An Interim Report for Designing of Coral Reefs Monitoring through Comparison of 3 Different Methods: Manta-Tow, Spot check and Reef Check transect

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1. Introduction

Since the establishment of five marine protected areas (MPAs) on coral reef of Tonga in 1979, no systematic survey or monitoring program has been conducted (eg. IUCN 1991). Although a qualitative study on scleractinian corals, fishes and mollusks was once conducted by the Marine Park Center of Japan in 1996 (MPCJ 1997), there is no known quantitative study for management of the MPAs. Although precise information on the current status of coral reefs in not necessarily the pre-requisite for commencement of managing protected areas(Johannes 1998), monitoring is a valuable, often the only, source of information for managers to conduct an effective management. The objectives of reef monitoring are not only to obtain up-dated knowledge on the status of coral reefs but also evaluate management measures. Only with the knowledge on a natural variance of variables of coral reefs through long-term monitoring, anthropogenic impacts on coral reefs can be detected.

The objective of this paper is to compare quantitative survey methods of coral reefs, which the Department of Environment of Tonga would use as a part of management of the MPAs. Comparison was made among three methods, namely, Manta Tow method, Spot check method and Reef Check's transect method. The variable of interest are basic ones such as live coral cover (%), dead coral cover (%), soft coral cover (%), density of the crown-of-thorns starfish. A suitable combination of methods for monitoring is recommended.

2. Methods

The Manta Tow and Reef Check methods were used in Pangaimotu Reef and the Spot check method in Monuafe Reef. In Pangaimotu, two different methods were compared at the same part of the reef.

(1) Manta Tow method

This method has been used to assess a large scale disturbance, such as coral bleaching and outbreaks of crown-of-thorns starfish, *Acanthaster planci* (COTS), in a

large area, such as entire reef, within a comparatively short time (English 1997). Another advantage of this method is that it does not require special qualifications such as SCUBA. On the other hand, disadvantages include inability of an observer to control the tow path, difficulty in counting the number of cryptic animals such as COTS and the limitation of the number of variables recorded.

The survey is conducted by a group: an observer, a boat operator and a recorder. The latter 2 people ride on a small boat towing the observer in the water by a rope (Fig. 1). The boat operator runs the boat along the edge of the reef at low speed (walking speed), while the observer records the results of observation such as the coverage of live hard corals, dead hard corals and soft corals as well as the number and size of COTS observed during each tow (Appendix 1). The entire path is divided into a number of 2-minute tows. The recorder writes down the coordinates of the point of the boat between tows by using a GPS.

On May 22, 2002, northern edge of Pangaimotu reef was surveyed by a group of the DoE staff: ‘Asipeli (boat operator), Taniela (recorder) and Seiji (observer).

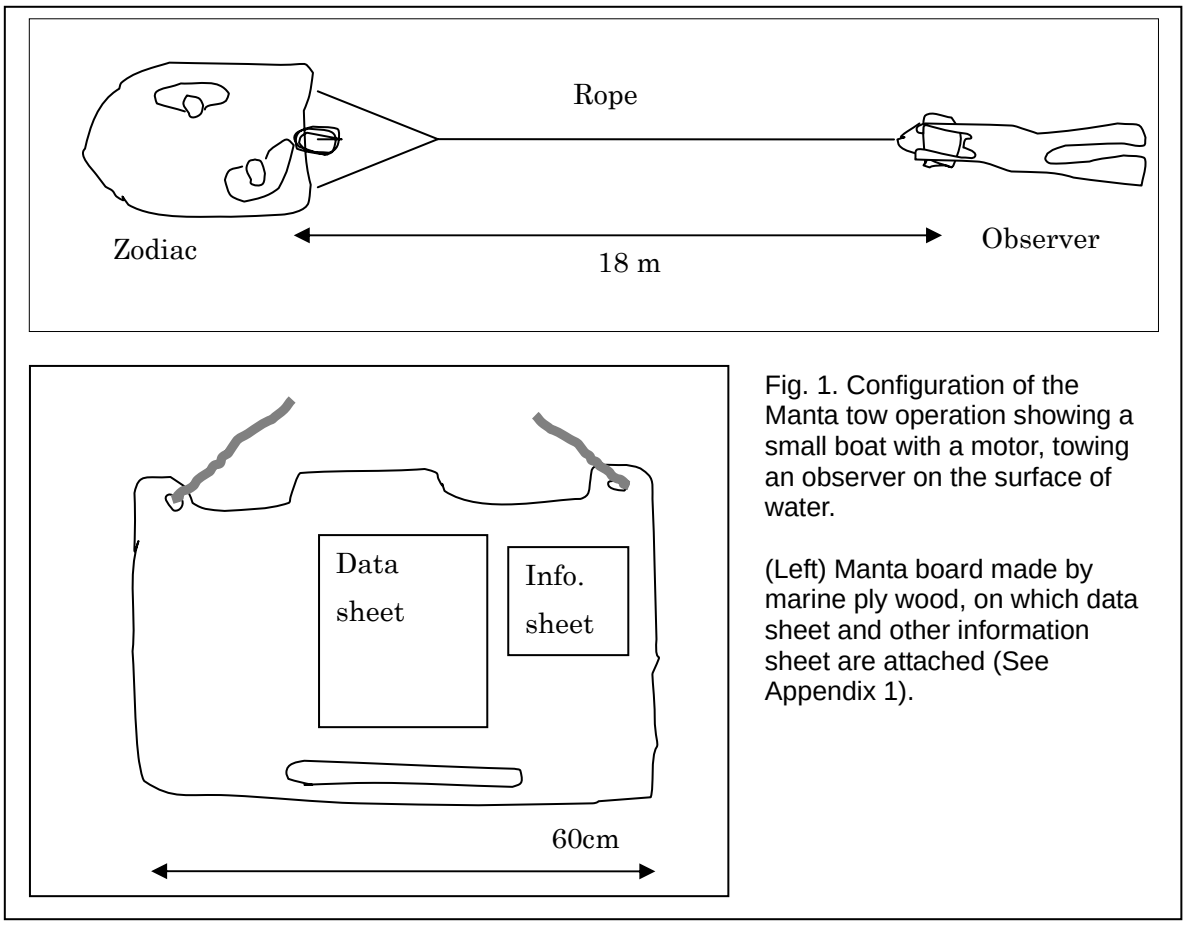


Fig. 1. Configuration of the Manta tow operation showing a small boat with a motor, towing an observer on the surface of water.

(Left) Manta board made by marine ply wood, on which data sheet and other information sheet are attached (See Appendix 1).

(2) Reef Check method

The Reef Check is a world-wide coral reef monitoring program supported by scientists and SCUBA divers on volunteer bases, organized by its headquarters at UCLA, USA (Hodgson 1999, 2000). A team of Tonga DoE staff was registered at the Reef Check Headquarters in January 2002. As the Reef Check method requires an input of SCUBA divers who are able to conduct an underwater observation of organisms, only a limited number of reefs (MPAs or non-MPAs) can be surveyed. As the number of staff who are qualified as SCUBA divers is limited (currently, 'Asipeli, Seiji, Peter and Dee), it is recommended to obtain participants from diving shops (guides and customers) and other government agencies, especially the Ministry of Fisheries. Basically Reef Check survey is done using a 100 measuring tape as a transect line. The numbers of individuals of benthic invertebrates and fishes of a small number of indicator species are counted within belt transects (5m wide x 20m long x 4 replicates x 2 depths (3m and 10m)). The types of substrata are recorded every 0.5 m on the same line above. See more detail on Appendix 2, which is an arranged document downloaded from www site: http://www.reefcheck.org/reefcheck.htm.

On January 16 and 18, 2002, a team led by the team leader ('Asipeli), team scientist (Seiji) conducted the first Reef Check survey in Tonga, on the northern edge of Pangaimotu Reef. 'Asipeli, Seiji and Peter surveyed substratum, invertebrates and fishes, respectively. Jason and Taniela assisted in the survey.

(3) Spot check method

On the shallow reef flat and in lagoon, where Manta tow can not be conducted, the spot check survey method is an alternative. About 5 points for observatio are selected randomly from the area of interest. Coordinates of the points were recorded by using a GPS. Two or more divers snorkel in a direction on haphazard bases for a determined duration 10-15 minutes and estimate a small number of parameters such as live and dead coral cover %, types of dominant coral growth forms, and the number of crown-of-thorns starfish and write on the record sheet (Nomura et al. 2001; Appendix 3). On May 23, 2002, 'Asipeli and Seiji surveyed Manuafe Reef by the spot check methods (10 minutes/diver/point).

3. Results

Manta tow and Reef Check methods

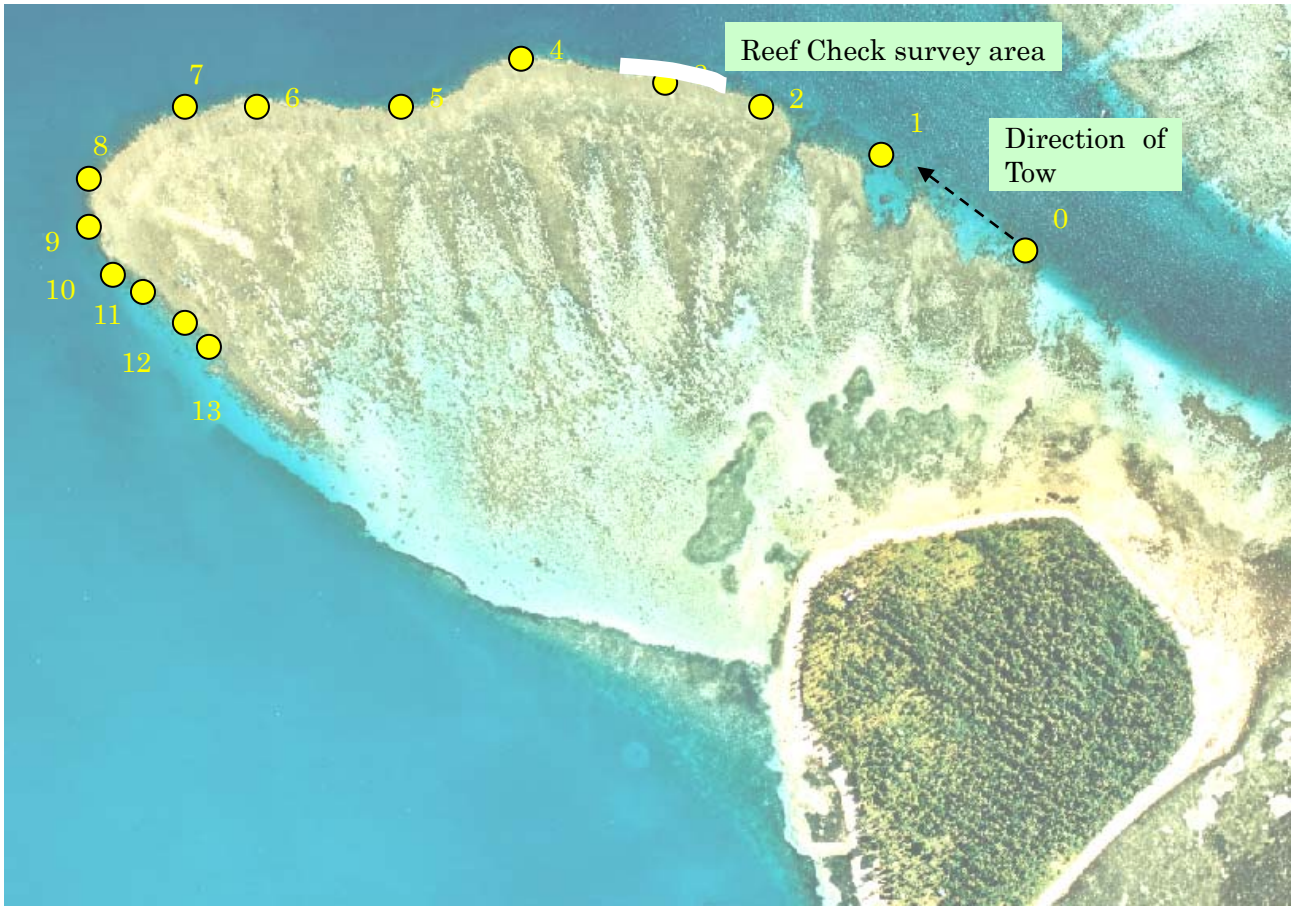
There were 13 tows from the reef edge near the northern tip of the Pangaimotu Island, through the north-eastern tip of the reef, to sheltered southern side of the reef

(Fig. 2). The Manta tow method successfully showed the distribution of the coverage of live hard corals, dead hard corals and soft corals (Appendix 4). The coverage of northern part of the reef was 31-50% (category 3 (Appendix 1)), while that of the western tip was as high as 76-100% (category 5). Coverage of dead hard coral on the northern reef was 11-30% (category 2) and that of soft coral in most part of the reef was 0-10% (category 1). On southern part of the reef, both live and dead coral cover was low (Fig. 2). No crown-of-thorns starfish was observed. The visibility of the water, which we planned to estimate by using the marks attached to the rope, could not be successfully measured as the marks were not clearly seen by the observer near water surface.

The Reef Check survey was also successfully completed. However, it was clear that the number of divers (only 3) was too small to conduct survey easily and safely. Live hard coral cover was 43% ± 0.8 SE and 38% ± 2.5 SE in 3m and 10m deep, respectively. These values are within the range obtained from the manta tow method (Fig. 2). On the other hand, the coverage of dead hard coral was 5% ± 0.4 SE and 4.5% ± 0.8 SE, in 3m and 10m deep, respectively. The values of dead hard coral cover obtained from Reef Check were lower than the observation by the manta tow. No crown-of-thorns starfish was observed. One person was spearfishing with a hand spear on the northern Pangaimotsu reef (within the MPA). 'Asipeli explained the area and regulations of the MPAs to the fisher.

Spot check method

The results indicate that the variability of coverage of both live and dead hard coral among the 5 points was small, ranging between 5% and 20%, in comparison with that of soft corals, ranging between 3% and 40% (Appendix 5). Scleractinian corals with a wide range of growth forms were observed. The area is full of scattered patch reefs on the 0.5 – 2 m deep sandy bottom (Fig. 3). In some points, dense population of *Sargussum* spp. was found (≈30%). An abandoned fishing net was seen in a point. During the survey, one fisher was seen fishing with a hand spear. 'Asipeli explained to the fisher that the area is protected (Fig. 4).



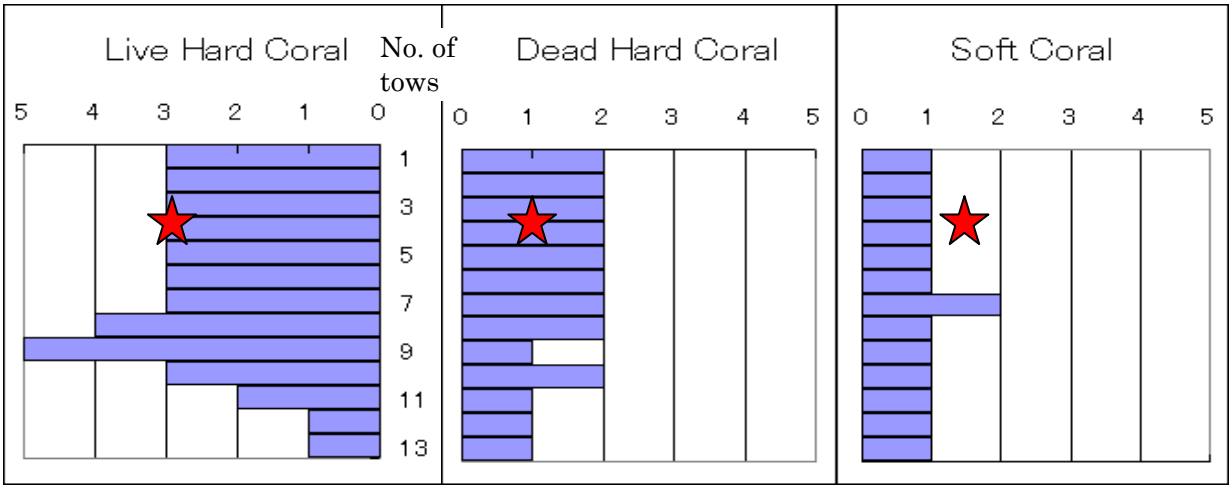


Fig. 2. Pangaimotu Reef showing the path of the manta-tow survey, the points and numbers that indicate the tows. The figure also indicates the area surveyed by Reef Check method. The graphs show the coverage of live hard coral, dead hard coral and live soft coral in categories (1:0-10%, 2: 11-30%, 3: 31-50%, 4: 51-75%, 5: 76-100%, after English 1997 (Appendix 1)) at each of tow 1 to tow 13). The star marks indicate the coverage obtained by the Reef Check survey.

Fig. 3. Monuafe Island and surrounding reef showing survey points.

Fig. 4. 'Asipeli in wetsuit indicates the boundary of protected area to a fisherman.

4. Discussions

No systematic monitoring of coral reefs has been conducted since establishment of the MPAs despite the facts that deterioration of coral assemblages was pointed out (MPCJ 1997) and that destructive fishing and over fishing have been seen as serious threats to the fisheries resources of coral reefs (World Bank 2000, AIMS 2000). The lack of monitoring may be due to insufficient budget and manpower in DoE, as well as appropriate methodology and sampling design. To addressing these problems, three of the most commonly used methods for surveying/monitoring coral reefs were conducted and compared in terms of usability.

(1) Manta tow method

Manga tow is an appropriate method to cover a wide area in a short time. Considering the current situation, in which no quantitative data exist on Tonga coral reefs and the resources for survey are limited, collecting data of a limited number of variables, such as live coral cover, from a wide range of reefs is the highest priority.

This time we used only one Zodiac, which was found to be ideal for this survey method as this is easy to handle. However, for survey of outer and further reefs such as Hakaumama'o, we may need a larger boat accompanying the zodiac for safety and for carrying more people, other equipment, water and food. (In the future, a boat that can carry a zodiac for survey may be needed.)

Limitation of the number of staff of DoE is always a problem. One day, a manta-tow survey was attempted by two persons on reef edge of the reef in front of the Vuna road, but it was found to be extremely unsafe and the survey was discontinued. Three persons is the minimum for conducting the survey.

The visibility of the water was not measurable by the methods of English's (1997) manual. The visibility should be measured in some selected points of each reef surveyed.

It is urgent to verify the accuracy and precision of this method. Standardization is extremely necessary to reduce the observer-origin biases. This can be done by observing the same point of the reef by several observers and by comparison of the estimate by these observers. Comparison of estimates of several observers could be done also using underwater photos or videos. Preparation of these materials may be needed.

Other conditions should also be standardized. The estimate from observation may be affected by a number of factors such as the speed of boat, time of the day, direction of tow and the direction of wind. Before monitoring program starts, a formal training may be needed. The training may include effective gestures for communication between observers and boat operators with no verbal communication. An revised procedure of the manta-tow survey is in Appendix 6.

In spite of some limitations in the method, the Manta tow method is efficient for an early warning. The limitations include: (1) limited number of variables measured, (2) limitation of the reef areas measurable, and (3) the counted number of crown-of-thorns starfish observed gives only relative abundance and not absolute density such as number/square meters. In the management plan of the MPAs, this method is to be used for reef edges of Hakaumama'u reef, Malinoa reef, and Pangaimotu reef (maybe excluding Ha'atafu, where the access by boat is not good). Other reefs

near MPAs such as Ualanga Lalo and Mounu Reefs, as well as the reef in front of Vuna Road of Nuku'alofa could be monitored by this method.

(2) Spot Check Method

Spot check method is an appropriate method for quickly surveying reef flats where Manta tow can not be conducted. One of the aspects users of this method have to pay attention is the patchiness of distribution of organisms in reef flats. On reef flats, in many cases, corals are distributed on micro-atolls, bommies in high density, while surrounding sandy or rubble areas are without few live corals. It is, therefore, important for all observers to consent to what is actually measured (including or excluding sandy bottoms from observation), to what extent one should consider the spatial population, from which samples are taken.

I would also recommend that, before getting the site, planning should be done consulting with aerial photos. Aerial photos give plenty of information, including suggestion for stratification of the areas, which may help obtain more meaningful interpretation of data.

Data could be measured on an ordinal scale, like the data of manta tow, or ratio scale (eg. 23 % live coral cover). I suggest estimating coverage (%) in the multiple of 5 and treating the data as data on a ratio scale, which allows parametric analysis.

The number of DoE staff is again a problem for this method. This time, only two people participated. More than two observes are needed for calculating variability (standard errors) for statistical tests of temporal and spatial differences. Standardization among observers is also needed for this method, and underwater video footage may help a great deal for this purposes.

In the management plan, this method is to be used at Monuafe reef and Ha'atafu beach.

(3) Reef Check method

Reef Check method is useful to obtain data that are comparable with other reefs in the Worlds. The live coral cover obtained from the Pangaimotu Reef Check was within the range of valued in 1997 Reef Check, in which the best sites were surveyed in Indo-Pacific areas (Hodgson 1999). Data include not only substrata but also invertebrates and fishes, which are difficult to be measured by the other 2 methods.

The comparison with Manta tow in this study indicated that coral cover estimates obtained by the two methods were similar, but those of dead hard coral cover differed. This may be, partly, due to the definition of dead hard coral cover in two

methods – Manta tow can't distinguish "rock" and "recently killed corals" that can be more easily identified by Reef Check method.

In many countries, Reef Check is seen as a broad-brush, low resolution survey, while detail surveys are expected to be done by research institute or university scientists (Hodgson 1999, 2000). However, the reality in Tonga makes Reef Check the most demanding and high resolution method. This time, the survey was conducted by all of the three DoE staff based in Nuku'alofa who are qualified for SCUBA diving. This situation prevents a surveyor to dive in a buddy, which is not recommended from the view point of safety. Therefore, DoE can conduct a Reef Check only if it obtains collaboration from diving shops (instructors and customers), other government agencies, especially, Ministry of Fisheries and/or aquarium fishing industry. A periodical Reef Check may not only be able to gather valuable information on coral reefs on cheap (volunteered participates), but also be extremely good opportunity for public awareness[1].

Conclusions

A detailed plan for monitoring of coral reefs for the management of the MPAs is currently being prepared. The plan will be basically a combination of Manta-tow, spot check and Reef Check methods, as shown in Table 1. Not only MPAs but also non-MPA reefs should be surveyed as controls for the purpose of evaluation of management measures. Basic indicators such as live coral cover, dead coral cover, the number of *Acanthaster planci* should be included in all the surveys. Other indicators such as the size distribution of stony coral colonies should be considered to be included in the surveys (Birkeland 1999). All the monitoring sites should be re-surveyed at least once a year.

As the limited resources of DoE, the monitoring plan should be made carefully in conjunction with the plan of surveillance. Frequent encounter with the fishers in the areas in a short time clearly shows the importance for the DoE staff to be on the reefs of MPAs for surveillance or monitoring. A ranger (newly employed or nominated from current staff) who drives boat, snorkels and SCUBA –dives is needed, as stated in the draft management plan. For manta-tow and spot check methods, a minimum of 3 persons needs to work. For Reef Check, collaboration with parties out of DoE is required. A rapid ecological assessment (eg. Maragos & Cook 1995) could be conducted during the surveillance anytime of the year. For the annual monitoring, based on the

[1] I sent an article on Pangaimotu Reef Check to the Reef Check Headquarters to be published on the www-based news letter of the next issue.

weather records, a month of the year should be designated as the month (maybe May is the most stable month).

Ensuring manpower, facilities and equipment for enabling the plan of monitoring and surveillance will help the MPAs out of the current paper parks situation

Table 1. Monitoring methods for each of the MPAs

Type of reefs	Reefs	Manta-tow	Spot check	Reef Check	Remarks
MPAs	Hakaumama'o reef	○	○*		
	Malinoa reef	○	○*		
	Monuafe reef		○		
	Pangaimotu reef	○		○	
	Ha'atafu reef		○		
Non-MPAs	Reefs in front of Vuna road	○			
	Mounu reef	○			Control for Pangaimotu
	Ualanga Lalo reef	○		○	Control for Pangaimotu
	Hakau Manu reef	○			Control for Hakaumama'u
	South Ha'atafu		○		Control for Ha'atafu
	East Monuafe		○		Control for Monuafe

*: supplementary method for reef flat

Reference

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Hodgson, G. 2000, Coral reef monitoring and management using Reef Check, Integrated

Coastal Zone Management, 1: 169-176.

Johannes, R. E. 1998, The case for data-less marine resource management: examples from tropical nearshore finfisheries, TREE, 13:6:243-246.

Maragos, J. E. and C. W. Cook Jr. 1995, The 1991 – 1992 rapid ecological assessment of Palau's coral reefs, Coral Reefs 14:237-252.

Nomura, K., T. Kimura, H. Kawagoe, The introduction of the spot check method as a simple monitoring method of large coral reef area, and that practical example in the Sekisei Lagoon, Southern Ryukyus, Marine Parks Journal, 131: 5-11 (in Japanese).

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Appendix 1. Preparation for Manta-tow method

(1) Record sheet for observer

Diver's Sheet for Manta Tow Survey

Reef Name: _____

Date: _____ Time start: _____ Time end: _____

Current: Strong……..None; Direction _____

Recorded by: _____ (Boat Driver: _____)

	Coral Coverage					
Map No.	**Live Coral**	**Dead Coral**	**Soft Coral**	**COTs (cm)**	**VIZ (m)**	Notes (Bleaching)
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

(2) Data sheet for recorder on boat

Map or Aerial Photo

Manta Tow Survey; Reef Name: _____

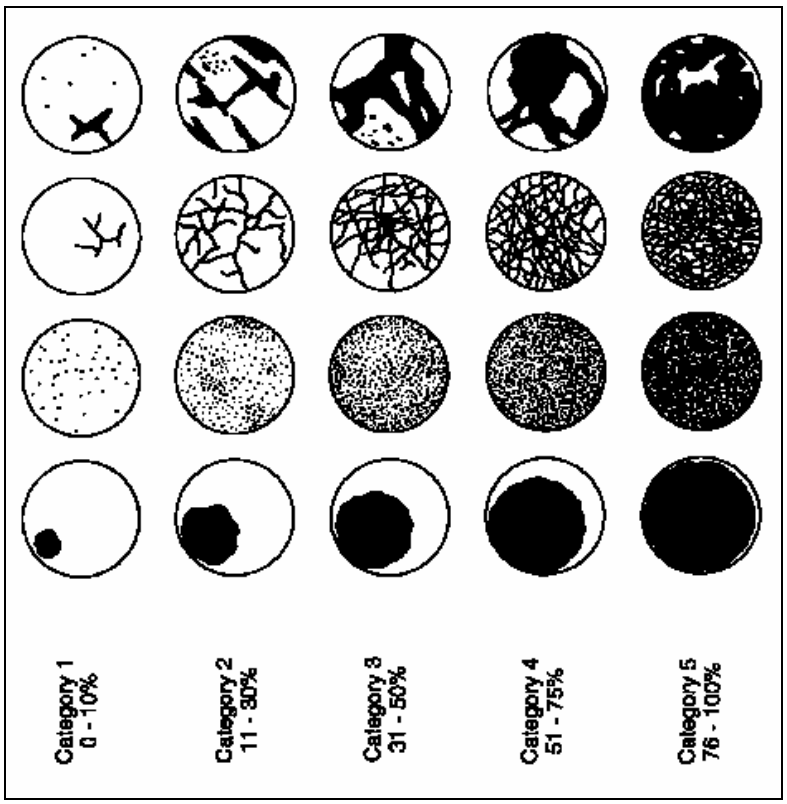
Date:_____ Time start:_____ Time end: _____

Wind:_____meters (Direction_____); Cloud: 0.....8/8

Recorded by:_____(Diver:_____)

Map No.	GPS No.	Coordinates	Remarks	Map No.	GPS No.	Coordinates	Remarks
0				18			
1				19			
2				20			
3				21			
4				22			
5				23			
6				24			
7				25			
8				26			
9				27			
10				28			
11				29			
12				30			
13				31			
14				32			
15				33			
16				34			
17				35			
18							

(3) Information sheet to be attached to the manta board for observer



Appendix 2. Reef Check Methods

The Reef Check surveys can be carried out anytime, however, for inclusion in our annual report, data should be submitted by 30 December. All teams should submit data using the data submission forms by 30 December 2001 to Reef Check Headquarters.

Each group can do whatever additional sampling they like. Reef Check Headquarters will include valid Core results from all properly registered Reef Check groups in our analyses and annual global reef health report, but we do not plan to report extra results unless they are extremely important. Click here for more information on long term monitoring.

Important!
Please submit data within 10 days of field work completion.

DON'T wait until the last minute to submit data, as this creates a traffic jam and increases the chances of your data not being included in the annual press conference and report.

Site Selection

Site selection is a critical factor in the success of Reef Check. One goal of Reef Check is to test the null hypothesis that there are reefs that are not affected significantly by human impacts. In addition, we would like information on the geographic distribution of human impacts of various types on all reefs. For this reason, Reef Check teams that can only survey one site should survey the "best" site they have access to in terms of least likely to have been affected by human impacts, fishing, pollution etc. with high living hard coral cover and dense fish and mobile invertebrate populations.

For groups willing and able to survey multiple sites, we suggest choosing 2 or more additional sites representative of moderate and heavy human impacts. In this manner, we will build up a picture of the distribution of human impacts on a cross section of reefs.

To standardize Reef Check, we will not be accepting surveys of steep wall reefs (drop-offs), reefs predominantly located in caves or underhangs. We would prefer moderately to fully exposed reefs with a reef crest and outer slope. The transects can then be placed seaward of the reef crest on the outer slope.

It is very important to describe the site and its position in relation to obvious human influences on the Site Description sheet.

Basic Design

The goal is to survey two depth contours, 3 m and 10 m below chart datum (lowest low water). However, on many reefs, the highest coral cover will not be found at these exact depths. Therefore, choose the depth contour with the highest coral cover within the following ranges:

- Shallow (2-6m depth)
- Mid-reef (>6-12m depth).

Note that particularly for the shallow transect, the tide should be taken into account. Along each contour, four 20m-long line transects will be deployed and surveyed. The transects should follow the designated depth contour one after the other, however, transect start and end points should be separated by a 5m space. The distance between the start of the first transect and end of the last transect will be 20 + 5 + 20 + 5 + 20 + 5 + 20 = 95m. The depth contours were chosen for practical reasons of time and safety.

Reefs in many areas are not suitable for survey at both depths. In this case, just survey one depth contour. At some reefs, it may be necessary to lay transects perpendicular to the reef face, i.e. following spurs or ridges. We recommend use of a single 100m fiberglass measuring tape available from hardware and survey equipment supply stores. In locations where reefs are broken into patches with large areas of sand/rock in between, it may be necessary to separate the transect into 20 m segments. A second tape may be useful for measuring distance from shore and for use if the first breaks.

Four types of data will be recorded. The three transect surveys will be made along the same transect line.

1. **Site description**. Anecdotal, observational, historical, locational and other data should be recorded on the Site Description sheet. These data will be important when we attempt to interpret global trends in the dataset.
2. **Fish belt transect.** Four 5m-wide (centered on the transect line) by 20m-long transects will be sampled for fish species typically targeted by spearfishermen, aquarium collectors and others. The fish transect should be carried out first.
3. **Invertebrate belt transect.** Same four 5m-wide (centered on the transect line) by 20m-long transects as above will be sampled for invertebrate species typically targeted as food species or collected as curios.
4. **Substrate line transect.** Same four 20m-long line transects, but this time, point sampled at 0.5m intervals to determine the substrate types on the reef.

Note: Reef Check Core Method protocol may be repeated individually, or as a set, as often as needed. See Monitoring for Management.

Pre-dive Preparation

The training needed for each team will depend on the experience and knowledge level. We recommend a half-day training on land prior to the dive day, so that the training can be absorbed and there is sufficient time for questions and discussion. This can be supplemented with a brief review on the dive day and shallow water training using snorkeling only. Few people can concentrate if training is attempted on board a rocking boat.

The Team Scientist (TS) is responsible for making a presentation that includes:

1. An explanation of the dual PR/science purpose of Reef Check.
2. A review of the sampling design and rationale of the indicator organisms.
3. Field identification training for all organisms and Reef Check definitions for substrata.
4. An introduction to the data recording format, and preparation of slates.
5. An explanation of the difference between work diving and pleasure diving and how to avoid smashing reef corals by proper buoyancy control.
6. Explanation of the post-dive data entry, checking and submission procedures.

The Team Leader (TL) is responsible for safety training and will need to assess the abilities of his or her team so that appropriate work assignments can be made.

There are three field data sheets (pro-forma) for the core protocols; the Site Description sheet, the Line Transect Sheet and a Belt Transect Sheet.

The Belt Transect Sheets are divided into a section for invertebrates and a section for fish.

Teams may use either underwater paper or a plastic writing slate. If you use the latter, the TS should keep a photocopy of each full slate for the records.

Ensure that you have sufficient slates or paper, either pre-printed or filled out manually. For slate users, the Line Transect and Belt Transect format can fit on the front and back of one slate respectively.

Familiarize yourself with the organisms and categories on the species identification chart. Photos can be printed in color and either laminated or placed inside a plastic "zip-lock" bag and then carried underwater for reference. Fill in as much site info as possible before getting into the water.

There are many acceptable ways to divide up the work load depending on the skills of the team members and team size. Some team members will feel more comfortable recording fish and others invertebrates. Others will just want to watch and serve as buddies. Because each team will be different, the data collection strategy will need to be adjusted to match each team's members.

The best quality data will be obtained by allowing the experienced Team Leaders to assign tasks appropriate for the team members. In case of a disagreement, Team Leaders will have the final say in deciding who should do what, and for ensuring that every team member understands their assignment and is capable of carrying it out properly. If there is some question about the reliability of data from a site, we will not include the site in our global report.

Before you jump in the water:

1. Record your location on a chart by hand or by GPS.
2. Record the name of the TL/TS on data sheets.
3. Start to fill in Site Description sheet.

Safety of divers should be a priority. No Reef Check surveys should be undertaken when weather or sea conditions are unsafe or if a diver does not feel well. In particular, teams should plan work to avoid decompression dives during Reef Check.

During the Dive

One buddy pair should lay out a 100m transect line (or four 20m transects separated by 5m breaks) along the specified contour (2-6m or >6-12m). Estimated time to deploy the transect is 30 minutes. After deployment, the entire length of the transect should be examined to ensure it is not snagged or floating too high off the bottom. Small marker floats should be attached to the start and end points and (optional) permanent stakes can be installed so that the site can be located next year.

A GPS reading should be obtained from the float at one end, and the compass bearing to the end marker buoy recorded (only those teams with precision navigation systems such as differential GPS need record the coordinates of both ends). Line-ups with landmarks should also be recorded in case the GPS has given false readings. Teams without a GPS should obtain the most detailed chart of the area available and record the coordinates of the location of the transect. We cannot use your data unless you record the location!

Fish Belt Transect Instructions

The fish belt transect should be the first work done after the transect is deployed. Try to begin the fish transect at about 9 to 10:00 am. Work can be started after a 15 minute period during which no divers disturb the area. Estimated time to completion is 1 hour. The maximum height above the transect to record fish is restricted to 5m. Data should be recorded on a slate using the Belt Transect Sheet format.

Each diver assigned to count fish will swim slowly along the transect and stop to count target fish every 5m. He will then wait 3 minutes for target fish to come out of hiding, before proceeding to the next stop point. This is a combination timed and area restriction survey, 4 sections x 20m long x 5m wide = 400m ². There are four 5m gaps where no data are collected. At

each depth contour, there are sixteen "stop-and-count" points, and the goal is to complete the entire 400m ´ belt transect in 1 hour.

Indicator fish

The indicator fish have been selected because they are typically shot out of reefs by spearfishing, removed as targets of cyanide fishing, and caught using hand-lines. Size minimums have been placed on some species to reduce the burden of recording many small fish. Given these limits and the magnifying effect of the water, divers should practice estimating sizes before attempting the fish surveys.

A measured 2.5m colored wire or rod can be used to help estimate the 5m belt transect width, and 20 or 30 cm sticks (hand-held or floating tethered to a small weight) can be used to estimate fish length.

We recommend that one diver record fish on one side of the line followed by the other side. By moving from side to side, the diver records 2.5m belts one at a time. If both divers are proficient at fish identification, we suggest that Diver 1 records the first and third 20m segments, while Diver 2 does the second and fourth 20m segments.

Care is needed to carefully label slates. We suggest tallying the fish on the slate using a vertical tick mark for each fish observed and after each four fish, drawing a horizontal line through the four, thus creating easily counted groups of five next to the correct name and under the appropriate column. It is crucial to remember to keep the counts for each of the four segments of the transect separate. For all grouper, a size estimate should be given of each fish.

All of the organisms to be counted within these fish belt transects are listed below and identification photos can be seen on the species identification page.

Indo-Pacific

- Grouper/coral trout over 30 cm (any species)
- Barramundi cod - *Cromileptes altivelis*
- Sweetlips - Haemulidae - *Plectorhincus* spp.
- Humphead (Napolean) wrasse - *Cheilinus undulatus*
- Bumphead parrotfish - *Bolbometopon muricatum*
- Parrotfish over 20 cm
- Butterfly fish (any species)
- Snapper - *Lutjanidae*
- Moray Eel

(Note: off-transect records of the two distinctive species of wrasse and the parrotfish will be accepted as these species roam near reefs at this size rather than strictly resident species).

A note should be made of any sightings of what are now becoming rarer animals such as large manta rays, sharks and turtles, but if these are off-transect records, they should be written at the bottom of the slate under "Comments".

Site Description Form Instructions

During the fish transect work, the other team members should be gathering descriptive site data and one should be responsible for filling out the Site Description form. Only one form is filled out per site. Some larger teams may desire to begin a second Reef Check survey while the first one is underway.

In 1998, some very large individual colonies of Porites were killed. Because it is fairly easy to measure the age of corals, these colonies are good "canaries" i.e. if they die, it may be an indication of an unusually severe stress. As large Porites are globally distributed, they make good indicators. We would like to ask all teams to make an attempt to identify and mark the location of up to five very large Porites colonies (3m or larger) at their sites. We recommend a measurement be made of the longest diameter, the diameter to the first, and the colony height. If it possible to mark the colonies permanently, this could be helpful. If future severe events, e.g. more heating, occur that damage or kill these large historical recorders, the data will be very useful to assess the geographic range and severity of the events.

Please record the data in the comments section of your Site Description form -- feel free to increase the size of this "cell" in the spreadsheet.

Invertebrate Belt Transect Instructions

When the fish belt transect is complete, Divers 3 and 4 could then carry out the belt transect survey for invertebrates. Estimated time to complete this work is 1 hour. If both divers want to record data, they can alternate 20m segments

as above or each do a 2.5m wide strip. To avoid confusion later, it is imperative that divers carefully mark their sheets with location and diver names.

Each belt transect is 5m wide with 2.5 m on either side of the transect line. The reason for choosing the relatively narrow belts is that visibility in many parts of the world is low, therefore it is necessary to restrict them for comparability. Total survey area will be 20m x 5m = 100m2 for each transect, for a grand total of 400m2 for each depth contour, the same as the fish belt transect.

All of the items and organisms to be counted within the invertebrate belt transects are listed below and photographs are shown on the species identification page. It is the responsibility of each team leader to ensure that his/her team is sufficiently prepared to identify these animals before work begins. Special attention should be given to identification tips for sea cucumbers given with the photos.

All sites

- Banded coral shrimp - *Stenopus hispidus*
- Long-spined black sea urchins - *Diadema* spp.
- Lobster (all edible species)
- Trash (describe type and size)
- Recently broken coral (anchor, blast, divers) - estimate area

- Giant clams - *Tridacna* (give size/species)
- Pencil urchin - *Heterocentrotus mammilatus*
- Edible sea cucumbers, holothurians
- Crown of thorns starfish - *Acanthaster planci*
- Triton shell - *Charonia tritonis*

In addition, each group should note the presence of coral bleaching or unusual conditions (eg. that might be diseases) along the transects.

At the base of the Belt Transect Sheet, there is a place to record comments. In particular, if bleaching, suspected diseases or *Acanthaster* predation are observed, it will be useful to record the percentage of the population that is affected, and for affected colonies, the mean percentage of each colony that shows some diseased area. For the belt transects, team members should be encouraged to look in holes and under overhangs to detect organisms, such as lobster, that may be hiding.

Line Transect Instructions

When the invertebrate belt transect is almost completed, the next designated buddy pair can begin point sampling on the line transect. The estimated time to complete this work is 1 hour.

The method chosen for Reef Check sampling of substrata is "point sampling." Point sampling was chosen because it is the least ambiguous and fastest method of survey and is easily learned by recreational divers. In use, the diver can simply look at a series of points where the transect tape touches the reef and note down what lies under those points. In cases where the tape is hanging above the substratum, it is useful to carry a 5mm diameter nut or other metal object tied onto a 2 m long cotton or nylon string for use as a plumb-line. The object is dropped at each designated point and it touches only one substrate type which can be recorded.

For Reef Check, substrate type will be recorded at 0.5m intervals along the line, i.e. at: 0.0m, 0.5m, 1.0m, 1.5m etc. up to 19.5m (40 data points/20m transect segment). This procedure will be repeated for the remaining three transect segments at 3m and the remaining four at 10m depth.

The Line Transect pro-forma has a space for each point sample result, 1-40 for the first 19.5m segment etc. Input the above abbreviations for the substrate types.

As above, Diver 1 could record the substrate types for the first and third 20m segments of the line transect, and Diver 2 could do the second and fourth 20m segments.

Substratum Categories

Abbreviation	Term	Reef Check Definition Note that these are practical definitions not technical
HC	Hard coral	Include fire coral (*Millepora*), blue coral (*Heliopora*)and organ pipe coral (*Tubipora*) because these are reef builders.
SC	Soft coral	Include zoanthids, but not gorgonians or sea anemones (the latter two go into "Other").
RKC	Recently killed coral	The aim is to record coral that has died within the past year. The coral may be standing or broken into pieces, but appears fresh, white with corallite structures still recognizable, only partially overgrown by encrusting algae etc.
FS	Fleshy seaweed	The aim is to record blooms of fleshy algae that may be responding to high levels of nutrient input. Therefore do not include coralline algae in this category. When algae such as *Sargassum* that are a normal part of a healthy reef are present, please note the species in the comments section.
SP	Sponge	All sponges (but no tunicates) are included; the aim is to detect sponge blooms that cover large areas of reef.
RC	Rock	Any hard substratum whether it is covered in e.g. turf or encrusting coralline algae, barnacles, oysters etc. should be placed in this category. Rock will also include dead coral that is more than about 1 year old, i.e. is worn down so that few corallite structures are visible, and covered with a thick layer of encrusting organisms and/or algae.
RB	Rubble	Includes rocks (often laying over sand) between 0.5 and 15cm diameter. If it is larger than 15cm it is rock, smaller than 0.5cm and it is sand.
SD	Sand	In the water, it is sand if it falls quickly to the bottom.
SI	Silt/clay	Sediment that remains in suspension if disturbed.
OT	Other	Any other sessile organism including sea anemones, tunicates, gorgonians or non-living substrata.

Post Dive Tasks

The Team Leader (TL)/Team Scientist (TS) are responsible for gathering the slates and data together as soon as the survey is completed and reviewing it immediately with the team members. The purpose is to make a quick assessment of the data to determine if some error has been made that can be corrected while the team is still on site, and the transect is in place. Typical errors that could be corrected would be "double-counting" of fish, mis-identification of organisms or mis-labelling the slate. When an error is suspected, a re-survey should be made to check or to correct it.

Before departing from the site, the TL/TS are responsible for ensuring that *all* required data has been collected, and that the slates have been filled out properly, in particular with each individual's work identified. This will allow the TL/TS to check with the responsible party if an error is detected later.

Data sheet for general description of the survey site

Site name				
Date				
Time of day that work started				
Time of day that work ended				
Longitude of transect start point				
Latitude of transect start point				
From chart or by GPS? (If GPS, indicate units)	chart_____	GPS_____		
Orientation of transect	N-S___	NE-SW___	E-W___	SE-NW___
Distance from shore	_____ m			
Distance from nearest river	_____ km			
River mouth width	<10m__	11-50m__	51-100m__	101-500m__
Weather	sunny_____	cloudy_____	raining_____	
Air temperature	___ degrees C			
Water temperature at surface	___ degrees C			
Water temperature at 3 m	___ degrees C			
Water temperature at 10 m	___ degrees C			
Distance to nearest population centre	_____ km			
Approximate population size	____x1000 people			
Horizontal visibility in water	_____ m			
Why was this site selected?				
Is this site -	sheltered_____	exposed_____		
Any major coral damaging storms in past years?	yes_____	no_____	unknown_____	
How do you rate this site overall in terms of anthropogenic impact?	none____	low____	moderate____	heavy____
What types of impacts do you believe occur?				
Dynamite fishing	none____	low____	moderate____	heavy____
Poison fishing	none____	low____	moderate____	heavy____
Aquarium fish collection	none____	low____	moderate____	heavy____
Harvest of invertebrates for food	none____	low____	moderate____	heavy____
Harvest of invertebrates for curio sales	none____	low____	moderate____	heavy____
Tourist diving	none____	low____	moderate____	heavy____
Sewage pollution	none____	low____	moderate____	heavy____
Industrial pollution	none____	low____	moderate____	heavy____
Other forms of fishing? (Specify)	none____	low____	moderate____	heavy____
Other impacts? (Specify)	none____	low____	moderate____	heavy____
Is there any form of protection (statutory or other) at this site?	yes_____	no_____		
If yes, what type of protection?				
Other comments				
Submitted by (enter TL/TS and your name)				

Data sheet for fishes and invertebrates

REEF CHECK 2001- Please fill in all Black outlined boxes							
Site Name:							
Depth:			Team Leader:				
Date:			Time:				
Indo-Pacific Belt Transect : Fish							
Data recorded by:							
	0-20m	**25-45m**	**50-70m**	**75-100m**	**Total**	**Mean**	**SD**
Butterfly fish					0	#DIV/0!	#DIV/0!
Sweetlips (Haemulidae)					0	#DIV/0!	#DIV/0!
Snapper (Lutjanidae)					0	#DIV/0!	#DIV/0!
Barramundi Cod (*Cromileptes*)					0	#DIV/0!	#DIV/0!
Grouper >30cm (Give sizes in comments)					0	#DIV/0!	#DIV/0!
Humphead wrasse					0	#DIV/0!	#DIV/0!
Bumphead parrot					0	#DIV/0!	#DIV/0!
Other Parrotfish (>20cm)					0	#DIV/0!	#DIV/0!
Moray eel					0	#DIV/0!	#DIV/0!
Indo-Pacific Belt Transect : Invertebrates							
Data recorded by:							
	0-20m	**25-45m**	**50-70m**	**75-100m**	**Total**	**Mean**	**SD**
Banded coral shrimp (*Stenopus hispidus*)					0	#DIV/0!	#DIV/0!
Diadema urchins					0	#DIV/0!	#DIV/0!
Pencil urchin (*Heterocentrotus mammilatus*)					0	#DIV/0!	#DIV/0!
Sea cucumber (edible only)					0	#DIV/0!	#DIV/0!
Crown-of-thorns star (*Acanthaster*)					0	#DIV/0!	#DIV/0!
Giant clam (*Tridacna*)					0	#DIV/0!	#DIV/0!
Triton shell (*Charonia tritonis*)					0	#DIV/0!	#DIV/0!
Lobster					0	#DIV/0!	#DIV/0!
For each segment, rate the following as: None=0, Low=1, Medium=2, High=3							
Coral damage : Anchor					0	#DIV/0!	#DIV/0!
Coral damage:Dynamite					0	#DIV/0!	#DIV/0!
Coral damage : Other					0	#DIV/0!	#DIV/0!
Trash : Fish nets					0	#DIV/0!	#DIV/0!
Trash : Other					0	#DIV/0!	#DIV/0!
Comments:							
Grouper sizes (cm)							
Bleaching (% of coral population)							
Bleach (% of colony)							
Suspected disease (type/%):							
Rare animals sighted (type/#):							
Other:							

Data sheet for substratum

Site name:															
Depth:							Date:								
Team Leader:							Data recorded by:								
Time:															
Substrate Code															
HC hard coral				**SC** soft coral						**RKC** recently killed coral					
FS fleshy seaweed				**SP** sponge						**RC** rock					
RB rubble				**SD** sand						**SI** silt/clay					
OT other															
(For first segment, if start point is 0 m, last point is 19.5 m)															

SEGMENT 1				**SEGMENT 2**				**SEGMENT 3**				**SEGMENT 4**			
0 - 19.5 m				**25 - 44.5 m**				**50 - 69.5 m**				**75 - 94.5 m**			
1		21		41		61		81		101		121		141	
2		22		42		62		82		102		122		142	
3		23		43		63		83		103		123		143	
4		24		44		64		84		104		124		144	
5		25		45		65		85		105		125		145	
6		26		46		66		86		106		126		146	
7		27		47		67		87		107		127		147	
8		28		48		68		88		108		128		148	
9		29		49		69		89		109		129		149	
10		30		50		70		90		110		130		150	
11		31		51		71		91		111		131		151	
12		32		52		72		92		112		132		152	
13		33		53		73		93		113		133		153	
14		34		54		74		94		114		134		154	
15		35		55		75		95		115		135		155	
16		36		56		76		96		116		136		156	
17		37		57		77		97		117		137		157	
18		38		58		78		98		118		138		158	
19		39		59		79		99		119		139		159	
20		40		60		80		100		120		140		160	

DO NOT TYPE DATA BELOW THIS LINE

Total S1		**Total S2**		**Total S3**		**Total S4**		**Grand total**			**Mean**		**SD**	
HC	0	HC	0	HC	0	HC	0	HC	0		HC	0	HC	0
SC	0	SC	0	SC	0	SC	0	SC	0		SC	0	SC	0
RKC	0	RKC	0	RKC	0	RKC	0	RKC	0		RKC	0	RKC	0
FS	0	FS	0	FS	0	FS	0	FS	0		FS	0	FS	0
SP	0	SP	0	SP	0	SP	0	SP	0		SP	0	SP	0
RC	0	RC	0	RC	0	RC	0	RC	0		RC	0	RC	0
RB	0	RB	0	RB	0	RB	0	RB	0		RB	0	RB	0
SD	0	SD	0	SD	0	SD	0	SD	0		SD	0	SD	0
SI	0	SI	0	SI	0	SI	0	SI	0		SI	0	SI	0
OT	0	OT	0	OT	0	OT	0	OT	0		OT	0	OT	0
#	0	#	0	#	0	#	0							

Comments:

Appendix 3. Data sheet for Spot check method

Snorkel survey data sheet

Reef Name: _____

Date: _____

Diver: _____

Time start: _____ ; Time end: _____

Point #	Hard coral %	type HC	Dead H C %	Soft Coral %	No. COTs, Size (cm)	Substratum	Remarks (GPS No.)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							

Appendix 4. Manta Tow Survey Results (Pangaimotu Reef Reserve)

Date:22 May 2002, Time start:1045 Time end: 1200

Wind:15meters (DirectionEast); Cloud: 4/8

Recorded by:Taniela(Diver:Seiji; Driver: Asipeli)

Map No.	GPS No.	S	W	Live C	Dead C	Soft C	COTS	Viz	Remarks
0	26	21.07.179	175.09.505						
1	27	21.07.090	175.09.637	3	2	1	0	*	
2	28	21.07.060	175.09.704	3	2	1	0	*	
3	29	21.07.048	175.09.798	3	2	1	0	*	
4	30	21.07.048	175.09.864	3	2	1	0	*	
5	31	21.07.080	175.09.921	3	2	1	0	*	
6	32	21.07.075	175.09.983	3	2	1	0	*	1 bleaching c.
7	33	21.07.088	175.10.054	3	2	2	0	*	Many branching c. dead (hawksbill)
8	34	21.07.118	175.10.116	4	2	1	0	*	
9	35	21.07.176	175.10.117	5	1	1	0	*	
10	36	21.07.195	175.10.096	3	2	1	0	*	
11	37	21.07.211	175.10.083	2	1	1	0	*	Too slow due to strong wind
12	38	21.07.226	175.10.066	1	1	1	0	*	
13	39	21.07.252	175.10.035	1	1	1	0	*	
14	40	21.07.275	175.10.003						

*: can't measure the viz.

Appendix 5. Spot check results (Manuafe reef, 23 May 2002)

Point	Diver	Hard coral %	Type of HC	Dead HC %	Soft Coral %	No. of COTS seen	Mean size of COTS	Substratum	Remarks
1	A	15	Porites, Montipora, Acropora, Favids	25	5	0		Sand 50%, Rubble 5%	A fish net seen
	S	10	High variety (dense Millepora)	5	5	0		Sandy	Current E to W
2	A	17.5	Wide range of forms; >1m massive Prites	10	3	0		Sandy, Rubble	
	S	10		10	5	0			
3	A	20	Various, massive	10	7.5	0		Sand, rock	
	S	10		10	40	0		Sand	
4	A	10	Various	15	3	0		Sand, rock and Rubble	
	S	10	Various	5	15	1	30cm		10% sargassum
5	A	7.5	Various	10	10	0			15% sargassum
	S	5	Various	5	10	1	35cm		30% sargassum
Average		11.5		10.5	10.4	0.2			

Appendix 6. Revised Procedure of Manta-tow method

Procedures will follow English (p. 14-p. 33; 1997).

1. A fleet of more than one boat is used by a team to survey remote reefs for safety and for carrying equipment, water and food.
2. After arriving at the reef, record basic information on the boat and fill the data sheet.
3. Set up the gear.
4. Get the Point 0
5. Measure the horizontal visibility.
6. Mark the point on the map as "0"; record the direction of the tows.
7. Write down the record number of the coordinates of GPS (To go back to the same point for the next survey, these coordinates will be used.)
8. Start the 1st tow
9. Tow for 2 minutes slowly (walking speed)
    - The observer records the data (coverage of live hard coral, dead hard coral and soft coral in categories, the number and average size of *Acanthaster,* as well as other remarks.
10. Stop
11. Driver marks "1" on the map; write the record number of the coordinates on GPS.
12. Start for the second tow. Tow to the point 2. Driver clearly convey the number of tow (no. 2) to the observer by gesture or plate on which the number is written.
13. Continue until completion.

Communication between the diver and boat driver/recorder is done by gesture such as "OK", "Stop", "Go to Right/Left", "Slow down", "Speed up", "Come back" and "Help".