3. AN ASSESSMENT OF LARGE-SCALE DISTRIBUTION OF BIODIVERSITY IN LAKE TANGANYIKA

3.1 Introduction

The surveys undertaken by BIOSS during the LTBP project represent one of the first attempts at quantitative, replicable and standardised surveys of components of the Lake Tanganyika biodiversity. These surveys were specifically designed to carry out comparative estimates of richness and diversity of fishes and molluscs. These surveys are therefore used as the primary source of advice for conservation planning (Chapters 4 and 5). There is, however, an extensive body of prior information on the biota of Lake Tanganyika, dating back to the late 19th Century (reviewed in Coulter, 1991). This body of literature (and some archived but unpublished data) provides an important complementary source of information. It has three important direct contributions to the work carried out by LTBP, as it provides:

- a historical record of survey activity and species distributions;
- additional information on spatial distributions; and,
- the only sources of information on taxa and environments not surveyed by the present project.

Most of the work done in Lake Tanganyika prior to this project was not undertaken for the purposes of conservation planning so it is not standardised for this purpose. This inevitably limits its value in comparative analysis, or as baseline data to assess changes over time. The previous work on Lake Tanganyika's biota falls mainly into four categories:

- Fisheries-related studies, mainly on the offshore pelagic fish community (summarised by LTR, 2000).
- Collecting expeditions for studies in alpha taxonomy and systematics (authors such as Poll, 1956 and Boulenger, 1920).
- Sample surveys for evolutionary studies (including molecular genetics for sub-specific studies, and fossil species for palaeological approaches).
- Studies in behavioural ecology (mostly work by Japanese research teams, summarised in Kawanabe, Hori and Nagoshi, 1997 and frequently reported in short abstracts under the title of: Ecological and Limnological Study on Lake Tanganyika and its Adjacent Regions).

This data provides a rich archival source, which, through the efforts of BIOSS in collating some of it into a relational database, is being made available to regional agencies for conservation planning and research purposes. Of the many possible uses to which this database can be applied, we choose to present in this report only those relevant to the aims and objectives of BIOSS. The analyses presented are therefore aimed at generating species lists for national biodiversity inventories and identifying major intra-lacustrine distribution patterns that will inform the choice of conservation strategy. We also aim to produce species lists from National Park areas, to compare with and supplement the standardised surveys described in Chapters 2 and 4. These can then be used for parks inventories, and for assessment of future survey requirements.

3.2 Methods

To date, information from 143 reference sources have been entered into the literature database, including the dataset generated by the BIOSS field programme. While the database has the capacity to include data from all species, the priority taxonomic group for data entry were the fishes. Over 13,000 individual "species at a specific location" data have been entered and are drawn on for this analysis. As many of the data entered were not collected for this purpose, some judgement is required to distil the relevant data for entry. For example, determining the latitude and longitude for a species location described as "offshore locality in southern Burundi". Also many of the surveys record only presence data, which is important to consider when interpreting the output of the database. In addition to location

data, the database stores information on diet categories, length, habitat categories, depth, survey description and timing for each species as well as full reference details of the literature sources.

The database has the facility to update and retain changes in species names and can also record the full range of common names used for a single species. This information is critical to keep track of taxonomic revisions and is in line with world-wide databases being developed to record species with important conservation status (for example the WCMC Animals Database and the IUCN Red List of Threatened Animals).

Several key datasets are not included as yet. Dr Kelly West supplied key mollusc data, namely her PhD, masters and SIAL surveys, but unfortunately this could not be entered in time for this analysis. The mollusc data collected during the survey field programme of BIOSS have been incorporated. The CRRHA[5] project (1992-1995) collected a great deal of fish location and habitat data along the Burundian and Congo coast using gill nets and diving. This type of data is incredibly valuable, supporting the aims of the database by providing a standardised source of species location information for planning and research. However, the data are coded and collated into tables in various project reports and unfortunately presentation in this format is inaccessible. Ideally these types of data could be made available to the lake-wide management body in an electronic format with explanatory notes, and then with some reformatting be imported relatively easily. These are a few examples of the huge wealth of data on Lake Tanganyika, which provides an incredible potential resource for planning and management.

During database development, a set of standard reports was included to allow users unfamiliar with the database software (Access) to interrogate the data. These reports were a preliminary set, developed before the more detailed analysis for this chapter. The established reports are as follows:

- fish species lists by reference, location (named site) and habitat category
- references for a single species, location or habitat category
- locations for a single species, reference or habitat category
- list of fish species at a depth
- depths recorded for all species
- list of species by diet category
- list of diet categories recorded for fish species
- full lists of all species, fish, cichlids, non noncichlid fish, bivalves, and ostracods
- list of all fish found only in the north, south, middle basins and those found in all three, i.e. circumlacustrine species

As noted in the introduction, this chapter focuses on a narrower set of issues and so additional queries have been developed to provide data for this analysis. These queries have yet to be built into the database and so, unfortunately remain unavailable to the non-Access user. However, it is hoped that building this latest set of reports into a user-friendly format will be part of the next project planned for the implementation of Lake Tanganyika's strategic action programme.

The database has been specifically developed to link with TANGIS, which is the GIS (geographical information system) system that was developed within LTBP. However, more technical work is required to fully integrate the database into TANGIS. Therefore, to generate maps for this report, we linked the database to another mapping programme (Mapinfo).

[5] CRRHA – Centre Regional de Recherche en Hydrobiologie Applique

The following analyses have been generated from the literature database to support this chapter.

- Map showing location of surveys included in the database.
- Map showing the location of different types of surveys used for the fishes, i.e. gill nets, scuba techniques and seine nets.
- Total species (fish) lists by country
- List of species (fish, molluscs) recorded exclusively in each country
- Total species (fish) lists by each of the three basins (north, middle, south) and those found in all three, i.e. circumlacustrine
- Total species (fish and molluscs) list for the waters off each national park (Rusizi, Gombe, Mahale, Nsumbu)
- List of species (fish and molluscs) recorded exclusively in each park, i.e. not found in any of the other parks
- List of fish species not recorded in waters adjacent to any of the four national parks – their locations illustrated on a map

An important point to note is that the results presented in this chapter draw from the literature database as it stands at the close of BIOSS, and the database does not include all available literature on Lake Tanganyika. As has been noted elsewhere in BIOSS reports (standard operating procedures, final outputs report, database documentation) this database will improve in its value as a planning and research tool the more data are entered and reviewed. It is important to understand that the database will never be 'completely final' for that 'ultimate' analysis we would all like. The database will always lag behind the ongoing clarification of the taxonomy of Lake Tanganyika's species, new papers and reports awaiting publication, data entry of existing literature, the huge wealth of data currently stored in researcher's notebooks and other sources not easily accessible[6]. Therefore, interpretation of the database's output must recognise that results will be a function of the data entered and its quality.

At times when significant analysis needs to be completed (for example, when the strategic action programme for Lake Tanganyika is reviewed), a decision has to be made to cease data entry and the data "cleaned' and queried". Such a process has happened at the close of BIOSS: entry of data from the literature has been stopped, electronic data from the BIOSS survey programme and the Ecotones survey (kindly provided by Dr Ntakimazi) were imported. A process of sorting and checking the data entered has occurred with a flurry of long distance email exchanges between England, Burundi and America. Despite all efforts, it may be expected that Lake Tanganyika's taxonomic experts will be able to correct some of the detail presented here and the authors would be very grateful for any feedback, which would be used to update the database.

In conclusion, the aim of this chapter is not to present definitive results, rather to illustrate the power of the database to deal with disparate, complex data that were collected for other purposes and yet still provide us with insights into the wider picture of Lake Tanganyika's biodiversity.

[6] The task of maintaining and continuing the data entry is onerous, given the extent and diversity of literature on Lake Tanganyika's biodiversity. Unfortunately, at the close of LTBP funding to support the ongoing data entry is not certain. It is hoped that this will be seen as a priority in all future work and that bodies with a stake in Lake Tanganyika such as the lake-wide committee initiated under LTBP, international researchers and relevant national institutions will allocate appropriate support to its continued development.

3.3 Results

3.3.1 Location data

The following maps indicate where various surveys taken place on Lake Tanganyika.
Figure 3.1 shows the location of all surveys currently entered into the database. Note that a single dot on the maps may represent a single species-location datum or a more intensive survey that provided many species-location data at that site.

As survey details are entered into the database, we have also produced maps showing where different types of surveys have been carried out. This should help identify areas that have been under sampled by specific methods and hopefully guide future work. The survey types illustrated here include: gill net surveys (Figure 3.2), seines nets (Figure 3.3), and scuba work (Figure 3.4).

With the exception of the Congolese coast and the southern most section of Tanzania (south of Kipili) the lake is remarkably well surveyed. The fish in waters adjacent to the national parks, the coast close to Bujumbura, Uvira and Mpulungu have been intensively surveyed with gill nets (reflecting BIOSS survey locations), while the remainder of the lake's coastline awaits such investigation. The use of seine nets to sample the fish is more widespread and scattered. The pattern of scuba surveying mirrors the map of all survey types, being concentrated on national parks and highlighting the coasts of DR Congo and Tanzania south of Kipili as those areas that remain under sampled.

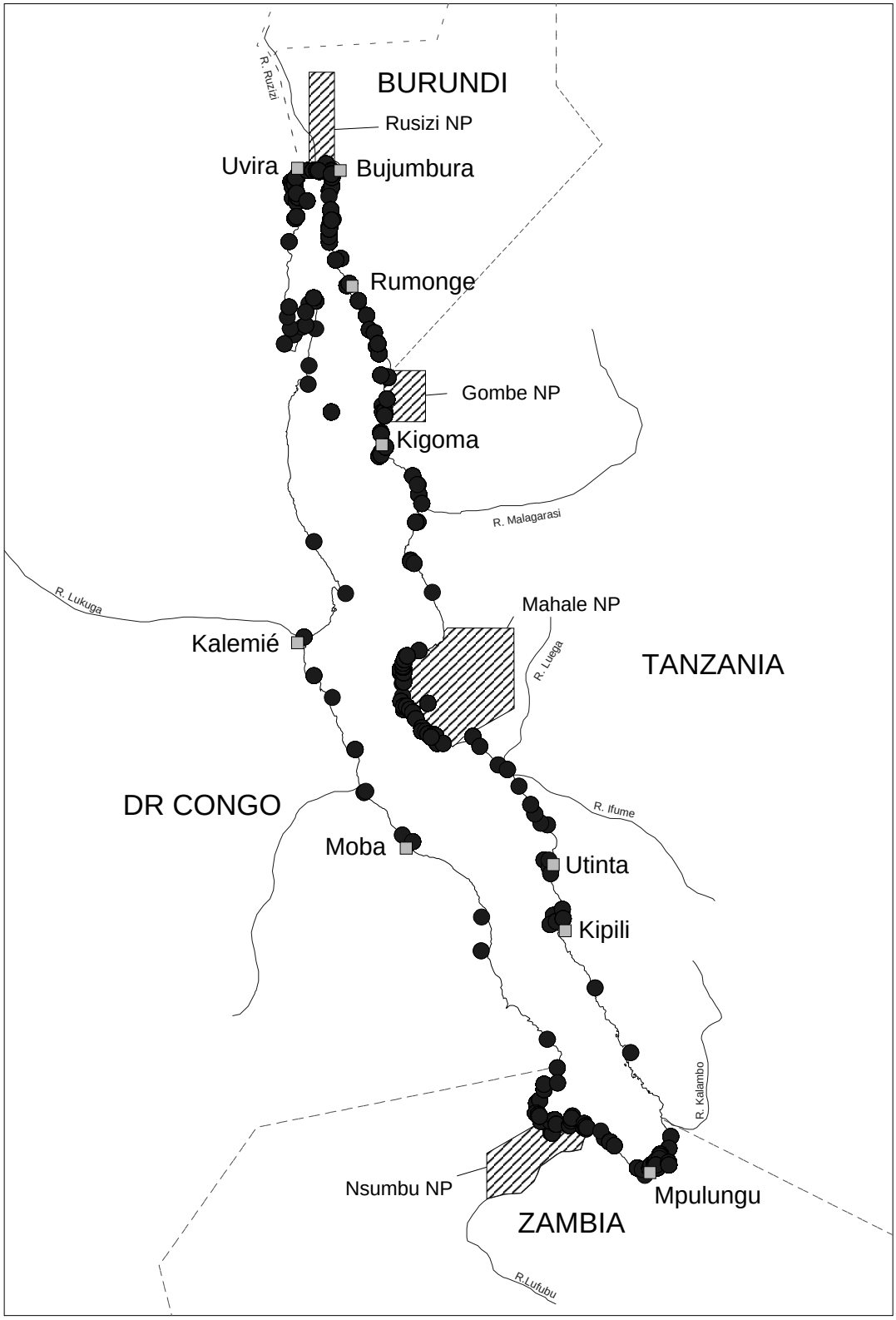

Figure 3.1 Map showing location of surveys conducted on Lake Tanganyika (source Literature database)

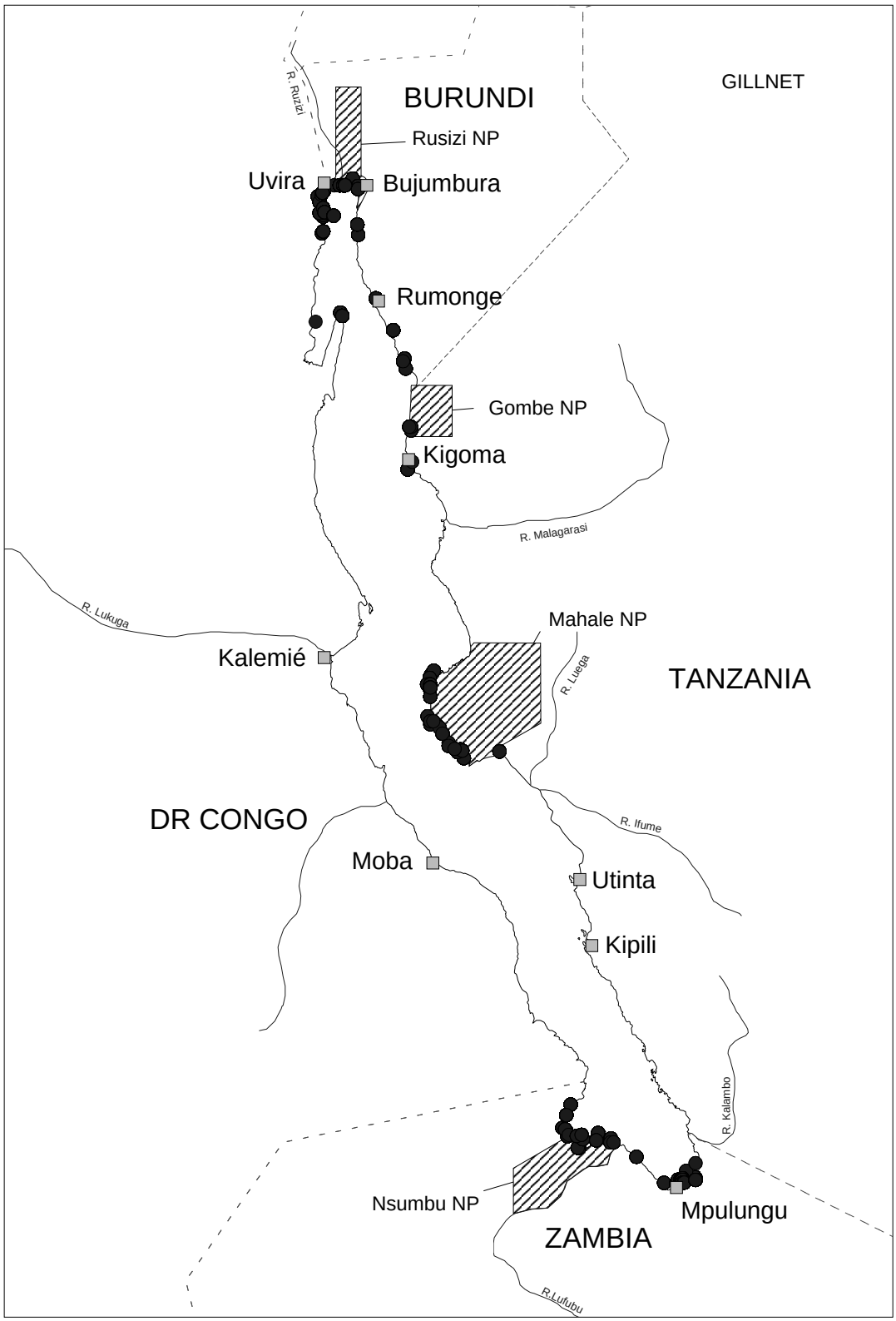

Figure 3.2 Map showing location of gill net surveys on Lake Tanganyika (source Literature database)

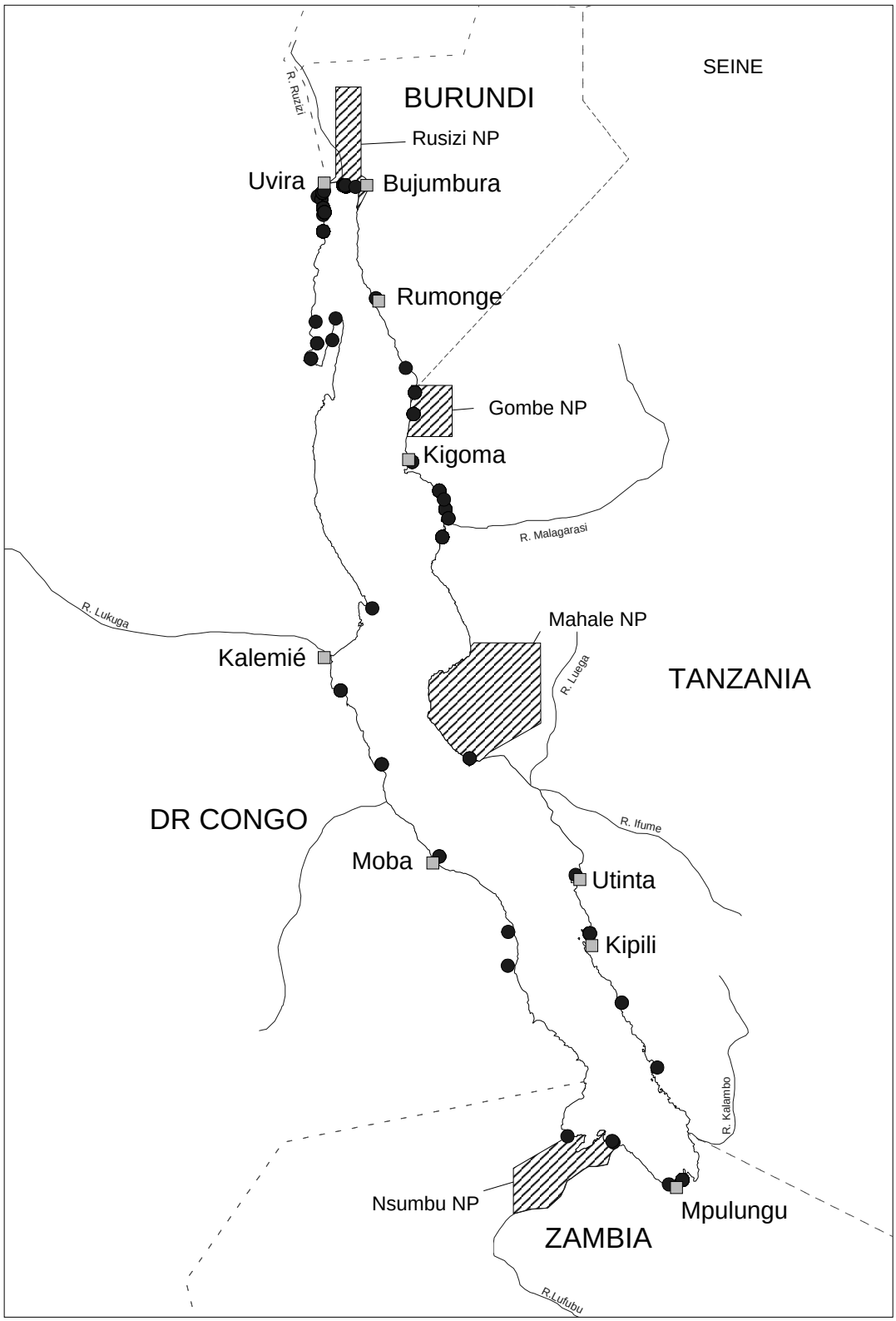

Figure 3.3 Map showing location of seine net surveys on Lake Tanganyika (source Literature database)

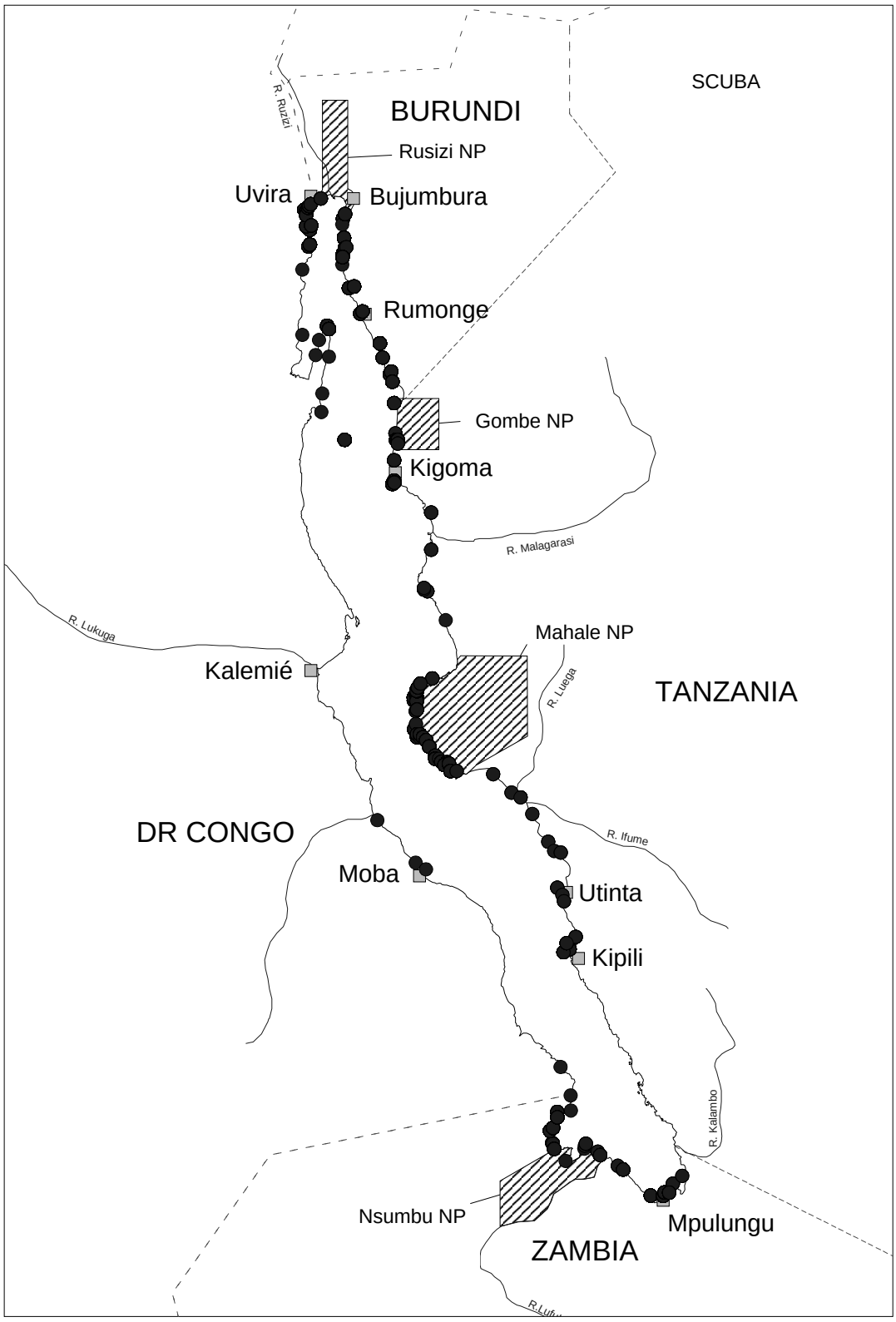

Figure 3.4 Map showing location of surveys using scuba on Lake Tanganyika (source Literature database)

3.3.2 Lists of fish found in each basin

Three intra-lacustrine basins are recognised in Lake Tanganyika, we drew from the bathymetric map presented in Coulter (1991) to define their boundary co-ordinates for analysis in the literature database. Analysis on this level provides the first gross assessment of the overall distribution of fish in the lake. The prompt for this level of assessment was that if, for example, 90% of fish species were confined to a single basin this would require a different management strategy than if we found 90% of fish were found in all basins, i.e. circumlacustrine.

Results are presented in Table 3.1. The literature database indicates that the largest percentage of fish species, 79%, is found to be circumlacustrine, i.e. found in one or more of the three basins. The middle basin is the poorest, with the south and north having 8 and 12% of the total respectively. Note that the total species included in this analysis (263) is less than the 287 fish noted in Coulter (1991) and the 330 species recognised in DeVos and Snoeks (1994). This represents the number of species that have corresponding 'basin' data entered into the database.

Table 3.1 Number of fish species recorded uniquely in each basin of Lake Tanganyika

Basin	Number of species	% of total
North	32	12
Middle	3	1
South	22	8
Circumlacustrine	206	79
Total with location data	263	100

De Vos and Snoeks (1994) report that 75% of littoral (i.e. excluding the six pelagic species) non-cichlids found in the lake (i.e. not in associated tributaries and marshes) are circumlacustrine. The data presented here doesn't differentiate between the lake proper and associated water bodies; however, 56 of the 85 non-cichlid species included in this analysis are found to be circulacustrine (66%)[7]. A higher proportion of non-cichlid species (37%) do not have basin data associated with them when compared to information on the cichlids (6% have no basin data) and so are not drawn on in this analysis. This probably reflects the focus on cichlid literature in Bujumbura during data entry: future work will have to redress this imbalance. De Vos et al (1994) note that further collecting work is required to further complete a list of all noncichlids: they prioritise the tributaries of the western and south-eastern coast of the lake.

[7] Note that the database has a function to differentiate species locations between the lake and its associated water bodies, however this has not been fully utilised to date.

Table 3.2 Fish species found exclusively in south, north or middle basins (species endemic to Lake Tanganyika in bold)

Family	North basin (32))	Middle basin (3)	South basin (22)
Anabantidae	*Ctenopoma muriei*		
Bagridae	***Lophiobagrus aquilus***		
	Phyllonemus brichardi		
Characidae	***Brycinus rhodopleura***		*Bryconaethiops boulengeri*
	Micralestes stormsi		
Cichlidae	***Astatoreochromis straeleni***	***Tropheus annectens***	*Astatotilapia stappersii*
	Astatoreochromis vanderhorsti		***Baileychromis centropomoides***
	Ctenochromis benticola		***Cunningtonia longiventralis***
	Neolamprologus boulengeri		***Greenwoodochromis bellcrossi***
	Neolamprologus falcicula		***Haplochromis paludinosus***
	Neolamprologus finalimus		***Lepidiolamprologus kendalli***
	Neolamprologus longicaudatus		***Lepidiolamprologus nkambae***
	Oreochromis leucostictus		*Neolamprologus cylindricus*
	Oreochromis niloticus eduardianus		***Neolamprologus leloupi***
	Simochromis margaretae		*Neolamprologus mustax*
	Spathodus marlieri		***Telotrematocara macrostoma***
	Trematochromis schreyeni		***Trematocara caparti***
	Xenotilapia nasutus		***Tropheus kasabae***
			Xenotilapia lestradii
Clariidae			*Clarias ngamensis*
Cyprinidae	*Barbus altianalis altianalis*	***Barbus taeniopleura***	
	Barbus caudovittatus	***Labeo dhonti***	
	Barbus serrifer		
	Barbus somerini		
	Barbus urostigma		
	Chelaethiops minutus		
	Raiamas salmolucius		

Family	North basin (32))	Middle basin (3)	South basin (22)
Distichodontidae	*Distochodus sexfasciatus*		
Mastacembelidae	***Afromastacembelus plagiostomus***		
	Afromastacembelus tanganicae		
	Caecomastacembelus flavidus		
	Caecomastacembelus zebratus		
Mochokidae	*Synodontis benthicola*		*Synodontis polystigma*
			Synodontis serratus
			Synodontis unicolor
Mormyridae			*Marcusenius stanleyanus*
			Mormyrops deliciosus
Polypteridae	*Polypterus ornatipinnis*		*Polypterus endlicheri congicus*

3.3.3 National lists for fish

National species lists are important for countries to be able to produce reasonably regularly. Particularly where they carry an international obligation to report under treaties such as CBD, and Ramsar as well as submitting accurate data to the IUCN hosted Red List of Threatened Species.

National lists of fish species have been generated by the database at the close of BIOSS. The full lists are given in Table 8.7, Appendix 8.4. The total number of fish recorded for each country is presented in Table 3.3.

Table 3.3 Number of fish species recorded by the database in each country

Country	Number of species	Length of coastline (km)
Burundi	192	165
DR Congo	175	790
Tanzania	192	662
Zambia	205	221

Taking the length of coastline into account, and drawing from the maps of survey sites (Figure 3.1) both DR Congo and Tanzania have been under sampled and should be targeted in future work.

Nakaya (1993) generated a national list of fish species for Zambia: recording a total of 140 species, excluding rivers. All species listed by Nakaya are included in the list generated by the literature database. The balance of families is very similar in both national lists, with cichlids dominating – 78% of the Nakaya list and 73% of the literature list. An additional three families are included in the literature database list, as follows: Citharinidae (single species); Cyprinidae (three species) and Tetraodontidae (a single species). The same author, with some colleagues also surveyed Burundian waters and generated a national list (Takahashi et al, 1995). Once again the literature database picks up the 76 species listed (82% cichlids) and adds more. A larger number of families are included in the literature database list, although are represented with few individual species as follows: Anabantidae (one species); Characidae (six species); Clariidae (three species); Clupeidae (two species); Distichodontidae (one species); Malapturidae (one species); Mormyridae (one species) and Protoperidae (one species).

Table 3.4 lists the number of fish species per family that are found in each country. The figures in bold indicate where one family contributes more than 5% to the overall total. As might be expected, the pattern is fairly standard among all countries: cichlids represent the majority of fish species found (68 – 73 %), with only one to three other families contributing >5% to the total national lists.

Drawing from the national species lists generated by the database, it is possible to identify species found exclusively in each of the riparian countries[8]. From the current dataset, a total of 49 fish species were found to be exclusive to one of the four countries, the numbers in each are as follows: Tanzania (6); Zambia (17); DR Congo (7); and, Burundi (17). While the high number of species found exclusively in Burundi and Zambia will reflect the intensity of aquatic survey work completed in these countries they also highlight the diversity of fish in their waters. These species are listed in Table 3.5.

[8] Data were extracted from the database and this analysis was completed in an Excel spreadsheet using the 'vlookup' function

Table 3.4 Number of species per family recorded in each riparian country

Family	Burundi		DR Congo		Tanzania		Zambia	
	no. spp	%	no. spp	%	no. spp	%	no. spp	%
Anabantidae	1	1%						
Bagridae	**13**	**7%**	**11**	**6%**	**10**	**5%**	**12**	**6%**
Centropomidae	4	2%	4	2%	4	2%	4	2%
Characidae	6	3%	1	1%	4	2%	5	2%
Cichlidae	**131**	**68%**	**127**	**73%**	**138**	**72%**	**149**	**73%**
Citharinidae					1	1%	1	0%
Clariidae	3	2%	4	2%	4	2%	4	2%
Clupeidae	2	1%	2	1%	2	1%	2	1%
Cyprinidae	**11**	**6%**	5	3%	7	4%	3	1%
Cyprinodontidae	2	1%	2	1%	2	1%	2	1%
Distichodontidae	1	1%						
Malapteruridae	1	1%	1	0%	1	1%	1	0%
Mastacembelidae	**9**	**5%**	**10**	**6%**	8	4%	5	2%
Mochokidae	6	3%	6	3%	7	4%	**10**	**5%**
Mormyridae	1	1%	1	1%	1	1%	3	1%
Polypteridae					2	1%	2	1%
Protopteridae	1	1%	1	1%			1	0%
Tetraodontidae					1	1%	1	0%
Totals	192	100%	175	100%	192	100%	205	100%

Table 3.5 National lists of fish species found exclusively in each country (species endemic to Lake Tanganyika in bold)

Family	Zambia (17)	Burundi (17)	Tanzania (6)	DR Congo (7)
Anabantidae		*Ctenopoma muriei*		
Bagridae		***Lophiobagrus aquilus***		***Phyllonemus brichardi***
Characidae	*Bryconaethiops boulengeri*	***Brycinus rhodopleura***		
		Micralestes stormsi		
Cichlidae	*Astatotilapia stappersii*	***Astatoreochromis straeleni***	***Neolamprologus leloupi***	*Neolamprologus longicaudatus*
	Baileychromis centropomoides	***Astatoreochromis vanderhorsti***	***Spathodus erythrodon***	***Trematochromis schreyeni***
	Cunningtonia longiventralis	*Neolamprologus boulengeri*		***Tropheus annectens***
	Greenwoodochromis bellcrossi	*Neolamprologus falcicula*		
	Haplochromis paludinosus	*Oreochromis leucostictus*		
	Lepidiolamprologus kendalli	*Xenotilapia nasutus*		
	Lepidiolamprologus nkambae			
	Neolamprologus mustax			
	Telotrematocara macrostoma			
	Xenotilapia lestradii			
Clariidae	*Clarias ngamensis*			
Cyprinidae		*Barbus altianalis altianalis*	***Barbus taeniopleura***	***Barbus urostigma***
		Barbus caudovittatus	***Labeo dhonti***	
		Barbus serrifer		
		Barbus somerini	***Varicorhinus leleupanus***	
		Raiamas salmolucius		
Distichodontidae		*Distochodus sexfasciatus*		
Mastacembelidae		***Afromastacembelus plagiostomus***		***Afromastacembelus tanganicae***
				Caecomastacembelus zebratus
Mochokidae	*Synodontis polystigma*	*Synodontis benthicola*		
	Synodontis serratus			
	Synodontis unicolor			
Mormyridae	*Marcusenius stanleyanus*			
	Mormyrops deliciosus			
Polypteridae	*Polypterus endlicheri congicus*		*Polypterus ornatipinnis*	

3.3.4 National lists for molluscs

Similar analysis was completed for the molluscs, and the complete national lists are presented in Table 3.6. The total number of species recorded in each country is as follows: Tanzania, 29; Zambia, 24; Burundi, 28; and, DR Congo, 18.

These results are very preliminary as this analysis only draws on data collected during the BIOSS field programme; mollusc data from other sources has yet to be entered into the database. Moreover, mollusc sampling from BIOSS is geographically limited to intensive studies at one or two sites in each country and broad and rapid surveys of portions of the Burundian, Tanzanian and Zambian coasts (as indeed are other investigations). However, these BIOSS lists are included here to provide some baseline data of molluscs sampled in each country as the study closed. It is interesting to note that the numbers of species found in each country are not vastly different, though the coastlines are quite variable in length. This will reflect differences in BIOSS sampling effort. Most of the species in Burundi were found over the course of two years of periodic surveys at a single site. More than 75 km of Tanzanian coastline was surveyed for molluscs, but the great majority of these were single survey events. A total of 30 species were recorded by BIOSS, representing less than half the 80 mollusc species that have been previously recorded in the Tanganyika Basin. Much mollusc survey work remains to be done.

Table 3.6 Complete national lists for mollusc species (from BIOSS surveys only), with species exclusive to one country indicated in bold.

Family	Tanzania	Zambia	Burundi	DR Congo
Mutelidae	*Mutela spekei*		*Mutela spekei*	*Mutela spekei*
			Spathopsis anceyi	
Unionidae	*Caelatura spp*	*Caelatura spp*	*Caelatura spp*	
	Pseudospatha tanganyicensis			
Thiaridae	*Anceya giraudi*	***Bathanalia howesii***	*Anceya giraudi*	*Anceya giraudi*
	Bridouxia giraudi	*Bridouxia giraudi* **	*Bridouxia giraudi*	*Bridouxia giraudi*
	Lavigeria grandis	*Bridouxia leucoraphe* **	*Bridouxia leucoraphe*	*Bridouxia leucoraphe*
	Lavigeria paucicostata	*Bridouxia praeclara* **	***Bridouxia ponsonbyi***	*Lavigeria grandis*
	Lavigeria nassa	*Lavigeria grandis*	*Bridouxia praeclara*	*Lavigeria sp A*
	Lavigeria sp A	*Lavigeria paucicostata*	*Lavigeria grandis*	*Lavigeria sp C*
	Lavigeria sp B	*Lavigeria sp A*	*Lavigeria sp A*	*Lavigeria spp*
	Nov. gen n.sp	*Lavigeria sp B*	*Lavigeria sp C*	*Nov. gen n.sp*
	Nov. gen spinulosa	*Limnotrochus thomsoni*	*Martelia tanganyicensis*	*Nov. gen spinulosa*
	Paramelania crassigranulata	*Nov. gen n.sp*	*Mysorelloides multisulcata*	*Paramelania imperialis*
	Paramelania imperialis	*Nov. gen spinulosa*	*Nov. gen n.sp*	*Reymondia horei*
	Paramelania iridescens	***Paramelania minor***	*Paramelania imperialis*	*Reymondia minor*
	Reymondia horei	*Reymondia horei*	*Paramelania iridescens*	*Spekia zonata*
	Reymondia minor	*Reymondia minor*	*Reymondia horei*	***Syrnolopsis gracilis***
	Reymondia tanganyicensis	*Spekia zonata*	*Reymondia minor*	*Syrnolopsis lacustris*
	Spekia zonata	*Syrnolopsis lacustris*	*Reymondia tanganyicensis*	*Syrnolopsis minuta*
	Stormsia minima	*Syrnolopsis minuta*	*Spekia coheni*	*Tanganyicia neritinoides*
	Syrnolopsis lacustris	*Tanganyicia neritinoides*	*Spekia zonata*	
	Syrnolopsis minuta	*Tanganyicia rufofilosa*	*Stormsia minima*	
	Tanganyicia neritinoides		*Syrnolopsis lacustris*	
	Tanganyicia rufofilosa		*Syrnolopsis minuta*	
			Tanganyicia neritinoides	
Viviparidae	*Neothauma tanganyicense*	*Neothauma tanganyicense*		

3.3.5 Protected areas lists for fish

Chapter five of this report deals in detail with the BIOSS surveys of the national park waters and provides the analysis, which informed the recommendations on conservation of aquatic biodiversity we made to the strategic action plan. However, by compiling full species lists from the literature database we can draw on a wider source of data as other researchers have recorded species in these waters. We have not used this full dataset for the conservation prioritisation exercise as the literature data are drawn from an extensive time period, and may not therefore reflect current diversity in the parks.

The references drawn on for each park are as follows:

Mahale National Park

- BIOSS (LTBP) survey, 2000
- Kuwamura, 1987b
- Poll, 1971
- Snoeks et al., 1994
- Takamura, 1993

Rusizi National Park

- BIOSS (LTBP) survey, 2000
- Boulenger, 1920
- Ntakimazi 1995 (Ecotone Survey)
- Kawabata and Mihigo, 1982
- Kwetuenda, 1983
- Kwetuenda, 1987
- Mihigo, 1983
- Moore, 1903
- Poll, 1956
- Poll, 1971

Nsumbu National Park

- Allgayer,1986
- BIOSS (LTBP) survey, 2000
- De Vos and Snoeks, 1994
- De Vos and Thys Audenaerde, 1997
- Hori et al., 1995
- Konings, 1988
- Moore, 1903
- Nakaya et al, 1993
- Poll 1956
- Poll, 1971

Gombe National Park

- BIOSS (LTBP) survey, 2000
- Ndaro, 1990
- Snoeks et al. 1994

Currently, only three of the national park boundaries actually extend into the lake (Mahale, Rusizi and Nsumbu), while Gombe's boundary falls short of the shoreline. Part of the BIOSS recommendations to the SAP was to consolidate and, where feasible, extend the boundaries of these parks to provide a network of protected areas for the lake's species (see Chapter 5 for detailed discussion and analysis). This section provides additional data in support of that recommendation and treats each park as if its boundaries include the littoral zone.

The complete list of fish found in the waters of each park is presented in Table 8.8 (Appendix 8.4). The total numbers of species recorded in each park and the contribution the BIOSS surveys made in adding to these lists are noted in Table 3.7.

Table 3.7 Number of fish species recorded in the waters adjacent each national park

National Park	Number of species	Number of species BIOSS contributed to the total (%)
Mahale	160	45 (28%)
Rusizi	102	5 (5%)
Nsumbu	99	66 (66%)
Gombe	67	52 (77%)

The BIOSS survey contributed to these park lists to varying degrees. In Gombe's waters, BIOSS found 52 species not recorded in any other references included in the literature database (i.e. 77% of the total). BIOSS added 66 species (66% of the total) to Nsumbu's total, 45 species (28% of total) to Mahale's list, but only 5 additional species (5%) to Rusizi's list. These results may indicate intensity of sampling in previous surveys for example the Ecotones survey was significant for Rusizi's waters, while Gombe has received less attention from aquatic surveys. It should also be noted that these results are also directly affected by

the literature entered into the database – the greater availability of Burundian publications in Bujumbura, where the bulk of the data entry was carried out, will have an influence. This sort of distortion will lessen as more data are submitted.

Takamura (1993) surveyed the waters off Mahale, recording 92 species of fish, 26% of which were non-cichlids. BIOSS recorded more species (128); but with the same percentage being non-cichlid fish. De Vos and Snoeks (1994) note the importance of Rusizi system to the diversity of non-cichlid fish, with some 30 species being recorded in its marshes and tributaries. Comparison of the database lists of species unique to the North basin (see section 3.3.2) and fish species found within the waters off Rusizi reinforces the importance of this park for non-cichlids. Of the 32 species found exclusively to the North basin, nine of the eleven species found within Rusizi's waters are nonciclids (Anabantidae, Characidae and Cyprinidae).

De Vos et al (1994) also note that the majority, i.e. 68%, of the 103 non-cichlids found in Lake Tanganyika's associated water bodies were found in the Malagarasi drainage system. In 1999 the Wildlife Division of the Tanzanian government submitted an information sheet to Ramsar seeking approval to designate 3.25m ha in the Malagarasi-Muyovozi Wetlands as a Ramsar site. This came to LTBP's attention after submission of the BIOSS advice to the SAP, which recommended that the riparian countries look to Ramsar as a way of raising the internationalprofile of Lake Tanganyika's waters. Tanzania's bid was successful and on the 13th of August 2000 the Malagarasi-Muyovozi wetland was designated as a Ramsar site. Fish are explicitly recognised in the paragraph listing the wetland's characteristics:

> "…The site is extremely important for large mammals, migratory and resident waterbirds, fish and plants (with perhaps as many as 50 indigenous fish species), as well as providing significant livelihood support to local communities."
>
> Source: www.ramsar.org/profiles_ur_tanzania.htm

From the park lists generated by the BIOSS literature database, it is possible to identify those species that have been recorded exclusively in one park (Table 3.8). The lists from Mahale and Rusizi support the advice BIOSS submitted to the SAP on the importance of these parks to the conservation of Lake Tanganyika's fish (see chapter 5). The low number of species recorded exclusively in Gombe is probably a reflection of the little attention its waters have received, and its smaller size relative to Mahale and Nsumbu, rather than the paucity of its aquatic biodiversity.

Table 3.8 Fish species recorded exclusively in the waters of each national park (bold indicates a species is endemic to Lake Tanganyika)

Family	Mahale (34)	Rusizi (26)	Nsumbu (15)	Gombe (2)
Anabantidae		*Ctenopoma muriei*		
Bagridae	*Phyllonemus filinemus*	*Bagrus docmak*		
		Chrysichthys grandis		
		Chrysichthys stappersii		
Characidaedss		*Alestes imberi*		
		Brycinus rhodopleura		
		Micralestes stormsi		
Cichlidae	*Bathybates horni*	*Astatoreochromis vanderhorsti*	*Lamprologus labiatus*	*Lamprologus kungweensis*
	Bathybates vittatus	*Gnathochromis permaxillaris*	*Lepidiolamprologus kendalli*	
	Cyprichromis microlepidotus	*Hemibates stenosoma*	*Lepidiolamprologus nkambae*	
	Julidochromis ornatus	*Oreochromis leucostictus*	*Lestradea stappersii*	
	Julidochromis transcriptus	*Tangachromis dhanisi*	*Limnochromis abeelei*	
	Lamprologus signatus	*Trematocara nigrifons*	*Neolamprologus mustax*	
	Neolamprologus buescheri	*Trematocara unimaculatum*	*Neolamprologus petricola*	
	Neolamprologus christyi	*Triglachromis otostigma*	*Neolamprologus pulcher*	
	Neolamprologus gracilis	*Xenotilapia caudafasciata*	*Perissodus eccentricus*	
	Neolamprologus hecqui	*Xenotilapia nigrolabiata*	*Simochromis pleurospilus*	
	Neolamprologus longior	*Xenotilapia ornatipinnis*	*Tropheus kasabae*	
	Neolamprologus multifasciatus			
	Neolamprologus wauthioni			
	Ophthalmotilapia heterodonta			
	Ophthalmotilapia nasutus			
	Paracyprichromis nigripinnis			
	Plecodus multidentatus			
	Pseudosimochromis curvifrons			

Family	Mahale (34)	Rusizi (26)	Nsumbu (15)	Gombe (2)
Cichlidae	*Spathodus erythrodon*			
	Tanganicodus irsacae			
	Telmatochromis brichardi			
	Telmatochromis burgeoni			
	Telmatochromis vittatus			
	Tropheus polli			
Citharinidae			*Citharinus gibbosus*	
Cyprinidae	*Barbus taeniopleura*	*Barbus altianalis altianalis*		
	Labeo dhonti	*Barbus lineomaculatus*		
		Barbus serrifer		
		Barbus somerini		
		Chelaethiops minutus		
		Raiamas salmolucius		
Mastacembelidae	*Afromastacembelus albomaculatus*	*Caecomastacembelus frenatus*	*Caecomastacembelus micropectus*	*Caecomastacembelus flavidus*
Mochokidae	*Synodontis dhonti*		*Synodontis serratus*	
	Synodontis granulosus			
	Synodontis nigromaculatus			
	Synodontis polli			
Mormyridae			*Marcusenius stanleyanus*	
Polypteridae	*Polypterus endlicheri*	*Protopterus aethiopicus*		

3.3.6 Fish not found in park waters

It is also useful to note which fish species have **not** been recorded within the national parks, and are therefore not subject to any direct conservation effort. Spreadsheet analysis was used to identify these species: a total of 163 fish species were found and using the literature database, we have determined where they have been recorded. Figure 3.5 shows the distribution of these 'unprotected' species.

Areas of interest highlighted by the map include: south of Uvira (already identified by BIOSS in its recommendations to the SAP[9] as deserving of some form of protection), the Burundi coast south of Rumonge, Kipili in Tanzania (also noted earlier as an area which has been under surveyed), Mpulungu (interesting considering its proximity to a population centre and therefore potentially more threatened) and the coast north of Nsumbu in Zambia.

This map has to be reviewed in light of the conservation strategy advocated by BIOSS. The strategy is presented in our advice to the SAP and chapter 5 of this report provides the supporting analysis for the recommended approach. In brief, we recommended to the SAP that the development of an integrated coastal zone management (ICZM) would provide the best strategy to address the largely localised threats facing Lake Tanganyika's biodiversity, and would enable some level of protection to be extended to species not represented in the park areas.

We regard this map as a good foundation to inform the development of ICZM for Lake Tanganyika. It draws from current knowledge of the conservation status of fish species in the lake and broadly identifies sites of potential conservation interest that can then be prioritised for future work in this area.

A subset of this broad analysis is the degree to which species found exclusively in one country fall within its protected area network, and perhaps most importantly, which species are not protected. Table 3.9 re-presents the exclusive national lists for fish and highlights those species falling outside of the protected areas in bold. Amongst the countries with aquatic parks, i.e. excluding DR Congo, Zambia records the highest percentage of species exclusive to its waters that are unprotected with 77% falling outside of Nsumbu's borders. Burundi is next with 44% of its species falling outside of Rusizi's waters (note the lack of formal protection afforded to these waters). Tanzania, with its two parks with boundaries extending into the lake has 29% of its exclusive fish species falling outside of Gombe and Mahale.

Similar analysis can be done by comparing species found exclusively in one of the three basins against park lists. Zambian waters host the majority of fish species found exclusively in the south basin (Table 3.2). Of the 22 species recorded in the southern basin, 17 are in Zambian waters and only six[10] of these are found within Nsumbu's waters, i.e. fall inside the current protected area network. This reinforces the need to look beyond protected areas as the only solution to species conservation: there is an obvious need to balance Zambia's reliance on Lake Tanganyika and its shores to support people in the area and the biodiversity in these waters. Rusizi offers more protection to the 34 species found exclusively in the north basin as 11 are found in its waters (see Table 5.8, Chapter 5 for a review of Rusizi's current status).

[9] See Allison et al (2000), the SAP document for more detail.

[10] Four cichlids and two noncichlids, a species each from Mochokidae and Mormyridea. Three of the six species are endemic to Lake Tanganyika.

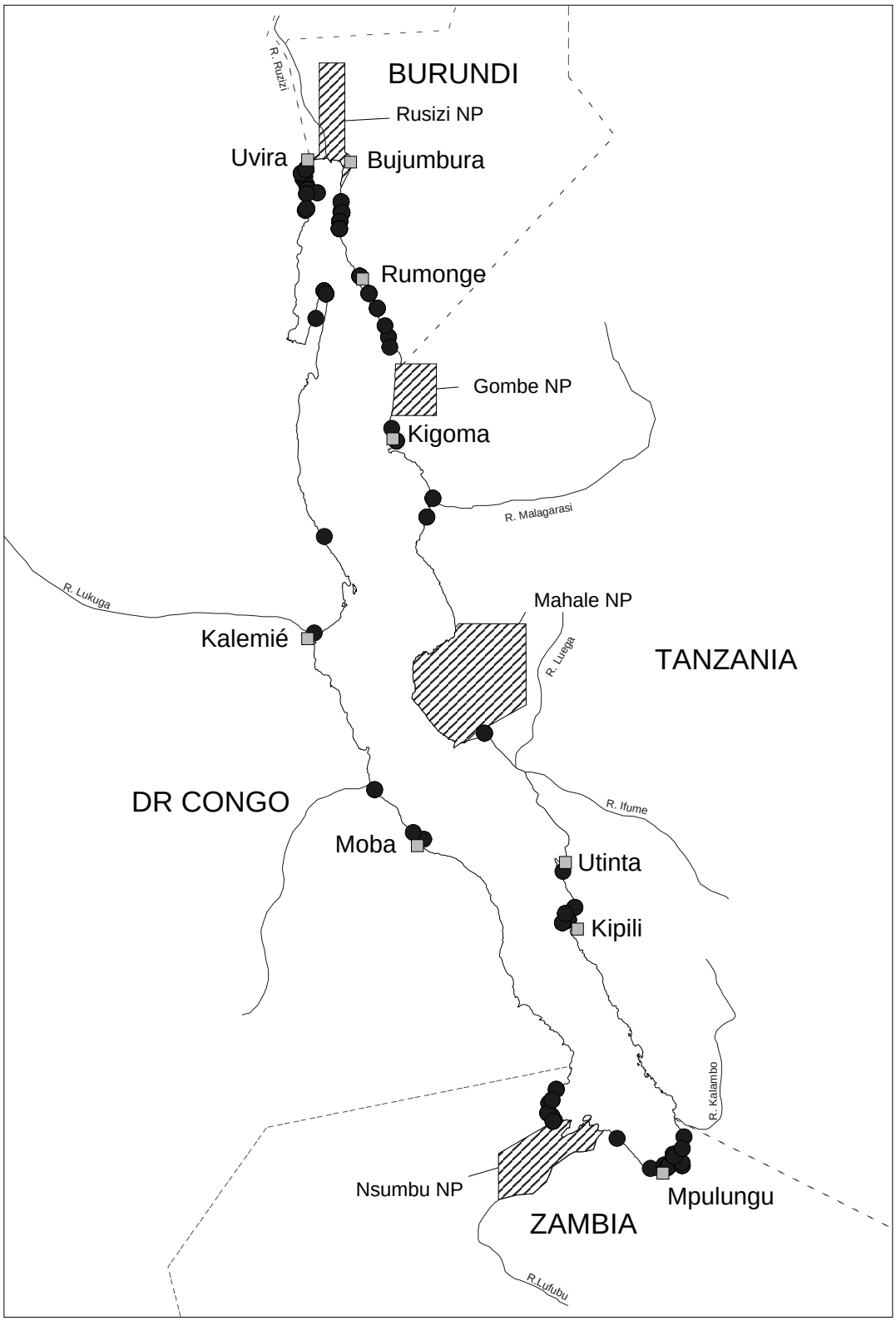

Figure 3.5 Map showing the location of those fish species not recorded in the waters off Lake Tanganyika's four national parks

Table 3.9 Protection afforded those species found exclusively in one country (unprotected highlighted in bold)

Family	Zambia (78 %)	Burundi (44 %)	Tanzania (29 %)	DR Congo (100 %)
Anabantidae		*Ctenopoma muriei*		
Bagridae		***Lophiobagrus aquilus***		***Phyllonemus brichardi***
Characidae	***Bryconaethiops boulengeri***	*Brycinus rhodopleura*		
		Micralestes stormsi		
Cichlidae	***Astatotilapia stappersii***	***Astatoreochromis straeleni***	***Neolamprologus leloupi***	***Neolamprologus longicaudatus***
	Baileychromis centropomoides	*Astatoreochromis vanderhorsti*	*Spathodus erythrodon*	***Trematochromis schreyeni***
	Cunningtonia longiventralis	***Neolamprologus boulengeri***		***Tropheus annectens***
	Greenwoodochromis bellcrossi	***Neolamprologus falcicula***		
	Haplochromis paludinosus	*Oreochromis leucostictus*		
	Lepidiolamprologus kendalli	***Xenotilapia nasutus***		
	Lepidiolamprologus nkambae			
	Neolamprologus mustax			
	Telotrematocara macrostoma			
	Xenotilapia lestradii			
Clariidae	***Clarias ngamensis***			
Cyprinidae		*Barbus altianalis altianalis*	*Barbus taeniopleura*	***Barbus urostigma***
		Barbus caudovittatus	*Labeo dhonti*	
		Barbus serrifer	*Varicorhinus leleupanus*	
		Barbus somerini		
		Raiamas salmolucius		
Distichodontidae		***Distochodus sexfasciatus***		
Mastacembelidae		*Afromastacembelus plagiostomus*		***Afromastacembelus tanganicae***
				Caecomastacembelus zebratus
Mochokidae	***Synodontis polystigma***	***Synodontis benthicola***		
	Synodontis serratus			
	Synodontis unicolor			
Mormyridae	*Marcusenius stanleyanus*			
	Mormyrops deliciosus			
Polypteridae	***Polypterus endlicheri congicus***		***Polypterus ornatipinnis***	

The following bullet points provide a preliminary list of additional information that would advance a strategy of ICZM for Lake Tanganyika on the basis of this map.

- Analysis of the species (fish and other taxa) at each site in terms of endemism, rarity, metapopulation dynamics, value to local communities or "globally".
- Analysis of the relative merit of the species (fish and other taxa) found at each site in comparison to the current network of protected areas, i.e. complementarity (see section 5.4.4).
- Assessment of the threats – nature and degree – facing each of these sites and prioritisation of action on a national and regional basis.
- Assessment of the current use of these waters and adjacent land by local communities to help determine the type and level of protection that could be implemented at each and the likely costs to these people of any change in status.

From this dataset it is possible to conduct analyses of interest at taxonomic levels above the species, for example in a 'higher taxon' (family and genus) assessment of the fishes not found in the existing parks network (Table 3.10). The 37 'unprotected' Cichlidae species are shared amongst 21 genera, with Neolamprologus making the greatest contribution of 19%. Of the remainder, no genera contribute more than 10% of the total number of species found outside the park network. While in the Cyprinidae, the Barbus genus contributes half of the 24 'unprotected' species (of which only 4 of the 12 are endemic to Lake Tanganyika).

Table 3.10 Number of fish species per family that are not recorded in a national park

Family	Number of species	Number of endemic species
Amphiliidae	2	-
Anabantidae	1	-
Bagridae	6	5 (84%)
Characidae	5	1 (20%)
Cichlidae	37	32 (86%)
Clariidae	6	-
Cyprinidae	24	5 (21%)
Cyprinodontidae	2	-
Distichodontidae	1	-
Kneriidae	1	1 (100%)
Mastacembelidae	4	4 (100%)
Mochokidae	5	-
Mormyridae	3	-
Polypteridae	3	-
Schilbeidae	2	-
Tetraodontidae	1	-

3.3.7 Protected area lists for molluscs

As noted earlier, the only mollusc data available for analysis at this stage is that collected within the BIOSS field programme. As we know this dataset very well it is possible to provide some background information to its collection to aid interpretation. In Mahale and Gombe divers[11] collected data over a range of habitats, while crocodiles in the waters off Nsumbu and Rusizi limited BIOSS to sampling sandy sites with a dredge. No molluscs were recovered in the Rusizi dredging and therefore this site is not included in further discussions of mollusc diversity in protected areas. Though at least three species are known to exist near the Rusizi (West, unpublished data), their distribution is clearly patchy, perhaps as a function of the heavy sediment loads deposited by the Rusizi. Table 3.11 presents the lists of all species

[11] At Mahale, divers sampled at greater depths, extending to 20m, however the sampling programme was later revised to a maximum of 15m and this is the greatest depth of samping at Gombe.

recorded in the waters of the three national parks; species found exclusively in one park are indicated in bold.

Table 3.11 Lists of all molluscs found in national parks during the BIOSS survey

Mahale	Gombe	Nsumbu
Anceya giraudi	*Lavigeria grandis*	***Bathanalia howesii****
Lavigeria grandis	***Lavigeria nassa***	***Limnotrochus thomsoni****
Lavigeria paucicostata	*Lavigeria sp A*	*Neothauma tanganyicense**
Lavigeria sp A	*Lavigeria sp B*	*Syrnolopsis minuta**
Lavigeria sp B	*Mutela spekei**	*Tanganyicia neritinoides**
*Mutela spekei**	*Neothauma tanganyicense**	*Tanganyicia rufofilosa**
*Neothauma tanganyicense**	***Paramelania imperialis****	
Nov. gen spinulosa	*Reymondia horei*	
Paramelania crassigranulata*	*Spekia zonata*	
Paramelania iridescens*	*Syrnolopsis lacustris**	
Pseudospatha tanganyicensis*	*Syrnolopsis minuta**	
Reymondia horei	*Tanganyicia neritinoides**	
Reymondia minor		
Spekia zonata		
Stormsia minima		
*Syrnolopsis lacustris**		
*Syrnolopsis minuta**		
*Tanganyicia neritinoides**		
*Tanganyicia rufofilosa**		
Bold text indicates species found exclusively in a park '*' indicates sand-dwelling species		

Protected waters off Mahale Mountains National Park host nineteen species of mollusc whereas waters off Gombe Stream National Park host twelve recorded species. Mahale has a potentially greater range of habitats for molluscs, including extensive shell beds, and is a larger area, (60 vs. 16 km of coastline). Nsumbu has similar habitats to those found at Mahale, and a slightly longer coastline (77 km). Unfortunately we cannot make direct comparisons of mollusc diversity between Nsumbu and the Tanzanian parks because the molluscs in the Nsumbu list were surveyed through dredging (thus these species are found on sandy substrates) whereas divers surveyed the Mahale and Gombe molluscs on a range of sandy and rocky substrates. However, if we consider only the sand-dwelling species from the Tanzanian Parks, noted with asterisks, Mahale dive surveys noted nine sand-dwelling mollusc species, Gombe dive surveys found six sand-dwelling species and Nsumbu dredge surveys noted six sand-dwelling species. Additional species, including *Tanganyicia michelae, Tiphobia horei* and *Paramelania* spp. are known from prior dredge surveys at Nsumbu (West 1995 unpublished data).

It is interesting to note that the extensive dredging at Nsumbu did not recover any bivalve species. This may be an artefact of the sampling gear and bivalve life history strategies. Bivalves in Tanganyika, especially the large *Mutela spekei*, spend considerable time buried in the substrate with only their siphon extended. Their burrows are obvious to divers who can readily excavate bivalves, but they may pass undetected by the dredge.

3.4 Discussion and Conclusions

In common with many biodiverse sites around the world, Lake Tanganyika has a long history of scientific investigation into its flora and fauna. As these historical records predate the relatively recent development of formal biodiversity assessment methods they present a rich but challenging source of data that can be called on to address current conservation issues. In this context, the BIOSS literature database provides a powerful tool for planners and researchers to organise and interrogate the wealth of data on Lake Tanganyika's aquatic species and their distribution.

As the data have been collected by a variety of methods and for different purposes they represent only presence data, failing to provide the statistically comparable data needed to infer absence at a particular site. This is compounded by a tendency for those making taxonomic collections not to record species already encountered and to direct their focus on the novel (Colwell and Coddington, 1994). Thus, as a survey typically proceeds from accessible areas to less frequently visited ones, the presence of common, ubiquitous species are no longer of interest, and tend to be under-recorded (Colwell and Coddington, 1994). In Lake Tanganyika, the emphasis of taxonomists and evolutionary biologists on the disjunct distribution of some species, in support for theories of sympatric and micro-allopatric speciation (see Martens, 1977) have tended to mask the fact that the vast majority of species are actually very widely distributed. This fact is seldom articulated, but can also be discerned by analysis of known distributions of species in the faunal lists in Coulter (1991) and other authors such as de Vos et al (1994) and . We emphasise this discrepancy between common portrayal and reality because it is of vital importance in determining the requirements for conservation. A lake in which each rock contained a unique assemblage of species found nowhere else would require a huge protected area network to ensure the majority of species were represented. In contrast, a lake in which most species are widely distributed and only a few species have limited distributions could be afforded protection through a careful selection of a limited number of suitable sites backed up by maintenance of environmental quality at a lake-wide scale.

Defendants of the 'every rock unique' view of Lake Tanganyika's biodiversity take refuge in sub-species genetic variability to support their thesis (e.g. Verheyen E, Ruber L, 2000). They do so once again on the basis of taxa that are selected because they are known, through the presence of sub-species or local morphotypes, to exhibit such population structuring. The extent to which this feature is ubiquitous is not known.

The literature database developed under BIOSS was ambitious given the size of the study and the field programme required. We are confident that although the full capability of the database is yet to be realised, its potential has been clearly illustrated. For the first time, planners and researchers can generate species lists for any specified area as illustrated by the national, park and basin lists presented in this chapter. Of the range of maps that could be produced from the database, we have presented maps showing locations of various survey types as well as those fish species not found within the current protected area network. These maps highlight areas of potential conservation importance and so prioritise sites for future research. Results have confirmed the contribution the BIOSS survey has made to the basic knowledge and understanding of Lake Tanganyika's biodiversity.

The key constraints now relate to the availability of further data and the resources needed, beyond the life of LTBP, to continue developing this planning tool. An informal relationship has been established to keep the database 'live' between researchers in Burundi and London: in recognition that this is not sustainable more permanent arrangements are being sought.

Future technical advances will include better integration with the GIS system so that mapping and integration with data from other disciplines (e.g. water quality data, fishing intensity etc.) is possible. The standard set of queries available to novice database users needs to be enlarged to include analyses presented here. As more data are entered on different taxa it should be possible to analyse relationships between the diversity of different taxonomic groups at a set of locations. This would provide important data on the relationship between diversity of different taxa in the same locations – a prerequisite for any attempt to generalise about biodiversity from 'total biodiversity surrogates'.

With a time series of data at particular sites, it should also be possible to look into the disappearance of species over time. The ability to analyse the relationship between species and habitat, so fundamental to biodiversity conservation, should improve as more studies are carried out.