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Biodiversity Special Study (BIOSS) Final Report

Nsumbu National Park, Zambia July/August 1999 Aquatic Survey

Date of issue: May 2000

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.

Preface

This report records the survey of Nsumbu National Park conducted by the Zambian Biodiversity Special Study team of the Lake Tanganyika Biodiversity Project. The names of all those who participated in the survey are listed below.

We would like to thank the Zambian Parks and Wildlife Service, and in particular Mr Miti and the staff of Nsumbu National Park, for their assistance and co-operation during the expedition.

In addition, we would like to acknowledge the support of Mr Clement Mwelwa and all the staff of the LTBP office in Mpulungu.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1. INTRODUCTION

1.1 Nsumbu National Park

Nsumbu National Park lies on the south-western side of Lake Tanganyika in the Zambian zone of the lake, approximately 40 km by boat from Mpulungu. The park was originally designated a game reserve by the British colonial authorities and was subsequently gazetted as a national park by the Zambian government in 1972. It covers an area of 6000-sq. km and at the time of the survey was administered by the Zambian Parks and Wildlife Service. The park headquarters is situated in Nsumbu village just outside the north-western park boundary. Access to the park is by boat from Mpulungu or by plane to Nkamba Bay. There is also a road from Kasama to Nkamba Bay, but this is only passable in the dry season.

The terrestrial sector of the park is largely characterised by low, undulating hills. The vegetation of the interior is dominated by dense *Chipya* forests, whereas the coastal areas around Nsumbu Bay, Cape Nundo, Cape Kabwe and the Ngosye headland are covered by more open woodland. The park supports over twenty species of mammal including all the "big five" apart from rhinoceros, as well as several species of antelope of high conservation importance such as sable and roan. No less than 329 species of birds have been recorded within the park (Mununga 1997). Many of the species are residents or visitors to the Iyendwe Valley, an important wetland abutting the south-western boundary of the park. The coastline is characterised by woodland running down to a rocky shore, interspersed with long stretches of sandy beach and indented bays. The latter are densely populated with crocodiles. In addition, there are extensive reed beds at the base of Nkamba Bay, which support a population of hippos.

The main attraction for visitors to the park is however the opportunity for sport fishing, provided by fishing holidays and annual angling competitions. Species such as *Boulengerochromis microlepis*, *Citharinus gibbosus* and the *Lates spp* are much prized as trophy fish. Three private lodges, two in Nkamba Bay and the other at Ndole outside the park cater for the tourists, offering luxury accommodation and facilities as well as the opportunity to fish and view game. They also provide limited employment opportunities for local people as domestic and catering staff as well as game and fishing guides. The park authorities provide alternative accommodation in the form of basic chalets.

The aquatic zone of the park stretches for 80km along the lakeshore from the southern edge of Nsumbu village (08^{o}31.52 S, 030^{o}29.51 E) southeast to the mouth of the Lufubu River (08^{o}33.51S, 030^{o}43.54 E). Along the entire length it projects 1.6 km into the adjacent lake waters. Apart from the tourism industry, utilisation of the fish resources within this zone has hitherto been limited to the two villages, Kabyolwe and Nsumbu, which are close to the park borders. Fishermen from these villages have been allocated seasonal rights to seine on certain beaches, however this is now under review. Some illegal fishing takes place within the park, most notably in Nkamba Bay where fisherman can take advantage of the ambiguity over the exact location of the park boundary caused by a narrow "tongue" of water, which extends deep into the bay. The Parks and Wildlife Service lacks the equipment and manpower to police the park. They rely on local boats or the Department of Fisheries (DoF) for transport. "Law enforcement" is largely driven by the management of the tourist lodges, who support the activities of the park authorities and who are themselves honorary game rangers. Increasing population pressure on north-western side of park caused by the influx of refugees from the war in Congo, may lead to an increase in the threat posed by illegal fishing in the future.

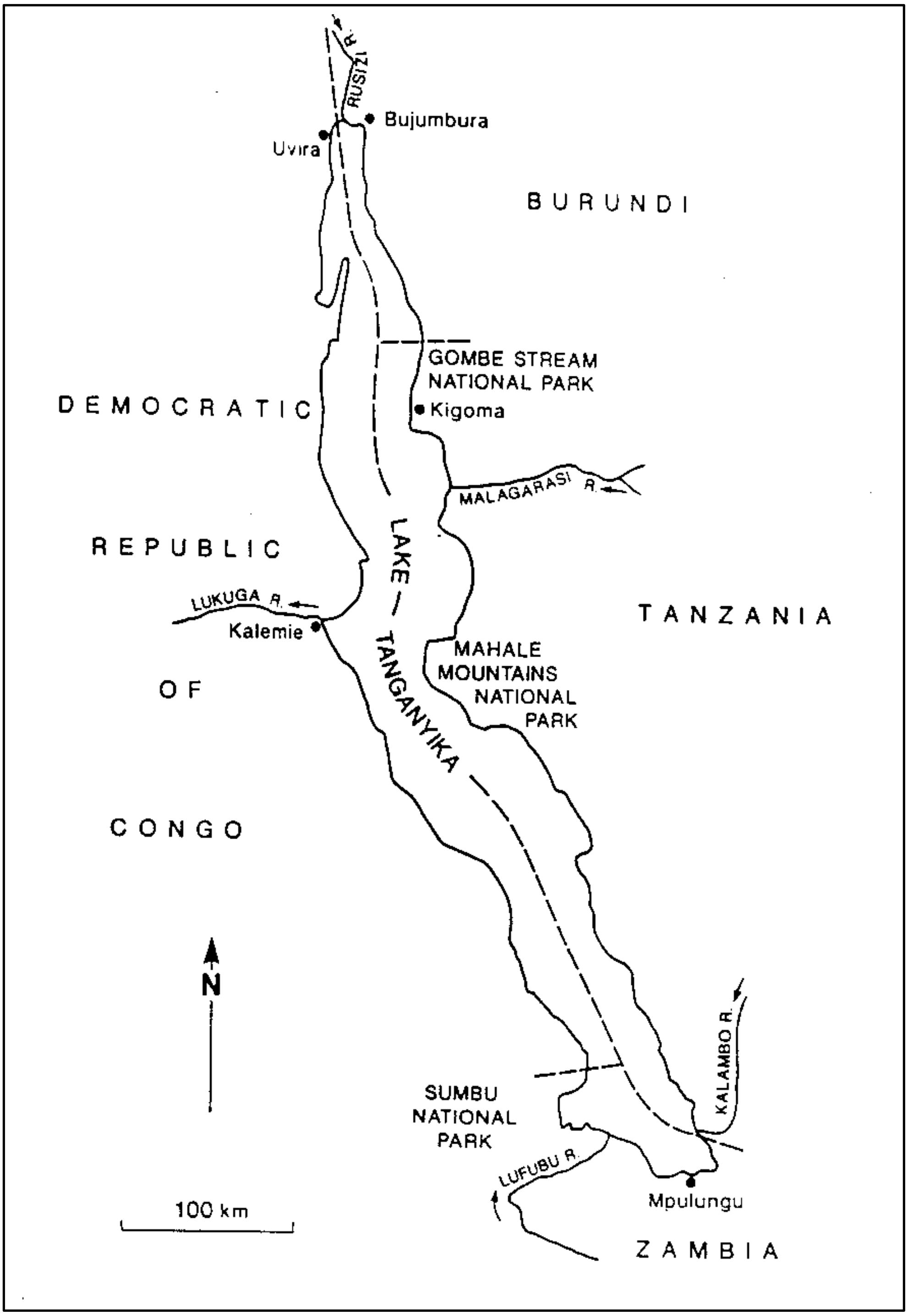

Figure 1.1 **Map of Lake Tanganyika showing national parks, major rivers and population centres**

1.2 Survey Aims

The survey was conducted in two phases, the first from 27th – 30th July 1999 and the second between 6th – 18th August 1999, by the Biodiversity Special Study (BIOSS) team, comprised of fisheries officers and technicians from DoF, Mpulungu. It was the last in a series of similar surveys on the waters adjacent to or within the protected areas bordering on the lake and was carried out in accordance with the BIOSS objectives to review current levels of biodiversity and identify the distribution of habitats in Lake Tanganyika.

As with previous such surveys the principal aims were to classify and map underwater habitat distribution, as well as to determine the diversity and the distribution of the fish and mollusc communities associated with these habitats. In this way, a set of baseline data could be acquired, which would help determine the conservation value of Nsumbu National Park to the lake and inform future management decisions.

All the Zambian BIOSS team members were involved in the planning and preparation for the expedition, building on experience gained in previous surveys and further strengthening the team's capacity to mount similar expeditions in the future.

1.3 Review of Previous Work

There have been a number of ecological studies of the Zambian lakeshore, which have included parts of Nsumbu National Park. Coulter (1966-88) carried out extensive work on the ecological and physical processes of the lake, as well as the littoral, benthic and pelagic fish communities. Other biologists and aquarium collectors such as Hans-J Hermann (1987) and the Pierre Brichard (1989) have concentrated on fish (predominantly Cichlid) taxonomy and behaviour. There are also a small number of unpublished reports from Department of Fisheries surveys, which include references to Nsumbu. Nevertheless, the BIOSS expedition covered by this report was the first comprehensive survey of the habitats and fauna covering the whole coastline of the park.

CHAPTER 2. METHODS

During a reconnaissance for the Nsumbu survey, it became clear through both observation and information gathered from local communities and agencies, that the high densities of crocodiles and hippos within the park posed a considerable threat to divers. A range of non-dive techniques was therefore developed so that habitats and fauna could be sampled safely. Furthermore, to sample the entire biota of an area such as Nsumbu was not possible; fish and molluscs were therefore selected as sub-sets, which could be used as 'indicators' of total biodiversity. These techniques are described in detail below and were subsequently incorporated into the 'Standard Operating Procedures for BIOSS Sampling' (Allison *et al* 1999).

Table 2.1 Summary of survey methods

Method	Purpose	Depth Range
'Croc-box'	Coarse-scale mapping of littoral zone habitats, coastal topography and land-use	3-10 m
Habitat Grab	Finer-scale habitat mapping	15,10 and 5 m
Mollusc Dredge	Mollusc species richness	15,10 and 5 m
Gillnetting (day and night)	Fish species richness and abundance	15,10 and 5 m

2.1 Habitat Mapping

2.1.1 "Croc box" surveys

During the first phase of the survey coarse scale habitat mapping was carried out using a modification of the manta tow technique. Instead of being towed, the team member recording the substrate characteristics remained in the boat and observed the lake bottom through the Perspex base of a rectangular wooden box attached to the side of the boat.

Visibility is not as good through the 'croc-box' as through a mask and therefore observations were rarely made for depths greater than 5 m. Nevertheless, in all other respects the technique differs little from the manta tow. The same data on substrate characteristics is recorded during the same 3-minute time intervals. This included percentage of each category of habitat (bedrock, rocks, boulders, gravel, sand), level of siltation and inclination. Likewise, 3-4 people are required to perform the functions of coxswain, timekeeper and GPS operator/position recorder, as well as recording the coastal topography, land cover and use.

Using the 'croc box' technique, a single team succeeded in mapping the coast of Nsumbu in 4 days. As with the Manta data, each section of shore sampled during a 3-minute period was given an overall substrate classification (Rock, Gravel, Sand, Mixed, Mixed Rocky or Mixed Sandy), depending on the percentage of each substrate type recorded. This information was then transferred onto photocopies of 1:50,000 maps of the area, with the substrates being represented by different symbols.

2.1.2 Selection of survey sites

As with all the BIOSS surveys, sites were selected so as to retain the statistical features of random sampling, while reducing sample numbers through stratification according to habitat prevalence. Having estimated the total number of sites that could be sampled within the time available, a quota of sites was allocated to each substrate type relative to the proportion of the Nsumbu shoreline represented by that substrate type. Each 3-minute Croc box-survey period was given a number according to substrate type and then those numbers were randomly chosen till the quota of sites for each substrate was filled. The exact location of the sample transect was as near to the centre of the shoreline represented by each 3 minute period as possible.

2.1.3 Habitat Grab

Since it was considered unsafe to carry out dive habitat profiles, detailed data on the habitats at each site was obtained using a grab. The purpose of this finer scale habitat mapping was twofold; to confirm the results of the "Croc-box" surveys and to extend the depth of the survey to 15 m, thus providing habitat data on same spatial scale as fish and mollusc censuses.

To carry out this technique a grab was attached to the winch of the DoF research vessel the Silver Shoal. At each site the team located the point at which the depth of the water was 15m using the boats echo sounder at the same time a secchi disc was used to determine visibility. Using this as a start point the survey vessel followed a course parallel to the shore while maintaining a depth of 15m. Grab samples were taken at approximately 15, 30 and 45m from the start point along the transect. Where necessary the sample was filtered through a sieve. The nature of the substrate was summarised on the appropriate field data sheet. This procedure was then repeated at depths of 10m and 5m.

On occasions the grab was found to be empty when recovered. An experienced winch operator was able to determine if this was due to the grab 'tripping' early, in which case it was reset and the process repeated till a 'true' sample was obtained. If however the grab operated correctly yet still returned empty, it was lowered once more and if the same result was obtained "No sample – probable rocky substrate" was entered on the Habitat Grab form.

The substrate data obtained by this method is inevitably somewhat crude. Consequently, for the purpose of analysis, substrates have been classified in three broad categories as shown in Table 2.2.

Table 2.1 Habitat categories used in data analysis

Habitat category	Substrate composition (%)
Soft	> 75% sand (including mud and fine gravel)
Hard	≥ 25% rock (including bedrock, boulders and cobbles)
Shell	> 50% *Neothauma* shells

2.2 Mollusc Dredge

Mollusc sampling was conducted using a 'naturalists dredge'. As with the habitat grab, the dredge was attached to the winch on the RV Echo and a second line secured to the boat and dredge, so the dredge could be located if the winch cable broke.

The vessel was located at the start of the 15m transect used for the habitat grab and the dredge was lowered to the lake bottom with additional slack in the cable to ensure the dredge was dragged at the correct angle to scoop up the substrate. The vessel then proceeded along the transect for approximately 60 m (which corresponds to the length of the gillnets used by BIOSS). At the end of the transect the dredge was recovered and its contents sorted using a sieve (mesh size 1.4 mm). The molluscs species identified in the sample were recorded on the field data sheet and where necessary placed in preservation jars for subsequent more detailed examination. This procedure is repeated at 10 and 5m using the same transects as for the habitat grab.

Dredging was not carried out where the habitat grab indicated the lake bottom might be hard or rocky, because the dredge is ineffective and susceptible to damage or snagging on such substrates.

2.3 Gill Nets

Gillnets were used to census the fish population at each site both day and night. The standard 60-m nets used by BIOSS were employed, consisting of 12 transparent mono-filament panels each with a different mesh size, ranging from 8 – 50 mm.

During the day 3 gillnets were set at 15, 10 and 5m respectively. They were positioned parallel to the shore, as far as was possible, along the same transect as used for the habitat grab and mollusc dredge. The nets were deployed in the morning and hauled in the late afternoon. The fish were sorted on the boat and the species and number of individuals recorded. In cases of doubt taxonomic keys and reference books were used to identify species. At night only one net was set at a depth of 10m. The purpose of this was to catch species that are more active nocturnally or migrate during the night from deep to shallower water to feed.

2.4 Analysis Methods

2.4.1 Index of similarity

As part of data analysis, species lists were drawn up for both sampling methods and each of the major habitat categories. An index was then calculated as a means of comparing lists and answering such questions as; whether day and night gillnets were catching the same range of species or how much difference there was between the species found on each of the major substrate types.

The formula is:

$$Similarity = \frac{2c}{a+b}$$ Krebs, 1978.

Where *a* is the number of the species recorded by one sampling method, *b* is the number of species recorded by the other sampling method and *c* is the number of species common to both. A high index would demonstrate that the two sampling methods were recording similar species. A low index would suggest that to obtain a comprehensive species list for a given area it would be necessary to use both methods.

2.4.2 Shannon Weiner diversity index

As with previous surveys undertaken by BIOSS, the Shannon-Weiner index was used as a measure of the biodiversity in Nsumbu National Park. In common with other indices used to estimate biodiversity it includes measures both of species richness and abundance within those species. It does not take into account other factors that determine conservation importance such as levels of endemicity, number of rare species or whether species have a limited or discontinuous range.

The formula used was:

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

where *H'* = amount of diversity in a group of *k* species, *k* = the number of species, *fi* is the frequency of each species and *n* is the sample size (total number of individuals recorded). Thus *H'* measures the uncertainty with which you can predict the species of the next individual in the sample. It follows that *H* for a given number of species will be highest when all species are equally abundant, since it is less easy to predict what the species of an individual will be.

During the Nsumbu survey gillnetting was the only technique employed which recorded data on both species richness and abundance. Diversity indices have been calculated therefore only for fish and not molluscs. The indices have been calculated separately for day and night gillnets because both methods are subject to different sampling bias.

CHAPTER 3. RESULTS

3.1 Summary of Surveys Conducted

The Nsumbu survey was divided into two phases. The first lasted 4 days and served both as a reconnaissance for the main part of the expedition and an opportunity to conduct broad scale habitat mapping of the park. During the second phase of 12 days the detailed surveys of specific sites were carried out. A total of 20 sites were selected using the procedure described in section 2.1.2 above. The allocation of sites to each substrate category is shown in Table 3.1.

Table 3.1 Number of sites selected in each habitat type

Stratum	Number of sites chosen
Rocky	9
Sandy	5
Mixed (rocky)	2
Mixed (sandy)	2
Mixed	1
Gravel	1
Total	20

A comprehensive list of sampling sites, co-ordinates and activities is given at Appendix I. Whenever possible two sites were sampled per day, using the techniques listed in Figure 2.1. There were however occasions when one or more techniques could not be carried out. At Nkamba Lodge 1 the gillnet set overnight was removed, probably by a crocodile. The resulting shortage of gillnets, meant that at Kala Bay 2 and Inangu 2 gillnets were set at 5 and 15 m only. Furthermore, rough weather conditions on the last two days of the survey meant that it was not possible to conduct some of the techniques at Capes Nambiyeye, Chikulula and Kasenga and Kasololo Bay.

3.2 Coarse Scale Distribution of Habitats

3.2.1 Shallow water habitats

Table 3.2 shows the distribution of habitats in the littoral zone down to a maximum depth of 5-10 m. Rocky substrates, which included bedrock, cobbles and boulders, were dominant accounting for 44% of the shoreline. Much of this rock was found in the eastern section of the park, particularly the eastern side of Nkamba Bay, as well as Capes Inangu, Nambiyeye and Chikulula. Sandy substrate constituted 23 % of shallow water habitats and was prevalent in the western part of the park from Nsumbu village as far as Nkamba Bay Lodge. Along these sandy stretches of shoreline visibility was frequently restricted to less than 5 m, due to the turbidity of the water. The terms Mixed rocky and Mixed sandy described mixed habitats where either rock or sand was predominant. Both these were well represented. Mixed areas where neither rock nor sand dominated were very limited in distribution. The same is true for gravel substrate, which was recorded along one short section near the base of Nkamba Bay. No shell beds were identified in the shallow water zone. Submerged macrophytes were encountered on sandy substrates, but only in small patches. The modification of the method to include the use of the ‘croc box’ meant sampling could be conducted even where crocodiles were present. The only area that was not surveyed was a stretch of approximately 2-km at the base of Nkamba bay where visibility was extremely poor. The maps at Appendix II depict the shallow water habitats along the Nsumbu coastline with symbols representing the different substrate types.

Table 3.1 Shallow water habitat distribution

Substratum	Length (km)	% of Total Shoreline
Rocky	34	44
Sandy	18	23
Mixed	2	3
Mixed rocky	13	17
Mixed sandy	9	12
Gravel	1	1
Total	77	100

3.2.2 Coastal physiography, terrain and land-use

The coastline of Nsumbu Park is characterised by a number of prominent headlands and two large and deeply recessed bays (Nkamba and Kasaba). There are numerous smaller bays and sandy beaches particularly along the coast between Nsumbu and Cape Kabwe Ngosye, as well as in Kala and Kasaba bays. The eastern side of Nkamba Bay and the shoreline of the Inangu Peninsula are fringed by rocks and in certain areas boulders. At parts of the shore from Nilambo Bay to Cape Nambeye, low but sheer cliffs drop to the water's edge. A large stand of emergent macrophytes covers much of the south-western end of Nkamba bay.

Natural vegetation covers most of the area inland from the shore in the form of forest and scrub. Human settlement is confined to the Nkamba Bay and Kasaba Bay tourist lodges. From these locations, visitors conduct short walking and vehicle safaris into the park and some sport fishing in the aquatic zone. Villagers from the neighbouring communities of Nsumbu and Kabyolwe have in the past enjoyed the right to seasonal fishing (June to November) with seines and gillnet at selected beaches within the park. This is however currently under review. Furthermore, certain areas inland from Cape Nundo are of sacred importance to the local tribes and periodically representatives of these tribes visit the area to perform religious observance. The Parks and Wildlife Service have three small ranger posts in the park. Two are co-located with the tourist lodges another is close to the mouth of the Lufubu River on the eastern park boundary.

3.3 Habitat Grabs

As stated in Chapter 2.1.3, for habitats from 5 to 15 m three broad categories of substrate types were used. Samples obtained from the grab were classified as either Soft or Shell. If the grab operated correctly but returned empty the substrate was designated Hard. At depths of 5 m it was sometimes possible to see rocks below, in which case the substrate was also designated hard.

In contrast to the profile dive, the habitat grab method cannot record accurate information on the profile of the lake bottom. Suffice it to say, however, that by estimating the distance to the shore and using the research vessel depth sounder to measure the depth, a general sense of the sharpness of the slope could be obtained. As expected, it generally appeared to be steeper where the substrate was hard than where it was soft.

Table 3.3 shows that when segregated by depth along the entire coastline the composition of the substrates remained fairly consistent. Soft substrates dominated throughout constituting almost 75% of the habitat at 5 m but dropping to just over 50 % at 15 m. Hard substrates remained constant at between 14 and 19 %. Shell beds steady increased with depth till at 15 m they represented just over a quarter of the substrates sampled.

Table 3.1 Composition of substrate by depth for the 11 sites for which complete habitat profiles were recorded

	Substrate type (%)		
Depth	Hard	Soft	Shell
5 m	18.5	74.5	7
10 m	14.5	68	17.5
15 m	19	53	28
Combined	20.5	62.5	17

At many of the sites substrate characteristics did not change significantly between depths. So it was possible to classify individual sites as predominantly soft, hard and in some cases shellbed. From Nsumbu 2 to Nkamba Lodge 3 the majority of sites had soft substrates, as did the sites by the eastern boundary at the mouth of the Lufubu River. The shellbed habitats were concentrated at the western extremity of the park at Nsumbu 1 and Nsumbu 3 with shells being found a certain depths at Kabwe 2, Kapalwe 1 and 2 and Nkamba Lodge 1. Most of the rocky sites were located on the Inangu Peninsula between Kala Bay and Cape Nangu.

3.4 Mollusc Census

3.4.1 Sampling effort

In order to ascertain whether sampling effort had been sufficient species-area, accumulation curves were plotted. The cumulative area was estimated by multiplying the width of the dredge (0.5 m) by the length of the transect (60 m). Figure 3.1 shows the species-area curve for all mollusc samples conducted during the survey. It appears to have reached asymptote when the cumulative area sampled reached 900 m^2. This would suggest that the sampling effort in this survey was sufficient to obtain a comprehensive list of the mollusc species present in Nsumbu National Park.

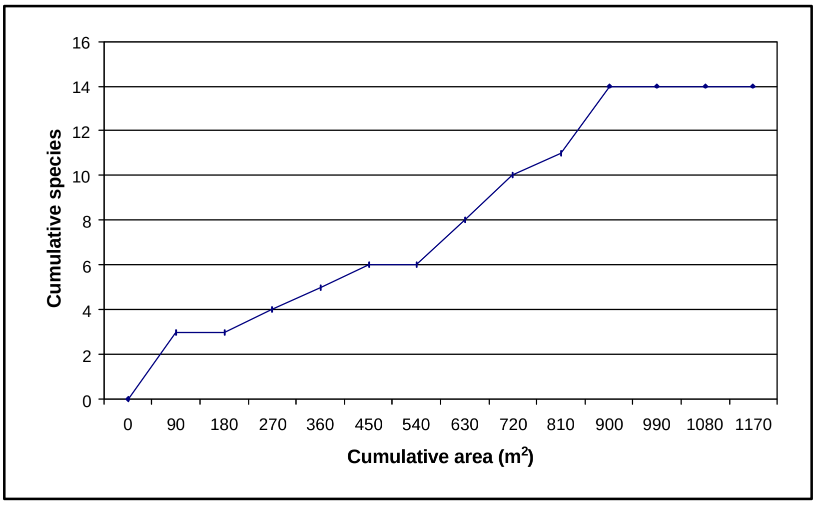

Figure 3.1 Species-area accumulation curve for all mollusc surveys

Figure 3.2 is the species-area curve plotted for all surveys conducted on soft substrates. Here too the curve has levelled off indicating that the number of samples obtained from soft substrates was adequate. It was not possible to carry out any mollusc dredging on hard substrate for the reasons stated in Chapter 2.2. Moreover, no curve was plotted for shell habitats owing to the small size of the data set

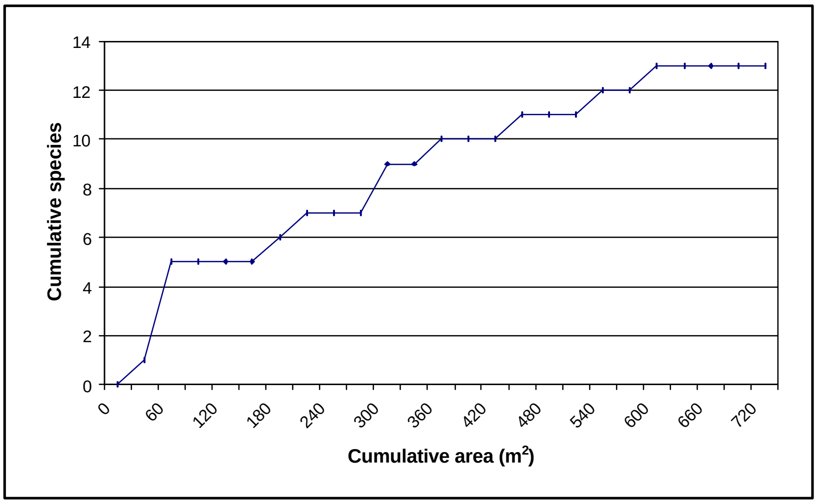

Figure 3.2 Species-area accumulation curve for mollusc surveys conducted on soft substrates

3.4.2 Species richness

A total of 14 mollusc species were recorded at Nsumbu, all of which are endemic to Lake Tanganyika (Table 3.4). They include only one species of bivalve mollusc (*Caelatura burtoni*); the others are gastropods. They were no unusual or new species, all having previously been recorded on the southern or Zambian coast of the lake. Since *Reymondia sp.* was the only individual recorded from that genus during the survey, it is included in the list of species. The taxonomic classification of *Novel Genus new species* is still under review.

Table 3.1 List of mollusc species at depth at which they were recorded

	Species	Depth at which recorded (m)		
		5	10	15
1	*Bathanalia howesii*	✓		
2	*Bridouxia giraudi*	✓	✓	✓
3	*Bridouxia leucoraphe*	✓		
4	*Bridouxia praeclara*	✓	✓	
5	*Caelatura burtoni*	✓	✓	✓
6	*Lavigeria sp. A*	✓		
7	*Limnotrochus thomsoni*			✓
8	*Neothauma tanganyicense*	✓	✓	✓
9	*Novel Genus new species*	✓		✓
10	*Reymondia sp.*	✓		
11	*Syrnolopsis lacustris*		✓	
12	*Syrnolopsis minuta*	✓		
13	*Tanganyicia neritinoides*		✓	
14	*Tanganyicia rufofilosa*	✓	✓	✓

Table 3.4 indicates the depths at which each of the species was found. Most species were encountered within their accepted depth range; a notable exception was *Bathenalia howesii*, which was identified at 5 m, but normally occurs at depths greater than 40 m.

All but two of the species were found on soft substrates of which 5 were also found in shell bed habitats. Table 3.5 gives the species recorded uniquely in each habitat. The three *Bridouxia spp.* listed there are normally located on the underside of cobbles.

Table 3.1 Species uniquely found on soft or shell substrates

Soft	Shell
Bathanalia howesii	*Lavigeria sp A*
Bridouxia leucoraphe	*Reymondia spp*
Bridouxia praeclara	
Caelatura burtoni	
Limnotrochus thomsoni	
Syrnolopsis lacustris	
Tanganyicia neritinoides	

The number of species encountered at each site ranged from 6 down to 1. The richest site was Cape Kabwe 1 (database code: ZB006/15) closely followed by Nsumbu Bay 2 (ZB006/7), Cape Kabwe 2 (ZB006/19), Cape Nundo (ZB006/23) and Cape Kapalwe 1 (ZB006/27) all of which registered 5 species. These sites were located in an almost unbroken sequence from the western park boundary to the mouth of Nkamba Bay. The highest number of species on soft substrate was recorded at Cape Kabwe 2 at 10 m (5 species) and on shell bed at Nsumbu Bay 1 (ZB006/3), 3 species.

3.5 Fish Census

3.5.1 Sampling effort

Species accumulation curves were plotted for day and night gillnets separately. In spite of efforts to standardise 'soak times', factors such as varying distances to sampling sites prevented this. For this reason cumulative species was plotted against cumulative number of gillnets set. The curve for day gillnets (Figure 3.3) indicates that sampling may have been sufficient, but further sampling would be required to confirm if this is the case. In Figure 3.4, the curve has clearly reached asymptote, suggesting that the species list obtained for night gillnets includes most of the species in Nsumbu, which are likely to be caught by this method.

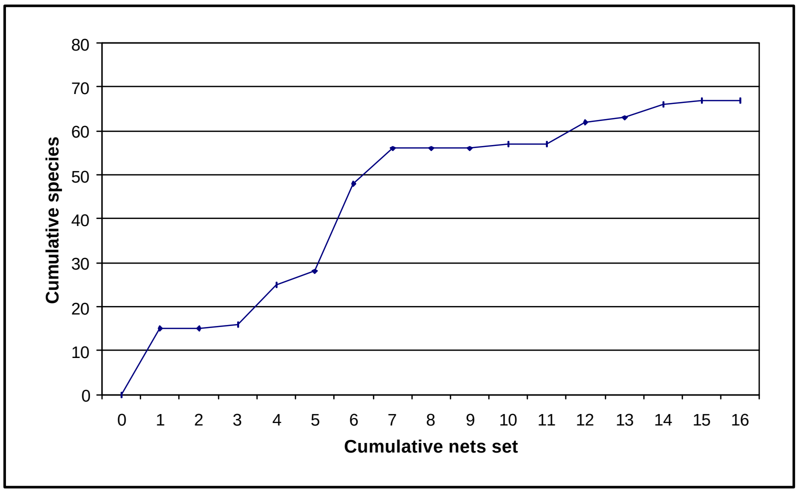

Figure 3.1 Species-sample curve for day gillnets

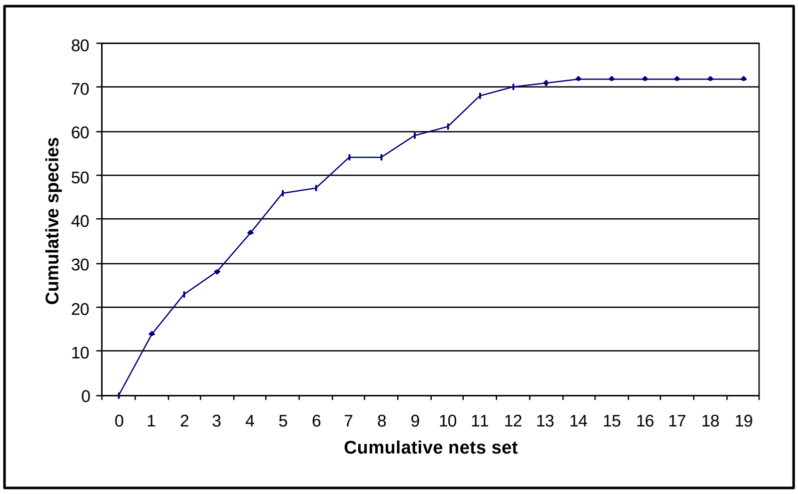

Figure 3.2 Species-sample curve for night gillnets

Species-accumulation curves were also plotted for day gillnet samples on both soft and hard substrates and for night gillnets on soft substrates (Appendix III). It was not possible to produce curves for night gillnets on hard substrates or either method in shell bed habitats, because the data sets were of insufficient size. The curves clearly show that for soft substrates the sampling effort for both day and night gillnets was sufficient to sample the species present. Day gillnet surveys on hard substrates amounted to less half the number of samples than for soft substrates and it is not surprising that the curve is only just reaching asymptote. It is likely therefore that further sampling with day gillnets on hard substrates would add further species to the list produced by this survey.

3.5.2 Species richness

A total of 91 species from 50 genera were recorded by day and night gillnets combined. Individuals identified only to genus level were not included in these totals, since in all cases the genus in question was represented elsewhere in the survey. Cichlids made up 76% of the species recorded, the remainder were divided among 10 other families. Ninety six percent of the species identified were endemic to Lake Tanganyika. A complete list of species can be found at Appendix IV.

3.5.2.1 Species caught uniquely by day and night gillnets

A total of 67 species were caught by day gillnets of which 19 were recorded exclusively by that technique. In spite of the fact that the number of nets set during the night was less than half that set during the day, night gillnets caught more species (72) and a higher proportion of these were unique to that technique. The calculated index of similarity was 0.69, indicating a significant degree of difference between the species caught by the two methods. Reference to the table of species at Appendix V, shows that night gillnets recorded a number of non-Cichlid species from genera such *Chrysichthys sp., Phyllonemus sp.* and species of the Mastacembelidae family, whereas a number of *Neolamprologus* and *Petrochromis spp.* were caught only by day gillnets.

3.5.2.2 Species unique to habitat

A similar comparison was made between species encountered in different habitats. Seventy-two species were encountered on soft substrates, 62 on hard substrates and 28 on shell beds. Of these 20, 14 and 5 were unique to soft, hard and shell bed habitats respectively. All the species unique to hard substrates and shell beds were Cichlids, whereas over half those found only on soft substrates were from other families (see Appendix VI). Table 3.6 shows the similarity indices for each pair of substrates. The similarity between species found in shell bed habitats with both soft and hard substrates is particularly low. Though this finding is inconclusive owing to the uncertainty as to whether sampling effort for both hard and shell bed habitats was sufficient.

Table 3.1 Species similarity between habitats

Comparison between habitat types	Similarity index
Soft/Hard	0.72
Soft/Shell bed	0.46
Hard/Shell bed	0.42

3.5.2.3 Species richness at site and habitat level

Table 3.7 shows the five sites with the highest species richness for both day and night gillnets. For day gillnets these sites are all situated on the eastern side of Nkamba Bay except Cape Nundo which is on the headland to the west of the bay. The night gillnet sites are located on the western side of Nkamba Bay at Cape Kapalwe 1 and 2 and at the western park boundary near Nsumbu Village. Only one site, Kala Bay 2, was among the 5 most species rich sites for both techniques. A complete list of sites together with number of species recorded at each is at Appendix VII.

Table 3.1 Sites with the highest species richness: day and night gillnets

Location	Sample	Species total
GILLNET DAY		
Kala Bay 1	ZB006 50	31
Kala Bay 2	ZB006 54	31
Inangu 1	ZB006 58	30
Nkamba Lodge 3	ZB006 46	26
Cape Nundo	ZB006 22	18
GILLNET NIGHT		
Cape Kapalwe 1	ZB006 28	26
Kala Bay 2	ZB006 56	23
Cape Kapalwe 2	ZB006 32	21
Nsumbu Bay 3	ZB006 12	19
Nsumbu Bay 2	ZB006 8	18

Species richness was also considered in relation to habitat type (Appendix VIII). The results for day gillnets on both soft and hard substrates showed strong similarities with those at site level. Table 3.8 shows that the most species rich samples from hard substrates were all from three adjacent locations (Kala Bay 1 and 2, Inangu 1) on the southern and western side of the Inangu Peninsula. The ranking of the shell samples tells us little, since the total sample size was only six. However they do show that of the three habitat types shell beds tended to be the poorest in species. From these results species richness does not appear to be depth dependent.

Table 3.9 shows the results from the night gillnet. It is difficult to make sensible comparisons or deductions, because numbers of samples from each of the habitat categories varies so widely (only one of the samples came from a shell bed habitat and three from hard substrates). A complete list of night gillnet samples is given at Appendix IX.

Table 3.2 Most species rich day gillnet samples by habitat type

Location	Sample		Depth (m)	Species total
SOFT				
Kala Bay 1	ZB006	50	15	20
Nkamba Lodge 3	ZB006	46	5	19
Cape Nundo	ZB006	22	5	15
Cape Kabwe 1	ZB006	14	5	11
Nkamba Bay	ZB006	34	10	10
HARD				
Inangu 1	ZB006	58	10	26
Kala Bay 1	ZB006	50	5	20
Kala Bay 2	ZB006	54	15	20
Kala Bay 2	ZB006	54	5	18
Kala Bay 1	ZB006	50	10	16
SHELL				
Nsumbu Bay 1	ZB006	2	5	9
Nsumbu Bay 1	ZB006	2	10	6
Nsumbu Bay 1	ZB006	2	15	5
Cape Kabwe 2	ZB006	18	15	3
Cape Kapalwe 1	ZB006	26	15	2

Table 3.3 Most species rich night gillnet samples by habitat type

Location	Sample		Species total
SOFT			
Cape Kapalwe 1	ZB006	28	26
Cape Kapalwe 2	ZB006	32	21
Nsumbu Bay 2	ZB006	8	18
Cape Kabwe 1	ZB006	16	17
Cape Kabwe 2	ZB006	20	16
HARD			
Kala Bay 2	ZB006	56	23
Inangu 1	ZB006	60	18
Kala Bay 1	ZB006	52	16
SHELL			
Nsumbu Bay 3	ZB006	12	19

3.5.3 Abundance

The total number of individuals recorded by day gillnets was 2441 and by night gillnets 1809 (a list of numbers for each species is at Appendix IV). The most abundant species in the catches of both day and night gillnets are given in Table 3.10. Cichlids dominate both lists and make up 3 of the 4 species common to both lists. The presence of representatives from other families in the night time catches is to be expected, since non-Cichlids include many species that remain deeper than 15 m during the day and move to shallow water to feed at night. The five most abundant species in each list constitute 49 and 45 % of the total abundance for day and night gillnets respectively. These figures are inflated by the presence of *Synodontis petricola*. Most of the individuals from this species were caught at two locations on the western side of Nkamba Bay and many were found to be carrying eggs. It is possible therefore that breeding activity maybe the explanation for such high densities and localised concentrations.

Table 3.1 Dominant species in day and night gillnet surveys

Day Gillnet			Night Gillnet		
Species	Number	% of total	Species	Number	% of total
Grammatotria lemairii	303	12.4	*Synodontis petricola*	390	21.6
Xenotilapia ochrogenys	281	11.5	*Cyprichromis leptosoma*	163	9.0
Synodontis petricola	266	10.9	*Limnotilapia dardennii*	107	5.9
Ophthalmotilapia ventralis	212	8.7	*Lates mariae*	92	5.1
Enantiopus melanogenys	134	5.5	*Bathybates ferox*	78	4.3
Limnotilapia dardennii	105	4.3	*Grammatotria lemairii*	69	3.8
Lestradea perspicax	103	4.2	*Lophiobagrus cyclurus*	68	3.8
Ectodus descampsi	100	4.1	*Cyathopharynx furcifer*	63	3.5
Boulengerochromis microlepis	87	3.6	*Chrysichthys sianenna*	60	3.3
Cyprichromis leptosoma	84	3.4	*Perissodus microlepis*	60	3.3

3.5.4 Diversity indices

Shannon Weiner diversity indices were calculated for both gillnet methods for the park as a whole. The index for night gillnets (1.41) was slightly higher than that for day gillnets (1.38). The diversity indices for all sites and for all samples by habitat are presented at Appendices VII, VIII and IX. The five sites/samples with the highest diversity indices in each of these categories are shown in Tables 3.11, 3.12 and 3.13. The results show a high degree of correlation between values for species richness and diversity indices. Day gillnets record the highest diversity along the edge of the Inangu Peninsula and eastern side of Nkamba Bay and the highest Night gillnet diversity occurs in Nkamba Bay and between Cape Nundo and Nsumbu Village.

Table 3.1 Sites with the highest diversity indices

Location	Sample	Shannon Weiner Index
GILLNET DAY		
Kala Bay 2	ZB006 54	1.28
Inangu 1	ZB006 58	1.23
Nkamba Lodge 3	ZB006 46	1.22
Kala Bay 1	ZB006 50	1.16
Nsumbu Bay 1	ZB006 2	1.04
GILLNET NIGHT		
Cape Kapalwe 2	ZB006 32	1.21
Kala Bay 2	ZB006 56	1.19
Cape Kapalwe 1	ZB006 28	1.15
Nsumbu Bay 2	ZB006 8	1.08
Cape Kabwe 1	ZB006 16	1.06

Table 3.2 Day gillnet samples with the highest diversity indices by habitat type

Location	Sample	Depth (m)	Shannon Weiner Index
SOFT			
Kala Bay 1	ZB006 50	15	1.42
Nkamba Lodge 3	ZB006 46	5	1.05
Cape Nundo	ZB006 22	5	0.84
Nkamba Lodge 3	ZB006 46	10	0.69
Cape Kabwe 2	ZB006 18	10	0.68
HARD			
Inangu 1	ZB006 58	10	1.25
Kala Bay 2	ZB006 54	5	1.13
Kala Bay 2	ZB006 54	15	1.10
Kala Bay 1	ZB006 50	5	1.06
Kala Bay 1	ZB006 50	10	0.94
SHELL			
Nsumbu Bay 1	ZB006 2	5	0.88
Nsumbu Bay 1	ZB006 2	10	0.66
Nsumbu Bay 1	ZB006 2	15	0.58
Cape Kabwe 2	ZB006 18	15	0.25
Cape Kapalwe 1	ZB006 26	15	0.24

Table 3.3 Night gillnet samples with the highest diversity indices by habitat type

Location	Sample	Shannon Weiner Index
SOFT		
Cape Kapalwe 2	ZB006 32	1.21
Cape Kapalwe 1	ZB006 28	1.15
Nsumbu Bay 2	ZB006 8	1.08
Cape Kabwe 1	ZB006 16	1.06
Inangu 2	ZB006 64	1.03
HARD		
Kala Bay 2	ZB006 56	1.19
Inangu 1	ZB006 60	0.76
Kala Bay 1	ZB006 52	0.65
SHELL		
Nsumbu Bay 3	ZB006 12	1.03

CHAPTER 4. DISCUSSION

4.1 Suitability of Methods

The Nsumbu survey was the first occasion on which BIOSS employed many of these sampling techniques. Inevitably a number of limitations were highlighted and where feasible methods were amended accordingly.

4.1.1 'Croc box' technique

This was found to be less effective than the Manta Tow technique. The field of view is more limited and the visibility through the Perspex 'viewing aperture' was less clear. The rate of progress was slower than the Manta Tow due to the 'drag' imposed on the boat by the box. Furthermore, due to the uncomfortable 'head-down' position that has to be adopted, the task of observer has to be rotated more often. Most of these shortcomings can be rectified by modifications to the design of the 'croc box'.

4.1.2 Habitat grab

The principal disadvantage of this technique is the lack of detail it provides. Unless sampling effort is very intensive no information can be collected on the relative proportions or spatial distribution of microhabitats within a site. Without direct observation it is only possible to obtain a detailed knowledge of soft substrate characteristics. In fact the presence of hard substrates, has to be inferred from empty grab samples, which is a considerable assumption to make. Nor does it provide any direct data on the profile of a site, though a knowledge of the depth (from boat or hand held depth sounder) combined with an estimation of distance from the shore, does allow for a rough approximation of the slope of the lake bottom.

4.1.3 Mollusc dredge

The value of mollusc dredge data is limited by the fact that it can only be used on soft substrates. As result samples will not include many of the species known to favour rocky or hard habitats. In addition, since it is impossible to know which section of the transect an individual mollusc came from, it is difficult to make detailed associations between species and habitat characteristics. Mesh size is also a key consideration when using this technique. The optimum will vary with substrate type and can be determined through experimentation. In general, 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 will however result in the smaller molluscs passing through the netting and being lost from the sample.

4.1.4 Gillnets

The principal advantage of using gillnets over direct observation methods, is the accuracy of species identification it affords. Underwater identification often requires the observer to make a snap decision on the basis of a fleeting or partly obscured sighting. Where necessary, identification of gillnet catches can facilitated by a thorough examination for particular species characteristics and reference to identification keys. Nevertheless, there are limitations to the use of gillnet. It is a passive method, which means that sedentary species and those that remain confined in burrows or crevices, or temporarily suspend their food searching, are caught with difficulty. Furthermore gillnets are subject to loss or damage by crocodiles. It is assumed that one of the nets used in the survey was lost in this manner, as the marker buoy was later found punctured by large tooth marks. They are also a very desirable item for fishermen and therefore susceptible to theft particularly at night.

Less than half the number of gillnets were set at night than during the day and yet they recorded significantly more species and almost as many individuals. This would suggest that in future surveys the day gillnet sampling effort could be considerably reduced. It is important however to employ both methods as comparison showed that they sampled slightly different fish communities and to dispense with one would result in the loss of valuable data.

4.1.5 Dive versus non-dive techniques

Dive techniques require greater logistical resources and a higher degree of skill and training in those undertaking the survey work. Nevertheless, they offer more flexibility, greater opportunity for comprehensive and detailed data collection and there is no substitute for confirmation by direct observation. In the majority of circumstances they would be preferred to non-dive survey methods. However in cases where divers cannot operate either for reasons of poor visibility or safety they are not an option and non-dive techniques must be employed.

4.2 Overview of Findings

4.2.1 Habitats

The broad scale habitat mapping identified a rich variety of rocky, sandy and mixed habitats in the 0-5 m zone, with rock dominating. The findings of the habitat grab surveys were inevitably constrained by limitations in survey techniques outlined in Chapter 4.1.2 above. The presence of hard substrates had to be assumed and the information obtained on soft substrates was at best limited. Nevertheless, it was established that in contrast to shallower waters, soft substrates are predominant along much of the park shoreline, in the depth range 5–15 m. The majority of the sites with hard substrates were identified along the eastern site of Nkamba Bay. The only specialised habitats identified were the shell beds concentrated near the western park border and the large stand of emergent macrophytes at the south-western end of Nkamba Bay. It is not known if any stromatolite reefs occur in the park.

In spite of the presence of two tourist lodges within the park and periodic fishing by local communities, there is little reason to think that these have impacted on underwater habitats. There are no obvious sources of pollution, and with the catchment largely protected by the park, sedimentation is unlikely to be a major threat. A more exact assessment of the state of the aquatic habitats would however require direct observation and water quality analysis.

4.2.2 Mollusc census

The mollusc species identified by this survey represent 20 % of the total number that have been recorded in the lake to date. Though the species accumulation curves appear to show that sampling effort was sufficient, these are valid only for sand dwelling species since no rocky habitats were sampled. A number of gastropod species occur exclusively on or underneath rocks and these are consequently poorly represented in this survey. It is almost certain therefore that the mollusc species richness of the park has been significantly underestimated. It also follows that the highest species richness was found in the sections of the park where soft substrates were predominant such as the western side of Nkamba Bay and the area between Nundo and Nsumbu Bay.

4.2.3 Fish

Thirty seven percent of all species known to inhabit Lake Tanganyika were identified in Nsumbu. This is a significant proportion of the lakes fish biodiversity and together with the high percentage of endemics, highlights the importance of the park in conservation terms. It should be noted that the gillnetting techniques used did not sample at depths between 0-5 m. As a result some species, which spend a large proportion of the time in this zone may not have been recorded. Furthermore, the diversity at the level of genera was very high with an average of less than two species being recorded in each genus.

Species richness and diversity appear to have been closely correlated whether analysed at site or sample level. The locations with the diversity indices and the highest number of species were mostly concentrated along the eastern edge of Nkamba Bay and in particular Kala Bay and Inangu Peninsula. Though other sites such as Kabwe and Cape Kapalwe featured prominently, particularly when sampled by night gillnets. The extent to which species richness and diversity were a function of habitat type can only be discerned in general terms. Soft and hard substrates supported similar levels of both, whereas fish communities in shell bed habitats tended to be poorer in species and less diverse.

The habitat-species associations deduced from the results are inevitably fairly crude given the lack of detail from the habitat surveys and the fact that without directly observing the fish underwater it is difficult to be certain which habitat they frequent. This is particularly in the case of hard and shell bed habitats, which were less well represented in the park and therefore produced a smaller data set.

Abundance was unevenly distributed with 5 species comprising half the catch for daytime gillnets, though these results were undoubtedly skewed by the concentration of large numbers of breeding *Synodontis petricola* at several sites in Nkamba bay. Further sampling is required to establish fully the relative abundance of species and which are patchily distributed or rare.

4.3 Future Work

The BIOSS survey of Nsumbu National Park is the most comprehensive to date; nevertheless there is a considerable amount of further work required gain a better understanding of the parks aquatic biodiversity.

- *Areas inadequately surveyed.* Rough lake conditions in the last two days of the survey meant that sampling at a number of sites from Kasaba Bay to the Lufubu River was either abandoned or only partially executed. It is therefore a priority that in future surveys of the park this area is included in the sampling programme so that an adequate data set can be obtained.

- *Habitat/species associations.* The habitat data from this survey lacks the detail to construct anything but the most general habitat/species associations. To be more specific further sampling is required to build up a more detailed knowledge of the habitat characteristics at each site. However, it is difficult to see how this could be achieved without more sophisticated sampling equipment (such as underwater video equipment), or a dramatic change in the density of the crocodile population in the park to allow profile dives to be conducted in greater safety.

- *Total biodiversity surrogates.* In this survey fish and molluscs were used to give an indication of what total biodiversity at Nsumbu might be. Other taxonomic groups may be equally or more suited for this purpose, but as yet the appropriate identification keys have not been produced. These should be developed so that future surveys can add data on these groups to the existing knowledge of biodiversity in the park.

4.4 Management Recommendations

The results from this survey show that Nsumbu National Park includes a wide variety of habitats supporting diverse fish and mollusc communities. These are currently adequately protected and there is no evidence of significant pollution, sedimentation or over-fishing. Nevertheless, growing population pressure on the park boundaries is likely to lead to increased impact on the aquatic resources within the park. With this in mind, BIOSS has the following recommendations for park management.

Capacity building. Current activities conducted by the park staff are almost exclusively directed towards management and monitoring of the terrestrial parts of the park. It is recommended that training be undertaken to improve knowledge and understanding of the aquatic zone and its management. Under the present conditions prevailing in the Zambian Parks and Wildlife Service it is unlikely that the resources would be available to do this. Nevertheless, a major reorganisation of the institutions responsible for protected areas in Zambia is in progress. It is hoped that the authority responsible managing Nsumbu National Park in the future, treat this requirement for capacity building as a priority.

Monitoring. This is critical to the successful management of any protected area, since it provides information on the status of aquatic habitats and biota, which may suggest necessary management interventions. An effective monitoring programme need not involve complex methods or major resources; it does require a basic level of knowledge and conscientious application. The park authorities are best placed to direct and undertake this work. However, should they continue to lack the capacity, it is hoped that Department of Fisheries, Mpulungu who now have considerable expertise in this field might assist with equipment and training.

Park boundary. The present park boundary, which extends 1.6 km into the aquatic zone, should be maintained. However, in Nkamba Bay where the coastline is deeply recessed this creates a tongue of unprotected water, which protrudes deep into the bay. This has led to ambiguity as to the precise location of the boundary and subsequent conflict between park authorities and local fishermen. It is therefore recommended that the boundary be adjusted to run directly from Cape Nundo to the northern side of Inangu Peninsula, thereby incorporating the whole of Nkamba Bay. This should however be implemented in consultation with the local communities, whose access to productive fishing grounds will be reduced by such changes.

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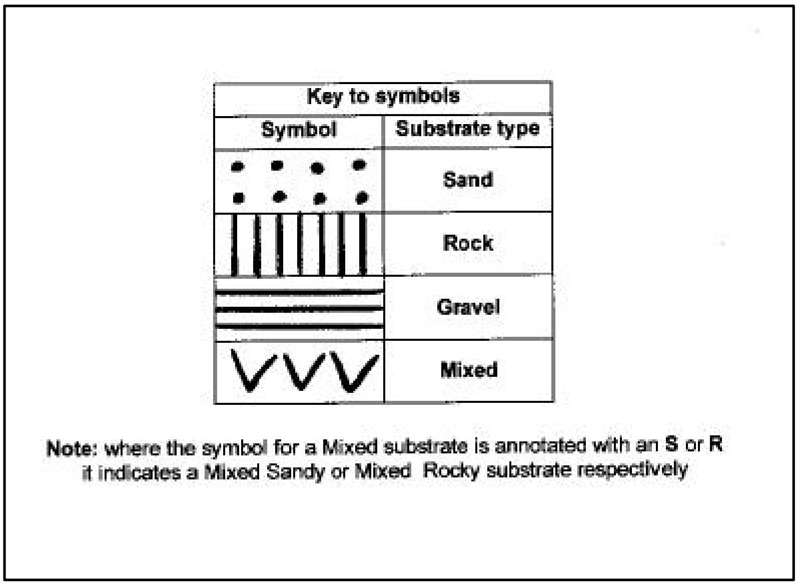
Appendix I Summary of survey sites and sampling events, Nsumbu National Park

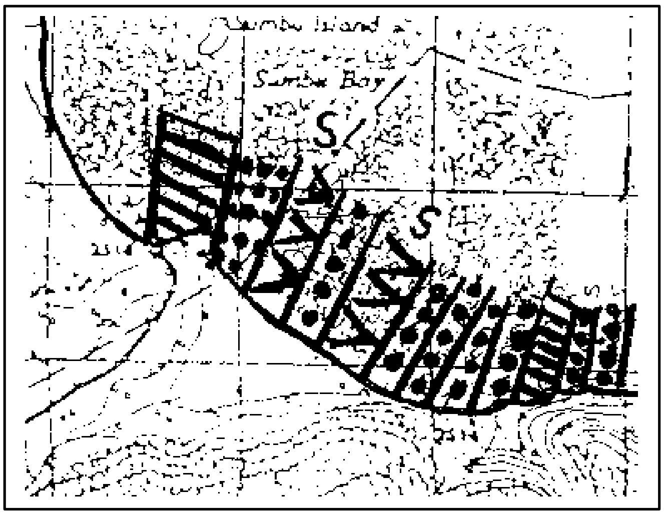
Location	Lat / Long		Sample		Activity
Nsumbu Bay 1	08.525 S	30.491E	ZB006	1	Habitat grab
			ZB006	2	Gillnet
			ZB006	3	Mollusc dredge
			ZB006	4	Gillnet (night)
Nsumbu Bay 2	08.522 S	30.496 E	ZB006	5	Habitat grab
			ZB006	6	Gillnet
			ZB006	7	Mollusc dredge
			ZB006	8	Gillnet (night)
Nsumbu Bay 3	08.522 S	30.509 E	ZB006	9	Habitat grab
			ZB006	10	Gillnet
			ZB006	11	Mollusc dredge
			ZB006	12	Gillnet (night)
Cape Kabwe 1	08.514 S	30.529 E	ZB006	13	Habitat grab
			ZB006	14	Gillnet
			ZB006	15	Mollusc dredge
			ZB006	16	Gillnet (night)
Cape Kabwe 2	08.509 S	30.546 E	ZB006	17	Habitat grab
			ZB006	18	Gillnet
			ZB006	19	Mollusc dredge
			ZB006	20	Gillnet (night)
Cape Nundo	08.509 S	30.557 E	ZB006	21	Habitat grab
			ZB006	22	Gillnet
			ZB006	23	Mollusc dredge
			ZB006	24	Gillnet (night)
Cape Kapalwe 1	08.534 S	30.574 E	ZB006	25	Habitat grab
			ZB006	26	Gillnet
			ZB006	27	Mollusc dredge
			ZB006	28	Gillnet (night)
Cape Kapalwe 2	08.540 S	30.572 E	ZB006	29	Habitat grab
			ZB006	30	Gillnet
			ZB006	31	Mollusc dredge
			ZB006	32	Gillnet (night)
Nkamba Bay	08.508 S	30.538 E	ZB006	33	Habitat grab
			ZB006	34	Gillnet
			ZB006	35	Mollusc dredge
			ZB006	36	Gillnet (night)
Nkamba Lodge 1	08.592 S	30.552 E	ZB006	37	Habitat grab
			ZB006	38	Gillnet
			ZB006	39	Mollusc dredge
Nkamba Lodge 2	08.503 S	30.571 E	ZB006	41	Habitat grab
			ZB006	42	Gillnet
			ZB006	43	Mollusc dredge
			ZB006	44	Gillnet (night)

Nkamba Lodge 3	08.576 S	30.591 E	ZB006 45	Habitat grab
			ZB006 46	Gillnet
			ZB006 48	Gillnet (night)
Kala Bay 1	08.538 S	30.637 E	ZB006 49	Habitat grab
			ZB006 50	Gillnet
			ZB006 51	Mollusc dredge
			ZB006 52	Gillnet (night)
Kala Bay 2	08.525 S	30.655 E	ZB006 53	Habitat grab
			ZB006 54	Gillnet
			ZB006 56	Gillnet (night)
Inangu 1	08.496 S	30.650 E	ZB006 57	Habitat grab
			ZB006 58	Gillnet
			ZB006 60	Gillnet (night)
Inangu 2	08.485 S	30.664 E	ZB006 61	Habitat grab
			ZB006 62	Gillnet
			ZB006 63	Mollusc dredge
			ZB006 64	Gillnet (night)
Cape Nambiyeye	08.530 S	30.721 E	ZB006 65	Gillnet (night)
Cape Chikulula	08.535 S	30.728 E	ZB006 66	Gillnet (night)
Cape Kasenga	08.543 S	30.727 E	ZB006 67	Habitat grab
			ZB006 69	Mollusc dredge
			ZB006 70	Gillnet (night)
Kasololo Bay	08.558 S	30.725 E	ZB006 71	Habitat grab
			ZB006 73	Mollusc dredge
			ZB006 74	Gillnet (night)

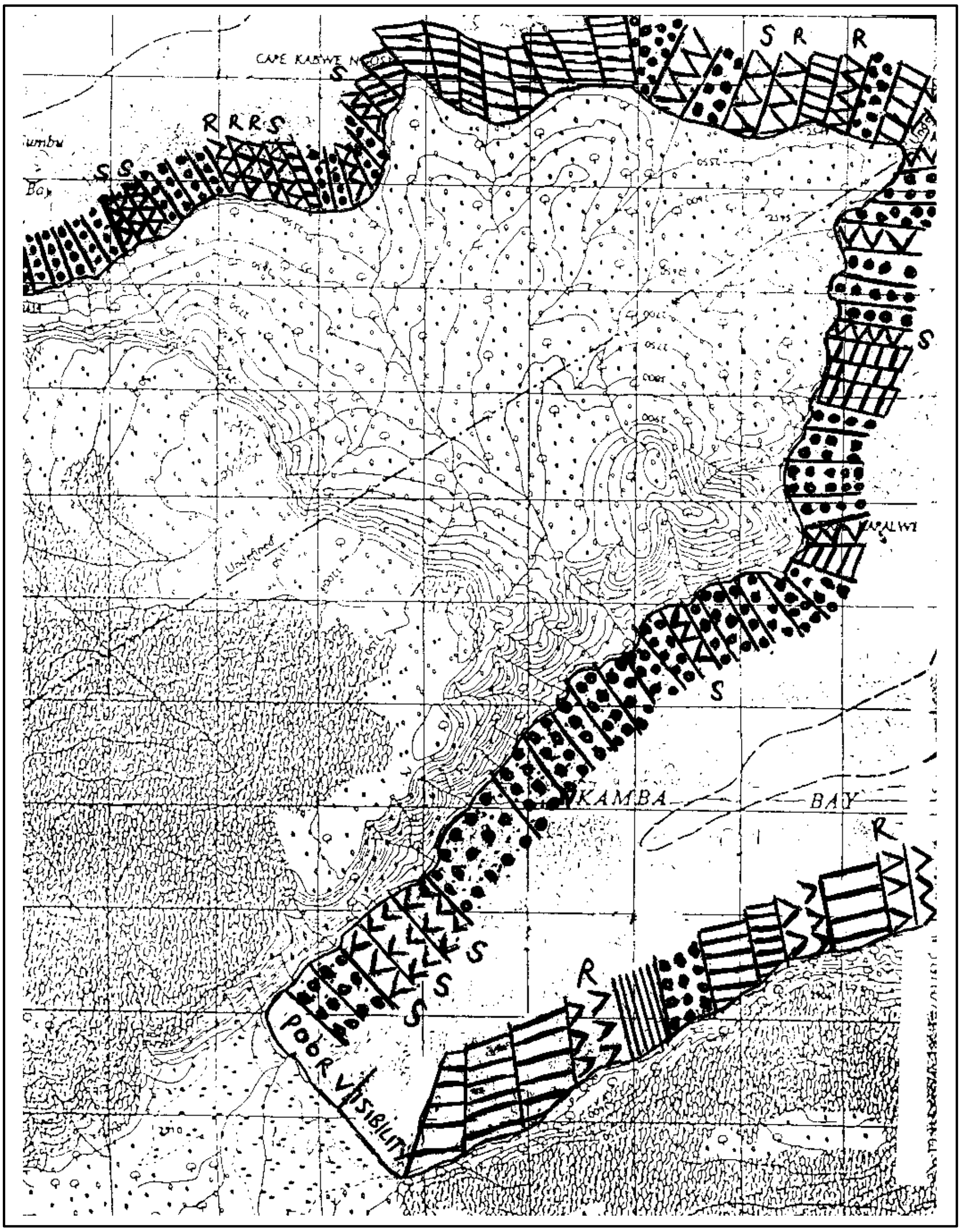
Appendix II Coarse scale habitat maps for Nsumbu National Park



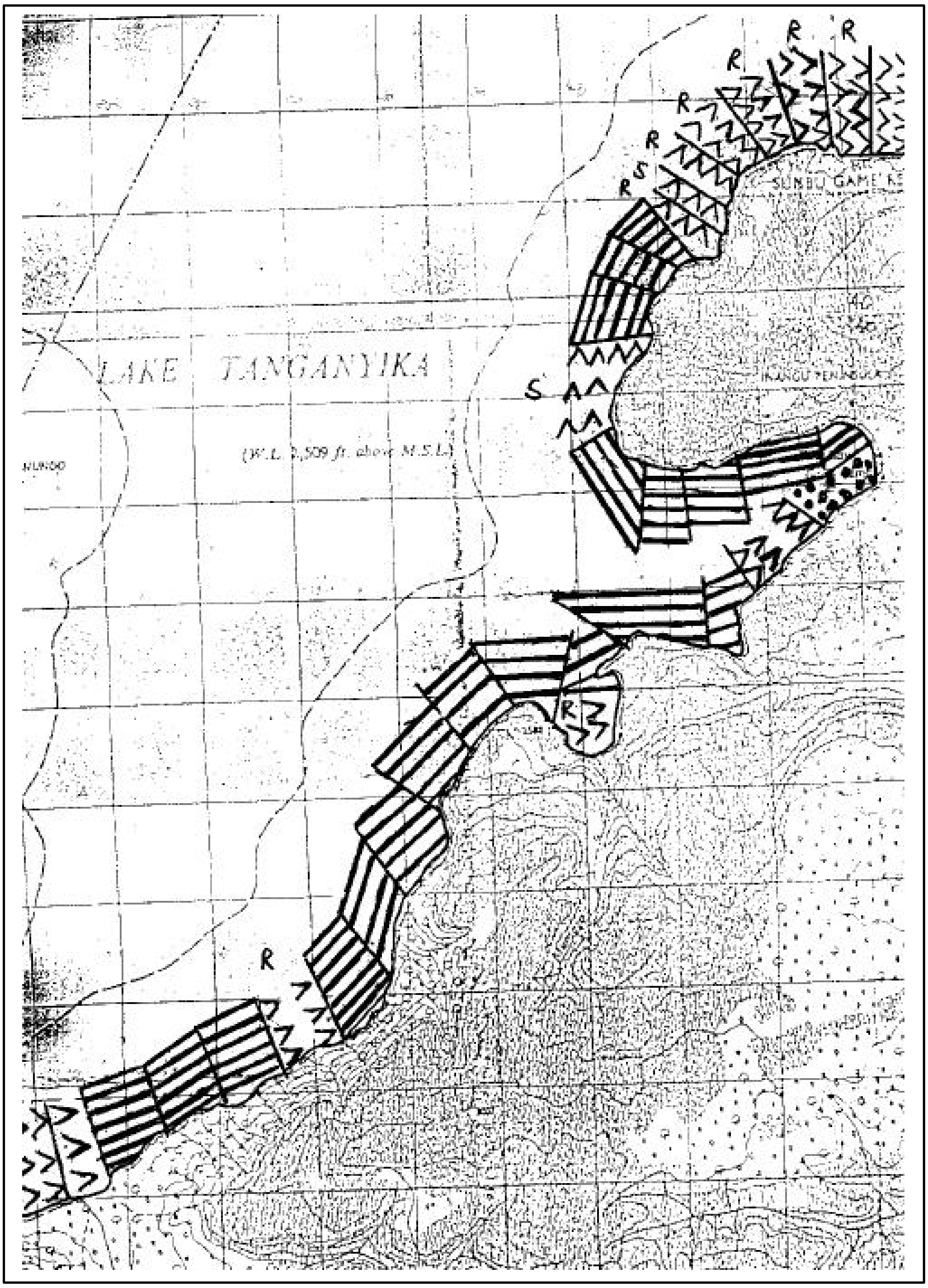
MAP 1



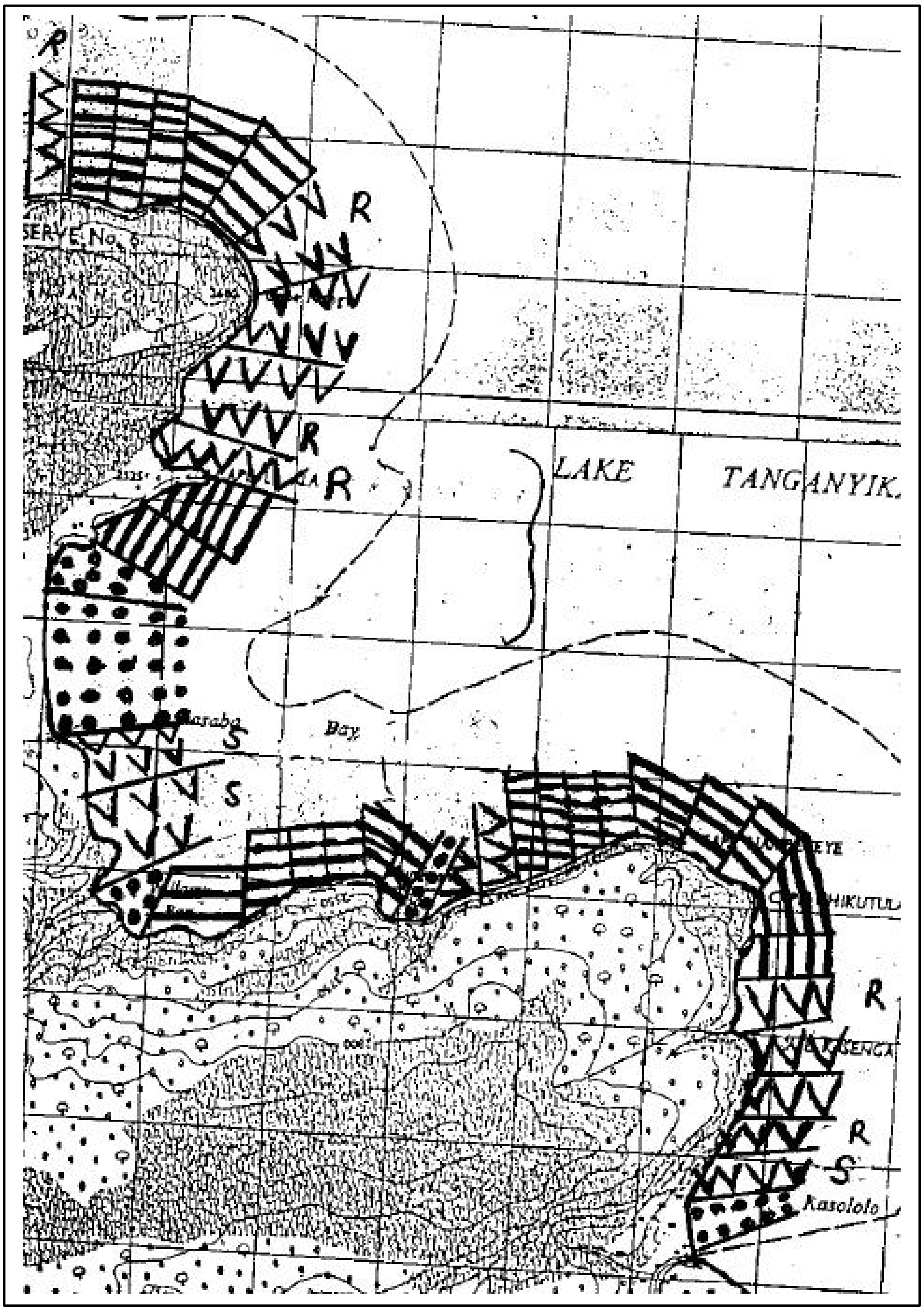
MAP 2



MAP 3

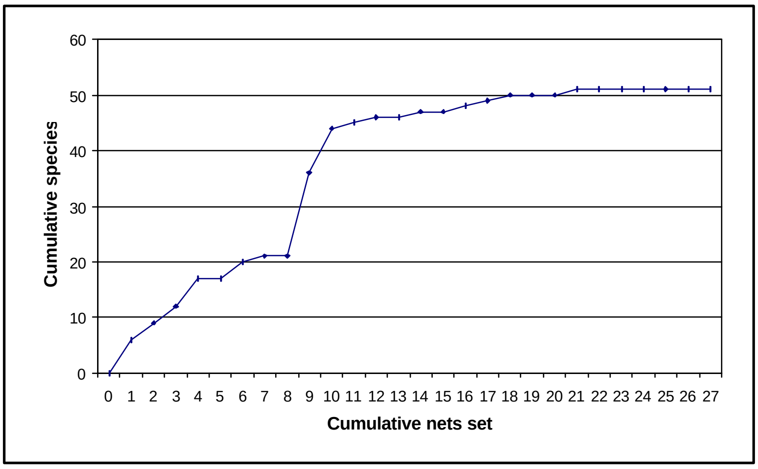


MAP 4

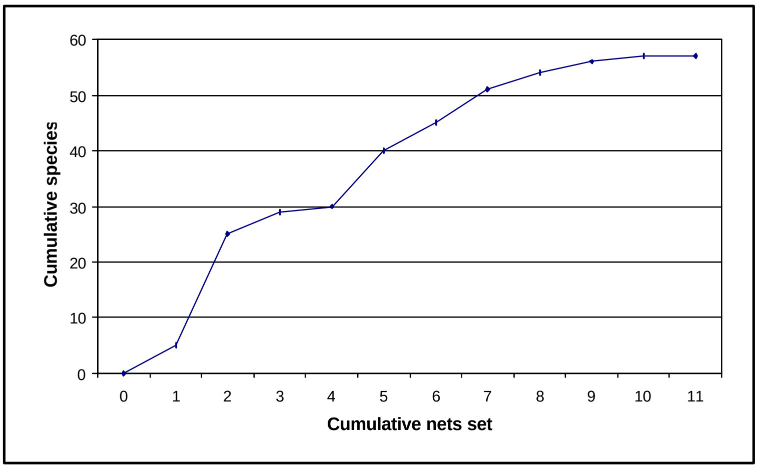


Appendix III Species accumulation curves by sample method and habitat.
a) Day gillnet; soft substrate b) Day gillnet; hard substrate c) Night gillnet; soft substrate

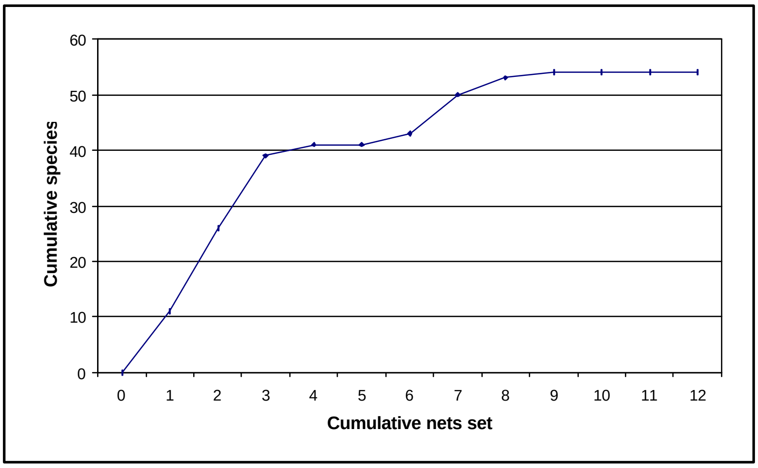
a)



b)



c)



Appendix IV Species list for Nsumbu National Park with total catch for day and night gillnets

	Species	Endemic	Family	Day Gillnet	Night Gillnet
1	*Aethiomastacembelus cunningtoni*	Yes	Mastacembelidae	5	4
2	*Aethiomastacembelus ellipsifer*	Yes	Mastacembelidae	-	5
3	*Altolamprologus calvus*	Yes	Cichlidae	2	-
4	*Altolamprologus compressiceps*	Yes	Cichlidae	1	-
5	*Auchenoglanis occidentalis*	No	Bagridae	-	2
6	*Aulonocranus dewindti*	Yes	Cichlidae	-	3
7	*Bathybates fasciatus*	Yes	Cichlidae	-	1
8	*Bathybates ferox*	Yes	Cichlidae	29	78
9	*Bathybates leo*	Yes	Cichlidae	10	12
10	*Boulengerochromis microlepis*	Yes	Cichlidae	87	28
11	*Caecomastacembelus micropectus*	Yes	Mastacembelidae	-	11
12	*Caecomastacembelus moorii*	Yes	Mastacembelidae	2	1
13	*Callochromis macrops*	Yes	Cichlidae	-	1
14	*Chalinochromis brichardi*	Yes	Cichlidae	7	1
15	*Chrysichthys brachynema*	Yes	Bagridae	-	57
16	*Chrysichthys grandis*	Yes	Bagridae	-	3
17	*Chrysichthys sianenna*	Yes	Bagridae	-	60
18	*Citharinus gibbosus*	Yes	Citharinidae	-	4
19	*Ctenochromis horei*	Yes	Cichlidae	4	-
20	*Cyathopharynx furcifer*	Yes	Cichlidae	11	63
21	*Cyphotilapia frontosa*	Yes	Cichlidae	7	5
22	*Cyprichromis leptosoma*	Yes	Cichlidae	84	163
23	*Ectodus descampsi*	Yes	Cichlidae	100	2
24	*Enantiopus melanogenys*	Yes	Cichlidae	134	-
25	*Gnathochromis pfefferi*	Yes	Cichlidae	8	-
26	*Grammatotria lemairii*	Yes	Cichlidae	303	69
27	*Haplotaxodon microlepis*	Yes	Cichlidae	39	21
28	*Hemibates stenosoma*	Yes	Cichlidae	-	1
29	*Hydrocynus vittatus*	No	Characidae	1	-
30	*Julidochromis marlieri*	Yes	Cichlidae	1	-
31	*Labeo cylindricus*	No	Cyprinidae	-	7
32	*Lamprichthys tanganicanus*	Yes	Cyprinodontidae	5	3
33	*Lamprologus callipterus*	Yes	Cichlidae	60	47
34	*Lamprologus lemairii*	Yes	Cichlidae	-	8
35	*Lamprologus ocellatus*	Yes	Cichlidae	1	-
36	*Lates angustifrons*	Yes	Centropomidae	-	11
37	*Lates mariae*	Yes	Centropomidae	3	92
38	*Lepidiolamprologus attenuatus*	Yes	Cichlidae	50	12
39	*Lepidiolamprologus cunningtoni*	Yes	Cichlidae	39	18
40	*Lepidiolamprologus elongatus*	Yes	Cichlidae	14	5
41	*Lepidiolamprologus profundicola*	Yes	Cichlidae	-	3
42	*Lestradea perspicax*	Yes	Cichlidae	103	24
43	*Lestradea stappersii*	Yes	Cichlidae	2	-
44	*Limnothrissa miodon*	Yes	Clupeidae	4	32
45	*Limnotilapia dardennii*	Yes	Cichlidae	105	107

46	*Lobochilotes labiatus*	Yes	Cichlidae	18	14
47	*Lophiobagrus cyclurus*	Yes	Bagridae	-	68
48	*Malapterurus electricus*	No	Malapteruridae	1	2
49	*Neolamprologus brevis*	Yes	Cichlidae	2	2
50	*Neolamprologus brichardi*	Yes	Cichlidae	13	-
51	*Neolamprologus caudopunctatus*	Yes	Cichlidae	-	1
52	*Neolamprologus fasciatus*	Yes	Cichlidae	4	1
53	*Neolamprologus furcifer*	Yes	Cichlidae	1	3
54	*Neolamprologus leleupi*	Yes	Cichlidae	2	-
55	*Neolamprologus modestus*	Yes	Cichlidae	2	-
56	*Neolamprologus moorii*	Yes	Cichlidae	15	-
57	*Neolamprologus mustax*	Yes	Cichlidae	2	-
58	*Neolamprologus savoryi*	Yes	Cichlidae	-	3
59	*Neolamprologus sexfasciatus*	Yes	Cichlidae	3	-
60	*Neolamprologus tetracanthus*	Yes	Cichlidae	39	12
61	*Ophthalmotilapia ventralis*	Yes	Cichlidae	212	17
62	*Oreochromis tanganicae*	Yes	Cichlidae	8	-
63	*Paracyprichromis nigripinnis*	Yes	Cichlidae	-	5
64	*Perissodus eccentricus*	Yes	Cichlidae	5	10
65	*Perissodus microlepis*	Yes	Cichlidae	83	60
66	*Petrochromis famula*	Yes	Cichlidae	4	-
67	*Petrochromis fasciolatus*	Yes	Cichlidae	4	-
68	*Petrochromis macrognathus*	Yes	Cichlidae	1	-
69	*Petrochromis orthognathus*	Yes	Cichlidae	44	3
70	*Petrochromis polyodon*	Yes	Cichlidae	37	6
71	*Petrochromis trewavasae*	Yes	Cichlidae	2	-
72	*Phyllonemus filinemus*	Yes	Bagridae	-	1
73	*Phyllonemus typus*	Yes	Bagridae	-	1
74	*Plecodus paradoxus*	Yes	Cichlidae	9	12
75	*Plecodus straeleni*	Yes	Cichlidae	18	3
76	*Simochromis diagramma*	Yes	Cichlidae	4	3
77	*Stolothrissa tanganicae*	Yes	Clupeidae	-	5
78	*Synodontis multipunctatus*	Yes	Mochokidae	1	15
79	*Synodontis petricola*	Yes	Mochokidae	266	390
80	*Telmatochromis dhonti*	Yes	Cichlidae	8	2
81	*Telmatochromis temporalis*	Yes	Cichlidae	2	2
82	*Trematocara marginatum*	Yes	Cichlidae	-	1
83	*Trematocara stigmaticum*	Yes	Cichlidae	-	28
84	*Tropheus moorii*	Yes	Cichlidae	60	10
85	*Tylochromis polylepis*	Yes	Cichlidae	20	8
86	*Xenochromis hecqui*	Yes	Cichlidae	1	1
87	*Xenotilapia boulengeri*	Yes	Cichlidae	19	28
88	*Xenotilapia flavipinnis*	Yes	Cichlidae	11	3
89	*Xenotilapia ochrogenys*	Yes	Cichlidae	281	34
90	*Xenotilapia sima*	Yes	Cichlidae	10	23
91	*Xenotilapia spilopterus*	Yes	Cichlidae	8	2
			Totals:	2441	1809

Appendix V Species uniquely recorded by day and night gillnets

	Day gillnet	Night gillnet
	Number of nets set: **46**	Number of nets set: **19**
	Total species recorded: **67**	Total species recorded: **72**
1	*Altolamprologus calvus*	*Aethiomastacembelus cunningtoni*
2	*Altolamprologus compressiceps*	*Caecomastacembelus micropectus*
3	*Ctenochromis horei*	*Auchenoglanis occidentalis*
4	*Gnathochromis pfefferi*	*Aulonocranus dewindti*
5	*Hydrocynus vittatus*	*Bathybates fasciatus*
6	*Julidochromis marlieri*	*Callochromis macrops*
7	*Lamprologus ocellatus*	*Chrysichthys brachynema*
8	*Lestradea stappersii*	*Chrysichthys grandis*
9	*Neolamprologus brichardi*	*Chrysichthys sianenna*
10	*Neolamprologus leleupi*	*Citharinus gibbosus*
11	*Neolamprologus modestus*	*Hemibates stenosoma*
12	*Neolamprologus moorii*	*Labeo cylindricus*
13	*Neolamprologus mustax*	*Lamprologus lemairii*
14	*Neolamprologus sexfasciatus*	*Lates angustifrons*
15	*Oreochromis tanganicae*	*Lepidiolamprologus profundicola*
16	*Petrochromis famula*	*Lophiobagrus cyclurus*
17	*Petrochromis fasciolatus*	*Neolamprologus caudopunctatus*
18	*Petrochromis macrognathus*	*Neolamprologus savoryi*
19	*Petrochromis trewavasae*	*Paracyprichromis nigripinnis*
20		*Phyllonemus filinemus*
21		*Phyllonemus typus*
22		*Stolothrissa tanganicae*
23		*Trematocara marginatum*
24		*Trematocara stigmaticum*

Appendix VI Fish species recorded uniquely on soft, hard and shell substrates

	Soft substrate	Hard substrate	Shellbeds
	Total species recorded by day and night gillnets: **72**	Total species recorded by day and night gillnets: **62**	Total species recorded by day and night gillnets: **28**
1	*Aethiomastacembelus cunningtoni*	*Altolamprologus compressiceps*	*Aulonocranus dewindti*
2	*Auchenoglanis occidentalis*	*Cyphotilapia frontosa*	*Bathybates fasciatus*
3	*Caecomastacembelus micropectus*	*Ectodus descampsi*	*Callochromis macrops*
4	*Chrysichthys brachynema*	*Julidochromis marlieri*	*Ctenochromis horei*
5	*Chrysichthys grandis*	*Lestradea stappersii*	*Hemibates stenosoma*
6	*Citharinus gibbosus*	*Neolamprologus brichardi*	
7	*Hydrocynus vittatus*	*Neolamprologus caudopunctatus*	
8	*Lamprologus ocellatus*	*Neolamprologus furcifer*	
9	*Lates angustifrons*	*Neolamprologus savoryi*	
10	*Lepidiolamprologus profundicola*	*Petrochromis famula*	
11	*Malapterurus electricus*	*Petrochromis fasciolatus*	
12	*Neolamprologus modestus*	*Petrochromis macrognathus*	
13	*Oreochromis tanganicae*	*Petrochromis trewavasae*	
14	*Paracyprichromis nigripinnis*	*Telmatochromis temporalis*	
15	*Phyllonemus filinemus*		
16	*Phyllonemus typus*		
17	*Stolothrissa tanganicae*		
18	*Synodontis petricola*		
19	*Trematocara marginatum*		
20	*Trematocara stigmaticum*		

Appendix VII **Day and night gill nets; total number of species, total number of individuals and Shannon Weiner index for each sampling location**

Location	Sample	Total number of species	Total number of individuals	Shannon Weiner Index
GILLNET DAY				
Nsumbu Bay 1	ZB006 2	15	87	1.04
Nsumbu Bay 2	ZB006 6	9	72	0.71
Nsumbu Bay 3	ZB006 10	2	12	0.24
Cape Kabwe 1	ZB006 14	11	194	0.63
Cape Kabwe 2	ZB006 18	10	412	0.75
Cape Nundo	ZB006 22	18	241	0.95
Cape Kapalwe 1	ZB006 26	4	11	0.55
Cape Kapalwe 2	ZB006 30	13	59	0.92
Nkamba Bay	ZB006 34	15	398	0.53
Nkamba Lodge 1	ZB006 38	12	36	0.97
Nkamba Lodge 2	ZB006 42	6	56	0.49
Nkamba Lodge 3	ZB006 46	26	138	1.22
Kala Bay 1	ZB006 50	31	318	1.16
Kala Bay 2	ZB006 54	31	101	1.28
Inangu 1	ZB006 58	30	181	1.23
Inangu 2	ZB006 62	16	125	0.91
GILLNET NIGHT				
Nsumbu Bay 2	ZB006 8	18	65	1.08
Nsumbu Bay 3	ZB006 12	19	50	1.03
Cape Kabwe 1	ZB006 16	17	113	1.06
Cape Kabwe 2	ZB006 20	17	117	0.98
Cape Nundo	ZB006 24	17	83	1.01
Cape Kapalwe 1	ZB006 28	26	142	1.15
Cape Kapalwe 2	ZB006 32	21	91	1.21
Nkamba Bay	ZB006 36	15	304	0.38
Nkamba Lodge 2	ZB006 44	11	80	0.69
Nkamba Lodge 3	ZB006 48	15	142	0.89
Kala Bay 1	ZB006 52	16	87	0.65
Kala Bay 2	ZB006 56	23	85	1.19
Inangu 1	ZB006 60	18	188	0.76
Inangu 2	ZB006 64	15	55	1.03
Cape Nambiyeye	ZB006 65	13	34	0.97
Cape Chikulula	ZB006 66	16	110	1.00
Cape Kasenga	ZB006 70	10	30	0.70
Kasololo Bay	ZB006 74	11	39	0.92

Appendix VIII Day gill nets; total number of species, total number of individuals and Shannon Weiner index for each sampling location at which substrate recorded

Location	Sample	Depth (m)	Total number of species	Total number of individuals	Shannon Weiner Index
SOFT					
Nsumbu Bay 2	ZB006 6	5	4	5	0.58
		10	2	3	0.28
		15	6	64	0.59
Nsumbu Bay 3	ZB006 10	5	2	8	0.29
Cape Kabwe 1	ZB006 14	5	11	126	0.58
		10	4	41	0.50
		15	3	27	0.47
Cape Kabwe 2	ZB006 18	5	3	25	0.26
		10	9	330	0.68
Cape Nundo	ZB006 22	5	15	162	0.84
		10	5	48	0.42
		15	4	31	0.35
Cape Kapalwe 1	ZB006 26	5	4	6	0.54
		10	1	1	0.00
Cape Kapalwe 2	ZB006 30	5	5	9	0.57
		10	5	10	0.53
Nkamba Bay	ZB006 34	5	7	25	0.57
		10	10	179	0.55
		15	8	194	0.14
Nkamba Lodge 1	ZB006 38	10	5	10	0.68
		15	3	8	0.39
Nkamba Lodge 2	ZB006 42	5	5	26	0.36
		15	4	30	0.51
Nkamba Lodge 3	ZB006 46	5	19	99	1.05
		10	7	22	0.69
Kala Bay 1	ZB006 50	15	20	102	1.42
Inangu 1	ZB006 58	5	5	9	0.62
HARD					
Cape Kapalwe 2	ZB006 30	5	7	40	0.72
Nkamba Lodge 1	ZB006 38	5	8	18	0.82
Nkamba Lodge 3	ZB006 46	15	6	17	0.73
Kala Bay 1	ZB006 50	5	20	106	1.06
		10	16	110	0.94
Kala Bay 2	ZB006 54	5	18	55	1.13
		15	20	46	1.10
Inangu 1	ZB006 58	10	26	111	1.25
		15	14	61	0.89
Inangu 2	ZB006 62	5	14	109	0.83
		15	5	16	0.65
SHELL					
Nsumbu Bay 1	ZB006 2	5	9	35	0.88
		10	6	38	0.66
		15	5	14	0.58
Nsumbu Bay 3	ZB006 10	15	1	4	0.00
Cape Kabwe 2	ZB006 18	15	3	57	0.25
Cape Kapalwe 1	ZB006 26	15	2	4	0.24

Appendix IX **Night gill nets: total number of species, total number of individuals and Shannon Weiner index for each sampling location at which substrate recorded**

Location	Sample	Total number of species	Total number of individuals	Shannon Weiner Index
		SOFT		
Nsumbu Bay 2	ZB006 8	18	65	1.08
Cape Kabwe 1	ZB006 16	17	113	1.06
Cape Kabwe 2	ZB006 20	16	115	0.96
Cape Nundo	ZB006 24	16	82	1.00
Cape Kapalwe 1	ZB006 28	26	142	1.15
Cape Kapalwe 2	ZB006 32	21	91	1.21
Nkamba Bay	ZB006 36	14	303	0.38
Nkamba Lodge 2	ZB006 44	11	80	0.69
Nkamba Lodge 3	ZB006 48	15	142	0.89
Inangu 2	ZB006 64	15	55	1.03
Cape Kasenga	ZB006 70	9	29	0.66
Kasololo Bay	ZB006 74	11	39	0.92
		HARD		
Kala Bay 1	ZB006 52	16	87	0.65
Kala Bay 2	ZB006 56	23	85	1.19
Inangu 1	ZB006 60	18	188	0.76
		SHELL		
Nsumbu Bay 3	ZB006 12	19	50	1.03