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Coral Reef Monitoring Handbook

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Based on techniques developed at an
Expert Meeting on Coral Reef Monitoring
(Motupore Island Research Centre, Papua New Guinea, August 1978)

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NOUMEA, NEW CALEDONIA

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Illustrations by Arthur Lyon Dahl

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Note to the user of this handbook

This handbook is printed on waterproof paper and bound with waterproof materials so that it can be used as a field reference without risk, or even taken into the water during training or while conducting surveys. It should, however, be rinsed in fresh water and be left open to dry after such use.

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Introduction

Coral reefs and lagoons are an important resource for tropical islands and coastal areas. They provide fish, other animals and seaweeds as food for local people. Reefs protect the coastline from waves and make natural harbours. They are a source of materials for construction and for handicrafts, provide tourism and recreation areas, and have potential for aquaculture. The animals, plants and ecosystems of coral reefs and lagoons are part of each country's natural heritage to be conserved for future generations, just like natural areas on land. Yet increasingly these resources are being damaged by overfishing, pollution, or the many other changes that come with development.

Coral reefs are very complex communities with many kinds of animals, plants and fishes, too many to be easily counted or understood. It is still hard for scientists to tell what all the plants and animals are that live on a reef or how the reef ecosystem works. If reef resources are to be developed, managed or protected, information about them must be collected, so that those responsible will know what is happening to them. This handbook explains a simple way to measure certain things on a reef or in a lagoon to show what the area is like and how it may be changing.

The first time a survey is done, it will give basic information on the condition or health of the coral reef ecosystem, measure some of the resources present, and perhaps show where more detailed studies are needed. Repeating the survey later in the same place will show what changes have taken place, whether natural or caused by man. The kind of changes and the rate at which they are taking place can show whether action is needed and perhaps what should be done to maintain an important resource.

The methods in this handbook were designed to be used both by scientists and by people without a scientific background who receive initial expert advice and some training in the methods. It is best, however, if those doing the surveys are at least familiar with the sea and reef areas, perhaps as fishermen or from living near the sea. Indeed, many traditional cultures have extensive knowledge of reef and lagoon life with local names for the corals, plants and animals, and this knowledge can be very useful. Simple indicators have been chosen for ease in definition and reliability in use under field conditions. Choosing more general measures and applying them only in small areas means overlooking many distinctive features of a particular reef, but the combination of measures should permit reasonable comparisons over time and between different areas even if much significant detail is not recorded.

It is necessary to use a mask or goggles and snorkel, and preferably flippers or fins, while making the various counts and measures, so reasonable swimming ability is essential. Depending on the location of the reefs a boat may be required to reach the survey sites. If trained scuba divers are available, surveys can be done in deeper water but this is not essential for satisfactory monitoring, as shallow reefs should be an indicator of the changes in the general state of the reefs in an area.

The techniques described here were developed by an Expert Meeting on Coral Reef Monitoring held in August 1978 at the Motupore Island Research Centre of the University of Papua New Guinea. The meeting was organized by the South Pacific Commission with the financial support of the Commonwealth Fund for Technical Cooperation, and involved fifteen participants from five countries (see list page vi) selected for their knowledge of various aspects of coral reefs or monitoring techniques.

This simple approach to coral reef surveys should be useful wherever a rapid measure of the state of particular reef areas is required and trained specialists are not available. It should be appropriate for:

- government resource management programmes,
- fisheries studies,
- environmental baseline studies and impact assessments,
- marine parks and reserves and other conservation programmes,
- rural or village fisheries management,
- scientific studies as a basis for comparisons or for further elaboration.

As this is a first attempt to define simple ways to measure a very complex system, there are bound to be problems that will arise. Any criticisms or suggestions for modification or improvement will be welcome, and should be sent to:

Regional Ecological Adviser
South Pacific Commission
P.O. Box D 5
NOUMEA CEDEX, New Caledonia.

1. Steps in establishing a coral reef survey

1.1. Initial expert advice

Before starting a coral reef survey or monitoring programme, it will be necessary to have the help of an expert to choose the areas to be surveyed, to adapt the handbook and methods to particular local conditions, and to train local survey personnel in the techniques. If no expert in coral reef studies is available locally, a short-term consultant will be needed. Depending on the amount of reef to be studied, the weather and working conditions, and the information already available, a few weeks to a few months should be sufficient for this expert assistance. The expert should complete points 1.2 to 1.7 below.

1.2. Aerial photographs

To get an overall view of the whole reef and lagoon area, a detailed study of aerial photographs will be needed. These should be vertical, map-quality photographs, such as are now available for most areas where mapping has recently been done. If such photographs are not available, the expert may need to fly over the area himself and perhaps take pictures from which the outlines of the reef areas can be taken. Other existing information on the reefs can be reviewed at the same time.

1.3. Choice of priority areas for study

On the basis of the purpose of the survey, the requirements of the government or other user of the data, and the analysis of the aerial photographs for general reef structure and relationships, priority areas can then be selected for detailed study.

1.4. Mapping

An outline map of the reef and lagoon areas of interest can be made from the aerial photographs, showing the major reef zones and discontinuities. Other useful information can also be added to this map, such as water circulation patterns, prevailing wind directions and terrestrial influences, which will help to interpret the results of specific plot surveys.

1.5. Field checks of map

Rapid field checks can then be made of the area to confirm the major zones determined from aerial photography. This can be done by swimming or walking across the area if it is small, by towing a swimmer with mask behind a boat, or by spot checks from a boat (by looking through a viewing box or by swimming around the boat).

1.6. Training of survey personnel

The people who will make the actual plot surveys should then be trained in the technique described in this handbook. They should be able to identify consistently the different categories of substrate, corals, plants, animals and fish in the field, and should preferably do several survey plots under the guidance of the expert to ensure that the procedure is well understood and the results repeatable. The expert can at the same time make any necessary modifications to the handbook and methods to adapt them to particular local organisms and circumstances.

1.7. Selection of study plots

Having determined the general zones on the reef, it is necessary to characterize those zones by describing the major corals, plants and animals that occur in them. The great density of reef life makes this extremely difficult, yet it is these that will change most quickly if the reef ecosystem is damaged or altered. The method described here is based on selecting plots that are typical of significant reef zones and then making measurements in those plots as described below.

Plots should be in the centre of reef zones identified above, rather than in boundary areas where the results will be difficult to interpret. They can be arranged along a line or transect across the reef, which may make it easier to find them again, but this is not essential. The following is the recommended priority order for reef and lagoon zones to be surveyed (see Figure 1):

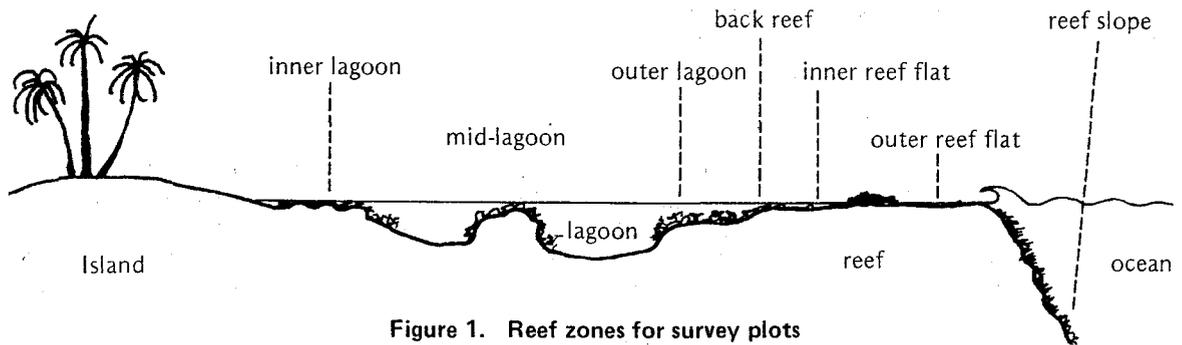


Figure 1. Reef zones for survey plots

- back reef — the back side of the reef as it slopes into the lagoon
- inner reef flat — the reef flat behind the rubble bank or boulder line (if present)
- reef slope — the outer or seaward slope of the reef
- outer reef flat — the reef flat between the outer reef slope or reef crest and the rubble bank (if distinct from the inner reef flat)
- outer lagoon — the shallow lagoon bottom just inside the reef
- inner lagoon — the lagoon bottom near the shore
- mid-lagoon — the centre of the lagoon if this is large enough, or possibly a patch reef in the lagoon.

Some of these zones may not be present on certain reefs, and others may be inaccessible because of weather or wave conditions, reducing the number of zones where survey plots are practical. Plot sites should be no deeper than two to four metres so that they can be surveyed from the surface, unless a diving capability is available.

Within each zone, plots should be chosen that seem typical or characteristic of the zone, avoiding channels or discontinuities. This judgement will be necessarily subjective, but the bias introduced by such an expert judgement will in most cases be less than that of a single sample at random in a highly variable environment.

The number of plots will depend on the purpose of the study, the diversity of the reef areas, and the resources available. For general monitoring, a single plot in each zone for a major section of reef may be sufficient. For environmental impact studies, some array of plots at different distances from the point of expected impact (sewage outfall, construction site, etc.) may be needed, as well as control plots on a similar reef beyond the range of possible impacts.

1.8. Frequency of surveys

The first survey of a reef will give a general measure of its actual state. However, reef communities may be very variable over time, either naturally or because of human impact. Repeating the measurements in the same survey plots will show what changes are taking place, and may suggest what the possible causes are. This monitoring of reef and lagoon areas is one of the principal uses for the present techniques.

For general monitoring of the state of reef resources, measurement once a year may be sufficient. Such measurements should be taken at the same time of year to avoid the seasonal changes that occur in certain plants and animals.

Wherever changes are expected, as in environmental impact monitoring, or are detected by annual monitoring, measurement of the plots every two months will be necessary. This will provide an early warning of problems as they arise.

Where it is intended to monitor the effects of an industrial, commercial or residential development likely to affect the coastal area, plots should be surveyed at two-month intervals for at least a year before the project begins. This will measure the amount of natural change in the area, and possibly suggest ways of modifying the project to reduce its impact. Monitoring should be continued during construction and after the project is operational to confirm expected impacts and to detect unexpected effects that might require corrective action.

Shallow plots should be re-surveyed whenever possible at the same tide level, as some measures may vary with the tide. Showing the water depth on the data sheet can help in correcting the data for tidal variations.

2. Monitoring plots

2.1. Establishment of plots

Survey plots for reef monitoring must be easy to find again since it is essential that the repeated surveys be done in exactly the same place. Otherwise, the results will be meaningless because the reef is so different from place to place. Finding the same spot underwater is not easy, so, if possible, plots should be easily related to objects visible to a swimmer, such as a channel or large coral block, or a line of sight on a major building, marker, headland or other coastal feature.

The centre of each plot should be permanently marked in some way, such as by a metal stake or ring concreted into the reef, a hole drilled in the reef rock, or a distinctive coral head. If a marker is too obvious, it may be taken by children or fishermen, yet it must not be too hard to find either.

All the information needed to find a plot should be carefully written down when it is established, preferably with a sketch map showing its relation to major reef features. Plot locations should also be marked on the map of reef zones described above.

Each survey plot is a circle with a radius of four metres (156 inches) around the central marker, covering an area of 50 square metres. This area is easily determined in the field with a rope attached to the central marker.

2.2. Parameters to be surveyed

Several different things will be looked for or counted in the circle, including the substrate (what the bottom is made of), the amount of bottom covered by corals, plants, etc. (percent cover), the presence of major types of coral and plants, and the numbers of certain animals. Fish will be counted not in the circle but along a line. These parameters are defined in detail in the following sub-sections.

2.2.1 Fish counts

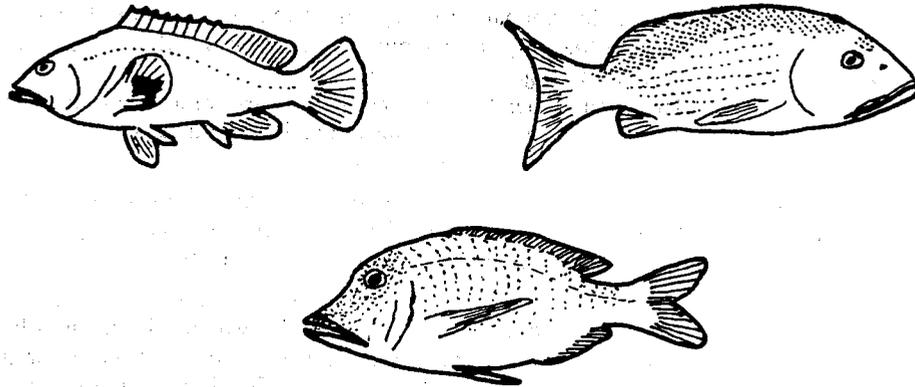
Since fish are disturbed by a swimmer in the water, they cannot easily be counted in a circle. Another way is needed to measure them. The method is to swim along the reef for 100 metres counting certain fish for two and a half metres on either side (width of the area counted: five metres; total area: 500 m²). The simplest way to swim for 100 metres is to attach one end of a 100 m rope or line to the plot marker or an anchored buoy, hold on to the other end, and swim until the line is stretched to its full length. Another count can be made by swimming back to the starting marker. A floating polypropylene rope line is best as it has less chance of getting tangled in coral. For frequent monitoring, permanent markers can be installed 100 metres apart. The lines should be parallel to the reef edge, with a first line along the back reef, a second, if conditions permit, along the outer reef slope, and a third across the reef flat if the water depth is sufficient. Changes in the depth of the reef along the line should be avoided if possible. In many cases where there is a slope, the 5 m width will go from the edge of the reef to near the depth at which fish become hard to recognize. Fish counting should either be done first before other activities have frightened the fish, or else a little away from the circle plots.

Two groups of fish are to be counted (see Figure 2):

- Predators:** These are larger fish, longer than an outstretched hand, that eat other fish, and include the groupers (Serranidae), the snappers (Lutjanidae) and the emperors (Lethrinidae). They should be counted first as they may be frightened away by a swimmer going by.
- Butterfly fish:** The butterfly fish or chaetodontids are small, brightly coloured reef fish that are quite easy to tell from other fish on the reef. They often swim in pairs and have a special way of biting and sucking around corals. They are not so disturbed by swimmers, tending to stay over the same part of the reef, and so can be counted on the return swim to the starting point.

All the other measures will be made inside the circle that marks the survey plot.

Predators (snappers, groupers, emperors)



Butterfly fish

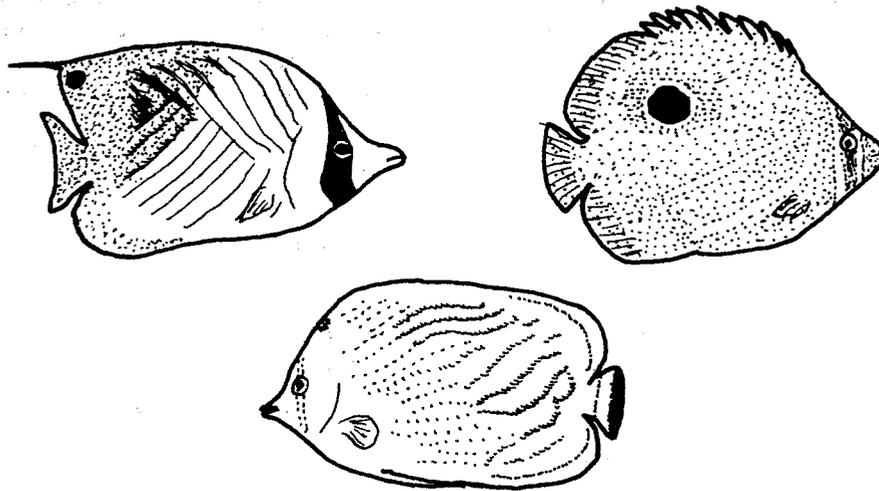


Figure 2. Fish to be counted (details of shape and colour pattern may vary; not to scale)

2.2.2 Percent cover

When looking at the bottom in the circle, you will see sand or bare rock in some places, and corals, plants or other things that are attached or fixed in place on the bottom.

- (i) The first measure is what the bottom is made of. Much of a reef is solid, hard rock all cemented together, but in some places, and particularly on the lagoon floor, there is loose rock or sand on top of this. For the survey, only the loose material is counted, and everything else is assumed to be solid rock of the reef. Measure what you see at the surface, not what you think is underneath if you dig down. The loose material is called "sediment" and is subdivided into four types based on the size of the individual grains:

- mud — very fine and soft, individual particles not distinguishable.
- sand — small bits of rock or shell where you can see the separate grains, but smaller than rubble.
- rubble — pieces of broken coral or rock ranging from the size of a finger joint up to the size of a human head.
- blocks — coral rocks larger than a human head but still not attached or cemented to the bottom. Any rock that is a solid part of the bottom is not counted.

(ii) A second measure is of the amount of bottom covered by major biological groups attached to it. The following categories are distinguished:

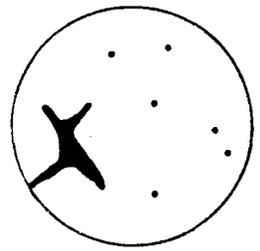
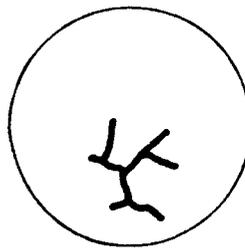
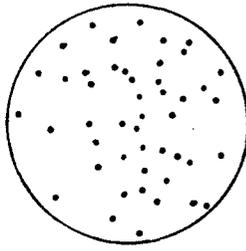
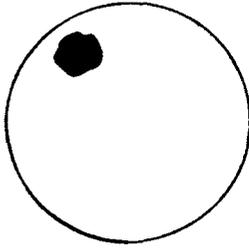
- live hard corals — these corals feel hard because they have a stony skeleton, and are covered by the tiny animals or polyps that live in holes in the skeleton. The holes may be like tiny craters, pinholes or valleys and are often rough or sharp around the edge.
The corals generally look “clean” and are coloured by the animal tissues. They may be of many shapes: big like boulders, small and branched like bushes, or just a crust on the rock.
- soft corals and sponges — these may have shapes like corals but they are soft to the touch, sometimes slimy or rough and flexible. Some are very brightly coloured. If there are waves, they may move back and forth.
- dead standing coral — when hard coral dies, only the white skeleton is left. Fuzzy plants may then grow on it, giving it a dirty brown, blackish, pinkish or reddish colour, but the outline of the coral skeleton is still very clear and it is still standing in the place where it grew. This is dead standing coral, and it is coral that has died not too long ago. Eventually the skeleton is broken up, eroded or overgrown by other things and becomes part of the reef rock or rubble. Then it is no longer counted as dead standing coral. If it is not clear that something is dead standing coral, do not count it.
- marine plants — these include the sea grasses and seaweeds and can range from a cushion-like turf to big floppy plants. They may be green, red or brown in colour. Only plants or clumps of plants large enough to grab hold of should be counted; fine algal fuzzes and films are too difficult to quantify.

(iii) The estimation of the percent cover, or area of the circle occupied by either a class of sediment or a group of organisms, is not easy and requires a certain educated judgement. Six classes coded 0 to 5 are used here:

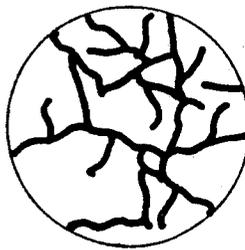
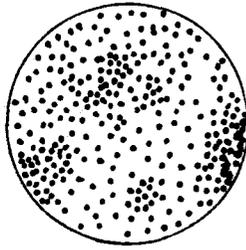
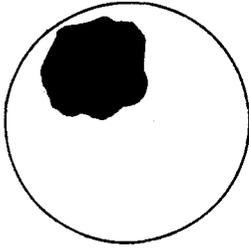
none		0%	=	0
a little	1	— 5%	=	1
some	6	— 30%	=	2
nearly half	31	— 50%	=	3
more than half	51	— 75%	=	4
almost all	76	— 100%	=	5

It is difficult to make accurate judgements for the area covered by many small scattered things, a few big things, and things that are unevenly distributed. Figure 3 illustrates some different amounts and types of area coverage. Area coverage is measured as a percentage of the whole area separately for sediments and organisms, but in neither case will the figures total 100 per cent because the first measure excludes solid rock and the second does not count areas without organisms.

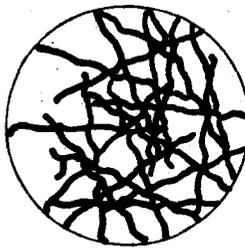
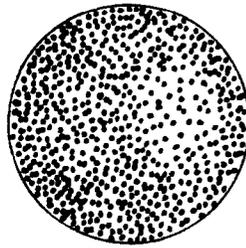
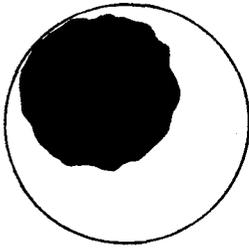
1 = 1 - 5% : a little



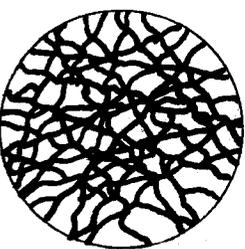
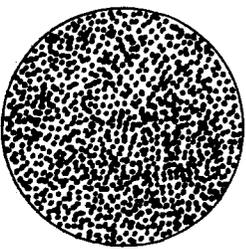
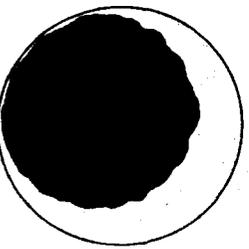
2 = 6 - 30% : some



3 = 31 - 50% : nearly half



4 = 51 - 75% : more than half



5 = 76 - 100% : almost all

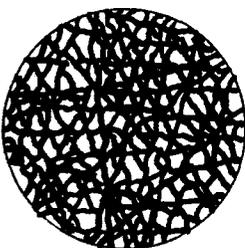
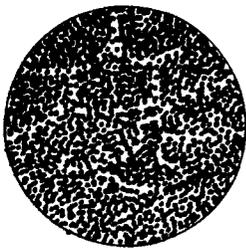
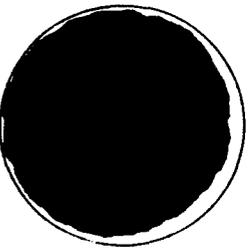


Figure 3. Percent cover

2.2.3 Forms present and dominant

This part of the survey records which major types of corals and plants are seen in the circle and which are the most important or dominant in their visual impact (what you see) and in the area they cover. There are three groups based on the categories for which percent cover is measured, each with two or more subgroups.

Hard corals — these are subdivided into eight different shapes corresponding to the major types of coral (see Figure 4):

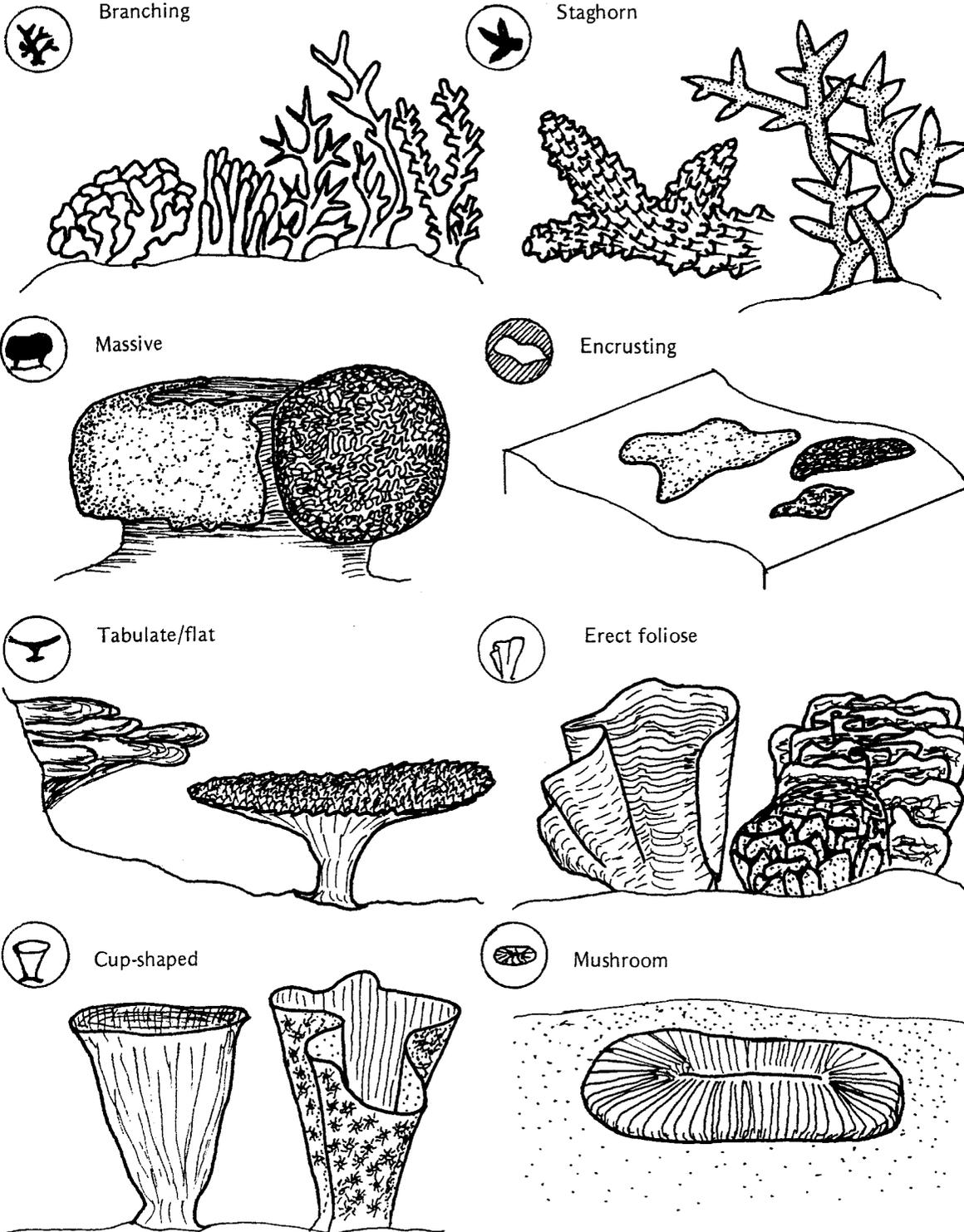


Figure 4. Hard coral forms

- branching: these corals have branches that are longer than they are thick; they may be delicate or very stubby or lumpy.
- staghorn: this is a certain kind of branching coral with branches about the thickness of a thumb or finger. The tips of the branches are pointed, often white or very pale compared to the rest of the branch, and have quite large holes for the coral polyps.
- massive: these ball-shaped or boulder-like corals may be as small as an egg or as big as a house. If some parts of the coral are killed they may develop irregular bulges, and in shallow water where the top is killed they can form a ring. The coral surface may be smooth, dented, or with little knobs or ridges.
- encrusting: corals that grow as a thin layer or crust on the surface of the reef. They have a hard, rough surface like other corals, with little holes or pits for the coral animals.
- tabulate/flat: these corals are like a table or a platform with a broad, flat surface (often with small lumps or knobs) facing up towards the surface of the water. They may stand on a central stem or be attached on one side like a bracket or shelf.
- erect foliose: these corals grow in flattened sheets or plates that stick up from the reef. The sheets may be smooth, folded or joined together.
- cup-shaped: corals that grow up from the reef in the shape of cups or pots. Corals that are not clearly cup-shaped should be classed as “erect foliose”.
- mushroom: these are distinctive round or oval corals that lie on the bottom as loose plates and look a little like mushrooms. They have many ridges which run from the edge of the plate to the central mouth.

Soft corals and sponges — the soft-bodied corals and sponges without stony skeletons may have many shapes; only two general categories are distinguished here (see Figure 5).

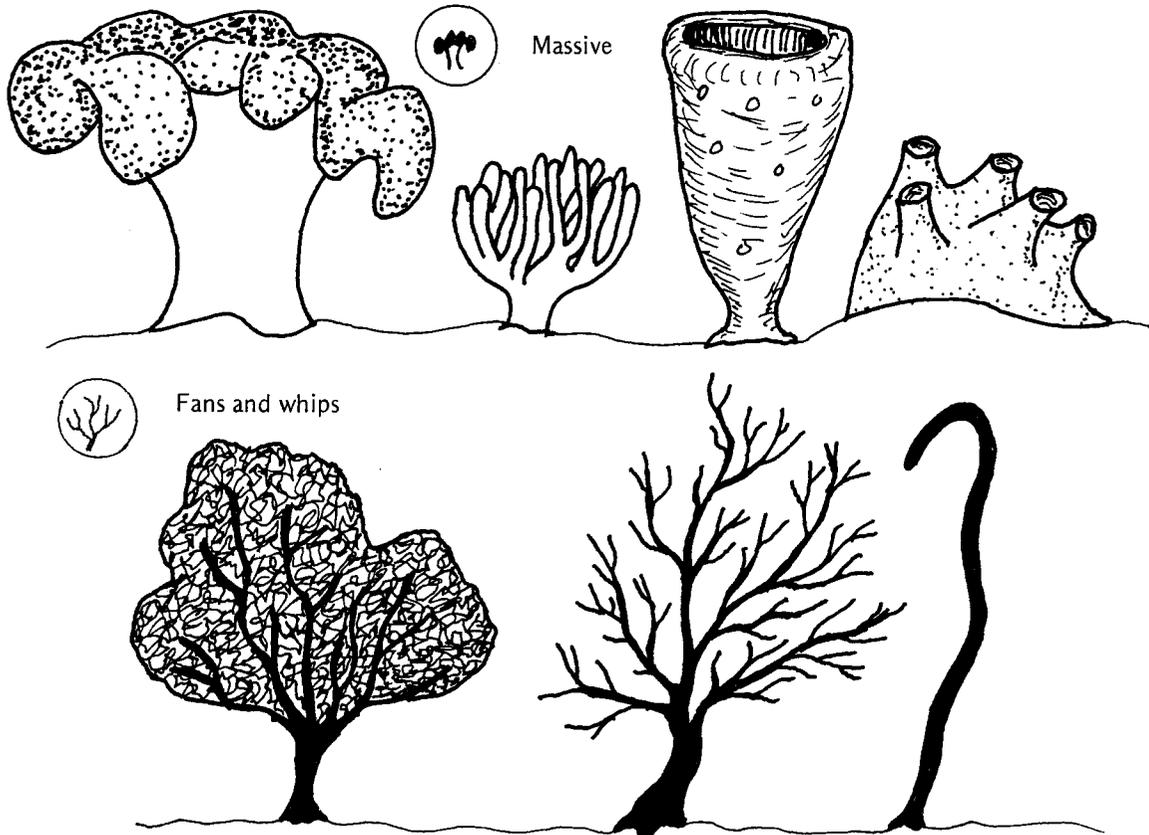


Figure 5. Soft coral and sponge forms

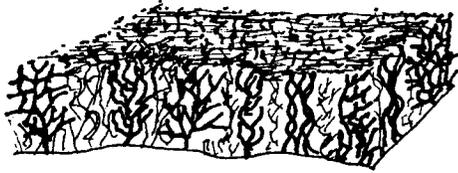
- massive: any big, thick or lumpy soft corals or sponges, whether or not they have branches or are cup-shaped or encrusting.
- fans and whips: this includes the sea fans (delicately branched or flat and often lacy animals that wave back and forth and often look like plants) and the sea whips, straight single stems the thickness of a child's finger and sometimes as long as a person is tall.

Plants — the plants on the reef are often very different from plants on land, since not all of them are green. Six categories are distinguished (see Figure 6):

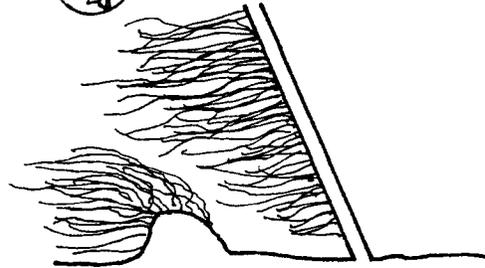
- thick turf: this is made up of many small plants crowded together like the turf of a lawn or a thick carpet and feeling a little soft or spongy. Its colour is variable depending on the plants in it. Do not include the very fine fuzz of algae that covers many reef surfaces, but only turfs thick enough to get a hold of.



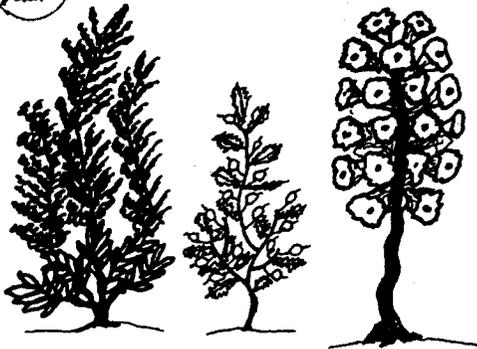
Thick turf



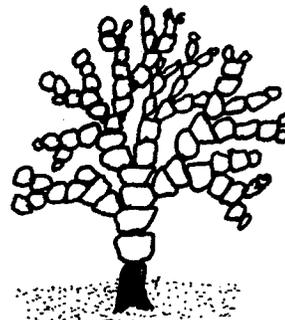
Long filaments



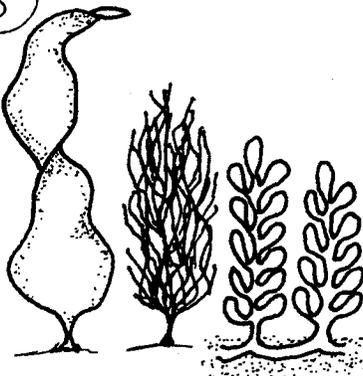
Large browns



Halimeda



Other fleshy



Sea grass

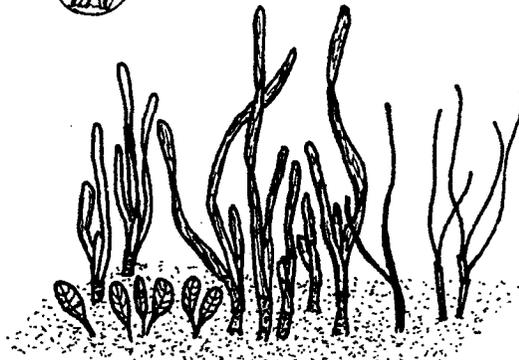


Figure 6. Plant forms

- long filaments: these algae look like tufts or mats of hair, and may be black, brown, red or green. They should only be counted if they are long and obvious.
- large browns: the large brown or yellow-brown seaweeds are branched with leaves, spiny projections or little round floats. They are generally tough and rubbery in feel.
- halimeda: this is the name for a group of green seaweeds made up of branched chains of hard discs, plates or cylinders.
- other fleshy: all other seaweeds (algae) big enough to grab hold of are grouped here. They may be green, red or brown, flat or highly branched, soft or tough, stiff or floppy.
- sea grass: the sea grasses look very much like green grasses on land, with flat or occasionally cylindrical blades. They usually grow rooted in sand or mud.

For each of the three groups of forms (hard corals, soft corals and sponges, and plants) three things are noted: first, whether each particular form is present in the circle plot; second, which form is dominant in its group, that is, which is the most obvious and covers the largest area of the circle; and third, the most common size in the dominant form. Size is measured in three classes, coded 1, 2 and 3 as follows:

- 1 : the size of a fist,
- 2 : in size or diameter about the length of a forearm,
- 3 : the size or span of outstretched arms from hand to hand.

For intermediate sizes, choose the closest class. If there are different sizes in the dominant group, the largest size present should be recorded.

2.2.4 Counts of animals

Some animals are relatively easy to see and can indicate the health of the reef. The number of each kind seen in the circle should be counted. If the number is more than 20, then a simple indication "more than 20" (> 20) is sufficient, as counting large numbers of animals can take too much time. Several animals are to be counted (see Figure 7):

- Mushroom coral – These unattached plate-like corals are also included above as a form of hard coral, but the number present is also of interest, so they should be counted as well.
- Giant clams – The different kinds of giant clams, with their coloured mantles, are combined here. They can be the size of a fist or of a pig, and free standing, attached or embedded in reef rock.
- Synaptids – This group of holothurians looks like wrinkled intestines with a flower at one end, waving slowly in a snake-like fashion.
- Other holothurians – Often known as "beche-de-mer" or sea-cucumbers, these sausage-shaped animals are most common in sandy areas.
- Acanthaster – The Crown-of-Thorns starfish is easily recognized by its covering of sharp spines.
- Other starfish – All starfish other than Acanthaster are grouped here.
- Urchins – The sea urchins or sea eggs are a distinctive group with their round shell and prominent movable spines.
- Trochus – This large conical snail with a thick shell is often collected for export.
- Other – If some other animal is particularly distinctive or obvious in a plot it should be noted as well.

2.2.5 Visible pollution

Several kinds of pollution can be recorded if seen: cans, bottles, plastics, tyres or other man-made objects (give the kind and number in the circle); leaves, palm logs, wood or other land plant debris; sediment or fine material making the water cloudy, milky or turbid and reducing visibility; the cloudiness or fuzziness and often a change in temperature that shows that fresh water is mixing with salt water; oil floating as a film on the surface or stuck on rocks as tar; etc.

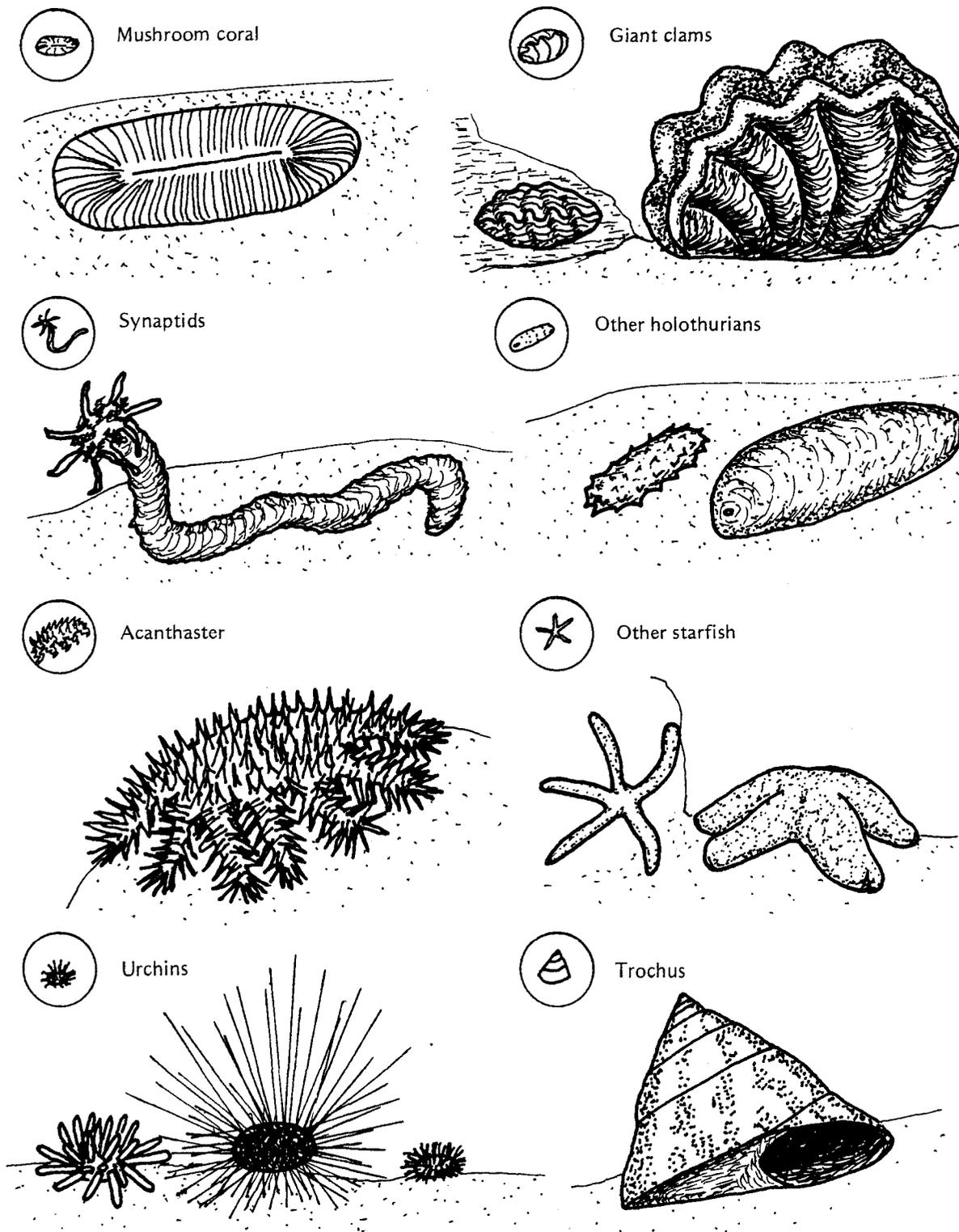


Figure 7. Animals to be counted

2.2.6 Other notes

Brief note can be made of any other observation that may help to interpret the survey results, such as the occurrence of a big storm since the last survey, some human activity affecting the survey plot (dynamiting, construction, etc.) or the loss of an earlier plot marker making the site of the survey only approximate.

2.3. Field survey procedure

Assuming that the plots have already been chosen and markers established, the following is the procedure for surveying the plots. Start with the most difficult part of the reef to reach, since you may be tired later and the wave and tide conditions may get worse. Fill out the top of the data sheet (locality, date, your name, circle number, reef zone, water depth). As your actions may frighten the fish away, do the fish count first along a 100 m line. Then attach a short rope to the marker in the middle of the survey plot, so that the free end is four metres long and ends in a loop, as this is easier to hold on to. (If you start with a four metre rope, it will be too short by the time you have tied the knots, so use a five metre rope to allow some extra.) Swim or walk around the circle holding the end of the rope in your outer outstretched arm. Choose an obvious feature for a starting point so that you can remember when you have made a complete circle. If the reef is very rough and it is hard to see all of the circle in one turn, it may be necessary to go around again looking at the middle part of the circle.

As you go around holding the rope in front of you, it will help you to measure or count as it crosses things of interest. Do not count anything outside the area covered by the rope. On your first time around, look at the amount of bottom (percent cover) of the different kinds of sediment (mud, sand, rubble, blocks) and write the code numbers on the data sheet. Do a second circle to estimate the percent cover of live hard coral. Then make circles for the percent cover of soft corals and sponges, dead standing coral, crustose corallines and marine plants.

Mark off the forms present (hard corals, soft corals and sponges, and plants), making as many circles as necessary to look for all the forms on the list. When you have checked all the forms that are inside the circle, go back and estimate which is the dominant form in each group, and write in the code for the largest size of that form.

For the counts of animals, make circles to count each kind of animal on the list. You may need to make one or more circles for each kind of animal, unless they are very rare. You can either make the count in your head and write it down when you have finished circling, or make a mark each time you see an animal in the circle, and then add up the marks later.

If there are signs of pollution or things made by man (garbage, oil, etc.), write down what they are, and how many are in the circle if it is something you can count. Finish the survey by making notes of any other things that seem unusual or important. Write everything down immediately, and make sure you can read all your notes by going over them again when you get out of the water.

All of the survey information for three survey plots can be written on a data sheet like those included with this handbook. Ideally, the data sheets should be printed or photocopied on waterproof paper. They can then be clipped to a clipboard or attached to a board, so that they are easy to write on under water with a pencil. The pencil should be tied to the board or it will float away or get lost. Make the string long enough to allow for ease of writing. The data sheet format can also be copied on to or scratched into sheets of plastic with a roughened surface on which a pencil can be used. Almost any flat, hard plastic (not polyethylene or vinyl) can be used if the surface is roughened with sandpaper. The data can then be carefully recopied on to plain paper forms after the survey, and the plastic sheet prepared for re-use by erasing the pencil or washing with scouring powder or cleanser.

Figure 8 shows a sample data sheet giving examples of the way it can be filled out. A blank data sheet suitable for photocopying is included at the end of the handbook (see Figure 11).

CORAL REEF MONITORING DATA SHEET

Locality Mopapea	Date 2 February 1982	Recorder S. Ale							
Circle number	1	2	3						
Location on reef	Reef slope	Inner reef flat	Back reef						
Water depth	1-2 metres	0.5 m	1m						
FISH COUNTS (100 metre line)									
Predators 	3	—	0						
Butterfly fish 	16	—	11						
PERCENT COVER Code: 0% = 0 1-5% = 1 6-30% = 2 31-50% = 3 51-75% = 4 76-100% = 5									
Sediment mud	0	0	0						
Sand	0	1	3						
Rubble	2	4	1						
Blocks	0	2	2						
Live hard coral	3	2	2						
Soft corals and sponges	0	1	2						
Dead standing coral	1	2	2						
Crustose corallines	3	2	1						
Marine plants	1	3	3						
FORMS PRESENT AND DOMINANT Size code: fist = 1 forearm = 2 arm span = 3									
	PRES	DOM	SIZE	PRES	DOM	SIZE	PRES	DOM	SIZE
Hard corals branching 	✓			✓			✓	✓	3
Staghorn 				✓	✓	1	✓		
Massive 	✓	✓	2	✓			✓		
Encrusting 	✓			✓					
Tabulate/flat 	✓								
Erect foliose 							✓		
Cup-shaped 									
Mushroom 	✓						✓		
Soft coral and sponges massive 				✓	✓	2	✓	✓	2
Fans and whips 							✓		
Plants thick turf 	✓			✓	✓	1	✓		
Long filaments 							✓		
Large browns 				✓			✓		
Halimeda 	✓	✓	1	✓			✓		
Other fleshy 	✓			✓			✓		
Sea grass 							✓	✓	2
COUNTS OF ANIMALS									
Mushroom coral 	2			0			3		
Giant clams 	0			7			6		
Synaptids 	0			0			5		
Other holothurians 	3			4			7		
Acanthaster 	0			0			1		
Other starfish 	2			3			2		
Urchins 	>20			4			2		
Trochus 	0			0			0		
Other (specify)							1 lobster		
VISIBLE POLLUTION (specify/count)	none			none			1 bottle, 2 cans		
OTHER NOTES							3 recently dead corals from Acanthaster		

Figure 8. Example of completed data sheet

3. Other samples and measures

The above survey tells us something about what is living on the bottom and in the water, but we also need some information about the water itself. It may not be possible to make measurements at each survey plot, but they should be made at least at one place in the lagoon as near as possible to the survey plots, and also outside the reef if there are survey plots on the reef slope.

3.1. Temperature

The temperature of the water can be measured by holding a thermometer [Figure 9(a)] under water for one minute or more, and then quickly reading it, preferably while the bulb end is still in the water. A better measurement is to use a maximum/minimum thermometer [Figure 9(b)], which measures both the warmest and the coldest that the water has been since the thermometer was last set. Such a thermometer can be used when re-surveying an area every one or two months, and between surveys it should be left in the water firmly attached to a pole or survey marker below the lowest tide level in a place where it will not be damaged or stolen. It should then be removed, read, reset and re-attached each time the survey is done.

3.2. Turbidity

Turbidity means how cloudy the water is, and is a measure of how far you can see under water and how far down the light can go. It is measured with a secchi disc [Figure 9(c)], which is a disc 20 cm in diameter painted black and white and attached to a weighted rope which is marked each metre to show its length. These can be easily made or purchased. To use the secchi disc, go by boat or swim until the water is sufficiently deep, and lower the disc until you can no longer see it. Then slowly pull up the disc until you can just see it again from the surface, and write down the distance to the disc as measured by the marks on the rope. If you do not know which mark it is, count them as you pull the disc back up.

3.3. Salinity

Salinity is a measure of how much salt is in the water, and thus tells whether fresh water or rain water has been mixed with the seawater. There are three simple ways to measure salinity, but some require expensive equipment. To measure salinity, you will need to collect a sample of water from the surface at the same place where you measured the turbidity. Put the sample in a clean bottle of a size appropriate to the technique being used, and take it back to the shore for measurement.

(i) Hydrometer:

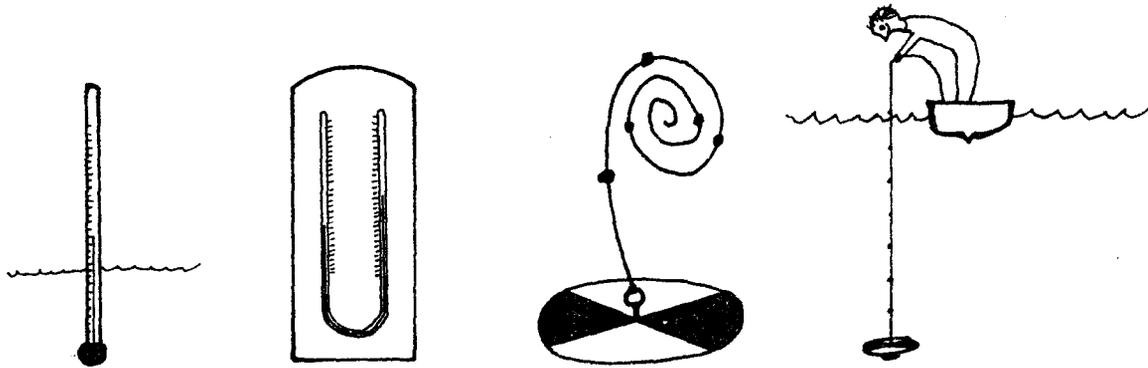
the hydrometer [Figure 9(d)] is a weighted glass tube that floats at a different depth in the water depending on the salinity (or specific gravity). Put the hydrometer in a transparent cylinder or deep jar and fill with sample water until the hydrometer floats. Then put your eye at the level of the water and read the number on the hydrometer scale. Write down the reading on the data sheet, remove the hydrometer, take the temperature of the same water and write this alongside the hydrometer reading. Hydrometers are very fragile and easily broken, so be very careful.

(ii) Refractometer:

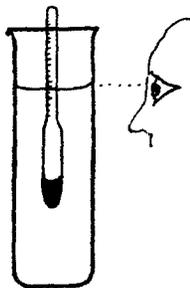
a refractometer [Figure 9(e)] is a little like a telescope with a measuring scale in it. It is more expensive than a hydrometer, but less fragile and easier to use. Take a small sample of the water and put it under the little cover. Hold the cover down without blocking the light, and read the salinity (or refractive index) by looking through the eye piece. Write down the reading.

(iii) Conductivity meter:

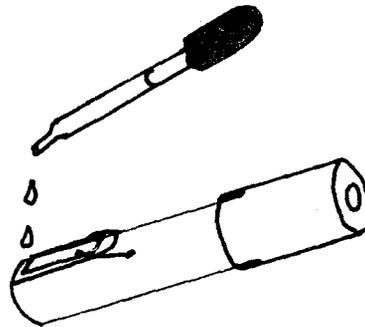
a conductivity meter [Figure 9(f)] is an expensive instrument that measures salinity by passing electricity through the water. Follow the instructions with the meter for measuring the sample and for compensating for the temperature, and write down the reading. You may or may not need to record the temperature also.



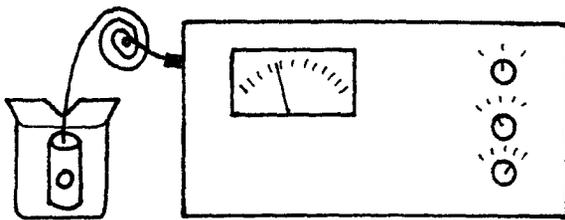
(a) Thermometer (b) Maximum/minimum thermometer (c) Secchi disc to measure turbidity



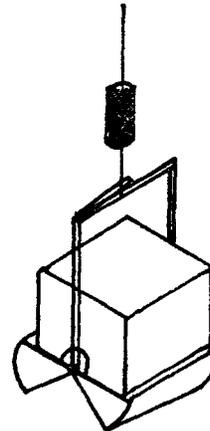
(d) Hydrometer



(e) Refractometer



(f) Conductivity meter



(g) Grab

Figure 9. Measuring instruments

3.4. Samples for chemical analysis

If chemical pollution is expected in an area, samples will need to be collected for chemical analysis. The following are some very simple ways to collect samples for certain important pollutants. The samples should be sent, with complete labels telling how, when, where and by whom they were collected, to an analytical laboratory. If possible, use containers supplied by the laboratory. For any more than the simplest sampling, consult a qualified person in advance.

Trace metals: Mud or sediment from the bottom of the lagoon, estuary or harbour is used for trace metal analysis. Collect the sample in the centre of the area, just downstream from the discharge or expected discharge of pollutants

or in the area likely to be affected. Samples should be collected both before and after the discharge if possible. The sample of surface sediment should be taken with a grab [Figure 9(g)], if available, or with a bucket attached to a rope. Three handfuls of sediments are then removed from the middle of the sample, placed in a flat, shallow, plastic tray to dry in the sun. Then they are packed in 500 ml widemouth polyethylene plastic jars to be sent to the laboratory. Do not use metal tools or let the sample touch metal during sampling.

Pesticides: Persistent pesticides are often concentrated in fish livers. Collect livers from five fish of the same species of top predators (such as snapper), ensuring the fish are from the same catch or area and of about the same size. Place a layer of salt in the bottom of a clean jar. Put a few livers on this, not touching each other, and cover them with another layer of salt. Add more livers and layers of salt until all the livers are completely covered by the salt, which will preserve them. Finish filling the jar with salt, and pack it carefully to send to the laboratory.

Excessive nutrients: Nitrate, phosphate and other nutrients may accumulate from sewage or excessive fertilizer use and cause too much growth of algae and seaweeds. Collect a sample of the water in a specially cleaned one-litre all-glass bottle. Fill the bottle so that there is no air or bubble inside when it is closed with the glass stopper. Tape down the stopper if necessary, and pack carefully in a plastic container to send to the laboratory.

Do not forget to attach a label to each sample telling where it is from and when it was collected. There are simple testing kits for doing some analyses with pre-measured chemicals if frequent analyses for water quality, trace metals or nutrients are required.

4. Evaluation and interpretation

Once the data sheets have been filled out and the survey has been completed, it is then necessary to see what the results can show about the health of the reef or how it may be changing.

If some of the measures are very high or very low in a plot, this can suggest that the reef is very poor or has some problem.

Three or more consecutive surveys at the same plot can also be compared. If some of the measures show a continuing increase or decrease of two points (classes) or more over three surveys, this might suggest that important changes are taking place. Small variations of only one point could be due to errors in counting or estimation, and are not significant. The important measures or changes are shown on the key sheet (see Figure 10).

For small-scale surveys, the original data-sheet columns for a particular survey plot or circle can be compared directly, but for long or complex monitoring surveys, the data should be compiled separately for each circle so that long-term changes or comparisons can be followed more easily. A clean data sheet can be used as a data compilation form. Use one sheet for each survey circle, and copy the data from the original data sheet each time the circle is re-surveyed. The original data sheets should never be thrown away, but should be carefully filed for permanent reference as they contain other information that may help in establishing what is the natural situation on the reef, and in interpreting later changes.

The key sheet in Figure 10 permits a quick evaluation of the data collected. Column 1 gives values that should be considered danger or problem levels in most coral reef areas. If at any time a survey plot reaches that level for any measure, there may be a serious problem on the reef. Column 2 is for evaluating three or more consecutive surveys of the same circle over time. A change between two surveys

1	2	3	
Problem indicator level for any one survey	Change (in three consecutive measures) suggesting a problem	Interpretations (see pages 17, 19)	
FISH COUNTS (100 metre line)			
0 on reef front only	decrease	B	Predators
10 or less, reef front or back	decrease	B	Butterfly fish
PERCENT COVER			
3 or more (except in lagoon)	increase	C	mud sand rubble blocks
4 or more (except in lagoon)	increase	C	Sediment
0	decrease	A	Live hard corals
4 or more		A	Soft corals and sponges
3 or more		A	Dead standing coral
		H	Crustose corallines
5		A, D	Marine plants
FORMS PRESENT AND DOMINANT			
	disappearance or change in dominant	H	branching
		H	staghorn
		H	massive
		H	encrusting
		H	tabulate/flat
		H	erect foliose
		H	cup-shaped
		E	mushroom
	disappearance	H	massive
		H	fans and whips ...
	appearance change in dominant disappearance	D	thick turf
		D	long filaments
		D	large browns
		D	halimeda
		D	other fleshy
		D	sea grass
COUNTS OF ANIMALS			
	decrease	E	Mushroom coral
	decrease	B	Giant clams
6 or more	increase	G	Synaptids
		H	Other holothurians
4 or more	increase	E	Acanthaster
	increase	H	Other starfish
		H	Urchins
	decrease	B	Trochus
			Other
VISIBLE POLLUTION (specify/count)	increase	I	
PHYSICAL MEASURES			
			temperature
	increase		turbidity
			salinity

Figure 10. Key for evaluating data sheets

may not be significant unless a problem level in Column 1 is reached, but a change that continues in the direction indicated after a third survey can also suggest a problem on the reef.

All the indicators on the key sheet should be reviewed by the expert who first establishes the survey plots, to be sure they are suitable for the particular coral reef area.

The key sheet is arranged so that a quick review of a survey can be made by lining up the left-hand margin of the key with the appropriate column and lines of the data sheet and directly comparing the survey results with the key. Significant values can be circled in colour or otherwise marked.

The letters in Column 3 refer to possible interpretations of a significant result in Column 1 or 2, which are given in the paragraphs below. If a significant result is observed, surveys in the area should be repeated more often, and if necessary a coral reef specialist should be consulted to determine the cause of the problem and to suggest possible remedies.

A. These are often signs that the reef is under stress or has been damaged by some event. The damage could be natural, as in a storm or cyclone, or could be caused by man through pollution from industry, chemicals, human sewage, mining, construction, etc. If the reef changes happen at the same time that new factories, town areas or mines are built, then these may well be the cause. Further surveys should be made every two months, and more survey circles could be established to see how far the damage has spread. The problem should be discussed within the government, and if necessary outside help should be requested.

B. The number of large predatory fish (snappers, groupers, emperors) and of large shellfish like giant clams and trochus is a good measure of the fishing pressure on the reef. If they become rare, there has probably been overfishing. The small reef fish like the butterfly fish show whether the reef can support many larger fish. They may decrease as a result of bad fishing methods like explosives, poisons, small mesh nets or traps, or because of aquarium fish collectors. Control of the kinds of fishing methods or the amount of fishing, either at the village level or by the government, can help to solve these problems.

The number of fish can also decrease because something has damaged the coral and other things that give the fish food and shelter (see A). This is serious and should be studied further through more surveys and by consulting appropriate experts.

C. Mud and sediment can smother coral reefs. Large or increasing amounts of mud are caused by increased amounts of run-off and erosion from land, resulting from bad agricultural practices, construction or mining. Rubble comes from broken, dead coral, so increasing rubble suggests that more coral has been or is being killed, again a sign of reef damage.

D. It is normal for some plants to come and go with the seasons, but pollution from agriculture or sewage can increase the number of plants and change the kinds seen. If the plants are crowding out and killing the corals, there may be a serious pollution problem. Sea grasses are important to the reef, and can be hurt by some kinds of pollution and by disturbing the bottom. An increase in plants may also be caused by over-collecting of shells and other plant-eating animals by villagers or tourists. Some control of such collecting may be necessary.

E. Mushroom corals are among the first things picked up by tourists. Their disappearance is a measure of tourist and visitor pressure on the reef resources.

F. The Crown-of-Thorns starfish, *Acanthaster planci*, eats corals. A few *Acanthaster* on a reef are normal and healthy, but large numbers can seriously damage the corals. Control measures may be necessary in areas important for local fishing or tourism.

G. Synaptid holothurians increase in coral reef areas with bad urban or organic pollution. They may indicate reef damage by pollution, although they may also be naturally common in some places.

H. The disappearance or change in dominance of major kinds of coral and other reef forms may happen naturally over long periods of time, but sudden changes could be caused by man and should be studied in more detail, particularly if other changes are also seen.

I. Some kinds of visible pollution (like bottles, tyres, etc.) can be ecologically harmless, although damaging to the tourist industry. Others can be damaging, or even associated with ciguatera fish poisoning. The presence of visual pollution can indicate that the reef is subject to other kinds of human pressures as well.

5. Limitations and possible modifications

The coral reef survey and monitoring techniques described in this handbook can only suggest that changes are taking place on a reef and that something might be wrong. They cannot give a complete and reliable picture of the state of the reef; reefs are too complex for that. Their intention is to provide an early warning that further studies and possible action are needed. In particular, major management decisions should not be made without confirmation of the survey results by appropriately trained experts, if this is possible.

The results will only be as good as the care taken in making the surveys. Errors can come from not repeating the surveys in exactly the same place, from changing observers between surveys, or from carelessness in writing down or re-copying data. Underwater work is not easy, since attention is divided between the work at hand and such basic things as breathing and personal safety. It is, therefore, important to re-read the whole handbook before starting a survey, so that the procedures and definitions are clear and consistent for each survey.

The survey procedure has been kept as simple as possible so as to require a minimum of time and expertise. It can, of course, be elaborated upon while keeping the standardization that makes it useful for comparative studies. For instance, the reef zones, for which the survey plots serve as indicative samples, can be described more completely during the initial field work, and periodic broad surveys of the zones, using trained observers towed behind a boat, can relate the observations in the circle surveys to the general state of the zones. Transect profiles can also be made perpendicular to the reef to determine the overall reef structure and composition as elaborately as time and expertise permit. The circle surveys can then become reference points along the transect.

It would also be possible to amplify the parameters recorded within individual survey plots. Individual species of butterfly fish may have indicator value and could be separately recorded. The sizes or size ranges could be given for each form of coral, etc. Such modifications should only be made where there is sufficient local expertise to carry them out, and when the extra precision is expected to provide additional sensitivity or information critical to the purpose of the survey.

The collection of information about coral reef resources using the methods described in this handbook will certainly be of interest to science. However, this is only the first step towards the national management of these resources. Those collecting the information must see that it is fed into the planning and decision-making processes of government, leading eventually to active management plans for coral reef areas. Such active management based on continuing knowledge of the status of the resource should make possible sustained reef productivity for the benefit of the country and its people.

CORAL REEF MONITORING DATA SHEET

Locality	Date	Recorder							
Circle number									
Location on reef									
Water depth									
FISH COUNTS (100 metre line)									
Predators									
Butterfly fish									
PERCENT COVER Code: 0% = 0 1-5% = 1 6-30% = 2 31-50% = 3 51-75% = 4 76-100% = 5									
Sediment									
mud									
sand									
rubble									
blocks									
Live hard coral									
Soft corals and sponges									
Dead standing coral									
Crustose corallines									
Marine plants									
FORMS PRESENT AND DOMINANT Size code: fist = 1 forearm = 2 arm span = 3									
	PRES	DOM	SIZE	PRES	DOM	SIZE	PRES	DOM	SIZE
Hard corals	branching								
	staghorn								
	massive								
	encrusting								
	tabulate/flat								
	erect foliose								
	cup-shaped								
mushroom									
Soft coral and sponges	massive								
	fans and whips								
Plants	thick turf								
	long filaments								
	large browns								
	halimeda								
	other fleshy								
sea grass									
COUNTS OF ANIMALS									
Mushroom coral									
Giant clams									
Synaptids									
Other holothurians									
Acanthaster									
Other starfish									
Urchins									
Trochus									
Other (specify)									
VISIBLE POLLUTION (specify/count)									
OTHER NOTES									

Figure 11. Coral reef monitoring data sheet