CRC REEF RESEARCH TECHNICAL REPORT

DEVELOPING RELIABLE CORAL REEF MONITORING PROGRAMS FOR MARINE TOURISM OPERATORS AND COMMUNITY VOLUNTEERS

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The Centre, established in 1993, undertakes an integrated program of applied research and development, training and education, aimed at increasing opportunities for ecologically sustainable development of the Great Barrier Reef and providing an improved scientific basis for Reef management and regulatory decision making.

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FOREWORD

The research by Barbara Musso and Graeme Inglis into the development of an effective Coral Reef Monitoring Program for use by the Marine Tourism Industry and local community volunteers is a valuable contribution to the ongoing needs of both management and other stakeholders of the Great Barrier Reef.

Despite the variable expertise levels of volunteers, this report shows that non-professional data collection can be accurate, reliable and a valuable contribution to the scientific understanding of the reef environment.

These findings are important for a variety of reasons. Not only does this monitoring program provide data on the health and general ecology of specific reef sites, but it also provides an "early warning" system able to identify environmental changes at specific sites and alert appropriate management agencies when necessary. This cooperation between industry, management, science and community groups is essential to the continued sustainable use of the Great Barrier Reef.

The increased awareness of the marine life and local ecology by both staff and passengers encourages a keener sense of stewardship and caring for the reef. This, in turn, has been shown to lead to positive changes in attitude and environmentally friendly behaviour.

The Coral Reef Monitoring Program presented in this report, with its detailed information and required training, provides an opportunity for the overnight sector of the Marine Tourism Industry (such as live-aboard and cruise ships) to be involved in coral reef monitoring. It augments other projects, such as the Eye-on-the-Reef Monitoring Program, which are being developed for use on day operations.

It is encouraging to see projects of this kind gaining respect and acceptance by all stakeholders within the Great Barrier Reef World Heritage Area. They are certainly important steps in the continued development and growth of the Marine Tourism Industry.

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1. EXECUTIVE SUMMARY

This project was initiated in response to growing interest by community groups and the marine tourism industry in the Great Barrier Reef region to become directly involved in monitoring the state of the coral reef sites that they visit on a regular basis. There was the need to have access to a low cost package of methods and procedures for monitoring which were easy to use and which could be used to collect data from regularly visited dive sites.

The major objectives of this project were to:

?? develop a reliable and low-cost protocol for gathering environmental data on the Great Barrier Reef that could be used by marine tourism operators and volunteer community groups;

?? develop a relevant training program that had a high environmental education value;

?? evaluate the quality of data collected by non-expert volunteers;

?? provide guidelines for the design of other volunteer-based reef monitoring on the GBR, and

?? develop protocols for data reporting and quality control.

We conducted a feasibility study that sought to develop quantitative methods that could be used by non-experts to monitor the condition of coral reef sites in the Great Barrier Reef Marine Park. The sampling methodology chosen for use in the program used point-intercept transects to measure the abundance of reef organisms. Pilot studies assessed the suitability of the sampling technique for volunteers by comparing estimates of the abundance of reef organisms obtained by volunteers to those obtained by scientists using both the point-intercept methodology and conventional line transect methods.

A training program was developed concurrently with the pilot studies. This consisted of interpretive materials - including a handbook, photographic guide and instructional manual for tour operators participating in the trials - and the script for a training session. Seven field trials and one laboratory trial were conducted over the 12 months of the project. During that time, a total of forty-five volunteers were involved. The trials aimed at assessing the feasibility of the methodology and evaluating the training/interpretive program.

Satisfaction with the program was evaluated by a questionnaire distributed to all participants. The aim of the questionnaire was to establish the value of volunteer involvement in reef monitoring as perceived by the participants and to obtain feedback on specific components of the program (e.g. training materials and session, difficulties with underwater data collection).

The results indicate that, with limited training, non-experts can collect reliable, quantitative information on the state of coral reefs. However, a number of requirements must be met to ensure this. The present study incorporated quality control procedures into the sampling methodology and the training and interpretive materials. Data obtained by this project suggest that the program cannot be used reliably by divers with < 30 hours SCUBA experience. It also indicates that it may not be suitable for use by visitors on tourism operations of short duration (< 3-days). The time required to assimilate the instructions given during the training, may be incompatible with the tight schedule of operations of short duration. Furthermore, the evaluation survey indicated a lower interest and willingness to be involved in volunteer research by visitors on board short trip operations.

The involvement of community groups in coral reef monitoring has strong possibilities. The positive response of community groups to the project, and the quality of data collected by them, suggest that they are a valuable resource for monitoring ecological changes on coral reefs at selected sites. During the course of the project, links were established with several community groups in the GBR region and elsewhere in Australia which were not directly involved in the feasibility study. All expressed a strong interest in and support for this kind of program.

This report provides a framework for developing volunteer-based monitoring in marine environments which identifies the components that need to be incorporated into the design of such studies to ensure the success of the program. Guidelines for the sampling design of volunteer-based monitoring have been prepared and are aimed at mitigating the effect of important sources of bias identified during the field component of this project.

2. BACKGROUND AND OBJECTIVES OF THE STUDY

2.1 Volunteer-based research and monitoring programs on coral reefs around the world

Rapid growth in international marine tourism over the past ten years has been associated with increased rates of participation in water sports like snorkelling and SCUBA diving. Scuba diving is now one of the fastest growing sports in the world, with recent estimates suggesting that there are currently more than 14 million qualified divers worldwide (Tabata 1989) and around 1 million new certifications each year (PADI 1994). Much of the growth in marine tourism and recreation has been centered on tropical coral reefs (Tabata 1989, 1992, Dignam 1990, Hawkins & Roberts 1993). The clear, warm waters and diverse geophysical and biological features of coral reef environments provide attractive settings for dive training and tourism. Markets for coral reef tourism have expanded greatly in recent years to include a range of destinations in the Pacific (Tabata 1989, 1992) and South-East Asia (Auyong 1995, Sudara & Yeemin 1995), the Red Sea (Hawkins & Roberts 1993), the Caribbean (Ward 1990, Dixon *et al.* 1993) and the Indian Ocean (Öhman *et al.* 1993, McLanahan & Obura 1995). As a consequence, a broad range of reefs, which previously were considered remote, are now accessible to a growing number of divers.

At the same time that this growth in tourism to coral reef environments has been occurring, the global future of coral reefs has become increasingly uncertain (Ginsburg 1993; Hughes 1994, Chou *et al.* 1994). The high diversity and productivity of these ecosystems are under serious threat in many countries from over-exploitation of resources, habitat destruction and environmental degradation resulting from unsustainable land- and water-based activities. Ten percent of the world's coral reefs are degraded beyond recovery and a further 30% are expected to become irreversibly degraded within the next twenty years (Jameson *et al* 1995). In the ASEAN region, up to 70% of the reefs have been significantly degraded by human activities (Chou *et al.* 1994). As public awareness of the value and plight of coral reefs has increased, concern for their protection has prompted a number of governments and non-government organisations to launch initiatives aimed at encouraging community involvement in the protection and management of coral reefs (Drake 1996).

A popular way in which this is achieved in terrestrial environments is through voluntary participation in environmental monitoring programs (White, Alexandra and Haffenden 1996; Campbell 1997). Recent examples in Australia include the national Waterwatch program, (Streamwatch in New South Wales and Ribbons of Blue in Western Australia) and Coastcare. Waterwatch, initiated in 1993, is a community-based water quality monitoring program. It aims principally to increase community awareness and understanding of issues affecting water quality by involving a variety of groups - particularly schools, community groups and landholders - in collecting data on water quality (Department of Conservation and Natural Resources and Melbourne Parks and Waterways 1994). Similarly, Coastcare is an initiative launched with the Commonwealth Coastal Policy in 1995, to coordinate the participation of local communities in conservation activities along the Australian coasts (DEST 1995). The 1995 Commonwealth Coastal Policy acknowledges local communities as important components of a national coastal monitoring network (DEST 1995; Jacoby *et al* in press).

There is increasing interest from marine tourism operators, dive organisations, and community groups to become involved in monitoring programs to assess changes in the conditions of coral reef sites that they visit on a regular basis. The rapidly increasing number of qualified recreational SCUBA divers represents a potentially large, enthusiastic and environmentally aware (McCawley 1993) pool of volunteers to assist in research on changes in coastal environments (Hunter & Maragos 1992). A number of existing programs around the world already involve non-professionals in research activities on coral reefs. In 1994, as part of the European Meeting of the International Society for Reef Studies, a workshop organised on the use of non-professionals in applied coral reef research described 13 extant programs around the world (Wells 1995).

Existing programs vary widely in their intent and focus, the methods used in the research, the degree of professional supervision, the financial and logistical resources available and the duration and format of the training programs. For example, in some programs (e.g.. 'Earthwatch'), paying volunteers assist research projects as part of a recreational experience. In others, the local community or the private sector (tourist operators) carry out the sampling in close collaboration with management and research agencies, as in the Community-based Monitoring Program in St.Lucia, which is coordinated by the Caribbean Natural Resources Institute (Smith 1994). In Singapore, in 1989, as a result of collaboration between a scientific institution, the Singapore Institute of Biology, and two community organisations, the Singapore Yacht Club and the Singapore Underwater Federation, more than 150 volunteer divers took part in a reef mapping program aimed to identify suitable reefs for the establishment of protected areas (Chou 1991).

Some of the longest established programs - e.g.. Coral Cay Conservation, REEFWATCH and Frontier Tanzania - carry out comprehensive reef assessment surveys during which a range of biological (e.g. abundance of corals and fish) and physical (e.g. water turbidity) variables are recorded (Wells 1995, Raines *et al.* 1994). Some programs, like the CANARI Community-based Monitoring Program in St. Lucia, also record patterns of use on the reef (e.g. numbers of visitors) to monitor levels of sport diving and fishing activities. REEFWATCH, which has been running since 1982, and the Reef Care program in Curaçao, coordinate volunteer assistance in the field components of existing scientific research projects (Wells 1995). REEF - Reef Environmental Education Foundation - responding to the specific interests of divers in Florida, has developed a Reef Fish Survey Project. REEF has a membership of over 5500 divers (at 1995), of which more than 1000 are actively involved in collecting information on sightings of 184 species of fish (pers. comm. REEF).

Each of the existing programs was designed specifically to respond to the interests of the volunteers involved and conditions in the local region. As a result, there has been little standardisation of methodology or training (Wells 1995). A variety of methods are used for the sampling of coral reefs in the existing volunteer-based programs, ranging from quadrats to belt transects and the use of underwater video-cameras (Wells 1995). Sampling of reef organisms by volunteers is often carried out in a semi-quantitative, or categorical fashion because of the time needed to train non-specialists in quantitative methods and concerns about the reliability of the data (Wells 1995). For example, in at least three existing programs - Frontier Tanzania, Coral Cay Conservation and Aquanaut - the abundance of individual organisms at a site is ranked according to a limited number of classes of cover or abundance. Categorical sampling, however, involves a degree of subjective judgement in the attribution of organisms to arbitrary abundance categories, which may affect the quality of the data. For this reason, recently a number of programs have undertaken validation studies to investigate the effect of observer variability in ranking organisms into classes of abundance on the estimates obtained by volunteers (Mumby 1995; Dartwall & Dulvy 1996; Schmitt and Sullivan 1996).

With few exceptions (e.g. the long running Florida Artificial Reef Research Diver Training Program) most of the existing volunteer-based research programs on coral reefs are assessment surveys that are aimed at describing the biological assemblages of remote reefs or documenting the distribution of rare or sensitive species (Table 2.1). Current concerns about the effects of humans and global climate change on coral reef systems (D'Elia *et al*. 1991; Buddemeier 1993) has led some to consider repeatedly sampling selected sites to monitor changes over longer time periods (Wells 1995). Recent initiatives as part of the International Year of Coral Reefs and the newly established Global Coral Reef Monitoring Network have highlighted the potential for non-scientific organisations to become part of a global network for monitoring the status of coral reefs worldwide (Drake 1996; Wilkinson 1996).

For this to be successful, however, there is a need for greater attention to the range of factors that affect the reliability of data collected by non-specialists. An informal workshop (attended by one of us - GI) held during the 8th International Coral Reef Symposium in Panama in 1996, reiterated the need for a collaborative effort towards achieving better standards in the quality of data and training procedures derived from volunteer-based programs. This needs not require standardisation of methodology - as the range of objectives covered by these programs is very large - but should involve standard implementation of quality control procedures to assess the effectiveness of training and the quality of data collected by non-specialists.

Table 2.1 Examples of volunteer-based coral reef monitoring programs around the world and in Australia

PROGRAM	LOCATION	START-END	AIMS OF THE PROGRAM	SOURCE
Overseas:				
Coral Cay Conservation	Belize	1986-	Reef assessment (physical and biological - corals, fish, macroalgae)	Raines *et al* 1994 Mumby *et al* 1995
REEFWATCH	mainly Red Sea	1982-	Reef assessment (biological, human use) - also assisting in research projects	in Wells 1995
Frontier Tanzania Project	Tanzania	1989-	Reef assessment (semi-quantitative, benthic groups and 56 spp. of fish)	in Wells 1995 Dartwall and Dulvy 1996
Reef Conservation Project	Singapore	1987-1990	Reef assessment (reef benthic life-forms)	Chou 1991
CORAL WATCH Environmental Monitoring Program	Florida	1992-	Assessment of rare or threatened species	in Wells 1995
REEF Reef Fish Survey Project	Florida/ Caribbean	1995*	Semi-quantitative assessment of 184 spp. of fish	REEF Notes Schmitt and Sullivan 1996; also in Bohnsack 1996
Florida Artificial Reef Research Diver Training Program	Florida	1980-	Pre- and post-placement surveys of sites for artificial reefs and monitoring	Halusky 1989
WWF Irian Jaya Conservation Project - IRDI	Indonesia	-	Development of methodology for survey of butterfly fish	Nash 1989
Reef Care Curaçao	Curaçao/ Bonnaire	1992	Assistance to scientific research projects	in Wells 1995
CORAL Divers Report - (Coral Reef Alliance California)	worldwide		Semi-quantitative/qualitative logbook for coral reef dives	CORAL website
Aquanaut (ICLARM, Philippines)	worldwide	1996	Semi-quantitative/qualitative survey of reef benthic biota	McManus, pers. comm.
Community-based monitoring/CANARI	St Lucia, Caribbean	1988	Monitoring of permanent sites by dive tourism operators	Smith 1994
In Australia:**				
COTSWATCH	GBR	1994?	Reporting numbers of crown-of-thorns starfish and dead coral	Engelhardt 1997
Whitsunday Reef Monitoring Project	GBR	1993-	Assessment and monitoring of anchor damage	in Wells 1995 Thompson J., pers. comm.
Bunbury Dolphin Discovery Centre Monitoring Programs***	Western Australia	in progress	Water quality	Jacoby *et al* (in press)

* REEF was founded in 1990 but monitoring activities commenced in 1995.

** Since the completion of this project, a number of community-based initiatives have started along the Australian coasts which attest the increase in the involvement of non-professionals in monitoring marine environments.
*** The Bunbury Dolphin Discovery Centre Monitoring program is not based on coral reefs but was included as one of the few examples of community-based monitoring in marine environments in Australia.

2.2 Volunteer-based monitoring on the Great Barrier Reef

The report by Wells (1995) highlighted a lack of organized volunteer programs on coral reefs in Australia (see also Table 2.1). This is despite a potentially very large pool of recreational divers. Around 100 000 new SCUBA divers are trained each year in Australia, adding to the existing pool of more than 700 000 qualified divers (Davis *et al.* 1995). Australia is also a major destination for international dive tourism. Between 1989 and 1993, the number of inbound tourists who went SCUBA diving or snorkelling increased by 53%. Around 13% of the more than 3.1 million international visitors to Australia in 1994 went snorkelling or SCUBA diving during their visit (Blamey 1995). Most did so at coral reefs within the Great Barrier Reef Marine Park (GBRMP), where it is estimated that more than 1 million dives are done each year (GBRMPA unpubl. data), at a broad range of locations.

In recent years there has been strong interest from community groups and the tourism industry in the GBR region for the development of monitoring programs that can be implemented by non-specialists. The few existing examples of volunteer participation in research and management in the GBR region have been successful. Recent examples include the highly positive response to COTSWATCH, an initiative undertaken by the Great Barrier Reef Marine Park Authority (GBRMPA) to encourage local communities and marine tourism operators to provide information on sightings of the coral-eating crown-of-thorns starfish. The success of this program has recently prompted GBRMPA to launch COTSWATCH as an international scheme (Engelhardt 1997). There has also been very useful collaboration between the Queensland Department of Environment and a group of dedicated volunteers - the Order of Underwater Coral Heroes (O.U.C.H.) - in mapping coral reefs around the Whitsunday Islands to delineate non-anchoring areas. Other recent developments include the trialing of an environmental logbook on some tourist vessels and the establishment of tourism ventures that specialise in assisting research on the GBR.

A number of community groups and tourism operators have indicated a willingness to assist in monitoring changes in the condition of their regular dive sites. Preliminary consultations suggested that the interest of these groups in taking part in volunteer-based monitoring programs was motivated by a variety of reasons including:

?? feelings of stewardship towards frequently visited dive sites;

?? a desire to be directly involved in research activities which may assist management of the GBR;

?? increases in the number and popularity of volunteer-based coral reef monitoring programs abroad, and the emphasis currently put on community groups and NGOs by international initiatives such as “The Year Of The Reef” and “Reef Check 1997”(Drake 1996; IYOR and Reef Check web sites);

?? the growth of nature-based tourism in the GBR and the desire for new and interesting forms of interpretation for visitors, including involvement in research and monitoring;

?? the desire to monitor changes at regularly visited sites associated with human activities and, where necessary, to use this information to initiate mitigative actions[1].

Despite the increased interest from non-experts, managers of the GBRMP have been hesitant to encourage the participation of volunteers in monitoring (Chapter 3). This is mainly due to a lack of targeted resources to establish and manage a volunteer-based monitoring program and concerns about the reliability of environmental data collected by unsupervised volunteers.

2.3 Objectives of the project

This project was initiated in response to requests by the tourism industry and community groups for involvement in coral reef monitoring. Its purpose was to assess the feasibility of developing a coral reef monitoring program for non-professionals that could incorporate a variety of groups on the Great Barrier Reef (GBR). In this study, we describe the development and assessment of a simple protocol for monitoring changes in the benthic communities of coral reefs. Our aim was to develop a procedure that was simple and could be used reliably by non-specialists, after a short period of training, to collect quantitative data on the structure and condition of coral assemblages. The report examines sources of variation in the data collected by volunteers and compares the reliability of the data to that collected by marine scientists using the same technique.

The specific objectives of this project were:

?? to identify the type of sampling that would provide useful information to managers of the GBR and which could be done easily by non-professionals;

[1] GBRMPA policy requires the environmental impacts of commercial ventures within the Marine Park to be monitored by an independent party that is administrated by the Authority. Because impact assessment monitoring requires rigorous experimental design and implementation, it was made clear at the beginning of this project that

?? to develop a simple, user-friendly protocol for gathering quantitative data on the condition of coral reef sites;

?? to develop a relevant training program with a high environmental education and information content;

?? to establish the reliability of data obtained by volunteers and to investigate potential sources of error associated with the use of non-experts;

?? to provide recommendations on minimum requirements for volunteer-based reef monitoring on the GBR, based on findings from the field trials and program evaluation.

Although the principal focus of this report is on the development and trialing of the methodology, we also discuss more general issues about the design and operation of volunteer-based monitoring programs that must be addressed if data obtained by volunteers are to be useful in detecting environmental change. In Chapter 3, we discuss the general benefits that may accrue from the use of volunteers in environmental monitoring and identify the limitations that are imposed on the design of research programs by the use of non-experts. Chapter 4 describes the development of the sampling procedure and field trials to determine its comparability with more established survey techniques for coral reef benthos. In Chapter 5 we outline the development of the interpretative and training materials used in the study. The results of field testing of the program with volunteer dive groups and tourist operators are presented in Chapter 6 and an evaluation of the experience by participants in the program is given in Chapter 7. Lastly, we discuss the feasibility of establishing a network of volunteer-based monitoring within the GBRMP based on the methodology developed in this report.

3. ADVANTAGES AND LIMITATIONS OF VOLUNTEER INVOLVEMENT IN ENVIRONMENTAL MONITORING

3.1 Benefits of volunteer-based monitoring

3.1.1 Increased resources for monitoring

There are strong incentives for managers of marine environments and environmental scientists to welcome the participation of volunteers in monitoring programs (Jacoby *et al*, in press). Monitoring changes in natural resources over long time periods is inevitably expensive and volunteers provide a potentially large resource of cheap labour for the sometimes-laborious

self-assessment of environmental impacts by tourism operators was not a desirable nor achievable objective for any volunteer monitoring programs.

task of collecting environmental data. In a recent survey of coral reef monitoring studies, lack of funds and labour were found to be the major constraints to the development of sustained scientific programs (McCorry 1996). Coral reef research in the GBRMP is particularly expensive because of the distance of most reefs from the mainland. Large variability in the structure of natural assemblages from reef to reef means that, to characterise broad-scale trends in the environment, sampling is needed at a range of spatial and temporal scales (Hatcher *et al* 1989; Dahl 1993). This requires a considerable commitment of financial resources and labour.

Long-term, broad-scale monitoring (e.g. state of the environment monitoring) is usually intended to provide information on temporal and spatial patterns of change in ecological assemblages. Such data are important for the management of most natural environments (Ottesen & Woodley 1992) but are rarely available. In patchy and/or highly variable communities, where there is large variation in the abundance of individual species, the detection of long-term trends in species diversity (Keough and Butler 1983) or population abundance (Underwood 1989) requires large numbers of independent censuses at a broad range of sites. For example, Keough & Butler (1983) estimated that at least six independent surveys were needed to detect any change in species diversity. To be totally independent, the surveys must be far enough apart so that the same individuals are not sampled. Thus, monitoring programs must be designed to take account of characteristics of the life histories of the study organisms that affect their response to environmental change (Underwood 1989). The rate of change in natural populations is influenced by the longevity of individuals, the frequency of successful recruitment and other attributes of the population that affect the way in which it responds to changes in its surrounding environment. The long life-span of some corals (e.g. hundreds of years for some *Porites* colonies - Done and Potts 1992) and reef fishes (e.g. up to 45 years for some acanthurids in the GBR - Choat and Axe 1996) means that monitoring studies that seek to describe natural change in reefal communities (usually termed baseline surveys) may require time frames of tens of years or greater (e.g. Hughes 1994, Connell 1997). Furthermore, studies of natural populations and ecological processes require sampling at several time-scales to account for seasonal and other short-term temporal patterns of change (Underwood 1991).

The limited funding for and large cost of marine research means that most long-term studies are carried out at relatively few locations and on an annual or biannual basis (McCorry 1996).

The few long-term (> 4 years) scientific studies which provide some insight into the patterns of decline and recovery of coral reefs have been carried out at few locations and under-represent the variety of coral assemblages that occurs worldwide (Connell 1997). For example, in the Indo-Pacific region more than 60% of the long-term monitoring of coral reefs has been done at only two locations - Heron Island in the GBR, and Kanehoe Bay, Hawaii (Connell 1997). It has been estimated that more than 80% of the research programs in the GBRMP have a duration < 3 years and that programs which do extend for longer time periods are usually done on a single reef (84% of studies $\geq$ 3 years duration, Gor Yaman 1995). Thus, even in the most intensively studied marine region in Australia (Fairweather 1990) there are relatively few adequate data on long-term environmental change over broad spatial scales.

The most comprehensive long-term study of coral assemblages in the GBRMP is in its infancy. The Australian Institute of Marine Science, in collaboration with the GBRMPA and the CRC Reef Research Centre currently surveys some 52 reefs on an annual basis to monitor changes in a number of biological and chemical parameters (Oliver *et al* 1995). The sampling regime, although comprehensive, incorporates only 2% of the total number of reefs in the GBR. The main aim of the program, which has been underway now for 6 years, is to determine trends in the distribution and abundance of reef biota and in water quality, and to provide managers with information pertinent to wise use of the GBRMP.

If carefully planned, volunteer-based monitoring on the GBR and elsewhere may complement current scientific programs, by providing information on changes at sites that are not included in existing research and which are subject to regular use. Because tourism operators and dive clubs visit individual sites on a regular basis, sampling by volunteers could occur more frequently and at less cost than the extensive scientific surveys.

3.1.2 Community education

Active involvement of volunteers in research also has strong educational value (Stokes, Havas and Brydges 1990). By participating in monitoring programs, volunteers increase their knowledge of the ecology of the organisms that they study and the effects of human activities on natural environments. Active participation also fosters a sense of responsibility and stewardship towards the environment and may encourage environmentally responsible behaviour (Hiller 1991; Quirolo & Quirolo 1993). While there is evidence that information alone (e.g. interpretation) does not necessarily promote environmentally responsible actions

(Kelly 1993), recent studies have shown that when community groups are directly involved in conservation activities and basic research, the individual participants develop more responsible attitudes towards the environment (Lein 1986; Blanchard & Monroe 1990 - cited in Kelly 1992). In addition, participation in monitoring provides greater understanding of research, including how it is done and the care and rigour needed to obtain useful information for science and management (Hiller 1991).

3.2 Limitations of volunteer-based monitoring

There are, however, a number of limitations associated with the involvement of non-experts in environmental monitoring which must be taken into account when planning volunteer-based research. These reflect the limited technical knowledge that could be expected within any group of non-specialists, the lack of familiarity with procedures for data collection and storage and the logistics of designing a meaningful sampling program that depends upon the motivation and availability of interested non-professionals. The importance of fundamental aspects of good sampling, such as the randomisation and replication of samples, and consistency in data collection and storage, is often difficult to convey to people with no scientific training. Without a basic understanding of these concepts, volunteers do not always appreciate the need for rigorous adherence to the sampling procedures. Accordingly, the involvement of volunteers in environmental monitoring presents scientists and managers with the challenge of developing research programs that are robust and which will produce interpretable results when a diverse and mutable source of non-professional labour is involved.

3.2.1 Loss of information in ecological sampling

Data collected by non-professionals are often regarded as being: i) information-poor and ii) less reliable than those collected by professionally trained marine scientists. The limited technical expertise of volunteers in the identification of organisms can restrict the collection of information to relatively coarse levels of taxonomic resolution (Phillips *et al* 1993). This is particularly a problem in very diverse environments such as coral reefs. Without extensive training (as in the Coral Cay Conservation program, Mumby *et al.* 1995) volunteers could not be expected to be able to identify coral reef organisms to the level of species. The loss in taxonomic resolution does not necessarily detract from the overall value of volunteer-based monitoring programs. With limited training, volunteers may be able to recognise well known (such as the crown-of-thorns starfish) or easily identifiable categories of organisms that have similar morphological or functional features (i.e. "lifestyle" or functional groups *sensu* Keough and Quinn 1991). Although there is some loss of information in the use of these aggregate functional groupings, it is a relatively common practice in marine environmental studies (Underwood 1986; Connell and Keough 1985; Oliver *et al* 1995). In some instances, scientists advocate the use of functional groups in environmental monitoring because it reduces the cost per sample and, thereby, allows the collection of larger numbers of samples (Keough and Quinn 1991; Warwick 1993; but see Carney 1996).

Warwick (1988) has shown that aggregating species into meaningful taxonomic groupings does not necessarily result in loss of ability to detect environmental impacts, as the responses of natural ecological assemblages to human-induced disturbance are often also evident at higher taxonomic levels. Thus, where there is not a requirement for very detailed information on changes in the structure of ecological assemblages, the collection of information on higher taxa by volunteers may be useful because it is cheap and reliable, if the program is carefully planned. Where resources are limited, it may be the only viable option for sustained, broad-scale monitoring.

3.2.2 Reliability of data

"we can only understand trends properly if we map expansions and contractions in variation among all items in systems, and cease to focus on the march of mean or extreme values through time."

Stephen Jay Gould (1997)

Scientists are sometimes sceptical about the ability of volunteers to collect reliable data (Beeh 1996). This attitude reflects concerns that the limited technical training of volunteers and the often laissez faire attitude to quality control in volunteer research programs can result in data that is inaccurate and highly variable in quality. Inaccurate identifications, poor adherence to the sampling protocol or sloppy data handling procedures can produce information that is of limited use in detecting real trends in environmental conditions. Relatively few studies using volunteers have attempted to estimate the sources or magnitudes of error in data collected by non-specialists (but see Inglis & Lincoln Smith 1995, Mumby *et al.* 1995; Dartwall & Dulvy 1996; Schmitt & Sullivan 1996) and, therefore, it is often unclear how much faith can be placed in the results.

The inherent variability in natural populations of plants and animals makes the design of programs of sampling to detect change very complex (Green 1979; Andrew and Mapstone 1987; Underwood 1990, 1992 and 1993; Fairweather 1991). Careful attention is needed to standardize sampling procedures so that any additional sources of variation that might affect the ability of the study to detect and correctly interpret environmental change are minimised. In recent years, marine scientists have devoted a considerable amount of effort to identifying sources of consistent inaccuracy ("bias") in their sampling procedures and to minimizing unsystematic sampling error ("imprecision") (Dayton and Oliver 1979; Underwood 1981; Hurlbert 1984; Andrew and Mapstone 1987). As many of these studies have shown, the sources of error in sampling can be considerable, even amongst trained professionals (Table 3.1).

3.2.2.1 Observer-related error

Any observer, even when professionally trained and experienced, introduces some degree of error into the measurements that they take (Andrew and Mapstone 1987). Where a single observer carries out all of the sampling, this form of error is usually assumed to be consistent throughout the study and, therefore, without major implications for the detection of spatial or temporal trends (although, in practice, this assumption is often likely to be wrong!). The use of volunteers, however, can introduce measurement error that is inconsistent among observers, because of large variation in the prior knowledge and technical skill of the individuals involved (Phillip *et al* 1993, Inglis & Lincoln Smith 1995). The potential for inconsistency and large inter-observer variability in the collection of the data is particularly problematic where a large number of different observers are involved, because it may obscure or be confused with the patterns that the study seeks to detect (Inglis and Lincoln Smith 1995; Thompson & Mapstone 1997).

Over the duration of a volunteer-based monitoring program, many different observers are involved in data collection and they may differ greatly in their knowledge of the environment, understanding of the sampling protocol and the degree to which they apply it. Without knowledge of the magnitude and consistency of variation among observers, differences among groups of volunteers that are used in different places or times during the program may be confused with differences among reefs or censuses (Mundy & Babcock 1993). More commonly, large variation among individual observers can make the study less able to detect natural patterns of change in space or time by reducing the precision of estimates obtained by the study (Andrew & Mapstone 1988, Inglis & Lincoln Smith 1995, Thompson & Mapstone 1997).

In sub-tidal environments there is also the added difficulty for volunteers in performing an unfamiliar task (scientific sampling) in an unfamiliar environment (i.e. underwater). The competency of the observer as a diver may contribute substantially to the consistency of observations obtained by them. For example, data collected by volunteers has been shown to be less reliable when sampling was done at depths known to affect judgment and dexterity in SCUBA divers (Mumby *et al* 1995).

Most literature on observer error in ecological research, however, comes from studies in terrestrial environments; particularly ornithological surveys and aerial surveys of macro-fauna (e.g. O'Connor 1981; Kepler & Scott 1981; Bart & Schoultz 1984; Marsh and Sinclair 1989; Sauer *et al* 1994). Observer-related error and bias are not often taken into account in the choice of sampling technique or in the design of marine research (Andrew & Mapstone 1989; St John et al 1990; Inglis & Lincoln Smith 1995). Only recently, have studies focussed in detail on the implications of observer bias for sampling in marine environments (Table 3.1).

Professionally trained observers may vary widely in their estimates of abundance or size of marine organisms (Table 3.1), particularly when sampling is done by visual surveys of the organisms *in situ*. Mundy (1991) found that differences among observers may account for as much as 40% of the total variation when the cover of massive corals was compared between two sites using line transects. Different observers have been found to vary substantially also in determining the sizes of fish underwater, with individual observers displaying biases for specific size classes (StJohn *et al.* 1990). Such biases may result in very different estimates of size structure for the fish population (StJohn *et al.* 1990). Meese and Tomich (1992) compared five methods for estimating the percentage cover of intertidal rocky organisms and found that variability among observers was seven times greater when they used methods which involved visual estimation *in situ* (e.g. fixed points on quadrats) compared to methods which involved electronic digitising of photographs of the same quadrats.

Table 3.1 Some recent studies which investigated the extent of observer-related variability in sampling and/or monitoring studies conducted in sub-tidal environments.

SOURCE	TYPE OF STUDY	FINDINGS ON OBSERVER-RELATED VARIABILITY
Thresher & Gunn 1986	Comparison of six visual census techniques for sampling reef fish	Significant observer bias in estimating perpendicular sighting distance used to calculate fish density
Lincoln Smith 1988	Methodology for reef fish census	Significant effect of observer's swimming speed on fish counts that biased estimates both within- and between-observers.
St.John *et al* 1990	Visual census of reef fish	Positive observer bias in estimating fish size-class possibly due to experience; also, specific size-class related bias for individual observers.
Fernandez *et al* 1990	crown-of-thorns starfish manta tow surveys	Differences in sightability of starfish among manta tow observers; no differences in starfish counts by SCUBA divers over the same transects.
Mundy 1991	Percent cover of life-form categories by line intercept transects	High and inconsistent differences between observers in estimating percentage cover of coral reef life-forms. Also, within-observer variability varied among observers.
Meese & Tomich 1992	Comparison of 5 methods to estimate percent cover of sessile intertidal biota	Inter- and intra-observer variability in estimating percentage cover of intertidal biota varied significantly among methods.
Mumby *et al* 1995*	Reef assessment through volunteer-based program	Differences between groups of observers in assessing corals and macro-algae and habitat. Also within-observers differences possibly related to SCUBA diving physiological constraints.
Inglis & Lincoln Smith 1995	Surveys of shoots of seagrasses	Differences among observers depend on the size of sampling unit but only for one species of seagrass. Also differences between novice and experienced observers.
Jaap 1996	Surveys of benthic sessile organisms using quadrats	No difference between two experienced observers in estimating abundance from sampling the same quadrats.
Miller & De'ath 1996	Surveys of the percentage cover of coral reef benthos by manta tow surveys	No differences among observers; precision varies with experience; survey method robust for different observers
Dartwall & Dulvy 1996*	Coral reef fish surveys volunteer-based program	Observer's relative accuracy in estimating fish abundance and size structure increased with practice.
Schmitt & Sullivan 1996*	Coral reef fish surveys volunteer-based program	Differences (26-31%) between paired observers in recording the number of reef fish species
Thompson & Mapstone 1997	Coral reef fish visual census	Decrease in observer bias with training depended on taxon considered. Effect of observer error on precision decreased at larger spatial scales and for more abundant taxa.

* studies addressing observer-related variability in volunteer-based sampling programs.

When inexperienced observers are involved in sampling, large differences in relative accuracy among the observers have been reported. For example, Inglis and Lincoln Smith (1995) found that the average difference between an expert observer and each of several inexperienced observers in counting seagrass shoots within a quadrat, may vary from 0.6% to 26% of the estimated density. Such magnitude of variation is large enough to confound spatial and temporal variation, and thus care should be taken when comparing estimates of seagrass shoots density derived from different groups of observers (Inglis & Lincoln Smith 1995).

Observer-related error, whether random or systematic (bias), can be large enough to prevent the detection of real patterns. When the error is not consistent over the duration of the study (e.g. when new volunteers join the program) or across different locations, false patterns may be created that do not reflect real changes in the environment. Conclusions on the presence or absence of ecological trends may, therefore, be drawn incorrectly (see also Bart and Schultz 1984 and Thomas 1996). For example, in the Breeding Bird Surveys in North America, one of the longest running volunteer-based monitoring programs in the world, an increase in the overall population of birds was later shown to be caused by recent volunteers being more able to detect a larger range of species and individuals than participants in earlier years of the survey (Sauer *et al* 1994).

In Table 3.2, we have outlined four realistic scenarios where variation among volunteers or groups of volunteers can significantly affect the interpretation of a monitoring program. In the first scenario, the same team of observers repeatedly samples a small number of locations. Any differences within the team, in the way observations are made or recorded can inflate the variation associated with estimates of the abundance of the population at each site and time. This increased "noise" reduces the power of the study to detect real spatial and temporal patterns of change.

In the second scenario, the sampling teams change on each census date. This might occur when each team of volunteers consists of visitors on a tourism operation that involves research or where the staff of a tourism operation take turns at monitoring the same site. Unless the procedures are fully standardised among sampling teams, subtle differences between the teams could be confused with temporal change in the population being sampled. The problems of this type of within-group and among-group error are compounded when the group composition changes regularly and a broad range of locations are surveyed. Standardisation of sampling procedures can be achieved more easily within a small, relatively stable team than it can be among constantly changing research teams that operate at a range of locations.

Table 3.2 Four hypothetical - but realistic – scenarios using volunteers where differences within and/or among groups of observers can significantly affect the interpretation of the study.

VOLUNTEER-BASED MONITORING	IF…	…THEN	IMPLICATIONS FOR MONITORING
Sampling program in which the same team of observers repeatedly visits a number of sites (e.g. local community group)	Significant differences among observers	Natural variation within each site is over-estimated	Smaller power to detect differences among sites or census dates.
Teams of observers alternate sampling at the same sites (e.g. dive tourism operators with rotating staff)	Significant differences among groups	Variance among census dates is over-estimated	Greater probability of detecting erroneous temporal changes
Network of tourist operators and community groups sampling a range of different reefs. Members of each survey team are the same on each census date.	Significant differences among groups	Variance among reef is over-estimated	Greater probability of detecting erroneous differences among reefs. Smaller power to detect trends at larger spatial scales (e.g. tests for latitudinal trends in hierarchical sampling designs)
Commercial dive tourism operations involving occasional visitors in data collection; or where there is large turnover in personnel	Significant differences within- and between-groups of observers	Natural variation within and among sites and within and among census dates is overestimated	Greater probability of committing both Type I and II sampling errors for statistical tests of differences among censuses and sites. Patterns are, therefore, difficult to interpret.

There is, therefore, a clear need to address potential observer-related error during the planning of volunteer-based sampling programs. The sampling methodology used by volunteers should be subjected to a process of validation to ensure that the extent of inter-observer variation is known and that potential sources of error are identified and minimised. Such validation exercises should be conducted repeatedly over the duration of the study to ensure the continued standardisation of the procedures among locations and censuses.

3.2.3 Limitations on the design of volunteer-based monitoring

A monitoring program invariably has the twin aims of describing patterns of change and differences in natural assemblages and of attempting to explain any patterns that are detected (Underwood 1989). The most effective monitoring programs are likely to be those that are designed with prior knowledge of the rates of natural change in the communities under study and of the spatial and temporal scales over which any change is expected to occur (Underwood 1989). For most communities, however, this type of information is not available and arbitrary choices must be made about the number and placement of samples in space and time. In scientific surveys, the choices of where and when to sample can be guided by the specific objectives of the study and by the size and distribution of natural biological or physical units (e.g. reefs or clusters of reefs, gradients across the coastal shelf, etc.). Where the objective of the study is to examine changes in the environment in response to management actions, sampling effort may be allocated according to appropriate units of management (e.g. zones or sections of the Marine Park). Where there are no clear biological or administrative units, a common way of accommodating uncertainty about relevant scales of sampling is to design the sampling program in a hierarchical fashion (Green & Hobson 1970; Andrew & Mapstone 1987; Underwood 1981; Oliver *et al.* 1995), so that several spatial and temporal scales of sampling are incorporated.

Volunteer programs also tend to incorporate dual goals. At a local level, individual groups of volunteers are usually most interested in monitoring changes at locations that are particularly valued by the participants (e.g. a favourite dive site or tourist destination). These isolated studies provide information on changes at a local level, but give no indication of how widespread the patterns of change may be. The recent interest in linking the findings of disparate monitoring programs through the development of "networks" of volunteer programs (e.g. Coastcare and the Coastal Monitoring System in the Commonwealth Coastal Policy; DEST 1995) recognises the need of coastal managers for information on broad-scale trends in the condition of the environment. There are, however, a number of problems with this approach to broad-scale monitoring.

First, the selection of sites included in the monitoring program is unlikely to be randomised, but will be determined by the specific objectives of each volunteer group. This means that the sites are unlikely to represent meaningful biological units and it will not be clear how representative any changes detected at them will be of broader-scale changes in the surrounding environment. A similar problem has been highlighted in recent attempts to document global patterns of change in coral reef systems (Oliver pers. comm.), where most long-term monitoring studies have been initiated at sites which initially had large coral cover. Most of the documented trends, therefore, have inevitably been for a decline in the abundance of corals.

Second, networks of monitoring programs tend to grow by a "snowballing" effect, usually starting from a small, enthusiastic group and expanding geographically as other groups hear about the program or wish to become involved. Within each group, the personnel involved are likely to change considerably over the duration of the program. New groups and personnel are likely to join and leave the program as enthusiasm for the project waxes and wanes. This presents difficulties in the design of programs to detect broad-scale change. Without considerable coordination, sampling at each site is likely to occur at different times, with differing frequencies, methodologies and effort. Amalgamation of such data is likely to be useless in the detection of long-term trends.

Whilst the greatest value of volunteer-based monitoring is its capacity for sustained, broad-scale sampling, because of the limited financial resources it requires, this same potential imposes a number of constraints on the implementation of the program (Thomas 1996). Volunteer-based studies rely on the good will of individuals and therefore, implementation of the program depends upon the availability and enthusiasm of those involved. Over the long term, the participants will change, as some drop out and new individuals and groups join the program. Some groups may miss scheduled sampling events due to the unavailability of individual observers or weather conditions. This lack of stability that unavoidably accompanies a volunteer-based program is likely to have a considerable influence on the outcomes of the program, by creating problems in the analysis and interpretation of data from missing data and unbalanced sampling designs. It is necessary for the program to be designed to accommodate potential changes in the monitoring arrangements without compromising the ability to analyse and interpret the data over the long term. This will require close collaboration and guidance from scientists and considerable foresight and planning for the growth and coordination of any large-scale monitoring effort. It is important that all parties are realistic about what can (and cannot!) be achieved by the program.

4. DEVELOPMENT OF THE SAMPLING PROTOCOL - PILOT STUDY

4.1 Outline and scope of the project

This project consisted of five stages (Figure 4.1):

I. Consultation. An initial phase of consultation with the volunteer groups which had expressed interest in being involved. The consultation also included personnel from the Great Barrier Reef Marine Park Authority and other marine scientists. The aim of the consultation was to define the objectives of the program based on the needs and motivations of the volunteers and environmental managers of the GBRMP, respectively.

Secondly, consultation with the volunteers was aimed at identifying the constraints which would apply to the program. Consultation with interested groups was maintained throughout the duration of the project. The first three chapters of the report include outcomes of the consultation and a synthesis of the issues relevant to volunteer involvement in monitoring which need consideration in the development of volunteer-based monitoring on the GBR.

II. Information gathering. Background information was gathered on similar current and past programs operating elsewhere to examine procedures that had already been implemented in other studies.

III. Methods development. A simple protocol for sampling reef benthic organisms was developed, together with a first draft of the interpretive materials used for training the volunteers. Objectives and constraints identified during consultation were used as guidance in the choice of both the variables to be measured and the sampling methodology. An important aspect of the development stage was the design of the interpretive materials to be used to train volunteers taking part in the field trials. A questionnaire was also developed to provide an evaluation of the program.

IV. Pilot study. A pilot study was conducted to evaluate the performance of the sampling protocol in comparison to more complex methods that are currently used by marine scientists on the GBR. The outcomes of the development phase are reported in Chapters 4 and 5.

V. Field trials. The sampling protocol and training materials were trialed in the field with a number of volunteer groups at different locations on the GBR. The field trials were intended to assess both the logistic feasibility of implementing the program with diverse groups of volunteers, and to assess the reliability of the data collected by non-experts using the proposed methodology. A questionnaire distributed to the volunteers was used to evaluate the response of the participants to the interpretive/training materials and the program in general.

VI. Program evaluation. Data from the field trials and responses to the questionnaire were analysed to evaluate the feasibility of the program. Results of the field trials and program evaluation are reported in Chapters 6 and 7 respectively.

VII. Integration. Results from the different phases of the study were used to i) provide recommendations on the feasibility of volunteer-based monitoring on the GBR; and ii) prepare the final monitoring package, inclusive of sampling methodology, training materials and design guidelines which could be adopted by groups of divers within a volunteer-monitoring framework.

4.2 Logistic constraints

Consultations were held with individual tourist operators, representatives of the tourism industry in the Cairns region and community groups to discuss constraints to the involvement of tourists and staff in the study during commercial dive tourism operations. On-board dive tourism vessels the major constraint to the involvement of visitors and staff was the time available to pursue extra activities. On each dive trip, the maximum time available for training the participants was approximately one to two hours. Depending on the duration of the trip, only one to two dives – each lasting approximately one hour – were able to be devoted to the involvement of visitors in data collection. There were also a number of time constraints for the involvement of the members of the volunteer group. Working commitments of individual members had to be accounted for and a time suitable to all had to be arranged. The volunteer group involved in the study - OUCH - relies on private boats to travel to dive sites. The time available for training and data collection had to be minimised to meet these limitations, although longer training sessions were possible with the community groups than with the tourist operators.

A major consideration for the involvement of volunteers in a research project is ensuring the health and safety of the participants. Activities undertaken by the volunteers as part of the program should not expose them or their property to any greater risk than they would normally encounter on a recreational activity. In underwater environments, extra care is needed to ensure that any risk of accidents is minimised. This requires careful planning and clear identification of the responsibilities of each of the parties involved in the program. At the onset of this study, we addressed safety and liability issues in consultation with the regional office of the Workplace Health and Safety Authority.

At the time that this project began, there was a lack of policy and regulations in relation to the involvement of volunteers in underwater activities carried out outside a recreational context (Chris Coxon, pers. comm.). This meant that there was a need to develop safety guidelines for volunteers taking part in the study. Conservative dive guidelines were prepared which included the presence of a dive supervisor in addition to the scientists involved in the training. The dive supervisor spent the duration of each dive observing the participants in the study to ensure their safety. This was particularly important when volunteers with limited SCUBA diving experience were involved in the trials. The volunteers who participated in the field trials as part of a commercial dive tourism operation were subject to the existing code of practice for recreational diving (Division of Workplace Health and Safety 1992).

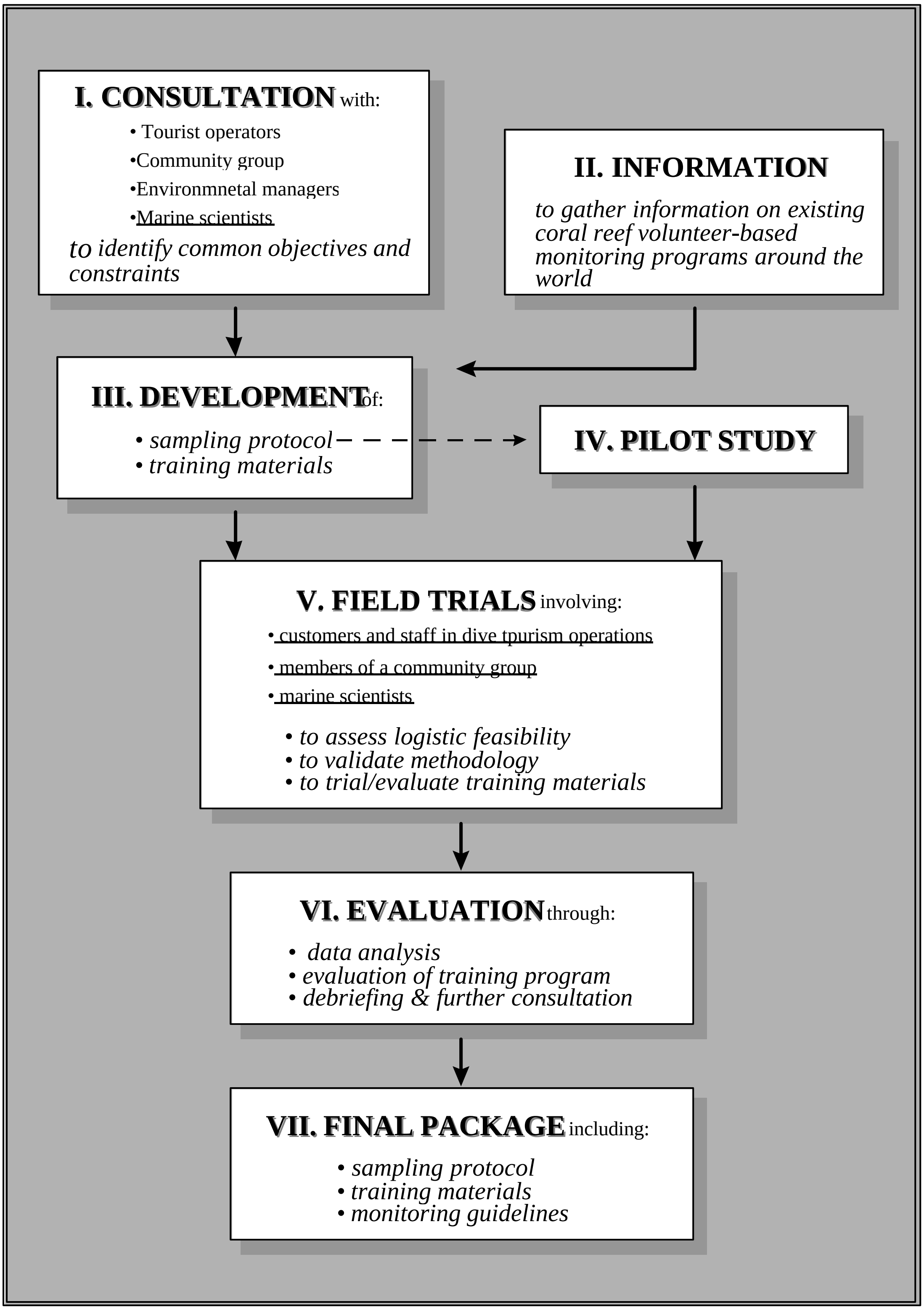


Figure 4.1 Steps followed in this study to develop and trial a coral reef volunteer-based monitoring program on the Great Barrier Reef

4.3 Choice of measures

Following initial consultations with staff at the Great Barrier Reef Marine Park Authority, tourism operators and interested volunteer groups, we decided to restrict the scope of the study to the development of simple procedures for the assessment and monitoring of sessile benthic organisms. Our intention was to establish a protocol for the development, validation and trialing of a sampling methodology for benthic life-forms that could subsequently be applied to develop other modules for volunteer monitoring projects (e.g. counts of reef fish or studies of the rates of recruitment or growth of common corals).

We did not consider sampling of reef fish by non-professionals to be feasible for this study, because of the large number of sources of bias that is known to occur in censuses done by trained scientists using established methodologies (Mapstone and Ayling 1993; Thompson and Mapstone 1997). Reliable data on fish abundance and length frequency distribution can be obtained by volunteer observers only after a minimum of two weeks training in the field (approximately 11 dives; Darwall and Dulvy 1996). The nature of the operations of most of the volunteer groups involved in the current project meant that training periods of such length were not, at least at this stage, feasible (see Section above).

Benthic life-forms were selected in the first instance because they are the major structural component of coral reef environments, are important habitat for a range of species and because there are a number of well-established techniques for the census of benthic life-forms that could be easily adapted for use by non-specialists. Importantly, we wanted to develop a sampling procedure that would allow the collection of quantitative data on the condition of reef sites that complemented the existing long-term monitoring program being conducted by the Australian Institute of Marine Science (Oliver *et al.* 1995; Sweatman 1997)

4.4 Choice of the sampling technique

A large body of literature exists on the relative merits of different methods for sampling the benthos of coral reefs (Loya 1978; English *et al* 1994). No single method is optimal in all situations and the best procedure depends largely on the purpose of, and constraints on, the study (Olhorst and Liddell 1994). Our choice of sampling methodology was guided by a number of practical considerations for the involvement of volunteers:

?? that the sampling protocol should eventually be able to be done by volunteers with a minimum of supervision;

?? that it should be simple to understand and implement;

?? that it should be comparable to methods commonly used by professional scientists for monitoring coral reefs;

?? that the time needed to train volunteers and survey a location should be compatible with the short duration (1-3 days) of most dive tourism operations in the GBRMP;

?? that the procedure be cheap to implement, with a minimum of on-going cost to the participants;

?? that the methodology was safe and complied with standards for recreational diving (Division of Workplace Health & Safety 1992)

?? that it involved minimal or no damage to the environment.

Plot survey techniques (e.g. quadrats and photo-quadrats) were not considered as they generally require large amounts of field-time (Dodge, Logan and Antonius 1982) or involve the use of expensive equipment. Similarly, the use of underwater video to survey coral reefs (Carlton and Done 1994) required equipment that was not likely to be available to all interested groups. Both photogrammetry (Done 1981) and video transects also involve considerable laboratory time to analyse the images and determine the abundance of reef organisms. These analyses are time-consuming, laborious and require expensive equipment (underwater camera or video; digitising equipment and specific software).

Another technique commonly used to sample reef benthos is the Line Intercept Transect (Loya 1978, Mundy 1991, English *et al.* 1994). This technique is well-established and is used to measure the percentage cover and size frequency distribution of coral colonies and other sessile organisms. A transect line of fixed length is placed over the reef surface and the abundance of each organism is determined by recording the points along the transect at which one benthic life-form changes to another ("transition points", English *et al.* 1994). The abundance of a life-form is estimated as the proportion of the total length of the transect that lies over that organism.

Line Intercept Transects require considerable concentration from the observer and a large amount of time underwater. A faster version involves recording only the organisms that occur under a predetermined number of points along the transect. This technique - "Point Intercept Transects" - was originally developed in the geological sciences and its relative performance has been investigated on coral reefs by Dodge *et al.* (1982). It is simple and fast to use in comparison with the three other common methods for coral reef surveys (Line Intercept Transect, Quarter Point Transect and Belt Quadrat; Dodge *et al.* 1982). Because of the ease and the speed with which data can be collected with the point-intercept method, we investigated its suitability for use in volunteer-based reef studies.

4.5 Level of taxonomic resolution

The level of taxonomic resolution used in surveys of coral assemblages depends, to a large extent, on the objectives of the survey and the expertise of the personnel involved. Because species of coral are difficult to identify *in situ*, transect-based surveys of coral reefs often use a functional classification system that is based on broad taxonomic affinities and morphological attributes of the colonies. The Australian Institute of Marine Science *Survey Manual for Tropical Marine Resources* has been developed to train personnel within the ASEAN Living Coastal Resources Project in coral reef survey methods (English et al. 1994; see also Miller 1994). It groups the benthos of coral reefs into 30 life-form categories that are based on taxonomic (e.g. sponges, algae etc.) and morphological similarities (e.g. branching or massive corals). The classification system is hierarchical and the number of categories used can be determined according to the expertise of the personnel involved in the study. The system is, therefore, quite flexible and is suitable for use in volunteer-based programs. Only a minimum level of training is required for non-professionals to be able to identify basic reef life-forms *in situ*.

Some of the life-form categories used by English *et al.* (1994) are, however, difficult to standardise among novice observers. In particular, the distinction between corals belonging to the genus *Acropora* and other genera would have been difficult to convey within the limited time available for training for most of the volunteers we were concerned with (< half a day). Because of this, we simplified the taxonomy of categories further by grouping all corals into categories that were based only on colony morphology (Table 4.1). Similarly, the five categories of algae used by English et al. (1994) – macroalgae, *Halimeda* spp., turf algae, coralline algae - were grouped into a single category (Table 4.1).

Table 4.1 Definition of the thirteen life-form categories used in the pilot study

LIFE-FORM CATEGORY	CODE	DEFINITION
CORAL MASSIVE	CM	Dome shaped and sub-spherical coral colonies, including meandering morphologies (brain corals)
CORAL BRANCHING	CB	Colonies with ramifying branches; includes caespitose, corymbose and arborescent morphologies and branching *Millepora* spp.
CORAL ENCRUSTING	CE	Thin, laminar coral colonies which adhere to the substratum
CORAL FOLIOSE	CF	Laminar colonies forming thin plates projecting into the water (includes 'cabbage-like' corals)
CORAL TABULATE	CT	Colonies forming a table upheld by a stalk - tabular portion made up of little and compact branchlets
CORAL DIGITATE	CD	Colonies with finger-like projections which sometimes may be ramified
CORAL COLUMNAR	CC	Colonies with massive column-like vertical projections
SOFT CORAL	SC	All morphologies of soft corals
SPONGE	SP	All morphologies of non-cryptic sponges
ALGAE	AL	All types of algae
SAND	SA	Abiotic substrate made up predominantly of fine sand
RUBBLE	RB	Abiotic substrate made up predominantly of fragments of skeletons of corals and other organisms
OTHER	OT	All biotic and abiotic components which do not belong to the above categories

4.6 Pilot Studies: developing the methodology

In May 1996 we conducted a range of pilot studies to optimise the use of the point-intercept transect method and to compare results obtained from it with the more widely used Line Intercept Transect technique (LIT). The primary objectives of the pilot study were:

?? to identify potential biases in the use of the point intercept method by scientists, relative to estimates obtained using the more standard Line Intercept Transect;

?? to determine the optimal number of points to be surveyed per transect;

?? to estimate the degree of consistency among trained scientists in the use of the survey techniques;

?? to estimate the field time required to complete surveys using each transect method.

4.6.1 Comparison of Point and Line Intercept Transects

Pilot studies were done on the fringing reef adjacent to Nelly Bay on Magnetic Island, approximately 20 km from Townsville, North Queensland. Three marine scientists, with between 1 to 5 years experience in coral reef surveys, each sampled seven independent 10 m line transects, distributed haphazardly along the reef slope. Each transect was surveyed twice; once using the Line Intercept Technique and once by the Point Intercept method. A total of 100 survey points - spaced at regular 10cm intervals - were sampled on each point-intercept transect. Organisms beneath each transect were recorded as belonging to one of the 13 life-form categories listed in Table 4.1.

A short training workshop was held among the three researchers before the field trial to outline the life-form categories to be used and the protocol for sampling both forms of transects. Underwater photographs, depicting examples of each life-form category, were used to obtain agreement in the identification of life-forms prior to entering the water. This pre-dive briefing was similar to that intended for volunteer divers later in the study.

Differences among observers and sampling methods in the mean percentage cover of life-forms estimated at the site were compared using a two-way ANOVA with repeated measures on each transect. "Sampling method" was the within-subject factor (two levels, LIT and point intercept) and "Observer" was the between-subject factor (three levels). Separate analyses were done for the total percentage cover of corals and for the percentage cover of each of 10 life-form categories: hard corals with massive (CM), branching (CB), encrusting (CE), foliose (CF), or digitate (CD) morphologies, algae (AL), soft corals (SC), sand (SA), rubble (RB) and other, unclassified components (OT). The remaining three categories usually comprised < 1% cover and, therefore, were not analysed. The significance level of all tests was set at ? =0.10, because maximising the power to detect differences between the methods was considered more important than maximising protection of the test (i.e. the probability of correctly not detecting a significant effect).

4.6.2 Optimising the sampling technique

To optimise the sampling procedure, we examined how the precision of estimates (measured as the ratio of the sample standard error to the sample mean - SE/mean - Andrew & Mapstone 1987) of percentage cover at the site varied as we changed the number of sampling points per transect. One hundred points had been surveyed on each point-intercept transect. Data from each transect were re-sampled in the laboratory by sequentially reducing the number of equally-spaced points sampled on each transect. Thus, we varied the sampling intensity over eleven levels: 100, 50, 33, 25, 20, 10, 6, 5, 4, 3, and 2 points per transect. A further level was added by including data derived from the line-intercept transects, which effectively contained 1000 sample points per transect (since transition points were recorded to the nearest centimetre). Estimates of sample precision were calculated separately for each observer over seven independent transects. We then plotted estimates of the mean sampling precision, averaged over the three observers, against the number of points surveyed per transect to examine the relationship between sampling effort and mean sampling precision.

Safety was a major consideration for this program, and we were concerned with minimising the amount of time underwater needed by the volunteers to survey a site. To obtain estimates of the average time needed per sampling unit, each diver recorded how long it took to complete each transect. The hypothesis that the time taken to survey a transect did not differ between the two methods was examined using Wilcoxon's Signed-Ranks Test for paired observations. Repeated Measures ANOVA could not be used as assumptions of homogeneity of covariance matrices and of variances were not met. A Kruskal-Wallis test was used to test whether the difference between the two methods in the time required to survey a transect varied among observers.

4.6.3 Consistency in the use of the procedures

A number of sources of error are possible when recording information from transect surveys. Data collected along the same transect by several observers may differ because: i) the transect line moved slightly between successive measurements, ii) the observers viewed the transect from slightly different angles ("parallax error", Mundy 1991), or iii) because they differed in their interpretation of the life-form categories.

To obtain a preliminary estimate of consistency in the use of the sampling procedures by scientists, each observer was made to survey the same transects. Our objective was to identify the life-form categories that caused the most confusion amongst trained scientists, so that we could subsequently modify the training materials to make it easier for volunteers to distinguish among the categories. Three 10 m point-intercept transects were sampled in random order by each observer. Life-forms were recorded beneath 50 regularly-spaced points along each transect. To obtain a measure of consistency (or more correctly, "relative accuracy"; Andrew & Mapstone 1987), one of the observers (BM), who designed the sampling protocol and who was involved in all of the field trials contained in this report, was used as a standard against which identifications made by the other scientists were compared.

The relative accuracy of identifications made by each of the other two scientists was calculated separately as the proportion of points on the transect at which the observer recorded the same life-form category as the reference observer. This measure of accuracy also contains a component of error associated with slight movements in the transect line and paralax error.

We also examined how the consistency of identification changed as the life-form categories were collapsed into coarser levels of classification. Categories that were frequently confused were sequentially grouped into new "super-categories" and the rates of consistency of identification were recalculated for each new set of taxa.

To distinguish variation among observers from that due to slight movements in the transect line or parallax error, we re-examined data collected by each observer on the original seven transects (section 4.6.1). Each observer had sampled seven independent transects twice; once using the line-intercept method and once using the point intercept method with 10 cm intervals. The data obtained using the line-intercept method were re-sampled in the laboratory for each transect by recording the life-form category occurring under every 10cm interval. The resulting observations were then matched with data from the same transect obtained using the point intercept method. In this way two observations were available for each observer for the same points on the transect. If observers were consistent in their identification of life-form categories, the proportion of observations per transect with non-matching categories could provide an estimate of the error due to movement of the transect line and/or the observer viewing the point beneath the transect from a different angle of observation.

Rates of within-transect error, measured as proportions of observations per transect with non-matching categories, were compared among observers using a 1-way Model II ANOVA, with Observer as random factor and seven transects per observer as replicates. This analysis was used to investigate the hypothesis that within-transect error at a given site does not differ among observers.

4.7 Results

4.7.1 Comparison of Point and Line Intercept Transects

Estimates of the mean percentage cover of all hard corals at the Nelly Bay site did not differ significantly between the line-intercept and point-intercept sampling methods nor among the three expert observers (Table 4.2). The mean values returned by each investigator were remarkably consistent, irrespective of the method used (Figure 4.2). Tests for differences among these treatments generally had low power (1-? < 0.35), reflecting the small average differences in estimates of total coral percent cover obtained by the two methods (2.9 % ? 0.88 (SE); n = 21).

Table 4.2 Repeated Measures ANOVA table for effect of Method - Line Intercept Transect versus point intercept transect (50 and 100 points) - and the three Observers on the estimates of percent total coral cover.

SOURCE OF VARIATION	MS	df	F	p
Within-Subjects:				
Method	.52	2	.041*	.96
Method*Observer	19.63	4	1.56*	.20
Residual	12.58	36		
Between-Subjects:				
Observer	377.73	2	.93	.41
Residual	406.35	18		

* Corrected tests using the Greenhouse-Geissner approximation of degree of freedom for non-sphericity.

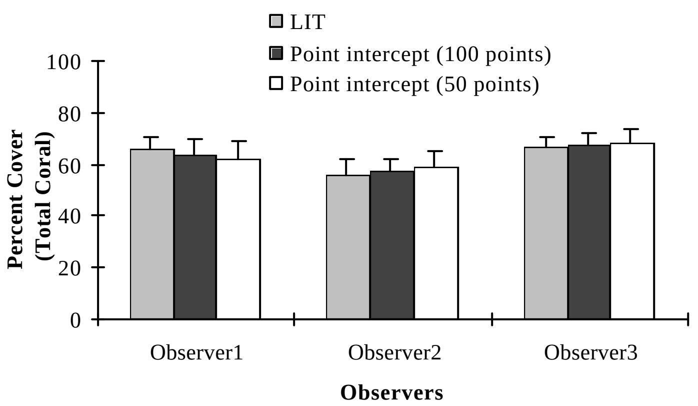


Figure 4.2 Mean percent total coral cover (± SE; n=7) as estimated independently by the three expert observers recording data using the LIT method, the point intercept method with 100 points and the point intercept method with 50 points.

There were no consistent differences between the three methods (LIT and point intercept with 100 and 50 points) for any of the individual life-form categories (Table 4.3). The three methods produced different site estimates of the cover of branching corals and of the cover of the "others" life-form category when used by different observers (Table 4.3). This may be due to the fact that the method and method*observer error terms encompassed the error associated with changes in both position of the diver in relation to the line and position of the transect line on the reef (when the observer swam twice along the transect to record life-forms with LIT and point intercept methods respectively). Within-transect error was high among observers (see below, Section 4.7.3), and therefore might have caused the interaction term to be significant for some life-forms. Observers varied significantly in estimating percent cover of encrusting, foliose and digitate corals at the site (Table 4.3).

4.7.2 Optimising the sampling technique

The precision of estimates of the mean percentage cover of total corals obtained by the three observers was generally very good; ranging between 0.07 to 0.11 when 100 sample points were used, and 0.05 to 0.10 when the line intercept transects were used. As expected, the sampling precision declined asymptotically (i.e. it improved) as the number of sample points per transect increased (Figure 4.3). The rate of change in the mean and variance of sampling precision appeared to stabilise when $\geq$ 20 points were used per transect. Precision of percent cover estimates for individual life-forms was lower than for aggregated coral life-forms, and varied among categories (Table 4.4.).

There were substantial differences in the time taken to survey individual transects using the line-intercept and point-intercept methods (Wilcoxon's Signed-Ranks Test statistics Z=-2.44; p=0.014; Figure 4.4). When 100 sample points were used, the point-intercept method was, on average, 1.8 $\pm$ 0.6 minutes faster per transect than the line-intercept technique. Over the seven transects, this equated to almost 15 minutes less time underwater for each observer, as there was no difference in the mean time taken by each observer for either technique (Kruskal-Wallis ?^{2}=2.62; df=2; p=0.27).

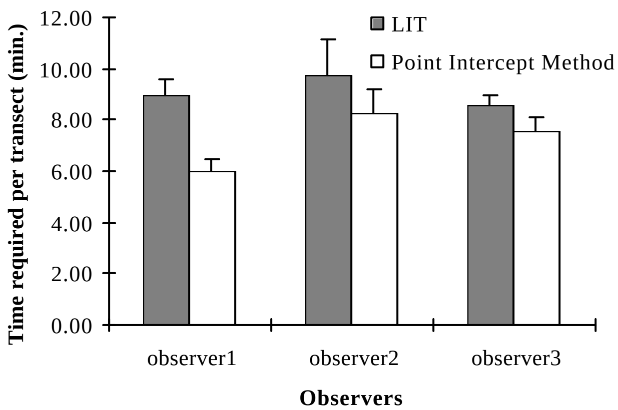


Figure 4.4 Mean ($\pm$S.E.) time taken per transect by each observer using the LIT and the point intercept method (*n*=7).

The dive time required to sample a reef site with a level of precision equal to 0.10 (SE/mean) was reduced approximately from 68 to 41 minutes when the point intercept transect (100 points) method was used instead of LIT, and was more than halved when only 50 points per transect were surveyed (Table 4.5). For each method, seven to eight transects were needed per site to obtain a level of sampling precision equal to 0.10.

Table 4.3 Repeated Measures ANOVA table for effect of Method - Line Intercept Transect versus point intercept transect (50 and 100 points) - and the three Observers on the estimates of percent cover of individual life-forms.

Category	**Within-subjects source of variation**					**Between-subjects source of variation**				
	Source of variation	df	MS	F	p	Source of variation	df	MS	F	p
Coral Massive[1,2]	Method	2	0.0053	0.054	0.94	Observer	2	0.0003	0.002	0.99
	Method*Observer	4	0.19	0.19	0.94	Residual	18	0.208		
	Residual	36	0.097							
Coral Branching[1,2]	Method	2	0.028	0.64	0.52	Observer	2	0.46	1.19	0.32
	Method*Observer	4	0.98	22.59	**0.00**	Residual	18	0.38		
	Residual	36	0.043							
Coral Encrusting	Method	2	14.76	0.08	0.92	Observer	2	2564.31	4.64	**0.02**
	Method*Observer	4	25.25	0.13	0.96	Residual	18	551.96		
	Residual	36	185.55							
Coral Foliose[1,3]	Method	2	0.037	1.18	0.31	Observer	2	5.40	12.62	**0.00**
	Method*Observer	4	0.013	0.42	0.79	Residual	18	0.42		
	Residual	36	0.032							
Coral Digitate[1]	Method	2	0.052	0.71	0.49	Observer	2	1.83	10.57	**0.00**
	Method*Observer	4	0.098	1.35	0.26	Residual	18	0.17		
	Residual	36	0.072							
Soft Corals	Method	2	1.12	1.04	0.36	Observer	2	3.45	0.95	0.40
	Method*Observer	4	0.75	0.69	0.59	Residual	18	3.60		
	Residual	36	1.07							
Algae	Method	2	8.90	0.11	0.89	Observer	2	29.54	0.18	0.83
	Method*Observer	4	55.76	0.69	0.59	Residual	18	159.23		
	Residual	36	79.94							
Sand[1]	Method	2	0.06	0.51	0.60	Observer	2	0.51	1.91	0.17
	Method*Observer	4	0.24	2.07	0.10	Residual	18	0.26		
	Residual	36	0.11							
Rubble[1]	Method	2	0.008	0.05	0.94	Observer	2	0.404	0.85	0.44
	Method*Observer	4	0.37	2.53	0.06	Residual	18	0.47		
	Residual	36	0.14							
Others[1]	Method	2	0.009	0.11	0.89	Observer	2	0.14	1.66	0.21
	Method*Observer	4	1.11	13.02	**0.00**	Residual	18	0.086		
	Residual	36	0.08							

[1] Data transformed as x'=Log(x+1) to achieve homogeneity of covariance matrices and/or of variances.
[2] Variables for which covariance matrices were not homogeneous despite transformation.
[3] Variables for which variances were not homogeneous despite transformation.

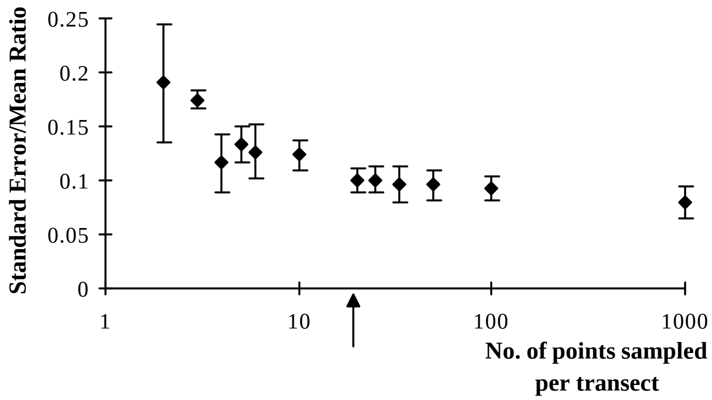


Figure 4.3 The relationship between the number of sample points per transect and estimates of the mean sample precision (± SE) for the site (n = 3 observers). The arrow on the horizontal axis corresponds to 20 points sampled per transect, the minimum value at which precision appeared to stabilise (see 4.7.2).

Table 4.4 Mean precision (expressed as mean/SE) of cover estimates for the 11 most abundant life-form categories, averaged over three observers. Error terms are Standard Errors

No. Points Surveyed	Life-form Category										
	AL	**CB**	**CD**	**CE**	**CF**	**CM**	**CT**	**OT**	**RB**	**SA**	**SC**
1000	0.12 ± 0.07	0.42 ± 0.20	0.60 ± 0.36	0.16 ± 0.08	0.36 ± 0.16	0.46 ± 0.10	0.86 ± 0.25	0.41 ± 0.15	0.61 ± 0.07	0.78 ± 0.26	0.64 ± 0.32
100	0.16 ± 0.06	0.45 ± 0.20	0.54 ± 0.40	0.19 ± 0.04	0.44 ± 0.19	0.44 ± 0.28	0.92 ± 0.14	0.38 ± 0.15	0.61 ± 0.08	0.70 ± 0.33	0.73 ± 0.26
50	0.17 ± 0.08	0.53 ± 0.23	0.52 ± 0.42	0.16 ± 0.07	0.48 ± 0.21	0.43 ± 0.28	0.90 ± 0.18	0.37 ± 0.13	0.60 ± 0.18	0.71 ± 0.34	0.72 ± 0.25
33	0.18 ± 0.07	0.61 ± 0.36	0.55 ± 0.40	0.14 ± 0.09	0.44 ± 0.16	0.49 ± 0.10	1.00 ± 0.00	0.43 ± 0.08	0.62 ± 0.06	0.62 ± 0.22	0.88 ± 0.20
25	0.22 ± 0.08	0.57 ± 0.26	0.68 ± 0.30	0.15 ± 0.06	0.46 ± 0.24	0.53 ± 0.31	1.00 ± 0.00	0.49 ± 0.18	0.68 ± 0.28	0.69 ± 0.34	1.00 ± 0.00
20	0.21 ± 0.06	0.57 ± 0.26	0.67 ± 0.31	0.19 ± 0.08	0.56 ± 0.25	0.57 ± 0.09	-	-	0.75 ± 0.22	0.77 ± 0.40	-

10	0.24 ± 0.07	0.72 ± 0.26	0.81 ± 0.32	0.20 ± 0.07	0.79 ± 0.36	0.66 ± 0.03	-	-	0.86 ± 0.24	0.78 ± 0.37	-

Table 4.5 Total time required underwater (u/w) to sample one site with a precision =0.10, using LIT and the point intercept transect method with 100 and 50 points respectively. The table reports data relevant to the observer (BM) for whom estimate of time needed using 50 points intercept transects was available.

	METHOD		
	Line Intercept Transects	Point transects (100 points)	Point transects (50 points)
Number of transects required[1]	8	7	8
Time per transect	9.00?0.57 min.	6.00?0.43 min.	4.10?0.43[2] min.
Total time u/w	68.36min.	41.03 min.	32.85 min.

[1] Calculated as $n=[s/(p*mean)]^2$ where p in this case is =0.10 (Andrew and Mapstone 1987).
[2] Estimated in a separate study over eight transects and using the data-sheet shown in Figure 5.3.

4.7.3 Consistency in the use of the procedures

Although estimates of the mean percentage cover of most life-forms did not differ among observers (Section 4.7.1), there was considerable inconsistency in the data recorded from the same transects by the three scientists. The rates of agreement between the reference observer and each other observer were surprisingly low, and ranged between 41.3 ? 3.7% to 55.3 ? 8.1% of the 50 sample points per transect. Almost half of this variation appears to be associated with parallax error and/or movement of the transect line between successive measurements, rather than consistent differences in the interpretation of the life-form categories. When a single observer resurveyed the same transects using point-intercept and line-intercept techniques, an average of between 15 % ± 2 % to 26 % ± 2 % of the same sample points were recorded differently during the repeat survey (Figure 4.5).

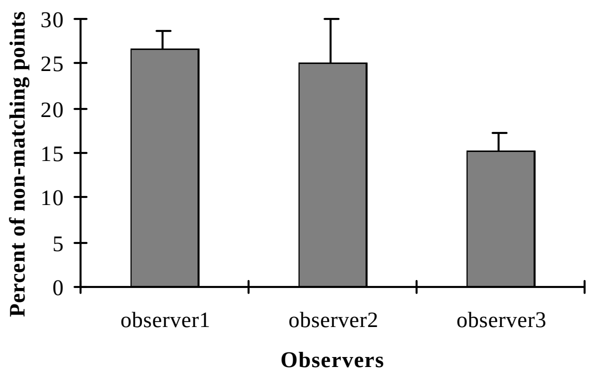
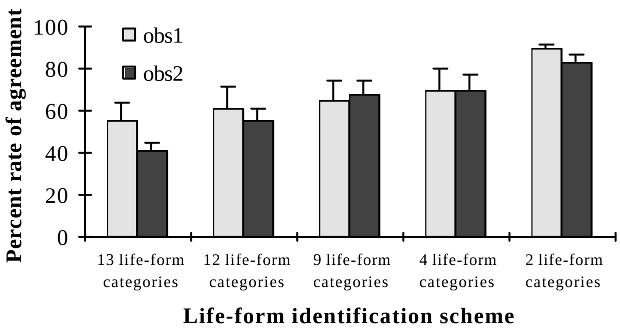


Figure 4.5 Mean estimates (+ SE; n=7) of within-transect error expressed as the proportion of non-matching points recorded along a same transect by each observer.

The degree of consistency in observations varied among the three scientists, with Observer 3 being more consistent on average than the other two observers in recording data from the same sample points (1-way ANOVA Model II; $F = 3.605$, $df = 2{,}18$, $P = 0.048$).

The rate of agreement among observers increased as the level of taxonomic resolution was reduced (Figure 4.6). Five levels of classification were considered sequentially. At the finest level of resolution, the 13 categories listed in Table 4.1 were used. The second classification pooled two coral categories - foliose corals (FC) and encrusting corals (EC) - because of difficulties in discriminating between the two morphologies at the site[2]. At the third level, all corals were identified as belonging to one of only three, very broad categories: branching, laminar and massive corals. Thus, the overall classification contained a total of 9 categories. The fourth level of resolution included just four categories: all hard corals, living substrata (excluding hard corals and algae), non-living substrata, and algae. Finally, the last level discriminated only between hard corals and everything else.

Not surprisingly, sequential pooling of the life-form categories improved rates of agreement, to a maximum value of 90 % ? 1.1% when organisms were grouped as either hard corals or non-corals. There was a large difference (approx. 14%) between the two observers in the rate at which they agreed with the reference observer when all 13 life-form categories were included. As the life-form categories were pooled, the rate of agreement between all three observers increased (Figure 4.6). This suggests that at least part of the variation in the data collected by the experts was due to differences in the interpretation of some of the coral categories.



[2] The site in Nelly Bay contained a large percentage cover of a *Montipora* sp, which displayed considerable variation in morphology, oscillating between "foliose" and "encrusting" forms.

Figure 4.6 Relative mean rates of agreement (± SE; n=3) in the identification of life-form between each observer and the reference observer calculated for five levels of taxonomic discrimination (see text).

4.8 Discussion

Our purpose in these pilot studies was to examine the usefulness of a simplified line-transect procedure - point-intercept transects - for surveys of coral reef benthos and to determine sources of error in its use by trained scientists. By identifying difficulties with the technique in these early stages of the study, we were able to refine the methods for later use with volunteers. Our results show that, for most life-form categories, the point-intercept method was broadly comparable to the more-established line-intercept transects. Estimates of the percentage cover of corals at the Nelly Bay site varied by an average of < 3 % between the techniques, with no apparent bias in the use of point-intercept transects. The average precision of estimates derived by the two techniques was also comparable, with relatively good estimates (S.E./Mean $\leq$ 0.15) being obtained at the site when just seven 10 m point-intercept transects were used.

Precise estimates of percentage cover were obtained when $\geq$ 20 sample points were used per transect. Because the precision of estimates derived from point-sampling techniques also varies with the abundance of the population being sampled (Foster *et al.* 1991, Inglis 1992), we decided to use 50 points per transect in subsequent surveys to maximise the precision obtained at sites with relatively small percentage cover of corals. Importantly, even when 100 points were used per transect, there were significant time-savings in the use of point-intercept transects relative to the line-transect technique. Each point-intercept transect took around 7.2 minutes to survey. Even allowing for their lack of familiarity with underwater survey techniques, this should mean that each buddy-pair of volunteers who are competent divers should be able to complete two transects per dive.

The overall estimates of percentage cover obtained by the observers in this pilot study appeared to be relatively robust to surprisingly low rates of agreement among trained observers in the identification of life-forms. Scientists differed in as many as 26 % of the sample points that they recorded on the same transects. Although some of this inconsistency appeared to be caused by movement of the transect, which may be unavoidable, it is, nevertheless, of concern. Debriefing sessions were held after completion of the field trials to discuss difficulties with the sampling procedures and ambiguity in some of the life-form categories. Information obtained from these sessions was used to refine the decision rules contained in the training materials for discriminating between potentially similar categories.

Given the results obtained in this pilot study, there are indications that differences in interpretation of individual categories have the potential to represent a major source of error in a volunteer-based monitoring program. A major priority for subsequent field trials that involved volunteers, therefore, was to develop the most efficient classification scheme of life-form categories that would maximise the consistency of identification of reef organisms.

The pilot study also highlighted the need to design a more efficient form for recording data from the point-intercept transects. Although the time required to sample the point-intercept transects was significantly shorter than the LIT method, all observers had suggestions for improving the format of the data sheet to make it more user-friendly and efficient underwater. This was therefore set as prerequisite for the field trials involving volunteers (see Section 5.2).

The large inconsistency within and among observers emphasised the need for clearer instructions in the training materials on the protocol for sampling. Subsequent training made particular reference to the angle and distance from which the transect line should be viewed when recording observations. The implications of large within-transect error have been discussed previously in the use of permanently marked transects for reef monitoring, where it may result in inflation of temporal variance and, therefore, be confused with changes in the reef community (Mundy 1991). Where the transects are randomly placed on each survey ? as they are in this study ? inconsistencies in the identification of organisms will contribute to spatial and temporal variance, and are more likely to obscure natural patterns of spatial and temporal change than to contribute to false patterns. It is likely that the size structure and level of aggregation of reef organisms at the site also has an influence on the rates of sampling error and that there may be consistent differences in the rate at which sampling error occurs for different types of organisms. For example, rare life-forms (e.g. sponges) and/or life-forms characterised by small individuals (e.g.. most algae) are more likely to be affected by movement of the transect line and/or parallax error than are more abundant or large life-forms. The abundance of these groups may, therefore, be substantially underestimated, particularly in turbulent environments.

Our results suggest that, with refinement, the point-intercept transect technique is suitable for use by volunteers. It is relatively simple and quick to use, returns data that is comparable to more-established techniques and involves a minimum of equipment and expertise. In subsequent chapters, we trial its use with groups of volunteers and examine the reliability of data obtained by them.

5. DEVELOPMENT OF INTERPRETIVE/TRAINING MATERIALS

5.1 Development of the training program

Interpretive training materials were developed concurrently with the sampling protocol in field trials with groups of volunteers. Training has a fundamental role in volunteer-based research which goes beyond the delivery of instructions on how to perform the sampling tasks (Kepler and Scott 1981; Wells 1995). The contents and procedures of the training program have to ensure consistency among volunteer observers, particularly in their understanding of the system under study and in the way they apply the sampling protocol. It was therefore a priority in this project to develop clear training materials for monitoring of reef benthic life-forms which contained comprehensive and unambiguous information on the identification of organisms and the protocol used for sampling.

The initial development of the training materials was done in consultation with an interpretation officer at James Cook University who had specific experience in the development of interpretation material for SCUBA divers. Evaluation of the initial draft was based both on an assessment of how successful the instructions had been in ensuring consistency among observers and on feedback obtained from the participants (Figure 5.1). Field trials were run to estimate the degree of consistency among observers and to identify elements of the sampling protocol which may cause observers to be inconsistent (see Chapter 6). The training materials were then modified to minimise these sources of inconsistency. Secondly, a formal evaluation of the training materials was sought through a questionnaire distributed among the volunteers who participated in the training and field trials. Responses to the questionnaire included specific suggestions on how to improve the training program (see Chapter 7). In addition, feedback was provided informally by the participants during debriefing sessions at the end of the field trials.

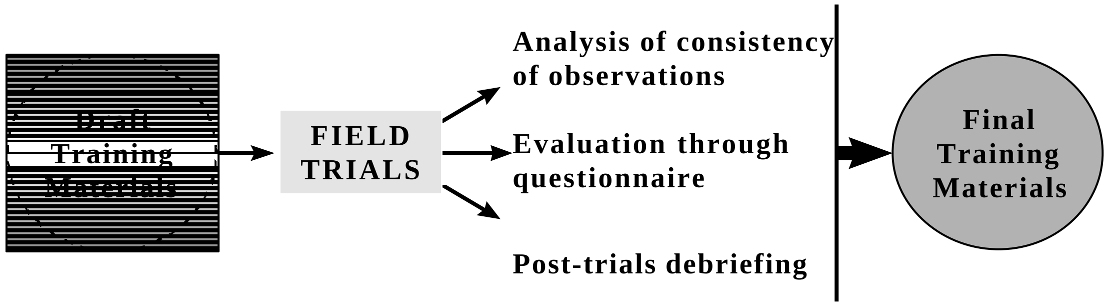


Figure 5.1 Schematic representation of the process of development and refinement of the interpretive materials used in training the volunteers in coral reef monitoring.

5.2 Objectives and outline of the training materials

The training materials developed for the study were intended to address four main objectives:

?? to control the quality of data collected by volunteers by delivering a standardised set of instructions on sampling methodology. Differences among observers may be minimised when all participants receive the same instructions about use of the methods and when these are delivered in a consistent and unambiguous fashion (Kepler & Scott 1981; Inglis & Lincoln Smith 1995). The instructions should be simple and clear and should not lend themselves to different interpretations;

?? to provide educational information on important aspects of reef ecology, research and management relevant to monitoring and about the useful role of volunteer-based programs. Understanding of, and compliance with, sampling procedures may be enhanced when volunteers appreciate the relevance of the tasks they are asked to do.

?? to foster interest and motivation in the program which may encourage the continued commitment necessary for the success of volunteer-based monitoring;

?? to deliver recommendations on responsible behaviour underwater, in relation to both potential environmental damage and personal SCUBA safety.

Tourist operators indicated that video was the preferred medium of interpretation, as it was accessible to all the groups involved (most marine tourist operators carry a video player on-board the vessels). However, for this pilot program, the production costs of a video could not be met, and we considered that a printed draft represented the most cost-effective alternative for the feasibility study.

The training materials included four components: 1) a data recording form designed to facilitate the recording of observations underwater; 2) a script for the training session which was aimed at ensuring consistency in the content and delivery of instructions during the different trials with the volunteers; 3) a photographic guide depicted examples of the life-form categories to be recorded along the transect; and 4) a handbook that was distributed to each participant and which was intended to reinforce the instructions delivered during the training session.

5.3 Data recording form

An important component of the interpretive materials was the data-sheet used by the volunteers to record observations during sampling. In designing an appropriate data-sheet for volunteers our main objectives were: 1) to facilitate the orderly recording of observations, in a way that would also allow accurate data entry; 2) to reinforce the instructions given during training in regard to the criteria for identification of the life-form categories; and 3) to minimise the time necessary for the recording of observations.

A first draft (Figure 5.2) was initially trialed with a group of 8 volunteers. Although none found it difficult to use the data-sheet and all 8 volunteers completed the field tasks successfully, a number of suggestions were made to improve the data-sheet. Accordingly, we prepared a second draft which was then maintained throughout the subsequent trials. This consisted of an A4 underwater sheet which was divided into two sections (Figure 5.3). The upper half of the sheet carried the information on identification of the life-form categories. The icons used in the sheet were the same as those used in the handbook and the photographic guide (see below) in order to facilitate the recollection of the instructions. Each icon was marked with an alphabetic code. A numeric code was used for five health status categories which were recorded for coral colonies occurring beneath each survey point. Coral colonies were attributed to one (or more) health category according to whether they were 1) completely alive i.e.. with no sign of damaged or dead tissue; 2) partially dead, when patches of dead tissue or overgrown skeleton were evident; 3) completely dead, but still recognisable as one of the coral morphologies included in the protocol; 4) bleaching, when all or parts of the colony displayed a characteristically bleached, i.e. white, appearance (there was the acknowledged potential for this category to be easily confused with a freshly dead colony e.g. just preyed upon by crown-of-thorns); and 5) broken, particularly relevant to those branching, digitate, tabulate and bushy colonies, where damage to the structure of the colony was evident. The lower part of the data-sheet consisted of pre-numbered cells, each corresponding to one of the 50 points surveyed along the transect. For each point, two blank cells were provided, one to record the code of the life-form category beneath that point, and the other to record the code for the health status category when the sampling point fell over hard coral. At the top of the page, space was provided for additional information (observer identification, site, transect number, air supply and time). The additional information was intended to allow identification of the data-sheets for data analysis, or included as a requirement of the safety protocol (i.e.. air supply), and to assist in the optimisation of the sampling effort during the development of the monitoring program (i.e.. time). Each volunteer was provided with a perspex board with plastic rings on which several data-sheets were inserted through pre-punched holes.

5.4 Training session, photographic guide and the "Instructional manual for research coordinators"

Before each field trial, a training session (approximately one hour in duration) was delivered by one of the researchers or by the dive master on-board the tourist vessels. The script for the session covered a brief description of the sampling program, including its rationale (with particular reference to scope for volunteer involvement in reef monitoring); an outline of potential environmental threats to coral reefs; how volunteers can monitor reef organisms (with specific instructions on what the life-form categories were, how to survey a line transect and how to record the observations in the data-sheet); best practice underwater and safety issues.

The training session was designed to be an interactive exercise to encourage active involvement of the volunteers. As a result, each session was slightly different to the previous ones. For example, participants in a trial could ask that a particular concept or procedure be explained further. In order to maximise the consistency of the training across different trials while allowing for interactive participation, 'question times' were included within the script at specific points. All the elements included in the script were presented during every session.

The description of the life-forms during the training session was aided by photographs and, when feasible, colour slides. Laminated posters were also used because they are easily handled on the boats. The photographic guide included examples of the general types of reef organisms likely to be encountered and was used to illustrate the grouping of different organisms into life-form categories. Photos for the identification guide depicted the typical appearance of individual life-forms and presented some of the organisms for which identification may be a problem (e.g. common ascidians, which were included in the category "others", but which may be easily mistaken with sponges by non-experts). Each category was represented by an icon, which was used throughout the photo guide, the handbook and the data-sheet. The photos included in the guide were carefully selected from hundreds contained in the personal collection of the interpretation researcher, who also had extensive experience as a professional underwater photographer.

An **"Instructional manual for research coordinators"** (Appendix A) was prepared for trials which occurred when coordinating scientists were not present. In these cases, the dive master took charge of both the training and the field component of the trial. The Instructional manual included the script and also additional information on how to perform the field trial. An Information Sheet was included for the research coordinator to record details of each trial (e.g. date, site, members of a pair, number of transects completed per pair etc.).

5.5 Handbook

The handbook (see Appendix B) was provided as an auxiliary resource to the training session. It was distributed to each participant after the talk. It gave each participant a permanent record of the instructional and educational elements of the procedure which could be used as a reference. It also reinforced the instructions so that, if volunteers were unsure of some of the material, they could consult it again before the field trial. The handbook included the same instructions and information as the script, and also comprised explanatory diagrams to assist in the identification of the reef organisms and in the data collection procedure. At the beginning of the draft handbook it was made clear that the field trials, in which the volunteers were taking part, served as a pilot study for developing a broader program. An outline of the handbook is given in Box 5.1. The Handbook is included as in Appendix B to this report.

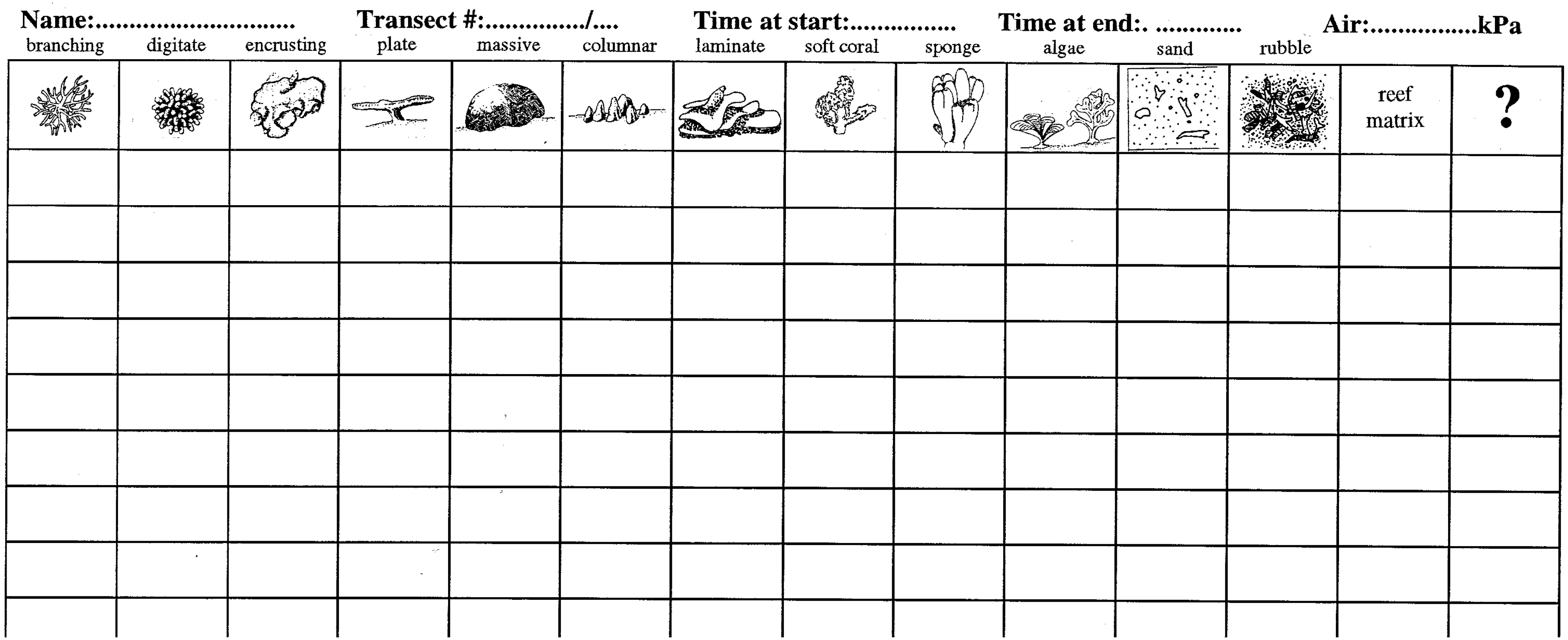
BOX 5.1

OUTLINE OF THE HANDBOOK

1. An introductory text box containing information on the project, the funding agency (the Department of Tourism), other sponsors (CRC Reef Research Centre, Reef Tourism 2005) and contributors.
2. The **"Introduction"** addresses recreational divers as a group particularly suitable to contribute to looking after the marine environment, and briefly outlines the objectives of the pilot study.
3. **"Why care for the Great Barrier Reef?"** highlights the uniqueness of the GBR and the collective responsibility to look after it.
4. **"What do you get out of this?"** identifies the educational value of volunteers' participation in this project, and emphasises the practical learning which results from being involved in volunteer-based research.
5. **"What is coral reef monitoring…"** introduces the concept of environmental monitoring and the need for information-based decisions in natural resources management.
6. **"…and how can you contribute?"** provides a role for recreational divers within the current framework of scientific monitoring on the GBR in particular. Existing volunteer-based schemes are used as an example.
7. **"How do we do the research?"** describes the specific objectives of the pilot study and the tasks that volunteers are asked to perform in order to achieve these objectives. An explanation is provided of how the observations gathered by the volunteers will be translated into useful information, and how this information will be used. One explanatory Text Box, and one illustrated Table, provide information on how to identify the

coral reef life-form categories used in this study. Practical instructions on where and how to record the observations are provided and this is exemplified in a diagram of a section of a coral reef. The data-sheet is reproduced at the back of the handbook, with an example on how to fill it with the observations provided in the diagram.

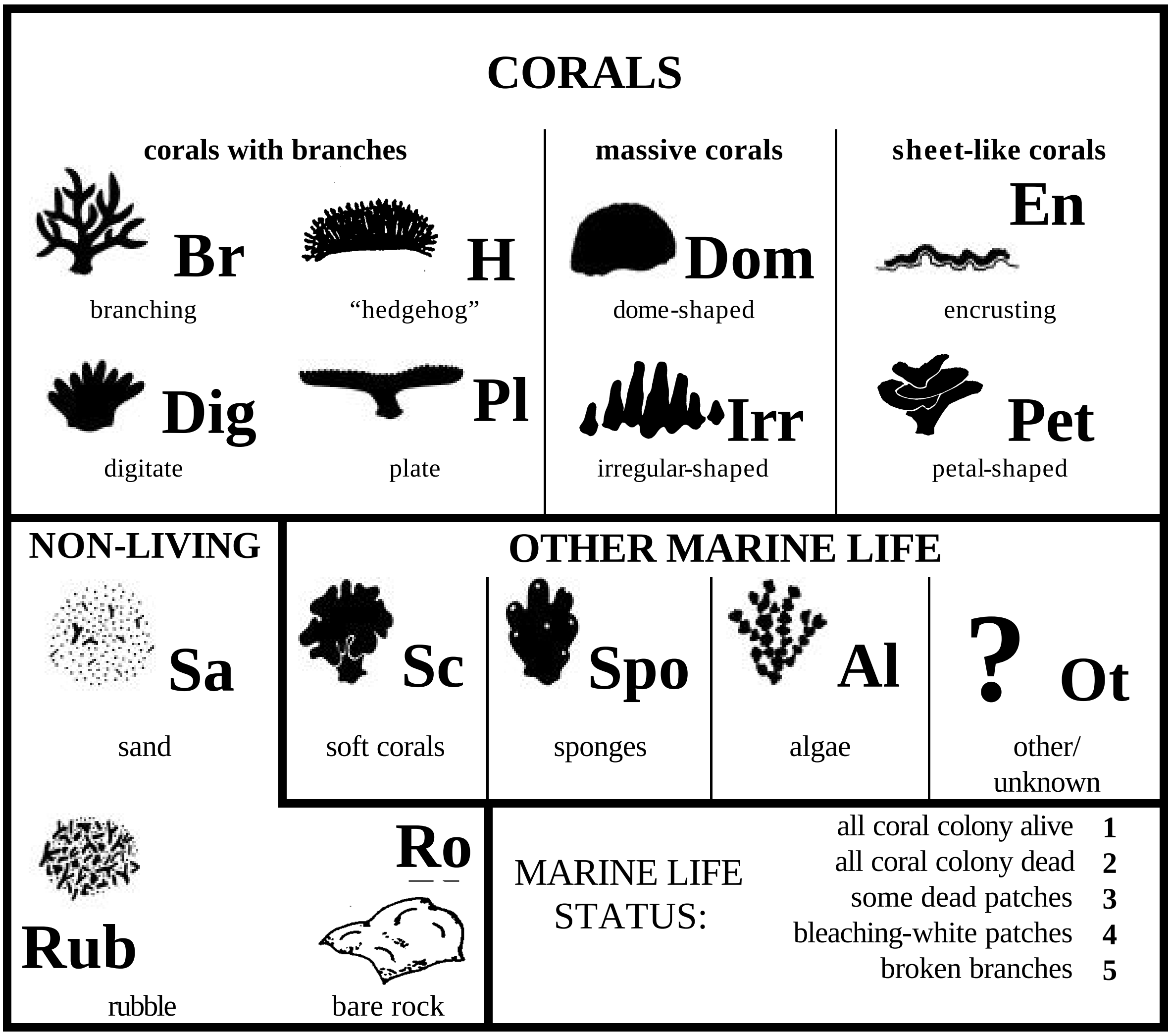
8. **"Working in the water"** provides basic safety recommendations specifically related to the tasks required by the project. Also a call for 'best underwater practice' is included here, with particular emphasis on buoyancy and equipment control. This section also emphasises the importance of feedback by volunteers on both problems encountered during the trial and the value - educational and recreational - of their participation. Volunteers are asked to fill the questionnaire provided at the end of the trial.



Name:.............................. Transect #:.............../.... Time at start:................ Time at end:. .... Air:................kPa

branching	digitate	encrusting	plate	massive	columnar	laminate	soft coral	sponge	algae	sand	rubble	reef matrix	?

Figure 5.2: Data-sheet used during the first trial to record the occurrence of 14 life-forms beneath 50 points regularly spaced along a 10 m line transect.



	cat.	status		cat.	status		cat.	status
20			**360**			**700**		
40			**380**			**720**		
60			**400**			**740**		
80			**420**			**760**		
100			**440**			**780**		
120			**460**			**800**		
140			**480**			**820**		
160			**500**			**840**		
180			**520**			**860**		
200			**540**			**880**		
220			**560**			**900**		
240			**580**			**920**		
260			**600**			**940**		
280			**620**			**960**		
300			**640**			**980**		
320			**660**			**1000**		
340			**680**					

Figure 5.3 Data-sheet used by the participants to field trials 2-6, to record observations of occurrence of 15 life-forms beneath 50 points spaced along a 10m line transect.

6. RELIABILITY OF VOLUNTEER-DERIVED DATA - FIELD TRIALS

6.1 Objectives of the field trials

The coral reef sampling protocol and the training materials (described in Chapters 4 and 5 respectively) were tested in the field with the assistance of volunteer SCUBA divers within the Great Barrier Reef Marine Park and in the Coral Sea. Volunteers were either tourists and/or staff participating in commercial dive tour expeditions from Cairns and Port Douglas, or members of O.U.C.H. - Order of Underwater Coral Heroes - a community group of divers dedicated to the protection of coral reefs in the Whitsundays region, in the Central Section of the GBRMP. The broad aims of the field trials were to: i) assess the logistic feasibility of the sampling protocol; ii) trial, evaluate and refine the training materials and iii) investigate potential biases and errors of data collected by volunteers.

This project was initially prompted by two groups of users of the Great Barrier Reef World Heritage Area (GBRWHA) - i.e. tourist operators and community groups - which independently but concurrently expressed an interest in becoming involved in reef monitoring (see 2.3). The circumstances under which volunteer divers take part in reef monitoring, and their motivations to do so, may affect their performance of the sampling tasks and, as a result, the quality of the data collected. Accordingly, a major objective for trialing the program in the field was to assess the feasibility (both logistic and in terms of usefulness of the outcomes) of involving a variety of volunteers in specific and standardised data-collection tasks. The logistic feasibility of the program was assessed firstly through informal discussion with the participants following field trials. A formal evaluation of the volunteers' response to the program, as well as to the training session and materials, was done through a questionnaire distributed to all volunteers immediately after the field trials. Specific objectives and results of the evaluation are provided in Chapter 7.

This Chapter reports on the objectives, methods and results of the field trials in relation to the third of the objectives outlined above, that is the potential biases and errors in data collected by volunteers. The field trials were intended to return information on the reliability of data collected by groups of volunteers and compare them to data collected by coral reef scientists. In particular, the field trials aimed at assessing:

?? the accuracy and precision of data collected by individual volunteers relative to estimates obtained by scientists. The assessment of the accuracy and precision of data collected by volunteers is required to establish how reliable the outcomes of the volunteer-based monitoring program are. The usefulness, and therefore the value, of the whole program depends upon the quality of the data returned from it. Lack of professional expertise in marine survey methods is likely to affect the accuracy and precision (i.e. repeatibility) of the estimates derived from data collected by volunteers. Absolute accuracy (i.e. how close an estimate is to the real value) is in most cases difficult to determine (Andrew and Mapstone 1987) and in this study we did not attempt it. Instead, we assessed the accuracy and the precision of estimates derived by volunteers relative to estimates obtained from the same sampling units, or from the same site, by trained marine scientists.

?? the inter-observer variation in estimating percent cover of reef benthic organisms. When groups of volunteers sample a reef site, data obtained by different individuals are combined to provide the mean estimates of cover of reef organisms for the site. If the different observers are not consistent in the way they survey a transect, record their observations or identify organisms, they introduce an error which will add to the levels of natural variation in the cover of the reef organisms, and it will make it difficult to detect patterns of change. Such error was measured in this study by comparing estimates obtained by paired observers sampling the same transects. The implications of inter-observer variation on the ability to detect changes between sites are investigated by comparing the power of tests using data coming from scientists and those coming from groups of volunteers.

?? the suitability of the proposed set of life-form categories and categories of coral colony health. As discussed in Section 4.4, consistency of identification is likely to be a major source of error in sampling schemes that involve numerous observers. Identification of reef organisms as belonging to a life-form category depends on individual interpretation of the different categories. Consistency of identification may be estimated by calculating the rates at which volunteers agree in attributing reef organisms to life-form categories. The estimated rates of agreement can be used as an indication of the reliability of the data collected by the volunteers, e.g. when volunteers disagree often in identifying reef organisms then it is likely that the estimates of cover will differ also. Rates of agreement are also useful to evaluate the choice of life-form categories that were included in the sampling protocol and the effectiveness of the training materials to convey unequivocal description of each life-form. For a given category, consistently low rates of agreement indicate the need to include clearer decision rules within the training materials, or to merge similar categories in one less likely to be misinterpreted.

?? the effect and implications of likely sources of bias, such as different levels of proficiency in SCUBA diving of individual volunteers and increasing familiarity with the monitoring tasks. The level of dive proficiency varies widely among recreational divers visiting the GBR. The proficiency of a diver is likely to depend on the extent of previous dive experience and is expected to influence the ability of a diver to successfully perform the tasks required for monitoring. Validation studies conducted by Coral Cay Conservation (a volunteer-based reef assessment program operating in the Belize reef which deploys teams of specially trained volunteer divers to survey the biota and describe the topography and bathymetry of selected reef areas (Raines *et al* 1994)) identified constraints due to diving as an important source of inconsistency among teams and of inaccuracy (relative to scientists) in recording occurrence of corals and macroalgae (Mumby *et al.* 1995). In that study, Mumby *et al.* (1995) suggested that physiological changes experienced by SCUBA divers at depths greater than 30 m, that are known to affect dexterity and concentration, may result in depth related bias in observations of occurrence and abundance of reef organisms. Sampling at depths greater than 20 m was incompatible with the safety protocol developed for this study. There was no need therefore to investigate the effect of depth on data reliability using the protocol developed in this study. However, we considered a priority to investigate the effect of the SCUBA diving proficiency as a potential source of bias in data collected by volunteers because i) it is likely that previous SCUBA dive experience affects the performance of divers and ii) volunteers potentially interested in taking part in monitoring include tourists who are likely to vary widely in their dive experience.

?? the effect of increased practice. Another source of bias examined during the limited field trials was the influence that increased practice with sampling had on the reliability of data collected by volunteers. Dartwall and Dulvy (1996) showed that the sampling precision of estimates of fish abundance obtained by volunteers increased with increased practice, and after approximately 11 dives the precision of the volunteers was only insignificantly lower than the precision of an expert diver. The effect of learning and time required to achieve proficiency in the sampling tasks, is important in the development of volunteer monitoring, to determine the extent of training necessary to achieve a desired level of data quality. This information may assist in determining the optimal training regime for the volunteers who wish to be involved in the program.

Table 6.1 Summary and definition of terms and the potential sources of error in volunteer-based monitoring procedures.

RELIABILITY PARAMETER	DEFINITION
Relative accuracy	Absolute difference between estimates of percentage cover obtained by volunteers and scientists.
Relative bias	The mean value, and direction, of systematic differences in estimates of percentage cover obtained by volunteers and scientists.
Inter-observers variation	Estimate of the variation in estimates of percentage cover obtained by different volunteer observers from the same sampling units.
Relative precision	Measure of the precision of estimates obtained by volunteers relative to the precision of those obtained by trained scientists, express as percent of the latter.
Rate of agreement *	Proportion of sample points per transect under which the same life-form category has been recorded by two different observers.

* This is likely to underestimate the real rate of agreement, as it cannot discriminate between differences due to disagreement and those due to the transect moving or different angles of observation (parallax error). Two independent estimates of the incidence of these two sources of variation are given in Section 4.7.3.

6.2 Methods

6.2.1 Relative accuracy and observer-related bias

In order to assess whether relative accuracy differed among observers and whether individual observers were biased (ie consistently different from a reference scientist) in estimating life-forms cover, a field study was conducted at Blue Pearl Bay, a popular dive site on the fringing reef surrounding Hayman Island, in the Whitsundays group, Central Section of the GBRMP (20°08'S-148°90'E). The trial was done in May 1996 with the assistance of members of the volunteer dive group Order of Underwater Coral Heroes (O.U.C.H.).

The sampling protocol used in this and other field trials was that developed from the pilot study described in Chapter 4. Four or five (depending on the logistic constraints of individual trials) 10 m point intercept transects with 50 regularly spaced points were used in all trials. For five of the six trials, sampling involved recording 15 life-form categories along the transect line (see 6.2.2 and Table 6.3). During those trials, when the organism recorded was a coral life-form, one of five colony health status parameters - coded 1 to 5 - was entered in a separate column (Table 6.4). The health status parameter described the state of the whole colony, not just the portion of the colony beneath the transect line. The time at start and finish of the transect, and the reading of the air pressure gauge, were also recorded for each transect. Data were recorded using the data-sheet shown in Figure 5.3. In all trials, a training session of approximately one hour was delivered to all observers immediately prior to the field study. The training session was designed to explain the objectives of the trial, to instruct the observers in the procedures required for sampling and to explain the criteria for the identification of reef organisms (see 5.3 for details).

The field trial described in this section used the same sampling technique, but classified reef organisms into 14 life-form categories (Table 6.2). The data-sheet used by the observers in this trial was the one shown in Figure 5.2.

The relative accuracy and bias (see Table 6.1) of volunteer-derived estimates were assessed by comparing estimates of the percent cover of life-forms made on the same sampling units by a group of five O.U.C.H. volunteers and by a marine scientist, the latter with more than 5 years experience in assessing reef benthic communities. The marine scientist was used as a reference against which to compare estimates obtained by non-experts. This approach does not imply that the reference scientist is necessarily more accurate, in absolute terms, than any of the volunteers. Rather it represents the only feasible way, at least within the scope of this project, to assess the accuracy of non-experts relative to each other and to an expert observer.

Table 6.2 Definition of the fourteen life-form categories used in the first field trial with volunteers.

LIFE-FORM CATEGORY	DEFINITION
CORAL BRANCHING	Colonies with ramifying branches; includes caespitose, corymbose and arborescent morphologies and branching *Millepora* spp.
CORAL DIGITATE	Colonies with finger-like projections - sometimes these may have short and stout ramifications
CORAL ENCRUSTING	Thin, laminar coral colonies which adhere to the substratum
CORAL PLATE	Colonies forming a table upheld by a stalk - tabular portion made up of little and compact branchlets
CORAL MASSIVE	Dome shaped and sub-spherical coral colonies, including meandering morphologies (brain corals)
CORAL COLUMNAR	Colonies with massive column-like vertical projections

CORAL LAMINATE	Laminar colonies forming thin plates projecting into the water (includes 'cabbage-like' corals)
SOFT CORALS	All morphologies of soft corals
SPONGES	All morphologies of non-cryptic sponges
ALGAE	All types of algae including corallines
SAND	Abiotic substrate made up predominantly of fine sand
RUBBLE	Abiotic substrate made up predominantly of fragments of skeletons of corals and other organisms
REEF MATRIX	Apparently bare reef substratum, not obviously covered by any organisms visible to the naked eye
?	All biotic and abiotic components which do not belong to the above categories

The five volunteer observers and the scientist, each sampled five transects at each of two adjacent sites. The transects were not randomly placed on the reef surface, as our purpose was to encompass a diverse number of reef organisms during the trial. This was done to maximise the number of life-forms covered by the transect, as an important objective of the study was to compare the rate of agreement of identification among observers (see 6.2.4). The two sites were approximately 30m apart and were also located at slightly different depths (3-4 and 6-8 m respectively), with the aim of encompassing different reef organisms assemblages.

Differences in relative accuracy among observers were analysed using a Repeated Measures two-way ANOVA, with 'observer' being the within-subject factor and 'site' being the between-subject factor. Response variables analysed using this model included both the differences in cover estimates between volunteers and the reference scientist, expressed as proportion of the estimate made by the scientist, and the absolute value of the differences. To assess whether estimates obtained by the group of volunteers were significantly different from the reference scientist, the hypothesis that the average difference across transects was zero was tested for each life-form category using t-tests and considering the ten transects as replicates.

6.2.2 Methods - Inter-observer variation in estimates of life-forms cover

In order to investigate the effect of professional expertise on between-observer variation and precision, a field study was undertaken where independent estimates of percent cover were obtained by pairs of volunteers and pairs of scientists. This study was undertaken in October 1996 at Blue Pearl Bay (see 6.2.1) with the assistance of six members of O.U.C.H.. For a description of the sampling protocol see previous section (6.2.1).

Two pairs of marine scientists and three pairs of volunteers took part in the trial. Each pair sampled five randomly placed 10m line transects. Inter-observer variation was calculated as the coefficient of variation in estimates of percent cover estimates between the two members of a pair for each transect. The effect of professional expertise (or lack thereof) on the inter-observer variation was analysed using a mixed model nested ANOVA, with expertise as fixed factor - with two levels, scientists and volunteers - and pair as a random factor nested within expertise. Cell replication consisted of five transects. As the design was unbalanced with respect to pair, in order to ensure robustness of the tests, even slight heteroscedasticity was corrected for by appropriate transformation of the data and the Type III Method was used to calculate the Sums of Squares (SPSS Release 7).

Table 6.3 The fifteen life-form categories used in 5 of the six trials. Codes, names and description shown in the table are those used in the training materials distributed to the volunteers.

CORALS WITH BRANCHES

A. Branching Coral colonies with slender branches resembling antlers. Commonly called "staghorn" corals	**B. Digitate** Distinguished by short and stout finger-like branches.
C. "Hedgehog" Coral colonies with a regular length branches and a bushy appearance. Their shape resembles a hedgehog or porcupine.	**D. Plate** Colonies that are plate like, with a stalk. Similar to the shape of most mushrooms.

MASSIVE CORALS

E. Dome-shaped Corals with a dome-like shape. They vary in size from very small heads to huge colonies few meters in diameter.	**F. Irregular-shaped** Massive corals that grow in irregular shapes. Some of them may resemble columns or blades.

SHEET-LIKE CORALS

G. Encrusting Corals that form a thin layer growing on the reef surface. May assume the shape of the organisms thay overgrow.	**H. Petal-shaped** Thin, petal-like corals sometime occurring in a layered formation.

OTHER MARINE LIFE

I. Soft Corals They are relatives of corals but they have a soft although firm body. Some grow upwards on a stalk, while others lay flat on the reef.	**J. Sponges** Filter-feeders which come in a variety of shapes and textures. Soft bodies with many tiny holes (water goes in) and few large holes (water goes out).
K. Algae There are many different fleshy or hard algae, varying in colour from green to red and brown. They may be either encrusting or free standing.	**L. Other/Unknown** Anything that does not fall within the above categories or is uncertain or unknown. This category provides information for a full 100% coverage.

NON-LIVING

M. Sand includes fine sediments like you found on the beach.	**N. Rubble** is made of fragments of broken corals and other organisms.	**P. Bare Rock** means areas of bare reef rock with no apparent lifeform

Table 6.4 Definition of the five broad coral colony health parameters used in the sampling protocol.

Code	Colony Health Status	Definition
1	*Colony 100% alive*	Coral tissue is alive throughout the colony.
2	*Colony partially dead*	Some dead patches of coral tissue evident on the colony
3	*Colony 100% dead*	All coral tissue is dead but the coral morphology is still identifiable. Coral skeleton overgrown by filamenatous algae and other organisms.
4	*Colony bleaching*	Some white patches evident on the colony. This category may include both episodes of bleaching or freshly killed patches of tissue as these may be difficult for volunteers to differentiate.
5	*Colony broken*	Applicable to corals with branching morphology – from A to D – which show signs of fractures.

6.2.3 Precision of estimates of life-forms cover

Estimates of the precision of the sampling technique when used by volunteers and scientists were obtained for data of total coral cover and individual life-forms collected during the field trial described in the previous section (6.2.2). Precision was estimated as the mean to Standard Error ratio (Andrew and Mapstone 1987). Precision estimates were compared between volunteers and scientists using a Repeated Measure design where expertise was the between-subject factor and observer within pair was the within subject factor. Replication was provided by pairs within each category of expertise.

6.2.4 Methods - Detecting differences between sites

To investigate the implications of inter-observer variation on the ability to detect changes in reef assemblages, the power to detect differences between two sites was investigated for data collected by a pair of scientists and 2 groups of eight volunteers. The study was undertaken during a field trial conducted in November 1996 in collaboration with staff and customers on-board the *Undersea Explorer*. Data were collected at two sites on Osprey Reef, in the Coral Sea, approximately 150 nautical miles North-North East of Cairns (approx. 13°80'S-146°60'E). At each site, four 10m transects were placed randomly on the reef surface. The first site was chosen solely on the basis of safety and logistics (it was relatively shallow (8m) and close to the start of the dive track regularly visited by divers from the *Undersea Explorer*), while the second site was selected because it appeared very different in cover and coral assemblages from the first one. The sites were approximately 4 nautical miles apart.

A pair of scientists and 4 pairs of volunteers surveyed the transects at each site. The pairs of volunteers who sampled the second site were not the same as those who sampled the first site (two volunteers participated in the trial at both sites, but as part of a different buddy pair). Due to the schedule of the trip, each pair was able to sample only one transect per dive. This was because the boat was anchored at each site only for the duration of the dive, and the paying tourists wanted to have a chance to explore the site as well as taking part in the research trial. Each buddy pair stopped at the site and carried out the sampling as part of the decompression stop. At each site, therefore, the pair of scientists surveyed all four transects, while each pair of volunteers surveyed only one transect. The aim of the study was to compare the power to detect differences between the two sites when the data were collected by a number of pairs of volunteers - and when potential inter-observer effects were ignored - versus a survey done using the same transects by a single scientist (or in this case a single pair of scientists) as in a regular scientific monitoring program. Separate one-way ANOVAs were done on the mean estimates of percentage cover of total coral and individual life-forms obtained at the two sites by the scientists and by the volunteers respectively. *A posteriori* power values, calculated for the test of the effect of site, were compared between scientists and volunteers.

6.2.5 Methods - Consistency in the identification of life-form categories

To investigate the robustness of the proposed set of life-form categories for use in the surveys, we examined the consistency in the identification of life-forms among observers. During all the trials, repeated observations were taken for all transects by paired volunteers and scientists. This allowed us to estimate the rates of agreement between scientists and volunteers and the agreement within pairs of volunteers and pairs of scientists in attributing reef organisms to the set of life-form categories. Agreement was measured as the proportion of total points surveyed by a pair of observers for which the two observers had identified the same life-form.

The rate at which five volunteers agreed with a reference scientist at two sites were calculated from the data collected during the field trial described in section 6.2.1. Differences among observers in rates of agreement with the reference identification were analysed using a Repeated Measures two-way ANOVA, with 'observer' being the within-subject factor and 'site' being the between-subject factor.

To examine whether volunteers were more likely to disagree in identifying specific life-forms than scientists, the agreement of paired scientists in the identification of life-forms was compared to the agreement of paired volunteers by pooling observations over three of the six trials (the remaining trials involved only one or no scientist). Merging the data provided a larger number of observations for each category. This was done in order to calculate rates of agreement for those categories which were poorly represented in the benthic assemblages surveyed (e.g. SP, SC and OT). In order to investigate whether differences in consistency of identification due to expertise occurred with decreasing degree of taxonomic resolution, data were manipulated by sequentially grouping the life-forms into broader categories. Agreement between paired scientists was then compared with that of paired volunteers when life-forms were classified using i) all 15 categories; ii) 5 categories ("corals with branches", "massive corals", "sheet-like corals", "biotic/non-corals", "abiotic"; see Table 6.3) and iii) 3 categories ("hard corals", "biotic/non-corals" and "abiotic").

Data collected during the field trial on-board *Undersea Explorer* (see section 6.2.4 for sampling protocol and design) were used to compared graphically the agreement rates between one pair of scientists and eight pairs of volunteers. During the same trial, an estimate of the rate of agreement between scientists and volunteers in the identification of life-form categories was also obtained through a laboratory test. An underwater video which included at least 38 reef organisms under a line transect was taken during a field trial on-board the *Undersea Explorer*, a dive tourism vessel operating 6-day trips out of Port Douglas to the outer barrier reefs and the Coral Sea. The video was taken by one of us (BM), who also classified each of the 38 organisms into one of the 15 life-form categories. This identification was used as a reference against which identification by 2 scientists and 10 volunteers was compared. The video was shown to both scientists and volunteers following the training session, but prior to the field trial. Identification of the 38 reef organisms was recorded on the same data-sheet used underwater, simultaneously but independently by each observer. Rates of agreement were compared between scientists and volunteers using a Mann-Whitney test.

6.2.6 Methods - Effect of SCUBA diving experience

The effect that competence as a SCUBA diver had on the reliability of data collected by volunteers was investigated in a field study conducted at Blue Pearl Bay (see 6.2.2.l) in May 1996. Eight volunteers, with varying levels of dive experience, participated in the trial. The volunteers were classified according to whether they had < 30 logged dives since gaining formal qualification ('inexperienced' divers), or > 100 logged dives ('experienced' divers). Five 10m transects were positioned on the reef flat at a depth of approximately 4 m. All eight volunteers and one scientist surveyed the five transects and recorded the life-form categories beneath 50 regularly spaced points on each transect.

To establish whether the level of SCUBA diving experience affected the reliability of data collected by volunteers, we compared i) the relative accuracy of inexperienced and experienced divers (see Table 6.1), ii) the extent of variation among observers of estimates obtained by experienced and inexperienced divers and iii) the agreement of the experienced and inexperienced divers with the reference scientist in identifying life-forms.

The hypothesis that there was no difference among the two groups in relative accuracy and rate of agreement was tested using a Repeated Measure 2-way ANOVA. Repeated

Measures was used to account for the lack of independence among observations across observers (as both experienced and inexperienced divers sampled the same transects). In the model, 'transect' was the within-subject fixed factor and 'group' was the between-subject, fixed factor which included the levels 'experienced' and 'inexperienced'.

The hypothesis that variation among observers did not vary between the two levels of dive experience was tested using a two-way ANOVA (dive experience as fixed factor and transect as random) on the deviates for each observer (absolute values of the differences between each observation on a transect and the Grand Mean for that transect). A paired t-test on the standard deviation of observers for each transect was done to test whether the spread of observations from each sampling unit was the same for 'inexperienced' and 'experienced' divers.

Because time restrictions are a particularly important factor in planning cost-efficient sampling designs in marine environments - due both to the cost of vessels and to the physiological constraints posed by SCUBA diving - the effect of dive experience on the time required to complete a transect was also investigated. The time at start and end of each transect was recorded by each observer on the data-sheet. The hypothesis of no effect of dive experience on time required per sampling unit was tested using the same Repeated Measure design described above.

6.2.7 Methods - Learning effect

To investigate whether reliability of data collected by volunteers improved with practice (i.e.. there was a learning effect), we examined how the relative accuracy of estimates and agreement with a scientist in the identification of life-forms changed over consecutive transects. Although observers working at the same trials would usually survey numbered transects in different orders for reasons of efficiency, observers were asked to record the time at the start and at the end of each transect surveyed. This meant that for each observer the temporal sequence of the transects was known. Estimates of percent cover were ordered temporally for each observer. The sequence of transects, from 1 to 5 for each of two sites, was used as a covariate representing the number of transects completed. The significance of the relationship between the number of transects completed and both the relative accuracy and the agreement with reference identification were analysed with an ANCOVA, in which number of transect completed was the covariate, and site was a random factor crossed with the random factor observer. The tests for site and observers were likely to have an inflated Type II Error due to the non-independence of error- as the same transects were sampled by the same observers at each site. However, the test of interest – that is the effect of number of transects completed - did not have this problem as different observers sampled the same transects in different order.

6.3 Results

6.3.1 Relative accuracy of estimates obtained by volunteers

The relative accuracy in estimating total coral cover- measured as the deviation from estimates made by the scientist - varied significantly among volunteer observers (Table 6.5, Figure 6.1). There was no significant difference in relative accuracy between the two adjacent sites (Table 6.5), although power for this test was small (observed 1-?=0.06, at ? =0.05).

All observers estimated a smaller cover of hard coral at Site 2 (Figure 6.2), but no significant difference was detected between the sites (Table 6.6). The reference scientist estimated a mean percentage cover of 58 ? 5.9 % (SE, *n*=10) for all hard coral at the two sites, and estimates obtained by the volunteers ranged between 52.8 ? 7.2 % to 58.2 ? 7.0 % (Figure 6.2).

Table 6.5 Analysis of the deviation in total coral cover between volunteer observers and a scientist for five observers and for two sets of line transects.

Source of variation	df	MS	F	p
Within-subjects:				
Observer	4	62.68	4.31	**.00**
Observer*Site	4	23.48	1.61	.19
Residual	32	14.53		
Between-subjects:				
Site	1	9.68	.035	.85
Residual	8	272.8		

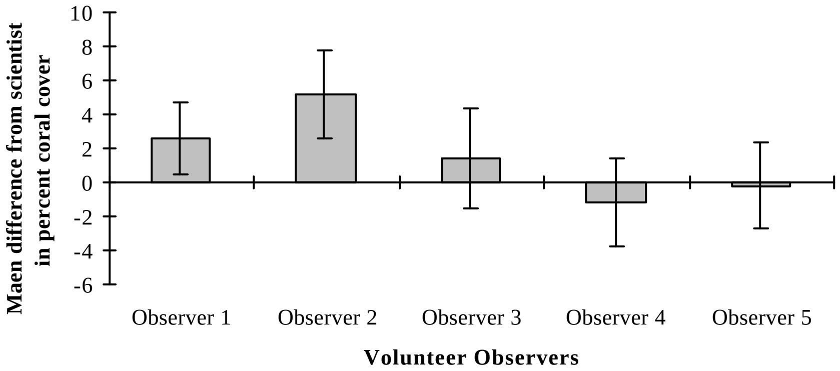


Figure 6.1 Mean relative accuracy of the five volunteer observers, measured as the deviation from the reference estimate across all transects (i.e. scientist minus volunteer).

Deviation from the reference scientist ranged between -5.20 ? 2.48 % to 1.2 ? 2.61 % across volunteer observers (SE, n=10) (Figure 6.1). One out of the five volunteers (Observer #2) consistently under-estimated total coral cover compared to the reference scientist (t_s=2.10, df=9, $p_{0.05(1)}$? 0.03).

The negative bias of this observer was probably responsible for the significant difference in relative accuracy among observers shown in Table 6.5. In fact, the absolute values of the differences from the reference scientist, analysed using the same model, did not vary among observers (F_s=0.474, df=4,32, p=0.75; observed power at ? =0.05 was 1-?=0.14).

The mean absolute deviation from the reference estimate of total coral percent cover was 6.28 ? 0.68% (SE; n=50). When expressed as a proportion of the estimate of cover at the sites, the mean accuracy of the volunteer observers relative to the scientist was 90.97 ? 1.25% (SE; n=50).

Table 6.6: ANOVAs of estimates of total coral cover compared between sites.

Observer	Source of variation	df	MS	F	p	Observed (1-?)	Estimate of % cover (? SE)
Scientist	Site	1	360.0	1.02	0.34	0.09	58 ? 5.9
	Error	8	352.1				
Volunteer #1	Site	1	291.6	0.65	0.44	0.06	55 ? 6.7
	Error	8	447.6				
Volunteer #2	Site	1	313.6	0.59	0.46	0.06	52.8 ? 7.2
	Error	8	527.0				
Volunteer #3	Site	1	384.4	0.64	0.44	0.06	56.6 ? 7.7
	Error	8	601.0				

Volunteer #4	Site	1	102.4	0.17	0.68	0.03	59.2 ? 7.7
	Error	8	595.4				
Volunteer #5	Site	1	547.6	1.10	0.32	0.09	58.2 ? 7.0
	Error	8	496.0				

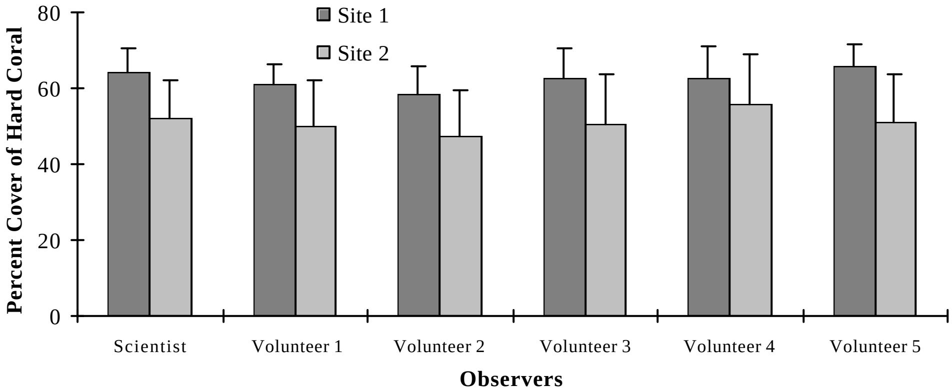


Figure 6.2: Mean estimates (+ SE, *n*=5) of percentage cover of all hard corals obtained by sampling the same set of five transects at two sites by six observers.

The volunteer observers differed in the relative accuracy with which they estimated cover of encrusting, massive and soft corals and the life-form category “reef matrix” (Table 6.7). Relative accuracy in the estimation of “reef matrix” was also affected by the site (Table 6.7). Volunteers as a group obtained percent cover estimates which did not differ from those obtained by the scientists for most of the life-form categories (Figure 6.3). However, volunteers were clearly biased, relatively to the scientist, in estimating cover of columnar and digitate corals (Table 6.8; Figure 6.4). When these two similar categories were merged, there was no difference in the estimate of cover at the two sites between the scientist and the volunteers, suggesting that volunteers were consistently classifying as digitate those coral colonies which were identified as columnar by the scientist. (Table 6.8; Figure 6.5). The mean difference in estimating percent cover for individual life-forms ranged between -6.00 ? 3.06% to 5.84 ? 2.82% (SE; n=10) across the 14 categories.

Table 6.7: Repeated Measures ANOVA of the relative accuracy of each observer relative to a reference scientist in estimating percentage cover of each life-form.

Category	**Mean deviation from scientist**	**Within-subjects source of variation**					**Between-subjects source of variation**				
		Source of variation	df	MS	F	p	Source of variation	df	MS	F	p
Coral Branching	- 0.9 ? 0.6	Observer	4	5.80	2.18	0.09	Site	1	4.50	0.24	0.63
		Observer*site	4	6.40	2.41	0.07	Residual	8	18.05		
		Residual	32	2.65							
Coral Columnar	- 3.0 ? 1..3	Observer	4	0.95	1.0	0.42	Site	1	288.00	2.9	0.12
		Observer*site	4	0.95	1.0	0.42	Residual	8	96.50		
		Residual	32	0.95							
Coral Digitate	2.9 ? 1.21	Observer	4	0.77	0.58	0.67	Site	1	307.52	4.15	0.07
		Observer*site	4	0.67	0.51	0.72	Residual	8	74.07		
		Residual	32	1.30							
Coral Encrusting	- 2.6 ? 1.4 to 3.3 ? 1.0	Observer	4	4.43	4.46	**0.00**	Site	1	0.18	0.025	0.87
		Observer*site	4	2.33	2.34	0.07	Residual	8	7.08		
		Residual	32	0.99							
Coral Massive	-1.1 ? 0.5 to 0.30 ? 0.57	Observer	4	2.67	3.63	**0.01**	Site	1	0.50	0.06	0.81
		Observer*site	4	0.65	0.88	0.48	Residual	8	8.31		
		Residual	32	0.73							
Rubble	1.1 ? 0..9	Observer	4	6.40	1.41	0.25	Site	1	220.50	5.14	0.05
		Observer*site	4	13.10	2.88	**0.03**	Residual	8	48.80		
		Residual	32	4.50							
Reef Matrix	-3.5 ? 0.87 to 1.3 ? 0.99	Observer	4	36.5	6.72	**0.00**	Site	1	212.18	5.86	**0.04**
		Observer*site	4	8.0	1.47	0.23	Residual	8	36.20		
		Residual	32	5.4							
Sand[1]	0.38 ? 0.22	Observer	4	1.22	1.50	0.22	Site	1	0.18	0.07	0.79
		Observer*site	4	1.58	1.94	0.12	Residual	8	2.55		
		Residual	32	0.81							
Soft Corals	-1.8 ? 0.64 to 2.8 ? 0.70	Observer	4	26.50	8.85	**0.00**	Site	1	0.72	0.15	0.70

Observer*site	4	5.12	1.71	0.17	Residual	8	4.67
Residual	32	2.99					

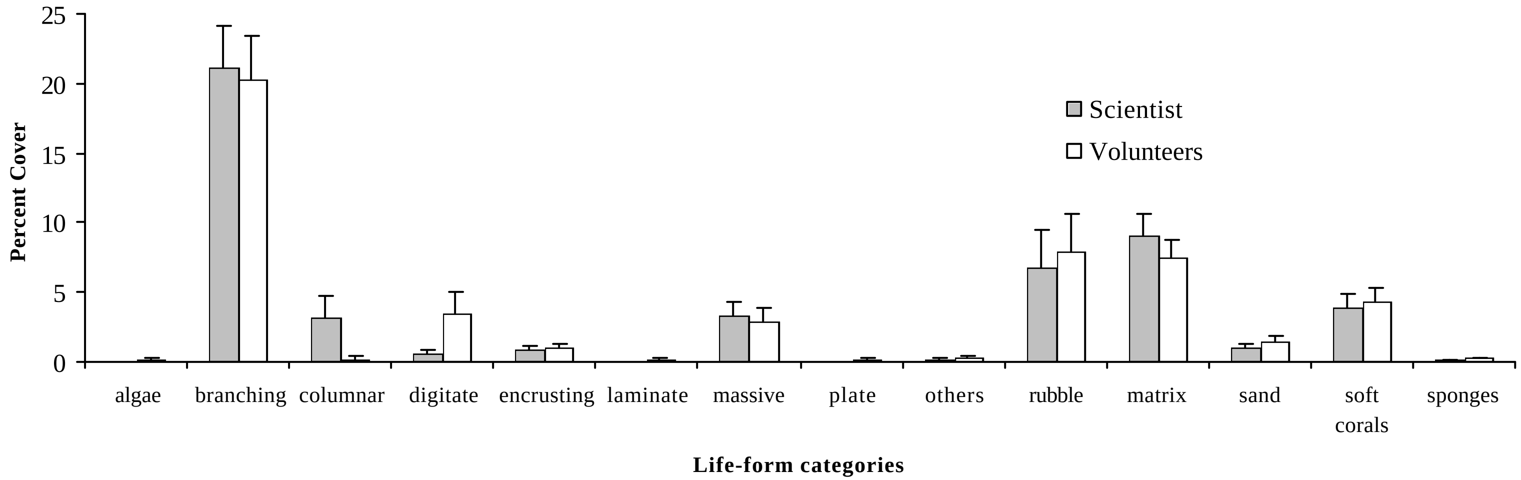


Figure 6.3: Mean estimates of percentage cover for the 14 life-forms obtained by one scientist and a group of five volunteers for the two sites. Error bars are Standard Errors (*n*=10).

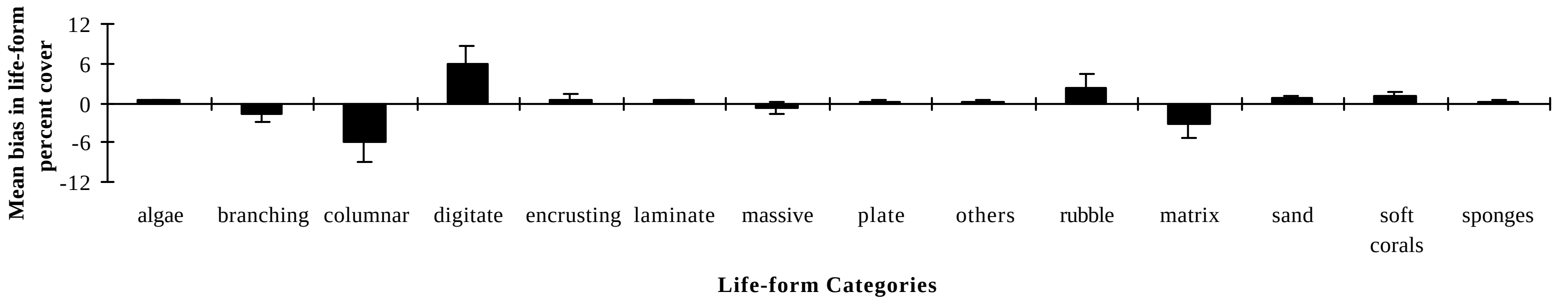


Figure 6.4: Mean difference per transect in estimates obtained by a reference scientist and the five volunteers for each of the 14 life-form categories. Error bars are Standard Errors, n=10.

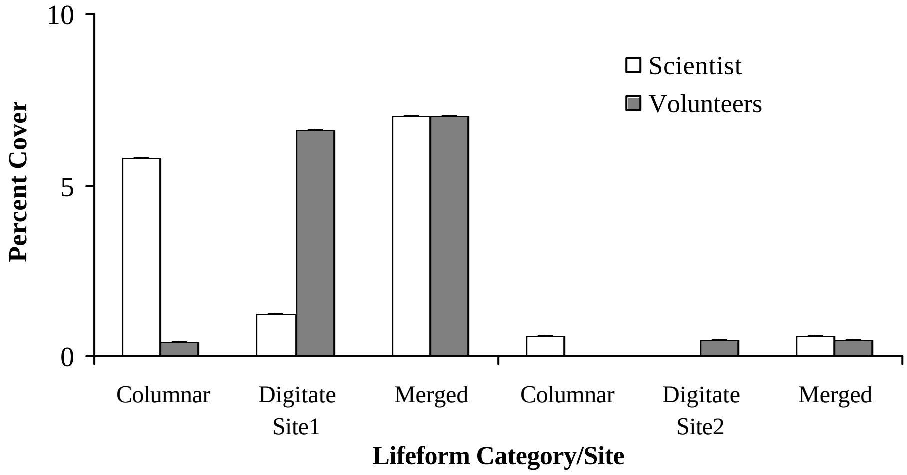


Figure 6.5: Mean estimates (+SE; *n*=5) of percent cover at the two sites for the categories “columnar” and “digitate” corals and for the two categories merged, obtained by a scientist and a group of volunteers from five transects.

Table 6.8: Repeated Measures ANOVAs of the percent cover of columnar, digitate corals and columnar and digitate merged together, compared between two sites and between a scientist and a group of volunteers (estimates obtained by volunteers were measured as average across observers on each transect).

Source of variation	**Columnar Corals[1]**				**Digitate Corals[1]**				**Columnar and Digitate Corals Merged**			
	df	MS	F	p	df	MS	F	p	df	MS	F	p
Within subjects:												
Expertise	1	0.61	5.04	0.05	1	0.41	11.1	0.01	1	0.03	0.04	0.84
Expert.*Site	1	0.26	2.17	0.17	1	0.17	4.64	0.06	1	0.03	0.04	0.84
Residual	8	0.12			8	0.03			8	0.74		
Between subjects:												
Site	1	0.53	12.87	0.00	1	1.36	50.1	0.000	1	209.9	8.02	0.02
Residual	8	0.04			8	0.02			8	26.16		

[1] Variables transformed as x’= Log(x+1).

6.3.2 Variation among volunteer observers

Inter-observer variation, measured as the coefficient of variation between two members of a pair estimating percentage coral cover on the same transect, was not affected by the level of expertise - i.e. scientists and volunteers - and was significantly different across pairs at ? =0.10 (Table 6.9; Figure 6.6). The coefficient of variation of paired observers ranged across pairs between 6.9 ? 2.5 % and 31.8 ? 7.0 %, indicating that considerable inaccuracy may occur even among professionally trained observers. Estimates of total coral cover for the site ranged across pairs between 38.8 ? 7.5 % to 66.6 ? 7.4 % (SE; *n*=5).

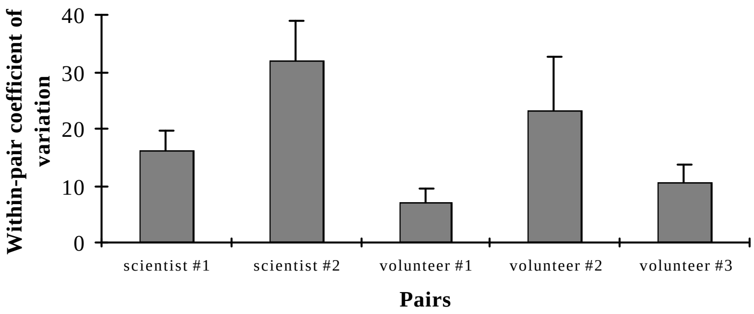


Figure 6.6: Mean within-pair variation (+SE; *n*=5) in the estimation of total coral cover, measured as coefficient of variation of estimates obtained by paired observers.

Table 6.9: ANOVA of the coefficient of variation per transect of the estimates of percent cover of all hard corals obtained by the two members of a pair, compared among different pairs and between pairs of scientists and pairs of volunteers.

Source of variation	df	MS	F	p
Expertise	1	645.58	1.43	0.31
Pair(Expertise)	3	451.32	2.72	0.07
Residual	20	165.48		

The absolute difference between the estimates of cover of digitate corals obtained by the paired observers was significantly greater for pairs of volunteers when compared with pairs of scientists (Table 6.10). This indicates that, for digitate corals, volunteers are likely to introduce additional error to the level of natural variability. Significant difference in within-pair variation, occurred among pairs for the life-forms dome-shaped (i.e.. massive) corals and bare rock (i.e.. reef matrix) (Table 6.10), indicating that paired observers may, or may not, vary considerably in the interpretation of these categories. For these two categories, the differences in cover estimates between the two observers of a pair, were as high as 12.8% (? SE = 2.1) and 14.4% (? SE = 3.9) respectively. For the other life-forms with estimates of cover greater than 2% (branching encrusting and soft corals, and sand and rubble), there was no effect of expertise or pair on the within-pair variation (Table 6.10). When mean estimates per pair of percentage cover of life-forms were compared between scientist and volunteers, these two groups were found to differ significantly in estimating cover of digitate corals (F_s= 74.15; df= 1,3; p= 0.003; Table 6.10). This indicates that volunteers not only introduce additional error in data of cover of digitate corals, but also have a different interpretation of this category compared to scientists. Estimates of percent cover of encrusting corals differed significantly among pairs (F_s= 4.01; df= 3,20; p= 0.02; Table 6.10). There was no difference between scientists and volunteers and among pairs in estimating cover for the remaining life-form categories (Table 6.10).

Table 6.10: ANOVAs of the absolute difference per transect between the estimates of cover of life-forms obtained by paired observers, and of the mean estimates of cover per pair, compared among different pairs and between pairs of scientists and pairs of volunteers. Data were transformed as x’=Log(x+1) for the categories Digitate and Dome-shaped corals in the ANOVAs of the inter-observer difference and for Encrusting corals and Sand for the ANOVAs of the mean estimates of cover.

Category	**Inter-observer difference**						**Mean estimate of cover**					
	Source of variation	**df**	**MS**	**F**	p	**Inter-observer difference (%)**	**Source of variation**	**df**	**MS**	**F**	p	**Percent Cover**
Branching corals	Expertise	1	3.22	0.09	0.78	2.3 ? 0.3	Expertise	1	60.16	0.14	0.73	20.0 ? 3.1
	Pair(Expertise)	3	35.51	1.22	0.32		Pair(Expertise)	3	428.61	1.71	0.19	
	Residual	20	28.96				Residual	20	250.00			
Digitate corals	Expertise	1	10.52	11.66	**0.04**	*Sc.*: 0.15 ? 0.07	Expertise	1	55.20	74.15	**0.00**	*Sc.*: 0.70 ? 0.74
	Pair(Expertise)	3	0.90	1.45	0.25	*Vol.*: 1.6 ? 0.32	Pair(Expertise)	3	0.74	0.13	0.93	*Vol.*: 3.73 ? 0.60
	Residual	20	0.61				Residual	20	5.54			
Dome-shaped c.	Expertise	1	1.11	0.63	0.63	2.4 ? 0.7 to 14.4 ? 3.9	Expertise	1	328.56	3.97	0.14	17.04 ? 1.92
(i.e.. massive)	Pair(Expertise)	3	3.98	0.007	**0.00**		Pair(Expertise)	3	82.66	0.89	0.46	
	Residual	20	0.73				Residual	20	92.82			
Encrusting corals	Expertise	1	0.42	0.06	0.82	0.92 ? 0.15	Expertise	1	0.15	0.38	0.57	1.4 ? 0.5 to 9.4 ? 3.2
	Pair(Expertise)	3	7.11	2.06	0.13		Pair(Expertise)	3	0.39	4.01	**0.02**	
	Residual	20	3.44				Residual	20	0.097			
Soft corals	Expertise	1	2.66	0.93	0.40	1.18 ? 0.20	Expertise	1	10.66	0.06	0.81	11.0 ? 1.7
	Pair(Expertise)	3	2.84	0.30	0.82		Pair(Expertise)	3	166.17	2.16	0.12	
	Residual	20	9.44				Residual	20	76.64			
Sand	Expertise	1	0.96	1.80	0.72	1.2 ? 0.19	Expertise	1	0.14	5.29	0.10	6.64 ? 1.13
	Pair(Expertise)	3	0.53	0.08	0.96		Pair(Expertise)	3	0.027	0.18	0.90	
	Residual	20	6.48				Residual	20	0.15			
Rubble	Expertise	1	0.10	0.007	0.93	1.12 ? 0.21	Expertise	1	32.66	0.31	0.61	6.8 ? 1.4
	Pair(Expertise)	3	15.64	2.75	0.07		Pair(Expertise)	3	104.17	1.85	0.17	
	Residual	20	5.68				Residual	20	56.14			
Bare rock	Expertise	1	15.36	0.13	0.73	3.6 ? 1.2 to 12.8 ? 2.9	Expertise	1	166.42	0.56	0.50	16.64 ? 2.0

(i.e.. reef matrix)	Pair(Expertise)	3	114.66	3.25	**0.04**	Pair(Expertise)	3	294.04	2.85	0.06
	Residual	20	35.20			Residual	20	102.96		

6.3.3 Sampling precision of volunteer observers

Precision of the estimates of total coral cover, expressed as the ratio of the standard error on the mean estimate, did not differ significantly between scientists and volunteers, although it varied considerably among pairs (Figure 6.7). The average precision of each pair in sampling cover of all hard corals ranged between 0.11 ? 0.01 to 0.17 ? 0.004.

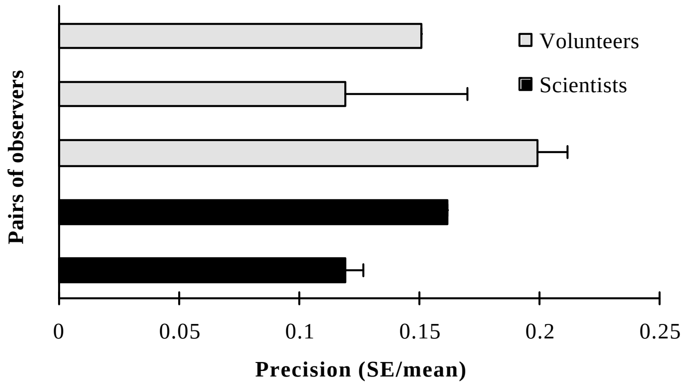


Figure 6.7: Mean precision (+SE), expressed as the ratio between the standard error and the mean, of estimates of percentage cover of all hard corals obtained by each observers within pairs of volunteers and scientists.

Sampling precision for individual life-form categories was generally small (Table 6.11). There was no significant difference between scientists and volunteers in sampling precision for most life-form categories (Table 6.11). The only exception was the coral category "dome-shaped" – i.e. massive corals – which the pairs of volunteers sampled with a precision greater (at ? =0.05) than the scientists (F_s=6.8, *df*=1,3, *p*=0.08).

Table 6.11: Mean precision (SE/mean) per pair of the estimates of cover of life-forms obtained by scientists and volunteers, for life-forms with cover >5%. Errors are standard errors (*n*=2 for scientists and *n*=3 for volunteers).

	Branching corals	**Massive corals**	**Soft corals**	**Sand**	**Rubble**	**Reef Matrix**
Scientists	0.21 ? 0.08	0.37 ? 0.03	0.28 ? 0.01	0.33 ? 0.06	0.44 ? 0.02	0.24 ? 0.04
Volunteers	0.42 ? 0.07	0.17 ? 0.05	0.42 ? 0.07	0.32 ? 0.09	0.42 ? 0.06	0.25 ? 0.03

6.3.4 Detecting differences between sites

The power to detect differences between two coral reef sites was greater for the team of two scientists than for heterogeneous groups of eight volunteer tourists. Scientists detected a significant difference in percent cover of coral between the sites at ? =0.05 (Table 6.12), while volunteers failed to detect a difference (power of the performed test was 1- ?=0.29). The difference between the two sites in total percent cover of coral as estimated by the pair of scientists was 16.3% (coral cover at the two sites was 62.0 ? 2.8% and 45.7 ? 3.7% respectively (Figure 6.8)).

Table 6.12: ANOVAs of the estimates of total coral cover compared between sites by a team of two scientists and different groups of eight volunteers.

Source of variation	df	MS	F	p	Observed 1-? *
<u>*Scientists:*</u>					
Site	1	528.12	11.96	**0.01**	
Error	6	44.12			
<u>*Volunteers:*</u>					
Site	1	132.03	2.80	0.14	0.29
Error	6	47.15			

? ? at ? =0.05

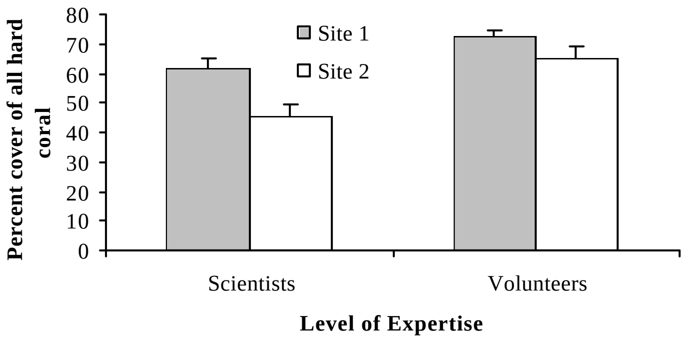


Figure 6.8: Mean percent cover of all corals at the two sites as estimated by scientists and volunteers respectively from the same sets of 4 transects.

When individual life-form categories and coral health parameters were considered, significant differences between the sites were detected at ? =0.05 by scientists for the “branching” (F_s=9.1; *df*=1,6; *p*=0.02), “massive-irregular” (F_s=21.1; *df*=1,6; *p*=0.004) and “encrusting” coral life-forms (F_s=94.6; *df*=1,6; *p*=0.000) (Figure 6.9). No difference was detected for the remaining categories, with the probability of committing Type II Error being > 0.5.

Tests done on data collected by volunteers had generally smaller power than those obtained by the scientists, with the exception of the category “dome-shaped” - i.e.. massive - corals, for which a significant difference between the sites was found for data collected by volunteers (F_s=6.3; *df*=1,6; *p*=0.046).

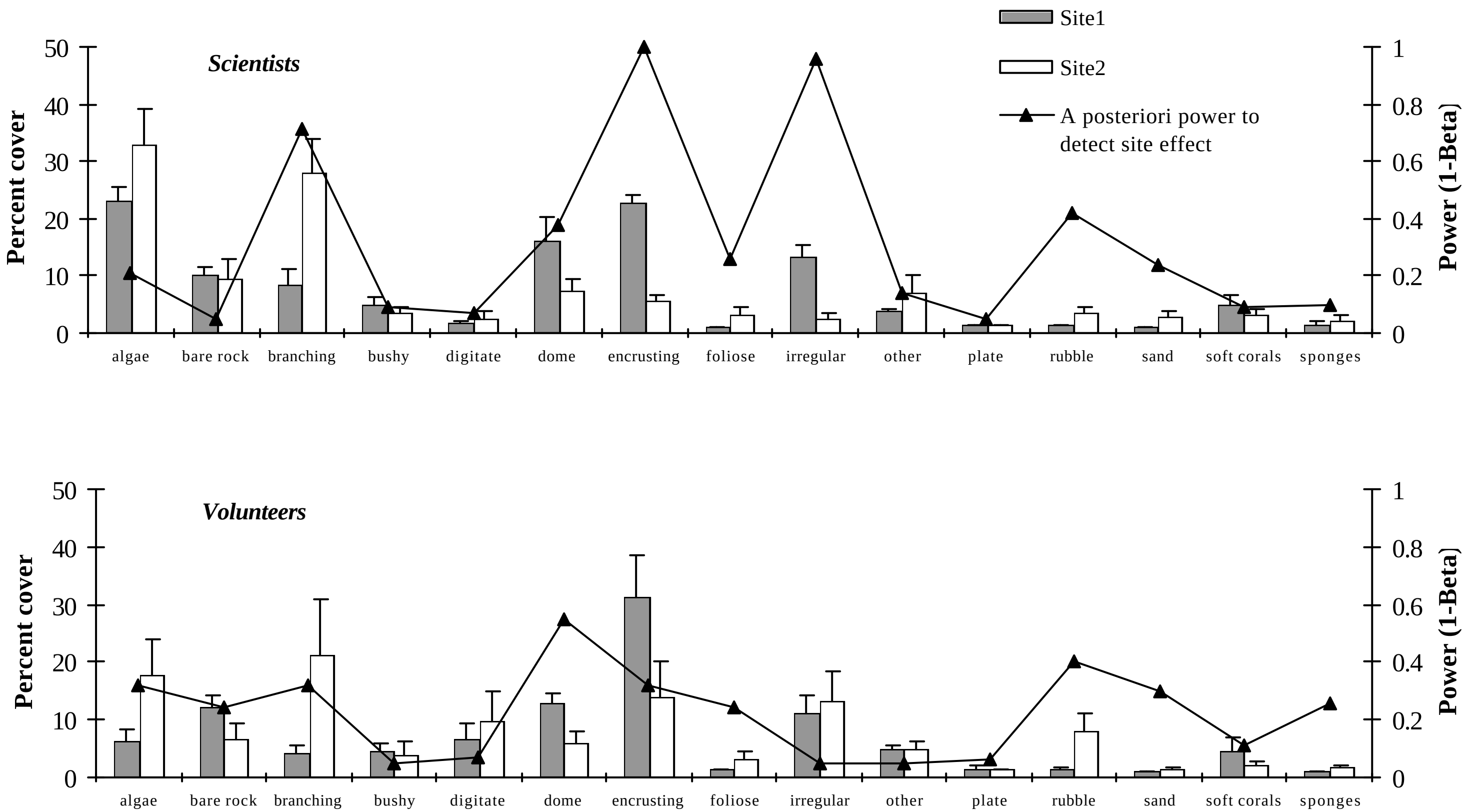


Figure 6.9: Percent cover of individual life-form categories (left axis) at the two sites estimated by scientists (above) and volunteers (below). Error bars are SE (n=4). The solid line depicts *a posteriori* power (1-?; right axis) to detect differences between the sites.

Among the coral health parameters, scientists estimated a significant difference in the cover of "100% alive" coral colonies between the two sites (F_s=64.2; *df*=1,6; *p*=0.000) (Figure 6.10). However, volunteers failed to detect any difference between sites (F_s=.000; *df*=1,6; *p*=1.00; 1-?=0.05), due to large variation both within transects and between transects at each site. For the health variables no differences were detected either by scientists or volunteers in the percentage cover of "partially dead" (Figure 6.10) and "100% dead" colonies. However, even in this case the power of the performed tests was greater for scientists than volunteers. The remaining two coral health parameters ("broken" and "bleaching" colonies) were not sufficiently represented in the data for analysis (percent cover < 2%).

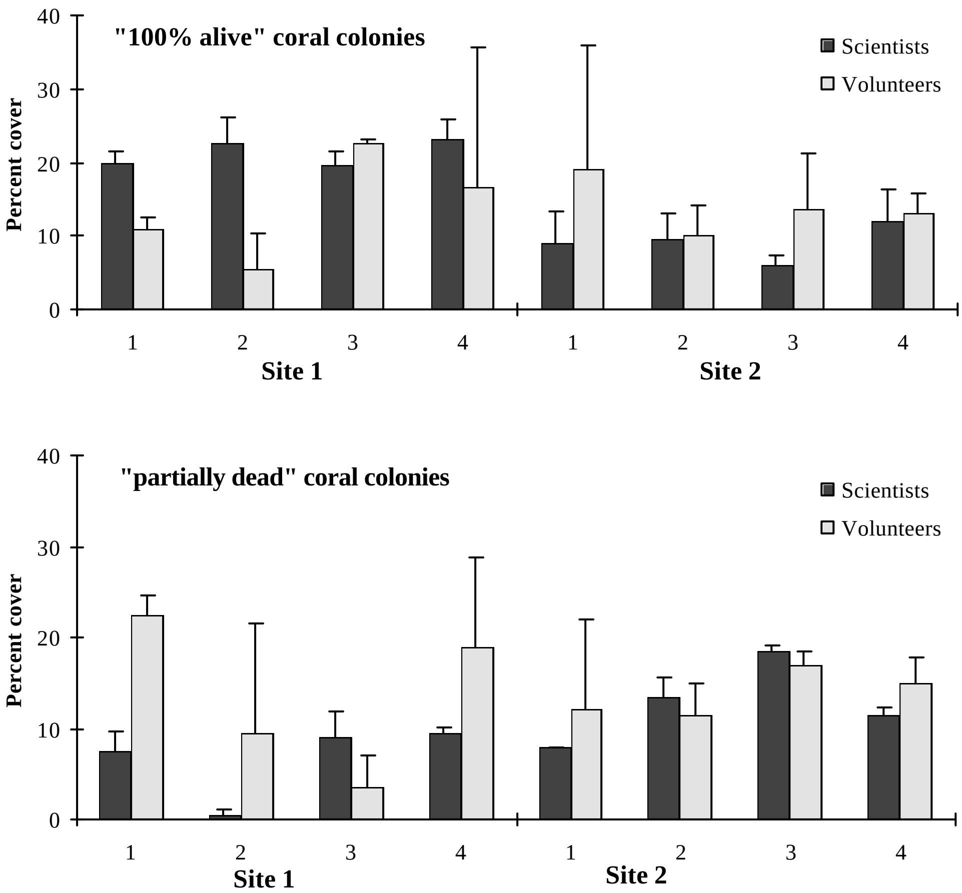


Figure 6.10: Mean percentage cover (+SE; *n*=2) of coral colonies with 100% live tissue (top) and with patches of dead tissue (bottom) obtained by the two members of a pair of scientists and 8 pairs of volunteers.

6.3.5 Consistency of identification of life-form categories

In the field, the rates of agreement of volunteers with the reference scientist ranged between 64.8 ? 2.5% to 71.8 ? 3.1% among observers. Rates of agreement differed significantly among observers at at ? =0.10 (F_s=2.38; df=4,32; p=0.072; Table 6.13).

Rates of agreement also varied significantly between two adjacent sites surveyed one after the other (F_s=16.84, df=1,8, p=0.003) (Figure 6.11), suggesting that observers were more likely to agree with the reference scientist as a result of increased practice (see 6.3.7).

Table 6.13: Repeated Measures ANOVA table for the rates of agreement in identification between volunteers and a scientist compared among five observers and between two adjacent sites which were sampled one after the other.

Source of variation	df	MS	F	p
Within-subjects:				
Observer	4	93.52	2.38	**.07**
Observer*Site	4	16.32	0.41	.79
Residual	32	39.27		
Between-subjects:				
Site	1	3427.92	16.84	**.00**
Residual	8	203.52		

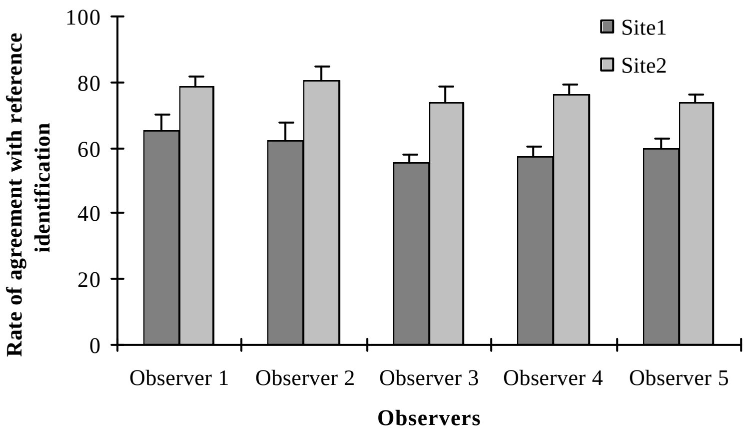


Figure 6.11: Mean percentage of points along a transect for which there was agreement of life-form identification between each of five observers and the reference scientist. Error bars are Standard Error (n=5 transects).

The mean rates of agreement within a pair of observers, calculated as the proportion of observations for each life-form on which the two observers agreed, were consistently greater among scientists (Figure 6.12). Interestingly, however, the pattern of variation in agreement for different life-forms was the same for volunteers and scientists. The life-form categories for which agreement was greatest among scientists were branching and massive corals (approx. 60% of the total observations), followed by foliose and soft corals (approx. 50%) and algae, sand, rubble and reef matrix (approx. 40%). All of the remaining categories (bushy, plate, sub-massive, digitate and encrusting corals and sponges and others) were identified consistently by the paired scientists less than 30 % of the time.

This pattern was similar for pairs of volunteers, although the rate of agreement between members of a pair were generally lower. Agreement was greater between paired volunteers in the identification of branching corals (55.9%) and others (22.6%), compared to the agreement between paired scientists (55.3% and 20.4 % for branching and others respectively). Rates of agreement between volunteers were very low (<20% of the times) for bushy, plate, submassive and digitate corals and for sponges. Out of 48 observations of sponges recorded over the three trials by volunteers, the members of a pair did not agree once.

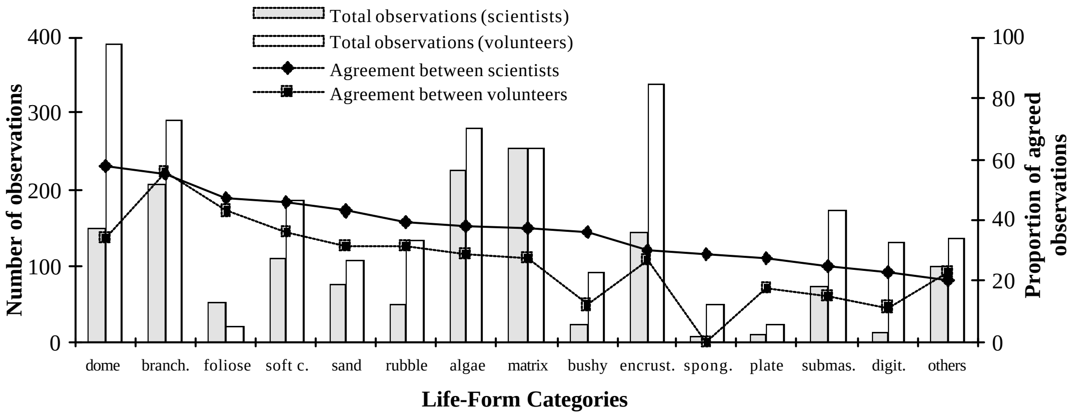


Figure 6.12: Rate of agreement within pairs of observers in identification of reef organisms. Life-form categories on the horizontal axis are in order of decreasing rate of agreement between scientists. Rates of agreement are here calculated as the proportion of agreement out of the total observations for each category (left Y axis).

Rates of agreement between paired observers increased by sequentially aggregating life-forms (Figure 6.13). When reef organisms were classified using all 15 categories (Table 6.3), rates of agreement between paired observers ranged from 38 to 68% (mean 56.2 ? 3.6%; SE, n=10) when observers were scientists, and from 18 to 62% (mean 38 ? 4.4%) when observers were volunteers. When organisms were grouped into 5 categories ("corals with branches", "massive corals", "sheet-like corals", "biotic/non-corals", "abiotic"; see Table 6.3) agreement between scientists increased to 44-81% (mean 63.1 ? 4.2%) and agreement between volunteers increased to 20 to 76% (mean 45.7 ? 4.8%). When life-forms were further grouped into only 3 categories ("hard corals", "biotic/non-corals" and "abiotic"), agreement between paired observers did not vary much between scientists and volunteers, ranging from 54 to 82% (mean 70.7 ? 3%) for scientists and from 50 to 76% (mean 64.2 ? 2.4%) for volunteers (Figure 6.10). Rate of agreement appears to increase more dramatically for volunteers with decreasing level of taxonomic resolution, suggesting that inconsistency in the identification of reef organisms (particularly of hard corals) is greater among non-professional observers (Figure 6.13).

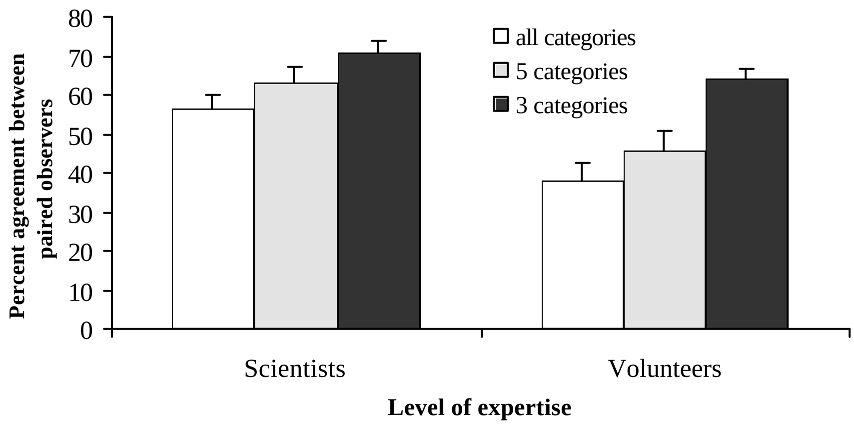


Figure 6. 13: Mean rates of agreement (+SE; *n*=10) between paired observers in the identification of life-forms and compared between levels of sampling expertise, i.e. scientists and volunteers. Agreement in identification was calculated for increasingly coarser levels of taxonomic resolution (15 life-forms categories; 5 life-form categories and 3 life-form categories).

A consistent bias in the identification of certain life-forms was found during one of the trials, where pairs of volunteers, each surveying one transect, appeared to overestimate consistently the total cover of corals compared to one pair of scientists who surveyed all the transects (Figure 6.14).

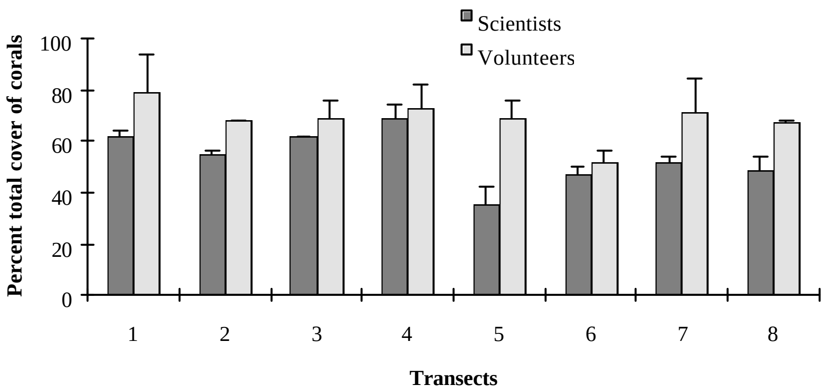


Figure 6.14: Mean estimates (+SE; *n*=2) of percent total cover of corals obtained by paired observers belonging to pairs of volunteers (each pair surveying only one of the eight transects) and one pair of scientists (surveying all eight transects). Transects 1-4 were at Site 1 and transects 5-8 at Site 2.

The identification bias was most likely due to the consistent misidentification by the volunteers of the category "algae", which at both sites on Osprey Reef was in large part represented by coralline algae. Percentage cover of coralline algae was estimated by one of the two scientists as 16.5 ? 3.3% at Site 1, and 12.5 ? 2.2% at Site 2, which represented the 41.6% and 61.1% of all algae recorded at the two sites respectively.

Scientists agreed 67.8% of the times with the volunteers when these identified algae (87 observations over ten transects), suggesting that volunteers could identify correctly some of the algae (Figure 6.15). However, when scientists recorded the category "algae" (209 observations over ten transects), volunteers agreed only 28.2% of the times, and instead recorded the categories "encrusting" corals and "reef matrix" on respectively 21.1% and 11.5% of the times (Figure 6.15). The total number of points along ten transects beneath which at least one of the observers had identified "algae" was 237. These results suggest that at sites with high cover of coralline algae, volunteers may provide biased estimates of coral cover, by consistently identifying those algae as encrusting corals and, to a lesser extent, as reef matrix.

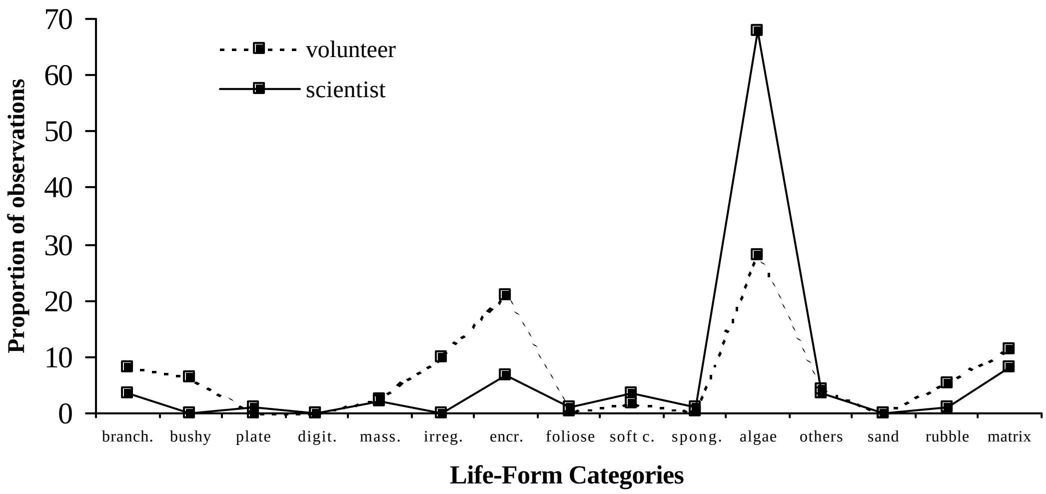


Figure 6.15: Profiles of the identification made by each of two paired observers (one scientist and one volunteer) beneath points where the other member of the pair recorded the category "algae". The continuous line represents the profile of the identification (frequency of observations for each category) made by the scientist for those points along the transects for which the volunteer identified the category "algae". The dashed line represents the profile of the identification (frequency of observations for each category) made by the volunteer for those points along the transects for which the scientist identified the category "algae".

hen 38 video frames, depicting a variety of reef life-forms identified *a priori* by one of us (BM), were shown to a group of 10 volunteers and 2 scientists, the mean rate of agreement of the scientists with the reference identification (75.0 ? 3.9%) was significantly higher than that of volunteers (47.4 ? 1.4%) (Mann-Whitney Test; p=0.025) (Figure 6.16). Eight of the twelve instances when scientists disagreed, involved identification of "irregular-shaped", or submassive corals, indicating that even among scientists, interpretation of this life-form category may differ.

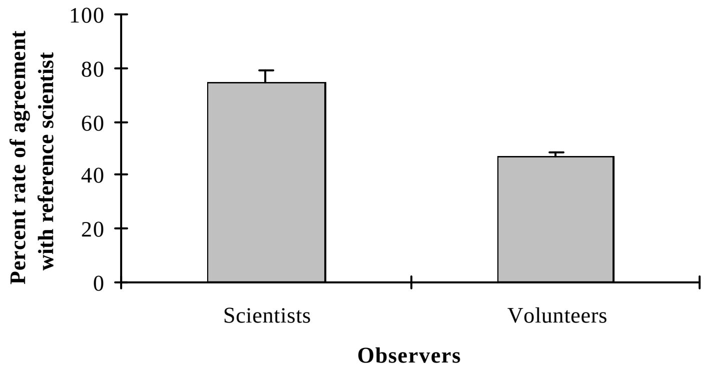


Figure 6.16: Rate of agreement of scientists and volunteers with the reference identification. Rate of agreement was expressed as the proportion of the total (38) reef organisms shown to two marine scientists and 10 volunteers.

6.3.6 Effect of SCUBA diving experience

The discrepancy between the estimates made by each volunteer and a reference scientist (i.e. relative inaccuracy) varied according to the SCUBA experience of the volunteer diver (Table 6.14). In general, volunteers who were relatively inexperienced divers (<30 logged dives) produced estimates of coral cover that deviated more from those of the scientist (15.9 ? 2.7%; SE, n=20) than did experienced volunteer divers (>100 logged dives) (7.5 ? 2.7%).

The mean cover of total hard coral estimated by the reference scientist was 64.0 ? 6.4%. Estimates obtained by experienced SCUBA divers for the same site ranged between 58.4 ? 7.4% and 62.8 ? 7.7%, while estimates obtained by inexperienced SCUBA divers ranged between 55.2 ? 6.7% and 65.6 ? 5.9%. Variation among inexperienced divers expressed as the coefficient of variation of the estimates obtained by different observers on each transect (14.0 ? 1.9%; SE; n=5), was significantly greater (t=3.09; df=4; one-tailed test: $0.01<p<0.025$) than that among the group of experienced divers (7.9 ? 1.6%).

The relative difference in variation between the two groups increased significantly with the total cover of coral at the site (r=0.955, n=5, p=0.012). That is, the effect of SCUBA diving proficiency on the reliability of estimates of coral cover was most pronounced on reefs with large cover of corals (Figure 6.17).

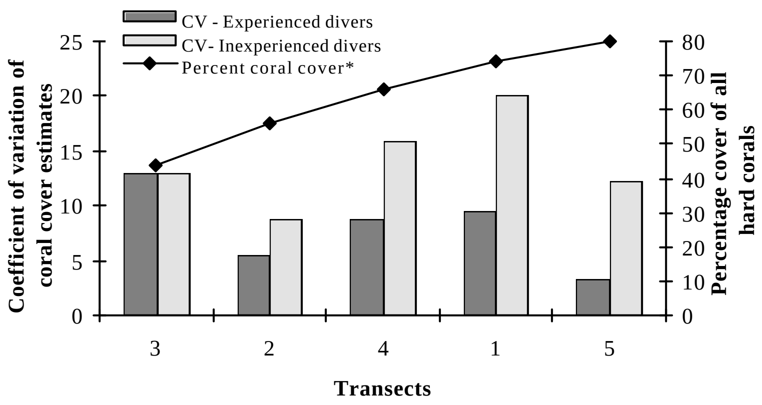


Figure 6.17: Relationship between the difference in inter-observer variation of experienced and inexperienced SCUBA divers and the total coral cover at the site as estimated by the scientists(*).

Table 6.14: Test statistics for the effect of SCUBA diving experience on the relative accuracy (expressed as percent proportion of the estimate made by the reference scientist) and on the rate of agreement in identification with the reference scientists.

Source of variation	df	MS	F	p
Relative inaccuracy:				
Within-subjects:				
Transect	4	195.43	1.28	0.30
SCUBA dive experience	4	21.94	0.14	0.96
Residual	24	152.63		
Between-subjects:				
SCUBA dive experience	1	701.51	4.68	**0.07**
Residual	6	149.77		
Rate of agreement with scientist in identification of life-forms:				
Within-subjects:				
Transect	4	205.85	3.74	**0.02**
SCUBA dive experience	4	30.65	0.55	0.69
Residual	24	54.98		
Between-subjects:				
SCUBA dive experience	1	532.90	4.61	**0.07**
Residual	6	115.56		

The level of SCUBA diving experience also affected the rate at which volunteers agreed with the identifications made by the reference scientist (Table 6.14; Figure 6.18). The overall rate of agreement between individual volunteers and the scientist differed between the two groups of divers (F_s=4.61; df=1,6; p=0.07; observed power = 0.43; Table 6.14; Figure 6.18). Overall experienced SCUBA divers agreed with the identification of the scientist 60.1 ? 2.4% of the time. Less experienced divers agreed with the scientist on just over half of all identifications (52.8 ? 2.4%). The two groups differed significantly in the rate of agreement with the reference scientist in the identification of massive coral and reef matrix (respectively F_s=7.4; df=1,6; p=0.03; F_s=19.3; df=1,6; p=0.005).

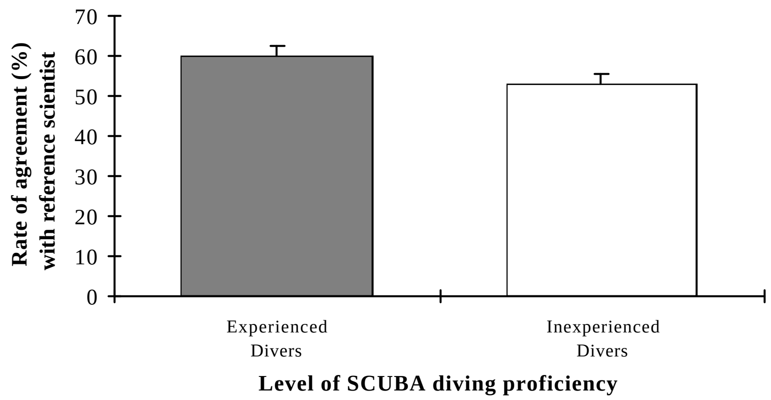


Figure 6.18: Mean rates (+SE; *n*=4) of agreement of experienced (>100 dives logged) and inexperienced (<30 dives logged) SCUBA divers with a reference scientist in identifying life-forms.

6.3.7 Learning Effect

Preliminary investigation of trends in the reliability of estimates obtained by volunteers suggest that both the relative accuracy and the rate of agreement with the scientists (Figure 6.19) increased with the number of transects that each volunteer surveyed (Table 6.15). Thus, there appear to be a rapid process of learning. The rate of increase in agreement with the scientist appeared to stabilise after the volunteers had completed 8-10 transects.

Table 6.15: ANCOVA tests for the effects of increasing number of transects completed (covariate), site and observer on the inaccuracy of cover estimates obtained by volunteers compared to estimate of cover obtained by a scientist; and on the rate of agreement of volunteer observers with a reference scientist.

Source of variation	df	MS	F	p
Relative inaccuracy:				
Number of transect completed	1	549.97	4.90	**0.03**
Site	1	164.19	1.39	0.30
Observer	4	24.72	0.21	0.92
Site*Observer	4	117.35	1.04	0.39
Residuals	39	112.19		
Rate of agreement with scientist in identification of life-forms:				
Number of transect completed	1	0.061	10.35	**0.00**
Site	1	0.343	210.04	**0.00**
Observer	4	0.009	5.73	0.06
Site*Observer	4	0.002	0.27	0.89
Residuals	39	0.006		

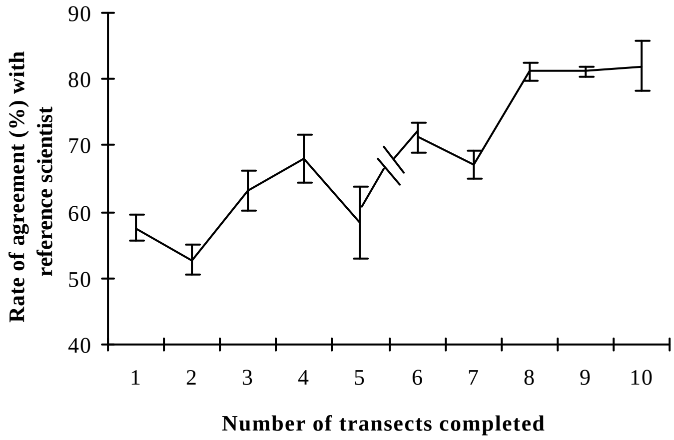


Figure 6.19: Mean (? SE; *n*=5 observers) rates of agreement of identification of life-form categories relative to a reference scientists. Transects are numbered according to the order they were surveyed by each observer. Transects 1-5 were surveyed at site 1 and transects 6-10 at site 2.

6.4 Discussion

The results from the field trials are, overall, supportive of the feasibility (both logistic and in terms of quality of the data returned) of the involvement of volunteers in monitoring coral reef organisms following a brief training program. However, a number of sources of error and bias were identified during this study which may seriously affect the reliability of data collected by volunteers, unless mitigating measures are incorporated in the sampling protocol and in the training procedures.

This study has shown that volunteers can estimate cover of corals with a relative accuracy greater than 90%. That is, generally the volunteers returned data of percentage cover for all hard corals and for most individual life-forms that departed little from those obtained from the same sampling units by an experienced and professionally trained observer. These results are encouraging as they indicate that volunteer divers have the potential to integrate existing scientific monitoring programs by providing useful information on the abundance of broad categories of reef organisms. These results also confirm findings from previous studies which compared data collected by volunteers and scientists. For example, in Florida, Mumby *et al.* (1995) found that volunteers trained in ranking the abundance of corals and macroalgae, provided estimates which were very similar (90%) to those obtained by experienced personnel. In Tanzania, volunteers were found to reach approximately 80% relative accuracy in the visual estimation of length distribution of reef fish, following a training program which consisted of three validation exercises conducted in the field (Dartwall and Dulvy 1996). In the present study, volunteers were trained for a much shorter period of time compared to those studies, being exposed only to a brief training session which did not include practice in the field. The brevity of the training was identified during the consultation as a necessary requirement for involvement of the dive tourism industry in the program. The high levels of accuracy achieved in this study are therefore remarkable, and indicate that the sampling protocol developed for the program is overall robust with regard to the expertise of the observer.

This was also supported in this study by findings that the sampling precision of estimates of cover, when the coral categories were aggregated, did not differ between scientists and volunteers and was generally high. Even when individual life-forms were considered, sampling precision did not differ significantly between volunteers and scientists, although it was much lower, particularly for those categories with a low estimate of cover. Imprecision, i.e. large variation among measurements relative to the mean value, in the estimates of abundance of organisms which occur at low densities is a common problem in ecological sampling (Bart and Schultz 1984; Andrew and Mapstone 1987; Mundy 1991; Thompson and Mapstone 1997). The statistical behaviour of data from these organisms is usually the reason why in many studies observations are taken at a species level but then aggregated in multi-species groups for analysis and interpretation (Mundy 1991). This problem has to be considered in the planning stages of a monitoring program and the choice of the level of taxonomic resolution to be included in the sampling should be determined by the objective of the program (Mundy 1991; Thompson and Mapstone 1997). In this study, we propose a life-form identification scheme which allows for the aggregation of the categories at three meaningful levels (see Section 6.2.4). Field trials during this project have confirmed that sequential aggregation improves the reliability of the data, particularly for those obtained by volunteers. Mundy (1991) draws attention to the fact that often data are analysed only for lower taxa and higher taxa may not be included in subsequent analysis. We suggest, however, that sampling at the highest level of taxonomic resolution included in this protocol - i.e. 15 life-form categories - may provide useful information on the longitudinal patterns of abundance of those organisms occurring at high density at a particular site.

Despite the high relative accuracy of estimates obtained by volunteers, variation among observers was found to be a potentially important source of error. In a field trial which compared independent estimates of cover obtained by paired observers, different pairs were found to vary considerably in the similarity of the estimates collected by the members of a pair, with members of some pairs differing as much as 30% in estimating percent cover of coral. However, there was no difference in within-pair variation between volunteers and scientists. Implications of high inter-observer variation in sampling programs which implement numerous observers may be serious (Mundy and Babcock 1993). This study has shown that ability to detect spatial patterns may be reduced drastically when different volunteers with limited training are involved in the collection of the data, compared to a program where estimates are obtained by two expert observers.

The comparatively great variation among observers as found during some trials in this study, confirms previous studies which investigated observer-related error in the sampling of reef benthic organisms. Mundy (1991), comparing four experienced marine scientists, found that observer-related error can contribute as much variance as natural spatial variation, and recommended that the error introduced by the observers be accounted for when investigating spatial and temporal patterns of percent cover.

Differences in estimates obtained by different observers may be a result of two sources of variation: i) the combined effect of parallax error and/or movements of the transect line, which is inherent in the sampling methodology and which can be influenced by the level of expertise of the observer only partially; and ii) the inconsistency among observers in the identification of reef organisms.

During the pilot study we estimated that parallax/movement error may affect as much as 26% of the points sampled along a transect line. Parallax/movement error may considerably impinge on the interpretation of patterns of change when fixed transects are used, and provide biased estimates of cover for small and/or rare organisms when random transects are used (Mundy 1991). The potential importance of parallax/movement as a source of error suggests that the rougher the sea conditions, the larger the overall variability among estimates obtained by different observers. This source of bias however is as likely to affect estimates obtained by volunteers as those by scientists. Clear procedural rules on the position of the observer in relation to the transect and avoiding of sampling in rough conditions may represent effective ways of minimising the problem.

The second source of variation of estimates obtained by a number of observers is the potential inconsistency in the identification of reef organisms. This is likely to be important particularly in the context of volunteer-based monitoring, due to the subjective nature inherent in the identification of arbitrary life-form categories and the extreme variability in growth forms that characterises hard corals. The use of a limited number of life-form categories to classify reef organisms presents considerable advantages for the involvement of non-professionals in monitoring, in that it requires a minimum of training. Some volunteer-based programs elsewhere in the world require the participants to classify reef organisms - usually corals and fish - to a fine level of taxonomic resolution. In Tanzania, volunteers are trained over a period of two to three weeks - with one dive per day - to identify 56 species of reef fish (Dartwall and Dulvy 1996). In the Caribbean, the Coral Cay Conservation program trains volunteers to identify reliably 34 individual species of corals and 31 species of macroalgae, but this requires an intensive eight days course which includes validation exercises in the field (Mumby *et al.* 1995). On the Great Barrier Reef, however, with approximately 330 species of corals known to occur, some of which displaying considerable growth form variation (Veron 1986), training volunteers in the identification of individual species is impossible, and it would require training periods incompatible with the constraints identified for a volunteer-based program in the GBR. Even scientific monitoring programs on the GBR, due to the high diversity and the current taxonomic uncertainty, make use of coarser grouping for classification of corals and algae (e.g. the AIMS Long Term Monitoring Program, Oliver *et al.* 1995).

However, the use of broad taxonomic grouping may be a problem if the categories chosen to group reef organisms are not clearly defined or easily and unequivocally understood by non-professionals. The field trials conducted during this project showed that some life-form categories used in the sampling protocol were consistently misidentified or difficult to interpret for non-professionals and scientists alike. In particular, life-form categories grouping hard corals were usually problematic for identification. This was not unexpected, given the considerable variation in morphology among corals. Remarkable variation in colony growth form are known to occur even within a species, usually, but not always, as a response to environmental factors such as light or exposure to wave action (Veron 1995). Such plasticity means that to assign a coral *in situ* to a morphological category may be a problem for some uncertain growth forms.

The problem of inconsistency of identification of life-forms as a source of error in sampling programs which involve multiple observers, simultaneously or over time, has been previously acknowledged to occur among expert observers (Mundy 1991). His study found that experienced scientists were likely to disagree in the identification of encrusting and sub-massive coral growth forms, introducing additional error to natural variation in cover of these life-forms (Mundy 1991). In a laboratory trial during this study, scientists also disagreed consistently in the interpretation of the coral category "submassive".

Significant bias in the identification of other categories, however, was found to be a problem specific to non-professional observers. Volunteer observers had problems in identifying the coral category "digitate" in most of the trials. Digitate corals were defined as coral colonies having finger-like, short and stout branches. This category was intended to group coral species, such as *Acropora gemmifera* and *A. humilis*, which are very common on exposed sides of the reef and on the reef flat (Veron 1986). In the first trial, where life-forms included the category "columnar" (which was meant to comprise, among others, some common corals as *A. cuneata*, *A.palifera* and some *Pocillopora* species) volunteers consistently identified as "digitate" those corals identified as "columnar" by the scientists. As a result, the category "columnar" was eliminated by the identification scheme and replaced in subsequent trials by the category "submassive". This category was wider and was intended to include all growth forms which could not be classified as one of the other seven, less equivocal, hard coral categories (see Table 6.2). However, in subsequent trials, volunteers still had problems in identifying digitate coral morphologies. For digitate corals, paired volunteers not only differed significantly from the scientists in estimating the percentage cover, but were also more likely to disagree on the estimates than paired scientists. These results indicate that the hard coral category "digitate" is not unequivocally interpreted by volunteers.

Volunteers also had consistent problems in identifying the lifeform categories “sponges” and “algae”. Sponges were very rarely encountered during all the field trials. However, even in those few instances, agreement of volunteers in identifying this category was extremely low. For example, out of three trials, volunteers recorded sponges as occurring beneath 48 points but did not agree once. This result may indicate both the difficulty in correctly and consistently identifying sponges - which, like corals present an enormous variety of growth forms - but it may be due also to the fact that generally sponges are represented by small individual colonies. This makes them very susceptible to the parallax/movement error, which in these trials was not separated by the error resulting from inconsistency of identification. Despite these problems, and the consequent very low precision and accuracy in estimating cover of sponges, we suggest that this may be a useful category for a broad scale monitoring program and should be maintained in the identification scheme, as sponges may be found at high densities at some locations in the GBR and Coral Sea (Wilkinson 1987) and are often important on coral reefs elsewhere in the world (Wilkinson & Cheshire 1990).

Volunteers undergoing only a limited training, as in these trials, may also be biased in estimating cover of algae and coral. In a field trial conducted at sites characterised by high cover of coralline algae, all 12 volunteers consistently identified coralline algae as encrusting corals. This resulted in a significant positive bias in the estimation of coral cover at the site. This bias can probably be corrected by incorporating clearer decision rules for discriminating between these two categories, and may also require validation exercises where the volunteers are specifically required in a number of instances to identify both coralline algae and encrusting corals in the field and are given feedback on the identifications they make.

The level of SCUBA diving experience is an important source of bias when a number of volunteers with varying proficiency in SCUBA diving participate in the same sampling exercise. It was clear from this study that relatively low previous experience in SCUBA diving (<30 dives logged) resulted in lower accuracy in estimating percentage cover of reef organisms relative to a reference scientist and in lower agreement in the identification of life-form categories. Divers with >100 dives logged, provided estimates of cover which were very similar to those obtained by the scientist and were more likely to agree with the reference identification. SCUBA diving proficiency, which is likely related to number of dives undertaken, may affect the performance of specific tasks underwater. Mumby *et al.* (1995) found that physiological constraints experienced by SCUBA divers at depths greater than 30m, by impairing cognitive and manual processes, affected their ability to rate the abundance of corals and macroalgae consistently. In this study, lower familiarity with the underwater environment and SCUBA equipment probably affected some divers' ability to undertake the unusual sampling tasks, leading to a greater variation among observers and lower relative accuracy. The results showed also that the effect of SCUBA proficiency on the reliability of the estimates may vary at different sites, being more prominent at sites with larger coral cover. The reason why the bias related to SCUBA proficiency increases with increasing coral cover is not clear. Inglis and Lincoln Smith (1995) found that some novice observers were biased in counting seagrass shoots relative to a scientist and that the bias appeared to increase with increased seagrass density. In these studies the effect that increased practice in the field may have in mitigating such biases was not investigated. It is likely that longer training periods, may standardise the performance of SCUBA divers that have different proficiency at the start. A number of practice dives could be incorporated in the training program in order to increase the familiarity of the divers with the equipment and the tasks required for sampling.

The likely effectiveness of training for improving reliability of data was also supported by other results from these field trials, which indicated that accumulated practice in surveying line transects may increase the relative accuracy and agreement rate of volunteers. From this study it was not possible to investigate whether such learning effect occurs for experienced and professionally trained observers as well. A recent study investigating the effect of observer training on the estimates of cover of corals and other reef organisms using the manta tow technique, found that both experienced and inexperienced observers underwent a 35% improvement in sampling precision over a period of three days and a total number of 126 tows (Miller and De'ath 1996). In that study, by the end of the field trial, inexperienced observers had achieved a level of sampling precision equal to that of the experienced observers at the start of the trial. Training was also found to mitigate the effect of observer related bias and imprecision in visual surveys of coral reef fishes (Thompson and Mapstone 1997). In particular training was effective in virtually eliminating observer specific biases for most fish taxa and this was attributed principally to the observers conforming, during the training period, their interpretation of the decision rules for counting the fishes along a transect. In a volunteer-based program, Dartwall and Dulvy (1996) found that reliability of estimates of fish abundance and fish size distribution reached satisfactory levels after 11 practice dives.

It is likely that most of the biases in the estimates obtained by volunteers that were identified during this study can be corrected through further training. Rigorous and standardised training are recommended as ways to maximise consistency among observers (Kepler and Scott 1981; Meese and Tomich 1992; Inglis and Lincoln Smith 1995) Thompson and Mapstone (1997) suggest that the training program should be continued until observer specific biases are eliminated.

However training does not completely eliminate imprecision among observers (Thompson and Mapstone 1997; Section 6.3.2), that is a level of inter-observer variation is to be expected even for trained observers. A number of additional measures can however be taken to minimise the problems identified. For example, bias related to SCUBA diving proficiency may be an important source of error in volunteer-based programs unless a minimum number of dives logged is set as a prerequisite for participating in the sampling. Also to minimise the potential for parallax/movement error to occur, sampling should be carried out during times of calm waters as this may minimise movements of the transect line. Procedural guidelines should also prescribe that sampling be carried out in shallow waters both for safety reasons and because depth has been shown to affect reliability of data collected by volunteers (Mumby *et al.* 1995).

An important procedure which may mitigate most sources of error and that can be easily adopted in a volunteer-based program is the implementation of paired observers for sampling individual transects. The involvement of paired observers in volunteer-based monitoring in sub-tidal environments does not call for special arrangements and coordination, as SCUBA divers do dive in pairs in any case as a requirement of dive safety regulations (Division of Workplace Health and Safety 1992). Estimates obtained by averaging paired observations are likely to be both more precise and accurate than estimates obtained by individual observers. The pairing of observers is a quality assurance practice rarely implemented in ecological sampling, probably due to the cost of engaging personnel in sampling in the field. However, in instances where the process of estimation involves a degree of subjectivity, mean estimates between two or more observers are to be preferred. For example, fisheries biologists regularly make use of paired estimation for the aging of fish done by counting rings in the otoliths, as the interpretation of density bands requires a high degree of subjective judgement (Kimura and Lyons 1991). In marine mammals studies, paired observers, or paired teams, are regularly used to count numbers of individual animals or pods from planes or elevated observation points, to compensate for bias which may affect individual observer's counts (Marsh and Sinclair 1989; Rugh DJ *et al.* 1990). Pairing of observers is also used as an effective method to eliminate observer-related bias in the volunteer-based Common Birds Census scheme of the British Trust for Ornithology (O'Connor 1981). Implementing pairs of observers also provides an ongoing quality control system by which the relative accuracy of the estimates and the consistency in the identification of life-forms among volunteers can be regularly assessed. This may be of particular value in long-term volunteer-based monitoring programs, where observers are likely to change during the course of the program.

7. PROGRAM EVALUATION BY THE PARTICIPANTS

7.1 Questionnaire - Objectives and Format

A formal evaluation of the monitoring program was obtained through a questionnaire distributed to the participants in the field trials. The aim of the questionnaire was to:

?? identify strengths and weaknesses of the training materials (see 5.5) and of the overall program as perceived by the participants;

?? gather additional information on the participants (e.g. age, dive experience, previous involvement in monitoring/volunteer activities) which might assist in the interpretation of the patterns in data quality observed during the field trials.

The questionnaire (see Appendix C) consisted of both multiple scores and open-ended questions and was divided into three sections.

a) The first section was aimed at gathering demographic information.
b) The second section was a dive log used to cross-check the reference data on the data-sheets. In this section, comments were sought in relation to particular dive sites and events/problems encountered during those dives. Feasibility of the underwater tasks required for the sampling was assessed based on these comments.
c) The third section was aimed at obtaining feedback on individual components of the training program and on the overall enjoyment and experience derived by the volunteers by taking part in the program.

7.2 Results of the survey

Thirty-eight questionnaires were completed during the feasibility study by volunteers who participated in a total of six field trials. This sample is too small to allow for a comprehensive analysis of the responses - i.e. comparisons among volunteer groups and trials. Ten volunteers (members of the community group) who participated in the first field trial (May 1996) did not fill in a questionnaire, as the evaluation program was finalised together with the training materials in July 1996. However, the summary of the answers provides a preliminary evaluation of the program. In particular, valuable feedback has come from detailed comments on various aspects of the training/underwater trials. Recommendations and suggestions by the volunteers who took part in the study were all carefully considered and, when appropriate, incorporated in the final version of the training material.

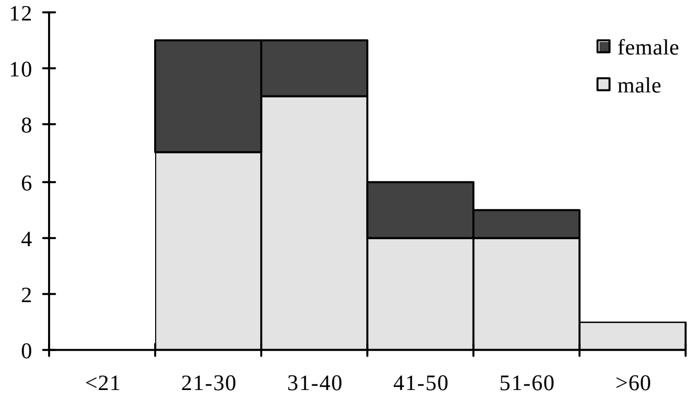


Figure 7.1: Age and gender composition of those participants in the field trials who also responded to the questionnaire.

Volunteers participating in the trials were mostly between 21 to 40 years old and were predominantly male. Participants varied widely in their previous SCUBA diving experience, which ranged from 0-20 to more than 2000 logged dives. While the greatest number of participants had completed between 21 and 50 logged dives, their previous experience of diving on coral reefs was generally lower, with most respondents having done fewer than 20 logged dives in coral reef environments.

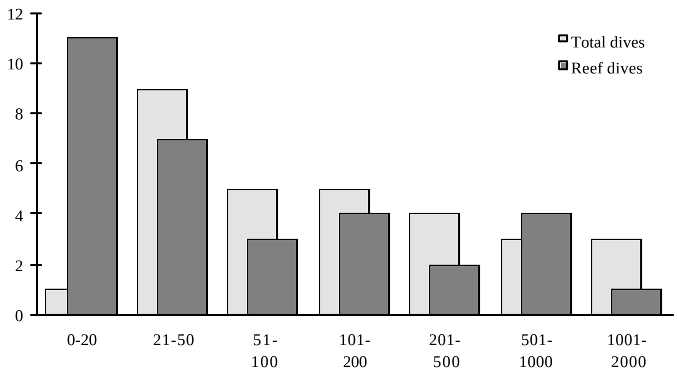


Figure 7.2: Frequency distribution of the previous dive experience of participants on coral reefs and in total, measured as number of previously logged dives, among the participants in the field trials (excluding the participants who took part in the first field trial - see text).

7.2.1 Evaluation - Structured responses

Most of the participants (88%) thought that the experience was enjoyable or very enjoyable. Some negative comments (6%) were expressed by visitors on-board the 3-day operation.

Detailed comments showed that lack of enjoyment was due mainly to the training and sampling proving demanding when forced in the tight schedule of a short dive trip.

Table 7.1: Summary of the structured responses given by three groups of volunteers taking part in the field trials to the statements/questions included in the evaluation survey. Responses were on a 1 to 5 scale, with 1 representing a very negative and 5 a very positive response. The three groups included a community group (n=6), visitors taking part in a short (2.5 days) dive trip (17 respondents over three trips), and visitors taking part in a long (6 days) dive trip (11 respondents from one trip). Figures are mean scores (? standard deviation).

QUESTIONS	COMMUNITY GROUP n=6	VISITORS ON TRIPS OF 3 DAYS n=17	VISITORS ON TRIPS OF 6 DAYS n=11
Presentation easy to understand	4.3 ± 0.5	4.1 ± 0.6	3.9 ± 0.5
Handbook useful	4.3 ± 0.8	4.2 ± 0.7	4.5 ± 0.5
Participation enjoyable	4.5 ± 0.5	4.0 ± 1.0	4.8 ± 0.4
Increased understanding of:			
?? good dive practice	2.8 ± 1.6	2.9 ± 1.1	3.4 ± 1.3
?? coral reef ecology	3.2 ± 1.3	3.8 ± 1.0	4.4 ± 1.2
?? coral reef research	4.2 ± 0.4	3.9 ± 1.1	4.6 ± 0.9
?? role volunteers can play	4.2 ± 0.7	3.7 ± 0.9	4.1 ± 1.2
?? responsibility to coral reefs	3.5 ± 1.4	3.8 ± 1.0	4.2 ± 1.3
?? responsibility to environment	3.3 ± 1.4	3.8 ± 1.0	4.0 ± 1.2

The interpretation session together with the data collecting experience was considered by most participants to have a high educational value with 76% and 85% of them indicating that they had a better or much better understanding of reef ecology and reef research respectively, as a result of involvement in the program. Only 45% of the volunteers involved thought the experience had some positive effect on their understanding of good underwater practice.

6.2.2 Evaluation - Open ended questions

Open-ended questions and opportunity for general comments resulted in a number of suggestions and/or remarks which provided useful feedback additional to the responses to the structured questions. Comments were divided into seven categories, which are listed below in order of decreasing number of comments received per category:

?? Appreciation/support comments: Comments supportive of the program were included in 14 questionnaires. In particular, the information/education and awareness-raising aspects of the program were commended; two respondents (respectively from the 3-day and 6-day dive trip) found the field trial particularly effective for learning about corals and other benthic organisms usually neglected by coral reef interpretation which tends to focus on fish life. Also, comments were made on the enhancement of the overall recreational experience through participation in the trial. Two respondents (both tourists on the 6-day trip) would have liked a higher degree of involvement (i.e.. more "research" dives).

?? Feedback/suggestions on training program: comments on the training program were included in 9 questionnaires. Of these, 3 respondents (all from the community group) provided recommendations on the final format of the data-sheet. Three volunteers recommended a trial (underwater or in game format) to practice identification before sampling. One suggested the use of a video for training. Two respondents would have liked more information on the program in general (overall goals and community involvement initiatives) during the training session.

?? Diving skills/difficulties: Eight volunteers provided general comments on diving aspects of their participation. Six of them found it difficult to achieve satisfactory buoyancy control while concentrating, writing and/or handling the board with the data-sheet. Two respondents expressed concerns about the undesirability of involving volunteers if conditions were not ideal (e.g. strong currents).

?? Recommendations/suggestions for the overall program: Seven volunteers provided recommendations/comments in regard to the overall volunteer-based monitoring program. Three participants recommended that appropriate feedback procedures be developed to keep the volunteers informed. One volunteer suggested that this program be used in conjunction with other initiatives to increase community involvement in reef management. One comment pointed out that this kind of program may be more suitable for dedicated divers rather than occasional visitors; however, someone else saw the program as a good incentive for visiting tourists to come back as follow up to their involvement. Specific suggestions on ways to reward the participation of volunteers were also included (e.g. bumper sticker, t-shirt).

?? Negative comments/criticisms: negative comments were included in 6 questionnaires, all of which were completed by tourists on-board the 3-day dive operation. Of these, two respondents expressed concerns about the consequences of the trials on corals (i.e. damage to the reef); three respondents found too many people were engaged in the trial at once; and one respondent lamented the time taken by the trial which could have been dedicated to diving.

?? Cognitive tasks/difficulties: Four volunteers commented on the difficulties they experienced in performing the required tasks underwater. In particular, problems were reported in concentrating on the tasks and in making decisions in relation to identification of reef organisms. Also, writing underwater was regarded as a positive challenge.

?? Sampling protocol: Finally, one suggestion was made by two volunteers (one member of the community group and one visitor on-board the 6-day dive trip) in relation to the use of lead weights at regularly spaced intervals along the transect, in order to minimise movements of the line during sampling.

Additional feedback was obtained also as part of informal debriefing sessions at the end of the sampling exercises. This feedback was particularly useful in highlighting specific difficulties encountered by the volunteers in identifying reef organisms *in situ*. The recommendations of the participants, together with the results from the trials, served as the basis for drafting the final version of the interpretive and training material (Figure 5.1).

7.3 Implications of the survey results for the program

Participation in coral reef research was, in the great majority of cases, welcomed with enthusiasm by volunteers. This was not surprising in the case of members of the community group, whose motivation provided the initial impetus for this project. However, strong support and approval was expressed by many of the occasional visitors who took part in the trial during commercial dive tourism expeditions. However, it was apparent that the training session and research dive had most difficulty fitting into the tight schedule of the 3-day dive trip. This resulted in the few negative comments made by participants throughout the trials and might also be reflected in the lower reliability of data collected during the trials on-board the short dive expedition. Quantitative monitoring of the type proposed in this study may, therefore, be unfeasible for tourism operations which offer expeditions of short duration. Staff on-board the trips of short duration may not be able nor willing to carry out the sampling with the continuity required by the program because of the already tight schedule of tasks on-board such operations. Given the outcomes of this study, inclusion of a research activity within the recreational experience should be given careful consideration by the industry. This is also supported by findings that a major source of dissatisfaction among coral reef visitors on one-day trips results from not having enough time available for enjoying the reef (Plant 1993 cited in Green 1997).

Positive feedback and supportive comments from the majority of the participants in the tourism dive trips and from members of the community group, indicated that the proposed sampling protocol and associated underwater tasks are suitable for use by non-professionals and can be adopted successfully for involvement of volunteers in quantitative monitoring of reef benthic organisms. However, some comments - i.e. problems in making decisions and handling unfamiliar equipment - pointed to the need for practice underwater prior to sampling to increase the familiarity of the volunteers with the tasks and equipment. This is also supported by the findings described earlier in this report (Chapter 6) where reliability appears to increase with increased practice. One - or more - practice sampling session could be incorporated as part of the training program, and could include, besides familiarisation with the tasks and equipment, validation exercises for the identification of reef life-forms *in situ*. Similar practice runs are used, for example, in training Coral Cay Conservation volunteers (Mumby *et al* 1995) and volunteers participating in the Frontier Tanzania fish censuses (Dartwall and Dulvy 1996).

Several useful suggestions for the improvement of both the training materials and the data-sheet used for recording observations underwater, were provided by the volunteers as part of their responses to the questionnaire and during debriefing sessions. The following modifications were incorporated in the final version of the interpretive materials (see Appendix B). In the data-sheet, the alphabetical codes for the life-form categories, both in the data-sheet and in the table included in the handbook, were changed to the initial one or two letters of the name of the category. And the sampling points were designated in metres (as along the measuring tape used as transect line) rather than in centimetres as in the draft. In the Handbook the following modifications were made: a text-box was inserted containing instructions on the correct positioning of the diver in relation to the transect line; clear instructions on the necessity of paired observations; description of the most problematic life-forms was expanded; recommendations on the number of practice runs to be completed before initiating sampling.

8. CONCLUSIONS AND RECOMMENDATIONS

In this study we have shown how a modified version of the Line Intercept Transect technique (English *et al.* 1994) can be used by non-specialist volunteers to provide useful information on the abundance and status of broad categories of coral reef organisms. Field trials of the sampling protocol with recreational divers and tourism operators showed that, with only limited training, volunteers can provide quantitative estimates of the total percentage cover of corals that are comparable in precision and accuracy to those obtained by qualified marine scientists. Coordinated programs of sampling by volunteers using these techniques have the potential, therefore, to complement existing scientific monitoring programs in the Great Barrier Reef Marine Park, by providing information on natural patterns of change from a greater range of sites and at more frequent time intervals than is currently possible. For this potential to be realised, however, careful attention must be given to minimising the sources of error that we identified in the use of the point-intercept technique.

The reliability of data obtained by individual volunteers varied according to:

?? their proficiency as SCUBA divers (measured here as the number of logged dives that the observer had completed since gaining SCUBA qualifications) (Section 6.3.6),

?? the extent of training each observer received and, in particular, the amount of field practice each completed before collecting data (Section 6.3.7), and

?? the level of taxonomic resolution used in field identifications and in final analysis of data (Section 6.3.4).

In some instances, these errors were exacerbated by variation in the abundance and diversity of coral life-forms at different sites. For example, differences among observers were most evident at sites where there was a comparatively large percentage cover of corals. It is important that such discrepancies are minimised and regularly evaluated to ensure that the sampling program is able to detect real patterns of change in natural assemblages. In the ensuing sections, we outline our recommendations for future use of the sampling protocol described in this report.

8.1.1 Requirements for training of volunteers

The importance of rigorous training for standardising the quality of the data in sampling programs involving numerous observers, has been emphasised many times (Kepler and Scott 1981; Inglis and Lincoln Smith 1995; Miller and De'ath 1996; Dartwall and Dulvy 1996; Thompson and Mapstone 1997). The constraints imposed by the short duration of the dive trips on which we trialed the sampling methodology meant that the time devoted to training volunteers was kept to a minimum (usually < 1 hr for the briefing). Although the results from the field trials indicated that this very brief mode of training could produce satisfactory sampling performance for broad taxonomic categories, substantial improvements in precision and accuracy could be achieved for individual life-forms, by expanding the training program beyond the minimum levels described here.

In particular, training volunteers in collecting quantitative data on the percentage cover of reef organisms using the protocol developed during the course of this project, should include the following:

?? Unambiguous decision rules to assign reef organisms to one of the 15 life-form categories. The categories which provided the most difficulties in identification for volunteers - "digitate" and "encrusting" corals, "algae" and "bare rock" (also called "reef matrix" in the first of the trials) - should receive particular emphasis in briefing sessions. A range of photographic examples needs to be included to expose observers to the variety of morphologies that the volunteers may encounter in the field for each of these problematic categories.

?? Clear procedural rules for recording the life-forms occurring beneath the transect line. A lack of repeatability in sampling from individual transects contributed as much as 26% of the error associated with different observers in this survey. This error was associated with variation among observers in the angle and height from which each point on the transect was surveyed. Whilst this is less of a problem for random transects than it is for fixed line transects (Mundy 1991), greater standardisation of observational procedures can help reduce unconscious (or conscious) biases which may predispose observers to count large, familiar or unusual corals. Pre-dive training should emphasise the need to maintain a constant distance from the transect and angle of observation during sampling.

?? Validation exercises in the field are required to ensure consistency in the identification of reef organisms and in sampling procedure. Validation exercises should require the novice observer to identify reef organisms in the field and to obtain immediate feedback from the instructor on the correct identification. Such exercises would provide the observers with an appreciation of how the different organisms appear *in situ*. We have shown that the identification of life-form categories becomes more consistent and estimates of percentage cover more precise after volunteers have completed between 6 - 8 practice transects. Validation exercises should take the form of practice field observations to increase the familiarity of the volunteers with the sampling procedure and the data recording form.

8.1.3 Guidelines for use of the sampling protocol by volunteers

The composition of volunteer groups is inevitably mutable and this poses particular problems for maintaining consistency in long-term data collection. Rigorous attention is needed, therefore, to procedures for maintaining control over the quality and reliability of data obtained from the program. More importantly, the ensured safety of participants in volunteer programs should be of paramount concern to all parties involved, particularly when it involves the use of SCUBA diving or snorkelling.

The following recommendations are intended to optimise the safety and reliability of the sampling protocol developed during this project when used by groups of unsupervised volunteers. They were derived by integrating the outcomes of the field trials conducted during the project with relevant findings of similar studies elsewhere in the world and with basic principles of sampling design.

?? Identification of responsibilities for safety and safety procedures. All steps should be taken to minimise the risk to participants in the program of injury and loss of property. This requires that each party in the program be made aware of potential risks associated with their participation in the research and that written statements clearly identify the responsibilities of each group for safety. Steps taken to assure the safety of participants should be consistent with standards for workplace, health and safety relevant to recreational SCUBA diving in a workplace (Division of Workplace Health and Safety 1992).

?? SCUBA diving proficiency. The proficiency of SCUBA divers used in the study has an important bearing on their ability to complete the sampling procedures safely and efficiently. Results from the field trials showed that data obtained by divers who had logged more than 30 dives were generally more reliable than those collected by less experienced divers. However, the risk involved to the diver and the usefulness of data collected by any individual are likely to be more closely related to the competence and skills of the divers than to the number of dives they have completed (the measure of experience used in this study). We suggest that a qualified dive-master should assess the ability of each diver to perform the tasks required in the sampling program prior to the commencement of any sampling activities. In particular, the dive-master should assess competence in buoyancy control, familiarity with SCUBA equipment and confidence underwater. Prospective participants whom the dive-master believes do not have sufficient confidence and skill to use the sampling techniques should be actively discouraged from participating. A number of safety features have also been incorporated into the sampling procedures, including regular reporting on the data sheet of the expended dive time and remaining air pressure. In addition, we strongly recommend the use of an in-water dive supervisor to maintain a roving watch on all participants.

?? Conditions under which sampling should be undertaken. Sampling should be done as much as practicable during periods of calm sea, as the effect of wave action may cause additional difficulties with buoyancy, result in movement of the transect line and lead to variation among observers and imprecise estimates of cover for some life-form categories. To maximise consistency in the identification of reef organisms, sampling should also take place under good conditions of visibility (> 5m).

All sampling should occur at depths shallower than 20m. Aside from considerations of safety, depth has been identified by a previous study as a potential source of error in data collected by volunteers, in that consistency and accuracy appeared to decrease at depths > 30m (Mumby *et al* 1995).

?? Pairing of observers to sample individual transects. Volunteer observers should always carry out the sampling in pairs, with each pair surveying the same transect. This has several benefits. First, for reasons of safety, all SCUBA divers on the program should be required to dive in "buddy-pairs"; if each pair samples the same transect, they will be in close visual contact throughout the dive. Second, data on the relative percentage cover of the life-forms used in the detection of trends can be derived from the average of the estimates obtained by each member of the pair for that transect, thereby reducing the impact of large individual variation among observers. As far as possible, an effort should be made to interchange pair members across transects, while sampling the same site. This requires some planning prior to the sampling, and good coordination in the field, but it ensures that the effect of inter-observer variation and of observer specific biases is minimised. Lastly, the paired observations from each transect provide an active means of continually assessing the degree of consistency between observers in the identification of life-forms and can be used to repeatedly check on the reliability of the information used.

?? Number of transects to be sampled at a site. At least 8-10 transects should be sampled at each site (Section 4.3.3; Mundy 1991). The transects should be positioned at approximately the same depth. All transects should have the same orientation and, although their exact position should be chosen at random, they should be distributed throughout the site to ensure the representativeness of the sample.

?? Training of new volunteers. Volunteers should be trained using the materials developed during the course of this project (Appendix C) and should take part in a number of practice runs before their observations are included in the monitoring program. The number of practice transects required is approximately 6-8 (Section 6.3.7), but training should continue until obvious inconsistencies have been overcome (Thompson and Mapstone 1997).

?? Quality control procedures. The estimates obtained by two members of a pair should be compared for all pairs on a regular basis. Potential biases and inconsistencies in the identification of life-forms may be exposed by regular checks and measures can be taken to obviate the identified problems. Validation exercises to compare the interpretation of specific life-form categories and the relative accuracy of the estimates among observers should be undertaken regularly.

8.2 A general framework for the development of volunteer-based monitoring programs - ideas from lessons learned

8.2.1 Framework for developing volunteer-based monitoring programs

At least three common elements must be incorporated into the planning of volunteer-based monitoring programs: arrangements for program management and coordination, technical design, and training of participants (Figure 8.1). The three components are inter-related and assume varying degrees of importance at different stages in the development of the program.

These relationships are described more explicitly in Figure 8.2. and in the following sections.
In general, any volunteer program passes through an initial period of consultation and negotiation among the interested parties, during which the overall objectives of the program are determined. Subsequent phases involve the development and trialing of the sampling methods and training materials and, finally, implementation and management of the program (Figure 8.2). Volunteers and experts (environmental managers and scientists) must work together in all stages of the program to ensure its success (Jacoby *et al* in press).

Figure 8.1: Schematic representation of the issues relevant to the involvement of non-professionals in monitoring programs, and the individual components of the program which need to be incorporated in the planning and development phase of the program.

Identification of common, achievable objectives

Volunteer programs will only be sustainable on a long-term basis if they are successful in meeting the aspirations of each of the parties involved. Such programs usually depend upon the continued input of time and resources from several different sectors - resource managers, scientists and community groups - and are contingent upon satisfactory outcomes being achieved by each sector. However, each group may initially have different expectations for the program and, therefore, different standards by which they will judge its success or failure. For example, during the consultation phase of this study we found that the motivations of the groups involved were diverse, as were the expectations for use of the information that was collected (Table 8.1). Among the tourist operators who expressed interest in being involved in the study, the objectives for monitoring ranged from providing data for management on remote reefs or reefs usually not surveyed by current scientific monitoring, to the gathering of information on the occurrence of particular events which were of interest to the industry (e.g. information on when and where dolphin and whale sightings occurred, which may assist in planning seasonal schedules for tourist operators). In contrast, the community group shared similar objectives to the reef managers, in that their willingness to participate arose from specific concerns about environmental deterioration of local reefs (O.U.C.H. was initially formed in response to an increase in recreational and commercial use of the fringing reefs surrounding the Whitsundays Islands, and the resulting potential damage to the reef from anchoring by high numbers of vessels; T. Fontes, pers. comm.).

Table 8.1: Motivations, objectives and desired outcomes for coral reef monitoring prevalent within each of the four groups involved in developing volunteer-based monitoring programs and possible constraints to collaboration among the four groups as envisaged during this project.

	VOLUNTEERS (COMMUNITY GROUPS - GENERAL PUBLIC)	VOLUNTEERS (DIVE TOURISM OPERATORS)	CORAL REEF ENVIRONMENTAL MANAGERS	MARINE SCIENTISTS
Motivations/ objectives for monitoring coral reefs	??Concern for local environment ??Response to specific problems (e.g. anchor damage) ??Direct involvement in management ??Dedication to marine environment ??Recreational activity	??"Looking after" re.g.ular dive sites ??Educational, nature-based activities for customers ??Information to management (sustainability of activities) ??Information useful for planning commercial operations	??Detecting impact of human activities ??Evaluating management strategies ??Obtaining data on natural environmental change for policy development	??Describe broad scale spatial and temporal patterns ??Estimating population parameters ??Detecting effects of natural and human induced disturbances
Desired outcomes of monitoring programs	??Information for management of local issues ??Wise use of the local environment	??Management for sustainable development of tourism on the GBR ??Interpretive/educati on materials	??Information basis for decision making ??Re-assessment of management policies/ strategies (adaptive management)	??Development of ecological theories ??Publication of results
Possible constraints to collaboratio n among groups	?? Local politics ??Logistic constraints ??Resources	??Poor understanding of requirements for scientific monitoring ??Logistics (especially tight time schedules) ??Lack of motivation of individuals involved	??Uncertainty about reliability of data ??Lack of resources ??Concerns for impact of volunteer-based monitoring	??Scepticism about data quality ??Issues of intellectual property ??Competition with volunteer groups for research funds ??Lack of professional incentives for involvement in community-based projects

Reconciling some of these differences, deciding upon common objectives and identifying the limitations of the program are the most critical component of volunteer programs and require a considerable investment of time in consultation. As the primary reasons for initiating volunteer-based programs, the aspirations of the volunteers themselves and the constraints imposed by their availability should define the scope of the program. Volunteers are often motivated by feelings of stewardship toward local environments and a desire for greater involvement in their conservation (Korten 1990; White *et al.* 1996). Nevertheless, it is important that these aspirations be tempered by advice on what is achievable and, if external resources are to be used, on what is useful. While the level of detail and the expectations of quality are necessarily lower for volunteer-based studies than for professional monitoring, the success of such programs will ultimately be measured by how useful the information obtained from it is for detecting trends in space and time and/or guiding management actions.

Identification of constraints.

The limitations of the program and the level of commitment necessary for its successful implementation must be explicitly acknowledged at an early stage, as they influence the scope of the program and the choice of methodology and training procedures (see 4.2). Additional limitations may be identified as a result of the initial field trials (Figure 8.2).

In this project, limitations inherent in the involvement of the dive tourism industry in quantitative monitoring of reef organisms, were identified initially by defining the logistic constraints posed by the dive trips schedules. These constraints were a major influence on the choice of methods used and the time for and content of training. However, the field trials undertaken in collaboration with two tourist operations of different duration (respectively 3 and 6 days) highlighted difficulties of involving paying customers on-board short trips in data collection. Results from the field trials and the program evaluation indicated that longer training which incorporates practice in the field, may increase the volunteers proficiency in the sampling tasks, and thereby improve the reliability of the data.

Development of methodology and training materials

Our study highlighted the advantage of developing the sampling methodology and training materials concurrently, in an interactive way. Training programs in volunteer-based environmental monitoring programs aim to maximise the quality of the data collected by the volunteers (Kepler and Scott 1981; Wells 1995; Miller & De'ath 1996) and to provide participants with a means of actively learning about the environment they are working in. Interpretative materials used to train participants should, therefore, be designed with the intent of achieving consistency among observers and imparting them with information they find new and interesting. Results from initial field trials of the sampling methodology and formal evaluation of the training program - such as those conducted during this project - can be used to identify aspects of the program that participants find difficult to understand or mundane. On-going evaluation is an important means of refining both the sampling and training materials to make them more effective and enjoyable. The use of video as part of the instructional materials, although not feasible for this study, is also recommended as it represents the best way to ensure consistency in the training program.

Implementation of the program: central coordination or self-reliance?

How the overall program is managed will depend to a large extent on its intended size and purpose. Where the objective is to develop monitoring from a 'network' of locations, some centralised coordination of the program is necessary to ensure that information obtained from the disparate groups is compatible, of a comparable standard and capable of being integrated to describe broad-scale trends. Whatever their function, however, the main difficulties faced in sustaining volunteer programs tend to be waning enthusiasm of the participants and reduction in the resources available to maintain the study. Problems arise when the participants cannot see how the information they collect is being used, when the tasks become repetitive and mundane (as repeated surveying of the same sites can often be), and when there appear to be few tangible benefits to individuals participating in the program. Different challenges in maintaining enthusiasm are faced when there is a need for continued commitment of local community or industry groups (as in Soufriere where dive operators take photographs at permanent sites; Smith 1994) as opposed to when volunteers are occasional participants in a program (e.g. tourists spending 10 weeks on a recreational/conservation trip with the Frontier Tanzania program; Dartwall and Dulvy 1996).

Careful planning is needed to ensure the sustained enthusiasm of volunteers (Armitage *et al.* 1989, Stokes *et al.* 1990). Regular reporting on the findings of the study, organised media exposure, systems of prizes and awards and special social events can all serve to reinforce feelings of involvement in and 'ownership' of the program by participants (EPA 1988 cited in Armitage *et* al. 1989; Christie and White 1997; Campbell 1997). A community-based program is more likely to be self-sustaining if most of the program tasks - from data collection to data storage and preliminary analysis - are able to be performed autonomously by the volunteer groups themselves, with only minimal on-going assistance from resource managers and scientists. Some help may be required in the overall coordination and dissemination of broad-scale information on trends and achievements to participants, but the principal responsibility for project management most appropriately lies with those carrying out the surveys; the volunteers.

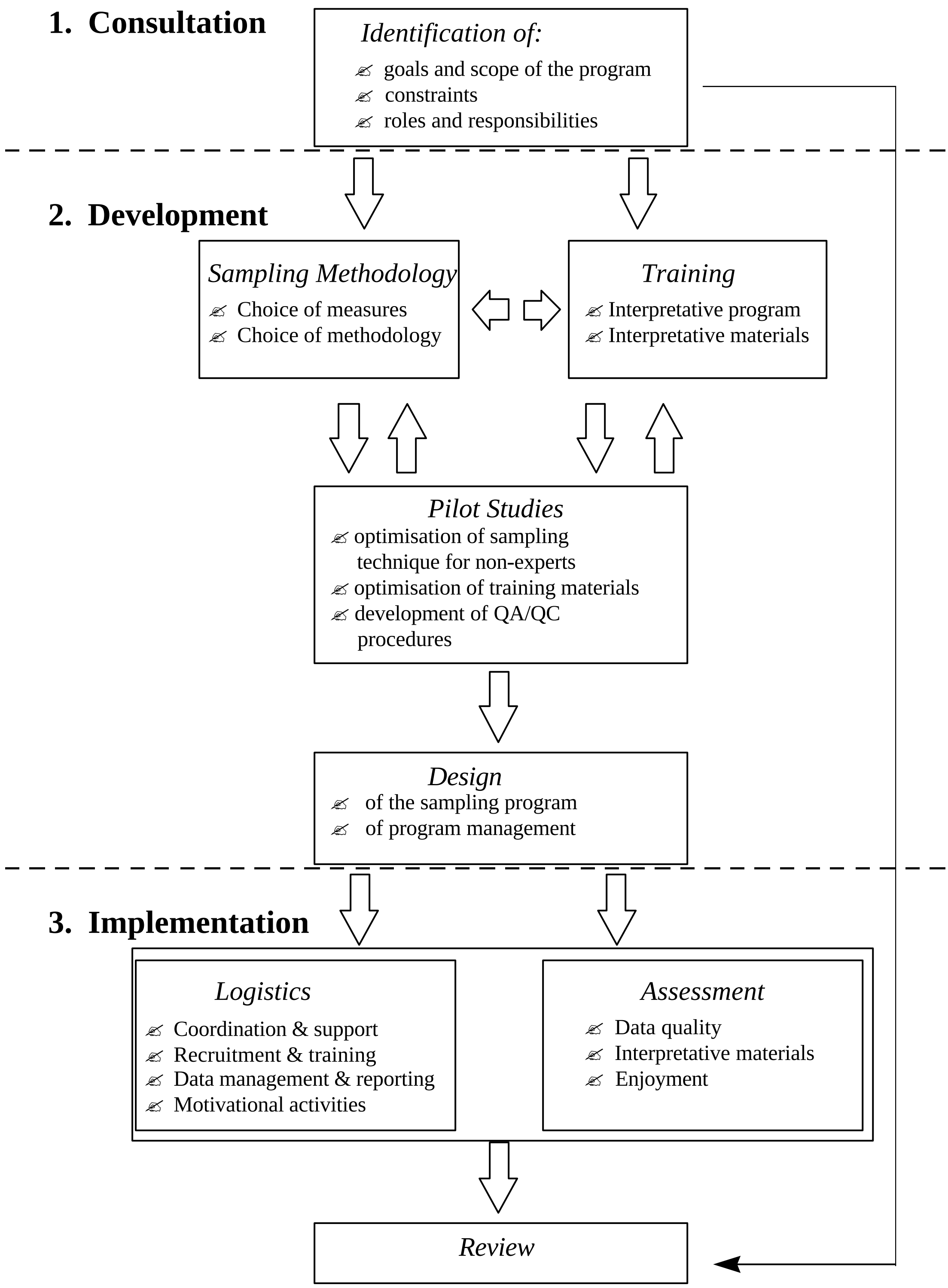


Figure 8.2: Schematic representation of the steps in the development and implementation of a volunteer-based environmental monitoring program.

To give it clear purpose and direction, management of the program should involve setting agreed targets and objectives that allow the success of the venture to be reviewed at predetermined intervals. These could include standards for maintaining data quality, reporting, participation, and enjoyment, but might also detail agreements on the actions to be taken by resource managers and participants under specific sets of circumstances (e.g. where there is cause for concern about the environmental deterioration of a site or sites, or conditions under which the program will be terminated). Unless there are clear, auditable targets, monitoring programs may consume considerable resources of time, effort and money for little discernible gain (Underwood 1991).

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Appendices

Appendix A: Instructional Manual for Research Supervisors (for use by dive-masters during those field trials done with no supervising scientists).

RECREATIONAL DIVERS' REEF MONITORING PROGRAM

Instructional Manual for Research Coordinators

DRAFT

A project funded by the

Office of National Tourism

and the

Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef

Project Coordinators : Barbara Musso & Graeme Inglis
Manual compiled by: Barbara Musso & Michael Cuthill

Introduction

This manual is designed to assist you in training the divers who participate in the monitoring program and it includes a script for the interpretive talk that you will give to the divers prior the research dive.

The interpretation needed for training the volunteer divers differs from usual coral reef interpretation in that it is meant to explain the relevance and technical details of monitoring on coral reefs. The two main objectives of the training are 1) to **motivate** divers to participate and 2) to **instruct** them in the monitoring techniques. The main points you have to get across to the divers are:

?? what is **monitoring** and the relevance of monitoring coral reefs;

?? what contribution can **recreational divers** make to coral reef monitoring;

?? and how we can monitor coral reefs in a **simple and effective way.**

Furthermore, you need to mention **underwater safety** and **best practice** issues.

The major condition for this program to be successful is that the divers have to **enjoy the experience** and **get something out of it**. At this stage however the possibilities of achieving this are a bit limited. When the program will be running in its final version it will include fancy things such as software to store and analyse the data on board the vessel and it will produce nice graphs representing what the divers have recorded and comparing it to previous data so that they will be able to see straightaway how their contribution is used. Other additions will include a test on the identification of the lifeforms so that they can practice what they learn from your talk before getting in the water. The reason why these aspects of the project are not ready now is that this is a **pilot stage**. In this stage we are looking at answering specific questions on the feasibility of the whole program and particularly on the quality of the data collected by volunteer divers. If this pilot study tells us in the end that the program is feasible, the data are good enough that the managers and scientists are prepared to use them and last, but not least, the divers involved enjoy doing it, then we will be putting all our efforts into making the program as attractive/interesting and educational as possible. You should stress the preliminary nature of the project with the divers and explain that their involvement will help us refining the program. So next time they come and visit the GBR they may be able to participate in the real program and know that they have contributed in making it happen. Tell them also that they will be included in our mailing list and we will keep them informed of the results of the project.

Coordinating the "research dive"

(pilot study protocol)

?? Lay down the 10m line transects (one for each buddy pair) always at the same site. However, avoid placing the transects on exactly the same point by, for example, choosing a certain coral as a start point. It is important that, within a general reef site, the transects are random. Transects should follow as much as possible a single depth profile.

?? Make sure that the divers label their datasheets accurately. The following information from each diver is essential: name, buddy's name, site, transect number (1 for their first transect etc.). Back on the boat, you should take few minutes to check that everybody has provided this information on their datasheet. You will also have to fill the "Research Dive record datasheet" provided at the end of this manual.

?? **For this pilot stage it is essential that data are collected by two divers for each transect. If the number of divers is uneven, you should collect the data with the single divers.**

?? Take the pair to the start of the transect and indicate to one of the two divers to start (the second diver in a pair will start when the first diver is about 2m down the transect, and you will have instructed the divers on this during the dive brief).

?? It would be ideal that each pair does two transects. However to carry out two transects may be unfeasible for some divers and/or if you have more than 2-3 pairs.

IMPORTANT: Remember to give out the questionnaires at the end of the dive. It is essential for this phase of the project to get feedback from the volunteers on how to make it better

INTERPRETIVE TALK

SCRIPT

The setting

Lounge of boat with

?? pens and paper,

?? ten metre tape,

?? data board with datasheets,

?? reference books (copy of Veron's coral book; GBRMPA 'Discover the GBR'; fish ID "Marine Fishes of NW Australia'),

?? "Guide to the identification of lifeform categories" and

?? copies of the "Recreational Divers Research Handbook" (one for each diver).

Comfortable setting so all of audience can see the presenter. Be sure to also invite those who are not participating in the project.

Introduction

?? *(Introduce yourself as the research coordinator).*

?? The CRC Reef Research Centre, in collaboration with some tourist operators is undertaking a pilot study funded by the Department of Tourism, to design ways of involving recreational divers in monitoring programs on the Great Barrier Reef.

?? There is no obligation for you to take part in this program, we offer it as an exciting way to learn more about the reef and hopefully make your diving even more enjoyable.

?? This presentation will take about 40 mins and will be delivered in three parts.

?? In the first part I will explain a little more about the project in general, why reef monitoring is important and what you can gain from being involved. This will be fairly brief and most of the questions you will be asking yourself at that stage will be answered in the next two parts of the presentation.

?? In the second part I will explain the type of work you will be doing, how to do it, and show some photographs which illustrate the type of lifeforms you will be measuring and recording.

?? We then finish up with a short discussion about safety and good diving skills while working in the water.

?? Jot down any questions as we go (provide paper and pens) and make sure that I have answered them for you by the time we finish. There will be a "Recreational Divers Research Handbook" given out to you at the end of the talk that outlines all of this information so don't worry if you miss some details during the talk.

Part 1

?? Monitoring means collecting information from the same area repeatedly over time.

?? Monitoring is used to understand how corals and other reef organisms change over time.

?? It can tell us for example how long a reef needs to recover from a severe storm or a cyclone. When monitoring shows that the amount of live coral is decreasing and the amount of dead coral is increasing over time, we know that the reef may be under stress and that we need to find out more.

?? Monitoring therefore helps us to make better management decisions and to set research priorities.

?? Monitoring is usually done by reef scientists; however, it is very expensive and there are considerable limits to the number of reefs scientists can monitor and how often.

?? Recreational divers can contribute to increase the number of reef sites that are monitored on the GBR and they can monitor them very often. This project aims at developing a simple but rigorous monitoring program to enable recreational divers to collect information that can be used by scientists and managers. By "donating" one of their dives to this program recreational divers can broaden the scale and resources of monitoring on the GBR considerably.

?? Diving for research is fun. You will learn to look at corals in a different, more informed way. You will have to perform specific tasks and take decisions underwater, which to most recreational divers is an unusual and challenging task. By participating to the "research dive" you will broaden your diving skills. We think that all this plus the awareness of contributing to looking after the reef will make your participation in this program a very positive experience.

Part 2

?? Coral reefs host an incredible variety of corals and other organisms. In fact coral reefs are probably the most diverse ecosystems on Earth. On the Great Barrier Reef there are more than 350 different species of corals and hundreds of species of other animals and plants. To identify each of them in order to measure their abundance is impossible. However, it is possible to group reef inhabitants in a small number of categories. These are called **lifeform categories.** For example, corals are grouped in categories according to their shape. There are "plate" corals, "dome-shaped" corals, "branching" corals and so on. The shape of a coral reflects to a large extent the environmental conditions in which the coral lives. Also the occurrence of certain organisms is indicative of particular conditions. Lifeform categories are very useful for monitoring. Recording lifeform categories at one reef site over time is an easy and effective way to keep an eye on the overall state of the reef. For example, monitoring may reveal that over a certain period of time algae and sponges are replacing corals and this may happen for example when the reef is polluted by sewage.

?? In this program we use 15 lifeform categories and you will be asked to identify them during your dive and to record where they occur along a 10m tape measure (*describe the categories to the divers using the poster and the photographic guide*).

?? The monitoring consists of recording the abundance of each of the lifeform categories at one particular site. The categories are recorded along several 10 meter long line transects. A line transect consists of a tape measure carefully placed on the reef surface. What you have to do is to swim along the transect and record which of the 15 categories occur under the tape every 20 cm. To record a lifeform category you just enter the letter code for that category as indicated on the top half of your underwater datasheet (*at this point show them the datasheet*). Everytime you record a category, you are also required to indicate for that record which of the "marine life status" descriptions apply to the organism you are recording. So for example, if at 160cm along the transect you find a branching coral that has few branches broken, you will write on your datasheet next to 160 the codes A (for branching corals) and 5 (for broken branches).

?? Your data will provide an indication on how abundant each of the categories are along that transect. Let's suppose that the category "branching coral" is recorded under 10 of the total 50 points that make up a transect, this provides for a 20% cover of "branching coral". Such information from several transects in the same area will provide a representative picture of the type and state of the organisms living on the reef surface in that area. If the information is collected at regular intervals, say every 2-3 months, we will be able to see whether there are changes.

?? (*at this point you should make sure that evrything is clear and ask for questions*)

Part 3

(below are the points you should mention in relation to safety and behaviour underwater)

?? Dive safety comes first. If you feel unconfortable, tell your buddy and discontinue the work.

?? Good buoyancy is very important to carry out this work. If your buoyancy is not correct, you will damage corals, spend lots of energy and air and you will end up not enjoying the experience at all. Make sure that your buoyancy is right at the very start of the dive.

?? Apart from the buoyancy, you have to consider other aspects of your diving practices in order to prevent damage to the corals. Beware of your fins. Try not to touch the reef and prevent your spare reg and gauge hanging loose and dragging on the corals.

At the end of the talk, ask whether they have any question; distribute a copy of the handbook to each diver; leave the other material accessible for perusal; make other texts on reef life available so that they can relate what you told them to other photographic material.

Thanks to everybody for participating and contributing to the realisation of this project.

RESEARCH DIVE RECORD DATASHEET

Vessel/Organisation:.. **Sheet #:........**

			Buddy Pairs			
Research Coordinator	**Date**	**Site**	**Buddy 1** (name as on u/w datasheet)	**Buddy 2** (name as on u/w datasheet)	**# Transects completed**	**Comments**

Appendix B: Training handbook (includes modifications required following program evaluation and data analysis)

RECREATIONAL DIVERS' REEF MONITORING PROGRAM

....

HANDBOOK

A project funded by the

Office of National Tourism

and the

Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef

Project Coordinators : Barbara Musso & Graeme Inglis
Handbook compiled by: Michael Cuthill & Barbara Musso

The CRC Reef Research Centre was established under the Australian Government's Cooperative Research Centres Program.

The Centre, established in 1993, undertakes an integrated program of applied research and development, training and education, aimed at increasing opportunities for ecologically sustainable development of the Great Barrier Reef and providing an improved scientific basis for Reef management and regulatory decision making.

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INTRODUCTION

Recreational divers are ideally placed to contribute significantly to the monitoring of coral reefs. They are very committed to, and quite knowledgeable about, the marine environment and its inhabitants.

They also feel a degree of responsibility to look after the places they visit while wanting to learn and understand more about the things they see. The program you are participating in, primarily seeks to provide useful monitoring data for management purposes, while offering you a way to learn more first-hand about coral reefs.

WHY CARE FOR THE GREAT BARRIER REEF?

The importance of the Great Barrier Reef has been recognised through its World Heritage listing in 1981; but for those of us who live here and those who come to visit, we know it also provides many other valuable gifts. It is an important ecological system on a global scale, it provides the opportunity for jobs for many people, and, increasingly so in this crowded and polluted world, it is being recognised as a very special place for its natural beauty and wilderness, and the unique experiences it can offer us.

The responsibility of looking after the reef does not lie with the managers alone. All of us who are using the reef have a responsibility towards protecting the reef environment. If all of us involved with the reef accept part of this responsibility then we all can contribute to the wise management of the Great Barrier Reef. We hope that by taking part in this program, you will feel that you are fulfilling part of our collective responsibility to protect the Great Barrier Reef.

WHAT DO YOU GET OUT OF THIS?

You probably will feel good that you have helped, but there is much more than that. In return for your involvement we will give you the opportunity not just to see the reef as a passive observer but also to start to learn from your own practical experiences how the reef ecosystem works. You will also be able to discuss and explore what you want to know about the reef with other people who have similar interests and desire for knowledge. This doesn't mean boring lectures and being fed lots of information, rather the chance to be **involved** in this work and learn through your own efforts. You will be kept informed through a regular newsletter about the results of the monitoring, not only in relation to the locality where you operate, but thoughout the region. And lastly, this work will also provide you with the opportunity to experience a new and enjoyable way to dive.

WHAT IS CORAL REEF MONITORING?......

Coral reef monitoring means collecting data on the state of one or more reefs repeatedly over time. This activity is very important because it allows us to detect changes in the state of the reef that may be due to natural fluctuations, human actions or natural disturbances, such as cyclones. In many parts of the world, reefs have been badly affected by human activities. Some reefs in South East Asia have seriously degraded. During the last few years scientists have increasingly recognised the need to monitor coral reefs throughout the world. The information gathered through monitoring programs is used to make better decisions on how to manage coral reef environments.

which are the major reef builders, whether they appear to be healthy.

.....AND HOW CAN YOU CONTRIBUTE?

There are scientific programs that currently monitor the state of the Great Barrier Reef. The largest one is being carried out jointly by the Australian Institute of Marine Science and the CRC Reef Research Centre, both based in Townsville. Every year a team of scientists visits about 50 of the 2500 reefs that make up the GBR, and collect data on fish and corals.

Recreational divers who dive on the GBR represent a wonderful opportunity for gathering regular information from a larger number of reefs and more frequently. Recreational divers on the GBR are already taking part in a very successful program developed by GBRMPA called COTSWATCH. In that program they are asked to report sightings of the coral-eating Crown-of-Thorns starfish. The data collected contribute to identify the onset and the patterns of starfish outbreaks.

HOW DO WE DO THE RESEARCH?

What we aim to achieve is the accurate recording of coral reef life forms, particularly non mobile reef animals and plants that live in contact with the sea floor such as hard corals, soft corals and algae. This marine life will be monitored over long periods of time and at many different locations up and down the Great Barrier Reef. Every time a group of divers like yourselves do the monitoring, information is gathered from a number of different line transects from each reef site. This monitoring program provides information on what types of reef organisms are there and how abundant they are relative to each other, and, in the case of hard corals, which are the major reef builders, whether they appear to be healthy.

The information collected represents a ‘snapshot’ of that reef site at that time. A series of ‘snapshots’ taken over time will help to understand what changes, if any, are occurring within those reefs.

Coral reefs under natural circumstances change all the time. This is because of the interactions between all the different organisms living there and the changing conditions in which they live. For example, major changes in the cover of hard corals usually occur as a result of severe storms or cyclones.

Coral reef scientists and managers use monitoring as a tool to understand how the reef changes and how quickly. Reef sites may be monitored once a year or more often, to provide an update on the state of that particular reef.

HOW DO WE COLLECT DATA ON REEF ORGANISMS?

The recording method we will be using is called an *line transect*. This style of data recording is similar to the one commonly used by marine scientists at the Australian Institute of Marine Science to obtain information on the cover and abundance of different types of marine life on the Great Barrier Reef.

The method consists of laying a 10 metre (30’) tape measure on the reef surface. You then move along the tape and record the reef organism that occurs underneath the tape at each 20 cm interval (you will also record additional information such as whether the coral you are recording is alive, dead or broken).

After you swim along the length of the transect, you will have a set of 50 data points. These will provide a representative amount of cover for the organisms. For example, if a ‘massive coral’ is recorded under 5 of the 50 points then this provides for an estimate of 10% cover of ‘massive corals’. The figure at the end of this handbook gives an idea of how the transect line will appear when placed on the reef and how the reef organisms which are beneath the sampling points should be recorded on the datasheet.

YOUR POSITION WHILE SAMPLING

Because of the irregularity of the reef, at some points the transect line will not be flush against the substrate but will be at a certain distance from it. In such cases, you may record different organisms beneath the line according to the angle from which you view the transect. To ensure consistency, it is very important that you maintain a **position perpendicular to the transect** while recording the lifeform categories occurring under the line.

It is also important that you maintain a **constant distance (≈ 0.8 m)** from the transect line while swimming along it. You can do this easily by considering that this is approximately the length of your arm. To maintain this distance is important for two reasons. Firstly it is a “safety”distance for the reef: you are not too close to the reef and it is less likely that you will come into contact with it. Secondly, it again ensures consistency in the data you collect. Due to the reef complexity, you may see things differently from different distances. Keeping the distance constant ensures that your

IMPORTANT: You and your "buddy" have both to record the data along a transect.

Each transect therefore will be surveyed twice, once by you and once, immediately after, by your "buddy". Besides being safer (by allowing you and your "buddy" to always be in visual contact), if each transect is surveyed by two divers the estimates derived from the paired observations are more reliable.

HOW DO WE IDENTIFY REEF ORGANISMS?

Because of the complexity of the reef and the enormous diversity of organisms living there, it is very difficult and time consuming to identify all reef animals and plants as individual species. To overcome this problems, often scientists doing monitoring use wider categories to group similar organisms. These are called life-form categories. We have selected 15 lifeform categories of marine life which can be easily recognised and which can provide useful information during monitoring. The 15 categories chosen for this work include important categories necessary for obtaining an overall view of the assemblages that live on the reef.

WHAT ARE LIFEFORM CATEGORIES?

Lifeform categories are groups of benthic (=*living in contact with the sea floor - in this case on the reef surface*) and sessile (=*non-motile*) reef organisms that are based on their broad taxonomic position (e.g. algae, corals, sponges..) and their **shape**.

To collect data on lifeform categories therefore does not require any complex taxonomic knowledge, but rather an eye for shape.

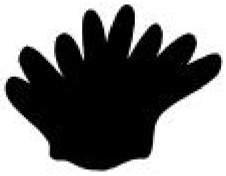
Corals have many different shapes. The shape of a coral reflects the type of environment that the coral lives in. For example, in a very exposed reef area, corals will be short and thick, to withstand the wave energy.

Therefore data on the abundance of different coral shapes provides a good indication of the type of environment the corals live in. Changes in the abundance of certain shapes of coral may indicate that the environmental conditions are changing in that area. In the same way, data on variations over time in the abundance of other organisms, such as algae and sponges, maybe important to indicate that environmental changes are taking place. For example, macroalgae and filter-feeding animals such as sponges, tend to overgrow corals and to become predominant in waters that are organically polluted.

Collecting data over time on life form categories is an easy and effective way of monitoring the overall state of a reef area.

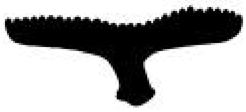
CORALS WITH BRANCHES

Br. Branching
Coral colonies with slender branches resembling antlers. Commonly called “staghorn” corals.



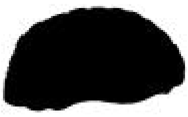
Dig. Digitate
Distinguished by short and stout finger-like or cone-like branches. The individual branches appear robust and thick compared to "hedgehog" and "plate" colonies and much shorter than the "branching" corals.

H. “Hedgehog”
Coral colonies with fine, fragile looking branches of regular length and a bushy appearance. Their overall shape resembles a hedgehog or porcupine.



Pl. Plate
Colonies that are plate like, with a stalk. Similar to the shape of most mushrooms. If observed closely, the flat part of the colony is made up by little branches.

MASSIVE CORALS

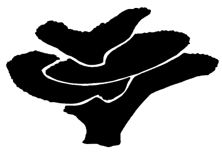


Dom. Dome-shaped
Corals with a dome-like shape. They vary in size from very small heads to huge colonies few meters in diameter.

Irr. Irregular-shaped
Massive corals that grow in irregular shapes. Some of them may resemble columns or wedges.

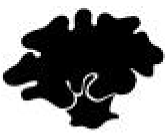
SHEET-LIKE CORALS

En. Encrusting
Corals that form a thin layer growing on the reef surface. May assume the shape of the organisms that they overgrow. Encrusting corals may be easily mistaken with coralline algae. These are usually smooth and brown-pink in color.



Pet. Petal-shaped
Thin, petal-like corals sometime occurring in a layered formation. Includes cabbage-like corals.

OTHER MARINE LIFE



Sc. Soft Corals
They are relatives of corals but they have a soft, although firm, body. Some grow upwards on a stalk, while others lay flat on the reef.

Spo. Sponges
Filter-feeders which come in a variety of shapes and textures. Soft bodies with many tiny holes (water goes in) and few large holes (water goes out).

Al. Algae
There are many different fleshy or hard algae, varying in colour from green to red and brown. They may be either encrusting or free standing.

?

?. Other/Unknown
Anything that does not fall within the above categories or is uncertain or unknown. This category provides information for a full 100% coverage.

NON-LIVING

Sa. Sand **Rub. Rubble** **Ro. Bare Rock**

These categories group non-living objects **Sand** includes fine sediments like you found on the beach. **Rubble** is made of fragments

of broken corals and other organisms. **Bare rock** means areas of bare reef rock with no apparent lifeform.

WHERE DO WE RECORD OUR OBSERVATIONS?

To easily and quickly record your observations while surveying a transect, you will have to use the **datasheet** provided at the end of this handbook.

The figure shows a section of a transect viewed from above, as you would see it if you were surveying it, and how to fill the datasheet with the data from that transect. At each point, when you identify what organism is beneath that point, you write in the appropriate box the **letter code** for that organisms. If it is a hard coral, then you will also fill the box with the **number code** corresponding to one of the five health status parameters.

CAN WE START THE SAMPLING NOW?

Trials done in the field with groups of volunteers using this sampling protocol have shown that the reliability of the data you collect increases with practice.
You will have to do approximately 6-8 **"practice transects"** before starting the sampling program.

It is important that you familiarise yourself with the identification of the lifeform categories. You can do that both using the photographic guide and also in the field, during the "practice transects". During these dives, you will have to survey a transect together with a diver experienced in identifying reef organisms. Your buddy will tell you when you identify a reef organism incorrectly.

HOW MANY TRANSECTS SHOULD WE SAMPLE?

The more transects you sample, the more the information you gather will be precise and representative of the site you are sampling. To give you an indication, some marine researchers think that you may need **at least 8** transects per site. If the number of transects is low, say less than five, then you may get very imprecise estimates from your sample. However, if you set too high a number of transects, it may become impracticable to complete them. The number of transects you sample will depend on the effort, in time and/or divers, you can put in the sampling. Remember that when you decide on a number of transects, it is preferable that you stick to it as much as possible, as using different numbers at either different sites or times may cause problems in the analysis of the data.

WHERE SHOULD WE PLACE THE TRANSECTS?

The positioning of the transects is very important. Remember that your sample of transects is meant to be representative of the site you want to monitor. This means that if you choose to place your transects always where there seem to be lots of nice corals to record, this will in the end provide an overestimate of coral for the site. The best way to go about it is to select the starting point of each transect **at random**. However, you should also try to space the transects regularly to make sure you cover most of the site you want to sample.

WORKING IN THE WATER.

There are some very important factors we would like you to remember when doing this type of work.

1) Safe diving is the major consideration. Nothing else is as important as this. To ensure safe diving standards are maintained we have listed some of the safe diving procedures we follow.

- All sites are situated in less than ten metres (30') of water ensuring that you will have ample bottom time to complete the work while remaining well within safe dive times.
- You will always dive - and work - in 'buddy pairs'.
- If you, or your buddy, experience any problems or discomfort while working underwater the dive should be abandoned. Gear and data can be replaced, or collected later, divers cannot be replaced. **DIVE SAFELY**. Remember to check your air supply and dive time as you would do in any normal dive.

2) To be useful, data must be accurate. If you follow the guidelines provided in this handbook you will have collected data to the level of accuracy required. If you have any doubts about the accuracy of the data you have collected please note this on your data sheets when diving, and ask your research coordinator to clarify the matter after your dive.

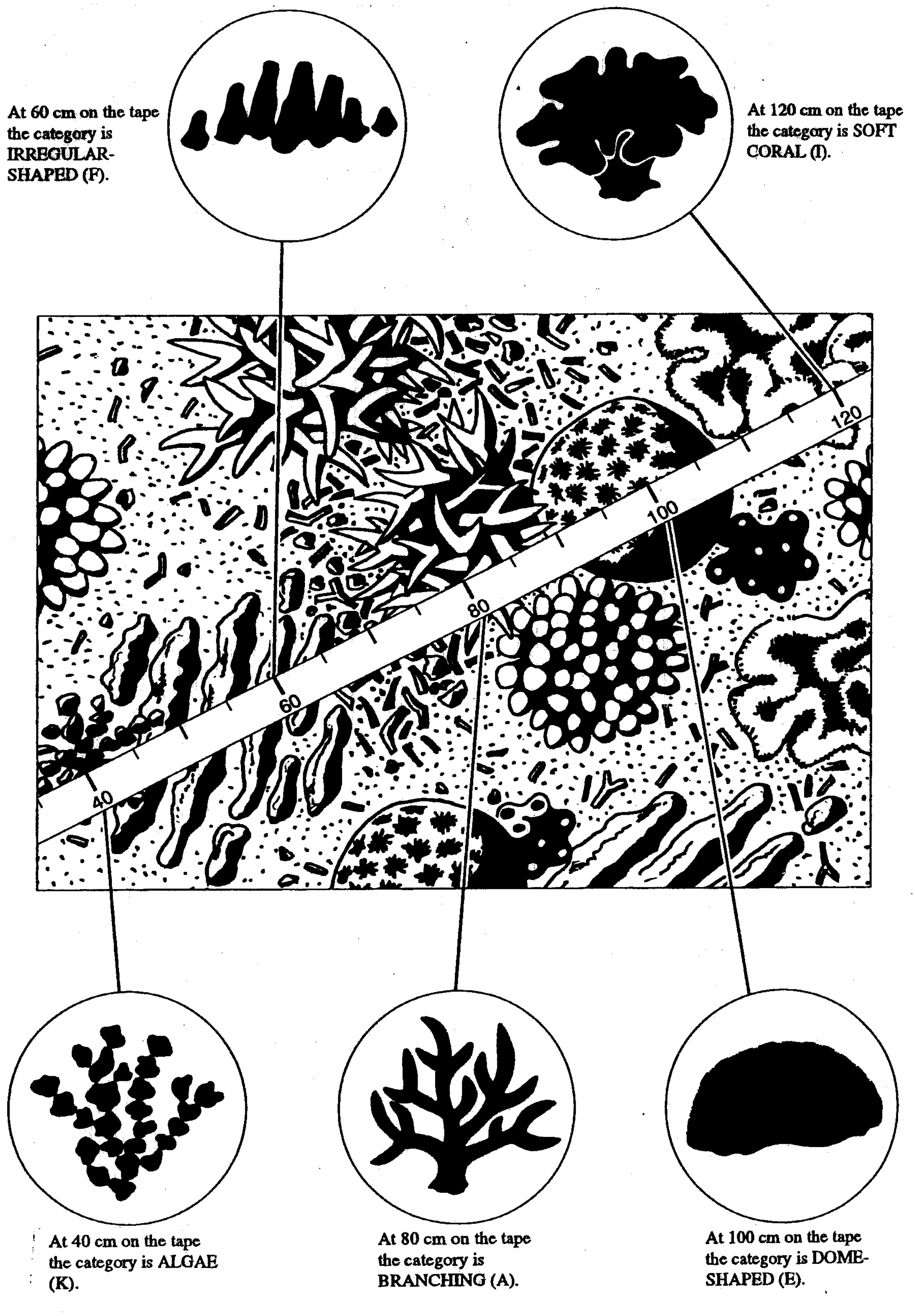
3) Participating in this project has benefits for you. The work you are undertaking is designed to be trouble free allowing you time to enjoy your diving while learning more about the reef environment.

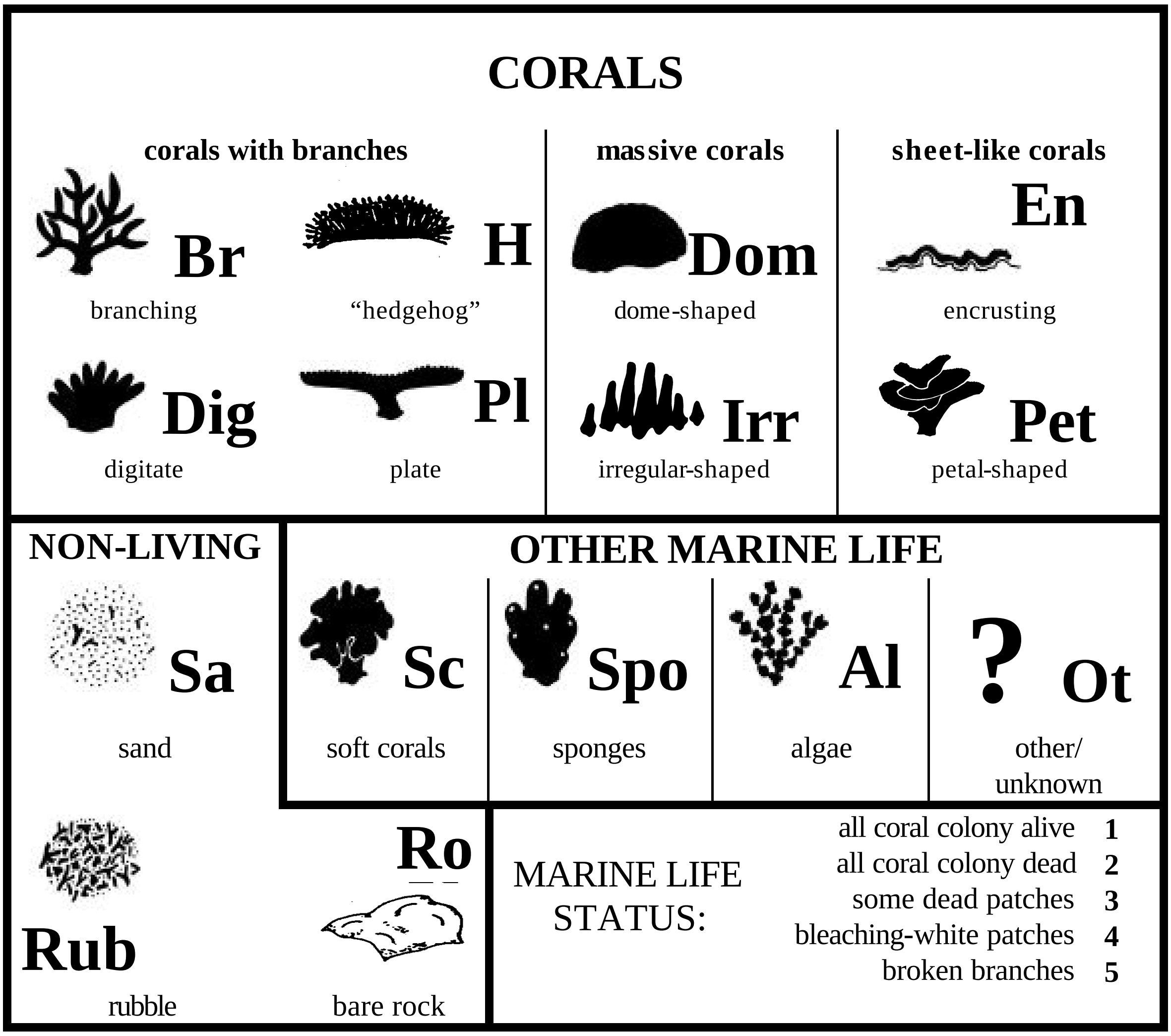
If you are not enjoying your experience, while learning about marine environments and conservation, our aims have not been successful. Our evaluation sheet (which we will ask you to fill in at the end of the trip) allows you to comment on any ways we can make this program more enjoyable or interesting for you.

4) Careful diving skills are important. It is important not to damage the monitoring sites while we are diving. We are looking for divers to implement 'best diving' practices.

- Maintain neutral buoyancy. Ask your research coordinator to check your buoyancy at the start of your first dive.
- Do not have gauges or other equipment hanging loose where they will drag across the reef.
- Be aware of your fins. Recent studies show that this is how divers cause most damage to the reef.
- Do not touch any marine life. This may cause damage to the marine life that is not immediately obvious as well as being potentially dangerous for you.

This is an example of a section of a line transect laid on the reef. It shows how to fill in the datasheet, which is reproduced on the following page.





	cat.	status		cat.	status		cat.	status
0.2	…	…	**3.6**			**7.0**		
0.4	Al		**3.8**			**7.2**		
0.6	Pet	1	**4.0**			**7.4**		
0.8	Br	1	**4.2**			**7.6**		
1.0	Dom	3	**4.4**			**7.8**		
1.2	Sc		**4.6**			**8.0**		
1.4	…		**4.8**			**8.2**		
1.6	…		**5.0**			**8.4**		
1.8			**5.2**			**8.6**		
2.0			**5.4**			**8.8**		
2.2			**5.6**			**9.0**		
2.4			**5.8**			**9.2**		
2.6			**6.0**			**9.4**		
2.8			**6.2**			**9.6**		
3.0			**6.4**			**9.8**		
3.2			**6.6**			**10.0**		
3.4			**6.8**					

Appendix C. Questionnaire used to evaluate the program and the training materials.

RECREATIONAL DIVERS REEF MONITORING PROGRAM

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QUESTIONNAIRE

for

The Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef

A project funded by the Office of National Tourism and the CRC Reef Research Centre

Project Coordinators : Barbara Musso & Graeme Inglis
Questionnaire compiled by: Michael Cuthill & Barbara Musso

DIVER INFORMATION RECORDS.

It is important for this project to maintain records of the amount of diving undertaken, the dive locations, and numbers of people participating. If you could; **1) provide some details about yourself, 2) fill in the dive log after each dive and 3) complete the evaluation sheet at the end of the trip** it would greatly help our work. We will send you a copy of your dive log and a summary of the results of this work when the pilot study is completed. Please detach this section (last three pages of handbook) and give it to the research coordinator at the end of the trip. Any information provided will remain strictly confidential. Please keep the rest of the 'Recreational Divers Reef Monitoring Program, Handbook" and if you require any more information about this project please use the contact address listed on the inside cover. Once again, thank you for your help with this project.

DETAILS ABOUT YOU. *(PLEASE PRINT CLEARLY)*

Name ....

Address ....

....

....

- Year of birth 19 ......
- Male ◯ Female ◯
- Usual occupation... ....
- Number of previous dives on coral reefs... .... dives
- Total number of scuba dives... .... dives
- Have you undertaken any research diving previously ?
  (*eg* as a volunteer, a specialist dive course, for work)

No ◯ Yes ◯ .... If yes, could you provide some brief details about this experience. ______

____

____

____

DIVE LOG.

Could you please complete this after each dive after each dive including any observations, experiences or problems for that dive in the comments area.

Date	Reef/dive site name	Max depth	Dive time
/ /96			
Comments: (*eg* about using datasheets, identifying categories, using tape measure, other problems?)			
Number of transects completed			

Date	Reef/dive site name	Max depth	Dive time
/ /96			
Comments: (*eg* about using datasheets, identifying categories, using tape measure, other problems?)			
Number of transects completed			

Date	Reef/dive site name	Max depth	Dive time
/ /96			
Comments: (*eg* about using datasheets, identifying categories, using tape measure, other problems?)			
Number of transects completed			

EVALUATION SHEET. *(Please complete at the end of trip)*

As this project is still in the developmental stages, we are interested in comments or suggestions that you might have about your experience of being involved in underwater research. *Any* comments you have would be appreciated.

?? **How would you rate the presentation given at the beginning of the trip ?** (please tick one box)

◯	◯	◯	◯	◯
very difficult to understand	difficult to understand	neither easy nor difficult	easy to understand	very easy to understand

Do you have any suggestions as to how we could improve it ?: ______________________________

____

____

____

?? **Was the information in the 'Handbook' useful ?** (please tick one box)

◯	◯	◯	◯	◯
not at all useful	not very useful	OK	somewhat useful	very useful

Do you have any suggestions as to how we could improve it ?: ______________________________

____

____

____

• **Did you have any difficulties working underwater ?**

No ◯ Yes ◯ If yes, could you provide a brief description.

____

____

____

- **Overall, how would you describe your involvement in this underwater research project ?**

  (please tick one box)

not at all enjoyable	not very enjoyable	neither enjoyable nor unenjoyable	enjoyable	very enjoyable
◯	◯	◯	◯	◯

- **We would like to know what <u>you</u> feel you have gained from participating in this project. Please tick one box that best describes your response to each question.**

Have you gained a better understanding of;	not at all	not very much	average	better	much better
Good diving practices ?	◯	◯	◯	◯	◯
The reef ecology ?	◯	◯	◯	◯	◯
Research on the reef ?	◯	◯	◯	◯	◯
The part you play in helping look after the reef? …..	◯	◯	◯	◯	◯
Your responsibility towards the reef ?	◯	◯	◯	◯	◯
Your responsibility towards the environment in general ? …..	◯	◯	◯	◯	◯

- **Do you have any other general comments about the project ?**
