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Biological monitoring methods for assessing coral reef health and management effectiveness of Marine Protected Areas in Indonesia

Version 1.0

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The authors would like to thank the many monitoring staff from numerous sites within TNC and partner organisations who have field tested various versions of this protocol and improved it through their suggestions.

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Executive Summary

Marine Protected Areas (MPAs) are an effective tool to protect biodiversity and sustainable fisheries on reefs from overfishing and destructive fishing practices. MPAs in Indonesia are usually managed through the development of multiple-use zoning and management plans to protect biodiversity, reef health and populations of key fisheries species. Biological monitoring described in this protocol is designed to determine if MPA zoning plans have been successful in achieving these objectives and to provide a basis for adaptive management. Benthic community strucure (coral, other invertebrate and algal communities) and fish communities are used as a meaure of the health of coral reefs. This document outlines methods for assessing benthic and fish communities on coral reefs which are simple, align with internationally recommended monitoring methods, are scientifically robust and can be undertaken by MPA management staff with some training.

Benthic communities are assessed using Point Intercept Transects where reef life forms are recorded every 0.5 m along 3 x 50 m transects at 10 m depth at each site. Fish communities are assessed using a combination of belt transects and long swims. The number and size of all commerial or target reef fish such as sweetlip, groupers and herbivores (in species or family groups) are recorded on 5 x 50 m transects at 10 m at each site. Large reef associated pelagic fish such as trevally and sharks are counted and measured over at least 400 m at a depth of 3-5 m at the reef crest.

The results of reef health monitoring can be used as a baseline assessment of an area, and if done repeatedly using the same or comparable methods, can provide information on the effectiveness of MPAs to:

- protect the health and biodiversity of benthic communities; and
- maintain or improve the abundance, size and biomass of reef fish especially those species which are targeted by artisanal or commercial fishers.

Modifications and simplifications of the standard protocol are outlined to take into account environmental conditions (e.g. strong currents), resources available and skills of the monitoring team.

1 Introduction

Marine Protected Areas (MPAs) are an effective tool to protect biodiversity and sustainable fisheries on reefs from overfishing and destructive fishing practices. MPAs in Indonesia are usually managed through the development of multiple-use zoning and management plans to protect biodiversity, reef health and populations of key fisheries species. Biological monitoring described in this protocol is designed to determine if MPA zoning plans have been successful in achieving these objectives and to provide a basis for adaptive management. The results of biological monitoring programs also provide information on changes resulting from improved management which can be reported to government agencies, local communities and other stakeholders. Monitoring information can also contribute to regional and world wide databases to assess trends in reef health across geographic regions and over time (Wilkinson 2008)

The Government of Indonesia has committed to the establishment of 10 million ha of MPAs by 2010 and 20 million by 2020. It is important that consistent and scientifically robust monitoring techniques that can be undertaken in remote areas are developed to assess the management effectiveness of MPAs. The monitoring methods described here allow a quantitiative assessment of the effectiveness of zoning plans in MPAs and are designed for situations where there are reasonable budgets, resources and skills to undertake scientific monitoring programs.

Semi-quantitative monitoring using manta towing and community based methods are also readily available and should be used in situations where broad scale surveys are required. These methods can also complement the quantitative methods described in this protocol. For example manta towing can provide a broad scale survey of reefs for assessment of threats such as crown-of-thorns, coral bleaching, coral disease, anchor damage, destructive fishing.

The monitoring methods described here are not suitable for community based monitoring as they are too complex and expensive. Where community based monitoring is required, the reader is referred to other documents (e.g. Uychiaoco *et al.,* 2001).

In addition to the threats of coastal development, destructive and overfishing, climate change represents a serious and increasing threat to the long term future of Indonesia's coral reefs. New monitoring methods are now required to assess not only the current condition of reefs, but their resilience[1] to climate change and other threats. Recently, the IUCN Working Group on Climate Change and Coral Reefs has developed new methods for assessing coral reef resilience (IUCN

[1] Resilience is the ability of an ecosystem to absorb shocks, resist phase shifts and regenerate after natural and human-induced disturbances (Nyström et al 2000). For coral reefs, it is the ability of reefs to absorb recurrent disturbances, and rebuild coral dominated systems rather than shifting to algal dominated systems (Marshall and Schuttenberg 2006, Hughes et al 2007).

2009, Green and Bellwood, in press). The methods described in this protocol align closely with these resilience assessment methods and therefore can be easily modified to incorporate these measures of resilience in the future.

1.1 Overview

The health of coral reefs is measured through an assessment of the structure of benthic (coral, other invertebrate and algal communities) and fish communities. The results of reef health monitoring can be used as a baseline assessment of an area, and if done repeatedly using the same or comparable methods, can provide information on the effectiveness of MPAs to:

- protect the health and biodiversity of benthic communities; and
- maintain or improve the abundance, size and biomass of reef fish especially those species which are targeted by artisanal or commercial fishers.

This document outlines methods for assessing benthic and fish communities on coral reefs which are simple, align with internationally recommended monitoring methods, are scientifically robust and can be undertaken by MPA management staff with some training (English *et al.* 1997, Hill and Wilkinson 2004). The monitoring program is designed so there is one basic monitoring module that should be conducted as a minimum at each MPA site to assess the effectiveness of the MPA and provide a basis for adaptive management. However, additional monitoring activities can be added to this basic monitoring module depending on the objectives of the MPA, the amount of funding, time and resources available and the taxonomic skills of the monitoring team.

The methods described here are consistent with currently recommended monitoring methods in the international scientific literature (English et al 1997, Hill and Wilkinson 2004). They are intended to be used as long term monitoring methods to be used by MPA staff/ NGO staff with some level of scientific/MPA management training, SCUBA certification, and the skills to accurately record life forms of benthic organisms, identify key fisheries species and herbivorous reef fish families.

1.2 Using and adapting these protocols

The monitoring protocol outlined below is recommended as a standard basic coral reef monitoring protocol to assess the effectiveness of a zoning plan in a MPA.

It is important to recognise that there may be specific conditions at each MPA site which may justify a slight modification or adaptation of these methods to allow scientifically valid data to be collected within the constraints of resources, environmental conditions, etc. For example, modifications may be required for sites with strong currents or where coral reefs are limited to shallow depths. In addition, at some MPAs there may be additional capacity and resources to allow additional monitoring at more sites or additional reef types. Where possible, modifications of the standard monitoring protocol are provided in this document to allow for a range of conditions. Issues to be considered in the implementation of this protocol include:

- Objectives of monitoring,
- Key threats and vulnerable species (i.e. fisheries species, rare and vulnerable species),
- Species common to the site,
- Resources, time and number staff available to undertake the monitoring,
- Skill and capacity of staff, and
- Budget available.

The final sampling design should be checked by an expert before proceeding to ensure it will achieve the objectives of the sampling.

1.3 Identifying objectives for monitoring

One of the most important steps in developing any monitoring program is to clearly articulate the objectives of the monitoring program. The objective should clearly define how monitoring data will be used.

The following monitoring protocol has been developed for the following objective:

1) To provide a quantitative assessment of the effectiveness of zoning plans in Marine Protected Areas in protecting health and biodiversity of benthic communities and key fisheries species on coral reefs

This protocol is based on two methods: belt transects and long swims for coral reef fishes, and point intercept transects for benthic communities.

2 Sampling design

2.1 Protected vs use zones

To determine the effectiveness of MPA zoning plans, multiple sites should be selected in different types of management zones. In Indonesia, there is a range of different types of zones in MPAs. The sampling design described below focuses on measuring differences between protected (no go and /or no take) and use zones (all other zones which allow fishing e.g. traditional use, general use).

2.2 Reef type

In order to detect differences between protected and use zones, it is important to compare sites with similar characteristics, particularly exposure and reef slope (i.e. similar coral reef types). This is because reefs with different exposure and slope will have different types of coral and fish communities. Therefore it is important to measure the difference between protected and use zones, not just the natural differences between different reef types (e.g. exposed versus sheltered reefs).

Therefore, where possible, monitoring should be standardized on one or two main reef types. Outer reef slopes on exposed linear reef fronts (e.g. not channels, reef passes or sheltered reef areas) is usually a good habitat to sample. This habitat is consistently available in most reef areas, and it is where the highest diversity and abundance of key fisheries species and other reef fishes can be found. However, other common habitat types can be considered if outer reef slopes are not common within the MPA or are difficult to sample due to weather or strong currents.

At many MPAs, reef types have been identified during Rapid Ecological Assessments and can be used to help guide the sampling design. Field teams should discuss sampling design with a coral reef scientist before finalizing their sampling plan.

In Indonesia, it is common to have more than one main habitat type within an MPA (e.g. outer reef slopes and inner reef slopes or inshore turbid reefs and offshore clear water reefs). Therefore, options for sampling designs for sampling one or two reef types are provided below.

2.3 Sampling design

2.3.1 Heirachical sampling design for one reef type – all zones

Chose the most common reef type within your MPA which is suitable for sampling i.e. suitable field conditions, not a vertical wall. Within each type of MPA zone (e.g. no take, traditional use, general use) choose 2-3 areas of each type of zone and at least 3 replicate sites within each of these areas (Figure 1, 4). Using this design (e.g. 3 zones x 3 areas x 3 replicates) requires at least 27 sites per habitat type to be sampled.

If there are no differences among sites within an area of a particular management zone (e.g. close to or far from a village), this sampling design can provide a strong basis for statistical analysis and we can be more confident in the conclusions about differences between different MPA zones. This is because a minimum of 3 replicates is required to take account of natural variation between sites so that differences between MPA zones can be seen more clearly.

2.3.2 Heirachical sampling design for two reef types – all zones

If it is important to monitor a second habitat type in your MPA and it is also represented in all zone types, repeat the above sampling design for the second habitat type (Figure 2).

2.3.3 Sampling design for two reef types – comparing no take vs use zones

The following sampling design allows for assessment of differences between protected and use zones for two common habitat types in a MPA. Protected zones may include no go and no take zones while use zones may include traditional use or general use zones which allow for fishing activities. This design is slightly different to the heirachical design above but is still statistically robust.

- Choose two most common reef types within the MPA which are possible to sample (considering weather conditions, currents, etc.) and are represented in both protected and use zones.
- In reef type A, choose at least 8-10 replicate sites within no take zones and 8-10 replicate sites within areas outside no take zones (Figures 3, 5).
- In reef type B, choose at least 8-10 replicate sites within no take zones and 8-10 replicate sites within areas outside no take zones (Figures 3, 5).
- This design maximizes the number of replicate sites within the resources that are usually available for a monitoring program of this type. This design will result in a total of 32-40 sites. If one site is done per day, field teams will need to allocate a total of 32-40 working days for sampling plus additional time to allow for gear breakage/bad weather as appropriate for each site.
- Individual sampling plans should be developed for each MPA that takes into account the unique reef types and environmental conditions, and the human and financial resources available at each site.

2.4 Site selection

Monitoring should be undertaken at multiple sites within a MPA and spread widely to ensure a good geographic cover of the study area. After the habitat type has been chosen, sites within that habitat type should be selected after a general survey of the area. This can be done by snorkeling or manta tows to ensure that they are representative of that reef type and zone (English *et al.* 1997), and there is adequate space to conduct the monitoring program. Fish and benthic surveys will be done at the same sites. Fish surveys need the largest area - at least 700 m of similar habitat is needed – 300 m for belt transects and 400 m for timed swims. Where possible, sites should be separated from each other by a reasonable distance (at least several hundred meters, preferably 500 m). Try to choose sites which are similar to each other e.g. in the middle of the no take zone, or similar distances from villages/other activities where possible i.e. avoid the edge of no take zones where fishing may occur (Figure 4)

2.5 Sampling frequency

This protocol is designed to be implemented once every one to three years. Ideally, surveys should be done every year for three years prior to implementation of the zoning plan. This is so differences in the reef communities can be measured before and after the zoning plan is implemented. As fish size and abundance can vary seasonally, it is recommended that sampling take place in the same month/season each time the sampling is repeated.

2.6 Modifying the protocol if required

If the MPA zoning plan has not yet been gazetted:

In situations where a zoning plan has not yet been gazetted/implemented, site selection should be at the discretion of the team but should be based on the above sampling design. Try to select sites throughout the MPA from one or two main habitat types and select areas which are likely to be included as no take areas. Ideally, these sites should be monitored every year for three years prior to zoning plan implementation.

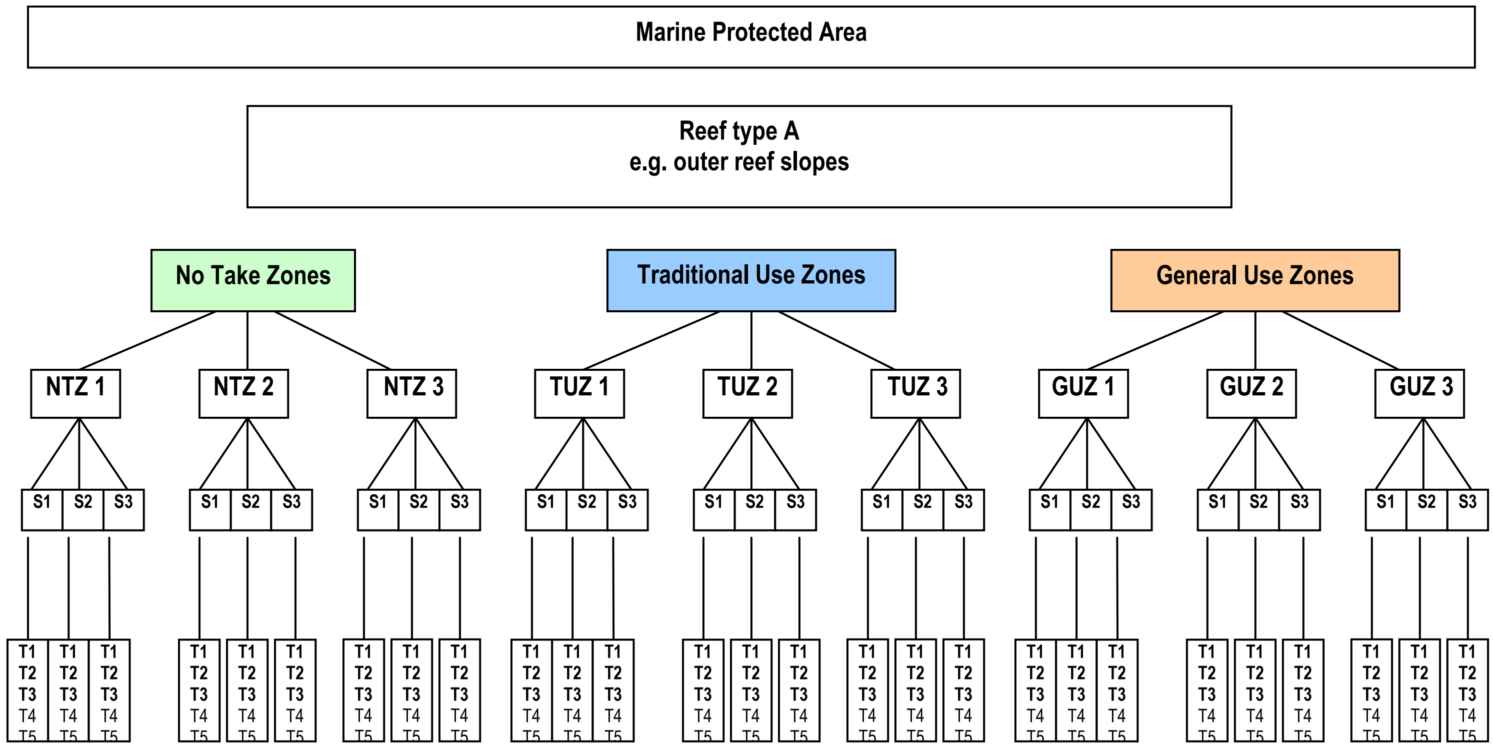

Figure 1: Example heirachical sampling design for quantitative assessment of benthic and fish communities on one reef type in Marine Protected Areas. S = Site, T = Transect. Please note that three transects are used for benthic communities and five transects plus a long swim are used for fish communities.

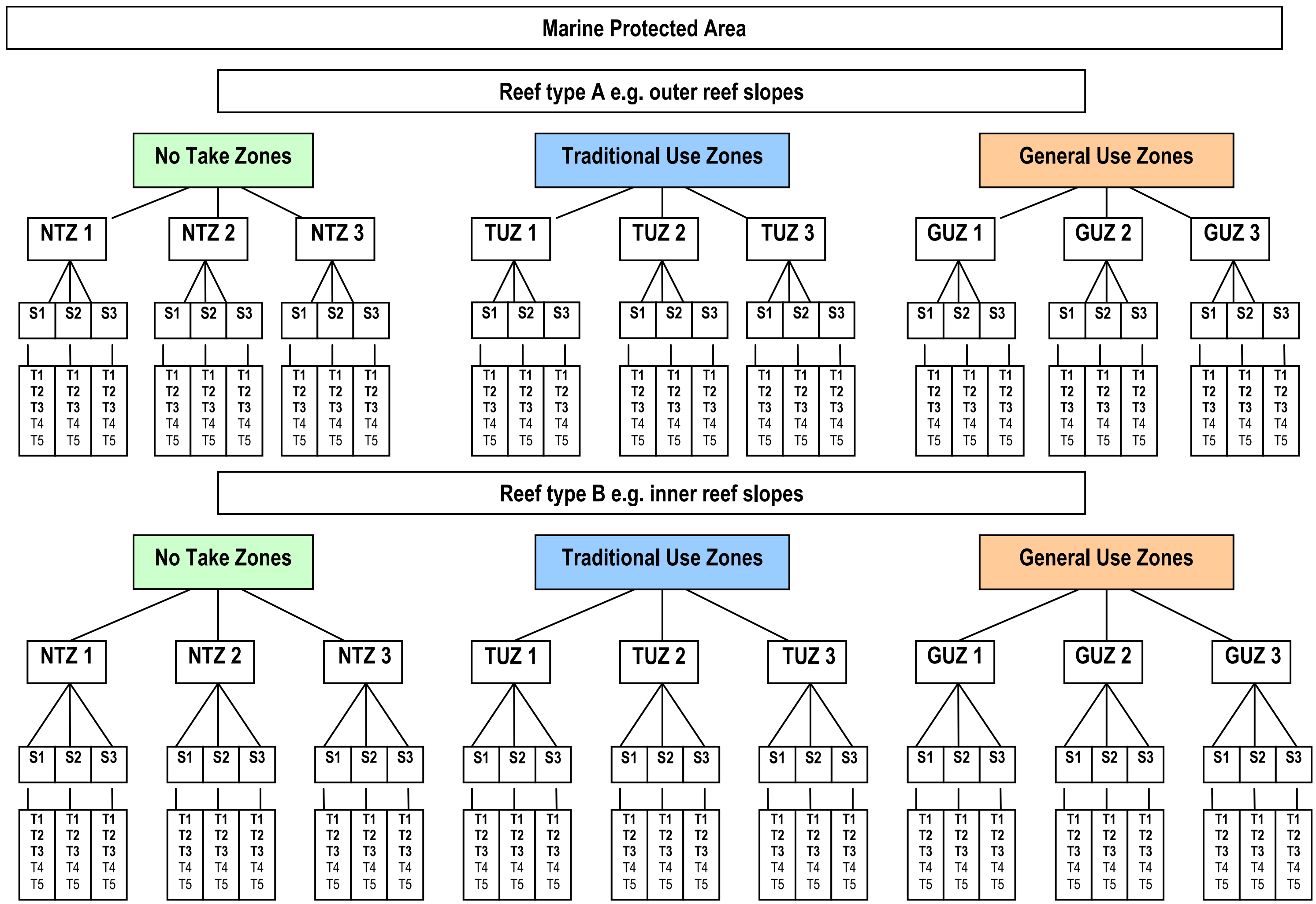

Figure 2: Example heirachical sampling design for quantitative assessment of benthic and fish communities on two reef types in Marine Protected Areas. Abbreviations as for Figure 1.

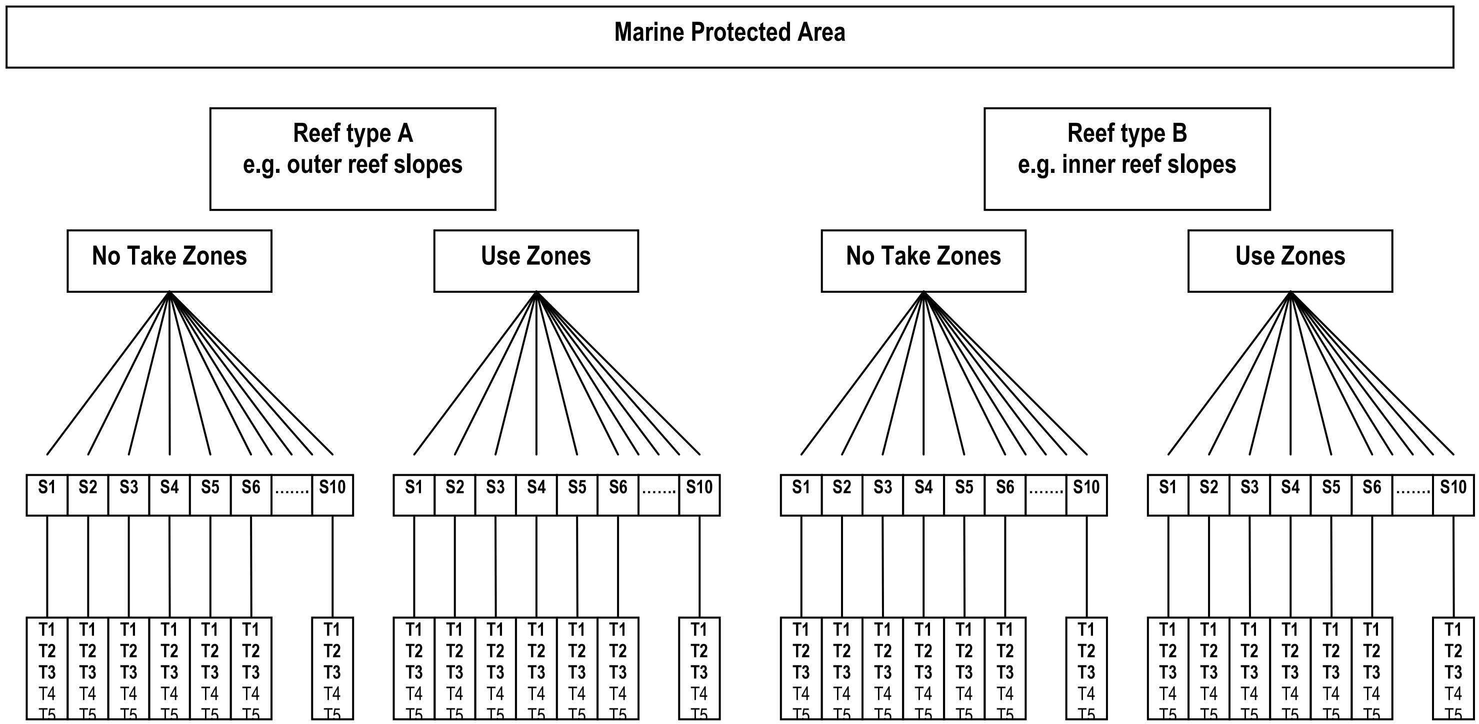

Figure 3: Example sampling design for quantitative assessment of benthic and fish communities on two reef types in a Marine Protected Area. S = Site, T = Transect. Please note that three transects are used for benthic communities and five transects plus a long swim are used for fish communities.

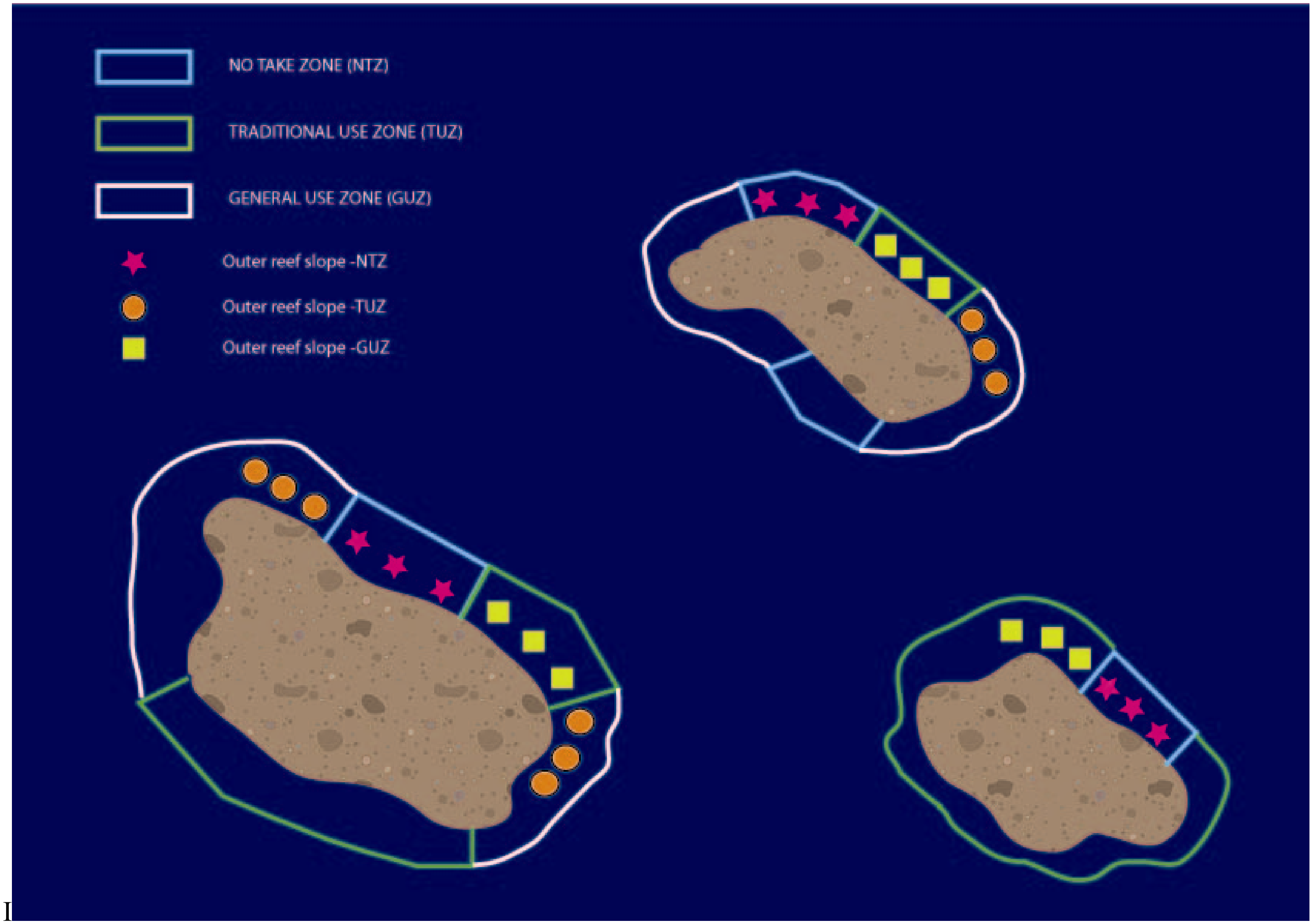

Figure 4: Example of possible arrangement of sampling design for one habitat type and three zone types (no take, traditional use and general use) in a coral reef MPA.

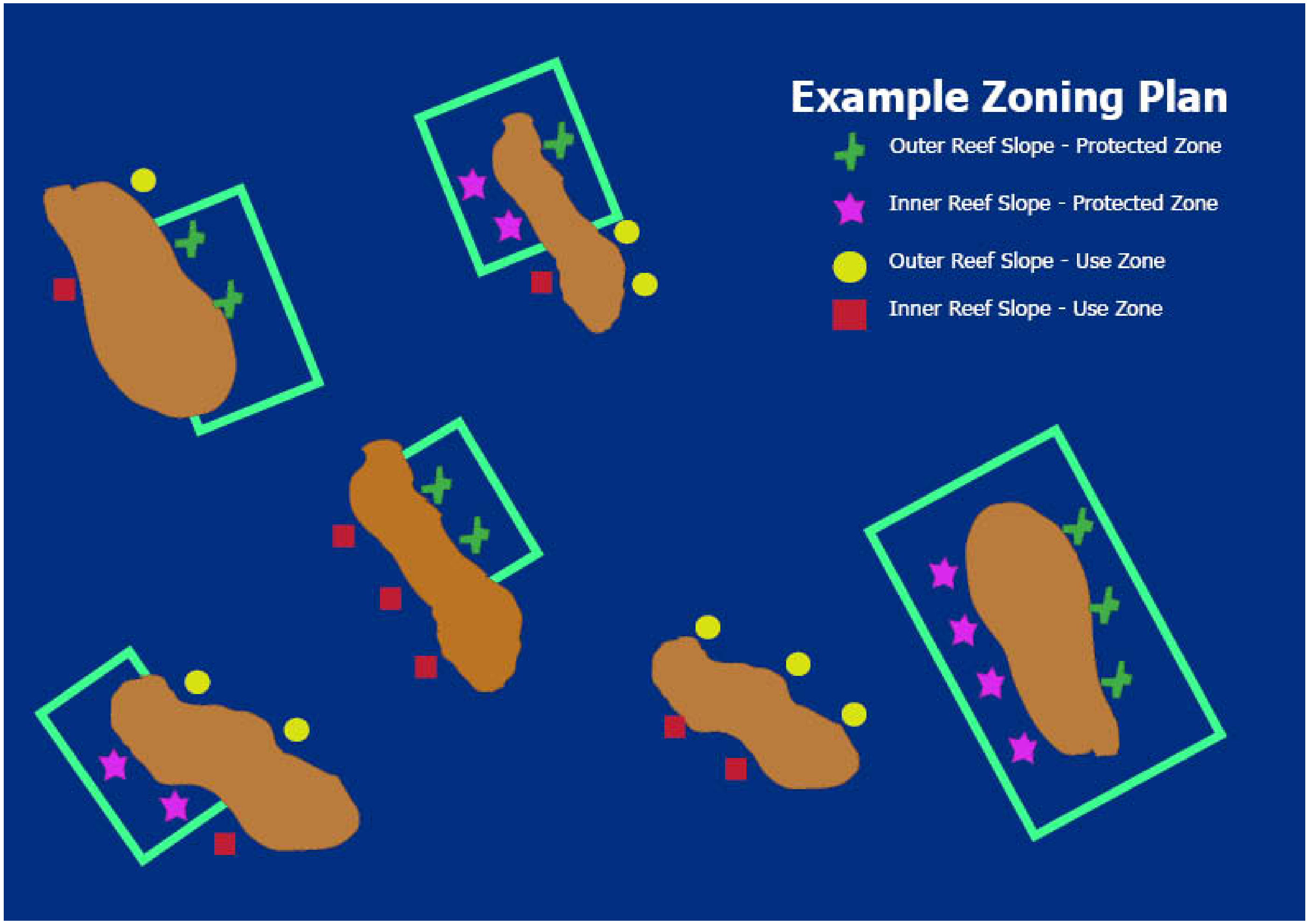

Figure 5: Example of possible arrangement of sampling design for two habitat types and two zone types (protected and use) in a coral reef MPA.

3 Field survey method

3.1 Fish communities

3.1.1 Background

Underwater visual census methods are the most effective method for monitoring coral reef fishes, particularly in remote locations (Choat and Pears 2003). Coral reef fish populations (focusing on key fisheries species) will be surveyed using underwater visual census methods described by English *et al.* (1997), Wilkinson *et al.* (2003), Choat and Pears (2003), Hill and Wilkinson (2004), Sweatman *et al.* (2005) and Green and Bellwood, in press.

Belt transects will be used as they provide a high degree of precision, and are suitable for monitoring for multiple objectives (fisheries and resilience) and because they allow for multiple passes of the transect to count different species (Green and Bellwood, in press). This method provides the most effective technique for monitoring most coral reef fishes that are amenable to visual census techniques. However, if possible, transects should be combined with a long swim method, which provides more precise estimates of the abundance and biomass of large, highly mobile species, that tend to be rare, patchy or clumped in distribution (particularly sharks, large groupers, wrasses and parrotfish) (Choat and Pears 2003).

3.1.2 Species list

A suggested list of key fisheries species and three herbivore fish families for coral reefs in eastern Indonesia is included in Appendix 1. However, a list of key fisheries / target species to should be developed for each MPA site. Species should include:

- species targeted by local artisanal/commercial fishers,
- species that observers can identify accurately,
- species that are suitable to counting by underwater visual census i.e. not cryptic species
- coral reef species common to the site and the reef type being surveyed (not highly mobile pelagic species such as tuna and mackerel)

In the case where field teams have excellent fish ID skills, herbivore species and or functional groups should be included in the fish list as per Green and Bellwood, in press as herbivores play a critical role in reef health and resilience .

Species for long swims are a subset of those recorded on the transects and are listed in Appendix 2. If only one observer is available, they should focus on :

- all sharks (all species)
- manta rays (*Manta* sp.) and eagle rays (*Aetobatus narinari)*

- napoleon wrasse (*Cheilinus undulatus*)
- four large species of parrotfishes listed in (*Bolbometapon muricatum, Cetoscarus bicolor, Chlorurus frontalis* and *Chlorurus microrhinus*).
- groupers, and
- all trevally species.

If a second observer is available they should focus on counting and estimating lengths of large snappers and lethrinids, particularly schooling species such as *Lujanus bohar* and *Macolor niger* that can be abundant.

3.1.3 Estimating lengths of fish

Estimating the length of each individual fish seen on transects or long swims as accurately as possible is an important component of this protocol. These data are needed to estimate the biomass of that family or species of fish. It is important that all fish observers are provided with adequate training so they can estimate the lengths of fish accurately while swimming underwater.

The level of accuracy of all fish observers should be recorded at the start of the monitoring so the degree of error of their estimates is known. Ideally, fish observers should be able to estimate the lengths of fish to within 5 cm accuracy and should aim to achieve that level of accuracy through training and practice. However it is likely that some fish observers who participate in monitoring assessments will able to estimate the lengths of fish to within 10 cm accuracy.

Fish size classes are divided into small to medium fish (10 - 35 cm) and large fish (>35 cm).

The following guidelines should be followed when deciding how to record the lengths of fish.

A. Ideally all fish observers should be trained to measure fish within 5 cm accuracy for a range of different size fish bigger than 10 cm. Fish lengths should be recorded in 5 cm intervals i.e. 10-15 cm (midpoint 12.5 cm),15-20 cm (mid point 17.5 cm) etc
B. If fish observers have not achieved 5 cm accuracy, they should record their estimate of the fish size and also record their level of accuracy underwater i.e 13, 24, 31 cm (accuracy within 10 cm)
C. The least accurate option is to record fish in 10 cm intervals i.e 10-20 cm (midpoint 15 cm), 20-30 cm (midpoint 25cm), 30-40 cm (midpoint 35cm). In this case small to medium fish are defined as those between 10-30 cm and large >30 cm.

3.1.4 Belt transects

Standard:

Reef fishes will be surveyed using 5 x 50m transects at each site. Each survey will consist of two observers swimming along the reef parallel to the reef crest at a constant depth of 10 m counting individual fish and estimating the size of the target fish species listed in Appendix 1. The most accurate biomass estimates will be (total length, TL, in cm see Section 3.1.3).

Each observer will census the same fish species using different transect widths for different size groups as follows:

- Observer #1 will swim 1-2 m above the substratum at maximum depth of 10 m, counting and estimating the size of small to medium sized individuals (10 - 35 cm TL) of the target species (Appendix 1) using a transect width of 5 m (2.5 m either side of the observer). Care should be taken to accurately estimate the width of the transect and fish found outside this range should not be counted. If a fish is on the edge of the survey area count it if more than half its body or its eyes are inside the area. Since this observer has to count the most individuals, he/she should be the most experienced fish observer.
- Observer #2 will swim slightly behind and above Observer #1 to provide a better view of the larger area and to minimize disturbance to small fishes by the passage of the divers. They will swim 3 m above the substratum, counting and estimating the size of all large individuals (≥35 cm TL) of the species listed in Appendix 1 using a wider transect width of 20 m (10 m either side of the observer). Care should be taken to accurately estimate the width of the transect and fish found outside this range should not be counted.
- If an assistant is available, they will follow immediately behind the observers rolling out the tape, attaching it to the bottom every few meters, and letting the observers know when each transect has started and ended. Transects should be laid consecutively along a depth contour of 10 m parallel to the reef crest. The start of each transect should be separated by at least 5 m from the end of the previous transect. Tapes will be deployed at a maximum depth of 10 m on the substratum to maximize dive time and minimise risk of decompression sickness. (Three of the five transects will be used for assessing benthic community (see 3.2 Benthic communities below).

Each observer will:

- Count all individuals of species from their list and size group within the area of the transects from the reef substratum to the surface of the water, and estimate the size of all fish counted.
- For fish in 10-35 cm size range – each fish will be assigned to size categories. Ideally 5 cm size categories should be used (i.e. 10 - 15, 15 –

20 cm etc). However, if training is limited then 10 cm size intervals can be used.

- Fish larger than 35 cm – the total length of each fish will be measured to the nearest cm.
- All data will be recorded directly onto pre-prepared datasheets printed on underwater paper (Appendix 3) which can be modified to suit the team and local conditions.

In order to calculate fish density and biomass (see *Data Analysis*), transect area must be calculated for each observer. The area of each transect surveyed by Observer #1 is 250 m^2 (50 m x 5 m), while the area of each transect surveyed by Observer #2 is 1000 m^2 (50 m x 20 m).

3.1.5 Long swim

Standard:

Once the two fish observers have reached the end of the end of the 5 x 50 m transect tapes at 10 m, they will continue on in the same direction conducting a long swim to survey large and vulnerable reef fish in Appendix 2 as described by Choat and Spears (2003).

The long swim method consists of a 20 minute timed swim at a standardized swimming speed (about 20 m per minute) swimming parallel to the reef crest at a depth of approximately 3-5 m on the reef front (just below the reef crest, so it is possible to simultaneously monitor the reef crest, flat and slope where most of the larger species tend to occur). All large individuals ($\geq$35 cm TL) of large and vulnerable reef fishes listed in Appendix 2 should be counted and their size estimated along a 20 m wide area of reef slope (10 m either side of the observer). Optimal transect dimensions are 400 m x 20 m. Using this method it is **very important** that the distance travelled is recorded accurately and is at least 400 m long. This can be done in 2 ways – by either permanently marking the area that should be covered by a long swim or accurately recording the GPS positions of the entry and exit points of the swim or marking with floats. Alternatively, a GPS can be attached to a floating buoy that is towed by the divers, which can more accurately record their track. The buoy will also help boat drivers keep track of the divers on long swims. If possible, a surface buoy should be used for all long swims for safety reasons.

This method is most appropriate for counting large and vulnerable species that are conspicuous in behavior (Choat and Spears 2003), because they tend to swim above the bottom: sharks, rays, napoleon wrasse, large parrotfish, some groupers (particularly *Plectropomus*, *Gracilia* and *Variola* species) and giant trevally.

All data will be recorded onto pre-prepared datasheets printed on underwater paper (Appendix 4).

3.1.6 It is difficult to lay five transects at my sites due to strong currents

If the team find it impossible after reasonable effort and training to layout and collect 5 transect tapes due to strong currents or other reasons, fish surveys on transects can be done on a minimum of 3 x 50 m transects (same transects as used for coral surveys). However, the accuracy of the counts will be less due to the extremely high natural variability of fish number on coral reefs and it will be more difficult to detect differences between protected and use zones and differences over time.

3.1.7 All my sites have very strong currents and I can't deploy any transects?

If the field teams cannot use transects at all due to **extreme** environmental conditions, fish biomass can be estimated using the long swim method only. This method was specifically designed for rapidly assessing reef fish populations (Green and Bellwood, in press), and is the best method for assessing populations of large reef fishes,while the transect method if best for small to medium sized fishes. In this case the long swim should be done over 20 mins making sure to cover a distance of 400 m in each long swim. One observer counts and measures all fish in Appendix 1 from 10 TO <35 cm length to a distance of 2.5 m either side of them (total 5 m wide) and the second observer counts and measures all fish in Appendix 2 >35CM length to a distance of 10 m either site of the observer (total 20 m wide). Again, this is not ideal as most accurate fish counts for small to medium sized reef fishes are made using transects and it will be more difficult to demonstrate the effectiveness of the MPA zoning system if less accurate methods are used. Therefore this method should only be used where it is impossible to use transects due to currents or other condiditions.

3.2 Benthic communities: Point Intercept Transects:

3.2.1 Background

A Point-Intercept Transect (PIT) method will be used to measure cover of sessile benthic invertebrates, algae and substrate type (hard and soft coral, sponge, macroalgae), because it is fast, efficient and provides good estimates of cover of benthic communities provided sufficient survey points are used (Hill and Wilkinson 2004). This method has been used extensively in the Pacific Islands, including Samoa and the Solomon Islands (Green 1996, 2002, Hughes 2006, Hamilton *et al.* 2007).

3.2.2 Method

Standard reef slopes:

The observers will swim along the first 3 x 50 m transects deployed by the reef fish team (see above) and record the life form category immediately below the tape at 0.5 m intervals along the transect starting at 0.5 m and finishing at 50 m (100 points per tape = total 300 points). If the tape is not lying on or directly over the reef, points should be haphazardly selected on the reef slope at the same depth and immediately adjacent to the tape on the reef slope (by closing your eyes and using a ruler to select the point).

Life forms are detailed in Appendix 4 and are sourced from English *et al.* (1997). If local monitoring teams can identify coral genera accurately then genera should be recorded as well as life form. It is important to record both types of information as some genera e.g. *Porites, Acorpora* can take more than one life form.

Data will be recorded directly onto pre-prepared datasheets printed on underwater paper Appendix 5.

Once the survey has been completed at 10 m, the benthic community team will pick up all the survey tapes (a total of 5 tapes).

Sampling additional habitats: (reef crest/shallow reef slope):

If time and resources allow the divers should move up the slope to a depth of 4 m and repeat the survey methods on three 50 m transects there. This is because coral communities at 4 and 10 m are usually quite different and respond differently to threats such as bleaching and crown of thorns.

If your reef is very patchy:

If your reef is highly variable/patchy, increase the number of transects to 4 or 5 instead of 3.

If your site has very strong currents:

If it is extremely difficult to lay out transect tapes at sites due to extreme currents or other conditions, it would be possible to permanently mark the position of the transects on the first field visit and use a string with knots every 0.5 m to do the transects each time.

3.3 Logistics and training

3.3.1 Preparing the team

Methods used, and species counted, will depend on how many team members are available for the survey and their skills in fish and coral/lifeform identification. The following monitoring methods in this protocol (belt transect/long swim followed by Point Intercept Transects) have been designed for teams of four to five experienced divers – two fish observers and two coral observers. However, in the field it may not always be possible to put together a team of four experienced monitoring staff. The following options outline how this method could be done by teams of two divers. There are several options:

Option 1

Observers 1 and 2 will enter the water and swim down to a depth of 10 m, mark the start of the transect with a surface buoy, wait 5 minutes and swim along the 10 m contour with observer 1 recording number and size of fish 10-35 cm. Observer 2 will record fish >35 cm and laying out the transect tapes. On the second dive, one observer will record the benthic categories according to PIT method and the second observer will pick up the transect tapes.

Option 2

Observers 1 and 2 will enter the water and swim down to a depth of 10 m, mark the start of the transect with a surface buoy, wait 5 minutes and swim along the 10 m contour with observer 1 recording number and size of fish >35 cm. Observer 2 will swim behind laying out the transect tapes.

After 5 x 50 m transects have been completed, the observers leave the tapes and move up the slope to 5 m and complete the long swim recording long swim species >35 cm as per the long swim method above.

At the end of the dive, the observers are picked up by the boat and move back to the beginning of the transects which have been marked with a surface buoy.

On the second dive, observer 1 records number and size of all transect fish species 10 – 35 cm then return together back along the transect to complete the benthic community assessment using PIT method / collect tapes together. An additional dive at the site may be required to complete all tasks.

Option 3

Observer 1 will enter the water and swim down to a depth of 10 m, mark the start of the transect with a surface buoy, wait 5 minutes and swim along the 10 m contour recording number and size of fish >35 cm and laying out the tape. Observer 2 will follow doing counts of the same fish species in the 10-35 cm size group. At the end of the transects both divers complete the long swim method.

On the second dive, observer 1 records benthic life forms using PIT method and observer 2 picks up the tapes.

Note: if two observers, the most experienced observer should do the medium sized fish because there are more species and individuals. Most people can be easily trained to do big fish because there aren't many species to learn and they are large and conspicuous in behavior.

3.3.2 Collecting site and data information:

Once the number and location of sites have been decided by the team, the name and GPS location of each site should be recorded upon arrival at the site. Other information which should be recorded include date, time, name of divers, boat crew, environmental conditions, strength and direction of currents and whether the reef surveys was on the left or righ of observers so its clear which section of the reef was sampled.

3.3.3 Minimising disturbance

Whatever methods are used, it is important to minimise disturbance to the fish populations at each site by not driving the boat over the census area, and by the fish observers being the first people to swim through the survey area, by swimming very quietly while surveying, and by waiting for at least 5 mins after getting in the water before starting the survey (Green and Bellwood, in press). Tapes should not be run out ahead of the observers on their first pass of the site, since many fish species are disturbed by the passage of a diver.

For belt transects, transect tapes should be laid during the first pass by an assistant following the observer. The tapes should then remain *in situ* until all the surveys are completed at that site, and will be picked up by the benthic community team when they have completed their survey. Fish counts (i.e. each pass of the transect) should be separated by a waiting period of ~5-10 minutes between counts If it is necessary to swim over ths same transect more than once

3.3.4 Training

Before this method is used by field teams it is very important that all observers receive training so they are competent in:

- Fish identification for the fish list chosen for the site,
- Identifying benthic life form categories,
- Underwater size estimation of reef fish species[2], and
- Recording GPS coordinates and calculating the distance travelled between GPS points.

[2] This is particularly important as inaccurate estimation of fish lengths is one of the largest sources of potential error in the method.

4 Data processing and analysis –

4.1 Fish abundance and biomass

The two fish observers will be responsible for analyzing their data and writing the report. All results will be entered into an excel spreadsheet[3] the same day as the survey (if possible) by the observer. If this is not possible, the observer should go through the data sheets the same day as the survey and ensure that the results are clear (species, abundance and size) so they can be entered reliably later. Once data is entered in the excel spreadsheet it should be checked for errors prior to proceeding with data analysis.

Counts and size estimates of reef fishes will be converted to mean (± standard error) density and biomass for each site for:

- Each species individually for large and vulnerable reef fishes (particularly sharks, *Cheilinus undulatus* and *Bolbometapon muricatum*).
- All key fisheries species combined
- Each family of key fisheries species
- Each functional group of herbivores (see Green and Bellwood, in press).

It is important to note that if large individuals of large vulnerable reef fishes (≥40cm TL) are counted using both transect and long swim methods, the results from the long swims should be used for the data analysis (instead of the transect counts). This is because the long swim method provides the most accurate estimates of the abundance of large individuals of these species (Choat and Spears 2003).

However, if long swims are not done, counts of large individuals from the transects can be used although they are not as accurate.

For each site, the number of individuals per sampling unit (transect or long swim) will be converted to a mean density (per hectare, or ha[4]) using the formulae: density per ha = (number of individuals per sampling unit ÷ area of the sampling unit in m^2) x 10,000.

For each site, size estimates will be converted to biomass estimates using known length-weight relationships for each species using the formulae $W = aL^b$ as described in Kulbicki et al (2005). Where: W = weight of the fish in grams (g); L = fork length (FL) of the fish in cms; and a and b are constants calculated for each species or genus. Biomass parameters (a and b) for each species are provided in Appendix 6. Mean biomass can then be calculated for each method using the formulae: biomass per ha = (biomass per sampling unit ÷ area of the sampling unit in m^2) x 10,000.

Please note that underwater visual estimates of size are generally based on total length (TL), which is easier to estimate than fork length (FL) for many species.

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[3] Example spreadsheets are available from The Nature Conservancy: info@coraltrianglecenter.org
[4] One hectare is equal to 10,000m^2.

However, length-weight relationships for biomass are generally based on FL. For species with rounded or square tails, FL and TL are the same. However for species with forked tails, TL should be converted to FL to use for biomass estimates. Where detailed conversion ratios are not available for local species, a good estimation is that FL is approximately 90% of TL for most species with forked tails (Kulbicki *pers. comm*.). Also, since size categories are used, fish lengths used for biomass estimates should be the mid value for each size category (e.g. use 12.5 cms for size category 10 - 15 cms). While there may be an error associated with this approach, it is generally considered less than the error associated with underwater size estimation, which is the greatest source of error in this method. Since underwater size estimation is highly dependant on diver training, observers should ensure that they are well trained prior to each census period.

4.2 Benthic communities

All results will be entered into an excel spreadsheet the same day as the survey (if possible) by the observer (see footnote 3). If this is not possible, the observer should go through the data sheets the same day as the survey and ensure that the results are clear so they can be entered reliably later. Once data is entered in the excel spreadsheet it should be checked for errors prior to proceeding with data analysis.

Cover of each life form category (or genus), as well as for all corals combined, all macroalgae combined and other benthic invertebrates combined, will be calculated by converting the number of points recorded to a percentage for each life form category on each transect. Where percent cover of each category = (number of points in that category ÷ total number of points on the transect) x 100.

Community structure (diversity of biotic life forms) will be calculated using the Shannon Wiener Index (H). Where $H = - \sum p(i) \ln p(i)$; and $\sum$ represents the sum for all categories, $p(i)$ is the proportion of the total assemblage in the *ith* category and *ln* is the symbol for natural logarithms.

Total percentage coral cover and dominant benthic life forms should be summarised in graphs which can be made in Excel.

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Appendix 1: Fish List for Belt Transects

FAMILY	Species	Common Name
Scaridae	All Scaridae	Parrot fish
	Bolbometopon muricatum	Bumphead parrotfish
Acanthuridae	All Acanthuridae	Surgeon fish
	Naso lituratus	Orangspine unicorn fish
	Acanthurus mata	Yellowmask surgeon fish
Siganidae	All Siganidae	Rabbit fish
	Siganus doliatus	barred rabbitfish
	Siganus guttatus	golden rabbitfish
	Siganus lineatus	lined rabbitfish
	Siganus corallinus	coral rabbitfish
Haemulidae	All Haemulidae	Sweetlip
	Plectorhinchus chaetodonoides	many-spotted sweetlips
	Plectorhinchus lessonii	striped sweetlips
	Plectorhinchus lineatus	diagonal-banded sweetlips
	Plectorhinchus picus	dotted sweetlips
Lutjanidae	All Lutjanidae	Snapper
	Aprion virescen	Green jobfish
	Lutjanus bohar	red bass
	Macolor macularis	midnight snapper
	Lutjanus rivulatus	Maori seaperch
Lethrinidae	All Lethrinidae	Emperors
	Lethrinus olivaceus	Long face emperor
Serranidae	All Serranidae	Groupers
	Cephalopholis argus	peacock grouper
	Cephalopholis miniata	coral grouper
	Cephalopholis urodeta	flagtail grouper
	Ephinephelus polyphekadion	camouflage grouper
	Epinephelus fuscoguttatus	flowery cod
	Epinephelus lanceolatus	Queensland grouper
	Plectropomus areolatus	polkadot cod
	Plectropomus laevis	Chinese footballer
	Plectropomus leopardus	coral trout
	Plectropomus oligacanthus	highfin coral trout
	Variola albimarginata	white-margined trout
	Variola louti	coronation trout
Wrasses	Cheilinus undulatus	Napoleon wrasse
Carangidae	All Carangidae	Trevally
	Caranx melampygus	bluefin trevally
	Caranx ignobilis	giant trevally
	Elagatis bipinnulatus	rainbow runner
	Gnathanodon speciosus	golden trevally
Scrombidae	All Scrombidae	Mackeral
	Gymnosarda unicolor	Dogtooth tuna
	Scomberomorus commerson	Spanish Mackeral
Carcharinidae	ALL SHARKS	Sharks
	Carcharhinus amblyrhynchos	grey reef shark
	Carcharhinus melanopterus	blacktip reef shark
	Triaenodon obesus	whitetip reef shark
Dasyatidae, Mobulidae, Myliobatidae	ALL RAYS	

Appendix 2: Fish list for long swims

Family	Species	common name
Snapper (Lutjanidae)	Aprion virescen	Green jobfish
	Lutjanus bohar	red bass
	Lutjanus gibbus	Humpback snapper
	Macolor macularis	midnight snapper
	Macolor niger	black and white snapper
	Other snapper	
Emperors (Lethrinidae)	Lethrinus olivaceus	longface emperor
	Other lethrinids	
Labridae	Chelinus undulatus	Napoleon wrasse
Scaridae	Bulbometapon muricatum	Bumphead parrotfish
	Cetosc arus bicolor	Bicolor parrrotfish
	Chlorurus frontalis?	Tan faced parrotfish
	C microrhinus	Steephead parrotfish
	Other scaridae	
Groupers (Serranidae)	Ephinephelus polyphekadion	camouflage grouper
	Epinephelus fuscoguttatus	flowery cod
	Pleactropomus aerolatus	Squaretail grouper
	Plectropomus sp	
	Variola albimarginata	white-margined trout
	Variola louti	coronation trout
Carangidae	C ignobilis	Giant trevally
	Other trevally	
Scombridae	Gymnosarda unicolor	Dogtooth tuna
	Scomberomorus commerson	Spanish Mackeral
	Other mackerals	
Sphyraenidae	Sphyraena barracuda	Great barracuda
	Other barracudas?	
Carcharhinidae	Carcharhinus amblyrhynchos	grey reef shark
	Carcharhinus melanopterus	blacktip reef shark
	Triaenodon obesus	whitetip reef shark
	Other sharks	
Mobulide	M. birostris	Manta ray
Myliobatidae	A narinari	Eagle ray

Appendix 3: Data sheets for belt transects and long swims (fish)

Please note: two options are provided. One data sheet per transect/long swim or one data sheet for three transects/two transects and long swim. These can be modified to suit individual observer preferences but all data and information on these forms should be collected and included on any modified form.

TRANSECT #:	IKAN KECIL 10-40cm	
Island/Reef:	Site name and number:	Habitat (exp, slope, depth):
Date:	Observer:	Visibility:
GPS Co-ord. Start:	GPS Co-ord End:	

Family	Species	common name	Ukuran x count
Sweetlips (Haemulidae)	Plectorhinchus chaetodonoides	many-spotted	
	Plectorhinchus lessonii	striped	
	Plectorhinchus lineatus	diagonal-banded	
	Plectorhinchus picus	dotted sweetlips	
	All other sweet lips		
Snapper (Lutjanidae)	Aprion virescen	Green jobfish	
	Lutjanus bohar	red bass	
	Macolor macularis	midnight snapper	
	Lutjanus rivulatus	Maori seaperch	
	All other snapper		
Emperors (Lethrinidae)	Lethrinus olivaceus	longface emperor	
	All other emperors		
Groupers (Serranidae)	Cephalopholis argus	peacock grouper	
	Cephalopholis miniata	coral grouper	
	Cephalopholis urodeta	flagtail grouper	
	Ephinephelus polyphekadion	camouflage gr	
	Epinephelus fuscoguttatus	flowery cod	
	Epinephelus lanceolatus	Queensland gr	
	Plectropomus areolatus	polkadot cod	
	Plectropomus laevis	Chinese footballer	
	Plectropomus leopardus	coral trout	
	Plectropomus oligacanthus	highfin coral trout	
	Variola albimarginata	white-margined trout	
	Variola louti	coronation trout	
	All other groupers		
Wrasse (Labridae)	Cheilinus undulatus	Napoleon wrasse	
Parrotfish (Scaridae)	Bolbometopon muricatum	bumphead parrotfish	
	all other Scarids		
Acanthuridae	Naso lituratus	orangespine unicornfish	
	Acanthurs mata	yellowmask surgeonfish	
	all other surgeonfish		
Rabbitfish (Siganidae)	Siganus doliatus	barred rabbitfish	
	Siganus guttatus	golden rabbitfish	
	Siganus lineatus	lined rabbitfish	
	Siganus corallinus	Coral rabbitfish	
	all other rabbitfish		
Trevally (Carangidae)	Caranx melampygus	bluefin trevally	
	Caranx ignobilis	Giant trevally	
	Elagatis bipinnulatus	rainbow runner	
	Gnathanodon speciosus	golden trevally	
	All other trevally		
Mackeral (Scombridae)	Gymnosarda unicolor	dogtooth tuna	
	Scomberomorus commerson	Spanish mackerel	
	All other mackeral		
Sharks (Carcharinidae)	Carcharhinus amblyrhynchos	grey reef shark	
	Carcharhinus melanopterus	blacktip reef shark	
	Triaenodon obesus	whitetip reef shark	
	All other sharks		
Rays	Aetobatus narinari	eagle ray	
	All other rays		

TRANSECT #:	IKAN BESAR >35 cm	
Island/Reef:	Site name and number:	Habitat (exp, slope, depth):
Date:	Observer:	Visibility:
GPS Co-ord. Start:	GPS Co-ord End:	

Family	Species	common name	size x count (e.g. 25x2)
Sweetlips (Haemulidae)	Plectorhinchus chaetodonoides	many-spotted	
	Plectorhinchus lessonii	striped	
	Plectorhinchus lineatus	diagonal-banded	
	Plectorhinchus picus	dotted sweetlips	
	All other sweet lips		
Snapper (Lutjanidae)	Aprion virescen	Green jobfish	
	Lutjanus bohar	red bass	
	Macolor macularis	midnight snapper	
	Lutjanus rivulatus	Maori seaperch	
	All other snapper		
Emperors (Lethrinidae)	Lethrinus olivaceus	longface emperor	
	All other emperors		
Groupers (Serranidae)	Cephalopholis argus	peacock grouper	
	Cephalopholis miniata	coral grouper	
	Cephalopholis urodeta	flagtail grouper	
	Ephinephelus polyphekadion	camouflage gr	
	Epinephelus fuscoguttatus	flowery cod	
	Epinephelus lanceolatus	Queensland gr	
	Plectropomus areolatus	polkadot cod	
	Plectropomus laevis	Chinese footballer	
	Plectropomus leopardus	coral trout	
	Plectropomus oligacanthus	highfin coral trout	
	Variola albimarginata	white-margined trout	
	Variola louti	coronation trout	
	All other groupers		
Wrasse (Labridae)	Cheilinus undulatus	Napoleon wrasse	
Parrotfish (Scaridae)	Bolbometopon muricatum	bumphead parrotfish	
	all other Scarids		
Acanthuridae	Naso lituratus	orangespine unicornfish	
	Acanthurs mata	yellowmask surgeonfish	
	all other surgeonfish		
Rabbitfish (Siganidae)	Siganus doliatus	barred rabbitfish	
	Siganus guttatus	golden rabbitfish	
	Siganus lineatus	lined rabbitfish	
	Siganus corallinus	Coral rabbitfish	
	all other rabbitfish		
Trevally (Carangidae)	Caranx melampygus	bluefin trevally	
	Caranx ignobilis	Giant trevally	
	Elagatis bipinnulatus	rainbow runner	
	Gnathanodon speciosus	golden trevally	
	All other trevally		
Mackeral (Scombridae)	Gymnosarda unicolor	dogtooth tuna	
	Scomberomorus commerson	Spanish mackerel	
	All other mackeral		
Sharks (Carcharinidae)	Carcharhinus amblyrhynchos	grey reef shark	
	Carcharhinus melanopterus	blacktip reef shark	
	Triaenodon obesus	whitetip reef shark	
	All other sharks		
Rays	Aetobatus narinari	eagle ray	
	All other rays		

LONG SWIM: **FISH SIZE GROUP:** >35 cm

Island/Reef:	**Site name and number:**	**Habitat (exp, slope, depth):**
Date:	**Observer:**	**Visibility:**

GPS Co-ord. Start:	**GPS Co-ord End:**

Family	Species	common name	Size and count		
Snapper (Lutjanidae)	Aprion virescen	Green jobfish			
	Lutjanus bohar	red bass			
	Lutjanus gibbus	Humpback snapper			
	Macolor macularis	midnight snapper			
	Macolor niger	black and white snapper			
	Other snapper				
Emperors (Lethrinidae)	Lethrinus olivaceus	longface emperor			
	Other lethrinids				
Labridae	Chelinus undulatus	Napoleon wrasse			
Scaridae	Bulbometapon muricatum	Bumphead parrotfish			
	Chlorurus bicolor	Bicolour parrotfish			
	Chlorurus frontalis?	Tan faced parrotfish			
	C microrhinus	Steephead parrotfish			
	Other scaridae				
Groupers (Serranidae)	Ephinephelus polyphekadion	camouflage grouper			
	Epinephelus fuscoguttatus	flowery cod			
	Pleactropomus aerolatus				
	Plectropomus sp				
	Variola albimarginata	white-margined trout			
	Variola louti	coronation trout			
Carangidae	C ignobilis	Giant trevally			
	Other trevally				
Scombridae	Gymnosarda unicolor	Dogtooth tuna			
	Scomberomorus commerson	Spanish Mackeral			
	Other mackerals				
Sphyraenidae	Sphyraena barracuda	Great barracuda			
	Other barracudas?				
Carcharhinidae	Carcharhinus amblyrhynchos	grey reef shark			
	Carcharhinus melanopterus	blacktip reef shark			
	Triaenodon obesus	whitetip reef shark			
	Other sharks				
Mobulide	M. birostris	Manta ray			
Myliobatidae	A narinari	Eagle ray			

Island/Reef:	Site:	Depth :	Vis:	Reef ke kiri atau ke kenan:	Habitat exposure/slope:	comments
Date:		Observer/partner:				
GPS Co-ord. Start (Transect 1) :				GPS Co-ord Middle (Transect 5):		GPS Coord End (Long Swim)

Species target	Species seen	IKAN KECIL / SMAL FISH			IKAN KECIL / SMAL FISH			IKAN KECIL / SMAL FISH		
		Transect I			Transect II			Transect III		
		size, count			size, count			size, count		
Scaridae	**Parrotfish (Scaridae)**									
Bolbometopon muricatum	Bolbometopon muricatum									
Acanthuridae	Other …………									
Naso lituratus	**Acanthuridae**									
Acanthurs mata	Naso ……………									
Rabbitfish (Siganidae)	Acanthurus ………									
Siganus doliatus	Other ………………									
Siganus guttatus	**Rabbitfish (Siganidae)**									
Siganus lineatus	Siganus ……….									
Siganus corallinus	Siganus ……….									
	Other ………………									
Haemulidae Sweetlip										
Plectorhinchus chaetodonoides										
Plectorhinchus lessonii										
Plectorhinchus lineatus										
Plectorhinchus picus										
Lutjanidae										
Aprion virescen										
Lutjanus bohar										
Macolor macularis										
Lutjanus rivulatus										
Lethrinidae										
Lethrinus olivaceus										
Serranidae										
Cephalopholis argus										
Cephalopholis miniata										
Cephalopholis urodeta										
Ephinephelus polyphekadion										
Epinephelus fuscoguttatus										
Epinephelus lanceolatus										
Plectropomus areolatus										
Plectropomus laevis										
Plectropomus leopardus										
Plectropomus oligacanthus										
Variola albimarginata										
Variola louti										
Wrasses										
Cheilinus undulatus										
Pelagics										
Caranx melampygus										
Caranx ignobilis										
Elagatis bipinnulatus										
Gnathanodon speciosus										
Gymnosarda unicolor										
Scomberomorus commerson										
ALL SHARKS										
ALL RAYS										

Island/Reef:	Site:	Depth :	Vis:	Reef ke kiri atau ke kenan:	Habitat exposure/slope:	comments
Date:		Observer/partner:				
GPS Co-ord. Start (Transect 1) :				GPS Co-ord Middle (Transect 5):	GPS Coord End (Long Swim)	

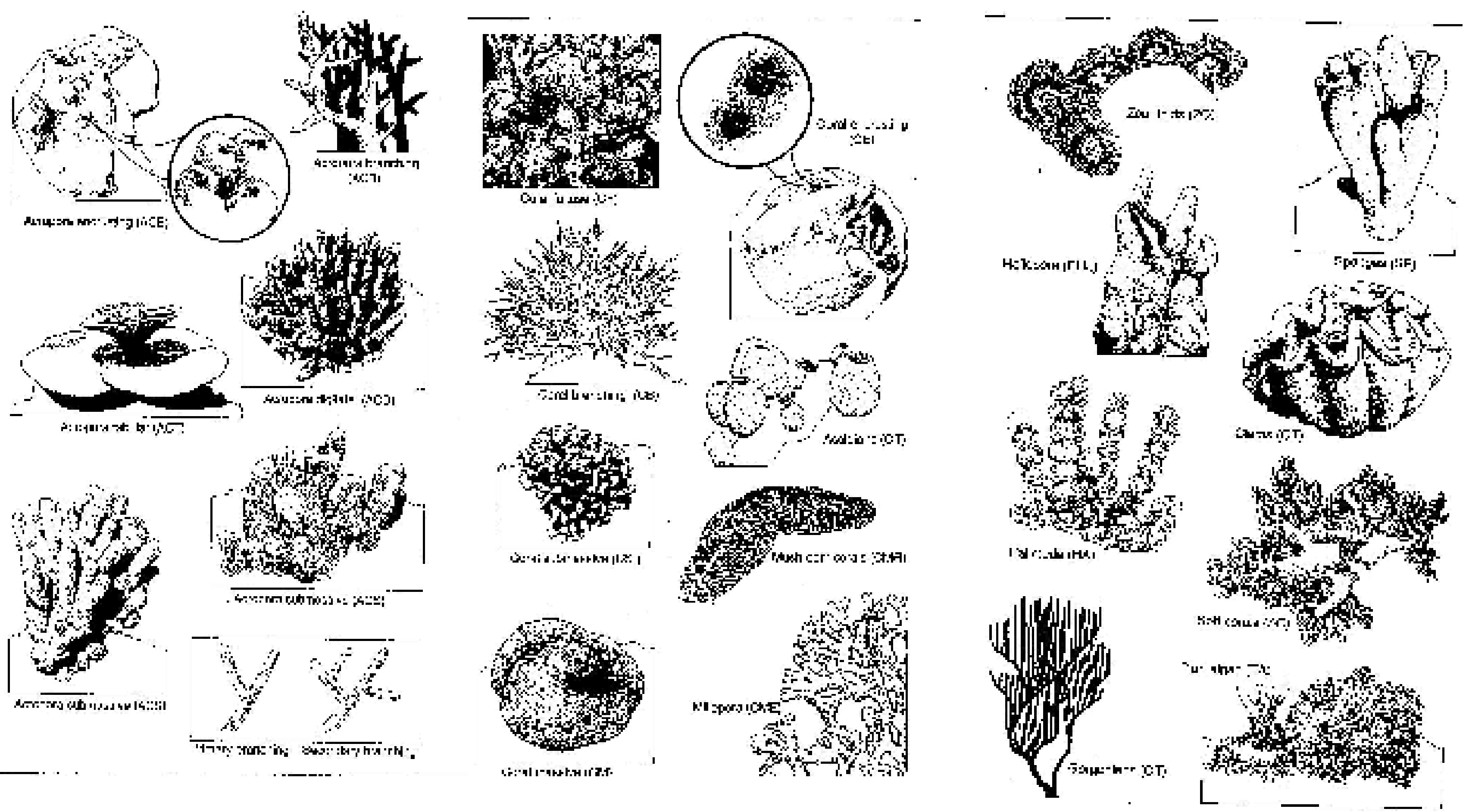
Species target	Species seen	IKAN KECIL / SMAL FISH			IKAN KECIL / SMAL FISH			IKAN BESAR / BIG FISH >40 cm		
		Transect IV			Transect V			Long swim		
		size, count			size, count					
Scaridae	**Parrotfish (Scaridae)**							**Snappers**		
Bolbometopon muricatum	Bolbometopon muricatum							Aprion virescen		
Acanthuridae	Other …………							Lutjanus bohar		
Naso lituratus	**Acanthuridae**							Lutjanus gibbus		
Acanthurs mata	Naso ……………							Macolor macularis		
Rabbitfish (Siganidae)	Acanthurus ……….							Macolor niger		
Siganus doliatus	Other ………………							Other snapper		
Siganus guttatus	**Rabbitfish (Siganidae)**							**Emperors**		
Siganus lineatus	Siganus ……….							Lethrinus olivaceus		
Siganus corallinus	Siganus ……….							Other lethrinids		
	Other ………………							**Napoleon**		
Haemulidae Sweetlip								Chelinus undulatus		
Plectorhinchus chaetodonoides								**Parrotfish**		
Plectorhinchus lessonii								Bulbo muricatum		
Plectorhinchus lineatus								Chlorurus bicolor		
Plectorhinchus picus								Chlorurus frontalis?		
Lutjanidae								C microrhinus		
Aprion virescen								Other scaridae		
Lutjanus bohar								**Groupers**		
Macolor macularis								E polyphekadion		
Lutjanus rivulatus								E fuscoguttatus		
Lethrinidae								Pleactropomus aerolatus		
Lethrinus olivaceus								Plectropomus sp		
Serranidae								Variola albimarginata		
Cephalopholis argus								Variola louti		
Cephalopholis miniata								Other groupers		
Cephalopholis urodeta								**Trevally**		
Ephinephelus polyphekadion								C ignobilis		
Epinephelus fuscoguttatus								Other trevally		
Epinephelus lanceolatus								**Mackerals**		
Plectropomus areolatus								Gymnosarda unicolor		
Plectropomus laevis								Scomb commerson		
Plectropomus leopardus								Other mackerals		
Plectropomus oligacanthus								**Barracuda**		
Variola albimarginata								Sphyraena barracuda		
Variola louti								Other barracudas?		
Wrasses								**Sharks**		
Cheilinus undulatus								C amblyrhynchos		
Pelagics								C melanopterus		
Caranx melampygus								Triaenodon obesus		
Caranx ignobilis								Other sharks		
Elagatis bipinnulatus								**Rays**		
Gnathanodon speciosus								M. birostris		
Gymnosarda unicolor								A narinari		
Scomberomorus commerson										
ALL SHARKS										
ALL RAYS										

Appendix 4: Benthic life form categories for Point Intercept Transects

Please note that life form categories from English et al 1997 were modified slightly to make the recording simpler and include categories such as Xenia which are relevant to Indonesian reefs (Xenia commonly forms large carpets on bomb affected reefs). The life form list can be modified to the full list in English et al. 1997 or simplified to a simple list of 6-10 categories to suit the skills of the team and objective of the monitoring. However, all modifications should be clearly explained so comparisons between sites/sampling times can be made.

Acropora Branching **ACB**
Acropora Encrusting **ACE**
Acropora Submassive **ACS**
Acropora Table **ACT**
Coral Branching **CB**
Coral Encrusting **CE**
Coral Foliose **CF**
Coral Massive **CM**
Coral Submassive **CS**
Coral Mushroom **CMR**
Coral Millepora **CME**
Coral Tubipora **CTU**
Coral Heliopora **CHE**
Dead Coral **DC**
Bleached Coral **BC**
Soft Coral **SC**
Xenia **XN**
Sponge **SP**
Hydroids **HY**
Other **OT**
Turf algae **TA**
Coralline Algae **CA**
Halimeda **HA**
Macro algae **MA**
Sand **S**
Rubble **R**
Silt **SI**
Rock **RCK**

EXAMPLE OF SOME LIFE FORM CATEGORIES (from English et al. 1997)



Appendix 5: Point Intercept Transect Data sheet

(See next page)

Island/Reef:	Site no and GPS::	Habitat (slope, exposure):
Date:	Reef ke kiri atau ke kenan?:	Observer:
Notes (COTS/ disease/bleaching):		Depth:

	TRANSECT I				TRANSECT II				TRANSECT III			
Code	**Point**	**Code**	**Point**	**Code**	**Point**	**Code**	**Point**	**Code**	**Point**	**Code**	**Point**	**Code**
Acropora Branching **ACB**	0.5		25.5		0.5		25.5		0.5		25.5	
Acropora Encrusting **ACE**	1		26		1		26		1		26	
Acropora Submassive **ACS**	1.5		26.5		1.5		26.5		1.5		26.5	
Acropora Table **ACT**	2		27		2		27		2		27	
	2.5		27.5		2.5		27.5		2.5		27.5	
Coral Branching **CB**	3		28		3		28		3		28	
Coral Encrusting **CE**	3.5		28.5		3.5		28.5		3.5		28.5	
Coral Foliose **CF**	4		29		4		29		4		29	
Coral Massive **CM**	4.5		29.5		4.5		29.5		4.5		29.5	
Coral Submassive **CS**	5		30		5		30		5		30	
Coral Mushroom **CMR**	5.5		30.5		5.5		30.5		5.5		30.5	
Coral Millepora **CME**	6		31		6		31		6		31	
Coral Tubipora **CTU**	6.5		31.5		6.5		31.5		6.5		31.5	
Coral Heliopora **CHE**	7		32		7		32		7		32	
Dead Coral **DC**	7.5		32.5		7.5		32.5		7.5		32.5	
Bleached Coral **BC**	8		33		8		33		8		33	
	8.5		33.5		8.5		33.5		8.5		33.5	
Soft Coral **SC**	9		34		9		34		9		34	
Xenia **XN**	9.5		34.5		9.5		34.5		9.5		34.5	
Sponge **SP**	10		35		10		35		10		35	
Hydroids **HY**	10.5		35.5		10.5		35.5		10.5		35.5	
Other **OT**	11		36		11		36		11		36	
	11.5		36.5		11.5		36.5		11.5		36.5	
Turf algae **TA**	12		37		12		37		12		37	
Coralline Algae **CA**	12.5		37.5		12.5		37.5		12.5		37.5	
Halimeda **HA**	13		38		13		38		13		38	
Macro algae **MA**	13.5		38.5		13.5		38.5		13.5		38.5	
Sand **S**	14		39		14		39		14		39	
Rubble **R**	14.5		39.5		14.5		39.5		14.5		39.5	
Silt **SI**	15		40		15		40		15		40	
Rock **RCK**	15.5		40.5		15.5		40.5		15.5		40.5	
	16		41		16		41		16		41	
	16.5		41.5		16.5		41.5		16.5		41.5	
	17		42		17		42		17		42	
	17.5		42.5		17.5		42.5		17.5		42.5	
	18		43		18		43		18		43	
	18.5		43.5		18.5		43.5		18.5		43.5	
	19		44		19		44		19		44	
	19.5		44.5		19.5		44.5		19.5		44.5	
	20		45		20		45		20		45	
	20.5		45.5		20.5		45.5		20.5		45.5	
	21		46		21		46		21		46	
	21.5		46.5		21.5		46.5		21.5		46.5	
	22		47		22		47		22		47	
	22.5		47.5		22.5		47.5		22.5		47.5	
	23		48		23		48		23		48	
	23.5		48.5		23.5		48.5		23.5		48.5	
	24		49		24		49		24		49	
	24.5		49.5		24.5		49.5		24.5		49.5	
	25		50		25		50		25		50	

Appendix 6. Biomass constants for fisheries species (from Green and Muljadi 2009).

Family	Species	A	b	Source
Serranidae	*Anyperodon leucogrammicus*	0.0014	3.548	Kulbicki etal 2005
	Cephalopholis argus	0.0093	3.181	Kulbicki etal 2005
	Cephalopholis boenak	0.0146	3.019	Kulbicki etal 2005
	Cephalopholis cyanostigma	0.0115	3.109	Kulbicki etal 2005
	Cephalopholis microprion	0.0115	3.109	Kulbicki etal 2005
	Cephalopholis miniata	0.0107	3.114	Kulbicki etal 2005
	Cephalopholis urodeta	0.0282	2.818	Kulbicki etal 2005
	Cromileptes altivelis	0.0962	2.489	Kulbicki etal 2005
	Epinephelus caeruleopunctatus	0.018	2.938	Kulbicki etal 2005
	Epinephelus chlorostigma	0.0122	3.053	Kulbicki etal 2005
	Epinephelus coioides	0.0099	3.102	Kulbicki etal 2005
	Epinephelus corallicola	0.0122	3.053	Kulbicki etal 2005
	Epinephelus fasciatus	0.0138	3.041	Kulbicki etal 2005
	Epinephelus fuscoguttatus	0.0134	3.057	Kulbicki etal 2005
	Epinephelus lanceolatus	0.0173	3	Fishbase (www.fishbase.com)
	Epinephelus macrospilos	0.0132	3.031	Kulbicki etal 2005
	Epinephelus maculatus	0.011	3.062	Kulbicki etal 2005
	Epinephelus malabaricus	0.0121	3.052	Kulbicki etal 2005
	Epinephelus melanostigma	0.0122	3.053	Kulbicki etal 2005
	Epinephelus merra	0.0158	2.966	Kulbicki etal 2005
	Epinephelus ongus	0.019	2.928	Kulbicki etal 2005
	Epinephelus polyphekadion	0.0083	3.166	Kulbicki etal 2005
	Epinephelus sp.	0.0122	3.053	Kulbicki etal 2005
	Epinephelus tukula	0.106	2.56	Fishbase (www.fishbase.com)
	Gracila albomarginata	0.0152	3.0063	Fishbase (www.fishbase.com)
	Plectropomus areolatus	0.0115	3.0889	Fishbase (www.fishbase.com)
	Plectropomus laevis	0.0059	3.238	Kulbicki etal 2005
	Plectropomus leopardus	0.0118	3.06	Kulbicki etal 2005
	Plectropomus maculatus	0.0156	3	Fishbase (www.fishbase.com)
	Plectropomus oligocanthus	0.0132	3	Fishbase (www.fishbase.com)
	Variola albimarginata	0.0139	3.0427	Fishbase (www.fishbase.com)
	Variola louti	0.0122	3.079	Kulbicki etal 2005
Carangidae	*Carangoides orthogrammus*	0.0156	3.026	Kulbicki etal 2005
	Caranx ignobilis	0.0164	3.059	Kulbicki etal 2005
	Caranx melampygus	0.0234	2.918	Kulbicki etal 2005
	Caranx sexfasciatus	0.0318	2.93	Fishbase (www.fishbase.com)
	Elagatis bipinnulata	0.0135	2.92	Fishbase (www.fishbase.com)
	Gnathanodon speciosus	0.0199	2.995	Kulbicki etal 2005
Labridae	*Cheilinus undulatus*	0.0113	3.136	Kulbicki etal 2005
Scombridae	*Gymnosarda unicolor*	0.0105	3.065	Fishbase (www.fishbase.com)
	Scomberomorus commerson	0.0162	2.856	Kulbicki etal 2005
Lutjanidae	*Aprion virescsen*	0.023	2.886	Kulbicki etal 2005
	Lutjanus argentimaculatus	0.028	2.844	Kulbicki etal 2005
	Lutjanus biguttatus	0.0151	3.057	Kulbicki etal 2005
	Lutjanus bohar	0.0156	3.059	Kulbicki etal 2005
	Lutjanus carponotatus	0.0151	3.057	Kulbicki etal 2005

Family	Species	a	b	Source
Lutjanidae	*Lutjanus decussatus*	0.0151	3.057	Kulbicki etal 2005
	Lutjanus fulviflamma	0.0205	2.96	Kulbicki etal 2005
	Lutjanus gibbus	0.0131	3.138	Kulbicki etal 2005
	Lutjanus lutjanus	0.0182	2.969	Kulbicki etal 2005
	Lutjanus rivulatus	0.0084	3.26	Kulbicki etal 2005
	Lutjanus semicinctus	0.004	3.428	Kulbicki etal 2005
	Macolor macularis	0.0211	3	Fishbase (www.fishbase.com)
	Macolor niger	0.0145	3	Fishbase (www.fishbase.com)
Sphyraenidae	*Sphyraena barracuda*	0.0062	3.011	Kulbicki etal 2005
Carcharhinidae	*Carcharhinus amblyrhynchos*	0.0023	3.373	Kulbicki etal 2005
	Carcharhinus melanopterus	0.0013	3.508	Kulbicki etal 2005
	Triaenodon obesus	0.0018	3.344	Kulbicki etal 2005
Mobulidae	*Manta birostris*	0.0164	3	Fishbase (www.fishbase.com)
Myliobatidae	*Aetobatus narinari*	0.0059	3.13	Fishbase (www.fishbase.com)
Haemulidae	*Diagramma melanacrum*	0.0144	2.988	Kulbicki etal 2005
	Plectorhinchus chaetodontoides	0.0173	3.04	Kulbicki etal 2005
	Plectorhinchus lessoni	0.0197	2.969	Kulbicki etal 2005
	Plectorhinchus lineatus	0.0126	3.079	Kulbicki etal 2005
	Plectorhinchus picus	0.0144	2.98	Kulbicki etal 2005
	Plectorhinchus polytaenia	0.0197	2.969	Kulbicki etal 2005
	Plectorhinchus vittatus	0.0197	2.969	Kulbicki etal 2005
Lethrinidae	*Gnathodentex aureolineatus*	0.018	3.063	Kulbicki etal 2005
	Lethrinus olivaceus	0.0294	2.851	Kulbicki etal 2005
	Lethrinus sp.	0.0165	3.043	Kulbicki etal 2005