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A field manual for survey methods in tropical marine ecosystems

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Preface

Frontier-Madagascar Marine Research Programme: ***A field manual for survey methods in tropical marine ecosystems***

This manual presents a synthesis of the various marine and terrestrial survey methods that have been developed by Frontier Madagascar Marine Research Programme (FMMRP) during its work to date. Methods need to be chosen according to the desired end-use of the consequent data, and by their suitability in the areas where the work is to take place.
Within each section, methods are described in chronological order of their use by FMMRP, to show their development and refinements. For each survey area, generally, the last method described is that which has been used most recently and found to be the most suitable for a given situation, although others may find preceding methods more effective where either conditions or the desired end-data set are different.

The Society for Environmental Exploration (SEE)

The Society is a non-profit making Company Limited by Guarantee, formed in 1989. The Society's objectives are to promote and advance field research into environmental issues and to implement practical projects contributing to the conservation and community management of natural resources. Projects organised by the Society are joint initiatives with national research agencies in the host countries. The Society also acts to promote links between scientists from developed and developing nations.

Institute Halieutique et des Sciences Marines (IHSM)

IHSM is a constituent body of the University of Toliara. IHSM is the foremost university centre of learning in the field of marine sciences in Madagascar, with courses provided for undergraduate and postgraduate students. IHSM also provides consultancy to government institutions, NGOs and individuals.

Frontier-Madagascar

Frontier-Madagascar was initiated in September 1999 when a Memorandum of Understanding was signed between SEE and IHSM. Its aims are to undertake field research in the southwest coastal region of Madagascar, to provide on-site training for resident and non-resident students, and to promote the sustainable use of resources within the region. Biological and resource use research is being undertaken in a variety of habitats in the area's coastal zone, a zone renowned for its high biological and conservation value. Habitats under threat include mangrove forests, coral reefs, seagrass beds and coastal scrub.

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1. MARINE SURVEYS

1.1 Coral Reef Surveys

Described below are the coral reef surveys that have been employed at MGM during various times over preceding years.

1.1.1 Benthic

1.1.1.1 P6 Based Method

A version of the P6 scale (after Dahl, 1981) is used to describe the approximate percentage cover of both substrate and benthos categories. The modified P6 scale is shown in Table 1.

Table 1: Equivalent percentage cover for the P6 scale

P6 Scale	Range
0	Absent
P	<1% (Present)
1	1-5%
2	>5-25%
3	>25-50%
4	>50-75%
5	>75-99%
6	>99%

Survey teams, using SCUBA, swim over portions of coral reef, noting in 5m-wide sections the cover of the following types of substrate:

- Mud/silt – Very fine particles that stay in suspension when disturbed.
- Rock – Any firm, stable substrate with no visible corallites.
- Rubble – Unconsolidated coral and rock fragments able to be shifted by water motion.
- Sand – Particles that settle rapidly following agitation, forming a layer deep enough to provide a habitat for burrowing organisms.
- Shell – Banks of shell fragments.

The biological cover is recorded using the same P6 scale.

- Algae – Includes all macroalgae, microalgal films and coralline algae.
- Coral: hard – All scleractinian corals.
- Coral: soft – Non-scleractinian corals.
- Seagrass – All species.
- Sponge – All types.

A further section of the survey records other factors:

- Recently killed coral – uses the P6 scale to give an estimation of dead coral. Defined as being white or off-white, with the corallites clearly visible and with no algal film. This category only includes coral that has been killed in the past year, and bleached coral.
- Dominant form – the particular hard coral form(s) that are most common (see below).
- Heterogenous/homogenous – describes whether or not coral communities are monotypic.
- Rugosity – uses a scale from 0-6 to assess the ruggedness of the reef (table 2). Rugosity should not include any element of inclination, i.e. a reef wall is not deserving of a high

rugosity value; all slopes should be perceived as being horizontal before analysing their rugosity.

Table 2: Description of the classifications of the rugosity scale.

Scale	Description
0	Flat surface with neither cracks nor holes.
1	Undulating surface. May have a few small projections and holes.
2	Low-lying substrate with cracks, fissures and projections.
3	Rugged reef architecture with a variety of forms, offering some shelter for animals.
4	Medium level reef structure, affording numerous crevices for reef animals.
5	Large structural morphs, frequently including small caves, overhangs and in-reef networks of crevices.
6	Highly irregular reef architecture, providing a multitude of concealed habitats for animals, both large and small.

The final part of the habitat survey involves identification of twelve 'hard coral' types, based on categories established by English *et al.* (1994):

- Branching – secondary branching present
- Digitate/submassive – only primary branching, or vertical wedges of coral.
- Encrusting – low-lying, follows the contour of the substrate.
- Fire – any *Millepora* coral.
- Foliose – vase/pencil-sharpening-shaped coral.
- Massive – large solid structures, exemplified by, but not limited to, brain corals.
- Mushroom – free-living corals that look like an upside-down mushroom.
- Plate – flat, sometimes overlapping plates derived from a broad attachment point. Almost always a complete surface without holes.
- Sea fans – Gorgonian coral.
- Sea whips – any whip-like coral structure (black coral).
- Staghorn – branched coral with appreciable, regular distances between axial branches.
- Table – flat coral colonies derived from one central or lateral attachment point, sometimes composed of fused branches.

The survey protocol is based on ten three-minute periods, during each of which a different portion of the reef is examined. The first two minutes are spent noting the presence of coral forms, whilst simultaneously gaining an appreciation of the cover of substrate and biological forms. In the final minute of each period, researchers complete the remainder of the information necessary for the survey, before moving on to a new section of the reef. An example of a survey slate is shown in Appendix 1, Figure 1.

This method was discontinued due to RAs finding it too complicated and not fully understanding the P6 concept. A common error was RAs producing percentage covers that totalled over 100% and therefore these surveys had to be discounted.

1.1.1.2 30m LIT Based Method

Staff lay weighted 50m tape measures following reef contours, travelling at a constant depth parallel with the reef crest. Each tape measure is a minimum of 5metres parallel from the next. The same line is used for reef fish surveys which are carried out first (see section 1.1.3.1). A surface marker buoy (SMB) is tethered to the start of the line to guide survey teams to the study site. 20 minutes after the fish survey teams have descended, pairs of benthic survey teams descend to each line and carry out a line intercept transect (LIT) using substrate and benthic categories based on those described in English *et al.* (1994). Table 3 shows the categories used and their abbreviations.

Table 3: Substrate and benthic categories used during LIT surveys (until phase 034)

Category	Abbreviation	Category	Abbreviation
Substrate		**Hard Corals (Cont.)**	
Sand	SSA	Foliose	CFL
Mud/Silt	SMS	Mushroom	CMU
Rubble	SRU	Fire	CFC
Debris	SDE	**Other**	
Rock	SRO	Sponge	OSP
Dead Coral Formation	SCF	Anemone	OAN
Dead Coral Debris	SCD	Ascidian	OAS
Hard Corals		Zoanthid	OZO
Branching	CBR	Soft Coral	OSC
Massive	CMA	Gorgonian	OGW
Sub Massive	CSU	Filamentous Algae	OFA
Encrusting	CEN	Coralline Algae	OCA
Digitate	CDI	Other Algae	OAO
Table	CTA	Sea Grass	OSG

Definitions of these categories are given below when different from those given in section 1.1.1.1

- Rubble – non consolidated rock fragments under 15cm in size
- Debris – non consolidated rock fragments over 15cm in size
- Rock – consolidated substrate with no visible corallites
- Dead Coral Formation – consolidated substrate with visible corallites
- Dead Coral Debris – non consolidated coral fragments with visible corallites
- Digitate – Only primary branching present, branches appear to stem from a central point
- Sub Massive – Vertical wedges or columns
- Anemone – All species
- Ascidian – All species
- Zoanthid – All species
- Gorgonian – All species
- Filamentous Algae – All turf-like, fine, filamentous algae
- Coralline Algae – Helimeda species and encrusting coralline species, including branching
- Other Algae – All other macro algae species

A survey team is made up of two divers. Both carry out a LIT along the same stretch of line for a maximum of 30 metres and a minimum of 10 metres. As the divers move along the tape measure they both record the benthic categories falling directly under the line and the length of each. For a detailed description of the LIT method see English *et al.* (1994). An example of a pre-drawn dive slate used to record data is shown below in Appendix 1, Figure 2.

Three transects are completed at each site and three repeat visits are made giving nine replicates for each survey site. At the end of the survey staff descend and retrieve the tape measure and SMB from each transect.

This method was changed due to RAs rushing the survey in order to complete a full 30 metre transect and therefore producing ambiguous results.

1.1.1.3 10m LIT Based Method 1

A similar method as that described in section 1.1.1.2 is used. Modifications to the method are the use of semi-permanent transect lines and a fixed, shorter transect length.

On locating a suitable study site on a reef, staff lay a tape measure and mark the beginning and end of the 50 metres with an underwater marker buoy. This consists of a brightly painted 1.5 litre bottle tethered to the reef and half filled with air. Further markers are placed at 5 metre intervals along the line. These are constructed of sections of dive slates, labelled from zero to 50 and tethered to the reef. Both buoys and markers are left on the reef.

During return visits to the site the underwater marker buoys are located by staff and the tape measure laid as described in section 1.1.1.2, but also through all 10 labelled markers. This allows replicates of each transect to be carried out, in addition to replicates at each site. Again the study site is marked with a SMB to guide divers to the transect.

Reef fish surveys are carried out first along the transect (see Section 1.1.3.2) with benthic surveys following 20 minutes after. Using the same benthos and substrate categories as in Section 1.1.1.2, a pair of divers swim along each tape measure and carry out a LIT for the first 10 metres of their line. The same pre-prepared dive slate is used as shown in Appendix 1, Figure 2.

Three transects are marked at each study site and three return visits made, totalling nine replicates per site.

Possible problems with this method include:

- Locating marked transect lines was not always possible. The underwater marker buoys were not durable and lasted a maximum of six weeks before they were lost or severely damaged. The slate tags were more hard-wearing however were still difficult to locate.

- It was necessary to wrap the tape measure around small protrusions on the reef when laying the line so the contours of the reef could be followed. This reduced the total length of the transect.

- It is not possible to keep a 50 metre length of tape measure taut along the reef under the conditions experienced at survey sites off Anakao. When surge and current are strong, the tape measure moves considerably and may defeat the purpose of installing semi-permanent transect lines.

- Weighted tape measures were often causing significant visible physical damage to the reef as they were moved by the swells, currents or divers.

1.1.1.4 10m LIT Based Method 2

The following method has been developed in collaboration with Blue Ventures and Reef Doctors for use by all members of the Coastal Capricorn Alliance (CCA). It has been modified subtly by the Frontier-Madagascar Marine Research Project (FMMRP) but is still comparable to data sets gathered by other CCA members.

The area of coast to be studied is first divided in to reef regions. These are independent areas of reef that differ from one another in an obvious physical and/or biological way. For example, regions may be divided into patch reefs, reef walls, slope areas, or systems comprising spur and groove or projecting ridges and inlets; the latter of which is the case with the reef to the south side of Nosy Ve South, off Anakao. Thought must also be given during site selection to the reef systems that the study sites belong to (e.g. mainland fringing reef, isolated patch reef, island fringing reef etc), and to what environmental factors they are subjected.

Within each reef region homogenous reef sites are located. These are smaller areas within the reef region that differ from one another in obvious physical and/or biological characteristics but that are still large enough to survey. Examples of a reef site may include areas that are dominated by a single genus of coral or other benthos such as sea grass or algae, an expanse of unconsolidated rubble within the region or, as is the case with the reef regions around Anakao, sites may be defined by depth. The depth categories used are those described in English *et al*. (1994).

Pairs of divers descend to the pre-determined reef site with a 50 metre tape measure. The tape measure is attached to a suitable anchor point on the reef with a length of cord from the free end so as the zero mark of the tape measure is not obstructed and the intercept measurements affected. The tape is rolled out along the reef at a constant depth, parallel with the crest, for 10 metres trying to minimise the length of tape that is more than 15cm off the substratum. On reaching the 10 metre mark the tape is wrapped around another suitable anchor point, ensuring the 10 metre mark is not obstructed and that the tape remains taut.

One diver from the survey team carries out a LIT along the 10 metre line using categories based on English *et al*. (1994) to describe the substratum under the tape measure. The categories used are shown in Table 4.

Table 4: Substrate and benthic categories used during 10 metre LIT surveys

Category	Abbreviation	Category	Abbreviation
***Acropora* Growth Forms**		**Other Benthos (Continued)**	
Acropora Branching Coral	ACB	Soft Corals	SC
Acropora Columna/Sub Massive Coral	ACC	Anemones	OTA
Acropora Digitate Coral	ACD	Clams	OTC
Acropora Encrusting Coral	ACE	Sponges	SP
Acropora Foliate Coral	ACF	Zoanthids	ZO
Acropora Massive Coral	ACM	Tunicates	OTT
Acropora Plate/Table Coral	ACT	**Algae**	
Other Scleractinian Coral Growth Forms		Halimeda	HA
Branching Corals	CB	Encrusting Coralline Algae	EA
Columna/Sub Massive Corals	CC	Turf	T
Digitate Corals	CD	Fleshy Algae	FA
Encrusting Corals	CE	**Substrate**	
Foliate Corals	CF	Dead Coral (Bleached)	DCB
Mushroom Corals	CMR	Dead Coral Formation	DCF
Massive Corals	CMT	Dead Coral Debris	DCD
Plate/Table Corals	CT	Rock	RK
Other Benthos		Large Rubble	RL
Fire Coral	FCM	Small Rubble	RS
Gorgonians	OTG	Silt	SI
Hydrozoa	OTH	Sand	SA

Definitions of these categories when different or additional to those described in section 1.1.1.2 are given below:

- *Acropora* branching, table, columna etc – the same growth forms as described for scleractinian corals in sections 1.1.1b but only belonging to the genus *Acropora*.
- Clams – All species
- *Halimeda* – All species belonging to this genus.
- Encrusting coralline algae – All species, including branching coralline algae.
- Turf – All species of fine, filamentous green algae.
- Fleshy algae – All other macroalgae species
- Dead coral (bleached) – A white colony with the corallites still clearly visible, no algal overgrowth and possibly still with a layer of living tissue.
- Large rubble – Unconsolidated rock larger than 15cm in diameter

- Small rubble – Unconsolidated rock smaller than 15cm in diameter

All data are recorded on a pre-drawn survey slate as shown in Appendix 1, Figure 3.

During the LIT survey the second diver collects observational data on, for example, physical damage to the site, signs of coral disease, visibility, current direction and strength as described in section 1.1.4.

A minimum of nine replicates are carried out at each site within each region.

1.1.2 Commercial Fish Survey

The commercial fish survey attempts to make a rudimentary estimation of the standing stock and population structure of commercially valuable fish families. The families under consideration are those specifically cited by Océan Consultant (2000) as comprising the bulk of the fishery produce in the Toliara region. Descriptions of the fishes are based on those given by Lieske and Myers (1994) and are shown in Appendix 2, Table 1.

Researchers, using SCUBA, swim along sections of the coral reef, marking the number and size of all commercial fishes seen within a 5m band during a 30 minute survey. Numbers of shoals of fish may be estimated by visualising a section of the shoal, counting the fish in that portion, and multiplying out by the fraction of the shoal counted. An example of a survey slate is shown in Appendix 1, Figure 4.

1.1.3 Reef Fish Surveys

1.1.3.1 50m Belt Transect Method

Surveys are conducted by pairs of divers swimming along the 50 metre tape used in the benthic survey described in Section 1.1.1.2. Species included in the census are visually and numerically dominant, without cryptic behaviour, are easily identified underwater, and are associated with reef slope habitats (English *et al.*, 1994). The target species used in the surveys are shown in Appendix 2, Table 2.

The survey teams swim slowly along each transect recording a tally of target fish species encountered 2.5 metres either side and 5 metres above the line on a pre-drawn dive slate, shown in Appendix 1, Figure 5.

1.1.3.2 50m Belt Transect Method

The same method of fish survey is used as described in Section 1.1.3.1 with an amendment to the target fish species list and the addition of a fixed swimming time of 30 minutes for carrying out the 50 metre transect survey.

Fish species added to the species list are shown in appendix 2, table 2 while all Labridae (wrasse) species were removed and not recorded during surveys. Tallies of target fish species are recorded on a pre-drawn dive slate based on that shown in Appendix 1, Figure 5.

1.1.3.3 20m Transect Method 1

This survey method has been developed by all members of the CCA for use at all survey sites. Survey sites are defined as in Section 1.1.1.4. Each belt transect is carried out by buddy teams of divers. On reaching the study site one diver attaches a 20 metre length of a 50 metre tape measure to a suitable anchor point on the reef as described in Section 1.1.1.4. Alternatively a length of rope marked with one metre increments can be used. An extra length of line at one is used to anchor the transect rope to the reef so the start of the 20 metre line is not obstructed.

The survey is composed of two passes of the 20 meter line. Both divers swim along the reef while one unwinds the tape measure or rope, ensuring the survey maintains:

- A constant depth
- An approximately constant direction parallel with the crest
- A constant speed so that the transect is swum in 20 minutes

The diver responsible for the transect tape steers the second diver by signalling direction, speed and the end of the line.

During the first pass the second diver records numbers and size estimates of all larger fish species that are disturbed by the presence of divers and will leave the study site, encountered 2.5 metres either side of the line and 5 metres above. Size estimate categories used are those described in English *et al*. (1994) (Table 5).

Table 5: Size categories and respective codes used during reef fish surveys (method 1). Size categories are based on those described in English *et al.* (1994).

Size Category	Size Category Code
0 – 20cm	1
20 – 40 cm	2
40 – 60 cm	3
60 – 80 cm	4
80 – 100 cm	5
Over 100 cm	6

Each fish recorded within the transect is allocated a size category code (Table 5).

On reaching the end of the first 20 metre pass the survey divers swap roles for the second half of the survey also lasting 20 minutes. One diver again steers the survey while reeling in the transect line. The second diver records all smaller fish species within the transect that are more likely to have ignored the divers and not left the transect area during the first pass. Size category codes are allocated to all individuals as before. Where both divers have recorded the same species the least conservative estimate of fish numbers is used.

When a fish species can not be identified a detailed drawing is made on the reverse of the survey slate and a size code allocated. If a species can be identified but the name does not appear on the pre-drawn slate it is added in the 'Other Fish' section of the survey slate. An example of a survey slate is shown in Appendix 1, Figure 6.

The core species list used during the survey and taught to RAs is shown in Appendix 2, Tables 1, 2 and 3.

On reaching the anchored end of the transect, the survey is stopped and the line retrieved. A minimum of nine replicates are carried out at each site within each region.

1.1.4 Invertebrate Surveys

1.1.4.1 General Invertebrate Survey Method (1)

The invertebrate survey attempts to assess the relative abundance of a number of classes of invertebrates, including those that are collected during commercial or subsistence fisheries, and those that are of ecological interest.

Researchers swim over a section of reef, using SCUBA, carefully examining the reef for selected target invertebrates. A list of target invertebrates is given in Appendix 2, Table 5. A belt 5m wide is surveyed for 30 minutes and a tally of target species recorded using a pre-drawn survey slate (Appendix 1, Figure 7).

During a survey care is taken that only live specimens are recorded. All shells are therefore checked to ensure they are not empty or inhabited by a hermit crab before being included in the survey.

1.1.4.2 General Invertebrate And Observational Survey Method (2)

This survey method is used in conjunction with the 10 metre LIT benthic survey described in section 1.1.1.4 and is carried out by the second diver in the survey team while the first diver completes the LIT.

The 10 metre survey line is laid at the chosen reef site as described in Section 1.1.1.4. For 2.5 metres either side of the transect line the survey diver records:

- **Depth of transect site in metres**
- **Horizontal visibility in metres**
- **Coral damage**
    - Extent – e.g. serious, not serious, killed, etc.
    - Source – anchor, diver, storm etc.
- **Litter pollution**
    - Extent – e.g. serious, not serious
    - Source – e.g. trash, lost fishing equipment etc
- **Sedimentation**
    - Extent – e.g. heavy, slight, etc.
- **Fishing**
    - Extent – e.g. heavy, slight, etc.
    - Methods – line, gill net, spear gun etc
- **Coral disease**
    - Extent of white band disease
    - Extent black band disease
- **Bleaching**
    - Coral category of colony affected (Table 4)
    - Size of colony affected – length, width and height in millimetres
    - Percentage of colony surface area affected
- **Urchin numbers**
    - *Diadema* species
    - *Echinothrix* species
    - *Echinometra* species
    - *Tripneustes* species
    - Pencil species
    - Other species
- **Crown-of-thorns sea star numbers**

30 minutes are spent searching the transect area with all data being recorded on a pre-drawn survey slate (Appendix 1, Figure 8). On completion of the survey the transect line is collected from the reef.

The data collected during this survey are flexible and can be altered to incorporate personal staff projects.

1.1.4.3 Nudibranch Surveys

Buddy teams of survey divers descend on a reef. A 25cm^2 plastic quadrat is placed gently on the reef by each diver and the start time of the survey noted. The area within the quadrat is searched thoroughly until either the diver is satisfied no nudibranchs are present or a nudibranch is encountered. When either occurs the time is again noted, giving an actual search time.

If a nudibranch is found the following data are recorded:

- Species - When a specimen can not be identified to species level a detailed description and drawing is made with care being taken to note all colours and patterns. Details of each of the following body parts are taken:
    - Skirt
    - Rhinophores
    - Gills
    - Caeratta
- Depth (m) specimen found at
- Length (mm) from anterior margin of head, excluding rhinophores, to posterior tip of tail
- Substrate specimen is found on

On resuming a search, having recorded a specimen, the timing of the survey is resumed until another specimen encountered and the process of noting the time and identifying the species repeated.

If a nudibranch is not found or all individuals have been recorded the survey for that quadrat is finished and the total time spent searching calculated. The quadrat is then moved to the adjacent 25cm^2 of reef and the survey repeated.

All data is recorded on a pre-drawn survey slate as shown in Appendix 1, Figure 9. A list of nudibranch species commonly encountered is shown in Appendix 2, Table 6.

The rational behind recording the actual time spent searching each quadrat is that this can be used to calculate numbers of nudibranchs encountered per m^2 per hour of search time. This takes in to account the varying levels of effort put in to the surveys by different RAs.

Incidental sightings of nudibranchs not during a survey are also recorded. Again the species is identified, the length in millimetres measured and the substrate it has found on recorded. This data is used to build a species list of nudibranchs in the region.

1.2 Cetacean Surveys

There are various cetacean species present in the waters around Anakao, Nosy Ve and Tulear. These include dolphins such as spinners (*Stenella longirostris*), humpbacks (*Sousa chinensis*) and bottlenose (*Tursiops aduncus)*, and humpback whales (*Megaptera novaeangliae*) pass through the area regularly during the 3rd and 4th research phases of the year (from around July to November) as part of their migration north to breed and calve. Other whale species may also be present.

There are a number of methods available for studying these species; each with its own costs and level of complexity. The suitability of these various methods depend upon the extent of the rest of the project's work programme and logistics, which will affect the available time, funding and equipment. Following are detailed some of the methods thought to be most apt for both the remit and capabilities of a Frontier marine project.

1.2.1 Shore Watch

The most simple, cost-effective method of recording cetacean presence/absence data is through use of a systematic shore watch. This involves making regular short scans of the sea from the same high vantage point at regular intervals throughout the day (or during the hours of daylight). Care must be taken to ensure that the same amount of effort is invested with each scan (with/without binoculars, 10 minutes for each scan, scans made from the same geographical point, same number of observers etc.)

Abiotic variables to record should be:

- Date
- Time
- Tide (either tide height or tide state)
- Cloud/brightness
- Sea state (rising scale - see Table 1)
- Wind force (rising scale - see Table 2)
- Wind direction

Biotic variables recorded should cetaceans be seen should include:

- Species
- Bearing of individual/pod position from viewpoint[1]
- Distance of individual/pod from viewpoint[1]
- Estimated number
- Behavioural observations (see Table 6)
- Any other observational notes

The advantage of this method is that it is easy to perform, low cost, and provides systematic, easily analysed data.

[1] If sample size is large enough, may allow density estimation using the DISTANCE point transect method (Burnham *et al*., 1996)

1.2.2 Opportunistic sampling

Frontier marine projects spend a large amount of time out at sea on boats, and it makes sense to keep a record of cetacean encounters and related data. This is simple as it requires only basic equipment that should be on board as a matter of routine (depth sounder, GPS etc), simple training and that a data slate is available at all times.

As a part of regular boat trips out to dive sites, keep a record of any cetacean sightings. The extent of the information recorded is dependent upon the purpose of the study, but basic observations could include:

- Time and date of encounter
- Location of encounter
- GPS co-ordinates
- Species
- Estimated number of individuals

1.2.3 Detailed transect method

For a more detailed transect method and consequently more detailed information, keep a record of each transect (boat trip). Transect information should include:

- **Time start**
- **Time finish**
- **Start location**
- **Finish location**
- **Start tidal state** (work out from tide tables)
- **Finish tidal state**
- **Sea conditions** (rising scale)
- **Brightness** (rising scale)
- **Any other observations**
- **Which boat is being used and whether it is under motor, sail or anchor**
- **Whether or not cetaceans are encountered, and if so how many encounters occur**

If cetaceans are then encountered during a transect, record observations on the following:

- **Time at start of encounter**
- **Time at end of encounter**
- **Time duration of encounter**
- **Location of encounter**
- **GPS coordinates**
- **Species**
- **Estimated number of individuals**
- **Behaviour states**[2]
- **Direction of travel** (if travelling)
- **Sea conditions/brightness**
- **Closest distance from boat**
- **The bearing of the group from the boats direction of travel** (to work out estimated density of pods – see Dedicated Transect method)
- **Tide state at time of encounter**

[2] for behavioural observations – it makes sense from a data analysis point of view to attempt to categorise behaviours into a series of behaviour states, possibly weighted towards the estimated priority behaviour of the pod or animal during the encounter. For examples please refer to table 6.

- **Tide state at end of encounter**
- **Presence/absence of calves/juveniles** (if possible; estimate number of each)
- **Whether the boat is under motor, sail or at anchor during encounter**
- **Depth to the sea floor at the location of the encounter**
- **Estimated distance from shore /nearest reef**
- **Any other notes of interest** – e.g. interesting behaviours, calving, species-specific etc.

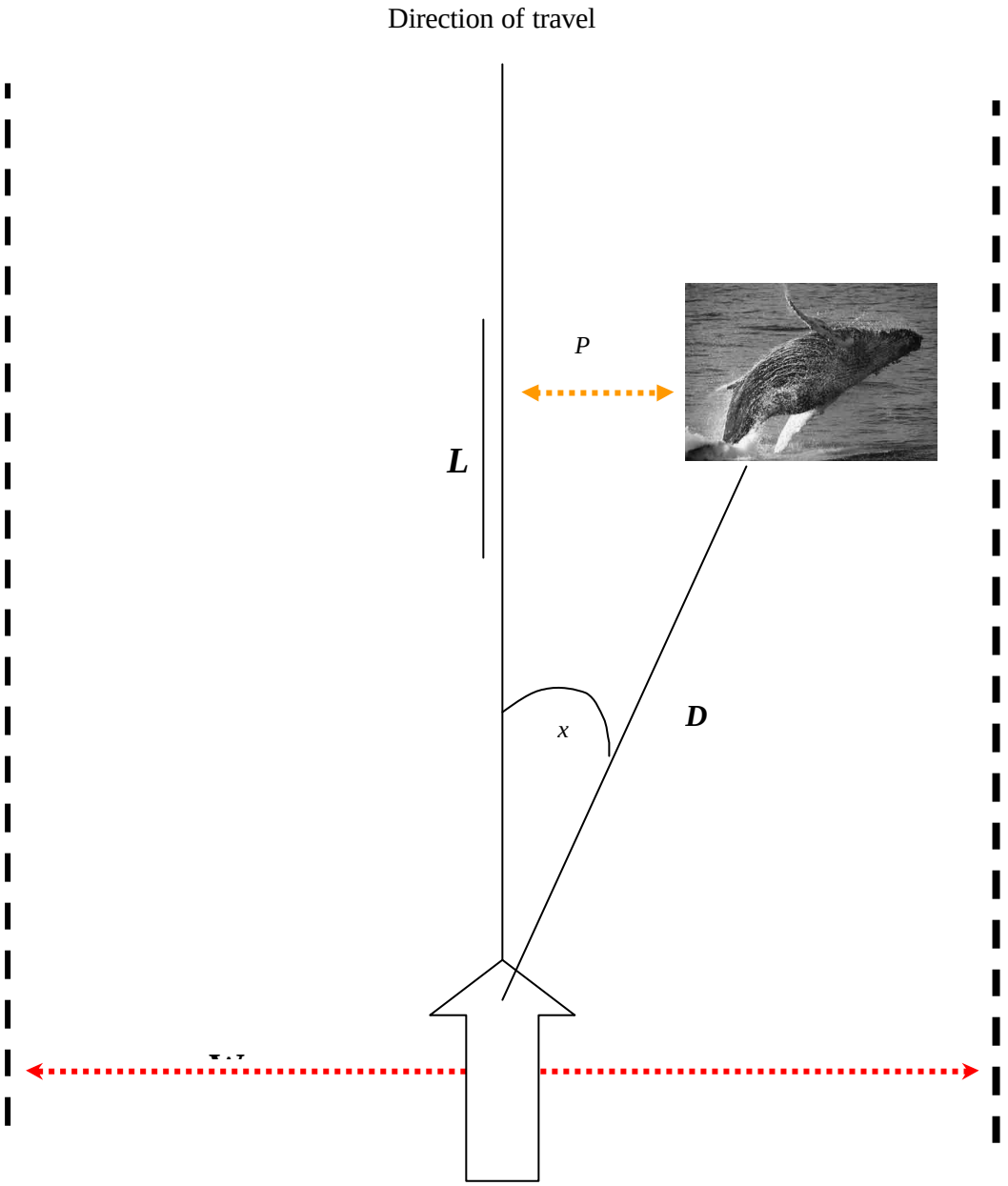
Table 6: Examples of behaviour states

Behaviour state	Characterised by:
Foraging/feeding	Frenzied activity at the surface and under water: difficult to determine. Sometimes obvious.
Sharking	Extremely fast swimming; often with the dorsal fin showing above the surface of the water. Often associated with foraging and occasionally sexual activity.
Sexual display/activity	Inter-pod physical contact, frequent breaching, repeated breaching patterns, aroused males.
Travelling	Purposeful swimming in a particular direction. Usually obvious.
Porpoising	Relatively fast surfacing, usually associated with travelling
Breaching	Leaping fully out of the water
Half-breaching	Leaping half out of the water
Chin-slapping	Half-breach followed by slapping the underside of the head on the water surface. Often associated with foraging or defensive posturing
Tail-slapping/lob-tailing	Slapping the tail fluke deliberately and repeatedly on the water surface. Often associated with foraging behaviour
Spy-hopping	Head coming vertically, deliberately and slowly out of the water, so that the eye is able to see above the water

1.2.4 Dedicated transects

In order to estimate the density of cetacean species in the study area using DISTANCE analysis (Burnham *et al.*, 1996), it is necessary to design surveys with more specific data collection methods incorporated. Principally, it is necessary to perform strict, explicit transects, continuing for a set distance (i.e. 10km), at a set speed. If animals are encountered, the angle between the track direction of the boat and the direction of the animal must be recorded immediately, as must the estimated distance between the boat and the animal (if distance can be measured more accurately in some way, this will be beneficial). Recording data of this nature will allow the perpendicular distance of the individual or pod from the transect 'line' to be calculated using basic trigonometry.

The method assumes that the probability of sighting a cetacean decreases together with it's distance away from the track-line, so that if this distance is recorded, an accurate probability of seeing cetaceans within the transect area during future can be calculated. This would then be taken to be a surrogate for cetacean density within that area.
For more detailed information on this technique, please refer to DISTANCE version 3.5 and accompanying book (both available on-line).



where:

W =	estimated maximum width of transect (observers would not see cetaceans if they surfaced outside this area)
L =	length of transect (ie 10km – use GPS to design)
D =	distance of individual or pod from boat
x =	angle between boat's trackline (bearing of transect) and direction of sighting
P =	calculated perpendicular distance of individual or pod from transect

Figure1. Diagram showing dedicated transect design for density estimation of cetacean species, using DISTANCE

1.2.5 Photo-identification

One of the most frequently used methods for cetacean research is that of photo-identification. This method is highly rated due to its non-intrusive aspect in contrast to other in-situ cetacean research techniques.

Dolphins

To pursue this method, attempt to take photographs of either the dorsal fins of individual dolphins from side on and at as low an angle as possible. As most dolphins, particularly older animals, have worn or marked dorsal fins it is often possible to recognise individuals from their fins. A photographic catalogue of local individuals can then be compiled from the photographs.

Humpback whales

For humpback whales, it is mostly desirable to obtain photographs of the ventral surface of the tail fluke as the animal begins its dive sequence, as the white patterning on all humpbacks is often unique to the individual. This may then allow comparison with the many online catalogues in order to establish the origins and history of the individual.

The data yielded by such a method can be extensive, although it is dependent upon constraints, interest, and desired outcome. For example, by performing basic mark/recapture calculations using the rate at which known individuals are re-sighted, it would be possible to estimate with some accuracy the total number of individuals in the study area. By recognising individuals, it would also be possible to ascertain mating success, inter-pod associations, site fidelity etc.

For the purposes of MGM this technique would be most suited to the humpback whales during the migration period, requiring photographs of the ventral surface of the tail flukes. Similarly, the information would be most effectively utilised if links were formed with other researchers, in order to compare shots. Other organisations carrying out whale research in Madagascar include *Megaptera* on the north east coast and Ile St Marie, and WCS in the Baie d'Antongil, Anakao and the Comores. Both these organisations have fairly extensive photo-id catalogues.

1.3 Fish Landing Site Surveys

Method

The exact methods used at the fish landing site are designed around the current activities seen. This is in order to minimise any impact on the fishermen. Consequently an accurate data set is collected.

Prior to commencement of surveying permission must be granted for surveyors to visit the landing sites. If activities are fully explained fishermen are normally willing for surveys to take place. As catch varies with tidal state it is important that surveying occurs over an entire tidal cycle (springs and neaps). Consequently the survey period should be a minimum of 2 weeks with daily visits to the landing site. Visits should be made at the same time everyday and for the same time duration. The time chosen should be based on the advice of the landing site manager. Typically most fish are brought in during the afternoon; consequently the best survey time is usually 1400hrs – 1600hrs. If multiple landing sites are being surveyed it is favourable to survey them all simultaneously allowing for exact comparisons to be made with variations due to weather accounted for.

At the landing site as each catch is brought in the total weight of the catch is recorded on the data sheet in kilograms. Separate catches are differentiated on the data sheet (Appendix 1, Figure 14) using catch numbers; F1, F2 etc, with F representing fish catch. The catch is subsequently separated into individual fish and following data are recorded on the data sheet for each fish:

1. Species (if species not possible then identify to family level).

2. **Total Body Length** (**TBL**): length of fish measured from most anterior part of head to end of longest caudal ray when the rays are squeezed together, but excluding the caudal filaments (Fish Base).

3. **Standard Length** (**SL**): length of fish from most anterior part of head to the posterior end of vertebra column (the last element has a broadened hypural plate forming the bony support for the caudal fin rays). In small dead fish the end point is detected by bending the caudal fin to one side (Fish Base).

4. If SL can not be measured because it is difficult to ascertain the end of the vertebra column or if the fish has a stiff forked tail as in tuna surveyors are to measure **Fork Length** (**FL**): length from most anterior part of head to posterior end of middle caudal rays (Fish Base).

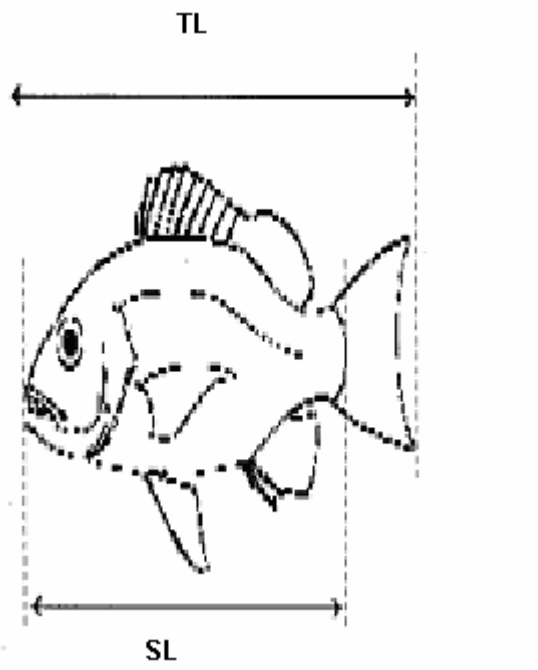


Figure 2. Measurements top be taken during fish landing site surveys

Length measurements are taken using a fish measuring board or a tape measure.

If the fishermen actually bring the catch into the landing site themselves then additional information can be collected in the form of a survey. IHSM students should be used to ask questions in Malagasy as most fishermen do not speak French. Survey questions **must not** be leading (e.g. "Did you catch your fish at Nosy Ve?"), but rather should be neutral (e.g. "Where did you catch your fish?") and should include the following:

- **Where were you fishing?**
- **What fishing method did you use?**
- **How long were you fishing for?**
- **How long is your pirogue?**
- **How many people were on the pirogue?**
- **Is this all you caught today?**

The responses should be recorded in the notes section of the data sheet. These questions are just six basic questions and can easily be changed to incorporate any specific aims of the study.

Any samples measured that are already at the landing sites when the surveyors first arrive are noted as 'stored'. Additionally, it is most likely that it is not just fish brought into the fish landing site and 'gleaners' (or 'foot fishers') will bring in octopus and squid. In this case, a total weight per catch is again recorded on the same data sheet with catch number being recorded as G1, G2 etc., with G representing Gleaner catch. It would be advantageous to gain individual size measurements (length of body excluding limbs and total length), total number of individuals per catch, and gender information for squid and octopus in addition to total catch weight, although this has not been possible at Anakao as part of a comprehensive fisheries survey. If information of this nature is required, it would be advisable to focus exclusively on squid and/or octopus. The following additional data can be collected from the octopus catch if it is desired on a separate data sheet (Appendix 1, Figure 15).

- **Count individual octopus** landed as well as total weight in order to obtain an accurate assessment of number of octopus being extracted in addition.
- For as many individual octopus as possible record:
    - Dorsal to mantle length.
    - Weight.
    - Sex.

- A simple questionnaire to obtain information regarding gleaning location and time spent gleaning.

There is a possibility that turtles may also be brought in. If they are the following is to be recorded on a separate turtle data sheet (Appendix 1, Figure 16):

- Species (if possible). If species identification can not be achieved a detailed description, including diagram, of the turtle must be taken to allow for the possible future identification.
- Number of scales between the eyes.
- Number of scute pairs.
- Curved carapace length (mm)

This will aid in species identification. It is important to additionally check if the turtle is tagged and if it is to accurately copy down what is printed on the tag.

1.4 Shark Landing Site Surveys

Sharks may also be landed, if they are as much information needs to be taken from them as possible. This includes:

- **Species Caught**
- **Weight**
- **Total Length**
- **Precaudal length**
- **Fork Length**
- **Sex**
- **What is in the stomach?**

If feasible also include the following:

- **Is the shark pregnant?**
- **How many pups are there?**

For the hammered head species include some line drawings of hammerhead head shapes with tick boxes in an attempt to ascertain whether the shark caught is a scalloped hammerhead (*Sphyrna lewini*) or a great hammerhead (*Sphyrna morkarran*), both of which occur in Madagascan waters and are caught, yet have the same Malagasy name.

Interviews

Conducting interviews with specialist shark fishermen can yield very useful data. The topics covered in these interviews include number of fishermen in each village; time spent fishing each week, value of shark products including fins, meat and teeth. In addition they are questioned regarding the Malagasy names for shark species using photos and drawings from books.

Shark Landing Sites

Sharks brought onto the beach are measured and if possible a weight obtained. The measurements taken are standard and are listed below:

- **Total length (TL**) = tip of nose to tip of tail (in a straight line along the ground)
- **Fork length (FL)** = tip of nose to the fork of the tail
- **Pre-caudal length (PCL**) = tip of nose to pre-caudal pit
- **Dorsal 1 to dorsal 2 (D1-D2)** = trailing edge of dorsal fon 1 to point where dorsal 2 starts.
- **Pectoral fin to pelvic fin (P1-P2)** = trailing edge of pectoral fin to point where pelvic fin starts.
- **Dorsal to fork (DF)** = trailing edge of dorsal 1 to the caudal fork (along the curve of the body).
- **Dorsal to pre-caudal pit (DPP)** = Trailing edge of dorsal fin to pre-caudal pit along the curve of the body)

Any weights of fins taken should be noted. In addition if the fin collectors are there any prices of fins bought should be noted. For some species fins are discarded as they are not thought worthwhile buying, so it should be noted which of the fins are used. Finally, it should be ascertained why other parts are taken (i.e. meat for consumption, teeth collected to sell to shell collectors etc).

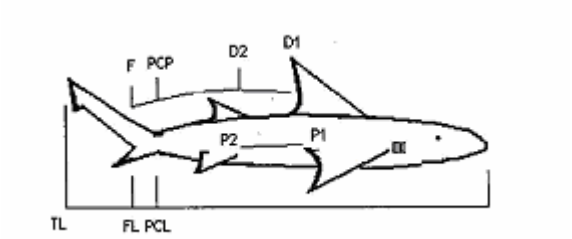


Figure 3. Measurements to be taken from landed sharks.

1.5 Urchin Density And Hatting Behaviour Surveys

Urchin surveys are carried out during low neap tides by teams of between two to four RAs. A starting GPS point is taken at the neap low tide water line as well as a bearing to the reef crest and recorded. A 50 metre tape measure, weighted at each end, is then laid from the starting point perpendicular to the reef crest along this bearing. The time the survey starts is also recorded.

Every 10 metres from the starting point the survey team records the distance from shore and examines a $10m^2$ circular quadrat for urchins. The quadrat is made from a 1.8 metre pole. A RA holds one end of the pole while standing at the 10m mark and slowly turns full circle with the pole held out horizontally over the water. Using pr^2, a circle with a radius of 1.8 metres has an area of $10m^2$, giving the desired quadrat size.

All urchins within the quadrat are identified to species level and a total number of each species recorded. Species commonly encountered and identifying characteristics are shown in appendix 2, table 7.

10 individuals of each species are then randomly chosen and the following details taken:

- Test diameter – This is done at the widest part of the test, ensuring the callipers are lying flat against the test and not caught on spines.
- Colour – This is subject to personal interpretation however variation between surveyors may be reduced by using colour categories:
    - Dark purple/black
    - Red/brown
    - Pink
    - White

- Percentage hatted – This is subject to personal interpretation. The upper most surface area of the individual covered by any material is estimated.
- Hatting type – This is the material the urchin has used to cover itself. Materials often used include:

    - Rock – Includes using large consolidated rock
    - Shell fragments
    - Coral
    - Algae
    - Sea grass
- Substrate – This is what is found directly underneath the urchin.

If 10 individuals of a species are not present or are inaccessible then as close to 10 individuals of that species are recorded. All data are recorded on a pre-drawn survey slate as shown in Appendix 1, Figure 17.

Quadrats are repeated every 10 metres until reaching the reef crest with the tape measure being moved along the same bearing each time the end is reached. On completing the transect the end time is recorded. Transects are repeated at 20 metre intervals along the beach.

2. TERRESTRIAL SURVEYS

2.1 Mangrove Surveys

2.1.1 Mangrove Mapping

On first surveying an area of mangrove forest it is important to ascertain the total area of the forest. To do this you need a survey team of at least four people; one to take bearings and three to pace out distances. The perimeter of the mangrove forest which is to be mapped is marked by a boundary of mangrove/salt marsh vegetation and terrestrial vegetation (e.g. Spiny forest).

Initially a start point is chosen on the perimeter and GPS co-ordinates are taken. A direction is then chosen along the perimeter and a bearing is taken to the first significant deviation in direction of perimeter (Figure 4). The pacers subsequently walk to this point counting and recording their paces on a data sheet (Appendix 1, Figure 18). Then a bearing is taken to the next significant deviation in boundary direction and paces recorded. This method is repeated around the entire external perimeter of the forest.

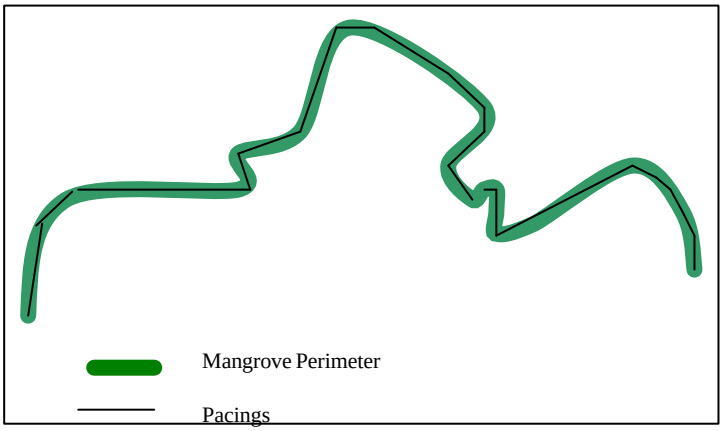


Figure 4: Schematic representation of a mangrove forest showing how to map the external boundary.

The internal mangrove-creek boundary can similarly be mapped with the internal limit of the forest being considered as the limits of root penetration into the creeks.

GPS co-ordinates can be taken when felt necessary on both the internal and external boundaries in order add co-ordinates onto the resulting map.

Length Calculations
In order to obtain an unbiased and accurate pace measurement lay out a 50m tape measure in similar terrain to that which has been sampled. Each individual pacer is to walk the 50m length at least 3 times counting their paces. From this an accurate average count per 50m can be obtained and subsequently length calculations can be calculated.

Area Calculations
Once all distances have been ascertained the perimeter of the mangrove forest can be drawn by hand or using a mapping computer program. The area of forest can then be calculated.

2.1.2 Density and Species Transects

In order to ascertain the density of the mangrove forest and the species found within the forest it is best to use a combination of three methods: general observations, transect line plots and belt transects.

General Observations
While mapping the external and internal boundaries of the mangrove forest note down which species are seen and where they are found i.e. are they on the creek edge or on the boundary with terrestrial vegetation.

Transect Line Plots
Transect lines can be used in areas of all densities of mangrove forest. Lines are established from the seaward margin of the forest, at right angles to the edge of the mangrove forest (Figure 5). The transect start point; transect end point and zone boundaries must be marked with the GPS. Each transect line is then divided into zones corresponding to the level of tidal inundation i.e. low, mid and high intertidal zone. Within each zone at least three quadrats are subsequently taken using the following method. Quadrat size depends on tree density; in dense forest use a 5m x 5m quadrat and in the tannes (clearings in the mangroves) use a 10m x 10m quadrat. Within each quadrat the surveyors record on a data sheet (Appendix 1, Figure 19) the following:

- GPS
- Number of adults (girth greater than 4cm and greater than 1m tall) of each species present.
- Number of saplings (girth less than 4cm and greater than 1m tall) of each species present.
- Number of seedlings (height less than 1m) of each species present.
- For up to three individuals of each species the girth at breast height (see below) and the height of the trees.
- Any dead trees.

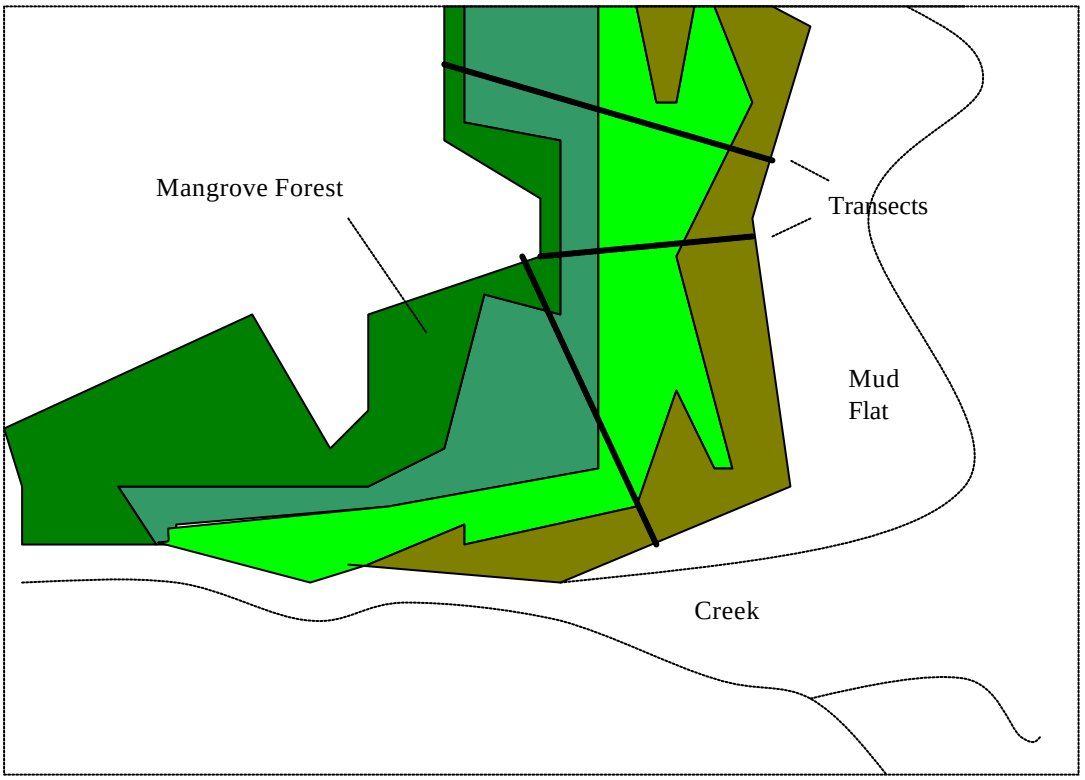


Figure 5: Transects are established through the mangrove forest from the seawards edge to the landward margin (English *et al.*, 1994).

Tree girth measurements are taken at breast height i.e. approximately 1.3m above the ground. However, measuring the girth in some shape and growth forms of mangrove trees can be difficult. Consequently a general procedure in measuring girth has been outlined by English *et al.* (1994) and is summarised below.

- When a tree forks below breast height, or sprouts from a single base close to the ground or above it, measure each branch as a separate stem.
- When the stem forks at breast height or slightly above it, measure the girth at breast height or just below the swelling caused by the fork.
- When the stem has prop roots or a fluted lower trunk, measure the girth 20 cm above the root collar.
- When the stem has swellings, branches or abnormalities at the point of measurement, take the diameter slightly above or below the irregularity, where it stops affecting normal form.

The girth measurements can be converted into diameter at breast height (DBH) measurements by dividing by π (3.14). Using allometric relationships between DBH and the biomass of individual plant parts, as outline by English *et al.* (1994), the above ground biomass for each mangrove species can be calculated and therefore a picture of community structure obtained.

Belt Transects

When tree density is not great e.g. in tannes belt transects can be used. Through each tanne three random bearings must be taken from an initial start point e.g. point of creek emergence into each tannes. GPS co-ordinates need to be taken at both the start and end points of the belt transect. Along each bearing a 10m wide belt transect is completed up to the MHWS mark. In the belt transect the following should be recorded on a data sheet (Appendix 1, Figure 20):

- Number of adults of each species present
- Number of saplings of each species present
- Number of seedlings of each species present
- Any tree mortality or damage.

2.1.3 Opportunistic Reptile and Bird Surveys

While completing the previous survey methods any birds and reptiles encountered should be identified with the assistance of staff members and or identification guides and recorded on a data sheet (Appendix 1, Figure 21). Specific reptile traps and bird surveys, as outlined in this methods handbook, can also be completed.

2.1.4 Human Resource Use Surveys

During surveying in the mangroves any human activity, including Zebu grazing, witnessed should be noted. If possible local villagers should additionally be interviewed in order to ascertain how they use the mangroves and whether they are being used at a sustainable or non-sustainable level.

2.1.5 Equipment

Compass
Note pad
Pen/pencil
GPS
Tape measures
Rope quadrats: 5m x 5m and 10m x 10m
Binoculars
Clinometer
Identification Guide (e.g. Richmond: Guide to the Seashores of East Africa)
Bird identification book (e.g. Birds of Madagascar, A Photographic Guide or Birds of the Indian Ocean Islands)
Reptile identification book (e.g. A Fieldguide to the Amphibians and Reptiles of Madagascar)

2.2 Reptile Trapping

Reptile trapping is either opportunistic or through using pitfall traps with drift fences. A pitfall trap is set up for a total of eight days and nights before it is moved to a different location. It comprises of three rows of buckets dug into the ground 10 metres apart, with the rims approximately 15cm below the surface. The three rows are arranged so they radiate out 100 metres from a central point. Each bucket has several small holes made in the bottom for drainage and has the handle removed.

A trench is dug along the centre of each row, approximately 20cm deep, running through the middle of each bucket. Bamboo poles are dug into the ground at regular intervals along this trench and a continuous 50cm wide plastic sheet attached to each to create the drift fence. The plastic is fixed to the same side of each pole with 20cm buried in to the trench and 30cm remaining above ground. Ideally the plastic should be coloured and not patterned. Where the plastic sheet passes over a bucket, two slits are made in the plastic at the width of the bucket to create a hanging flap.

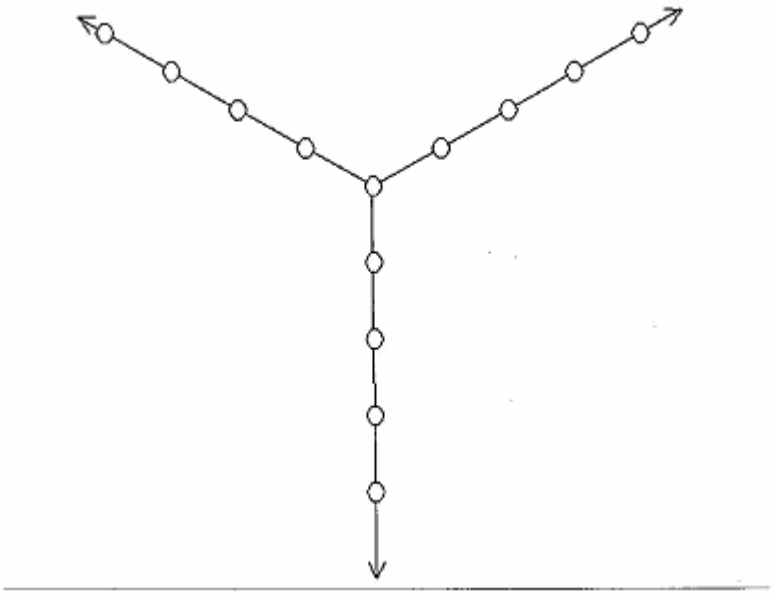


Figure 6: Diagram showing the layout of the 3-arm bucket line pitfall trap. Circles indicate buckets dug into the ground at 10 metre intervals, and the arrows show the positioning of the bamboo pole-supported plastic.

The traps are checked a minimum of three times a day. Any repairs to the traps are made and each bucket examined. Any reptiles found in a bucket are gently removed and brought to camp for identification. Any insects, arachnids or mammals caught in the traps are released. Sand and leaf litter that collects in the buckets is also removed.

Ensuring the reptile is not harmed, the following data are recorded on a pre-prepared data sheet (Appendix 1, Figure 22):

- Species – Established using Glaw and Vences, (1994)
- Snout to vent length (mm) (SVL)

- Tail length (mm) (TaL) – The distance from the vent to the end of the tail
- Total length (TL) – The SVL length and the TaL length combined

- Time of day specimen was found
- Row number specimen was caught – Each row is labelled with a number
- Bucket number specimen was caught – Numbered starting from the outermost bucket
- Whether specimen is an adult or juvenile
- Whether the specimen has been marked, already has a mark or is released without a mark. Marks are made by dabbing a small spot of nail varnish on the dorsal side of the tail base.

All specimens are released in the vicinity of the trap they were caught in immediately after measurements are taken.

When the traps are dismantled care should be taken so as to allow the drift fence to be reused at the next location.

Reptiles that are caught opportunistically are recorded in the 'Reptile Log Book'. The same measurements are taken as before. When tortoises are encountered their measurements are recorded on separate data sheets as shown in appendix 1, figure 23.

When a reptile is identified this should be verified by a member of staff. If a positive identification can not be made than high resolution digital photographs are taken if such equipment is available, detailed sketches drawn or alternatively a specimen may be killed and preserved.

2.3 Nocturnal Flying Insect Trapping

A malaise trap is set up shortly before dusk in a natural clearing. The base is pegged securely to the ground while the top is attached to nearby vegetation, ensuring the walls of the trap are taut. Approximately 5cm of ethanol are placed in the collection container and the trap left overnight.

Each morning the ethanol, containing the specimens caught during the previous night, is poured into a suitable container, labelled and the malaise trap disassembled. This procedure is repeated each evening and following morning.

Different locations may be used for the malaise trap with GPS coordinates for each being recorded.

2.4 Bird Surveys

2.4.1 Casual Bird Walks

Bird surveys are completed using the simple method of a group of observers walking through the spiny forest and or along the shore recording any bird species encountered. A species list can consequently be generated. An alternative method can be that the surveyors walk to a predetermined spot and stay there for a specific length of time, e.g. 1 hour, recording bird species which appear. In order to maximise the bird species seen and to minimise any disturbance observers are to be as quiet as possible while surveying.

When a bird is spotted observers must attempt to identify it to species level using the identification guides. In their note books they must record the following:

- Time bird spotted.
- Species (if can identify it in the field).
- Habitat e.g. Euphoribia scrub or shore.
- Number of birds seen.
- Height seen above the ground.
- Bird description. To aid in a positive identification the description must included an annotated sketch including colours, length, markings (e.g. eye strips), leg and feet colour, flight patterns (if seen), bill description (thin, thick, short, pointed etc) and tail shape.
- Bird behaviour.
- Observers.

On returning to camp the bird species is either confirmed or established, again using the bird identification guides, and all information is copied up onto the data sheets (appendix 1, figure 24). When entering the species name both the common and Latin names must be recorded as common names can vary with identification guide. Care must be taken to copy information from note books exactly and accurately. The route taken must additionally be recorded onto the data sheets.

2.4.2 Bird density/habitat association surveys (detailed point transects)

Suitable for: comparative studies of species densities in areas where surveys take place, studying relationships between relative species abundance, richness etc, with habitat associations.

Birds are surveyed using distance sampling. The variable circular plot method is used (Reynolds *et al.* 1980) rather than linear transects as in sparse spiny forest habitats the method is effective for point counts and allows subsequent mapping of survey points with GPS/GIS.

Count points are laid out systematically as a N-S, E-W grid, calculated using *Microsoft Excel* (Figure 7) and *GPS Trackmaker* (Figure 2) and then download directly onto a GPD. 36 points (6x6) are positioned at least 100m apart to ensure their independence (Bibby *et al.* 2000), providing a survey area of 2500m^2 . If survey time and resources exist, lay out multiple grids in contrasting habitats (i.e. disturbed, non-disturbed etc).

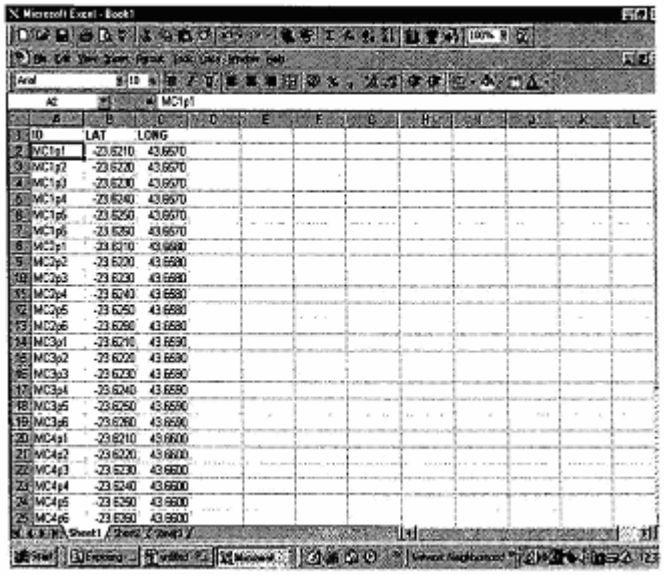


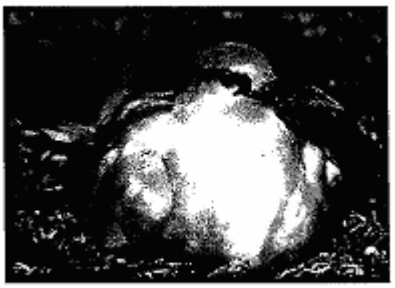
Figure 7: Designing the point transect grid by simple calculations with Microsoft Excel

2.4.3 Red Tailed Tropic Bird Surveys

The monitoring programme of red tailed tropic bird (*Phaethon reubricauda*) on *Nosy Ve*, should be conducted every month at a convenient time. Depending on the number of surveyors, three or four teams are needed. Each team is equipped with binoculars, a GPS unit, and a quantity of numbered tags.

Teams systematically sweep the island checking under all likely nesting bushes (usually large busy non-aloe species, of which there are few). Once a nest (a simple scrape in the ground) is located, the number of adults, juveniles, chicks or eggs is recorded. The definition of each is as follows:

Adult: Large, white seagull-like bird with some streaks of black on the wings. Adults have red bills and distinctive red tail streamers (usually two).



Juvenile : A black beak instead of red, the head is free from down, but they may have a few tufts on the body.

Chick: Covered in grey, fluffy down which is replaced by feathers as they get older. If the head is covered in down, even if the rest of the body is feathered, the bird is classified as a chick.

The GPS co-ordinates and tag number of the nest are recorded. If it is a new nest a tag is tied to the bush above it.

Every 30 minutes an aerial count of birds is made, to account for any that may have been disturbed during surveying.

3. NON-SPECIALIST VOLUNTEER TRAINING

3.1 Fish Training

Training for fish species identification combines theory and practical surveys, using a series of lectures on reef survey, and identification of commercial and reef fish species using slides and ID books. An introduction to survey methods and the use of underwater slates is also done prior to training in the water. Each researcher must complete four training snorkel surveys and six training diving surveys, initially with an experienced researcher to enable cross comparison of results. In later training surveys the pairs will both survey either fish or substratum and compare results.

3.2 Size Estimation

A 100m length of line is laid along sand adjacent to the reef in approximately 6m depth of water. 50 cut out sections of plastic are attached at intervals along the line. Each plastic section is approximately 5cm wide and they range in lengths of 10cm from a minimum size of 10cm to a maximum of 100cm. The distribution of lengths is approximately normal. A reference stick showing 10cm size intervals is placed at the beginning of the line. Observers remain 3m from the line and swim its length estimating the size of each plastic strip. Following the survey each distribution of sizes recorded is entered on the computer and compared with the 'true distribution'. Observers are then informed as how well they estimated sizes before they repeat a trail. It has been found that following three trials observers obtain a size distribution not significantly different to the true distribution. Thus we can say that the observers can now estimate fish size distributions underwater to a level of accuracy sufficient for the requirements of fisheries management planning.

3.3 Benthic work

Training for benthic species/morphology identification should take the form of point outs and lagoon walks at low tide with staff. Lectures should also be given with pictures and diagrams.

3.4 Terrestrial surveys

Training for terrestrial species identification and survey methods should take place as lectures, and then with staff guiding practical aspects in the field.

3.5 Quality control

Quality control for all sub-tidal species identification skills should take the form of strictly regulated tests, on computer, whereby a photographic slide show is set up and automatically scans through the pictures for volunteers to identify. For fish training, to best simulate a survey, each photograph should only remain on the screen for a maximum of 7 seconds. There are 100 slides (some species are shown twice, perhaps in a different setting) and volunteers are required to achieve pass mark of 95%. Pictures for tests should not be easy, side-on images (i.e. scans from Collins Pocket Guide: Coral Reef Fishes), but should include low quality, project-taken photos to further emulate conditions on a survey. Quality control for coral identification should take a similar form.

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Appendix 1

Time (min)	0/ 3	3/ 6	6/ 9	9/1 2	12/ 15	15/ 18	18/ 21	21/ 24	24/ 27	27/ 30
Depth (m)										
SUBSTRATE										
Mud/silt										
Rock										
Rubble										
Sand										
Shell										
BIOLOGICAL COVER										
Algae										
Coral: hard										
Coral: soft										
Seagrass										
Sponge										
OTHER FACTORS										
RKC										
Dominant										
Homo/Hetero										
Rugosity										
PRESENCE OF HARD CORAL FORMS										
Branching										
Digitate/Submassive										
Encrusting										
Fire										
Foliose										
Massive										
Mushroom										
Plate										
Sea fans										
Sea whips										
Staghorn										
Table										

Figure 1: A survey slate used during the P6 survey method described in section 1.1.1.1

Name: Buddy:		Date: Site:		Depth:	
Distance	Code	Distance	Code	Categories	
				Sand	SSA
				Mud/Silt	SMS
				Rubble	SRU
				Debris	SDE
				Rock	SRO
				Dead Coral Formation	SCF
				Dead Coral Debris	SCD
				Branching	CBR
				Massive	CMA
				Sub Massive	CSU
				Encrusting	CEN
				Digitate	CDI
				Table	CTA
				Foliose	CFL
				Mushroom	CMU
				Fire	CFC
				Sponge	OSP
				Anemone	OAN
				Ascidian	OAS
				Zoanthid	OZO
				Soft Coral	OSC
				Gorgonian	OGW
				Filamentous Algae	OFA
				Coralline Algae	OCA
				Other Algae	OAO
				Sea Grass	OSG

Figure 2: A survey slate used during the 30 metre LIT survey method described in section 1.1.1.2

Name: Buddy:		Date: Site:		Depth:	
Distance	Code	Distance	Code	Categories	
				Acropora Branching	ACB
				Acropora Columna	ACC
				Acropora Digitate	ACD
				Acropora Digitate	ACE
				Acropora Foliate	ACF
				Acropora Massive	ACM
				Acropora Table	ACT
				Branching	CB
				Columna	CC
				Digitate	CD
				Encrusting	CE
				Foliate	CF
				Mushroom	CMR
				Massive	CMT
				Table	CT
				Fire	FCM
				Gorgonian	OTG
				Hydroid	OTH
				Soft Coral	SC
				Anemone	OTA
				Clam	OTC
				Sponge	SP
				Zoanthid	ZO
				Tunicate	OTT
				Halemida Algae	HA
				Encrusting Coralline	EA
				Turf Algae	T
				Fleshy Algae	FA
				Bleached Coral	DCB
				Dead Coral Formation	DCF
				Dead Coral Debris	DCD
				Rock	RK
				Large Rubble	RL
				Small Rubble	RS
				Silt	SI
				Sand	SA

Figure 3: A survey slate used during the 10 metre LIT survey method described in Section 1.1.1.4

Family	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm	>60cm (specify)
Barracuda							
Emperors							
Flatheads							
Fusiliers							
Goatfishes							
Groupers							
Jack and trevallys							
Moray eels							
Needlefishes and halfbeaks							
Parrotfishes							
Rabbitfishes							
Sharks and rays							
Snappers							
Soldier/squirrelfishes							
Surgeonfishes							
Sweetlips							
Triggerfishes							
Unicornfishes							
Wrasses							
Other							

Figure 4: A survey slate used during commercial fish surveys described in Section 1.1.2

Angelfishes		***Surgeonfishes***	
Ear-spot		Blackstreak	
Emperor		Blue-lined	
Regal		Brushtail tang	
Semicircle		Convict	
Three-spot		Eyestripe	
Two-spined		Goldring	
Yellowbar		Lieutenant	
Butterflyfishes		Palette	
Bennett's		Powder-blue	
Black-backed		Sailfin tang	
Blackburns		Striped bristletooth	
Black pyramid		Thompson's	
Chevroned		***Triggerfishes***	
Klein's		Black	
Lined		Bluethroat	
Longfin bannerfish		Clown	
Longnosed		Mousetache	
Madagascar		Orange-striped	
Masked bannerfish		Picasso	
Meyer's		Redtooth	
Raccoon		Rippled	
Redfin		Scythe	
Saddleback		Wedge	
Somali		Yellow margin	
Spotted		***Unicornfishes***	
Teardrop		Bluespine	
Threadfin		Orangespine	
Vagabond		Spotted	
Yellowhead		***Wrasses***	
Zanzibar		Bird	
Goatfishes		Checkerboard	
Dash-and-dot		Goldbar	
Two-barred		Humphead	
Yellowsaddle		***Other fishes***	
Groupers		Moorish Idol	
Coral hind		This space free for drawing unidentified fishes	
Lyretail			
Peacock			
Potato			
Saddleback			
Squaretail			
White spotted			

Figure 5: A survey slate used during reef fish surveys described in section 1.1.3.1

Name:	Date:	Depth:	
Buddy:	Site:		
Butterflyfish		Triggerfish	
Lined		Redtoothed	
Threadfin		Black	
Saddleback		Yellowmargin	
Blackback		Blue	
Vagabond		Bluethroat	
Teardrop		Scythe	
Bennett's		Clown	
Zanzibar		Orangestriped	
Madagascar		Titan	
Klein's		Wedge-tail	
Yellowhead		Picasso	
Raccoon		Grouper	
Somali		Peacock	
Spotted		Coral	
Redfin		Potato	
Meyers		Blue and yellow	
Chevron		Whitespotted	
Blackburn's		Blacktip	
Black pyramid		Lyretail	
Longnose		Saddleback	
Longfin bannerfish		Surgeonfish	
Masked bannerfish		Desjardins's sailfin	
Angelfish		Brushtail	
Ear-spot		Convict	
Emperor		Powderblue	
Regal		Palette	
Semicircle		Striped	
Three-spot		Eyestripe	
Two-spined		Thompson’s	
Yellowbar		Lieutenant	
Wrasse		Striped bristletooth	
Napoleonfish		Goldring bristletooth	
Checkerboard		Blackstreak	
Goldbar		Orangespine unicorn	
Indian Ocean bird		Bluespine unicorn	
Tripletail		Spotted unicorn	
Barred thicklip		Moorish idol	
Moon		Damselfish	
Six bar		Blue-green	
Goatfish		Two-tone	
Dash-and-dot		Humbug	
Two-barred		Skunk anemonefish	
Yellowsaddle		Sulphur	
Snapper		Pufferfish	
Bluelined		Spotted toby	
Onespot		Blackspotted puffer	
Emperor		Black blotched	
Longface		Other Fish	
Parrotfish			
Bicolour			
Saddled			
Bullethead			

Figure 6: A survey slate used during reef fish surveys described in section 1.1.3c

Name: Date:		Site:
Invertebrate		Tally
Sea anemone	All species	
Flatworm	All species	
Shrimp	Mantis shrimp	
Lobster	Long-legged spiny lobster	
	Ornate spiny lobster	
	Painted spiny lobster	
Gastropods	All *Cymatium* species	
	Horned helmet	
	Red helmet	
	All *Murex* species	
	Spider conch	
	Tiger cowrie	
	All other cowrie species	
	Triton shell	
	Tulip shell	
	All nudibranch species	
Bivalves	Giant clam	
	All reef-boring clam	
	All other clam species	
	Other bivalve	
Cephalopods	All cuttlefish species	
	All octopus species	
	All squid species	
Feather stars	All species	
Brittle stars	All species	
Sea stars	Crown-of-thorns	
	All other sea stars	
Sea cucumbers	All species	
Urchins	All *Diadema* species	
	Echinometra mathaei	
	All *Echinostrephus* species	
	Tripneustes gratilla	

Figure 7: A survey slate used during general invertebrate surveys described in Section 1.1.4.1

Name:	Date:	Depth:	
Buddy:	Site:	Horizontal Visibility:	
Coral Damage:	Sources:	Level:	
Litter:	Type:	Level:	
Sedimentation:	Level:		
Fishing:	Method:	Level:	
Coral disease:			
Bleaching:	Colony Morph:	Size of Colony:	% Bleached:
Urchins:	Species:	Numbers:	
Crown-of-Thorns:	Numbers:		

Figure 8: A survey slate used during general invertebrate and observational surveys described in section 1.1.4.2

Name:	Date:				
Buddy:	Site:				
Quadrat No:	Start Time:		End Time:		
Species:	Depth:	Substrate:	Length:	Time Stop:	Time Resume:
Quadrat No:	Start Time:		End Time:		
Species:	Depth:	Substrate:	Length:	Time Stop:	Time Resume:
Quadrat No:	Start Time:		End Time:		
Species:	Depth:	Substrate:	Length:	Time Stop:	Time Resume:
Unidentified:					
Time Stop:	Depth:		Length:		
Time Resume:	Substrate:		Quadrat No:		
Rhinophores:	Gills:		Skirt:	Ceratta:	
Time Stop:	Depth:		Length:		
Time Resume:	Substrate:		Quadrat No:		
Rhinophores:	Gills:		Skirt:	Ceratta:	

Figure 9: A survey slate used during nudibranch surveys described in section 1.1.4.3

Cetacean Shore-watch Data Sheet

Date:	Obs. 1	Obs.	Weath	Sea state	Wind force	Wind dir.	Tide state	Enc?	Est. Nº. (ind.s)	Est. Nº. (pods)	Dist. o/sh.	Bearing	Observations
6am													
7am													
8am													
9am													
10am													
11am													
12pm													
1pm													
2pm													
3pm													
4pm													
5pm													
6pm													

Sheet entered date:

Date:	Obs. 1	Obs.	Weath	Sea state	Wind force	Wind dir.	Tide state	Enc?	Est. Nº. (ind.s)	Est. Nº. (pods)	Dist. o/sh.	Bearing	Observations
6am													
7am													
8am													
9am													
10am													
11am													
12pm													
1pm													
2pm													
3pm													
4pm													
5pm													
6pm													

Sheet entered date:

Figure 10: A cetacean shore watch data sheet

Sheet number:	Encounter number:

Opportunistic Cetacean Data Sheet

(Boat based observations)

Date		
Time start		
Time end		
Position (name or nearest location)		
Long.	**START**	
Lat.		
Long.	End	
Lat.		
Species (HBW/HBD/BND/SD)		
Est. Number of individuals	Min.	
	Max.	
	Best guess	
Observer 1st sighting		
Destination of boat		
Motor/anchor/sail?		
Reason for trip (diving; sat camp etc.)		

Environmental

	6.1.1	**End**
Depth (m.)		
Sea state		
Wind force		
Tide state		
Tide height		
Cloud brightness		

HBW:	*Humpback whale*
HBD:	*Humpback dolphin*
BND:	Bottlenose dolphin
SD:	*Spinner dolphin*

Behaviour

Dive times	Time down	Time up	T°t. time (sec.s)
Individual 1			
Individual 2			
Individual 3			
Individual 4			
Individual 5			
Individual 6			
Individual 7			
Individual 8			
Individual 9			

Behaviour 1	
Behaviour 2	
Behaviour 3	
Behaviour 4	
Behaviour 5	
Behaviour 6	
Behaviour 7	

Breach: BR	*Spyhop*: SH
Half breach: ½ BR	*Sexual*: SX
Porpoising: PO	*Bowriding*: BR
Sharking: SH	*Tailout*: TO
Tailslap: TS	*Foraging*: FO
Chinslap: CS	*Feeding*: FE

Observational notes:

Sheet entered date:

Figure 11: An opportunistic cetacean sighting data sheet

Cetacean Transect Data Sheet

Sheet number:	Transect ref:

Observers:							

Transect N^{o}.		From (*embark*)	
Date		To (*destination*)	
Time start		Transect length (Km)	
Time end		Boat speed start (Km^2)	
T^{ot}. Time (mins.)		Boat speed mid (Km^2)	
Transect name		Boat speed end (Km^2)	

	(°)		(*Km*)
Bearing 1		*Dist. 1*	
Bearing 2		*Dist. 2*	
Bearing 3		*Dist. 3*	
Bearing 4		*Dist. 4*	
Bearing 5		*Dist. 5*	
Bearing 6		*Dist. 6*	

6.1.2 Weather/Sea Conditions

	Start (time)	*Mid (time)*	*End (time)*	Mean
Sea state				
Wind force				

Wind direction	
Time high tide	
Time low tide	
Tide state start	
Tide state end	

6.1.3 Encounter

Number of encounters	
Species	
Observer	
Data sheet reference	

Notes:

Sheet entered date:

Figure 12 : A cetacean transect data sheet

Sheet number:	Encounter number:

Cetacean Encounter Data Sheet

Date		
Time start		
Time end		
Position (name or nearest location)		
Long.	**START**	
Lat.		
Long.	End	
Lat.		
Species (HBW/HBD/BND/SD)		
Est. Number of individuals	Min.	
	Max.	
	Best guess	
Observer 1st sighting		

Environmental

	6.1.4	**End**
Depth (m.)		
Sea state		
Wind force		
Tide state		
Tide height		
Cloud brightness		

HBW:	*Humpback whale*
HBD:	*Humpback dolphin*
BND:	*Bottlenose dolphin*
SD:	*Spinner dolphin*

Density

Angle of 1st sighting from track (°)	
Distance from boat to indiv. (m.)	
Perpendicular distance (m.)	
Closest distance (m.)	
Distance from shore (approx. m.)	

Photo id.

Film No.	
Frame start	
Frame end (gap shot)	
Id?	
Dig. pic. file names	

Behaviour

Dive times	Time down	Time up	Tot. time (sec.s)
Individual 1			
Individual 2			
Individual 3			
Individual 4			
Individual 5			
Individual 6			
Individual 7			
Individual 8			
Individual 9			

Behaviour 1	
Behaviour 2	
Behaviour 3	
Behaviour 4	
Behaviour 5	
Behaviour 6	
Behaviour 7	

Breach: BR	*Spyhop*: SH
Half breach: ½ BR	*Sexual*: SX
Porpoising: PO	*Bowriding*: BR
Sharking: SH	*Tailout*: TO
Tailslap: TS	*Foraging*: FO
Chinslap: CS	*Feeding*: FE

Observational notes:

Figure 13: A cetacean encounter data sheet

Sheet entered date:

Date:		**Start Time:**	
Landing Site:		**End Time:**	
Survey Day:		**Total Survey Time:**	
Weather:		**Tidal State during survey:**	
Surveyors:		**Spring/Neap?**	

Catch Number	Total Weight (kg)	Fish Species	TBL (mm)	SL (mm)	FL (mm)	Notes

Key: **Catch Number:** **F: Fish Catch**
G: Gleaner Catch
O: Other (shark/turtle etc.)

TBL: Total Body Length
SL: Standard Length
FL: Fork Length

Figure 14: A fish landing site data sheet used during surveys described in section 1.1.6

Date:		**Start Time:**	
Landing Site:		**End Time:**	
Survey Day:		**Total Survey Time:**	
Weather:		**Tidal State during survey:**	
Surveyors:		**Spring/Neap?**	

Gleaner Number	Weight (kg)	Dorsal to Mantle Length (mm)	Sex

Figure 15: An octopus landing site data sheet used in surveys as described in section 1.1.6

Date:		**Start Time:**	
Landing Site:		**End Time:**	
Survey Day:		**Total Survey Time:**	
Weather:		**Tidal State during survey:**	
Surveyors:		**Spring/Neap?**	

Species:	
Diagram	
Number of scales between eyes (2 or 4)?	
Number of pairs of lateral scutes (5 or 6 or more)?	
Curved Carapace Length (mm):	
Method used to catch the turtle:	
Where was it caught?	
Any presence of a tag?	
If yes what is printed on the tag (make sure check both sides of tag)?	
Notes:	

Figure 16: A turtle landing site data sheet used during surveys as described in section 1.1.6

Date:		Bearing:		Survey Team:	
GPS:		Time Start:			
Transect No:		Time End:			
Quadrat No:		Species Present:		Total No:	
Depth:					
Species	Teste Width (mm)	Colour	% Hatted	Hatting Type	Substrate
Quadrat No:		Species Present:		Total No:	
Depth:					
Species	Teste Width (mm)	Colour	% Hatted	Hatting Type	Substrate
Quadrat No:		Species Present:		Total No:	
Depth:					
Species	Teste Width (mm)	Colour	% Hatted	Hatting Type	Substrate

Figure 17: A pre-drawn survey slate used during urchin surveys as described in section 1.2.1

Date:		**Start Time:**	
Location:		**End Time:**	
Weather:			
Surveyors:			

Start GPS	**Bearing**	**Pacers**			**Notes/GPS**
		**	**	**	

Key: ** Pacers initials.

Figure 18: A mangrove mapping data sheet as used in surveys described in section 1.3.1.1

Date:		**Start Time:**	
Location:		**End Time:**	
Weather:		**Transect Number:**	
Surveyors:		**Intertidal Zone:**	
		Quadrat Size:	

GPS Co-ordinates

Transect External Edge:		**Transect Internal Edge:**	
Intertidal Zone External Edge:		**Intertidal Zone Internal Edge:**	

Species 1:		**Species 2:**	
Number of adults:		Number of adults:	
Number of saplings:		Number of saplings:	
Number of seedlings:		Number of seedlings:	
Adult girth 1:		Adult girth 1:	
Adult girth 2:		Adult girth 2:	
Adult girth 3:		Adult girth 3:	
Dead trees:		Dead trees:	
Any other observations:		Any other observations:	
Species 3:		**Species 4:**	
Number of adults:		Number of adults:	
Number of saplings:		Number of saplings:	
Number of seedlings:		Number of seedlings:	
Adult girth 1:		Adult girth 1:	
Adult girth 2:		Adult girth 2:	
Adult girth 3:		Adult girth 3:	
Dead trees:		Dead trees:	
Any other observations:		Any other observations:	

Adults: Girth greater than 4cm and greater than 1m tall.
Saplings: Girth less than 4cm and greater than 1m tall.
Seedlings: Height less than 1m.

Figure 19: A mangrove transect line data sheet used during density and species composition transects as described in section 1.3.1.2

Date:		**Start Time:**	
Location:		**End Time:**	
Weather:		**Belt Transect Number:**	
Surveyors:		**Bearing:**	

GPS Co-ordinates

Start GPS:		**End GPS:**	

Species 1:		**Species 2:**	
Number of adults:		Number of adults:	
Number of saplings:		Number of saplings:	
Number of seedlings:		Number of seedlings:	
Dead trees:		Dead trees:	
Any other observations:		Any other observations:	
Species 3:		**Species 4:**	
Number of adults:		Number of adults:	
Number of saplings:		Number of saplings:	
Number of seedlings:		Number of seedlings:	
Dead trees:		Dead trees:	
Any other observations:		Any other observations:	

Adults: Girth greater than 4cm and greater than 1m tall.
Saplings: Girth less than 4cm and greater than 1m tall.
Seedlings: Height less than 1m.

Figure 20: A mangrove belt transect data sheet used in density and species composition surveys as described in section 1.3.1

Date:		**Start Time:**	
Location:		**End Time:**	
Weather:			
Surveyors:			

Time	Species (Common and Latin name)	Where seen (tree, scrub, ground etc.)	Number seen	Description (including any measurements taken) and Behaviour	Observer

Figure 21: A mangrove opportunistic bird and reptile data sheet used during surveys described in section 1.3.1.3

Date: Name:

Day: 1 2 3 4 5 6 7 8

Time	Line No.	Bucket No.	Species	SV Length (mm)	TaL Length (mm)	TL Length (mm)	Adult/Juv	Marked

Figure 22: A reptile pitfall trap data sheet used in surveys as described in section 1.3.2

Region:	Lat.:	Taxon:	
Area:	Long.:	Genus:	
Phase No:		Species:	
Collectors:	Time:	Sub-species:	
Date:			
Capture Method:		Specimen Active/Inactive	
TOPOGRAPHY			
Valley:	Hill Top:	Gentle Hillside:	Alt.:
Ridge:	Plateau:	Steep Hillside:	Slope:
Gully:	Plains:	Other:	Aspect:
VEGETATION TYPE			**VEG. COVER**
Spiny Scrub:	Lowland Forest:		Ground Layer (%):
Disturbed S Scrub:	Submontane Forest:		Shrub Layer (%):
Gallery Forest:	Montane Forest:		Tree Canopy (%):
Disturbed G Forest:	Marsh/Swamp:		
Dry Spiny Forest:	Grassland:		Canopy Height (m):
Rocky/Barren:	Cultivation:		
MICROHABITAT			**WATER ASSOCIATION**
Tree Bark:	Leaf Litter:	Water Edge:	River:
Tree Base:	Grass:	Bare Ground:	Stream:
Branch:	Rock:	Burnt Land:	Pond/Lake:
Leaf:	Path:	Other:	Marsh:
Log:	Water:		None:
Metres Above Ground:			Dist. To Water:
Associated Plant Spp.:			
SEX		**COLOUR NOTES**	
AGE			
Years Old:			
Unknown:			
BIOMETRICS			
Weight (g):			
Carapace	Curved Length (mm):		
	Curved Width (mm):		
	Length (mm):		
	Height (mm):		
Plastron	Length (mm):		
	Width (mm):		
	Height (mm):		
Total Height (mm):			
Other:			DNA Sample Taken:

Figure 23: A tortoise data sheet used in surveys described in section 1.3.2

Route:

Date	**Time**	**Species**	**Habitat**	**Number**	**Height**	**Description and Behaviour**	**Observers**

Figure 24: A bird survey data sheet as described in section 1.3.4

Appendix 2

Table 1: Descriptions of fish families, based on Lieske and Myers (1994), recorded during commercial fish surveys as described in section 1.1.2

Family	Description
Barracuda (Sphyraenidae)	Elongate silvery piscivores. Two widely spaced dorsal fins, small scales, and a pointed head with a sharp-toothed large mouth
Emperors (Lethrinidae)	Medium to large fishes with a large eye set high up on a sloping forehead. Continuous dorsal fin, emarginated to forked tails, and thickened lips
Flatheads (Platycephalidae)	Elongate, flattened, bottom-dwelling (benthic) fishes. Bony, spiny body with two dorsal fins
Fusiliers (Caesonidae)	Elongate fusiform planktivores with small protusible mouths, small scales, continuous dorsal fins and forked tails. In this area, fusiliers usually have black dots at base of pelvic fins and/or at tips of caudal fin
Goatfishes (Mullidae)	Medium elongate bottom feeders with two dorsal fins and two sensory barbels on the chin for sourcing invertebrate prey
Groupers (Epinephenili)	Robust-bodied fishes with large mouths. One continuous dorsal fin, spiny anteriorly and rounded posteriorly
Jacks and trevallys (Carangidae)	Medium to large silvery fishes with two dorsal fins, a narrow caudal peduncle and forked tail. Usually feature a pronounced lateral line
Moray eels (Muraenidae)	Extremely elongate fishes with large, many-toothed mouths. Accurately estimating the size of crevice-dwelling morays may be impossible
Needlefish and halfbeaks (Belonida and Hemiramphidae)	Elongate, silvery, surface-dwelling piscivores and omnivores. Single, posterior dorsal fin and an abdominal ventral fin
Parrotfishes (Scaridae)	Medium to large fishes with a beak-like, toothless mouth. Large cycloid scales and a continuous dorsal fin
Rabbitfishes (Siganidae)	Rugby ball-shaped herbivores with a small terminal mouth and a continuous, spiny dorsal fin
Sharks and rays (Chondrichthyes)	Any cartilaginous fishes
Snappers (Lutjanidae)	Medium to large fishes with a continuous dorsal fin and an emarginated to forked tail. Often possess a very pointed operculum
Soldier/squirrelfishes (Holocentridae)	Large-eyed, bony fishes, predominantly red in colour
Surgeonfishes (Acanthuridae)	Laterally compressed fishes with continuous dorsal and anal fins, and one sharp blade located at the base of the tail
Sweetlips (Haemulidae)	Medium to large invertivores with thick lips, continuous dorsal fins, flattish underside, and truncate to rounded tails
Triggerfishes (Balistidae)	Rhomboid-shaped fishes with a small terminal mouth
Unicornfishes (Nasinae)	As surgeonfishes, but with two bony plates at the base of the tail. May have an anterior protrusion
Wrasses (Labridae)	Typically with terminal mouth, slightly thickened lips, elongated body and a single unnotched dorsal fin
Others	Any other commercially fished organism. Includes tuna, marlin, turtles, dolphins, whales, dugongs, cuttlefish and squid

Table 2: The species list of reef fish used during surveys described in section 1.1.3.1, including defining characteristics and page numbers of pictures in Lieske and Myers, 1994.

Scientific Name	Common Name	Page	Defining Characteristics
Chaetodontidae	Butterflyfish		
Chaetodon lineolatus	Lined butterflyfish	57	Vertical lines, black back
Chaetodon auriga	Threadfin butterflyfish	57	Spot, thread, no chevrons
Chaetodon falcula	Saddleback butterflyfish	57	Vertical lines, 2 blotches on back
Chaetodon melannotus	Blackback butterflyfish	57	Horizontal lines, black back
Chaetodon vagabundus	Vagabond butterflyfish	57	Black back, no chevrons
Chaetodon unimaculatus	Teardrop butterflyfish	58	Upside down tear on side
Chaetodon bennetti	Bennett's butterflyfish	58	Black spot & 2 blue smiles on side
Chaetodon zanzibarensis	Zanzibar butterflyfish	58	Sunset over Zanzibar
Chaetodon madagaskariensis	Madagascar butterflyfish	58	Chevrons, orange rear, white body
Chaetodon kleinii	Klein's butterflyfish	58	Belt holding up orange Calvin Klein jeans
Chaetodon xanthocephalus	Yellowhead butterflyfish	58	Yellow head, white body, faint chevrons
Chaetodon lunula	Raccoon butterflyfish	59	Black & white racoon pattern on face
Chaetodon leucopleura	Somali butterflyfish	60	Smiley/Somali face
Chaetodon guttatissimus	Spotted butterflyfish	60	Pale body, spots arranged in diagonal rows
Chaetodon trifasciatus	Redfin butterflyfish	62	Blue, horizontal lines, faint red dorsal fin
Chaetodon meyeri	Meyers butterflyfish	62	White body, black diagonal/horizontal lines
Chaetodon trifascialis	Chevron butterflyfish	63	Chevrons, black tail, yellow dorsal & ventral fins
Chaetodon blackburnii	Blackburn's butterflyfish	63	Sunburnt tourist
Hemitaurichthys zoster	Black pyramid butterflyfish	64	Black head, white body, black tail
Forcipiger flavissimus	Longnose butterflyfish	65	Long nose, yellow body
Heniochus acuminatus	Longfin bannerfish	66	2 black bars, white face
Heniochus monoceros	Masked bannerfish	66	2/3 black bars, black face
Pomacanthidae	Angelfish		
Pomacanthus chrysurus	Ear-spot angel	72	Dark body, white bars, blue lines on face, spot
Pomacanthus imperator	Emperor angel	72	Yellow body, blue horizontal lines
Pygoplites diacanthus	Regal angel	72	Yellow body, white bars edged in black
Pomacanthus semicirculatus	Semicircle angel	72	Green body with blue smile on operculum
Apolemichthys trimaculatus	Three-spot angel	67	Yellow body, blue lips, spot on top of head
Centropyge bispinosus	Two-spined angel	69	Blue, orange belly, black bars
Pomacanthus maculosus	Yellowbar angel	73	Grey body, yellow botch on flank
Acanthuridae	Surgeonfish		
Zebrasoma desjardinii	Desjardins's sailfin tang	124	Large D&V fins, pale bars, face & belly spotted
Zebrasoma scopes	Brushtail tang	124	Circular, brown body, white scalpel
Acanthurus triostegus	Convict surgeonfish	124	Spot above & below scalpel
Acanthurus leucosternon	Powderblue surgeonfish	124	Black face, blue body, yellow D & V fins
Paracanthurus hepatus	Palette surgeonfish	124	Dark blue belly & face, black back with blue spot
Acanthurus lineatus	Striped surgeonfish	125	White belly, blue lines on yellow body
Acanthurus dussumieri	Eyestripe surgeonfish	125	Pale yellow body, dark yellow stripe through eye
Acanthurus thompsoni	Thompson's surgeonfish	126	Black body & face, white tail
Acanthurus tennentii	Lieutenant surgeonfish	126	Kiss/lieutenant stripes behind head
Ctenochaetus striatus	Striped bristletooth	126	Blue, broken lines over brownish body & head
Ctenochaetus strigosus	Goldring bristletooth	126	Yellow ring around eye
Acanthurus nigricauda	Blackstreak surgeonfish	127	Black dash behind eye
Naso lituratus	Orangespine unicornfish	128	Grey body, 2 pairs of orange scalpels
Naso unicornis	Bluespine unicornfish	128	2 pairs of blue spines, green body
Scientific Name	**Common Name**	**Page**	**Defining Characteristics**
Acanthuridae (Cont.)	Surgeonfish (Cont.)		

Naso brevirostris	Spotted unicornfish	128	White collar, rest brown, brown bars & spots
Zanclidae	Moorish idol		
Zanclus cornutus	Moorish idol	124	Orange splodge on snout
Balistidae	Triggerfish		
Odonus niger	Redtoothed triggerfish	132	Blue body, red tooth
Melichthys niger	Black triggerfish	132	Black with white line at base of D&V fins
Pseudobalistes flavimarginatus	Yellowmargin triggerfish	132	Large, pale body, yellow margin to D&V fins
Pseudobalistes fuscus	Blue triggerfish	132	Uniform blue, blue ripples
Sufflamen albicaudatus	Bluethroat triggerfish	133	Blue throat, orange tail with white peduncle
Sufflamen bursa	Scythe triggerfish	133	Pale body, dark curved line through eye
Balistoides conspicillum	Clown triggerfish	133	Black body, white spots on belly, orange lips
Balistapus undulates	Orangestriped triggerfish	133	Green body, orange diagonal lines
Balistoides viridescens	Titan triggerfish	133	Large, brown/orange body, dark spots, moustache
Rhinecanthus rectangulus	Wedge-tail triggerfish	133	Black wedge on peduncle, black streak eye to vent
Rhinecanthus aculeatus	Picasso triggerfish	133	Black & blue through eye, ‘handprint’ on body
Epinephelini	Grouper		
Cephalopholis argus	Peacock grouper	24	Brown with blue spots over body, fins blue
Cephalopholis miniata	Coral grouper	25	Red with blue spots over body
Epinephelus tukula	Potato grouper	26	Pale body, large black spots
Epinephelus flavocaeruleus	Blue and yellow grouper	26	Blue body, yellow fins
Epinephelus coeruleopunctatus	Whitespotted grouper	26	Dark body, large white blotches
Epinephelus fasciatus	Blacktip grouper	26	Orange tiger stripes, black tipped D fin
Variola louti	Lyretail grouper	29	Sickle shaped tail, red body, yellow edge to fins
Plectropomus laevis	Saddleback grouper	29	Dark saddles along back, pale body
Labridae	Wrasse		
Cheilinus undulates	Napoleonfish	92	Bump on head, black streak behind eye, large
Halichoeres hortulanus	Checkerboard wrasse	98	Yellow spot behind head, above pectoral fins
Thalassoma hebraicum	Goldbar wrasse	103	Vertical yellow stripe behind pectoral fin
Gomphosus caeruleus	Indian Ocean bird wrasse	101	Cigar shape with long snout
Mullidae	Goatfish		
Parupeneus barberinus	Dash-and-dot goatfish	54	Black through eye along body, spot on peduncle
Parupeneus bifasciatus	Two-barred goatfish	54	2 black bars on pale body, red eye with black spot
Parupeneus cyclostomus	Yellowsaddle goatfish	55	Yellow saddle on peduncle, blue lines on face

Table 3: Additions to the species list of reef fish used during surveys described in section 1.1.3.2, including defining characteristics and page numbers of pictures in Lieske and Myers, 1994.

Scientific Name	Common Name	Page	Defining Characteristics
Lutjanidae	Snappers		
Lutjanus kasmira	Bluelined snapper	44	Yellow body, blue lines, white belly, yellow lines
Lethrinidae	Emperors		
Lethrinus olivaceus	Longface	53	Very elongated snout
Pomacentridae	Damselfish		
Chromis viridis	Blue-green chromis	78	Blue/green with forked tail
Chromis dimidiate	Two-tone chromis	79	Black brown head & body, white rear & tail
Dascyllus aruanus	Humbug dascyllus	82	3 black bars on white body, black D fin

Table 4: Additions to the species list of reef fish used during surveys described in section 1.1.3.3, including defining characteristics and page numbers of pictures in Lieske and Myers, 1994.

Scientific Name	Common Name	Page	Defining Characteristics
Lutjanidae	Snappers		
Lutjanus monostigma	Onespot snapper	44	Yellow/golden body, one spot on flank
Pomacentridae	Damselfish		
Amphiprion akalloisos	Skunk anemonefish	75	Orange with white stripe along back
Pomacentrus sulfureus	Sulphur damsel	86	Yellow body with black spot under pectoral fin
Tetraodontidae	Pufferfish		
Canthigaster solandri	Spotted toby	137	Blue spots/lines, brown body, large spot on back
Arothron nigropunctatus	Blackspotted puffer	138	Pale body with black spots, black around eyes
Diodon liturosus	Black blotched porcupinefish	138	Black blotches on brown body, spines lie flat
Scaridae	Parrotfish		
Cetoscarus bicolour	Bicolour parrotfish	105	Scales green with pink edge, pink edge to fins
Chlorurus cyanascens	Saddled parrotfish	107	Bump on head, blue front, green rear
Scarus sordidus	Bullethead parrotfish	105	Green body, pink & blue fins, pink through eye
Labridae	Wrasse		
Cheilinus trilobatus	Tripletail wrasse	92	Tail with 3 points, red edge, 2 white bars on body
Hemigymnus fasciatus	Barred thicklip wrasse	100	Black bars on white body, green face with pink
Thalassoma lunare	Moon wrasse	103	Green body, yellow crescent on tail
Thalassoma hardwicke	Six bar wrasse	103	Pale body with vertical black bars

Table 5: Target species list for invertebrate surveys described in section 1.1.4.1

Phylum	Class	Species
Cnidarians	Sea anemone	All species
Platyhelminthes	Flatworm	All species
Crustaceans	Shrimp	Mantis shrimp
	Lobster	Long-legged spiny lobster
		Ornate spiny lobster
		Painted spiny lobster
Molluscs	Gastropods	All *Cymatium* species
		Horned helmet
		Red helmet
		All *Murex* species
		Spider conch
		Tiger cowrie
		All other cowrie species
		Triton shell
		Tulip shell
		All nudibranch species
	Bivalves	Giant clam
		All reef-boring clam species
		All other clam species
		Other bivalve
	Cephalopods	All cuttlefish species
		All octopus species
		All squid species
Echinoderms	Feather stars	All species
	Brittle stars	All species
	Sea stars	Crown-of-thorns
		All other sea stars
	Sea cucumbers	All species
	Urchins	All *Diadema* species
		Echinometra mathaei
		All *Echinostrephus* species
		Tripneustes gratilla

Table 6: Common nudibranchs recorded in the Anakao region

SPECIES	Suborder	Family	Debelius Page Number
Nembrotha pupureolineolata	Doridacea	Polyceridae	178
Chromodoris elizabethina	Doridacea	Chromodorididae	200
Chromodoris africana	Doridacea	Chromodorididae	200
Chromodoris quadricolor	Doridacea	Chromodorididae	200
Chromodoris boucheti	Doridacea	Chromodorididae	202
Chromodoris geminus	Doridacea	Chromodorididae	208
Tamja limaciformis	Doridacea	Polyceridae	
Chromodoris lochi	Doridacea	Chromodorididae	203
Chromodoris geometrica	Doridacea	Chromodorididae	210
Hypselodoris maculosa	Doridacea	Chromodorididae	236
Halgerda tesselata	Doridacea	Halgerda	256
Chromodoris gleniei	Doridacea	Chromodorididae	205
Glossodoris pallida	Doridacea	Chromodorididae	228
Hypselodoris maridadilus	Doridacea	Chromodorididae	239
Phylidiella rosans	Doridacea	Phyllidiidae	267
Glossodoris cincta	Doridacea	Chromodorididae	226
Tamja kushimotoensis	Doridacea	Polyceridae	185
Glossadoris rufomarginatus	Doridacea	Chromodorididae	228
Marionopsis cyanobranchiata	Dendronotacea	Tritoniidae	283
Phestilla lugubris	Aeolidacea	Tergipedidae	305
Phyllidia ocellata	Doridacea	Phyllidiidae	260
Phyllidia varicosa	Doridacea	Phyllidiidae	265
Phylidiella zeylanica	Doridacea	Phyllidiidae	267
Chromodoris hamiltoni	Doridacea	Chromodorididae	
Glossodoris hikuerensis	Doridacea	Chromodorididae	227

Table 7: Urchin species commonly encountered and defining characteristics

Species	Average Test Diameter (cm)	Description
Diadema savignyi	7	Obvious black spines up to 30cm long. Iridescent blue lines radiating around test.
Diadema setosum	7	Obvious black spines up to 30cm long. Conspicuous red/orange ring around anus.
Astropyga radiata	20	Densely packed short (up to 5cm long) spines. Bare zones around anus are pink, bordered with iridescent blue spots. Anal sacs are conspicuous and white.
Echinothrix diadema	9	Primary spines up to 7cm long and banded. Secondary spines orange/pink. Ambulacral spines barbed. Anal sac conspicuous and grey.
Echinometra mathaei	9	Short spines up to 4cm long. Colour variable from black/purple to pink/red. Very common species.
Tripneustes gratilla	15	Very short, usually grey/white, spines up to 2.5cm long. Often well camouflaged with sea grasses, shell fragments etc.
Toxopneustes pileolus	15	Spines reach 3cm in length and are red at base, green to white at tips. Flower-like, toxic pedicellariae are three times spine length.
Heterocentrotus mammillatus	8	Thick, cylindrical spines up to 10cm long and triangular at tips. Often pink.
Echinostrephus molaris	3	Spines up to 3cm long, shorter around the sides. Often grey in colour and found in shallow holes with longer top spines exposed.