Standard Operating Procedures for BIOSS Field Sampling, Data Handling and Analysis

BIOSS REPORT

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Pollution Control and Other Measures to Protect Biodiversity in Lake Tanganyika (RAF/92/G32)

Lutte contre la pollution et autres mesures visant à protéger la biodiversité du Lac Tanganyika (RAF/92/G32)

Le Projet sur la diversité biologique du lac Tanganyika a été formulé pour aider les quatre Etats riverains (Burundi, Congo, Tanzanie et Zambie) à élaborer un système efficace et durable pour gérer et conserver la diversité biologique du lac Tanganyika dans un avenir prévisible. Il est financé par le GEF (Fonds pour l'environnement mondial) par le biais du Programme des Nations Unies pour le développement (PNUD)"	The Lake Tanganyika Biodiversity Project has been formulated to help the four riparian states (Burundi, Congo, Tanzania and Zambia) produce an effective and sustainable system for managing and conserving the biodiversity of Lake Tanganyika into the foreseeable future. It is funded by the Global Environmental Facility through the United Nations Development Programme.

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Preface

This document sets the field sampling methods and subsequent sample processing techniques to be used in work that contributes towards the biodiversity special study. The document has been developed from the biodiversity work-plan, tests of field sampling methods undertaken during training activities in Tanzania and Burundi during 1997 and 1998, and from literature on biodiversity survey techniques from other areas. The document aims to leave in place clear instructions to special study participants, and those involved in biodiversity assessment and monitoring programmes on the lake in subsequent years.

This document does not contain detailed assessment of alternative methods, reviews of literature on sampling theory and biodiversity assessment and discussion of conservation practices. It is intended as a reference and instruction manual for use by biodiversity field teams in Lake Tanganyika, and a record of the methodology used by BIOSS. It should also provide a framework which allows development of additional survey protocols, while maintaining the overall integrity of the regional approach and thus a long term data set for the lake.

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SECTION 1. THE BIODIVERSITY WORKPLAN

1.1 Aims

The main aim of the BIOSS is to support the development of the strategic action plan to manage Lake Tanganyika. The aim of the strategic action plan is:

> "to provide for the regional management of Lake Tanganyika to enable the sustainable management of biodiversity and the livelihood's of present and future generations of lakeside communities."

The specific objectives of the SAP that this study addresses most directly are to 'define and prioritise the management actions required to conserve biodiversity of Lake Tanganyika' and 'enable the Lake Basin Management Committee to provide guidance to the international community on the needs of the Lake Tanganyika region in terms of biodiversity conservation and sustainable use of resources'.

1.2 Objectives

To achieve these aims the BIOSS has four key objectives:

- Review current levels of biodiversity in Lake Tanganyika;

- Identify the distribution of major habitat types, with particular focus on existing and suggested protected areas;

- Suggest priority areas for conservation, based on existing knowledge and recommendations from other SS and supplemented by additional survey work where necessary; and,

- Develop a sustainable biodiversity monitoring programme.

Objectives 1, 3 and 4 will be carried out in close consultation with the other SS teams.

1.3 Overview of Major Elements of the BIOSS Programme

This section gives brief background information on the rationale for the key objectives of the programme. Throughout the project these ideas were developed and communicated through the biodiversity work plan which was used as a working document. The technical details of each programme are explained in Sections 2-5 of this report.
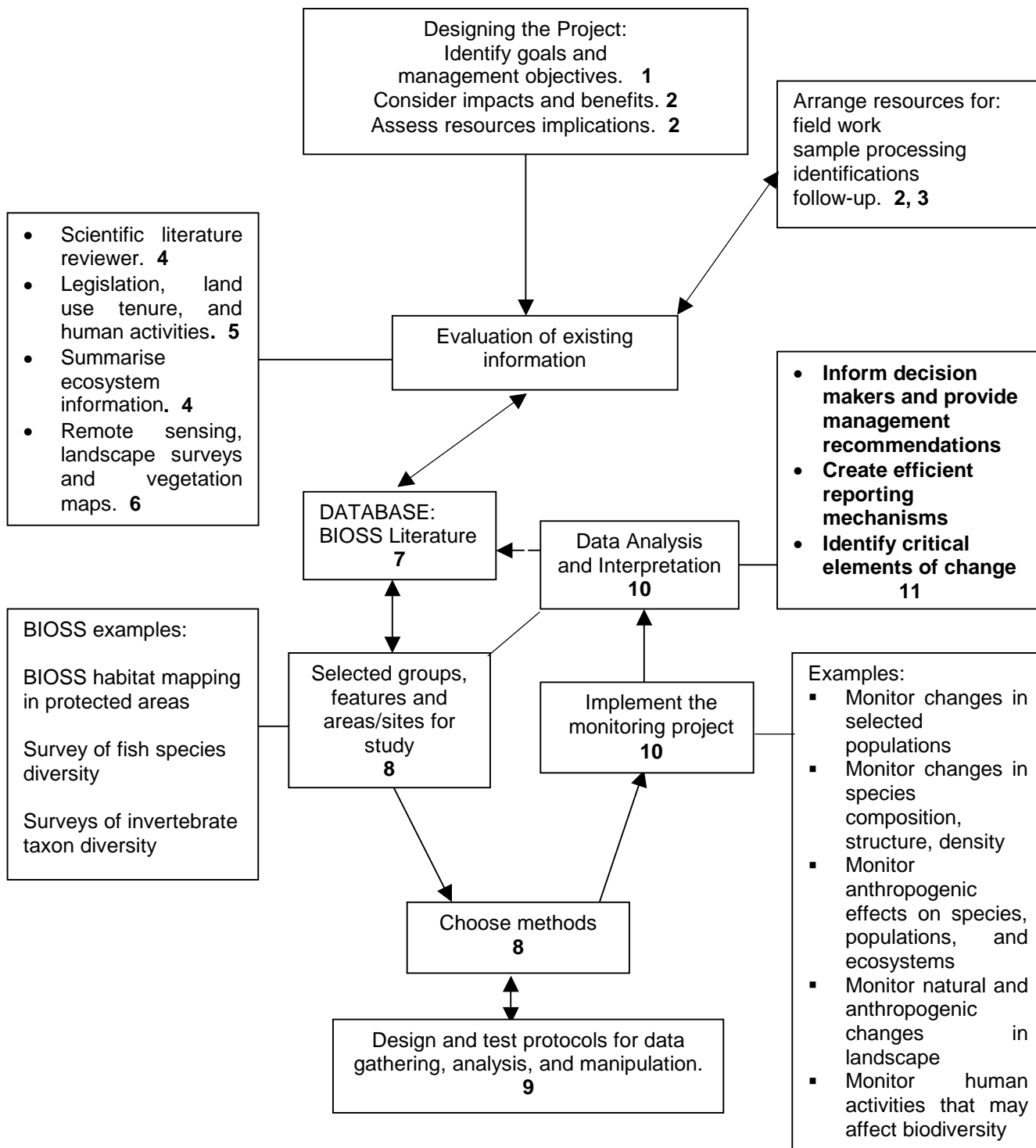
Figure 1.1   Best Practice – Planning Biodiversity Inventories[1].   Annotated with BIOSS/LTBP activities.   See Box 1 for the components of LTBP associated with numbers in this figure.

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[1] Adopted from Jermy, Long, Sands, Stork, Winser (Eds) (1995). Biodiversity Assessment: a guide to good practice. Department of the Environment/HMSO, London

BOX 1 Components of LTBP which refer the numbers in the boxes of Figure 1.1

1. Strategic Action Plan, SAP
2. Institutional analysis
3. Laboratory refurbishment, training workshops, equipment purchase
4. Baseline Reviews, BIOSS/FPSS, POLSS, SEDSS,
5. Baseline Reviews: SESS and Legal and Institutional
6. TANGIS
7. BIOSS Databases
8. BIOSS work plan
9. Training programme, methods testing, this document
10. All SS, 1998 – 2000
11. Technical advice submitted to the SAP

1.3.1 Review current levels of biodiversity in Lake Tanganyika

There is a considerable body of work on the flora and fauna of Lake Tanganyika. Much of the original data is not yet published in internationally available literature, and less still is deposited in the riparian countries from which it was collected. Much of the data resides in the archives and internal reports of various research institutions in developed countries far from the region. To review extant knowledge of the biodiversity of Lake Tanganyika, these databases need to be collated. To do this a literature database, linked to a GIS system (TANGIS), has been developed at MRAG to provide a record of known biodiversity in Lake Tanganyika.

The database will be used to answer some of the following questions, which have implications for conservation management strategy and planning, as well as for the subsequent development of the survey work plan:

- What links can be made between habitat types and species distributions?
- Is the diversity of one taxonomic group linked with the diversity of another?
- Are there major geographical boundaries that separate distinct communities, or populations of species? Where are they? Are they in the same place for different taxa?
- Do existing aquatic reserves afford protection to an adequate proportion of the known flora and fauna of the lake? What proportion of species are represented in the complementary set of all existing protected areas?
- Have some particularly diverse locations been identified where there is currently no protection? Would adding these areas to the existing set of protected areas add significantly to the total complement of species receiving protection? In what order of priority should these new areas be added, on the basis of adding to the total set of diversity (genetic, taxonomic or ecological) that receives protection?
- Which areas, habitats and taxa have been neglected in past sampling programmes?
- Have the coverage of past surveys and the methodologies used been adequate for conservation planning? If not, how should future surveys be conducted?

It has already been determined that few of the existing studies on the lake have been carried out specifically with quantifying biodiversity (genetic, taxonomic or ecological) in mind. The majority of studies are for museum collections, studies in evolutionary biology, behavioural ecology and paleo-limnology. There is therefore little standardisation of survey methodology between studies. These data, do, however provide a representation of what is known of the diversity and distribution of flora and fauna within the lake. Typically, it is 'presence' data, rather than 'presence/absence'; i.e. - the absence of a taxa from a particular area does not mean it was not there, or even was not common, only that those sampling there didn't include it in their samples or surveys. This makes interpretation of spatial and temporal distribution data problematic, but is not untypical of biodiversity databases in other areas where there has been little systematic survey work conducted.

It is envisaged that the database will provide a resource for future management of the lake, as well as a research tool for scientists from both riparian and international research groups.

1.3.2 Identify the distribution of major habitat types, with particular focus on existing and suggested protected areas

It is a central tenet of conservation biology that characteristic species are associated with particular habitats. Thus, the distribution of habitat types is fundamental to the distribution of biodiversity. In fact, more recent conservation plans are often based on protecting particular habitats and ecosystems (coral reefs, mangroves, chalk grassland, tropical montane forest) rather than individual species or species groups. The rationale for habitat mapping within the project is that it is not possible or necessary to measure diversity at all scales (habitat, ecosystem, species, genotype), and that protection of the largest scale of diversity is fundamental to protection of the diversity within it.

The major habitat types within the littoral, benthic and pelagic zones of Lake Tanganyika are well known, and have been mapped to a certain extent. There are several specialised topographical features and associated habitats that have limited distribution, and which may not be protected by existing or proposed reserves. These may include the Lukuga effluent, reed-bed habitats, stromatolite reefs, shell-deposit areas and the benthos of the deep-water shelf in Chituta and Nsumbu Bays. Future surveys should concentrate habitat mapping efforts on the location of restricted habitats known to be threatened (from other SS work) and diverse sources (e.g. literature, database and personal consultations).

The sand/gravel/boulder/rock mosaic that characterises the majority of the littoral cannot be protected in its entirety, and has, in any case been studied quite extensively. Focus of new survey work will be on describing the habitats available within existing protected areas.

Changes in extent and quality of habitat (a visual indicator of pollution effects, and world-wide, the major cause of biodiversity loss) can be monitored using simple visual census. Comparison with photographic records can also be made where these exist.

1.3.3 Suggest priority areas for conservation, based on existing knowledge and recommendations from other SS, supplemented by additional survey work where necessary

While the project must continue to question whether additional protected areas are the best way to protect biodiversity in Lake Tanganyika, and the choice of protected areas is an interdisciplinary undertaking, BIOSS aims to provide data to input into the decision-making process.

Broadly, additional protected areas should be chosen on the basis of:

i) their contribution to representation of total lake Biodiversity, of which uniqueness of habitats and floral or faunal assemblages is one component;

ii) the extent to which they are threatened and to which this threat can be alleviated by designation as a protected area (e.g. can the catchment be protected also if sedimentation is a problem?).

iii) the financial and administrative viability of the reserve, e.g. is finance through tourism revenue a realistic option? Are the resources and staff available to administer a new protected area? Is the region politically stable enough to incorporate a meaningful protected area?

iv) the disruption to riparian communities caused by denial or restriction of access to the area and its natural resources.

The work of the biodiversity special study described in this manual will address mainly the first consideration. The key elements of this programme are:
i) Review of existing information through development of a database (SECTION 2)
ii) Surveys of habitat types in existing and suggested protected areas (Section 3.4)

iii) Rapid surveys of key elements of diversity, for comparative analysis between protected areas, and between impacted and unimpacted sites (SECTION 5 and Section 8.4.3)
iv) Storage of information from ii) and iii) on a database of survey activities (Section 8.1)

1.3.4 Develop a sustainable biodiversity monitoring programme

Changes in biodiversity and its causes can only be properly assessed through long-term monitoring. As there is a limited and fragmented database of past studies, monitoring programmes will need to continue beyond the life of the project. The emphasis of the biodiversity monitoring protocol developed by the BIOSS is on *sustainability*. The programme is designed to use the expertise and institutional capabilities that exist, and to negate the need for further outside technical assistance or finance. In some cases institutional capability and individual expertise have been enhanced through project-funded training courses, laboratory and research vessel refurbishment and the provision of equipment.

The monitoring programmes are designed to assess changes in biodiversity due to identified threats (pollution, sedimentation, fishing) and can also be used to assess positive changes that may follow from the introduction of new conservation measures or pollution control strategies.

The programme monitors the presence and relative abundance of key indicator taxa and is based on regular samples taken at sites accessible to the main institutions concerned with research, monitoring and management of Lake Tanganyika. The monitoring programme must be tied to regular monitoring of water quality, sedimentation and fishing activity implemented by the other special studies. Collection of biodiversity data without parallel data from other impact-based studies is a waste of field effort and resources.

Key activities supporting the monitoring programme are:

- Identification of key indicator groups for quantification of biodiversity, threats of major pollutant types (including sedimentation) and fishing practices.
- Maintenance of a specimen reference collection of indicator taxa at the main monitoring centres.
- Collation and production, where necessary of diagnostic field keys to support the monitoring programme
- Collation of relevant literature at each of the four field stations.
- Maintenance and updating of the literature database*.*

SECTION 2.   REVIEWING CURRENT LEVELS OF BIODIVERSITY IN LAKE TANGANYIKA: DATABASE OF PUBLISHED INFORMATION

2.1   Introduction to BIOSS Literature Database

The BIOSS literature database has been developed as a tool for conservation planning and management.   It will provide information on the spatial distribution of all biota in the lake, based on a compilation extracted from all the available literature and past studies (some unpublished) on the lake.   It is the basic tool for saying what species are where.   It was developed specifically to fulfil objective 1 in the BIOSS work plan: assess the current status and distribution of Biodiversity in Lake Tanganyika.

It is anticipated that the most important users of the database will be conservation and environmental planners.   In terms of managing biodiversity the following types of questions that may be asked of it in the future:

- Which part of the Lake has the highest diversity of fish?
- How restricted is the distribution of that endangered cichlid that is being over-exploited by the aquarium trade?
- What species have disappeared from Burundian waters since they were first surveyed in 1948?
- What minimum area of lake would include, within possible protected areas, 90% of known biodiversity, and how would those areas be distributed among the four countries and between different habitat types?
- Has heavy fishing in Zambian waters had any effect on fish species richness over the last 50 years?
- Which areas have not been surveyed?
- Where in the lake has (water hyacinth)* been found, when, and by whom? *Insert exotic nuisance of your choice.

As with any database, the quality of the answers reflects the scale and quality of the data entered.

Currently, the database records the following data for fish, molluscs, crustaceans etc: taxonomic details, full literature reference details, location (site, latitude/longitude), habitat, depth, survey information, diet, $L_∞$ and timing of survey.   Clearly, collation of this data will be of interest to the scientific community, although its primary use is as a resource management tool.

The idea is also that this database continues to be updated for as long as this type of information is needed for lake management (i.e. as long as the lake exists!).   In order to maintain the flow of data into the database, all researchers visiting Lake Tanganyika could be asked to submit their data.   In fact, this type of requirement could be tied to the allocation of research permits.   In this role, it will function as the basic biodiversity information source for the Lake Basin Management Technical Advisory Committee.   They may need to use it in future Environmental Impact Assessments (e.g. if someone proposes to build a tannery here near the lake – the TAC may reply "you can't do that, it's right next to the only known habitat of *Lavageria westii*").

Detailed instructions on management and operation of the literature database can be found in the user manual – LITDBUsermanual.

2.2   Data Sources

As part of the development of the database, some data (primarily fish) from literature held the Natural History Museum, London has been entered into the database. The development of this work, i.e. the identification of appropriate papers and entering of the data, was managed

from Bujumbura as the extensive literature collection held there makes this a key focus in the region. Professor Ntakimazi and the BIOSS team in Bujumbura identified the following sources of data available to continue this work:

- The INECN library at Gitega
- The FAO library in Bujumbura
- The FAO/FINNIDA library in Bujumbura
- LTBP Library (ex-CHHRA)

All people working on the biodiversity special study, and on the project, should be aware of this work and direct interested researchers and relevant sources of data to Dr Ntakimazi at the University of Burundi.

NB: a second database as been developed for BIOSS for the management of survey data collected within the BIOSS field programme. This is described in more detail in SECTION 8.

2.3 Links To Mapping Software

A key output of the database will be data plotted onto maps of Lake Tanganyika. The IT team who have developed the database have consulted the team at NRI who are developing a GIS Geographical information system) for the project. This has ensured that this database is compatible with the other analysis tools being generated in the project. When the amount of data held in the database is considered sufficient, the database will be linked to the GIS for analysis. Then researchers can begin to seek answers to questions such as those posed under Section 2.1.

SECTION 3.   BIODIVERSITY ASSESSMENT

3.1   Approaches to Biodiversity Assessment

Biodiversity assessment is a new science. The techniques for assessing biodiversity are still developing, and there is no single method appropriate for all situations. BIOSS reviewed the different approaches and their theoretical and practical basis in early consultancies reported in internal project documents. In developing the methods reported here, we have paid particular attention to the following points:

- Surveys and monitoring should be designed to provide information about biodiversity that is relevant to *achievable* conservation aims.
- Surveys and monitoring should build on and add to existing knowledge and experience of regional institutions.
- Surveys and monitoring should be based on sound ecological practice - replicability, stratified random sampling and standardised protocols.
- The level of technical and taxonomic knowledge required to carry out the surveys and monitoring programmes should be compatible with the capabilities of the riparian country institutions involved in survey and monitoring activities. This institutional and human resource capacity will be enhanced through training and provision of facilities.
- The survey and monitoring techniques should be appropriate for use after the completion of the present project, with minimal dependency on outside support (this does not mean such support is discouraged, only that we do not wish to foster dependency).
- The biodiversity programme - surveys, monitoring, database development, training - is designed to enable local institutions to commission their own survey and monitoring programmes according to requirements, conduct their own surveys and produce their own reports to support decision-making in environmental management.

3.2   Selecting Sub-sets of Total Biodiversity

Biodiversity inventories are seldom, if ever, based on sampling the entire biota. Biodiversity surveys in terrestrial systems tend to focus on vegetation types, and on groups that are well-known or easily identified (birds, mammals, amphibians). Aquatic biodiversity surveys have tended to focus on habitat mapping, and on conspicuous flora and fauna (macroalgae, fish, macroinvertebrates), although other groups have found use as indicators of particular threats: e.g. microalgae in pollution monitoring.

It is important to distinguish between two separate uses of the word 'indicator' in biodiversity assessments. The traditional use of the term is in talking about taxa that are taken to be particularly sensitive or indicative of some form of perturbation, such as pollution. A more recent usage is in talking about a sub-set of total diversity that can be used to give an indication of what differences in total (usually species) diversity might be. For example, one might use the diversity of cichlid fish as an 'indicator' for total biodiversity. For this latter use, we will use the term 'total biodiversity surrogate' (TBS) rather than 'indicator'.

Guidelines have been developed to assist the choice of suitable taxa for use as surrogate measures of total biodiversity and as indicators for impacts such as pollution and sedimentation. However, the choice of these TBS's and indicator species requires formal testing in Lake Tanganyika before they can be recommended as the basis for future, sustainable indicators of biodiversity and of ecosystem health.

In this section, we will discuss the choice of total biodiversity surrogates. Criteria used to select taxa for use as indicators of threats from pollution, fishing or sedimentation are discussed in Section 4.   The intention is that users of this document will be aware of the reasons why only

certain taxa are being surveyed as part of this project. Users will then also be able to evaluate which other taxa could be used in future biodiversity surveys.

The features that both indicators and total biodiversity surrogates should ideally possess are reported in the following table.

Table 3.1   Features of potential total biodiversity surrogate taxa

Indicator Groups should be:
- Taxonomically well-known so that populations can be reliably identified and named;
- Biologically well-understood;
- Easy to survey (e.g. abundant, non-cryptic) and manipulate experimentally;
- Widely distributed at higher taxonomic levels (e.g. order, family, genus) across a large geographic and habitat range;
- Diverse and include many specialist taxa at lower taxonomic levels (i.e. species, subspecies) which would be sensitive to habitat change;
- Representative of distribution and abundance patterns in other related and unrelated taxa; and,
- Actually or potentially of economic importance.

At present, it has been determined that the BIOSS field programme within LTBP should include:
- surveys of habitat type and distribution in the littoral and sub-littoral;
- identification of all fishes to species level; and,
- identification of molluscs to genus, and to species where possible.

Even these few taxa do not fulfil most of the 'ideal' requirements of organisms on which to base comparative survey work. Work is in progress to improve knowledge of some of the above chosen groups. For example:
- A taxonomic key to Thiarid gastropods has been prepared (West and Michel, 1999)

It is important to remember that as taxonomic and ecological knowledge about particular groups accumulates the evaluation of what is a suitable group for analysis of diversity may change. Further groups can be added to surveys, or existing groups can be resolved to lower taxonomic levels, as identification keys become available.

The overall rationale for the choice of a sub-set of total diversity for rapid comparative analyses remains the same. The protocols for surveying the above groups are described in subsequent chapters. Field identification materials are provided as separate documents.

3.3   Strategy Adopted for BIOSS

Having selected the surrogate taxa most appropriate for the aims of BIOSS and LTBP, the next question is: what is the purpose of the field work?   BIOSS addressed its objectives through two field programmes as follows:
- Biodiversity and habitat surveys from areas adjacent to existing national parks to allow comparison *between areas* (the SURVEY programme*).
- Monitoring changes in the biodiversity at *one place over time* in partnership with impact based studies (the MONITORING programme).

A **programme of surveys** will describe areas that are not well known and are of conservation interest to the developers of the strategic action plan. Priority areas for this survey programme are the aquatic areas adjacent to existing terrestrial national parks (Gombe, Mahale, Rusizi, Nsumbu). It was the intention that BIOSS should sample an additional site in DR Congo with a view to a recommendation for gazetting as a protected area, however this did not prove possible

owing to the deterioration in the security situation. The skills and experience of the BIOSS teams to survey sites and provide information will be an important resource for the planning and management of the lake's biodiversity. For example, if a site is being considered for protected area status, the teams can carry out an assessment of the aquatic biodiversity using standardised procedures. So all future survey data will be directly comparable to earlier surveys of other sites in the Lake carried out during the current project.

A longer term **monitoring programme** will provide regular data for a series of sites selected for their special characteristics. For example the sites may be impacted by pollution, sedimentation or fishing practices, alternatively a site may have a unique habitat or exceptional biodiversity. The monitoring programme requires input from the other impact-based special studies in helping to identify sites, suitable monitoring species, associated environmental data collection etc. The scope of the monitoring programme after the current GEF project finishes will be dependent on demand from the developers of the strategic action plan and national resources.

Drawing from the discussion of biodiversity subsets in Section 3.2 the following diagram illustrates how TBS and indicator species are to be used in the BIOSS survey and monitoring programmes. The monitoring programme will draw a subset of the TBS's identified for the survey programme (taxa with established protocols and identification keys that the field teams are familiar with) to be used as monitoring species. In addition, it is hoped that in future other taxa will be chosen as biotic indicators for monitoring at joint sites with the other impact-based special studies of LTBP.
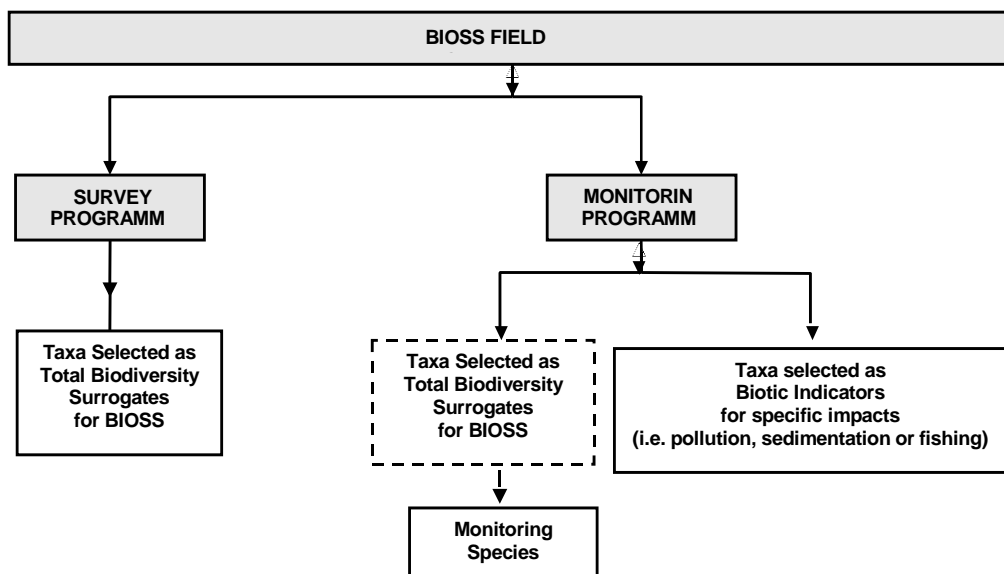
Figure 3.1   Illustration of how the survey and monitoring programmes will use TBS's and indicator species.

Many of the **sampling methods** will be common to both the survey and monitoring programmes. As part of the BIOSS strategy, the sampling techniques have been developed and tested as an integral part of the survey programme. So early tests of habitat survey and fish and mollusc census were carried out as part of a training exercise in Gombe (September 1997). The teams continued to test and refine the sampling protocols at Rusizi National Park and in Zambia (through 1998) and during the survey of Mahale National Park in March/April 1999. The monitoring programme was refined during the latter half of 1999.

3.4 Structure of BIOSS Surveys in Existing and Potential Conservation Areas in Lake Tanganyika.

Survey designs must be adapted to individual circumstances. The exact number of sampling events and their spatial distribution will be determined by the observed variability of habitat types, the number of personnel in the survey team, the equipment available and other logistic considerations. This section provides the basic template for a survey protocol. These should be adhered to where possible, but adaptation to circumstances must also be considered.

The first decision to be made is whether an area is suitable for diving – safety is of prime importance and should be carefully considered at all times during an expedition. If the presence of crocodiles or hippos in the water makes diving unsafe, non-scuba techniques should be employed. Similarly if the visibility of the water is very poor or the gradient very steep, making the water too deep to dive safely, surveying should be carried out from a boat. No dive areas may include the Malagarasi delta, Rusizi Delta and Nsumbu Bay.

Where conditions have been assessed and diving proves possible, the first step is to carry out coarse scale mapping from which sites for more detailed surveys can be selected. These more detailed surveys will consist of the following SCUBA /snorkel activities: habitat profiles followed by a series of fish and mollusc survey techniques. Gillnets are also set overnight to supplement species lists produced from daytime visual surveys. It is anticipated that as capacity within the region increases, the range of survey techniques may be broadened to include other taxonomic groups.

The SCUBA and boat based survey techniques with their main outputs are summarised in Table 3.2. The detailed protocols for each activity are given in subsequent sections.

One other type of fish census that may also be used to supplement gillnet and stationary visual censuses is the full species census. This would give fish species richness data for a 2m x 25 m transect, associated with the habitat profile transect. This technique, a modification of the other fish surveys, would provide presence/absence data only and is stratified by depth. However, it has not been included in the BIOSS survey programme.

Table 3.2   Summary of survey techniques and their output

	TARGET	TECHNIQUE	OUTPUT
Preliminary	Expedition planning	Collation and assessment of large scale topographical maps	Delineation of survey area.
DIVING SAFE **SCUBA TECHNIQUES CAN BE USED**	Habitat	Manta Board Survey	Maps of coastal topography, land form and land use, and littoral zone (sub- and supra-) habitats to maximum depth of 10 m
		Habitat profiles: SCUBA	Fine-scale habitat map (15m x 5m strip for each profile)
	Species	Mollusc census: SCUBA then snorkel shallows	Mollusc species or genus richness data for depths 15, 10, 5 & 0 m
		Stationary visual fish census: SCUBA	Fish species richness, abundance and diversity index data in 10 m diameter cylinders at 15, 10, 5 & 0 m
		Rapid Visual Census: SCUBA then snorkel shallows	Fish species richness data for 15 minute transects at each of four depths (15, 10, 5, 0). Likely to include patchily distributed, more diver-wary and rare species missed by stationary visual fish census, as it covers a larger area. No abundance data recorded, but relative rarity can be calculated
		Multi-mesh survey gillnets set before dusk (1700) and retrieved after dawn (0800)	Fish species richness, relative abundance and diversity, to complement visual census data.
DIVING UNSAFE **DO NOT ENTER THE WATER**	Habitat	Manta with crocodile box	Maps of coastal topography, land form and land use, and littoral zone (sub- and supra-) habitats to maximum depth of 10 m
		Grab samples and echo sounder	Survey of soft substrates (sand and silt). Not possible on hard substrates
	Species	Mollusc dredging	Replaces mollusc survey, on soft substrates only. Not possible on hard substrates
		Gill nets	Day and night (as above) replaces stationary visual census.

3.4.1 **Indicative Survey Timetable**

Clearly the amount that can be achieved by a survey team is dependent on capacity of the divers (i.e. training, skills and resources), the weather and other logistic constraints. However, for planning purposes it is useful to have an indication of how much surveying has been done with what resources in the past. The experiences of previous survey expeditions demonstrated that the BIOSS team could achieve the following timetable.

Ideally, Manta survey work is completed prior to diving and snorkel work, so that initial habitat data are available as a basis for choosing sites to profile and survey. With a team of 5/6 people, it has been possible to cover up to 15km of coast per day. Following selection of the dive sites from the results of the Manta survey (see section 4.3.1 for a description of the selection method), a team of 6 divers can achieve the following programme of surveys at one site in a day. Surveys in sequence: profile dive, mollusc survey, stationary visual census, rapid visual census (and snorkel), gill net set (evening) and retrieval (next morning).

Using the Mahale expedition as a worked example: Three teams of six divers completed the manta survey of the 60km long coast in just under 3 days (had all team members been experienced in the technique at that stage the task could have been completed in day and a half). As expedition time was the main constraint, the number of sites selected for detailed surveying was limited to 27. Three teams of six completed this work in nine diving days with an additional five days being required for logistics and planning. So the entire expedition took 18 divers 17 days. Nevertheless, the presence of surplus divers is desirable in case of ill health or injury among the divers and so some administrative and logistical tasks (such as cylinder filling) can be carried out concurrently with survey work.

3.4.2 **Survey Logistics**

Each survey should have an appointed 'Scientist in Charge' to:
• Select and brief the survey team
• Oversee the survey work
• Select sites for profiling
• Allocate tasks to team members
• Ensure data are properly recorded and transferred to data forms
• Ensure data forms are transcribed to the survey database
• Analyse the survey data and produce survey reports

Each team should have an appointed logistics officer for each survey, who will be responsible for:
• The survey budget
• Compliance with appropriate health and safety procedures
• Arranging transport to the survey area
• Purchase of fuel and provisions
• Finding accommodation and making cooking arrangements
• Checking all survey equipment is functional
• Packing all equipment, checking against list
• Scheduling SCUBA tank filling
• Transport and storage of samples back to laboratories
• Reporting all equipment losses, breakage's and faults

3.4.3 Data management

3.4.3.1   Field data sheets

Most data is originally recorded in underwater notebooks, rather than on the prepared data forms for each technique. Therefore, the data must be transcribed on to these forms at the end of each day. The scientist in charge is responsible for managing the forms, checking they are filled in correctly each night and keeping them safe for entry into the database after the expedition. The full range of survey activities are summarised on the field log sheet (Section 13.1). The field log sheet should be used as a planning tool, and the scientist in charge should allocate sample and event numbers to planned survey activities for the day.   Divers should start each dive having noted the relevant survey, sample and event number allocated to their technique. This will be transcribed onto the appropriate form with the data from diver's underwater notebooks.

Table 3.3 lists the data forms for each survey technique and their corresponding templates saved as Excel spreadsheet files.

Table 3.3   Survey technique field data forms and templates

Activity	Forms	Template files	Section
Field log sheet	Fieldlog sheet	Fieldlog.xls	13.1
Manta board surveys	Manta form 1/3	Manta1.xls	13.2
	Manta form 2/3	Manta2.xls	13.3
	Manta form 3/3	Manta3.xls	13.4
Habitat Profile (dive)	Dive Profile 1/1	Profile.xls	13.5
Habitat survey (grab)	Habitat Grab 1/1	Grabhab.xls	13.6
Stationary visual census	Stationary Visual Census 1/1	SVC.xls	13.7
Rapid visual census	Rapid Visual Census 1/1	RVC.xls	13.8
Gillnet survey	Gillnet Set 1/1	Gillnet.xls	13.9
Mollusc transect survey	Mollusc Transect 1/1	Molldive.xls	13.10

The scientist in charge should ensure that enough copies of each form have been taken on the expedition!

3.4.3.2   GPS coordinates

GPS coordinates can only be entered into the BIOSS survey database as decimal degrees. Check what your GPS reading is given in, and if necessary convert from seconds and minutes to decimal degrees using Table 3.4 below. Remember to divide both minutes and seconds separately, then add one to the other as follows. Experience has shown that it is more efficient and less inconvenient to convert the coordinates as the data is transcribed onto the field data sheets immediately following the dive than when large amounts of data is being entered into the database.

e.g. 3º 33' 39" would be 3.561 as calculated below and is the figure you enter in the database:-

calculation	result
3	3.000
33/60	+ 0.550
39/3600	+ 0.011
	= 3.561

Table 3.4   Conversion of minutes and seconds into decimal

GPS Reading	Minutes to decimal	Seconds	GPS Reading	Minutes to decimal	Seconds
0	0.000	0.000	30	0.500	0.008
1	0.017	0.000	31	0.517	0.009
2	0.033	0.001	32	0.533	0.009
3	0.050	0.001	33	0.550	0.009
4	0.067	0.001	34	0.567	0.009
5	0.083	0.001	35	0.583	0.010
6	0.100	0.002	36	0.600	0.010
7	0.117	0.002	37	0.617	0.010
8	0.133	0.002	38	0.633	0.011
9	0.150	0.003	39	0.650	0.011
10	0.167	0.003	40	0.667	0.011
11	0.183	0.003	41	0.683	0.011
12	0.200	0.003	42	0.700	0.012
13	0.217	0.004	43	0.717	0.012
14	0.233	0.004	44	0.733	0.012
15	0.250	0.004	45	0.750	0.013
16	0.267	0.004	46	0.767	0.013
17	0.283	0.005	47	0.783	0.013
18	0.300	0.005	48	0.800	0.013
19	0.317	0.005	49	0.817	0.014
20	0.333	0.006	50	0.833	0.014
21	0.350	0.006	51	0.850	0.014
22	0.367	0.006	52	0.867	0.014
23	0.383	0.006	53	0.883	0.015
24	0.400	0.007	54	0.900	0.015
25	0.417	0.007	55	0.917	0.015
26	0.433	0.007	56	0.933	0.016
27	0.450	0.008	57	0.950	0.016
28	0.467	0.008	58	0.967	0.016
29	0.483	0.008	59	0.983	0.016

SECTION 4. SITE ASSESSMENT & HABITAT MAPPING

What is a habitat?

From a purely ecological perspective a 'habitat' can be defined simply as a place where plants and animals live. In most cases, that means the area of the lake-bed where they can be found. Examples of habitat type are sand or bedrock. Some plants or animals can also provide habitats. For example, reed beds are habitats. Animals and plants can be found living on, or around, the reeds. Habitat can also include very small features, such as cracks and crevices in rocks.

How have we defined 'Habitat'?

We use the word 'habitat' in this guide to mean the places where plants and animals live. We also define habitats in terms of SCALE. A habitat is typically defined in terms of an area with a radius of 5-10 m, which relates to the scale at which a diver or snorkeller underwater perceives the lake. Habitat patches may, of course, be either larger, or smaller than this.

Larger scale lake scenery is defined in terms of TOPOGRAPHY. Examples of the topographic scale include: profiles of lake beds, the littoral zone, shelf areas, and river mouths. The project aims to provide 'habitat maps', where the location and extent of different habitat types are identified *within* surveys of larger topographical features, such as the rocky coast of Burundi, Ubwari Peninsula, Gombe Beach, Nsumbu Bay and the Rusizi Delta.

4.1 Site Assessment

Before surveys are conducted, it is vital to know the areas that are being surveyed. The first step towards planning and carrying out a survey is to collate existing information. The assessment of a site before deciding on a survey plan is achieved through the following process:

4.1.1 Obtain maps of the area.

These may include relief maps, bathymetric charts, terrestrial vegetation maps, geological maps, political maps, aerial photographs, remote sensing images and multi-layer GIS systems.

You can use information from maps to find out, for example:
- the location of national park boundaries;
- the location of major affluent river systems;
- land use in the sub-catchment adjacent to the lake sector of interest; or,
- main centres of population in the survey area.

This will help you plan your survey to take into account both logistic and scientific considerations such as:
- likely distribution of major habitat categories (rocky shore, river deltas, sandy beaches);
- areas likely to receive minimal human disturbance; and,
- choice of location for survey base.

4.1.2 Check literature database for previous biodiversity survey work in the area

The literature database, described in Section 2, hold records from previous surveys of the biota of Lake Tanganyika. You can call up species lists for an area, recover the literature in which single species have been recorded etc. This will give you a summary of previous survey work and known taxa from the area. You could use this as a basis for choosing to re-survey previously studied sites, or comparing your survey results with previous work.

4.1.3 Review other LTBP special study plans and activities

Before planning and carrying out a survey in your chosen area, a check should be made of information collated for that area by other special studies in their baseline reviews and subsequent studies and technical documents. This may include:

- possible sources of pollution such as villages, industry, mining activities, pesticides on crops;
- possible sources of sediment input from degraded land, steep deforested hills or major river systems; or
- areas that are heavily fished.

Overall, they contribute to the identification of 'pristine' and 'impacted sites. This is also an important consideration for the monitoring programme (see SECTION 9).

4.2 Coarse Scale Mapping Of Coastal And Underwater Topography And Habitat

Having reviewed the features of an area from existing maps and chosen the boundaries of the survey, the next task is to implement a survey of the main habitat and ecological features of the chosen area.   Side-scan sonar is one method of mapping, however it requires specialised equipment. The output is a bathymetric map with classification of the substrate into rocky and various grade of sediment. Tests with this method as part of the sediment special study have proved problematic. Therefore, BIOSS advocates the use of Manta tow survey to support biodiversity surveys and monitoring programmes.

4.2.1 Manta tow survey

The standard method of mapping the shallow sub-littoral area and coastal topography is the manta tow. The procedure for carrying out a Manta Tow Survey is as follows:

4.2.1.1   Equipment and personnel required
Inflatable or other small boat
Outboard Engine (15-45 HP) + sufficient fuel
Safety equipment (paddles, bailer, lifejackets)
GPS
Waterproof watch with stopwatch facility
Manta Board with tow rope and slate (see Figure 4.1)
Snorkel equipment (masks, snorkel, fins, wetsuit)
Clipboards and forms
Plastic bag or folder to store forms
Soft pencils + sharpeners/knife
4 – 5 survey-team members (all should wear wetsuits, as tasks will be rotated)

Important reminders

! Check whether GPS reads decimal degrees, or degrees, minutes and seconds. Note this on all data forms as will have to be in decimals to be entered in the database. Also check GPS batteries and spares before departure

! Ensure that a copy of the habitats recording form is transcribed to the Manta slate before the survey begins, and that the data are transcribed to forms then erased after each survey.

! Ensure that sufficient copies of all forms are prepared, including a photocopied map of the area to be surveyed.
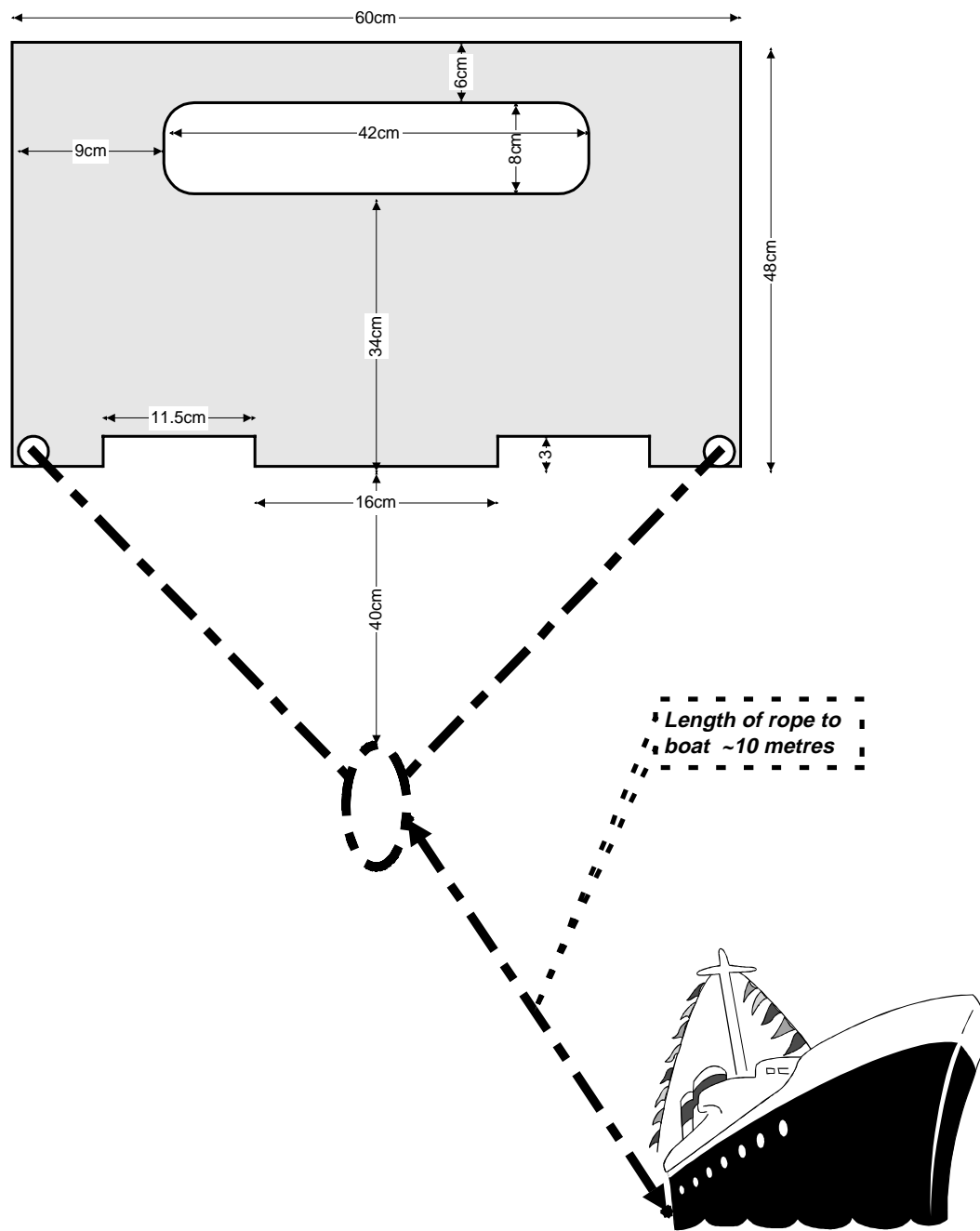
Figure 4.1   Plan for the manufacture of a wooden manta board, including dimensions

4.2.1.2   Manta survey procedure

The manta tow is a technique used to map the distribution of shallow water habitats using a surface snorkeller towed behind a small boat. It is relatively cheap and easy to carry out, rapid (15 km per day are possible) and gives sufficient information on major habitat distributions in depths of 3-10 m (depending on water clarity) to create habitat maps and identify locations for more detailed study.

The manta tow procedure, as implemented by BIOSS is as follows:

Step 1   A team of five people, all wearing wetsuits, load up an inflatable with the equipment listed above, and attach the Manta board to the boat transom with 10 m of rope. Start in the water at the deepest point you have good visibility (3m – 10m) adjacent to a prominent landmark or coastal feature (so you are certain where you are on the map).

Five jobs need to be done, as listed below. Note that if only four people make up the team then one person can either do tasks ii) and iii) **or** iii) and iv). At regular intervals (18 minutes was found to be best), the team change tasks, mainly to give the underwater habitat recorder a rest, but also to ensure all members are involved in and proficient at all tasks.

i) Boat driver. The speed maintained should be approximately constant, although different operators will be able to tolerate different speeds in the position of underwater recorded. In practice this will be approx. 3-5 km/hr

ii) Position recorder. Has a clipboard and form Manta 3/3 (with photocopied map), plus GPS. Responsible for noting the GPS position at three-minute intervals, and for marking the position every 3 minutes on the map. GPS and map markings are later crosschecked. This conventional map reading in addition to using the GPS means that the manta survey can continue even if the GPS develops a fault.

iii) Time recorder. Notifies the boat driver when each 3-minute interval is complete. Also watches the underwater habitat recorder for signals to stop, speed up or slow down. (Remember to agree on these signals beforehand)

iv) Shoreline recorder. Uses Manta form Manta 2/3 to record main features of the shore and coastal zone (e.g. coastal vegetation type, land use, relief, above-water shoreline characteristics).

v) Underwater habitat recorder. Observes the underwater habitats while being towed on the Manta Board. At 3-minute intervals, stops and records habitat features on Manta form Manta1/3.

Note: all those in the boat should look out for hazards in the water such as submerged rocks and dangerous animals i.e. crocodiles or hippos.

Step 2   Once roles have been allocated, record the start position and zero the stopwatch. Steer the boat parallel to the shore, taking care to ensure that the boat remains in 5-10 m of water. Where the slope of the lake bottom is gentle and the substrate is still visible some way offshore the team should keep to within 50m of the shore throughout. After three minutes, the timekeeper calls the boat driver to stop, and stops his/her stopwatch. The boat driver should put the engine in neutral. The position recorder records the GPS co-ordinates. The shoreline recorder summarises the coastal and landscape features seen during the last 3 minutes on form Manta 2/3. Using the slate attached to the Manta form, the underwater habitat recorder records the habitat composition and main features of the sub-littoral habitat observed over the previous 3 minutes.

Step 3   At the signal from the underwater habitat recorder that he/she has completed the recording, the boat starts again, and the survey is repeated for another three minutes. The surveying and recording methods detailed above are repeated at 3-minute intervals until it is time to change recorders (6 cycles, i.e. every 18 minutes).

Apart from the change round of personnel, the method remains the same until the day's survey objectives have been completed.

Step 4   Once the form on the manta slate has been completed, it is transcribed on to paper. These paper forms are the first rough output for survey planning (see Figure 4.2) and on return to the laboratory or research centre are entered into the survey database.

These data can be used to provide maps of major habitat categories, and for more detailed analysis of habitat type and quality. They also provide the basis for finer-scale habitat mapping prior to conducting underwater surveys of the diversity or species richness of the biota.

4.2.1.3 *Coarse scale habitat survey procedure in areas where there is a threat from crocodiles or hippos*

In areas where there is a risk of encountering crocodiles or hippos a modified procedure should be employed. In essence the technique remains the same as for the manta tow with the exception that the underwater habitat recorder does not enter the water but remains in the boat viewing the substrate through a "croc box". This is a wooden-sided box with one end open and the other covered with Perspex. The box is strapped to the side of the boat with the Perspex end just below the surface of the water. The underwater recorder positions himself above the open end and observes the substrate below. Visibility is improved if light is prevented from entering the open end by a shroud, which is placed over the head and shoulders of the observer.

While this method is less effective than the manta tow owing to restrictions on the field of view, it does ensure the security of the observer and thus enables the habitat to be mapped where otherwise it would be unsafe to do so. The initial rectangular design of the "croc box" was found to exert considerable drag on the boat at speeds greater than 3 km/h. It is therefore suggested that future versions have a rounded or pointed leading edge to reduce drag. Within BIOSS only one "croc box" was constructed and used in Zambia.

4.2.2 Classification of substrate types

On form Manta 1/3 the percentages of each habitat observed during a particular 3 minute period are recorded using the following substrate types: bedrock, rock, gravel, sand, shell bed, stromatolites. For the purposes of habitat mapping the following method is applied to give an overall substrate classification to each 3-minute period.

- If one of the above substrate types comprises ≥75% of the habitat then it is classified by that type, e.g. >75% bedrock/rock = "rocky".
- If one substrate type comprises <75% but ≥50% then the classification would be "mixed sandy/rocky/gravel etc" depending on which substrate type is dominant, e.g. <75% but ≥50% Sand = "Mixed Sandy".
- If all the substrate types comprise ≤50% of the total then it is classified as "Mixed".

Note: For the purpose of this classification rock and bedrock substrates are both categorised as rocky.

Key to symbols	
Symbol	Substrate type
• • • • • • • •	Sand
‖‖‖‖‖	Rock
≡≡≡	Gravel
VVV	Mixed

Note: where the symbol for a Mixed substrate is annotated with an **S** or **R** it indicates a Mixed Sandy or Mixed Rocky substrate respectively
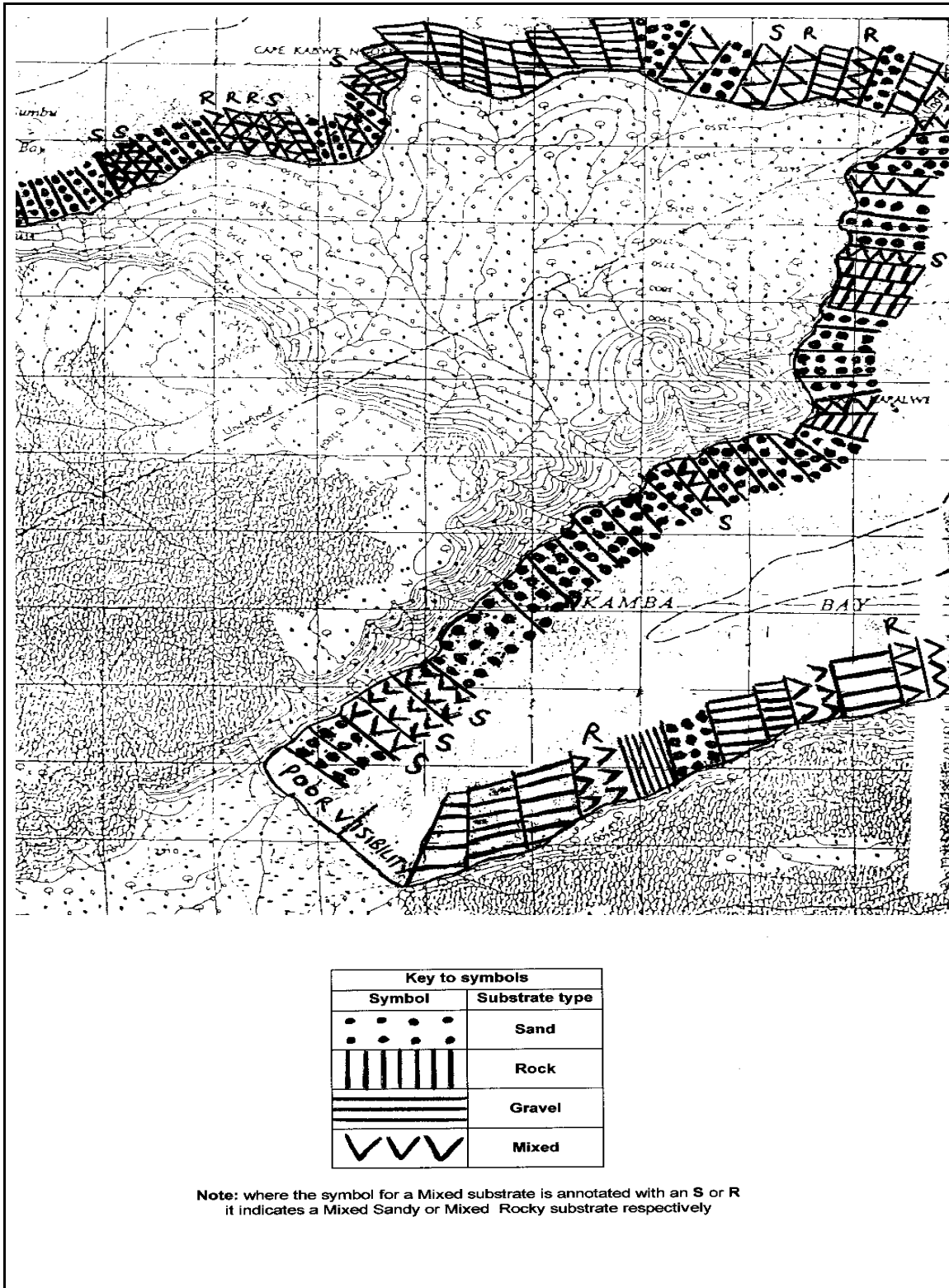
Figure 4.2   Manta survey data presented on map of Nsumbu National Park, Zambia

4.3   Finer Scale Mapping Of Underwater Habitats

Dive profile mapping is the finest scale of habitat mapping used, and involves carrying out a profile of the littoral habitat, from a depth of 15 to 0 m. The habitat profile serves three functions:
- it verifies the coarse-scale habitat survey conducted using the Manta board;
- it extends the depth of habitat survey beyond the depth of the Manta survey, and provides a depth/habitat profile for the sub-littoral zone; and,
- it provides a habitat survey at the same spatial scale as the surveys of biota carried out in the biodiversity surveys, so that species richness and/or diversity can be linked with habitat type. It can also be used to ensure that inter-site comparisons are only carried out between similar habitats, thereby accounting for a major source of difference among biotic communities.

4.3.1 Choosing location of survey sites

This is done on the basis of habitat mapping (i.e. results of the manta tow). All habitat types that are available within the area surveyed by the manta should be represented in profiling programme, and the number of samples should be weighted by the relative amount of each substrate present along the coast. Basically this means that if you have twice as much rocky habitat than sandy, you will have twice as many profile dives on the rocky than sandy areas.

An example of how you might do this is given in Table 4.1 below. In this case first column shows the relative proportion of habitat types present in a 50km stretch of coast as recorded by the manta survey. Assuming that logistics limits the team to 25 profile dives, the second column indicates how you would distribute your profiling effort amongst the habitat types. The number of profiles is roughly estimated as follows: sand represents one fifth (10/50) of the total coast, so you should do one fifth of your 25 dives in sandy habitats, i.e. 5.

Table 4.1   Example of possible allocation of sampling sites between habitat types

Habitat type and length of coastline	Number of sites
10 km sandy	5
5 km gravel	2
10 km mixed sandy	5
20 km rocky	10
5 km mixed rocky	3
50 total length of coast	Total = 25

The exact locations of each profile dive within each of the different habitat types should be determined randomly. To do this you should allocate a number to each 3-minute manta-survey period in each habitat type.   The consecutive series of numbers should be applied separately to each main habitat type, i.e. "1, 2, 3, …" for sandy and "1, 2, 3, …" for rocky etc. Next the particular 3-minute areas of the manta survey to be profiled are chosen at random. If the number of areas is large, you should use a random number table from a statistics book, but generally within BIOSS we simply wrote the allocated numbers on small bits of paper, mixed them in a "hat" and drew them out one by one.   The profiles should be located approximately near the centre of each 3-minute manta section. This design is called stratified-random sampling. It retains the statistical features of random sampling, while reducing sample numbers through efficient stratification by habitat prevalence.

Another stratification parameter that could be used is expected within-sample variance. In this case, more samples would be taken in highly heterogeneous habitat types. If you had a coastline that was 9 km sand and 1 km mixed rock/boulder/sand, stratifying by habitat prevalence might mean you do 9 profiles in sand and one in the mixed habitat. Given that the sand habitat may be less variable at the scale sampled, it may be better to give greater weighting to sampling in the mixed habitat area. It is suggested that this latter stratification method only be used in surveys of

areas >50% sandy substrates. In areas where sand < 50%, weighting by prevalence of major substrate categories is recommended.

4.3.2 Profile dives
Once the sites for the profile dives have been selected, the procedure is as follows.

4.3.2.1 Equipment
    Full SCUBA set
    Underwater note pad or slate – pre-prepared with profile form
    Pencil – sharpened at both ends in case of breakage
    2 SMB reels: one with the line marked at 25 m and a marker buoy attached; the other with the line marked every 10m and weighted at one end
    Underwater watch or depth timer

4.3.2.2 Procedure
Step 1   On arrival at the dive site the survey team should immediately determine the point at which the water depth is 15m. If this is more than 100m from the shore it is unlikely that the divers will be able to complete the dive before exhausting their air supply. The team should therefore consider carrying out the procedure outlined in Section *4.3.2.3* below. Otherwise they should proceed with Step 2.

Step 2   Having taken a compass bearing to the shore, the divers enter the water and descend to 15m. The time of descent should be recorded.

Step 3   At the bottom the divers attach the reel with the marker buoy to the weighted end of the reel marked at 10m intervals. They then summarise the visible habitat types over an area of 5m radius from their position recording the details in their waterproof notebooks. Having completed this they swim towards the shore on the pre-determined compass bearing. One diver winds out the line counting the number of 10m marks as he proceeds. The other monitors his depth gauge.

Step 4   At 10, 5 and 0 meters respectively the divers stop and carry out the same procedure as at 15m, in addition noting the distance travelled along the line at each stop. Once the surface has been reached the reel is left in place, well weighted, for the fish and mollusc surveys to follow. Note the time on completing the dive.

Step 5   Transfer underwater notes to the profile data form (see Section 13.5). The recorded habitat data are then used to provide habitat data for the subsequent fish, mollusc and invertebrate sample surveys.

IMPORTANT NOTE: As with all the dive techniques described in this document, it is most important that the deepest area (15 m) is surveyed first and the shallowest (0 m) last. If this order of survey is not followed divers run the risk of contracting decompression sickness.

4.3.2.3   Procedure if underwater habitat is a very gradual slope.
If the area to be surveyed is a very gradual slope two teams of divers should share the profile surveying, following the same protocol as above, with the following modifications. The first team should dive at 15m follow the protocol above for taking down details of habitat, then resurface, rather than swimming to the next site.   The boat will transport the entire team to a depth of 10m and the second team should descend and sample as above, and again they should return to the

boat. The first team then, having had a 15-minute break on the surface can safely continue the profile by sampling at 5m. They or the second pair of divers can then complete the profile at this site by doing the sampling at the surface, i.e. at 0m.

The activities for the two teams of dive pairs sampling gradual slopes are summarised in Table 4.2

Table 4.2   Technique for sampling sites with gradual slopes

Dive pair 1	Dive pair 2
Profile at 15m	*Rest in boat*
Surface	*Rest in boat*
Rest in boat	Profile at 10m
Rest in boat	Surface
Profile at 5m	*Rest in boat*
Surface	*Rest in boat*
Rest in boat	Profile at 0m

4.3.2.4   Procedure in "no dive" areas

In areas where it is not possible to dive for reasons of safety or poor visibility (See Table 3.2) detailed information on the substrate should be gathered using a grab. For this technique a survey vessel is required, which is large and stable enough to mount a small winch to which the grab can be securely fixed. Always attach a second line with plenty of slack to the grab, so that if the winch cable breaks the grab can be located and recovered. The sampling procedure is as follows:

Step 1   At the survey location the team finds the point at which the depth of the water is 15m. Using this as a start point the survey vessel follows a course parallel to the shore but maintaining a depth of 15m. Grab samples are taken at approximately 15, 30 and 45m from the start point along the transect. If appropriate the contents of each sample should be sifted through a sieve, before the nature of the substrate is summarised on Habitat Grab form 1/1. A note should also be made on the form of any invertebrates identified in the sample.

Step 2   This procedure should be repeated at depths of 10m and 5m.

Note: Occasionally the grab will return empty. There are two possible explanations for this; firstly the grab may have "tripped" prematurely. With a little experience the winch operator will be able to detect this and the process can be repeated until a true sample is obtained. Alternatively, the substrate may be rocky, in which case the grab should be lowered once more and if the same result is obtained "No sample – possible rocky substrate" entered on the Habitat Grab form.

A sample copy of the survey form is presented in Section 13.6.
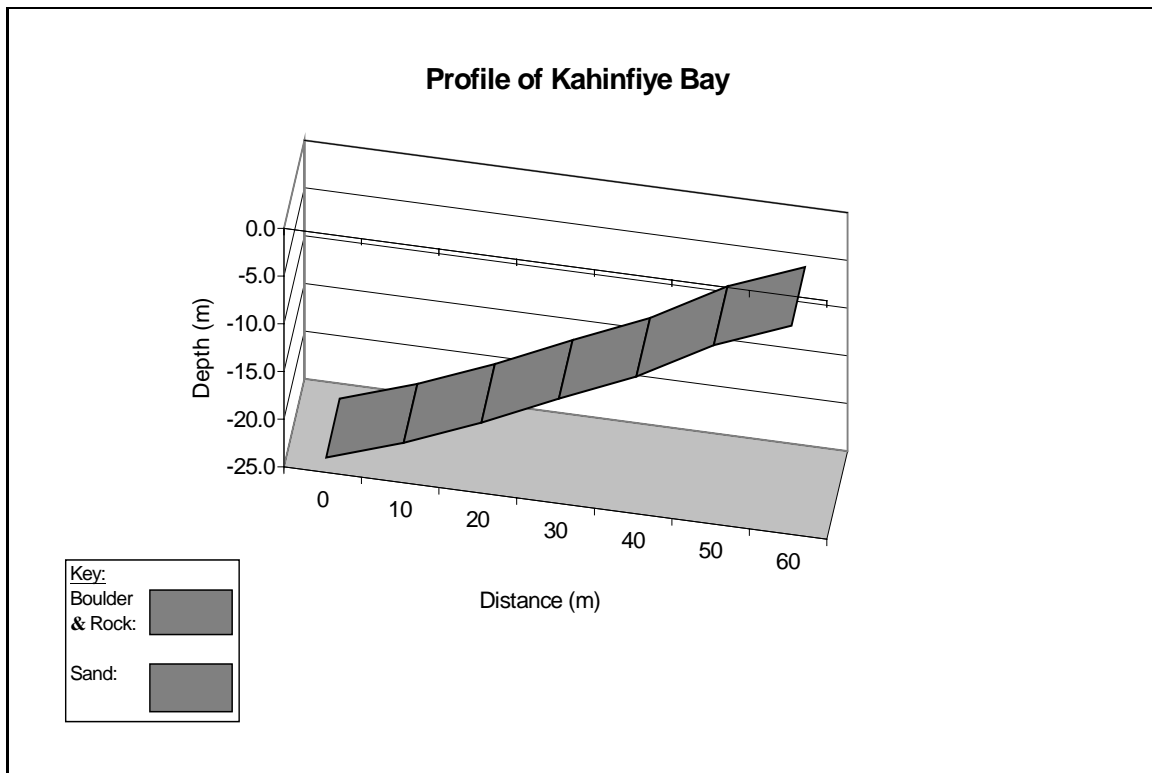
Figure 4.3   Example of dive profile data from Mahale Mountains National Park, Tanzania

SECTION 5.   SAMPLING METHODS FOR TAXA SELECTED AS TOTAL BIODIVERSITY SURROGATES: FISH

5.1   Identification

Identification of fish species is currently done from a variety of sources. These include past survey experience of individuals, aquarium guides, particularly Brichard (1989), and various keys including the original keys and descriptions of Max Poll, from the 1940s. An attempt has been made to produce a dichotomous key to the cichlid genera (Roger Bills), but the fact remains that there is no single, accessible source for field identification of the fishes. Some of the work completed during the project should help towards the development of such field guides.   As an aid to enhancing identification skills, reference collections of fish and mollusc specimens have been started or augmented at each of the stations from samples collected during the BIOSS surveys.

A range of survey techniques was evaluated for the underwater visual census of fish populations in Lake Tanganyika. The following techniques and protocols were found to most appropriate for use on the BIOSS surveys.

5.2   Stationary Visual Census (SVC)

This technique provides information on the relative abundance and diversity of littoral fish species (Bohnsack, 1986). It should be employed for both temporal monitoring of selected sites (SECTION 9) and, in combination with the Rapid Visual Census (see below), for mapping of fish distributions throughout Lake Tanganyika.

5.2.1 Equipment

> Full SCUBA set
> Underwater note pad or slate – pre-prepared with census form
> Pencil – sharpened at both ends in case of breakage
> Underwater watch or depth timer

5.2.2 Procedure

The technique used here has been modified from the original technique (Bohnsack 1986) to better suit the distributions and behaviours of fish found within Lake Tanganyika.

On the BIOSS surveys, this activity takes place directly after the profile dive has taken place. There will therefore be a transect line in place, and a buoy in 15m of water.

Step 1   Using the marker buoy a pair of divers descends to 15m. They position themselves over the transect line at its start.

Step 2   **Species Richness and Abundance**. While rotating above the transect line each diver scans the field of view within an imaginary cylinder extending from the lakebed to a height of 5m and having the same radius. For the first 10 minutes all species observed are recorded using abbreviations of the genus and species names to save time and space on the form. The number of individuals seen is also recorded. When large shoals are present numbers should be estimated by counting in 10's, 20's or even 100's.

Step 3   **Cryptic Species**. When the ten minute period is completed each diver systematically searches the lakebed within the survey area for all cryptic and crevice dwelling species (e.g. *Syndontis spp.*, *Julidochromis spp.*) which may not have been visible from the central point. As each species is observed the species name and number of individuals are recorded. The area is searched for five minutes. Care should be taken to avoid stirring up sediments during this time – swimming in a predominantly "head down" position is recommended.

Step 4   The above procedure is repeated at 10, 5 and 0m. Sampling is stratified with depth, as many of the fish species under census are known to be depth limited (e.g. *Cyphotilapia frontosa*, *Tropheus spp.*). At the end of the dive the main profile transect line should be left in place for the subsequent mollusc transects.

Note: Juvenile fish should not be included in the counts as, (i) estimates of numbers in large shoals are highly variable, and (ii) a large shoal of juveniles of a single species may significantly skew the final figure for the diversity index calculated.   Conclusion: presence of juveniles should be noted but not included in counts.   A sample copy of the survey form is presented in Section 13.7.

5.3   Rapid Visual Census (RVC)

The rapid visual census technique (Jones and Thompson, 1978) provides information on relative abundance and species richness, but not on population density. The entire census period is spent searching for unrecorded fish species with no additional data on the fish recorded. Given that a larger area can be censused than by the stationary visual census the technique is likely to pick up the more diver-wary or rare species. However, as some of the smaller more cryptic species may not be observed, a combination of the Stationary Visual Census and the RVC should be used for the diversity distribution surveys in order to provide a full species list.

5.3.1 Equipment

Full SCUBA set
Underwater note pad or slate – pre-prepared with census form
Pencil – sharpened at both ends in case of breakage
Underwater watch or depth timer
Surface Marker Buoy – large distances may be covered underwater

5.3.2 Procedure

Surveys should be stratified with depths of 15 m, 10 m, 5 m and 0 m as for the Stationary Visual Census. The basic technique for a 60-minute census is presented below.

Step 1   A pair of divers descends to a depth of 15 m.

Step 2   Both divers swim along the 15 m depth contour parallel to the shore for 15 minutes. This census period is divided into five, three-minute time intervals. The name of each species is recorded in the time interval in which it is first seen. The divers carry with them a reel with marker buoy attached throughout, so as to indicate their position to the team members on the surface.

Step 3   On completion of the first 15 minutes of census the divers ascend to 10 m depth and conduct a second 15 minute census in the opposite direction i.e. back along the same transect censused at 15 m. Species are again recorded in the time interval they are first seen EVEN IF ALREADY NOTED AT 15m.

Step 4   The divers ascend to 5m and carry out the same procedures

Step 5   The divers surface and conduct a final 15-minute census on the surface using snorkels.

The purpose of this sampling is to estimate the relative abundance of species. To do this, each species is given a score based on the interval when it was first recorded. The more abundant species are likely to be recorded in the earlier intervals and the more rare or cryptic species in the later intervals. Species recorded in the first interval receive a score of 5, in the second 4, and so on, with those recorded in the final interval scored as 1.

A sample copy of the survey form is presented in Section 13.8.

5.4 Gill Nets

When set overnight, gillnets can be used to complement dive survey methods, catching species that are more active nocturnally or migrate from deep to shallower water to feed. Furthermore, field identification of some species is particularly difficult underwater. Gillnetting enables samples to be caught and thoroughly examined in order to verify taxonomy, and to ensure consistency between observers.

There are however limitations to the use of gillnets. It is a passive method, which means only moving fish can be caught. For that reason sedentary species and those that remain confined in burrows or crevices, or temporarily suspend their food searching during the reproductive phase, are caught with difficulty. Furthermore, nets with uniform mesh sizes are selective, only catching fish of a particular size or morphology. For this reason BIOSS uses gillnets with a variety of mesh sizes, which provide an efficient method for semi-quantitative evaluation of fish populations.

5.4.1 Equipment
The characteristics of the multi-mesh gillnet used by the BIOSS teams are:
- material - transparent blue mono-filament which is not easily seen under water;
- mesh size - 12 panels with mesh sizes of 8, 10, 12.5, 16.5, 18.5, 22, 25, 30, 33, 38, 45, 50 mm respectively; and,
- net size - each panel 5m by 1.5m, sewn together making a net of 60m in length.

The following additional equipment is also required for gillnet sampling:
- buckets/basins for handling and sorting-out the catch;
- scales (range 1gr to 2 kg) if weighing fish;
- pliers/scissors for extracting fish from the net; and,
- jars and alcohol (at 70% concentration) and labels for preservation of samples.

5.4.2 Procedure
The gill net is set parallel to the shore at a depth of 10 m. The net is positioned at the required depth with the weighted "foot-line" resting on the lakebed and the buoyant "float-line" suspended above, in such a way that it forms a slight overhang. The ends of the foot-line should be anchored to the lakebed by attaching to them a lead or stone weight. A surface buoy should be attached to the float-line to mark the location of the net. The time for setting nets should be consistent, preferably towards dusk. In areas frequented by fishermen it may be necessary to place a watch over the nets to ensure they are not tampered with or stolen. The nets should be hauled the following morning after sunrise.

Once the catch is ashore, the fish are sorted. The numbers of individuals in each species are recorded. When surveying at monitoring sites the total weight of each species should also be recorded. In cases of doubt or lack of experience, species identity should be confirmed in the laboratory. Specimens may be preserved in jars containing a solution of 70% ethanol, and if possible photographs should be taken to preserve a record of coloration.

5.5 Fish Sampling In "No Dive" Areas

In spite of the advantages attached to using direct observation diving methods for fish censuses, these techniques are not safe for areas with high densities of crocodile and hippopotamus, nor are they practical in conditions of poor visibility near the mouths of many rivers and some shallow bays. In such circumstances gillnets are set during the day as well as at night and provide a viable alternative to dive census techniques.

During the day 3 nets are set, one at 15, 10 and 5m respectively using the same procedure as described in section 5.5.2 above. The nets should be positioned, as far as possible, along the same transect as for the habitat grab sampling. The nets are deployed after sunrise and hauled before dusk. At night only one net is set at a depth of 10m.

SECTION 6.   SAMPLING METHODS FOR TAXA SELECTED AS TOTAL BIODIVERSITY SURROGATES: MOLLUSCS

6.1   Identification

The thiarid gastropods are the most diverse and speciose group of molluscs in Lake Tanganyika, with 18 endemic genera comprising more than 40 species. Dr's Kelly West (LTBP's Scientific Liaison Officer) and Ellinor Michel have developed a key for Tanganyika's thiarid gastropods, which the BIOSS teams have field tested during the surveys of Mahale and Nsumbu National Parks. Currently there are no dichotomous keys for the non-thiarid gastropods or the bivalve molluscs of Lake Tanganyika.   Until such materials are developed, the interested reader is referred to Leloup (1950 & 1953) for pictures and descriptions of these taxa and Brown & Mandahl-Barth (1987) for the most recent update on taxonomic nomenclature for these groups.

Experienced workers may be able to identify the species in situ, but it is probably best to make a preliminary identification of larger species underwater, and retain a few specimens to check on shore or in the laboratory. Samples of small species, collected by sieve or suction sampler should be examined either onshore under a hand-lens, or in the laboratory under a low-power dissecting microscope.

6.2   Overview Of Survey Methods

The heterogeneity of habitats makes comparable surveys of relative abundance (and hence calculation of diversity indices) meaningless without a very large number of replicates, and without a precise estimate of the relative or absolute areas of each habitat type present. Accordingly, for littoral and sub-littoral habitats it is recommended that qualitative surveys be conducted. These surveys will provide species richness data only, and will serve as comparative presence/absence data, **provided the time spent searching is standardised**. Note that the lack of abundance data does not allow calculation of diversity indices for molluscs.

6.3   Search Notes

Within each habitat, search for **live** molluscs. Live gastropods have an operculum or 'door' closing the aperture or 'entrance' to the shells' interior. Any gastropod shells that do not have a tan, brown or black operculum blocking the entrance, are empty or dead shells. Live bivalves have 2 shells that are attached by a ligament along one edge. Live bivalves will close their valves together tightly if they are disturbed. Single bivalve shells or paired bivalve shells that do not close are not alive.

In rocky and mixed habitats, live gastropods adhere themselves to rocks using their foot. Thus concentrate your search efforts on the under and outer surfaces of rocks in these environments, for most of the shells you find on the interstitial surfaces are empty or dead (molluscs do not bury their dead, so you will find many of these!). Also avoid chipped, broken, old and weathered-looking shells, since they are dead as well. *Lavigeria* spp often dominate the outer surfaces of rocks, but many other species adhere themselves to the under sides of rocks. Live bivalves bury themselves in sediment and extend their siphon to filter water and feed. You won't find live bivalves in rocky areas, but you may find them in mixed areas if the habitat has a significant sand matrix.

You should turn over many cobbles in your search for molluscs, but remember to replace the rocks in the same manner you found them. Look in cracks in larger rocks, and on the stems and leaves of macrophytes as well.   It may also be necessary to brush sediments off rocks to see rock-dwelling species that may be encrusted with filamentous algae or aufwuchs, and difficult to see.

On sand substrates, look for snail trails. You can pick out the individual snails by tracing their tracks and trails to the terminal point. Also, unlike snails attached to rocks, snails on sand will retract into their shells when they sense your presence. Thus, if you are watching carefully as you pass over them, you will see the shells clamp down in the sediment. Remember to look for bivalves on sand substrates. The animal will bury itself almost fully in the sand, with a small fraction of the shell and perhaps the siphon, visible from the surface.

In sandy habitats and mixed habitats with significant sediment, you will want to sieve a sample of sediment for micromolluscs.

Sieving technique
The top 2-3 cm of sediment is passed through the sieve and the molluscs are collected. The sieving is best done by holding the sieve in one hand and scooping a thin layer of sediment into a wide-mouth jar. Transfer the sediment from the jar into the sieve and shake the sieve from side to side. Carefully transfer the contents of the sieve to a wide mouth sample bottle with a well fitting lid.   Use your hand as a funnel, to ensure that the contents are transferred effectively from the sieve. A bottle or jar with a wide neck is a big help. The more conversant divers become with the technique the more sand they will be able to sieve in the allotted time.

Figure 6.1   Photograph of Mollusc Sieving Activity

6.4   The Mollusc Dive Census

6.4.1 Equipment

Scuba equipment
Underwater notebook
Pencil – sharpened at both ends in case of breakage
Underwater watch
Sample bags with jars labelled for depth and event
1 sieve (1.4 mm mesh)

6.4.2 Procedure

For the Mollusc Dive Census, protocols will differ depending on substrate type. Using the buoy as a marker the divers descend to 15m and conduct the census along the transect line laid for the profile and SVC.

At each of 15, 10, 5 and 0 metres, the divers stop next to the transect line.   Sampling must be carried out on both sides of the transect line, at a distance of no more than 5m from the line.   It is important for safety reasons that the two divers do not work too far from each other. Therefore both divers should sample first one side of the transect line using the appropriate technique and then repeat the techniques on the other side.

The task of each diver will vary depending on the habitat found at each depth. For the purposes of simplification the different types of habitat have been divided into three categories. Since communication underwater is difficult, before commencing the mollusc census and while still on the surface, the divers must:

▪   Confirm which category of habitat is at each depth with the dive pair who carried out the profile dive survey.
▪   Agree between themselves which tasks each will carry out.
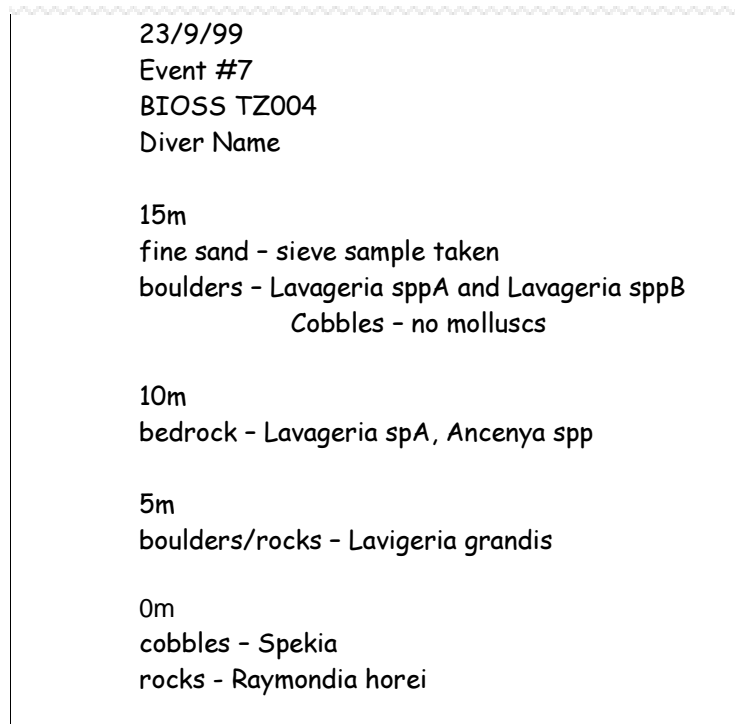
The tasks to be carried out by each diver in the different habitat categories at all depths are shown in Table 6.1.

Table 6.1   Divers mollusc sampling activities in different habitats

Habitat Category	Diver 1 Tasks	Diver 2 Tasks
Non Sandy (All types of rock and gravel)	Search rocks/gravel for 5 minutes	Search rocks/gravel for 5 minutes
Mixed	Search all micro habitats for 5 minutes	Search all microhabitats for 2½ minutes 1 x sieve sample from the sandy habitat during remaining 2½ minutes.
Sandy	Search for 5 minutes for larger molluscs	2 x sieve samples during 5 minute period

NOTE: the tasks are carried out on one side of the transect line for a total of 5 minutes and then repeated on the other side of the transect line. The total time spent sampling at each depth is therefore 10 minutes.

Throughout the census you should be making notes in your dive notebook (see Figure 6.2) recording species which you can identify without collecting samples and linking species as well as sieve samples with their habitat. As soon as is practical after the dive, notebook entries should be transcribed to the "Mollusc Dive Transect: Form 1/1". A copy of this is in Section 13.10. Remember to include the survey and event numbers on your notebooks, and forms. These should match those on the 'Field log sheet'.

```
23/9/99
Event #7
BIOSS TZ004
Diver Name


15m
fine sand – sieve sample taken
boulders – Lavageria sppA and Lavageria sppB
                Cobbles – no molluscs


10m
bedrock – Lavageria spA, Ancenya spp


5m
boulders/rocks – Lavigeria grandis


0m
cobbles – Spekia
rocks - Raymondia horei
```

Figure 6.2   Sample Page of Dive Notebook: Mollusc Dive Census

6.5   Mollusc sampling in "no dive" area

At locations where diving is not possible a 'naturalists dredge' is used to sample for molluscs (Figure 6.3). This technique can only be employed in areas where soft substrates have been identified. The dredge is ineffective and is easily damaged on rocky substrates. As in the case of the habitat grab a vessel is required, which is large and stable enough to mount a small winch to which the dredge can be securely fixed. Always attach a second line with plenty of slack to the dredge so that if the winch cable breaks it can be located and recovered. The sampling procedure is as follows:

Step 1   Having positioned the vessel at the start of the 15m transect used for the habitat grab and gillnet sampling, the dredge is lowered to the lake bottom. Further cable is then unreeled to ensure that the dredge is dragged behind the boat at a flat angle, so as to "bed in" to the substrate properly.

Step 2   The vessel then proceeds at a slow speed along the transect for approximately 60-100m. The winch operator observing the tension on the cable to watch for any indication that the dredge has become snagged.

Step 3 At the end of the transect the dredge is reeled in and its contents carefully sorted using a sieve. Molluscs identified in the sample are recorded on "Mollusc Transect: Form 1/1" (section 13.10).

Step 4 This procedure is repeated along the 10 and 5m transects.

Figure 6.3   Photograph of Naturalists Dredge

Note on mesh size: the optimum mesh size will vary with substrate. Thick, dense or muddy substrates will require a larger mesh size in order to allow the particles to filter through the netting and the dredge to operate effectively. Too large a mesh size however will result in the smaller molluscs also passing through the netting and being lost from the sample.

SECTION 7. SAMPLING METHODS FOR TAXA SELECTED AS TOTAL BIODIVERSITY SURROGATES: OTHER INVERTEBRATES

7.1 Introduction

BIOSS invertebrate sampling has been confined to molluscs, however it is hoped that future surveys will broaden their scope to encompass other invertebrate taxa, suitable for biodiversity assessment. These might include macrobenthic (> 1mm size) and meiobenthic (< 1mm > 0.1mm size) organisms. The taxonomy of most meiobenthos is known only to a few specialists at present, but some groups are highly diverse and contain a large number of endemic species. One key area of research identified as important for future long-term monitoring is the use of macroinvertebrates (primarily aquatic insect larvae) as biotic indicators.

7.2 Identification

Field identification materials to the invertebrates have been prepared by Dr Koen Martens. These include a visual key to crab species and a guide to the identification of Ostracod Genera. Meiobenthos are in many cases only identifiable to Family, Class or even Phylum level, these should be identified as far as possible using Koen Marten's 'Key to Invertebrates'. and a dichotomous key to identify invertebrates to phylum or class.

7.3 Sampling Possibilities

With the exception of molluscs, detailed protocols for invertebrate sampling were not devised by BIOSS, nevertheless some general points on sampling possibilities are included below as an initial guide for future development.

7.3.1 Mobile Predators or scavengers

Such invertebrates include crabs and shrimps. These can be caught in overnight traps, either with light or bait as a source of attraction. Crabs are regularly caught in fish nets. Large, less-mobile, invertebrates, such as molluscs, can also be handpicked from rocks while diving or snorkelling.

7.3.2 Benthic Invertebrates

Invertebrates from sandy and/or muddy habitats can either be collected by hand nets while SCUBA diving (down to 15m) or by dredging or with grabs (entire depth range). Dredges are pulled over the surface and give at best semi-quantitative samples; grabs take a given surface and, if used correctly, produce quantitative samples. There are several types of commercially available grabs and corers. A few of the presently used types are here discussed.

7.3.3 Littoral Invertebrates

These will mostly be collected with hand nets (qualitatively) or, by SCUBA, with a suction device (quantitatively). Care must be taken to sample all available microhabitats: amongst submerged macrophytes, amongst roots of emergent macrophytes, on sandy flats, under stones in splash zones, amongst rocks and algae on rocks, in shell debris etc.

7.3.4 **Pelagic Invertebrates**

Free-swimming littoral or offshore dwelling invertebrates can be collected with plankton nets or with sampling bottles at various depths. Note the presence of vertical migration patterns in the behaviour of these organisms, so that timing of sampling is as important as the choice of device.

SECTION 8.   BIOSS SURVEY DATA STORAGE AND ANALYSIS

It is important that at the end of each sampling day the data collected by divers is transferred from diver's notebooks to the relevant field data sheets. The team member responsible for data management must ensure that data is transcribed accurately and neatly. If vital information such as survey number, event number, location and date is omitted or illegible it could render good data unusable.

8.1 BIOSS Survey Database

The BIOSS survey database was developed by MRAG Ltd to support the field survey programme and provides a complementary tool for conservation planning and management. The design of the database was based on the sampling protocols and data forms described in this document. As with the literature database (SECTION 2) the data can be incorporated into the LTBP GIS system (TANGIS) and so be available for project-wide analysis.

The database stores the results of the BIOSS surveys. The central screen is modelled on the log sheet used by the teams in the field, which summarises all the sample events that have taken place during a particular survey. A particular sample event is recorded according to sampling technique, location, time and place. Each event entry is in turn linked to an activity sub-form, which contains the detailed data pertaining to that event, which will obviously vary according to the technique. Habitat surveys include data on the type and characteristics of the substrates present and faunal surveys record the species and abundance data by depth.

The following list gives an indication of the types of analysis that can be done using the survey database.
- What habitats types are found at a particular location and in what proportions.
- Comparison of diversity between different survey sites in terms of species richness or diversity indices.
- Proportion of species which are endemic
- Depth species association.
- Changes to habitat and faunal communities over time.
- Habitat species association.

The database has also been designed to run using both national and regional data and to synchronise between data input at different locations. It also automatically references the literature database in order to harmonise the use of species codes between the two systems. At the close of BIOSS, standard analysis queries have not been developed within the database. Therefore, analysis has to be supported by someone with Access experience, interested people should contact Dr Ntakimazi (University of Burundi) or Vicki Cowan (MRAG).

Detailed instructions on the operation and management of the survey database can be found in the user manual for the BIOSS survey database – userman v3.0.

The following forms have now been finalised in the field and incorporated in the database, so data from these forms can be entered into the database

Table 8.1   Data recording forms for each sample type

Sample type	Form name	Can be found in this section-
Overview	Field log sheet (FL1)	(13.1)
Habitat surveys	Manta1 (MS1)	(13.2)
	Manta2 (MS2)	(13.3)
	Manta3 (MS3)	(13.4)
	Dive profile (DP1)	(13.5)
	Habitat Grab (HB)	(13.6)
Fish Census	Stationary point census (SF1)	(13.7)
	Rapid visual census (RVC)	(13.8)
	Gill net (GN1)	(13.9)
Mollusc Census	Mollusc transect (MTRANS)	(13.10)

8.2   Analysis of Survey Data

The detailed analyses that are performed on the survey data will depend on the requirements of the report being prepared.   The fundamental analytical requirement, however, is for some measure of diversity, such as species richness, or a diversity index, for comparison between areas. We present some guidelines and an overview of the methods likely to be employed in analysing the data generated by survey methods described in this manual.   More specific detail on some of the analytical methods used to analyse data for the BIOSS final report are given there.

8.3   Analysis of Habitat Mapping

There are four important uses for the habitat mapping data:
- To assess habitat representation within protected areas
- To map habitats for choice of sampling areas
- To assess habitat quality as a measure of anthropogenic impact (e.g. sedimentation of rocks)
- To provide a means of comparing diversity measures between similar habitat types in different areas

Detailed habitat map analysis is awaiting the integration of the survey database with the developing Geographical Information System. At present, the following graphical analyses are sufficient:

- Maps of the coastline indicating main lake-shore (1 km inland, or line of sight) land use categories – e.g. urban, village housing, farmland, grazing land, mature forest, scrubland, wetland.
- Broad substrate categories from Manta surveys (see below)
- SCUBA profile graphical summaries

These maps are generally drawn by hand on copies of lakeshore charts – examples are found in the BIOSS national park survey reports. The profile graphical summaries can be produced from EXCEL spreadsheets.

8.3.1 **Manta survey data**
Summary maps of major habitat types (as indicated on the manta forms). These are used for highlighting the distribution of major habitat types (rocky, sandy, cobbles, mixed). If there were small, localised habitats of particular interest, these could be annotated on the map.

The Manta surveys are used to assess habitat representation within protected areas, map habitats for choice of sampling areas, and may, especially in the case of repeat surveys over time, give some indication of areas impacted by sedimentation, eutrophication or other visually obvious factor.

They are limited to the littoral and shallow sub-littoral, but are none the less useful for broad classification.

8.3.2 Profile data

Individual profiles can be summarised using the 'surface' chart option in Microsoft EXCEL. (see section 4.3 on habitat mapping for example printouts of profiles). The profiles allow biodiversity survey data (fish, molluscs) to be associated with substrate, depth and other habitat characteristics. This is useful as it allows the development of habitat-community associations (which can be investigated through principal components analysis). These associations can then be used as the basis for prediction of the effects on overall biodiversity of the loss or damage of particular habitat types, or the biodiversity value of habitats where it has not been possible to conduct surveys.   For example, if we know what the fish community in an unimpacted rocky area in the central lake is, we can make an estimate of the fish community likely to be present at such a site, without having surveyed it. This is obviously useful when it is not possible to conduct detailed surveys, but the distribution of habitat types is known.

8.3.3 Grouping or comparing samples within comparable habitats.

The most important consideration for analysis of biodiversity is to classify the results of the habitat surveys, so that comparisons can be made, for example, between similar habitats in different areas.

There are two potential approaches. The first is to make very detailed assessments of the habitat, and to use large numbers of very precise categories. This will minimise the within-category variance, but will probably result in very small sample sizes (e.g. very few fish censuses) within each category. This is not recommended at present, but may become feasible in future as data availability increases.

The second, and recommended, approach is to use a fairly small number (<10) of fairly broad categories:

> Bedrock, Boulders, Cobbles, Shellbeds, Sand or Mud, Reed-beds,

and five sets of mixed habitats:

> Boulders/Sand, Cobbles/Sand, Boulders/Cobbles,
> Sand/Macrophytes Boulders/Cobbles/Sand/Shells

Mixed habitats for two habitat types are any habitat where the two categories together make up more than 90% of the substrate, and within that 90%, each of the two categories is represented by more than 10%

Mixed habitats for more than two habitat types are where <90% of the substrate can be allocated to two habitat types.

e.g.   95% sand 5% bedrock would be recorded as SAND
83% sand 17% bedrock would be recorded as MIXED: SAND/ROCK
45% sand 50% bedrock and 5% cobbles would also be recorded as MIXED: SAND/ROCK
33% sand 20% bedrock, 17% cobbles and 30% shell would be recorded just as MIXED

It may be necessary to further combine the above 10 categories for some analyses. Bear in mind that for fish, you have 10 categories of substrate, 3 depth zones (with not all habitats present at all depths) and several geographical areas sampled, and you begin to realise that you need a lot of samples to have more data than categories of sample!

For the analysis in the BIOSS final technical report, we have combined depths between 5 and 15 metres, and have reduced habitat categories to the following:
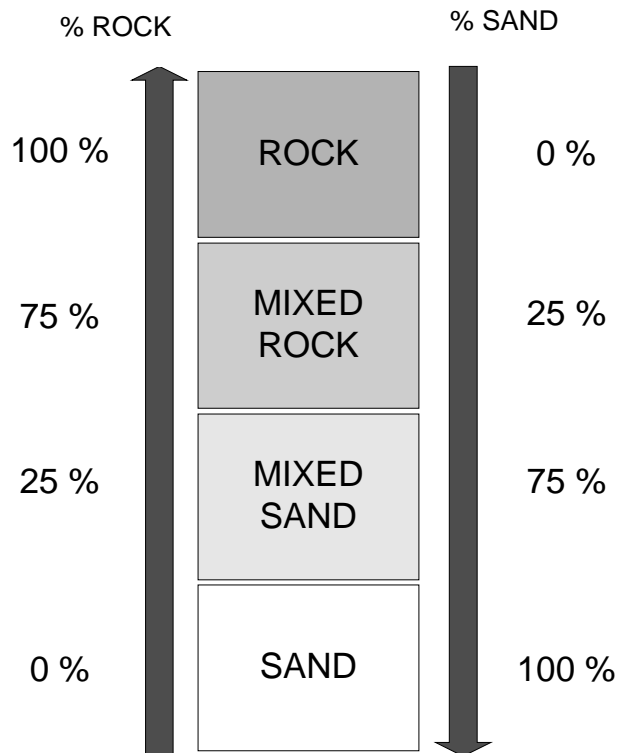
Figure 8.1   Major substrate-based habitat classifications. 'Rock' includes boulders, bedrock and cobbles. 'Sand' includes all grades of soft substratum from mud to fine gravels.

The rationale for choice of these boundaries and for this restricted range of habitats, defined purely in terms of physical substrates is as follows:

- The presence of rocks in a sand or soft substrate has a greater ecological effect than the presence of some sand in a predominantly rocky habitat.
- Mixtures of rocks, boulders, cobbles and shells effectively function as a hard substrate, and were therefore classified as either rock (if no soft substrates present) or rock (mixed). The type of rock (bedrock, boulders etc) and other features (crevices, overhangs etc) were recorded in the original profiles, but insufficient data on biota is available to investigate associations with these more detailed features of the habitat.
- All diving transects were from depths of 5m or greater, therefore habitats characteristic of the littoral fringe, such as pebble or cobble substrates and emergent macrophytes (reedbeds) were not present in the main fish and mollusc surveys.
- Submerged macrophyte stands were not common in the areas surveyed, and are recorded as a secondary characteristic associated with sand and sand(mixed) substrates.

- Shellbeds occur overlaying soft substrates (sand, mud). Where shellbeds occur, they are normally extensive, flat areas. The shells normally form dense layers, so that the substrate in normally uniform – ie it was usually recorded as 100% shell. There is a distinctive fish community associated with these *Neothauma* shell beds, so we have classifed this as a separate habitat category.

For fish, we further reduced the number of habitat categories to just four: shellbed, sand, mixed (>10% sand, < 90% rock) and rock. We retained the classifications above for mollusc surveys, as mollusc distributions are much more closely linked with details of locally available substrate.

8.4 Analysis of Biodiversity Survey Data

The immediate overall objective of the biodiversity survey data is to use estimates, or measures, of biodiversity to compare the diversity of different areas. These could be areas that are protected or unprotected, fished or unfished, sedimented or unsedimented, etc. The estimates may also be used to establish comparative estimates for similar habitat types in different parts of the lake (e.g. Gombe, Mahale, Nsumbu). Some comparison with previous surveys may also be possible for certain taxa, to examine changes in diversity over time.

When comparing LTBP BIOSS surveys with previous ones, remember that different peoples' surveys may have used different sampling techniques, different sampling effort, and even different taxonomy! When doing comparative analyses, you should always find out as much as you can about how the surveys were done.

The possible measures of biodiversity include species richness, diversity indices and related measures such as proportion or number of endemic species, or higher-taxon richness. There are also non-taxonomic measures, such as functional and morphometric diversity, more commonly applied in ecosystem studies and plant community structure analysis. It is necessary to have indexes or measures of biodiversity to answer questions like:

- Which of the existing national parks has the highest fish biodiversity?
- Is the biodiversity of fish higher inside parks than selected areas that are currently not protected?
- Has biodiversity changed in the last 10 years?
- Which rocky-littoral zone area in the lake has the highest species diversity?
- Which method of fishery management has been most successful at conserving biodiversity?
- Has improving pollution control in factories in Bujumbura resulted in increased biodiversity in Bujumbura Bay?

Note that these questions are just hypothetical examples to indicate the kind of management-orientated issues that require indices of biodiversity to answer them.

It is possible to measure biodiversity in many ways.

You can distinguish between organisms based on differences in their:	These are measures of the following types of diversity:
- biogeographical distribution	- Biogeographical
- ecology	- Ecological
- genetic composition	- Genetic
- morphology	- Morphological
- role in the ecosystem	- Functional

In practice, the most common method uses a combination of genetic and morphological measures, and uses the classification system (species, genus etc). Of course, the classification system is based on the understanding that different taxa are both morphologically and genetically different.

This project is currently using taxonomic diversity as the measure of diversity, but it is worth knowing for the future that there are people using the other types of diversity measures indicated above. The methods BIOSS used are given below.

8.4.1 Species richness

For surveys where data on abundance or relative abundance is NOT collected, the only summary statistics that can be produced are estimates of species richness. This is simply the number of species collected for a given level of sampling effort.

The advantages and disadvantages of species richness as a measure are given in the table below:

Advantages	Disadvantages
An integral measure of several elements of biodiversity	Loss of information regarding species identity and no information on ecological structure and function
Relatively easy to survey, measure (taxonomic difficulties permitting!) and explain to non-specialists	No information on relative abundance of species
Comparable to existing data from literature and previous surveys	Comparability depends on adequate sampling effort in all cases

In order to compare species richness estimates between areas (or depths, or other parameter of interest), you should ensure that the sampling effort has been adequate to make a proper comparison.

There is an approximate method, and several more detailed analytical or statistical methods. It is worth first using the approximate method described here. This is best done by first plotting the cumulative number of species against the number of samples within an area. Let us take an example where you have done 10 stationary visual census measurements at 15 m depth, in Mahale, and the same number of censuses in Nsumbu.

You select one of your ten sites at random, count the number of species. Then you pick the second site, at random, this time looking for species that were not found at site 2. Then you repeat with site 3, again recording the number of species not found at either sites 1 or 2. Repeat until you have a species-accumulation curve for all your sites.
The results might look like this (this is just a hypothetical example).
The results might look like the graphs in Figure 8.2.
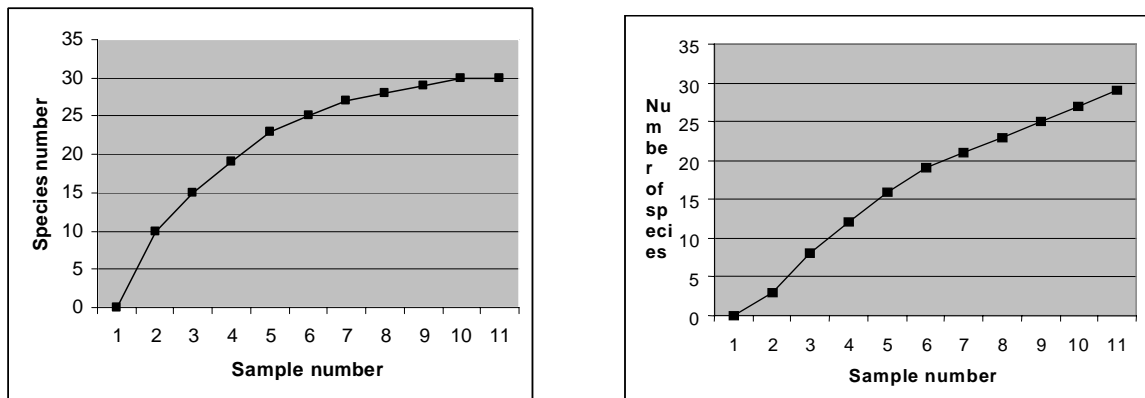
Figure 8.2   Hypothetical example of species accumulation curves, which indicate whether or not sufficient sampling has been completed.   (a) Mahale (b) Nsumbu.

In the graph (a), the curve has levelled off. This indicates that if you took more samples, you would probably not add many more species. You have probably taken enough samples to provide a good estimate of species richness for that location.

In the graph (b), the curve has not yet levelled off. This indicates that doing more samples is likely to result in you finding more species. In other words, you have underestimated the true species richness of that location.

In the above (hypothetical) example, you could not make a valid comparison of species richness between the two locations. Although your sampling effort was the same, your effort relative to what was required to find most of the species was not. This could be that in this hypothetical case, the fish are more patchily distributed in Nsumbu, there are more rare species, or the density of fish is lower, or the richness is higher, or combinations of all of the above! You would come to the WRONG CONCLUSION that fish species richness in Mahale and Nsumbu were about the same if you just compared the richness without thinking about whether the sampling effort was adequate in both cases. In this case, you would have to do additional sampling in Nsumbu before making the comparison.

If, instead, you found your species-accumulation curves were both the same shape as in a), then you could do a valid comparison and come to the CORRECT CONCLUSION that the species richness at Nsumbu was higher than at Mahale.

Please note again that the above is a hypothetical example only!

Two important points:
- plot your species accumulation curves before doing comparative analyses; and
- you should also plot your species-accumulation curves before using diversity indices to compare sites.

There are two problems with this method. First, the shape of the curve often depends on the order in which the samples were picked! Although the randomisation prevents bias, it leaves a lot of error. You could do the exercise three times and find the shape of the curve different in each case.   We get round this by doing the randomisations lots of times (say 100), then averaging the resulting curves. There is no way you could do this by hand, so we use a computer package called 'ESTIMATES' to do this.

'ESTIMATES' also helps us with our second problem – we need to be able to compare richness, even if some samples are incomplete. Previously, a method called 'rarefaction' was used – this basically looks at how many species would be represented if the sample sizes were all equal to the smallest sample size in the set of data being compared. This means throwing away a lot of data! Instead, we prefer to use methods that fit a statistical model to the average species-accumulation curve, and extrapolate the 'true' species richness. We can then use this estimated 'true' species richness as the basis for our comparison between areas, habitats or depths. More details on the models and the 'ESTIMATES' software are given in the BIOSS final technical report (Chapter 2) and in Table 8.2.

Table 8.2   Summary of main features of 'Estimates' software

ESTIMATES 5: Statistical Estimation of Species Richness and Shared Species from Samples By Robert K. Colwell. Version 5.0.1 (December 1997).

Estimates website: http://www.Viceroy.eeb.uconn.edu/estimates
Email: colwell@uconnvm.uconn.edu

Estimates 5 computes randomised species accumulation curves, statistical estimators of true species richness, and a statistical estimator of the true number of species shared between pairs of samples, based on species-by-sample (or sample-by-species) incidence or abundance matrices. Estimates 5 also computes Fisher's alpha and the Shannon and Simpson diversity indices for each sample, as well as the Morista-Horn index of biotic similarity between samples. A user manual and the software itself can be downloaded free of charge from the website given above. Most of the techniques used are described in:

Colwell, R.K. & J.A. Coddington, 1994.   Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society* (Series B) 345, 101-118.
(Note that this publication was is in the LTBP library in Kigoma, so should be available regionally).

For analysis of adequacy of sampling effort, and the estimation of 'true' species richness (subject to sampling gear selectivity effects) we suggest using ESTIMATES to compare randomised species-accumulation curves using the appropriate species richness estimators, rather than the Coleman (rarefaction) curve. In addition to the MM and Chao estimators, we have used both Incidence-based and Abundance-based estimators.   For the RVC and mollusc survey data, only the Incidence-based estimators are used (although beware: abundance-based estimates will be computed automatically as well, even if the data is only 'presence' data).

To see if sample sizes were adequate to obtain unbiased diversity indices, we recommend you examine the 'ESTIMATES' data output for each successive sampling size. If the indices are reaching an asymptotic value as you add successive samples, then you have sampled adequately and have an unbiased index. Beware of indices that are based on small sample sizes.

8.4.2 Calculating and comparing diversity indices

There are many different types of diversity index, but they all have the same basic idea: they incorporate measures of both the number of taxa (e.g. species) and the number of individuals of each species in the sample. None of the indices available are ideal, and all were developed for other purposes. Despite these reservations, it is still useful to calculate diversity indices as a summary biodiversity measure, but you should not calculate them across different sampling

methods, or across different taxonomic groups. E.g. a combined diversity index derived from a combination of gillnetting, stationary visual census and mollusc dredging is not particularly useful or comparable.

At present, the appropriate survey data to calculate diversity indices on are fish from gillnets and stationary visual census data (separately). Depending on what you are wishing to compare, you could pool across depths, or calculate depths separately, or compare individual sites within an area before pooling them to compare within an area. As in all analyses, the exact procedure will depend on what questions you wish to answer.

The most common index is variously known as the Shannon, Shannon-Weaver, or Shannon-Weiner index:

$$H^{'} = \sum_{i=1}^{k} p_i \log p_i$$

where k = the number of species and p_i is the proportion of the total number of individuals sampled in each of i species. For the logarithms, you can use either base 10, natural logs or base 2. You will see all three used in the literature. For this project, BIOSS always used log base 10.

To save you having to calculate proportions, you can calculate the Shannon-Weiner diversity index directly from the sample size and frequency of each species:

$$H^{'} = \frac{n \log n - \sum_{i=1}^{k} fi \log fi}{n}$$

H' is known to be an underestimate of the diversity of the sampled population, however, this bias decreases with increasing sample size.

Once you have calculated a diversity index for a sample or set of samples, you may wish to make comparisons of diversity indices between two or more different sites. There is a statistical test for comparing calculated diversity indices, that is similar to the well known t-test.

$$t = \frac{H^{'}_1 - H^{'}_2}{s_{H^{'}_1 - H^{'}_2}}$$

In words, the above equation translates into the difference between the two calculated diversity indices divided by the standard error of the difference.

The standard error of the difference is the square root of the difference between the variances of each diversity index:

$$s_{H^{'}_1 - H^{'}_2} = \sqrt{s^2_{H^{'}_1} - s^2_{H^{'}_2}}$$

The variance of each diversity index is calculated from:

$$s^2_{H'} = \frac{\sum f_i \log^2 f_i - (\sum f_i \log f_i)^2 / n}{n^2}$$

$\log^2$ means you log the number, then log that logarithm!

So we have our variances, to allow us to calculate the standard error, and we have our diversity indices. We can therefore solve for *t*. Those who have done some statistics before will recall that you need to look up the calculated value of *t*, and compare it to an appropriate critical value. This is done using the t-tables that are found at the back of all statistics text-books. But before you do this, you need to know the appropriate degrees of freedom for the t-test. You can calculate the appropriate degrees of freedom from:

$$v = \frac{(s^2_{H'_1} - s^2_{H'_2})^2}{\dfrac{(s^2_{H'_1})^2}{n_1} + \dfrac{(s^2_{H'_2})^2}{n_2}}$$

In all cases the null hypothesis you are testing is that the two diversity indices are the same, and the alternative hypothesis is that they are different. You can test both one-tailed and two-tailed hypotheses (i.e. you can specify in advance whether you want to say that one index is bigger or smaller than the other, or whether you want to just say whether they are different). Use the 95% confidence limit throughout. The null hypothesis is rejected if the calculated value of *t* exceeds the critical value in the tables.

The only problem with the above statistical test is that you can only compare pairs of areas. There is no multi-sample test (although you may find some people have done Analysis of Variance on these data, even though this is not valid). The best way of doing multiple comparisons with the t-tests described above is to adjust the significance level of each test, using the Bonferroni approximation. Most statistics texts will tell you how to do this.

As we mentioned before, the Shannon-Weiner diversity index is not the ideal measure of biodiversity. In fact, what it measures is the uncertainty with which we can predict the species of the next individual in the sample.

What does this mean?
If we have taken a sample of 100 individuals and found only three species, then we can be fairly sure that the next individual we sample will be one of those three species. Therefore our uncertainty about which species it will be is relatively low, and our calculated diversity index is low.

If, on the other hand, we have taken a sample of 100 individuals and found 38 species, then it will be very difficult to predict what species the 101st individual would be. It could be one of the 38 we have, or it could be another one altogether. Our uncertainty is high, so our Shannon-Weiner index is high. This reflects the higher species richness.

A little more difficult to understand is why, when we have two samples with the same number of species (species richness), the one with greater 'evenness' is more diverse. Evenness is a measure of how equal the number of individuals in each species are.

Again, if you think about it, it becomes clearer. Suppose you have 10 species represented in 100 individuals, but 90 of them belong to one species, and the others are only represented by one

individual. If you sampled one more individual, there is a good chance it will belong to the species with 90 individuals already sampled. The uncertainty in predicting what it will be is low, therefore the diversity index is low.

If, however, you had 10 species each represented by 10 individuals, the 101st individual could equally belong to any of those 10 species and you cannot be very certain which one it will be. The uncertainty is higher, and therefore the calculated diversity index is higher.

The sensitivity of H' to both richness and evenness can be regarded as both an advantage and disadvantage. The index is relatively insensitive to the presence of a few individuals of rare species in large samples. It is, however, sensitive to large differences in abundance. A sample containing a huge number of individuals from one species will always have a low diversity index. This is why juvenile fish have been excluded from the stationary visual census – because of their biased effects on calculated diversity indices. This bias makes the index useful for studies that aim to follow changes in community structure, perhaps in response to pollution. It is less useful as a measure of diversity for comparison of areas for studies of conservation value, where rare species (those few individuals in large samples) are potentially important.

There are other diversity indices that use the same principle. Simpson's index measures the increase in the number of species per individual sampled:

$$D_v = \sum_{i=1}^{k} \frac{1}{p_i^{\,2}}$$

All diversity indices are sensitive to sampling size. In order to test for undersampling, you can plot the index based on a single sample, then two samples, then three from the within the sampling strata you wish to characterise. If the index keeps changing, you know your overall sample size is too small. Once it stabilises (when it doesn't change much as you add more samples) you know you have a sufficient sampling size. This can be done in a spreadsheet, but is rather laborious. You can also do this in the 'ESTIMATES' software package (see Table 8.2).

8.4.2.1 Alpha, beta and gamma diversity.
The diversity of samples all from the same community is usually referred to as alpha diversity. All the diversity indices and species richness measures mentioned above are estimates of alpha diversity.

The differences in diversity between different areas or communities is known as beta diversity. The procedures for testing differences between areas, given above, are indirect measures of beta diversity.

Gamma diversity measures the extent to which ecological counterparts occur as allopatric replacements throughout COMPARABLE habitat type, across a geographical transect (e.g. from north to south in the lake).

Beta and Gamma diversity become important when we begin to think about conservation strategies and the notion of COMPLEMENTARITY when considering the design of conservation areas.

8.4.3 Complementarity, rarity, endemism: biodiversity criteria for conservation planning
Although species richness and diversity indices provide useful summaries for comparative purposes, you lose information about which species are involved. It also makes the assumptions that all species are equal in conservation value. In practice, there are a number of considerations

other than richness or diversity that are important for making decisions about conservation. The most important of these are:

- **Endemism** – a high number of endemics is obviously a major consideration for deciding on conservation value
- **Rarity** – species with small ranges, specialised habitat types, or small population sizes (or all three). These species, which may be vulnerable to extinction, may be considered more valuable in conservation terms than common species. In most cases, we do not know enough about distribution and population sizes of Lake Tanganyika organisms to usefully identify rare species, but this may apply to certain aquatic birds, or lake-associated amphibians, reptiles or mammals. These are not currently surveyed by the biodiversity team, but could form part of future surveys.
- **Limited or discontinuous range**. Some species, although quite common, may not be found all over the lake. This could be because they are associated with particular habitat types that are found only in parts of the lake, or because of the barriers to speciation in the lake and its evolutionary history have led to the presence of very localised species. When designing a network of conservation areas, a major consideration then becomes:

What 'network' of areas includes the most species?

It is a useful start to consider that including a large proportion of all species in the lake in a protected areas network will require the inclusion of all the different habitat types in that protected area network. This is because each habitat type has its own species assemblage, so that if you miss one type of habitat (e.g. sandy shore), then you will fail to include all the species associated only with that habitat.

The Manta and profile data allow us to consider whether or not all the major habitat types in the lake are included in the proposed protected areas, or which areas should be considered for addition to what is already protected.

There is a form of analysis called complementarity analysis.

e.g. Consider four sites, and eight species, distributed as follows:

Site 1	Site 2	Site 3	Site 4
A	D	A	A
B	F	B	B
C	G	C	C
D		E	E
E			H

If you could only pick two sites, to protect the maximum number of species, which two would you pick?

If you used species richness criteria only, you would pick site 1 and 4, as they have the highest species richness or diversity. This would only protect six of the eight species.

If, however, you picked sites 2 and 4, you would include all eight species in your protected area network, despite the fact that site 2 has the lowest species richness. As a set, sites 2 and 4 have the HIGHEST COMPLEMENTARITY of any pair of sites.

Of course, things become much more complicated if you are dealing with a large number of sites and large number of species and computer algorithms to do the searching and comparison of species richness must be employed. At present, the analysis can be done manually, with a small group of people. Further details are given in the BIOSS final technical report.

It must also be noted that biodiversity value cannot be the only criteria for selection of protected areas. Potential for tourism, setup and running costs, feasibility of implementing conservation measures, degree of threat to diversity, socio-economic effects of reserve creation must all be considered as part of an integrated parks planning process.

8.5 Summary

Remember that comparative analyses should always seek to answer a particular management or conservation question. If you can't think of this question in advance, don't do the analysis!

Check to see that your sample size was adequate in all cases before making comparisons. Species accumulation curves are the best way of doing this.

Comparisons of biodiversity should take place either between samples pooled across all habitat types, or only between samples from comparable habitat types. It is not especially interesting to do a comparison of fish diversity between a sandy and rocky site in the same area. It will tell you that fish communities in rocky areas are more diverse than in sandy areas. You probably knew this already.

Where you are able to sample only species richness (no relative abundance areas), you can use these values, corrected for different relative sampling effort, to make quantitative comparisons of diversity in different areas.

Where you are able to sample both richness and relative abundance, you can use t-tests of difference between two diversity indices to compare samples.

Diversity and species richness measures, although useful for comparative analysis, don't tell you which species are present, neither to they distinguish between types of species. They assume all species are equal, and do not account for higher-level taxonomic diversity i.e. - a site with two different species of *Grammatotria*, of equal abundance, will have the same diversity index as a site with one species of *Grammatotria* and one species of *Trematocara*, even though their 'biodiversity' is different.

By looking at the actual species found in each area, you can incorporate other considerations for conservation planning, such as rare, endemic or charismatic species.

Looking at the actual species found in each area, rather than just richness or diversity, allows you to use complementarity analysis to choose your protected area network.

Habitat complexity and ecological diversity can be used to make inferences about species diversity. In the absence of species diversity surveys, they can be useful inputs into conservation planning, especially if you have been able to derive habitat-type: biotic community associations.

Biodiversity criteria are not the only factors to consider in planning conservation strategies.

SECTION 9. THE LONG-TERM MONITORING PROGRAMME

A key objective of BIOSS is to 'develop a sustainable biodiversity monitoring programme'. This recognises that whilst the results from the BIOSS survey programme have informed the first draft of the Strategic Action Programme (SAP), the biodiversity input into future iterations of the SAP should be based on data gathered as part of an appropriate long-term monitoring programme.

9.1 Criteria for Selection of Monitoring Sites

Given the emphasis on sustainability, it was decided that four sites in each country would be sufficient to collect useful data, without putting excessive burden on the implementing institutions.

It was agreed that the composition should include:
- A control site set up in a relatively pristine area free from anthropogenic impacts.
- Three other sites impacted by one or more of the major threats to biodiversity:

Other criteria considered were:
- Impacted sites should be located where conditions are believed to be in a state of transition from pristine to degraded or vice versa, so that changes in biodiversity can be recorded in the context of changes in levels of pollution, sedimentation or fishing effort.
- The range of major habitat types found in the lake should be reflected in the sites selected.
- Sites should be accessible by vehicle or boat regardless of season to ensure that monitoring can take place throughout year.
- Sites should be located as close to the research base as possible, to avoid excessive costs associated with long distance travel and the need to accommodate researchers away from their base overnight.

9.2 Site Locations

The final selection of sites was carried out in consultation with the other special studies to ensure that they incorporated the same sites into their programmes, thereby achieving the aim of joint monitoring. The list of sites for each country together with location, threats to biodiversity and suggested joint monitoring institution are given in Table 9.1.

9.3 Monitoring Techniques

At each monitoring site the census transects should be marked permanently, with painted rocks or metal pickets, to ensure that sampling is carried out at exactly the same location on each occasion.

The techniques used will be the same as for the surveys of existing and potential conservation areas in Lake Tanganyika, as outlined in Table 3.2. One repetition of each technique should be conducted in each sampling period. In summary:

In areas where diving is feasible the following techniques will be employed:
Habitat Profile, SVC, RVC, Mollusc Census, Night Gillnets.

At sites where visibility is poor or diving dangerous the following non-dive techniques should be used: Habitat Grab, Mollusc Dredge, Day and Night Gillnets.

Table 9.1 Sites selected for long-term monitoring in each riparian country

	Location	Lat/long	Threat to biodiversity	Joint monitoring institution
Burundi	Gatororongo Site A	03° 37' 44" S 029° 20' 30" E	Nil – control site	Nil
	Gatororongo Site B	03° 37' 57'' S 029° 20' 27'' E	Sedimentation – landslides	DGGM, Bujumbura (sedimentation team)
	Ntahangwa River (mouth)	03° 22' 34" S 029° 20' 30'' E	Pollution – industrial, domestic (nutrients)	INECN, Bujumbura (pollution team)
	Nyamugari Village	03° 33' 02" S 029° 20' 17'' E	Fishing - Beach seines	DEPP, Bujumbura (beach enumerators)
DR Congo	Luhanga	03° 26' 01" S 029° 07' 51'' E	Control	Nil
	Kalimabenge River (mouth)	03° 25' 12'' S 029° 08' 25'' E	Sedimentation – suspended matter discharge	CRH, Uvira (sedimentation team)
	Kalundu Port	03° 31' 24" S 029° 08' 57'' E	Pollution – industrial and transport	CRH, Uvira (pollution team)
	Bangwe Beach	03° 34' 09" S 029° 09' 02'' E	Fishing – beach seine	DoF, Uvira (beach enumerators)
Tanzania	Jacobsen's Beach	04° 54' 35'' S 029° 35' 52'' E	Control	Nil
	Hilltop Cliff, Kigoma	04° 53' 08'' S 029° 36' 45'' E	Pollution – sewage, industrial fuel leakages	TAFIRI, Kigoma (pollution team)
	"TT" Kigoma	04° 53' 10'' S 029° 36' 46'' E	Pollution – sewage, industrial fuel leakages	TAFIRI, Kigoma (pollution team)
	Kahama Sth (Gombe NP)	04° 41' 25'' S 029° 37' 06'' E	Fishing - Gillnetting	DoF, Kigoma (beach enumerators)
Zambia	Katoto	08° 47' 86'' S 031° 01' 27'' E	Control	Nil
	Lunzua River (mouth)	08° 44' 20'' S 031° 10' 02'' E	Sedimentation – suspended matter discharge	DoF, Mpulungu (sedimentation team)
	Samaki Fisheries,	08° 46' 07'' S 031° 06' 34'' E	Pollution – industrial and domestic	DoF, Mpulungu (pollution team)
	China Beach, Mutondwe Is.	08° 43' 20'' E 031° 07' 42'' E	Fishing – beach seining	DoF, Mpulungu (catch assess team)

9.4 Monitoring Organisms

As outlined in Section 3.2, fish and molluscs were the taxonomic groups selected by BIOSS for use as Total Biodiversity Surrogates (TBSs) for the survey programme. For long-term monitoring, a sub-set of each group has been selected. These monitoring species have been chosen on the bases of the following criteria with representative species taken from the full spectrum of trophic guilds.

- Easy to identify
- Ubiquitous throughout the lake
- Relatively common within specific habitats
- Relatively sedentary with a small home range / territory
- Non-cryptic both in coloration and in behaviour

Additional species with more restricted distributions may be added to the lists of each country if they fulfil the other requirements as listed above.

9.4.1 List of fish species recommended for monitoring (diving observations)

In the list below, the fish species selected for monitoring are grouped under each of the major habitat types.

9.4.1.1   Rocky shore habitats
Cichlids

Altolamprologus compressiceps
Perissodus microlepis
Cyphotilapia frontosa
Petrochromis polyodon
Cyprichromis sp
Plecodus paradoxus
Eretmodus cyanosticus
Spathodus marlieri
Haplotaxodon microlepis
Tanganicodus irsacae
Julidochromis marlieri
Telmatochromis bifrenatus

Lamprologus lemairei
Telmatochromis dhonti
Lepidiolamprologus elongatus
Telmatochromis temporalis
Lobochilotes labiatus
Telmatochromis vittatus
Neolamprologus brichardi
Tropheus moorii
Neolamprologus furcifer
Ophthalmotilapia nasuta (males)
Ophthalmotilapia ventralis (males)

Non Cichlids

Lamprichthys tanganicus
Afromastacembelus moori

Synodondis multipunctatus

9.4.1.2   Mixed and soft substrate habitats (sand, mud, weed beds)
Cichlids

Boulengerochromis microlepis
Lepidiolamprologus cunningtonni
Callochromis pleurospilus
Lestradea perspicax
Ctenochromis horei
Limnotilapia dardenii
Cyatopharynx furcifer

Neolamprologus mondabu
Ectodus descampsi
Neolamprologus tetracanthus
Gnathochromis pfefferi
Simochromis diagramma
Grammatotria lemairii
Xenotilapia ochrogenys

Lamprologus callipterus   Lepidiolamprologus attenuatus
Xenotilapia sima

Non Cichlids
Lates sp   Acapoeta tanganicae

9.4.1.3 Shell habitats
Lamprologus callipterus   Neolamprologus ocellatus
Neolamprologus brevis

9.4.2 List of mollusc species recommended for monitoring

9.4.2.1 Rocky shore habitats
Lavigeria grandis   *Novus Genus spinulosa*
Lavigeria paucicostata   *Reymondia horei*
Lavigeria sp. A   *Spekia zonata*
Novus Genus new sp.   *Stormsia minima*

9.4.2.2 Mixed and soft substrate habitats (sand and mud,)
Limnotrochus thomsoni   *Syrnolopsis minuta*
Paramelania crassigranulata   *Tanganyicia rufofilosa*
Paramelania imperialis   *Neothauma tanganyicensis (nonthiarid)*
Paramelania iridescens   *Mutela spekia (bivalve)*
Stanleya neritinoides

9.4.2.3 Shell habitats
Reymondia horei
Nov. gen. n. sp.

9.5 Biotic Indicators

To enhance the monitoring programme, particularly with respect to joint sampling with teams recording the environmental changes, it is hoped that in the future species suitable as biotic indicators will be identified. Appropriate techniques can then be incorporated into the sampling regime (See Section 3.3).

SECTION 10.   ANNEX 1 - A GUIDE TO GOOD PRACTICE FOR VISITING RESEARCHERS

Visiting researchers who wish to make use of LTBP or any of the national institutions to facilitate their research, and to remove biological material from the region, should be aware of the following guidelines, widely accepted as 'good practice', both legally and ethically.

A Code of Practice for Collectors of Biological Material [2]

A visiting collector should:

- Arrange to work with a local scientist(s) and institute(s).

- Respect regulations of the host country; for example, by entering on the appropriate visa, and observe both national and international regulations for export of biological specimens, quarantine, the need for CITES licences, etc.

- Enter into an official agreement (by an exchange of carefully worded letters, or by more elaborate *Research Agreements, Statements of Collaborative Intent* etc.) with the site managers and/or government department concerned which will include permission for all collecting both in national parks or protected areas and elsewhere

- When budgeting (and applying for) a travel study or expedition grant, include equal expenses for local counterpart(s) and an amount to cover the cost of processing museum specimens or other costs of the visit to the host institute

- Where equipment to be used in the proposed scientific programme is difficult to obtain in the host country consider donating it to the appropriate department

- Leave a complete set of adequately labelled duplicate specimens with the institute before departing from the country. When material has to be left unidentified (e.g. a possible new species) send determinations to the host institute as soon as possible

- Ensure that 'type specimens' of new species described as a result of the research are deposited in the National Museum or Herbaria of the country of origin.

- Inform the national collections repository in the country of origin where duplicate specimens are to be deposited.

- Do not exploit the natural resources of the host country by removing high-value biological products; for example, collecting without prior permission plants with potential horticultural, medicinal, cultural, or other economic value.

- When possible, and before your visit, obtain a list of rare and endangered species of the country visited and become familiar with their identity; collect these species only for a specific purpose, and then with permission

- Inform the host institute or appropriate organisation of the whereabouts of any rare or endangered species that are found. Leave photographs/slides that document your record.

- Collect no more material than is strictly necessary; collect cuttings or seeds for live plant specimens, rather than uprooting whole plants; collect subsections rather than whole

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[2] Source: Jermy, Long, Sands, Stork, Winser (Eds) (1995). Biodiversity Assessment: a guide to good practice. Department of the Environment/HMSO, London

organisms, wherever possible, for marine specimens

- Collect identified reference voucher specimens for all biological products (e.g. textiles) to be exported.

- Send copies of research reports and publications to collaborator(s) and host institute(s). Publish in journals of the host country and use the official language of that country or as joint publications whenever possible.

- Acknowledge all collaborator(s) and host institute(s) in research reports and publications.

- Do not collect material for commercial use or development unless there is an existing Agreement with the host country

SECTION 11.   ANNEX 2 – PRESERVATION AND STORAGE OF SURVEY SPECIMENS

As identification for most groups will not be possible in situ, samples will have to be preserved and processed in the laboratory. On shorter trips, it may be possible to return live organisms to the laboratory to ease identification, but in most cases samples will have to be preserved for later identification.

11.1 Preservation From Gill Net Surveys

It is recommended to collect and preserve for each species or population a maximum of 5-6 specimens in order to be able to describe the morphological variation. Specimens may be preserved in jars containing a solution of 70% ethanol. A good field picture of the species should also be taken in order to evaluate the live coloration of the fish. Particularly interesting for taxonomic studies in the future are samples of the groups *Synodontis, Tropheus, Julidochromis, Protopterus, Labeo, Phyllonemus, Eretmodini, Afromastacembelus, Xenotilapia* e.g., and of many fluviatile groups.

11.2 Preservation Methods For Invertebrates

The table (after De Pauw & Vannevel, 1991) below shows suggested methods for preserving samples of different invertebrate groups.

Animal group	Fixation	Preservation
Hydrozoa	menthol; propylene- phenoxetol 1%; formol 20%	formol 10%; EtOH 70%
Platyhelminthes	investigate alive; put drops of Steinmann's liquid* on specimen, rince with EtOH 30%	EtOH 70-90%
Oligochaeta	EtOH 5-10%; propylenephenoxetol 1%	formol 4%; EtOH 70%
Nematoda	hot (70ºC) formalin 4%	formalin 4%
Hirudinea	sparkling water, followed by EtOH 10-30% or formol 4%; MgC12 7%; EtOH 5-10%	EtOH 70-85%; formol 4%; Koenike's solution**
Mollusca	study alive; propylenephenoxetol 1%; formol 4%; EtOH 70%	dry; EtOH 10%
Acari	Ether; ethylacetate	EtOH 70-90% Koenike's solution**; Viets' solution***
Crustacea	Formol 4%; 1% propylenephenoxetol	EtOH 70-90%
Ephemeroptera	EtOH 70-75%	EtOH 75%
Plecoptera	EtOH 70-80%	EtOH 80-90%
Hemiptera	hot water 70ºC; ethylacetate	dry; EtOH 70%
Odonata	EtOH 70%	EtOH 80%
Coleoptera	ethylacetate + EtOH 70%	EtOH 80%
Diptera	hot water 70ºC; formol 4%	EtOH 70%
Trichoptera	Ether; chloroform; formol 2% + EtOH 90% and dry	EtOH 80%; formol 2%
* Steinmann's solution: 1 part salpeter acid, 1 part mercurychloride in 50% NaCL, 1 part distilled water		
** Koenike's solution: 5 parts glycerine, 2 parts vinegar, 3 parts distilled water		

Animal group	Fixation	Preservation
*** Viet's solution: 3 parts vinegar, 11 parts glycerine, 6 parts distilled water		

11.3 Museum Storage

All samples, sorted or unsorted material, must be properly labelled, catalogued and stored in a collection. Such collections need continuous curating, to prevent drying out, damage by fungi or museum beetles etc.

Labels must be water resistant (or resistant to other liquids used) when put in the container, or be properly attached, so that they cannot dissolve or detach. Writing on the label must be permanent (pencil or Chinese ink). Labels must contain: species name, locality name (if possible, with co-ordinates), date of collection and collector, one or more identification codes, which then refer to catalogues in which more extensive data are recorded.

Containers must be large enough following size of specimens or of sample. In general, there should be at least twice as much preserving liquid in the container as the volume of the specimens or sample. Lids must seal very good, but the level of the liquid should be checked annually, to prevent samples from drying out.

Catalogues must contain all pertinent information related to specimens and samples in a collection. All data entered must refer with a code to the appropriate place of collection, so that the sample or specimen can be retrieved with minimal effort. Catalogues can be a book, a card index or (preferably) a computer file, but at all times copies should be kept and stored in a different place from the original. Information in the catalogues should repeat the information on the labels, but should also contain additional data such as measurements and habitat descriptions, co-ordinates and altitude of locality, cross-references to other taxa from the same sample etc.

If possible, summaries of available collections should be posted on the appropriate websites of the internet.

SECTION 12.   ANNEX 3 – DIVE SAFETY

12.1 General Diving Advice

!   Do **not exceed the maximum depth** that your dive qualification permits.

!   If departing from the techniques as laid down in this document, ensure that you have carried out the required safety stops to prevent **decompression sickness**

!   Only conduct a **maximum of two dives per day** below 10m

!   After six consecutive days diving, **do not dive the seventh day** in order to complete offgassing

!   Commence your ascent with a **minimum of 50 Bar reserve** in your cylinder.

!   Keep a **record of all dives** completed in a dive log and fill this in each evening.

12.2 Standing Instructions For Sampling In Areas Where Crocodile And Hippopotamus Are Present

12.2.1 Introduction

When working in any area where there are potentially dangerous animals such as crocodiles and hippopotami, you should bear in mind the following:

♦   **Wild animals** are wary of humans and will usually avoid close contact them.

♦   **But**, animal behaviour is unpredictable and in certain circumstances individuals will attack. In the case of crocodiles and hippos this could result in serious injury or death.

♦   **Therefore**, always exercise caution in areas where crocodiles and hippos are present.

♦   **However**, by taking sensible precautions the risk to you and your colleagues can be minimised.

The purpose of this instruction is to outline some sensible and practical guidelines, which will assist you in carrying out your field work on the lake safely. Ultimately, the final decision on how to proceed with work in areas where crocodiles and hippos are present, will be based on the assessment of those on the ground.   Nevertheless, when engaged in LTBP work on the lake, you will be expected to abide by the procedures outlined below.

12.2.2 General Procedures

1. Before you conduct any fieldwork find out as much as you can about the distribution of crocodiles and hippos in the area. Identify the places where they are known or the habitats where they are likely to occur. Favoured habitats for crocodiles include; river mouths, reed beds and sandy beaches though they can also be encountered moving between such locations.   Hippos tend to inhabit sheltered waters and bays with plenty of vegetation close to the shore for grazing.   Potential sources of information include: local communities, fisherman, your colleagues and those working for other organisations which operate on the lake (e.g. parks and wildlife services, fisheries departments, water affairs, research

institutions).

2. If you know an area is likely to be populated by hippos or crocodiles, then you should employ the range of sampling techniques given in the standing instructions as alternatives to the dive techniques and manta tow (i.e. grab sampling, gill nets, dredging and the "croc box").

3. Whether or not you are certain of the presence of crocodiles or hippos, you should approach any site carefully observing both the shoreline and surrounding water. Crocodiles can often be seen slipping into the water at the approach of boats or people on foot; also look out for their tracks which can clearly be seen on the sandy beaches they frequent. Hippos will usually raise their head above water to observe an approaching motorboat. If the boat is without engine, periodically tap the hull of the boat with paddle or pole to warn them of your approach.

4. Vigilance should be maintained throughout the conduct of the fieldwork. It is the best safeguard against injury to you or your colleagues. Even if accompanied by an armed escort (i.e. park ranger) do not place your faith in weapons of any kind. Even the most skilful marksmen will find it extremely difficult to get an effective shot at an attacking hippo or crocodile. They are more likely to wound the person being attacked or the animal, making it more dangerous.

*12.2.3*Crocodiles

In areas where there is a possibility that crocodiles might occur. The following guidelines should be adhered to:

1. **Actions by the boat crew.**

   a. When team members are underwater the dive boat should remain close to the buoy marking their location and the engine should be left idling. This should deter crocodiles from approaching too close.
   b. If a crocodile is sighted the boat handler should rev the engine three times as a warning to the divers, who should surface immediately and be recovered to the boat.
   c. Whenever divers are on the surface or carrying out snorkel techniques, the boat should shadow them maintaining a maximum distance of 5m. On sighting a crocodile the engine should be revved three times and the divers instructed to return to the safety of the boat.

2. **Actions by divers/snorkellers.**

   a. When in the water try not to shout or splash. This is the classic behaviour which will attract crocodiles and may induce them to attack.
   b. Don't stay very long in a single place especially while on the surface of the water.
   c. Standing knee deep in the shallows mimics the behaviour of drinking animals and is more dangerous than swimming quietly.
   d. According to one celebrated Lake Tanganyika fish specialist (Axelrod), reports show that if a crocodile has a close encounter with a SCUBA diver underwater it will normally flee. It has even been suggested that grunting loudly may drive it away. Whatever happens don't panic and do not attempt to flee yourself, again this may induce the crocodile to attack.
   e. Even though a crocodile may have been deterred once, it does not mean it will not return. After a sighting, terminate your diving in that location.

*12.2.4*Hippopotomi

Unlike crocodiles, hippos are not predators, but they can be highly aggressive particularly when protecting young calves or defending territory. Nevertheless, as long as they are not surprised at

close quarters, hippos will normally submerge and move away on seeing an approaching boat.

1. **Actions by boat crew.** The same procedures should be observed by the boat crew as for crocodiles, when divers are in the water. On sighting a single or group of hippos the engine should be revved three times. The divers should immediately return to the boat, which should then proceed to a safe distance from the hippos. Remember a small boat with outboard engine does not guarantee protection from an adult hippo.

2. **Actions by divers**. Reports of divers encountering hippos underwater are few. But one member of the Burundi BIOSS team has had such an experience. His immediate action was to dive to a greater depth, the hippo did not follow.   Hippos are sensitive to pressure at greater depths and according to the Burundians are unlikely to descend beyond 5 metres.

*12.2.5*Conclusion

If you follow these simple guidelines, the risk posed by crocodiles and hippos to BIOSS team members will be significantly reduced. However, once in the field it is your vigilance and application of basic common sense that will do most to ensure that you and your colleagues can carry out your work in safety. Remember, no data is so important as to justify taking undue risks to life and limb.

SECTION 13.   ANNEX 4 – DATA ENTRY FORMS

13.1 Field Log Sheet

LAKE TANGANYIKA BIODIVERSITY PROJECT (LTBP) BIODIVERSITY SPECIAL STUDY (BIOSS) FIELD LOG SHEET											
SURVEY#	GROUP#	SAMPLE#	ACTIVITY	DATE	AREA	LOCALITY	VESSEL	GPS - START	GPS -END	TIME - START	TIME - END

SURVEY CODES			ACTIVITY CODES							
BURUNDI:	BIOSS_ _ _ _ BD		manta 1	coarse substrate mapping		SVC	stationary visual census		dredge	dredging for molluscs
CONGO:	BIOSS_ _ _ _ CG		manta 2	shoreline mapping		RVC	rapid visual census		grab	benthic grab sample
TANZANIA:	BIOSS_ _ _ _ TZ		profile	habitat profile		FSC	full species census		NAME:	
ZAMBIA:	BIOSS_ _ _ _ ZB		mtrans	mollusc transect		gill	gill nets set		DATE:	

13.2 Manta 1 Form (Underwater Data)

LTBP BIOSS - MANTA SURVEY : FORM 1/3																								
SURVEY # :						GROUP #:						SAMPLE # :												
AREA :												LOCALITY :												
TIME: Start				End:								DATE :												
GPS: Start				End:																				
	Diver 1:						Diver 2:						Diver 3:						Diver 4:					
SUBSTRAT(%)	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9	12	15	18
Bedrock																								
Rock																								
Gravel																								
Sand																								
Shellbed																								
Stromatolites																								
HETEROGENOUS																								
Y/N (YES/NO)																								
FEATURES	(1 - 5)			1 = rare,		5 = abundant						(1 - 5)												
Shells																								
Silt on rocks																								
Macrophytes																								
INCLINATION				Above				✓																
Vertical																								
Oblique																								
Horizontal																								
				Below				✓																
Vertical																								
Oblique																								
Horizontal																								
Others																								
NAME:				DATE FORM COMPLETED:																				

13.3 Manta 2 Form (Coastline Data)

LTBP BIOSS - MANTA SURVEY : FORM 2/3																								

SURVEY # :						GROUP #:						SAMPLE # :												

AREA :												LOCALITY :												

TIME Start :						End:						DATE :												

GPS Start :					End:																			

	Recorder 1:						Recorder 2:						Recorder 3:						Recorder 4:					
Physiography	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9	12	15	18	3	6	9	12	15	18
Linear																								
Island																								
Estuary																								
Bay																								
Terrain												✓												
Cliffs																								
Rocky shore																								
Gravel beach																								
Sandy beach																								
Reedbeds																								
Land Use												✓												
Forest																								
Scrub																								
Cultivation																								
Fishing																								
Settlement																								
Others																								

Special Features of Area

NAME:						DATE FORM COMPLETED:																		

13.4 Manta 3 Form (Location Data)

LTBP BIOSS - MANTA SURVEY : FORM 3/3		
SURVEY # :	GROUP #:	SAMPLE # :
AREA :	LOCALITY :	
TIME Start: Finish:	DATE :	
GPS Start :	GPS Finish:	

Recorder A :

Mins	GPS-LATITUDE		GPS-LONGITUDE		REMARKS
3		S		E	
6		S		E	
9		S		E	
12		S		E	
15		S		E	
18		S		E	

Recorder B :

Mins	GPS-LATITUDE		GPS-LONGITUDE		REMARKS
3		S		E	
6		S		E	
9		S		E	
12		S		E	
15		S		E	
18		S		E	

Recorder C :

Mins	GPS-LATITUDE		GPS-LONGITUDE		REMARKS
3		S		E	
6		S		E	
9		S		E	
12		S		E	
15		S		E	
18		S		E	

Recorder D:

Mins	GPS-LATITUDE		GPS-LONGITUDE		REMARKS
3		S		E	
6		S		E	
9		S		E	
12		S		E	
15		S		E	
18		S		E	

NAME: DATE FORM COMPLETED:

13.5 Dive Profile Form

LTBP BIOSS - DIVE PROFILE: 1/1								
SURVEY # :				SAMPLE # :			GROUP#:	
AREA :				LOCATION :				
GPS:				DATE :				
TIME Start:				TIME Finish:				
DIVERS:				WATER VIZ:				
Depth (m)	15	10	5	0	Depth (m)	15	10	5	0
Distance (m)					Distance (m)				
Substrate (%)					**Rock Characteristics**	(1few - 5 many))			
Bedrock					Fissures/crevisses				
Boulders					Overhangs/underboulders				
Rocks					Calcite				
Gravel					Shells				
Sand					Algae				
Shellbed					Silt cover				
Stromatolites									
Inclination (✓)					**Sand Characteristics**	(1 - 5)			
Vertical					Firmness/stability (soft-firm)				
Oblique					Surface relief (flat-uneven)				
Horizontal					Triage (poor-well)				
Taxa (✓)					Ripples (few-many)				
Macrophytes					Burrows (few-many)				
Filamentous Algae					Diatom mats (few-many)				
Sponge					Nests (few-many)				

SITE DESCRIPTION

NAME: DATE FORM COMPLETED:

13.6 Habitat Grab Form

LTBP BIOSS - HABITAT GRAB : FORM 1/1												

SURVEY #:			GROUP #:				SAMPLE #:					
DATE:	AREA:					LOCATION:						
GPS:						SECCHI DISC (M):						
TIME Start:		Finish:				RECORDERS:						

SUBSTRATE

Depth	15m				10m				5m			
Approx distance from shore (m)												
Grab #	1	2	3	Grabs 1,2 & 3	1	2	3	Grabs 1,2 & 3	1	2	3	Grabs 1,2 & 3
Substrate (%)				Average (%)				Average (%)				Average (%)
Gravel												
Sand												
Shells												
Stromatolites												
No result (possible rocky)												
Sand characteristics (1-5)												
Sorting (poor well)												
Taxa (✓)												
Macrophytes												
Filamentous Algae												
Sponge												

Site description:

Name:	Date form completed:

13.7 Stationary Visual Census Form

LTBP BIOSS - STATIONARY VISUAL CENSUS : FORM 1/1								
SURVEY # :			GROUP # :			SAMPLE # :		
AREA:			LOCATION:					
DATE:			TIME In:			Out:		
GPS:						WATER VIZ (m):		
DIVERS:								
Depth (m)	SPECIES	NO	Depth (m)	SPECIES	NO	Depth (m)	SPECIES	NO
NAME:					DATE FORM COMPLETED:			

13.8 Rapid Visual Census Form

LTBP BIOSS - RAPID VISUAL CENSUS : FORM 1/1								
SURVEY # :				GROUP # :			SAMPLE # :	
AREA:					LOCATION:			
DATE:					TIME In:			Out:
GPS:					WATER VIZ (m):			
DIVERS:									
Depth (m)	Time period	SPECIES	Depth (m)	Time period	SPECIES	Depth (m)	Time period	SPECIES
NAME:				DATE FORM COMPLETED:				

13.9 Gill Net Form

LTBP BIOSS GILLNET SET: Form 1/1				
SURVEY #:		GROUP #:	SAMPLE #:	
AREA:		LOCATION:		
GPS:		RECORDERS:		
DATE:		TIME SET:	TIME HAULED:	
Depth (m)	SPECIES		Total Catch	
			No	Wt (gr)
NAME:		DATE FORM COMPLETED:		

13.10 Mollusc Transect Form

LTBP BIOSS - MOLLUSC TRANSECT : FORM 1/1		
SURVEY #:	GROUP #:	SAMPLE #:
AREA:	LOCATION:	GPS:
DATE:	TIME In:	Out:
DIVERS:		WATER VIZ (m):
TICK APPROPRIATE BOX:	DIVE	DREDGE

DEPTH	GENUS, SPECIES	SUBSTRATE (if known)
15m		
10m		
5m		
0-2m snorkle		
Name:		Date form completed: