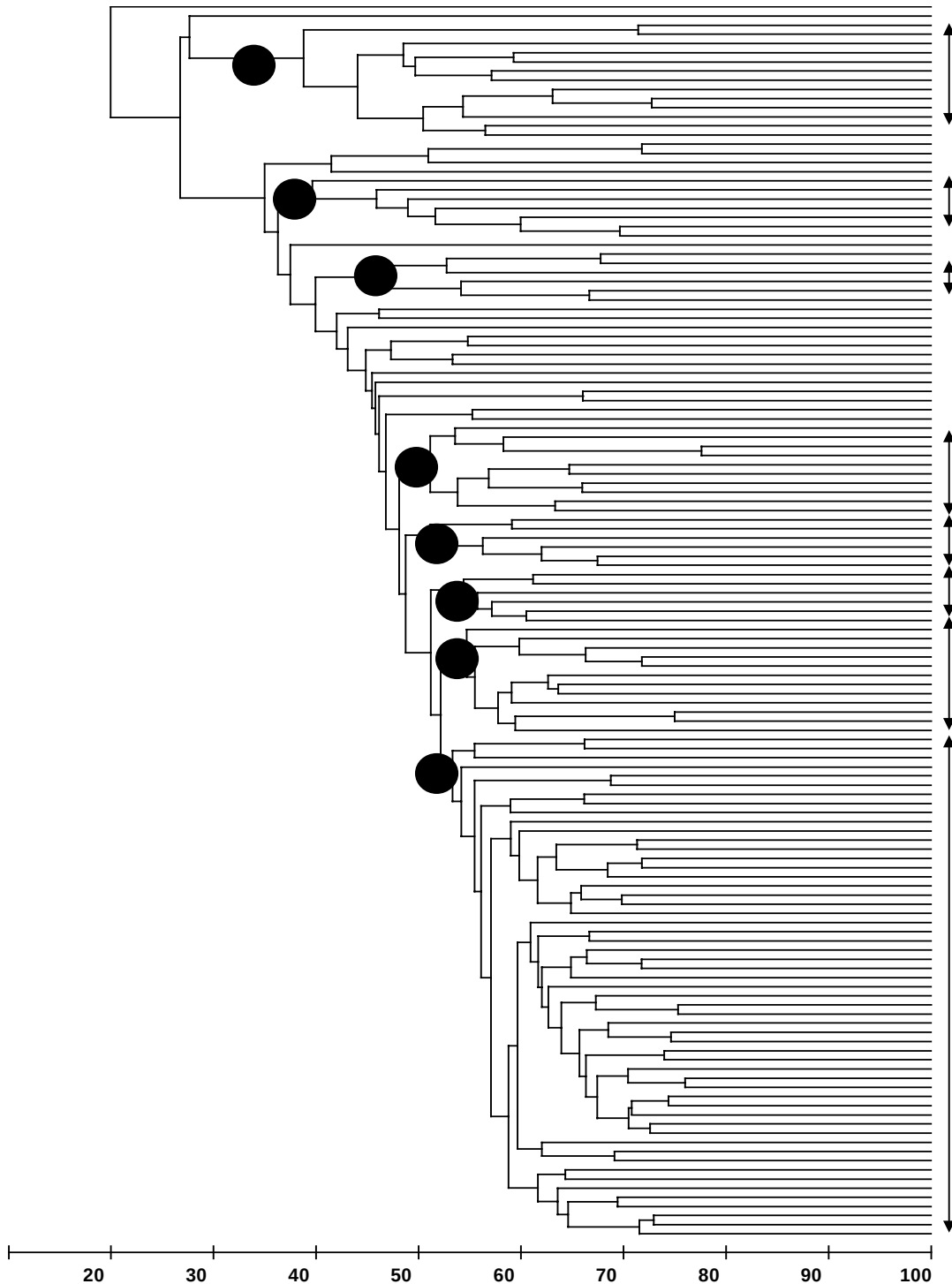


Figure 16. Dendrogram from cluster analysis of baseline survey data.

Each line represents benthic and substratum data from each Site Record (one completed biological form). Solid black circles and arrows highlight the eight major clusters representing the benthic classes discriminated with this analysis. Horizontal axis represents similarity as calculated with the Bray-Curtis coefficient (%).

Table 7. Major characteristics of the eight benthic classes discriminated during the EKCRC Project.

Figures in parentheses indicate median abundances derived from 0-5 ratings assigned during surveys. The most characteristic life forms or substratum categories (greater than 5% contribution to cluster similarity as highlighted by SIMPER analysis) in bold.

BENTHIC CLASS	NO. SURVEYS	SUBSTRATUM	HARD CORALS	OCTOCORALS	SPONGES	ALGAE / SEAGRASS	COMMENTS
BC 1: Sand and Sparse Algae	11	Dominated by sand (4.8).	Very few: mushroom (0.7), non- <i>Acropora</i> branching (0.6) and foliose (0.6).	Only "tree" octocorals (1.2) frequently seen.	Encrusting (0.9) and Lumpy (0.7) occasionally seen.	Only <i>Dictyota</i> (1.2) and green filamentous (0.9) occasional.	
BC 2: Rubble and Dead Coral	8	Mainly rubble (4) with dead coral (3), and dead coral with algae (2.2).	Few are common: Mushroom (2), Porites massive (1.5), non- <i>Acropora</i> massive (1.2).	Sea whip (1.7) frequent.	Encrusting (1.5) and tube (0.5) most common.	Green filamentous (1.8), <i>Dictyota</i> (1.5), red filamentous (1.2) are common.	Habitat usually characteristic of human impact, such as destructive fishing.
BC 3: Sand and Foliose Corals	6	Dominated by sand (3.5) and rock (2.5).	Only Non-<i>Acropora</i> foliose (2.5), particularly <i>Montipora foliosa</i> (1.5) common.	"Tree" octocorals (1.2) and sea fans (1) frequently seen.	Tube (1.3) common, with some branching, rope and lumpy (each 0.5).	<i>Dictyota</i> (2.1) abundant with some green and red filamentous (each 0.8).	Presence of rapid growing foliose corals with few other corals may indicate recovery from human impact.
BC 4: Branching Corals	10	A mix of sand (2) and rock (2).	A diverse community with <i>Acropora</i> branching (1.9), non- <i>Acropora</i> branching (1.8) most abundant.	Xenids (2.1) dominant. Some "tree" octocorals and (1.5) sea fans (0.7)	Elephant ear (1.5) and encrusting (1.5) frequent.	Algae abundant, particularly red filamentous (2.5), green filamentous (1.8) and <i>Dictyota</i> (1.5)	Although Xenids are most characteristic, this habitat is visually dominated by branching corals.
BC 5: Non- <i>Acropora</i> Coral Dominated	6	Dominated by sand (3.2) and rock (2.8).	A diverse community with non- <i>Acropora</i> foliose (2.1), particularly <i>Montipora foliosa</i> (1.8), Non-<i>Acropora</i> encrusting (2) and mushroom (2) dominant.	Very few but some sea whips (0.5) and pulsing soft corals (0.3).	Tube, branching, barrel (each 0.8), rope (0.5) and lumpy (0.5) occasionally seen.	<i>Dictyota</i> (1) and green filamentous (0.3) occasional.	
BC 6: Coral and Sponge Dominated	6	Dominated by rock (3) and dead coral with algae (2).	Diverse and abundant: <i>Acropora</i> tabulate (2.3), Non-<i>Acropora</i> foliose (2.2), <i>Acropora</i> foliose (2.2), <i>Acropora</i> branching (2) and non- <i>Acropora</i> massive (2).	"Tree" octocorals (1.5) and sea fans (0.5) most common.	Abundant, particularly, lumpy (2.3), encrusting (2.1) and branching (1.5).	Mainly <i>Dictyota</i> (2.5) with green filamentous (2) and brown filamentous (0.5).	
BC 7: Dense Foliose Corals	12	Dominated by rock (3.5).	Dominated by non-<i>Acropora</i> foliose (3.3), especially <i>Montipora foliosa</i> (3.3) but non- <i>Acropora</i> encrusting and mushroom common (1.8).	"Tree" octocorals (1.3), Xenids (1), sea fans (0.9) and sea whips (0.7) frequently seen.	Tube (1.6), lumpy (1.3), barrel (1.1) and branching (1) frequent.	<i>Dictyota</i> (2.2) common with green filamentous (1) and red filamentous (0.8).	Abundant foliose corals within a diverse community indicate minimal human impact.
BC 8: Medium Dense Foliose Corals	55	Dominated by rock (3.2).	Dominated by Non-<i>Acropora</i> foliose (2.8), particularly <i>Montipora foliosa</i> (2.2), but also mushroom (1.8) Non- <i>Acropora</i> encrusting (1.9).	"Tree" octocorals (1.9), sea fan (1.8) and sea whip (1.3) common.	Lumpy (2), encrusting (1.8), branching (1.6), barrel (1.4) and rope (1.2) frequent.	<i>Dictyota</i> (1.7) and green filamentous (1.5) common.	Abundant foliose corals within a diverse community indicate minimal human impact.

Data on the median abundance of algae, sponges, octocorals and coral life forms in each class is given in Appendix 4.

A minimum of six Site Records was selected following interpretation of the dendrogram since this represents a conservative approach to data analysis and ensures that erroneous data are excluded from further analysis. Twenty one Site Records (15.5% of the total) collected during the EKCRC Project could not be assigned to one of the eight major benthic classes. These Site Records represent either erroneous data or minor habitats which are represented by fewer than six Site Records and which therefore require further fieldwork to describe.

5.1.3 Oceanographic data

Data on water temperature, wind strength and direction, current strength and direction, vertical turbidity and salinity were gathered during the course of each baseline survey.

Measurements of sub-surface water temperature throughout the water column remained constant at approximately 27⁰C (Figure 17a). Mean surface temperature was 30.9⁰C (standard deviation 1.9).

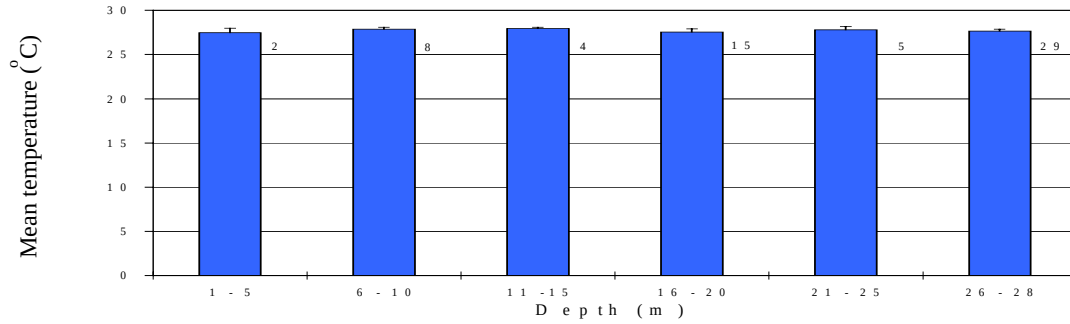
The prevailing wind direction was from the north-east and most commonly “2” on the Beaufort Scale (Figure 17b).

Current data were analysed by relating the strength and direction to the state of tide at the time of sampling (Figure 17c). Figure 17c shows that the tide generally flooded towards the south or south-west (highest number of “medium” or “strong” recordings) and then reversed at high tide and ebbed towards the north or north-east.

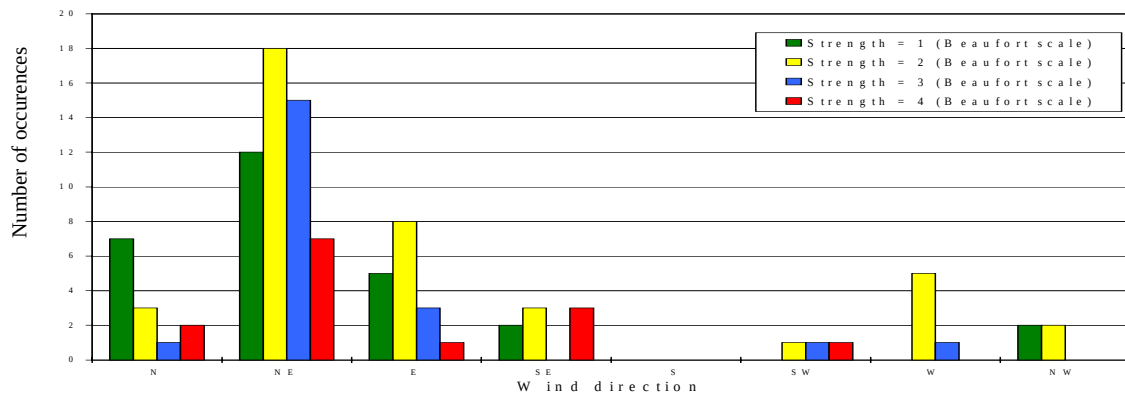
Mean salinity within the EKCRC Project area was 32.6‰ (standard deviation 3.5‰). Salinity was similar at North Marker Reef, Bengalon Reef and Miang Besar (approximately 34‰) but was slightly lower at South Marker Reef (approximately 30‰; Figure 18a).

Vertical turbidity (Figure 18b) levels were slightly higher at North Marker Reef and South Marker Reef compared with Bengalon Reef.

(a)



(b)



(c)

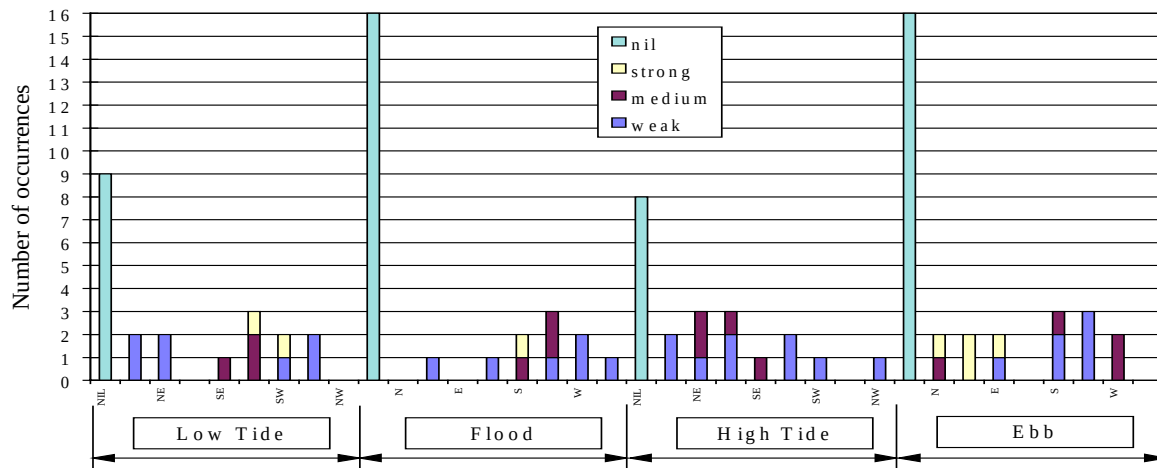


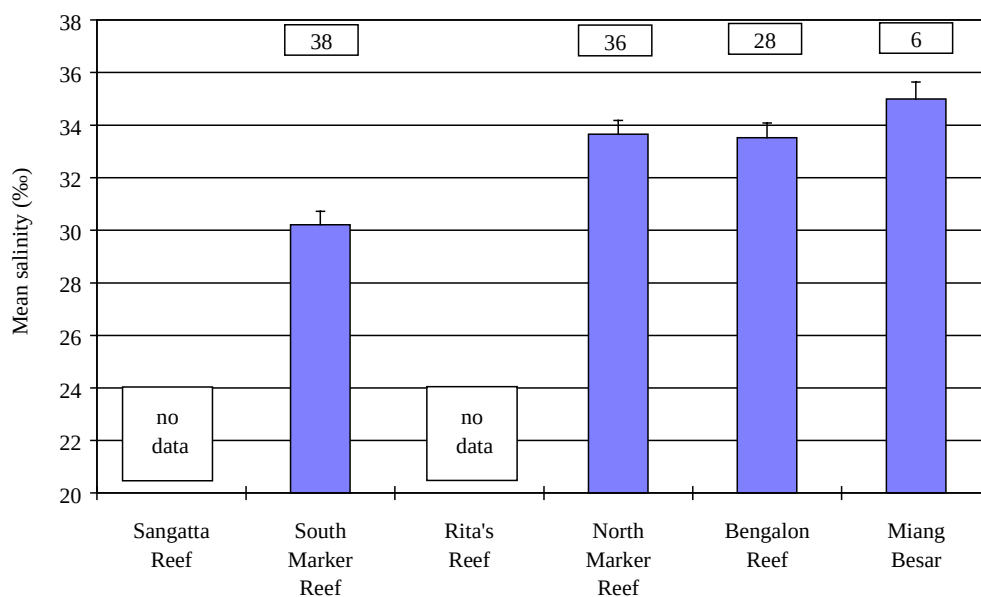
Figure 17. Summary of oceanographic data from 116 surveys during the EKCRC Project.

(a) Mean water temperature at different depths. Bars represent standard error and additional figures show sample size.

(b) Summary of wind strength and direction data. No wind recorded on 13 surveys.

(c) Summary of current strength and direction data in relation to tidal flow.

(a)



(b)

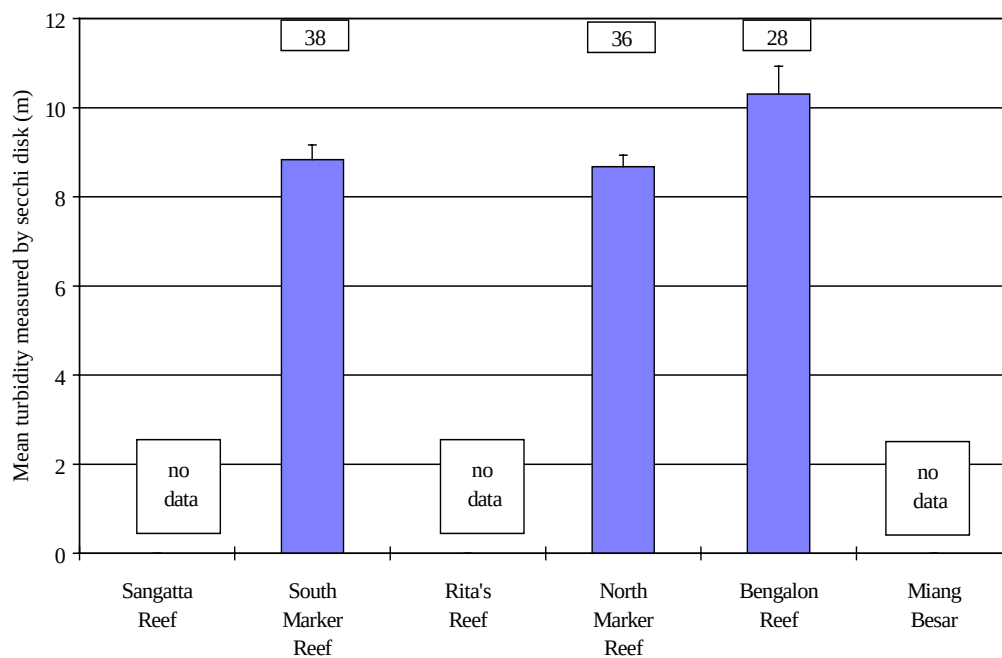


Figure 18. Summary of oceanographic data from 116 surveys during the EKCRC Project.

(a) Mean water salinity. Bars represent standard error. Additional figures show sample size.

(b) Mean water turbidity measured by the depth reached by a secchi disk. Bars represent standard error. Additional figures show sample size.

5.1.4 Anthropogenic impacts

During the course of each baseline survey, anthropogenic impacts were assessed from observations of the number and activity of boats sighted in the vicinity of the survey sites and observations of gross physical damage to reefs during each dive.

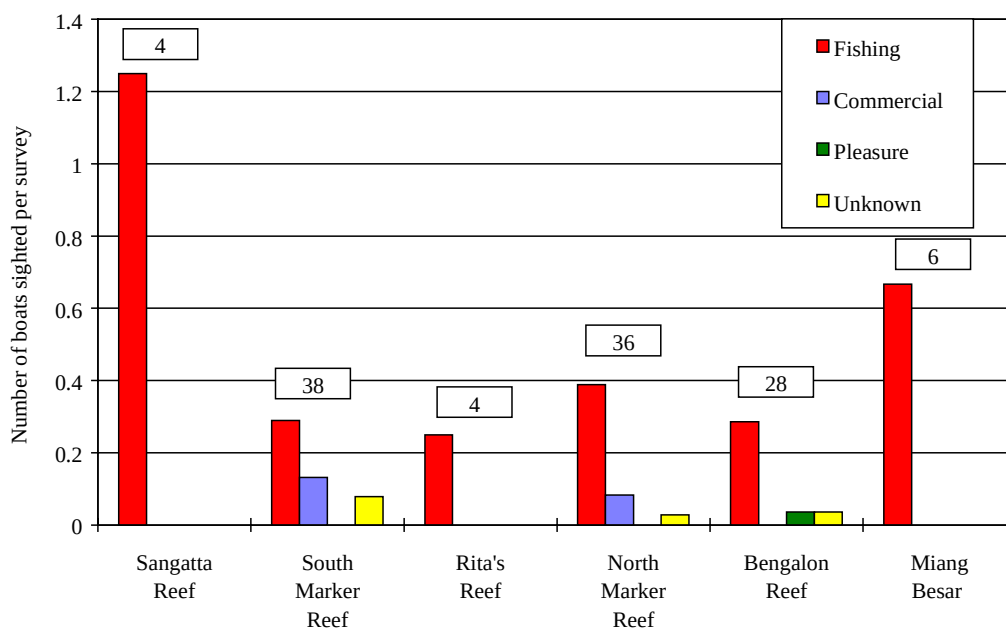
Data on boat numbers and activities distinguished three main activities: fishing, commercial and pleasure, along with some boats whose activities were unknown. To compare boat activity at each reef, these data were converted into sightings per survey (i.e. number of boats divided by number of surveys; Figure 19a). Most boats observed were actively fishing, with the highest number of fishing boats per survey observed at Sangatta Reef and Miang Besar (1.25 and 0.67 boats per survey respectively).

During the EKCRC Project the presence or absence of litter, broken coral, fishing traps, lines, sedimentation, explosive impacts, algae overgrowth and sewage on each survey were recorded. Figure 19b shows these data expressed as the frequency of occurrence on each reef (i.e. the number of times each impact was recorded on each reef divided by the number of surveys on that reef expressed as a percentage). The most commonly observed impact was broken coral, with a maximum frequency on South Marker Reef (recorded on more than 50% of surveys). Sangatta Reef and Bengalon Reef also had numerous broken corals (recorded on 40-50% of surveys). Litter, algal overgrowth and fishing lines were observed on most reefs but evidence of sedimentation, sewage and the impacts from the use of explosives were rare, although on one occasion a discarded home-made explosive device was observed on South Marker Reef and another occasion, large numbers of dead fish were observed on Bengalon Reef which was presumed to have been caused by cyanide fishing. Fishing traps were not observed at any time.

5.2 Taxonomy

During the EKCRC Project, 344 reef fish species (from 54 families) and 166 reef invertebrate species or genera were identified (Appendix 5).

(a)



(b)

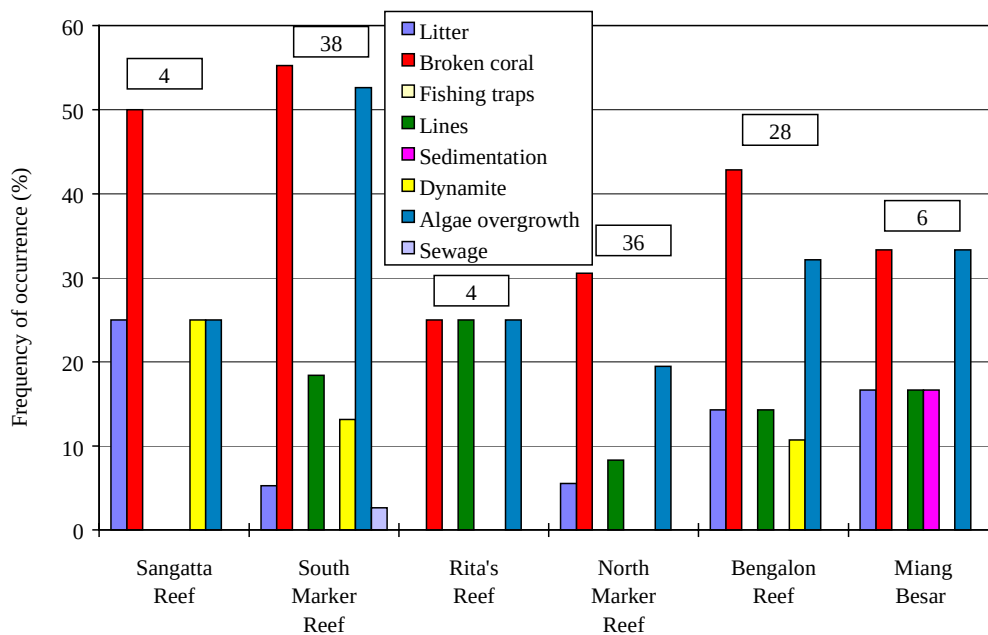


Figure 19. Summary of anthropogenic impact data from 116 surveys during the EKCRC Project.

- (a) Number and activity of boats seen at each reef. Additional figures show sample size.
 (b) Frequency of occurrence of anthropogenic impacts at each reef. Additional figures show sample size.

5.3 Monitoring programme

5.3.1 Permanent transect monitoring

Initial analysis of the data gathered using the LIT protocol during the EKCRC Project focused on assessing the consistency of volunteer divers. This was achieved by surveying 36 of the 48 permanent monitoring transects in both March and April (Bengalon Reef was not re-surveyed) with the assumption that the results should be identical as no significant change in the benthic community would be expected over such a short time period.

The mean Bray-Curtis similarity coefficient for the 36 comparisons between LIT data gathered by volunteers in March and April was 49.7% (standard deviation 19.5%). This was substantially lower than expected and compared unfavourably with a consistency of greater than 60% achieved by trained volunteers using CCC's standard baseline reef assessment techniques (Mumby *et al.*, 1995).

The data were then analysed to determine which benthic categories were poorly recorded. This was achieved by calculating (for each category) a Bray-Curtis similarity coefficient between records of categories (on any given transect) in March with the equivalent record in April (Table 8). Since there were 36 re-surveys in April the maximum sample size was 36 pairs of records, i.e. that category was recorded on every transect.

Acropora-branching corals were surveyed most consistently since the similarity coefficient calculated for the 15 pairs of values (March and April) was 77.6% (Table 8). Only six categories were surveyed with a consistency of greater than 50%: *Acropora*-branching corals, non-*Acropora* foliose corals, sponges, soft corals, sand and rubble. Many of the categories were recorded with a high degree of inconsistency particularly when there was a small sample size. For example, *Heliopora* was recorded on only one transect and the similarity coefficient was 0% (i.e. it was recorded in one month but not the second).

The level of inconsistency within the LIT data indicates that data from each transect line cannot be reliably used for comparisons with other transects or future re-surveys (i.e. studying change in percentage coral cover along a particular transect). However, the mean values (from the two surveys of three replicate transects at each depth) for each benthic category provide valuable quantitative data for general comparisons with future data sets. These data are summarised for each reef on Figures 20 and 21 and listed in Appendix 6.

Detailed comparisons using the LIT data are inappropriate but general patterns are apparent (Figures 20 and 21). All the sites were dominated by substratum categories, particularly rubble. *Acropora* was only abundant at the 5m depth contour on Sangatta Reef and Bengalon Reef where the branching category was approximately 55% and 35% respectively. Non-*Acropora* foliose was common, especially on the deeper transects, at all reefs except Sangatta Reef. Non-*Acropora* encrusting covered approximately 10% of the

reef at the 5 m depth contour. Soft corals were abundant at North Marker Reef and turf algae was particularly common at South Marker Reef.

Table 8. Consistency, measured using the Bray-Curtis Similarity Coefficient, between March and April values of each benthic category when recorded on any of the LIT survey transects. Maximum sample size - 36. NR - not recorded.

BENTHIC CATEGORY	SAMPLE SIZE	BRAY-CURTIS SIMILARITY COEFFICIENT (%)
<i>Acropora</i> branching	15	77.6
Non- <i>Acropora</i> foliose	22	67.0
Sponge	35	65.3
Soft coral	20	63.2
Sand	25	62.3
Rubble	36	54.2
<i>Acropora</i> tabular	9	48.4
Non- <i>Acropora</i> encrusting	25	45.9
Non- <i>Acropora</i> mushroom	8	40.6
Non- <i>Acropora</i> branching	18	34.8
Turf algae	9	34.2
Others	20	32.6
Rock	28	30.6
Dead coral with algae	25	22.1
Non- <i>Acropora</i> sub-massive	22	21.5
Non- <i>Acropora</i> massive	21	20.2
<i>Millepora</i> spp.	9	18.8
Algal assemblage	19	13.9
Dead coral	10	7.0
Water (fissures > 50cm deep)	8	3.8
Macroalgae	11	1.3
<i>Acropora</i> digitate	2	0.0
Coralline algae	9	0.0
<i>Heliopora</i> spp.	1	0.0
Silt	1	0.0
<i>Acropora</i> encrusting	NR	-
<i>Acropora</i> sub-massive	NR	-
<i>Tubipora</i> spp.	NR	-
<i>Halimeda</i>	NR	-
Zoanthids	NR	-

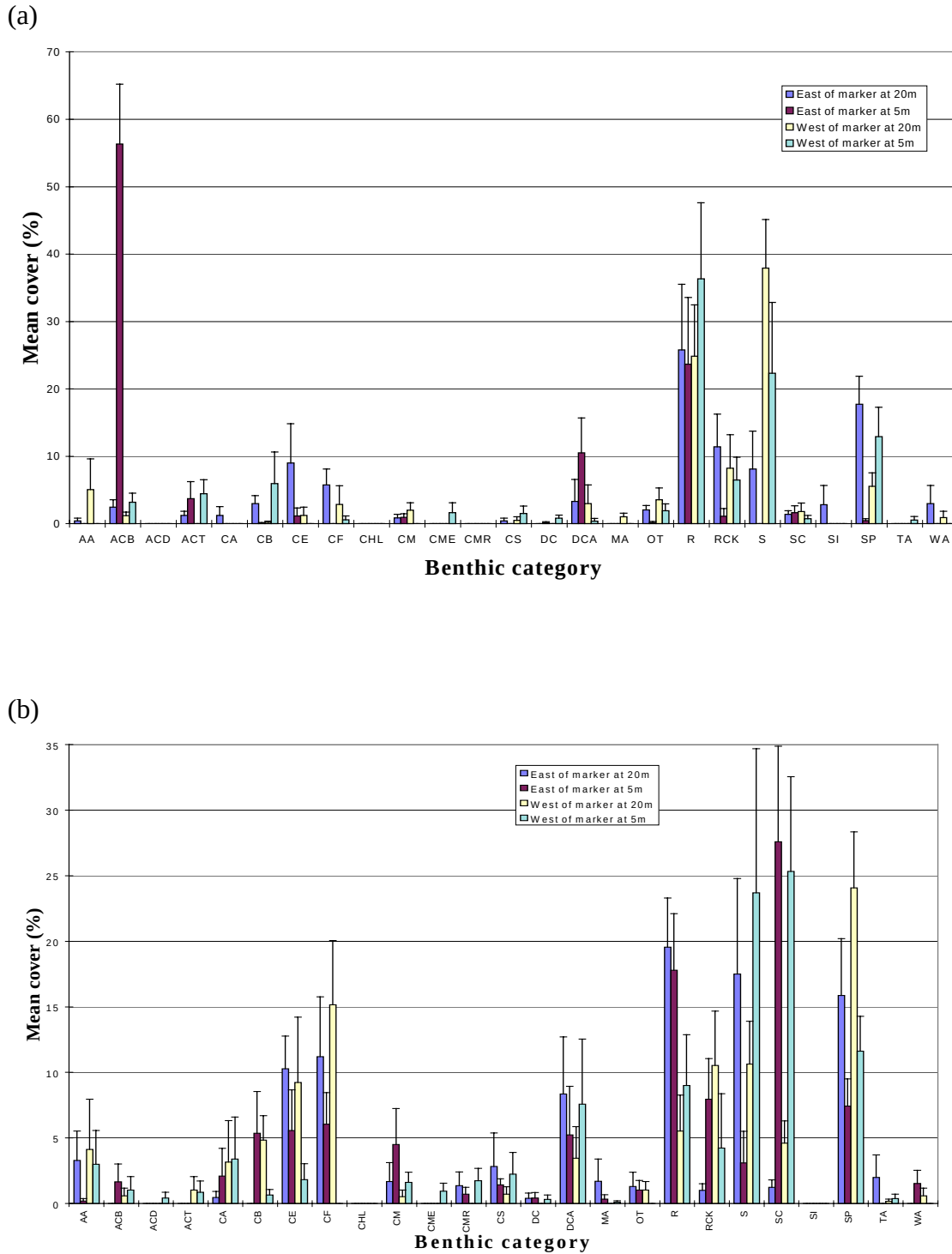


Figure 20. Summary of line intercept transect data from the EKCRC project.

Charts show mean cover for each benthic category at each set of permanent transects. Category codes documented in Appendix 3. Sample size = 6 (3 replicates each surveyed twice). Bars represent standard error.

- (a) Sangatta Reef
 (b) North Marker Reef

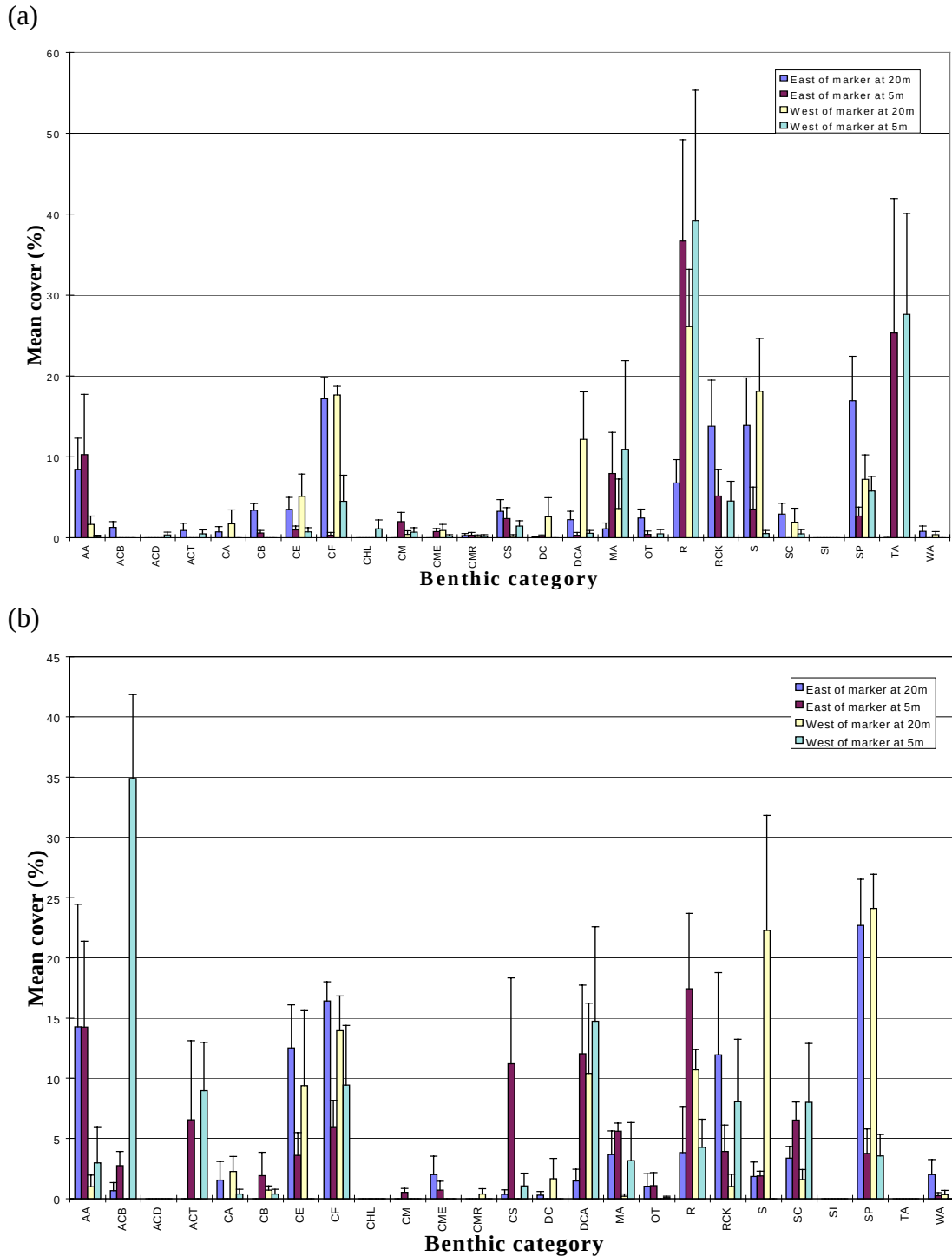


Figure 21. Summary of line intercept transect data from the EKCRC project.

Charts show mean cover for each benthic category at each set of permanent transects. Category codes documented in Appendix 3. Bars represent standard error.

(a) South Marker Reef. Sample size = 6 (3 replicates each surveyed twice).

(b) Bengalon Reef. Sample size = 3 (3 replicates each surveyed once).

5.3.2 Water quality monitoring

A water sampling programme was established to provide baseline data for a monitoring programme and to document evidence of possible impacts caused by El Niño, forest fires, mining operations and local people. Water sampling was integrated with the permanent transects established at Sangatta Reef, South Marker Reef, North Marker Reef and Bengalon Reef. During the course of the EKCRC Project, samples (from depths of 0, 15 and 28 m) were taken on three separate occasions from Sangatta Reef (8 March, 10 March and 14 April) and North Marker Reef (4 March, 6 March and 26 March) and on four separate occasions from South Marker Reef (23 February, 5 March, 30 March and 4 May) and Bengalon Reef (25 February, 26 February, 2 March and 31 March).

The mean value of the data gathered from all sites and depths for each parameter analysed are given in Appendix 7 and summarised in Table 9 together with other published values. The concentrations of certain parameters were below the detectable threshold level of the analytical technique used (Table 3).

Table 9. Mean values of water quality parameters measured during the EKCRC Project compared with published values ⁽¹⁾ Milne, 1995; ⁽²⁾ Parker, 1982; ⁽³⁾ Duxbury and Duxbury, 1989; ⁽⁴⁾ Huetter, 1990).

PARAMETER	UNIT	EKCRC PROJECT	PUBLISHED VALUES			
			(1)	(2)	(3)	(4)
Oxygen	mg/l	6.12	9.71	-	-	<8.5
Salinity	g/l	32.15	34	-	-	-
pH-value	pH	8.38	-	-	7.5 - 8.5	-
Sulphate	mg/l	2350	2650	-	2710	2701
Conductivity	µS/cm	67137.6	-	-	-	-
Total dissolved solids	mg/l	33556.8	-	-	-	-
Total suspended solids	mg/l	4	-	-	-	-
Turbidity	mg/l	4	-	-	-	-
Hardness	mg/l	5990	-	-	-	-
Bicarbonate	mg/l	372.4	140	-	140	145
Nitrite	mg/l	0.01	-	-	-	-
Phosphate	mg/l	0.024	-	-	-	-
Arsenic	mg/l	0.0014	-	0.003	0.0017	-
Calcium	mg/l	404.6	400	400	410	416
Cadmium	mg/l	<0.0001	-	0.00011	0.00008	-
Cobalt	mg/l	<0.001	0.0003	0.0004	0.00001	-
Iron	mg/l	0.023	0.01	0.01	-	<0.02
Lead	mg/l	<0.001	-	0.00003	0.000021	-
Magnesium	mg/	1209	1350	1350	1290	1295
Mercury	mg/l	<0.00005	-	0.0002	0.00001	-
Nickel	mg/l	<0.001	-	0.007	0.005	-
Potassium	mg/l	383	380	380	390	390
Sodium	mg/l	6751	10500	10500	10760	10752
Total carbon	mg/l	26.17	-	-	-	-
Total inorganic carbon	mg/l	24.71389	-	-	-	-
Total organic carbon	mg/l	1.447222	-	-	-	-

Most of the parameters measured lay either within or below typical ranges published in the literature (Table 9). Mean bicarbonate concentration (alkalinity) was significantly higher than the typical published values (372 mg/l compared to approximately 140 mg/l). The mean concentration of iron (0.023 mg/l) was slightly higher than the highest typical value (<0.02 mg/l). However, since the majority of individual samples from which the mean was calculated had concentrations below the detection level (0.01 mg/l), which was used as a conservative estimate, the true mean concentration (i.e. using the actual values) would be less than 0.02 mg/l.

Spatial variations in key water quality parameters (salinity, pH-value, total suspended solids, dissolved O₂, SO₄ and total carbon) between reefs and within the water column were examined by plotting mean values for each parameter against depth (Figure 22). Means were calculated from repeat samples (between three and four) at each depth from each reef.

None of the parameters exhibit a clear trend with increasing depth (Figure 22) and suggests that during the EKCRC Project the water column was relatively homogenous within the study area. However, the data suggests some inter-reef variations in the water column: Sangatta Reef exhibited a higher salinity and pH-value than the other reefs, and both Sangatta Reef and North Marker Reef exhibited higher sulphate concentrations than Bengalon Reef and South Marker Reef.

5.3.3 Sedimentation study

Analysis of sediment samples collected during the EKCRC Project is currently being completed by KPC and to date, results from the analysis are unavailable.

5.4 Socio-economic assessments

A rapid assessment of fish landings and fishing methods used by fisherfolk at Sangatta Village offered an initial insight into the local fisheries within in the EKCRC Project area.

Traditional techniques (nets, traps and hook-and-line) are commonly used. Night fishing using lights to attract fish is also prevalent. Large Serranids, Haemulids and Lutjanids (greater than 35 cm in length) are often caught using large fish traps woven from wood which are lowered onto a reef or rock and marked with a buoy, and recovered after about four days (although none were observed on the study reefs during the course of the EKCRC Project). It was reported that the use of fish bombing using locally manufactured explosives to kill and stun fish is common within the area.

The main families of fish sold at the local market were Lutjanidae (snappers), Siganidae (rabbitfish), Haemulidae (sweetlips), Lethrinidae (emperors), Mullidae (goatfish), and Serranidae (groupers). Large numbers of small Lutjanids range (less than 12 cm in length) were observed for sale at the market which local fisherfolk explained was

indicative of fish bombing. Larger Lutjanids, Serranids and Haemulids were generally sold to traders who supply local markets.

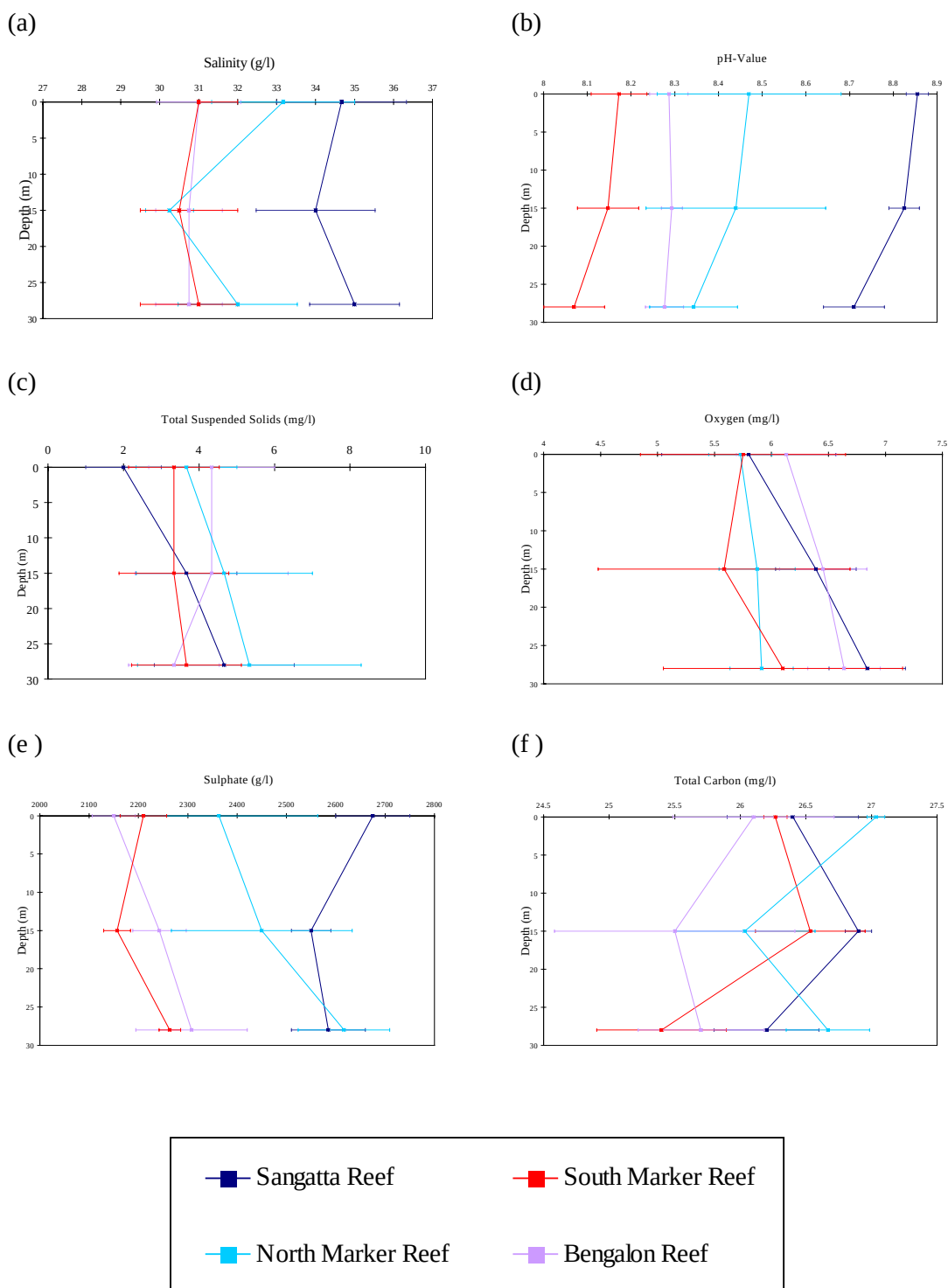


Figure 22 a-f. Profiles of key water quality parameters within the EKCRC Project area.

Graphs show mean values from sets of samples taken over the course of the project. Sample size = 3 (Sangatta Reef and North Marker Reef) and 4 (South Marker Reef and Bengalon Reef). Bars represent standard errors.

5.5 Training and conservation education

5.5.1 Science training programme

A total of 36 TBDC members and CCC volunteers successfully completed the CCC science training programme and majority went on to participate with data collection (Table 10).

5.5.2 Dive training programme

A total of 30 TBDC members, Indonesian counterparts and KPC employees undertook PADI SCUBA training courses and received certifications ranging from Open Water Diver to Medic First Aid level (Table 10; Figure 23).

Table 10. A summary of TBDC volunteers and Indonesian counterparts who undertook SCUBA diving and science training courses during the EKCRC Project. (O/W = PADI Open Water Diver).

NAME	PADI DIVE TRAINING				SCIENTIFIC TRAINING	
	O/W Course	Advanced O/W	Medic 1st Aid	Rescue	Identification	Survey
Marie Grewar	✓	-	-	-	-	-
Potro Soeprapto	✓	✓	-	-	✓	✓
Yohanes Rudijanto	✓	-	-	-	-	-
Mike Paembonan	✓	-	-	-	-	-
Paul Arkinstall	✓	✓	-	-	-	-
John McCrae	✓	-	-	-	-	-
Allison Reddick	✓	-	-	-	-	-
Wayne Cox	-	✓	-	-	-	-
Thomas Tjahjono	-	✓	-	✓	✓	-
Hartina Widychrisanti	-	✓	✓	-	-	-
Inez Nastiti	-	✓	✓	✓	✓	✓
Howard Russell	-	✓	-	-	-	-
Raymond Nirwan	-	✓	✓	✓	✓	-
Ira Kamelia	-	✓	✓	✓	✓	✓
Mike Paembonan	-	✓	-	-	-	-
Chris Conroy	-	✓	✓	✓	✓	✓
Graham Davidson	-	✓	✓	-	-	-
Sally Jeffrey	-	✓	-	-	✓	✓
Robin Smith	-	✓	-	-	-	-
Suzannah Conroy	-	-	✓	-	-	-
Kevin Raven	-	-	✓	-	-	-
Leon Allen	-	-	✓	✓	✓	✓
Ken Osland	-	-	✓	-	-	-
Andre Adins	-	-	✓	-	-	-
David Pearce	-	-	-	✓	✓	✓
Dan Michaelson	-	-	-	✓	✓	✓
Nadia Natoka	-	-	-	✓	✓	✓
Patrick O'Neill	-	-	✓	-	✓	✓



Figure 23. EKCRC Project volunteers undergoing PADI SCUBA training.
(Photo: Ridley, 1997).

5.5.3 Conservation education programmes

• *YPP Swarga Bara (Swarga Bara Junior High School)*

Twenty students from the YPP Swarga Bara students successfully completed a two week coral reef ecology course (Figure 24). Nine project reports were submitted by the students (Table 11, Appendices 8.1 & 8.2). The course proved to be very popular and rewarding for both students (see example of feedback below) and teachers and led to a better local understanding and appreciation of the marine environment and the need for conservation of natural resources.

Impressions of Carrie and Verheina

- We really have fun ~~to~~ and we want to do this again.
- But sometimes we are ~~boring~~ boring.
- About the journey on the boat, we like it and we hope we can do that tomorrow.
- The reefs under the sea is very beautiful and ~~with~~ ~~with~~ we would like to see it again.
- About the volunteers, they are ~~are~~ very kind and they do their job very good.



Figure 24. YPP Swarga Bara conservation education course (Photo: Bradley, 1998).

Table 11. Pupils from YPP Swarga Bara who attended the coral reef ecology course and their assigned projects (figures in parentheses refer to the detailed project descriptions given in Appendix 8.1).

NAME	PROJECT
Caroline Ruth Kristina	(8) Reversal sex in wrasses
Verheira Rezana	(8) Reversal sex in wrasses
Yeyen Avrinike Yonastuti	(9) Reef fish shapes
Sari Yunita Fitriani	(9) Reef fish shapes
Fajar Ardianti Putri	(6) Reef fish feeding strategies
Kartikawati	(5) Reef fish protection strategies
Yunita Arianti	(5) Reef fish protection strategies
Ardiena Pitaloka	(6) Reef fish feeding strategies
Van Indriani	(6) Reef fish feeding strategies
Yenita	(7) Fish associated with reef organisms
Indah Ratna Purwanti	(7) Fish associated with reef organisms
Herlina	(7) Fish associated with reef organisms
Van Sukma	(1) Fish comparison: dead / live corals
Eros Wardhana	(1) Fish comparison: dead / live corals
Fransiskus Xaverius Kia Wisang Soge	(4) Resettlement on damaged coral
Michael Insani	(3) Coral growth
Anjas Pria Prakoso	(2) Symbiosis
Jhon Ucok	(3) Coral growth
Eko Herry Purwanto	(2) Symbiosis
Sanny Sanjara	(4) Resettlement on damaged coral

• **Tanjung Bara International School**

An introductory course on coral reefs was organised for approximately 50 pupils from the Tanjung Bara International School. 20 pupils also participated in a field visit to the local mangrove boardwalk. The course, field visit and involvement of EKCRC Project volunteers had a very positive impact and increased awareness amongst the pupils regarding marine ecology, which was reflected in a show about mangroves and marine creatures organised and presented by the pupils to their parents (Figure 25).



Figure 25. Four to six year-old pupils from Tanjung Bara International School during their parents reception show illustrating their field visit to the mangrove boardwalk. (Photo: Bradley, 1998).

- ***Educational wall chart (Gugus karang dan hutan hujan Indonesia)***

Final artwork for the wall chart is being prepared at the time of writing this report and will be disseminated in October 1998.

6. DISCUSSION

6.1 Coral reef assessments

The six target reefs within the EKCRC Project area were quantitatively and qualitatively assessed by a series of survey dives with additional qualitative information provided by the TBDC. The following descriptions of South Marker Reef, North Marker Reef and Bengalon Reef are based on both qualitative and quantitative data. Descriptions of Sangatta Reef, Miang Besar and Rita's Reef are based on qualitative data only because of the limited number of transects (less than five) surveyed on these reefs.

- **South Marker Reef**

South Marker Reef is comprised of a narrow ridge, approximately 200 m long, which curves in a south-westerly direction. The cardinal mark is located at the north end on a shallow, flattened area at approximately 5 m deep.

The shallow area close to the cardinal mark is characterised by the benthic class *BC2: Rubble and Dead Coral* (Section 5.1.2). There is a notable amount of filamentous green algae in this habitat, which also includes filamentous red algae and calcareous green algae such as *Halimeda* spp. This rubble area is likely to have been caused by blasting during installation of the cardinal mark approximately nine years ago.

The sides of South Marker Reef are characterised by escarpments which are steepest on the northern side. The west side of the reef is mainly *BC5: Non-Acropora Coral Dominated* compared to the rest of the reef which is comprised of *BC7: Dense Foliose Corals* and *BC8: Medium-dense Foliose Corals*. The latter habitat has a large proportion of *Montipora* sp. and non-*Acropora* foliose corals (known to include *Echinopora lamellosa*). The abundance of these delicate life forms suggest that there has not been excessive physical damage to this area from activities such as explosive fishing or anchoring. At a depth of approximately 28 m, the south-west tip of South Marker Reef is characterised by *BC3: Sand and Foliose Corals*.

Observed fish populations were diverse, including shoals of fusiliers, snappers and surgeonfish and pelagic fish such as sailfins.

- **North Marker Reef**

North Marker Reef is an elongated, narrow reef with steeply sloping sides. It is approximately 300 m long and an average of 10 m wide. The cardinal mark is located at the northern end.

The reef is dominated by *BC8: Medium-dense Foliose Corals* which is comprised of a mixture of foliose corals, rock, gorgonians and sponges. The presence of foliose life forms and sponges with limited algal growth, suggests that the reef has not been subject to the physical destruction associated with explosive fishing or anchor damage. The shallow area surrounding the cardinal mark is not dominated by the rubble benthic class

found at South Marker Reef but by a dense soft coral cover. Presumably North Marker Reef was also blasted in order to install the cardinal mark and, therefore, either sustained less damage or has recovered faster than the blasted area at South Marker. The north-east corner of North Marker Reef is characterised by *BC5: Non-Acropora Coral Dominated* and *BC1: Sand and Sparse Algae* below a depth of approximately 15 m.

A highly diverse population of nudibranchs was recorded on North Marker Reef.

- ***Bengalon Reef***

Bengalon Reef is roughly circular in shape. The central shallow area of the reef, where the cardinal mark is located, is characterised by *BC6: Coral and Sponge Dominated*. The central eastern edge of Bengalon Reef is characterised by *BC7: Dense Foliose Corals* which is comprised of a mixed habitat of foliose, encrusting and mushroom corals with a distinct lack of Acroporids.

Bengalon Reef supports more benthic classes than any of the other reefs studied. There are small areas of *BC1: Sand and Sparse Algae* on the north side, *BC3: Sand and Foliose Corals* on the west side, *BC2: Rubble and Dead Coral* in the south and *BC4: Branching Corals* in the south east. The south-east also has a steep, coral-rich wall. This range of benthic classes suggests a high diversity of habitats and associated flora and fauna.

The steep slopes have a relatively high number of invertebrates, such as soft corals, black corals and sponges. Fish include shoals of barracuda, fusiliers and snappers.

- ***Sangatta Reef***

Sangatta Reef is the largest reef in the project area, extending 2 km north and south from the cardinal mark. The top of the reef lies at a depth of approximately 2 m and near the cardinal mark is a large area of rubble. To the north-west the reef supports a very rich and diverse coral garden (Lillian's Garden) with nearly 100% hard coral cover. Fish here were very diverse and numerous. The reef sides slope down steeply and comprise of coral boulders with numerous large sandy patches.

- ***Rita's Reef***

Rita's Reef is a small reef located between North and South Marker Reef. This reef is not permanently marked by a cardinal mark and was located using information provided by fisherfolk. It is circular in shape with a flat plateau and steeply sloping sides. Whereas coral diversity and abundance were only moderate in comparison to other reefs, the fish life on this reef was outstandingly rich.

- ***Miang Besar***

Miang Besar is a small island north of the main project area which is surrounded by fringing reefs and supports a small fishing village. Although the amount of data gathered from Miang Besar was limited due to its remoteness from the main survey area, the surrounding reefs appear to support very diverse benthic and fish communities.

The above descriptions of reefs within the EKCRC Project area suggest limited damage caused by human impacts such as destructive fishing. The more diverse and species rich benthic classes, such as *BC7: Dense Foliose Corals* and *BC8: Medium-dense Foliose Corals*, were recorded more frequently than classes which generally support less species, such as *BC2: Rubble and Dead Coral*. The relatively high median abundance's of hard coral species and life forms, and the large number of fish species recorded, also indicate healthy reefs.

The inventory of fish species established within the EKCRC Project area is comparable to that collected by Allen (unpublished but summarised in Tomascik *et al.*, 1997) in Sangalaki Island and Kakaban Atoll (East Kalimantan), which listed 72 families and 478 species. Although preliminary, the fish species list compiled within the EKCRC Project area documented 75% of the families and 72% of the species found by Allen.

Data collected on anthropogenic impacts are also consistent with healthy reefs since the frequency of occurrence of impacts per survey was less than 60% for all categories on all reefs, although there was evidence that destructive fishing methods are used in the area. Most fishing activity was observed at Sangatta Reef and Miang Besar, possibly due to their proximity to fishing communities.

Other qualitative observations made during baseline surveys also indicate good reef health, namely:

- No sightings of the coral eating Crown-of-Thorns (*Acanthaster planci*) seastar and frequent sightings of their main predators, Triton shells (*Charonia tritonis*);
- A low incidence of coral breakage and overturning;
- No obvious signs of eutrophication;
- Mushroom corals, cowries and other shells popular with the curio trade were common on the reefs;
- Incidents of coral bleaching were uncommon.

The most damaged areas were concentrated around the base of the cardinal marks which had been installed nine years previously. This damage, located at the shallowest point of each reef, radiates between 5 and 10 m around the cardinal mark and is characterised by rubble, rock and algal communities, with some fast growing corals such as Fungids and Acroporids indicating possible signs of recovery. Observations on Rita's Reef (the only reef surveyed which did not have a cardinal mark) revealed patchy areas of damage in the shallow areas which may have been the result of damaged caused by fish bombing.

6.2 Monitoring programme

6.2.1 Permanent transect monitoring

The primary aim of establishing permanent transects on Sangatta Reef, South Marker Reef, North Marker Reef and Bengalon Reef was to provide a baseline for monitoring temporal changes to the benthic community.

Analysis of data collected using the LIT methodology on the same transects in both March and April showed significant inconsistency between the data sets and therefore this data cannot be relied on a basis from which to make future comparisons. However, the mean values from each set of replicates does provide an important quantitative indication of the status of the reefs at that time and may be used to monitor gross changes over time, e.g. changes in *Acropora* cover and rubble, both of which can be used as indicators of anthropogenic impacts. The data also allows general comparisons of intra-reef (east or west of the cardinal mark) and inter-reef changes, and changes between depths (i.e. shallow versus deep transects).

The measure of consistency (similarity using the Bray-Curtis coefficient) encompassed surveyor errors from both misidentification (i.e. life form wrongly assigned) and mis-measurement (i.e. life form percentage cover wrongly recorded). Categories which were measured relatively consistently were the most easily identified, such as *Acropora*-branching (Harborne, pers. obs.) and suggests that there was misidentification of those categories with low similarity coefficients. There is also likely to be inconsistency caused by mis-measurement as precise repositioning of the transect lines between permanent markers proved difficult. It is also possible that surveyors may have interpreted the protocol differently, particularly within highly diverse reef communities.

The inconsistency of the LIT data gathered during the EKCRC Project does not necessarily suggest the need for use of a different protocol but rather that data should be gathered by the same set of divers and that additional practical training is required for volunteer divers carrying out such surveys, focusing on improving the identification of each benthic category and accuracy of repositioning transects on spatially complex reefs.

6.2.2 Water quality monitoring

During the EKCRC Project water samples were collected from Sangatta Reef, South Marker Reef, North Marker Reef and Bengalon Reef to establish a baseline and to determine possible anthropogenic impacts. The data are limited both spatially and temporally and were gathered during extreme drought conditions within Southeast Asia associated with the El Niño Southern Oscillation and therefore may not represent typical seasonal values.

The parameters analysed were chosen specifically to detect possible anthropogenic influences. Mining activities or erosion from deforestation, for example, can result in increases in the concentrations of certain heavy metals such as arsenic, cadmium, nickel, lead and mercury within coastal waters. Similarly, pH-values can be used as an indicator to determine acidification associated with forest fires and runoff from soil erosion.

Most of the values determined were comparable with known typical ranges. The mean bicarbonate concentration was higher than expected and may have been related to elevated atmospheric CO₂ levels resulting from extensive forest fires during that period. However, elevated bicarbonate concentrations are usually associated with lower pH-values and such a correlation was not observed during the course of this study.

Concentrations of heavy metals were comparable with published typical values and suggests that terrigenous inputs from local mining operations and soil erosion were not significant at that time. The nearest source of terrigenous inputs to the EKCRC project area is from the Sangatta River, the outflow of which was significantly reduced because of the unusually dry seasonal conditions related to the El Niño Southern Oscillation.

Oceanographic data generated during the course of the baseline surveys (Section 5.1.3) provided a general overview of conditions during the EKCRC Project. The prevailing wind direction was from the north-east and tides flooded towards the south and ebbed to the north. Temperature, salinity and turbidity data suggested a relatively homogeneous water column. Similarly, the values of each of the parameters measured during the course of the water quality monitoring programme remained relatively homogenous throughout the water column, suggesting a high degree of mixing within the area. However, because of the El Niño Southern Oscillation, these results may not be seasonally typical.

The high salinity and pH-values recorded at Sangatta Reef may be erroneous data as they do not compare with data sets gathered during the course of baseline surveys.

Turbidity levels throughout the EKCRC project area were unexpectedly high, given the unusually dry weather and hence reduced outflows from local rivers. Whilst airborne ash from local forest fires may have contributed to the level of suspended solids within the water column, the primary cause appeared to be related to relatively high densities of plankton observed in the water column. Planktonic “blooms” are usually related to elevations in certain nutrients, particularly NO₃ and PO₄, which in coastal areas are often related to excessive nutrients entering the water column from polluted land sources (e.g. sewage). However, NO₃ and PO₄ concentrations measured within the EKCRC Project area were not unusually high. Plankton blooms reduce levels of dissolved oxygen and the levels of dissolved oxygen recorded within the EKCRC project area were lower than published typical values.

6.2.3 Sedimentation study

Sediment samples collected during the EKCRC Project are currently being analysed and the results will be published separately as an addendum to this report.

6.3 Socio-economic assessments

Assessments of the fishery within local fishing communities were preliminary but provided some useful initial insights. Identifying the exact area where fish were caught proved problematic as there is no local fishing cooperative or records maintained of fish landings. The majority of fish are bought direct from fishermen by a few local buyers who sell on to markets at Sangatta and Bengalon.

Hook-and-line and fish traps are commonly used and are likely to be the least damaging and most sustainable fishing methods employed in the area. The large number of small Lutjanids landings which were reported to have been caught from fishing with explosives poses a significant threat to fish stocks in the area.

6.4 Training and conservation education

The training and conservation education initiatives carried out within the EKCRC Project were highly successful. Scientific training for project volunteers and local counterparts enabled the research programmes to be carried out within the limited amount of time available.

Awareness of conservation issues within the local communities is rudimentary and there is a lack of awareness of the importance and fragility of coastal marine resources. The conservation education programmes provided during the course of the EKCRC Project proved popular and rewarding for all concerned and showed that there was genuine interest amongst the local community for these kinds of programmes. The project work undertaken with the Tanjung Bara International School and YPP Swarga Bara should be considered as the first step towards a more comprehensive, integrated educational programme focusing on coastal zone ecology and conservation, which will require teacher training programmes and access to appropriate teaching aids such as the KPC-sponsored *Gugus karang dan hutan hujan Indonesia* educational poster.

7. CONCLUSIONS

7.1 Coral reef assessment

During the course of the EKCRC Project, the status and biodiversity of South Marker Reef, North Marker Reef and Bengalon Reef were described and analysed in detail using qualitative and quantitative data. Three other reefs (Sangatta Reef, Rita's Reef and the fringing reefs at Miang Besar) were surveyed in less detail and described using only qualitative data.

Baseline surveys identified the distribution and size of eight major benthic classes on the target reefs. The most common benthic class, *BC8: Medium-dense Foliose Corals*, was determined from 55 of 135 Site Records, indicating that large areas of healthy coral communities exist on the majority of reefs surveyed. Less biodiverse benthic classes such as *BC1: Sand and Sparse Algae* were less common and confined to the shallow reef plateaux and small areas of reef slopes. Bengalon Reef had the highest diversity of benthic classes identified and may therefore be a suitable initial candidate site for protection as a marine sanctuary.

The surveys showed that there is some physical damage to isolated areas of the reefs, most notably associated with blasting for installation of cardinal marks. Other obvious human impacts appeared to be limited although there was evidence to suggest that cyanide and fish bombing fishing techniques are used in the area. The close proximity of some reefs to fishing communities (e.g. Sangatta Reef and Miang Besar) is likely to have had a significant impact on fish stocks within these reef areas.

Although the data collected on the reefs are incomplete, the EKCRC Project has provided reasonably detailed biological and physical descriptions of at least three reefs. Further fieldwork is required to fully describe the remaining known (marked) reefs and from records provided by fishermen and TBDC, it is also likely that future work will reveal additional uncharted reefs which may provide interesting comparisons with the reefs surveyed to date and a better understanding of impacts from the use of marine resources in the area.

7.2 Monitoring programme

The EKCRC Project has established permanent transects on Sangatta Reef, South Marker Reef, North Marker Reef and Bengalon Reef and a baseline data set for the establishment of monitoring programmes to determine temporal changes in benthic communities, water quality and sediment loading.

Analysis of data acquired using the LIT protocol showed that improvements in theoretical and practical training are required if non-specialist volunteer divers are to be used to provide accurate and consistent quantitative information for monitoring reefs. Accuracy

and consistency will also be improved if the monitoring programme is carried out by the same set of divers. The LIT data collected during the course of the EKCRC Project does, however, provide a useful baseline data set from which gross temporal and spatial changes may be compared.

The water sampling programme established during the course of the EKCRC Project provides a useful baseline data set of the physico-chemical characteristics of the coastal waters adjacent to KPC's mining operations. Although limited spatially and temporally and taken under highly unusual environmental conditions and during extensive forest fires associated with the El Niño, these data do offer scope for temporal comparisons with future samples and for monitoring seasonal variations.

Analysis of the water samples suggest that there was little evidence of significant anthropogenic impacts (other than possible nutrient enrichment) during the EKCRC Project and provided no evidence to suggest any significant correlation with the nearby KPC mining operation at that time.

7.3 Socio-economic assessments

Over-fishing and the use of destructive fishing methods is one of the most significant threats to reef health in Southeast Asia and socio-economic data on fish catches, fishing techniques and attitudes towards conservation are of vital significance in establishing management plans for the sustainable use of coral reef fisheries.

Socio-economic data gathered during the course of the EKCRC Project was only cursory and a more thorough programme of work is required before any significant interpretations of the data can be made. Local fisherfolk confirmed that fish bombing is a commonly used fishing practice in the area.

7.4 Training and conservation education

Improving environmental awareness is a fundamental prerequisite for the conservation of natural resources and protection of biodiversity. Conservation education programmes offered within the EKCRC project area are extremely limited due to the lack relevant teacher training opportunities and access to appropriate curricula and educational materials.

The EKCRC project provided conservation education courses for 70 local school children. These programmes were well received and actively supported by the local community. Feedback from both YPP Swarga Bara and Tanjung Bara International School was very encouraging and suggests that there is scope for incorporation of conservation education programmes within local school curricula.

Technical capacity within the TBDC for coral reef surveys and monitoring was improved through the provision of training courses in marine ecology and survey techniques for 24 TBDC members. The specific aim of the training provided was to develop local capacity to continue and expand upon monitoring programmes established during the course of the EKCRC Project.

The EKCRC Project provided entry level and advanced PADI SCUBA courses for 30 local counterparts and helped improve the standards of dive safety within the TBDC.

8. RECOMMENDATIONS

The EKCRC project has shown that the reefs within the Sangatta area of East Kalimantan are diverse and healthy relative to other reefs within Southeast Asia. These reefs are an important fisheries for local communities and the primary threats to them arise from over-fishing the use of destructive fishing methods.

In order to protect and sustainably use these reefs, a Coastal Zone Management Plan (CZMP) is required which integrates coastal forest and marine resources and takes into consideration all processes within the coastal environment, including ecology, biodiversity, local culture, economic potential and different aspects of human use and interaction. The success of any CZMP depends upon complete involvement by and support from local communities and must take into consideration the socio-economic and cultural needs of these communities.

The integrity of coastal mangrove forests and lowland rain forests adjacent to the Sangatta area is crucial to the survival of adjacent reefs and any CZMP should encompass a holistic approach. Adjacent to the KPC mine area lies the Kutai National Park, a 200,000 ha. area of primary forest. Established in 1936, the Kutai National Park protects some of the most important lowland rain forest in Borneo and is a refuge for 80% of the bird species on Borneo and half the mammal fauna, as well as more than 500 tree species. The Kutai National Park functions as an important water catchment area, balancing water supply for coastal mangroves, wetlands and lakes. As part of its commitment to environmental protection, KPC is a leading member of the “Friends of Kutai National Park” and provides financial support to help protect and manage Kutai.

It seems appropriate, therefore, to consider the Kutai National Park and the neighbouring coastal zone as a single biosphere and develop a CZMP for the Sangatta area which integrates reef, mangrove and rain forest habitats.

In order to establish a CZMP for Sangatta, the following activities will be required:

- **Social preparation**

A programme to establish dialogue with local communities and stake-holders is required in order to ascertain the socio-economic and cultural basis upon which a realistic CZMP can be prepared and to build consensus within the local community. This should include regular meetings with representatives from local communities, stake-holders, government units and co-opted experts.

- **Conservation education**

There is an urgent need to improve environmental awareness within schools and local communities. A schools curriculum for conservation education, including field trips to local forest and coral reef habitats, should be developed and a range of appropriate educational materials distributed to local schools, such as the KPC-sponsored educational wall chart, *Gugus karang dan hutan hujan Indonesia*. Teacher-training workshops will

be required in order to train school teachers in conservation education and the use of supporting educational materials. Outreach programmes to provide conservation education opportunities for local communities should also be developed.

- **Research and monitoring**

A systematic baseline survey of the reefs and adjacent mainland coastal areas will be required in order to provide data to create habitat maps required for the development of a CZMP. Phase 1 reef surveys should focus on surveys of Sangatta Reef, Miang Basar, Bengalon Reef and Rita's Reef in order to complete data sets gathered during the course of the EKCRC Project. Phase 2 reef surveys should focus on other reefs in the area.

The baseline survey data can be incorporated into a GIS database and overlaid onto geo-rectified base maps (prepared from aerial or satellite imagery) for the synthesis of habitat maps.

Monitoring programmes established during the course of the EKCRC project should be continued and expanded upon, with additional permanent monitoring sites established throughout the Sangatta area.

- **Training**

Training programmes established during the course of the EKCRC Project should be continued and expanded upon to provide key personnel within KPC and other host-country counterpart groups with the technical skills necessary to conduct marine survey and monitoring programmes and analyse data.

KPC maintains a high standard of safety in the workplace and similar standards should be applied to all SCUBA-related activities to avoid accidents or injury. CCC has developed a code of safe diving practice for use by volunteer SCUBA divers undertaking marine research activities (Appendix 9).

- **Capacity strengthening**

Development of the Sangatta CZMP will require co-ordination via a CZM unit at the local, provincial and national level and linking with relevant agencies and universities.

The foundation of a local community resource centre would help facilitate educational and training programmes, project management and data management. The centre would also serve as focal point for public meetings, displays (including aquariums) and exhibitions designed to promote environmental awareness within the area.

The success of the EKCRC Project was the result of a unique partnership forged between KPC and CCC, each complimenting the other in terms of providing appropriate resources and technical skills to provide a cost-effective way of helping protect natural resources in East Kalimantan. Of primary significance in this partnership is KPC's continuing commitment to supporting conservation initiatives in Borneo.

KPC and CCC are now in a position to continue to support key components of some of the activities suggested above and it is recommended that the KPC/CCC partnership should continue in 1999, focusing on the following activities:

AIM	OBJECTIVE	ANTICIPATED OUTPUTS
➡ Resource assessment.	➊ Systematic surveys of Sangatta, Miang Besar & Rita's Reefs and rapid assessments of other reefs in the area. ➋ Human impacts assessments on reefs. ➌ Initiate mangrove forest surveys. ➍ Develop a marine habitat classification scheme for Sangatta.	➊ Establish a GIS database. ➋ Synthesis of habitat base maps. ➌ Documentation of anthropogenic impacts. ➍ Preliminary CZMP recommendations.
➡ Environmental monitoring.	➊ Refine and continue environmental monitoring programmes.	➊ Establish additional permanent monitoring sites. ➋ Expand current baseline data set.
➡ Training and conservation education.	➊ Provide scientific and SCUBA training for key project counterparts. ➋ Establish a schools curriculum for conservation education. ➌ Establish a community resource centre.	➊ Establish a team of specialised volunteer Indonesian survey divers. ➋ Creation of conservation education opportunities for local schoolchildren and community members

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