Back to links page

CONTENTS

VOLUME III
Land Use Change and Human Impacts

Back to links page

CONTENTS (cont'd)

VOLUME III
Land Use Change and Human Impacts

LIST OF TABLES

LIST OF FIGURES

Back to links page

CONTENTS (cont'd)

VOLUME III
Land Use Change
and Human Impacts

Back to links page

CONTENTS (cont'd)

VOLUME III
Land Use Change
and Human Impacts

Back to Contents

CHAPTER 1
LAND USE CHANGES ON THE FLOODPLAINS OF THE UPPER ZAMBEZI IN WESTERN ZAMBIA

Mike Bingham

1.1 THE PREHISTORIC BACKGROUND

Before considering the land use changes which have occurred in the Upper Zambezi wetlands during this century, we should look back further in time to consider the prehistory of human settlement on the plains. Although a series of Stone-Age settlements are known from the Victoria Falls (Clark 1970), none has yet been discovered in Western Province. The almost complete absence of surface rocks and the generally acid environment of the wetlands has resulted in a dearth of evidence of early human habitation.

We do not know when the Upper Zambezi was first settled. For the duration of the Pleistocene period, starting about 1.5 million until about 14,000 years ago, the global climate went through numerous oscillations of warm wet periods alternating with dry cold periods. There can be little doubt that the wetlands of central Africa played a crucial role in maintaining humanity during the dry periods. Many of the aquatic plants are edible, and even today the communities of remote parts of Shangombo District subsist on tubers of waterlilies during periods of scarcity. There seems no reason to suppose that there was ever a period since the origin of bipedal pre-hominids four million years ago when the plains were not settled, at least in the drier periods.

The impact of the human settlements is likely to have been minimal until the introduction of iron. Even the introduction of cattle, by the pre-Bantu Hottentots some time during the first millennium, would have had little effect (Ford 1960). There appears to be no good evidence for the inception of the Iron Age in central Africa, but on the Jos Plateau in Nigeria and at Meroe on the middle Nile iron was in use about 2500 years ago (Birmingham 1983).

Yet the Upper Zambezi has little ferricrete or other ores of iron, which would have needed to be imported from Kaoma or Livingstone, and thus there was little prospect of manufacturing iron tools. In the absence of both stone and iron (or any other metal), people would not have had the means to cut trees. This restriction must have kept the communities in a very primitive state of development until effective trade was established.

1.2 GEOMORPHOLOGY

The Kalahari Basin is a vast area covering much of the central axis of the subcontinent from the equator to South Africa's Northwestern Province. The characteristic feature of the basin is the blanket of unconsolidated sand which covers the surface to a depth of up to 300 m. Water percolates freely through the sand leaching the finer silt and clay particles, which are subsequently deposited in the depressions.

In Zambia's Western Province the land surface has an average elevation of 1000 m, with a gradual slope from 1200 m in the north, where the Congo-Zambezi divide runs from west to east, to 900 m in the south where the sand has been eroded away to expose the underlying basalt above the Victoria Falls (Money 1972).

The general slope of the land from north to south determines the direction of flow of the major rivers, which have carved out broad, shallow basins in the sand plateau. The Geological Map of Zambia (Geological Survey [second edition] 1977) shows a single geological fault line running from north to south about 20 km east of the eastern sand scarp of the Bulozi Plain, and a geological boundary on the north side of the Luanginga River. Both these features are hidden by the overlying sand. It is very unlikely that this is the full story, and further drilling or seismic probes can be expected to reveal a complex of faults, as has been found to underlay the Okavango Delta (Cooke 1976).

The basalt underlying the lower southern end of the Upper Zambezi Basin has resisted channelling of the river above the Victoria Falls and has effectively dammed the river, thus giving rise to the vast floodplains of the Zambezi and its tributaries. This system of floodplains is comparable in size and importance to the Bangweulu Swamps, the Kafue Flats and the Okavango Delta.

The rise and fall of the level of the Zambezi River determines the life of the biological communities which inhabit the Bulozi and associated floodplains. Fluctuations in the volume and extent of the annual flood eliminate species which cannot adapt to the extremes of wet and dry imposed on them. Changes in water levels by just a few centimetres can be of great significance to sensitive species.

1.2.1 **Pans and dambos**

Floodplains are not the only wetland features of the Upper Zambezi; dambos are common on the flat plateaux. Those of the Mongu-Kaoma terrace are relatively broad and widely spaced, characteristics determined by the very gradual longitudinal tilt of the land. In the western section of the Mongu-Kaoma terrace dambos are largely replaced by circular pans. Here, the absence of any slope to give direction to flow has resulted in the formation of a series of pans and a chaotic surface drainage pattern. The significance of pans and dambos is that they provide suitable habitat for wetland cultivation, especially of paddy rice.

According to McFarlane (1995), pans and dambos are formed by subsurface leaching followed by subsidence. She describes them as "silicate karst" features, essentially similar to limestone karst in their origin. Leaching and subsidence occurs when the water table is low, and infilling when it rises above the level of the floor of the pan. The deposited material forms an impervious seal enabling the pan to hold water when the seasonal watertable falls to a level below the floor of the pan. During wet periods, when the watertable remains high, the infilling process may eventually fill the pan entirely. Many of these "ghost" pans are clearly visible in aerial photographs. Although they soon become wooded, they are frequently selectively cleared for cassava cultivation.

1.2.2 **Hydrology**

Rainwater percolates freely through the sandy soil of the upland areas down to the watertable. Except for the larger rivers the flow of water is subsurface, draining into the depressions, and emerging at seeps on the wetland margins or further out onto the plains.

The Western Province Land and Water Management Project, which grew out of a rice project, commissioned a study of the pans and dambos of the area (McFarlane 1995). The study was undertaken after the drought of 1994, when the water levels were the lowest on record.

Although rice has been grown on the Bulozi Plain for decades, increasingly it has been grown in pans and dambos, which have the advantage of being subjected to smaller fluctuations of the water levels. This crop is grown in the wetland peat. Peat occurs where groundwater emerges at perennial springs. In normal years pans are recharged from groundwater sources when the watertable rises above the floor of the pan, which is then "topped up". In 1994 there was no topping up because the watertable did not rise sufficiently. The result was that when the rice crop residues were burnt (November), the peat ignited and burnt underground in many cases. Peat accumulated over a period of centuries was destroyed, leaving dust and sand. This was a new experience for the Lozi farmers.

McFarlane takes a pessimistic view that the poor rainfall over recent decades indicates a trend towards aridification of the southern African region. She recommends: (a) better management of the spring water by means of irrigation ditches in order to avoid excessive loss through evaporation of standing water; (b) no burning of crop residues in order to protect the peat; and (c) selective cutting and utilisation of the large trees in the woodlands to reduce transpiration losses, which she estimates to account for "some seventy percent of the rainwater recharging the groundwater through the sandy interfluves".

1.2.3 **The canals**

The Lozi built canals to ease navigation and also in some cases, such as the Sefula River where the channel is kept open, to drain marshy areas and make them more productive. While the larger river channels remain navigable at all times, the small channels, such as the Luanginga, are very long and contorted and tend to become clogged with plant growth.

The effect of channelling a floodplain is to speed up the throughflow since there is far less resistance to flow in the straight and unobstructed canals than in the natural channels. This means that the floodplains are flooded to a lesser extent and for a shorter period. As a result evaporation is significantly reduced. A proposal to channel the Kafue Flats was designed to conserve water for irrigation (Beaumont 1982), but was met by strong objections from environmentalists. The consequences of lower and shorter floods as a result of canal construction would mean a reduction in the flooded area. Since fish breed in shallow water the reduction in the breeding area probably also means a decline in fish production. On the other hand, shortening the flood period would favour crop production and reduce the time that cattle are denied access to the plains. The implication is that the benefit of improved transport provided by the canals is gained at the cost of lower fish yields. A village such as Ndau, which is primarily dependent on fish and accessible by natural waterways, may be expected to have suffered a net loss.

1.2.4 **Land regions**

The landforms of Barotseland have been described by Trapnell and Clothier (1957), Verboom and Brunt (1970) and, most recently, by Jeanes and Baars (1991). Whereas Trapnell and Clothier were primarily concerned with agricultural systems, the other studies were primarily interested in rangeland. Jeanes and Baars divide Western Province into nine land regions, based on the landform patterns. Each region has a distinctive drainage pattern as is revealed by the dominant type of wetland.

1.3 WILDLIFE

The only wildlife regularly to be seen on the Bulozi Plain, apart from the abundance of water birds, are crocodiles, which are an ever-present threat to people and cattle, and the water monitor, *Varanus niloticus*.
Ostrich were last recorded on the west bank in Sesheke District in 1912 (Benson *et al*. 1971). Species distribution maps of larger mammals in Smithers (1966) show many species occurring in the province, more especially in the southern part. These are presumably based on recorded sightings, but sources are not given. According to Geoffrey Zyambo, former Director of the Department of National Parks & Wildlife Service, game was plentiful in the southern part of Shangombo District (formerly Senanga West) as recently as 1969, and he saw giraffe there. He blames the easy access to semi-automatic weapons during the various liberation wars affecting the area for the destruction of the wildlife. Correspondence on wildlife in the Zambian National Archives rarely mentions Barotseland Province (as it was previously called), and when it does it relates only to the teak forest areas in Sesheke District.

Kudu are occasionally seen near the State Ranch in Shangombo District, and calves are reported to have been killed by lion a few years ago. Common duiker are quite frequently seen, but are not always a good sign, since they are favoured by human habitation. Hippo, which are now mostly confined to the rivers bordering the Liuwa Plains National Park, occasionally move onto the Bulozi Plain, mostly as individuals but occasionally in small parties. According to the Wildlife Warden at Mongu, Mr M. Walusiku, when hippo appeared on the Plain, villagers would call in Wildlife Scouts to shoot the animals claiming crop damage, and would then share the meat. In 1995 the Litunga, advised by Mr Walusiku, issued a ban on the unnecessary culling of hippo. However, sightings have remained few and occasional. Hippo prefer to graze short grasses on the higher ground. As these are also the favoured grazing areas of cattle, there can be little doubt that cattle have simply replaced the hippo. Since cattle are kraaled at night when hippo graze, there should be little conflict as long as there is adequate grazing to support both. However, during the flood period all the best pastures are inundated. This is a difficult time for cattle because the quality of fodder on the uplands is very poor. No doubt hippo experience the same problem to an even greater degree since the crop residues are kept for cattle.

1.4 FISH

Fish are the main source of protein to the inhabitants of the Bulozi Plain. Cattle provide milk, or are sold, but are never slaughtered in the villages for meat. Only when an animal dies is it eaten.

On 30 May 1994 a meeting was held in Mongu to discuss nutrition and food security in Western Province, with contributions from the Ministry of Health, and the Departments of Agriculture and Veterinary & Tsetse Control Services (PHC Programme 1994). The introduction begins "Malnutrition under children under 5 years of age is a very serious problem in Zambia, and probably even worse in the Western Province..... The numbers of children with malnutrition are increasing: over the last 5 years the percentage in Western Province has increased from around 25% to over 35%." Since the Fisheries Department was not represented there was no mention of fish, not even in the introduction. This surprising omission may give the impression that malnutrition is a problem throughout the province, whereas those communities which have access to fish are generally well nourished.

1.4.1 **Fish statistics**

Fish catches are reported to have declined over recent decades, but this is not borne out by statistics published by the Department of Fisheries in its annual reports. There is probably more to be learnt from what is missing from these reports than from the figures published. For the years 1973 and 1974 estimates of catches are given as 2000 tonnes and 3500 tonnes, respectively, for the Upper Zambezi. Of the eight main fisheries of the country there are monthly production figures for all but the Upper Zambezi. There appear to be no estimates, either monthly or annual, for earlier years and, unlike the other fisheries, there was no research, extension or development in the Upper Zambezi fishery. The first report based on field assessments appears to be for 1975, when the total catch for the Upper Zambezi was estimated at 5827 tonnes. There are figures for total catches for all subsequent years, ranging from 3301 tonnes in 1983, to 9200 tonnes in 1988. There is no obvious pattern in these figures.

Production figures are collected from five "strata" (geographical areas) in the Province. There are many gaps in these records. For example, in 1995 figures were submitted only in the month of May from the Senanga stratum. No estimates are made to fill these gaps, thus the annual totals are simply the sum of figures submitted and it is impossible to make any comparisons. All we can say is that the figures given are far short of the actual catches. Monthly sales of fresh fish for the Province in 1995 were 33,509 kg in February and 7700 kg in November. The total annual sales of fresh fish were recorded as 179,229 kg, and for dried fish 172,000 kg.

Of the major fisheries the Upper Zambezi is ranked about midway, behind Bangweulu and Mweru waNtipa but ahead of Lake Tanganyika, Mweru, Lukanga, Kariba and the Lower Zambezi, and on a par with Kafue. However, the figures show wide and inexplicable variation from year to year.

Local residents tend to blame itinerant squatters who come to catch fish for sale to traders for the decline in catches. These squatters are not welcomed by the local residents, who accuse them of using fine nets and fishing during the closed season (December to March), which spans the rainy season. In fact, as we were informed by a number of people, the problem is probably not serious because most fish disperse during the rains and are then not easily trapped. Only barbel (*Clarias* spp.) and other bottom-living species can readily be caught at this time. Since the commercially important fish breed in shallow water the extent of the annual flood is a major factor determining yields. Many years between 1980 and 1994 when the rains failed and the flood was low may explain the decline, and in 1999, after two good seasons, fish are again abundant.

However, there have been other developments which might account for the drop in fish yields. The construction of canals for improved navigation results in a rapid throughflow of floodwater, and thus reduces the extent of flooding. This could significantly reduce the extent of the breeding grounds.

1.4.2 **Hippo and fisheries**

Hippo were no doubt once numerous on the Bulozi Plain, but are now reduced to small populations along the rivers bordering the Liuwa Plains National Park. They spend the days in deep pools and come ashore at night to graze. Although the groups always return to the same pool in the mornings, at night they move up and down the rivers, or from lake to lake, before leaving the water to graze. Thus they open up channels which facilitate the flow of water between lakes and the rivers and can be instrumental in bringing about changes in river courses (McCarthy *et al.* 1998). By dunging and urinating in the water hippo also help to maintain the fertility of the fish breeding grounds. Although cattle urinate and dung mostly on dryland, the nutrients become available when these grazing areas are flooded. In the Okavango Delta the fish stocks tend to be highest in the peripheral areas where there are most cattle (Fox 1976). The relative advantages of hippo and cattle are not well understood, and although McCarthy *et al.* (1998) make case a for the specific advantages of hippo, a better understanding of the ecology of both species is needed.

It is possible that the replacement of hippo by cattle on the Bulozi Plain will permanently affect the geomorphological and hydrological situation, and that these changes might adversely affect fish stocks. However, the construction and maintenance of canals for navigation would seem to have much the same effect as the hippo channels.

1.4.3 **The impact of commercial fishing**

Most of the fish caught for sale must be dried since ice is not available. In the past fish were smoked, but this led to deforestation, and fish are now mostly sun-dried. Extensive deforestation is apparent around Mongu, and the introduction of cashew was partly in response to the need for re-afforestation. The woodland areas which have been cut over have partly regenerated as evergreen thicket (c. 2-4 m high), which continues to be harvested.

1.5 THE PEOPLE

More than 20 tribes now occupy Zambia's Western Province, all owing allegiance to the Lozi Litunga. Most of the tribes are dependent upon the Bulozi Plain and its associated wetlands, but use them in different ways. The human population and growth rates of Western Province from the 1990 census are shown in Tables 1.1 and 1.2.

The 1830s saw the northward migration (*mfecane*) of breakaway groups from a number of tribes in South Africa, who preferred migration to submission to the Zulus under Shaka. A group of Sotho, the Kololo, invaded Barotseland and defeated the dominant Luyi. The surviving Luyi rallied under Lewanika, and in 1865 wiped out the Kololo and re-established their dominance.

In spite of the short period of their occupation, the Kololo brought about profound changes. When David Livingstone arrived in Barotseland in 1853, he found a functional kingdom, willing to trade (Holmes 1993). A number of improvements in cattle husbandry were introduced.

The modern siLozi language owes more to siKololo than Luyana, which is now an extinct language, used only for ceremonial occasions. As the only languages taught in the schools are English and siLozi, respectively the national and provincial official languages, many of the other languages are in decline and are likely to be subsumed within the next generation. This process of the merging of tribes is likely to accelerate driven by rapid changes in the economy and of opportunities for trade.

While many Lozis have risen to high positions in government, the professions and in business, far fewer of the other tribes of the Province have prospered and few are met outside their home areas. This advantage can be traced back to the time of independence when all the elite were Lozis, and their benefits have been passed on to the children. One Lozi elder justified the subservient position of the lesser tribes: "They deserted us when we were invaded". The reverse side of the coin is illustrated by the Nyengo, whose men are traditionally employed as labourers by the Zambia Sugar Company estate at Nakambala in Southern Province. The work of harvesting cane is particularly arduous and unpleasant.

Table 1.1 Human population of Western Province (126,386 km^2) in 1990.

	Male	Female	Total
Total	282,053	324,760	606,813
Rural	244,788	283,558	528,346
Urban	37,265	41,202	78,467

Table 1.2 Population density and growth rates in Zambia.

	Density (persons/km^2)			Annual growth rate (%)	
	1969	1980	1990	1969-80	1980-90
Zambia	5.6	7.8	10.3	3.1	3.1
Western Province	3.3	3.9	5.1	1.6	2.8

1.5.1 The money economy

A money economy came about as a result of the introduction to Barotseland of a hut tax, later changed to a poll tax, between 1902 and 1907 (Beerling 1991). The Lozi and other tribes owning cattle were able to sell cattle or milk to pay the tax. Those tribes without cattle had no alternative but for the able-bodied men to seek employment, and most went to the mines of South Africa. The money earned abroad was often in excess of what was needed to pay the taxes and much of the excess was invested in cattle. Beerling points out that it is unlikely that the cattle were imported, since the herds of the Tonga, Ila and other tribes in the region were depleted after the rinderpest epizootic. The only cattle available would be those owned by the indunas, and thus the purchase of such cattle represented a redistribution of wealth within the kingdom. The wealth earned from mine labour and from trade, enabled ordinary people to acquire wealth in the form of cattle. Cattle owners acquired sledges and ploughs which they could hire out. These innovations enabled farmers to grow cash crops for trading.

At that period, immigrants, including a number of enterprising Jews from eastern Europe, set up trading stations in Barotseland. Much of the trade was with the Mbunda and other tribes in Angola. Ivory, beeswax, animal skins and latex for making rubber, were traded for guns, gunpowder, blankets and fabrics and salt.

After the first outbreak of contagious bovine pleuropneumonia in 1915, the enforced restrictions on cattle movement prohibited the export of cattle from Barotseland, and thus destroyed the market for the most valuable commodity. Now many of the cattle owners were obliged to accept jobs on the South African mines. Much as WENELA, the recruiting organisation for the Witwatersrand gold mines, has been criticised, the ban placed on it by the UNIP government resulted in a decline in the economy of the Province, which is reflected in the low human growth rate between the 1969 and 1980 censuses – 1.6% compared with the national average of 3.1% (see Table 1.1).

1.6 AGRICULTURE

Floodplains produce protein in abundance but place severe restrictions on carbohydrate production. Crops are regularly lost through either drought or flooding. The removal of subsidies on maize and fertilizers after 1991 coincided with serious droughts, particularly in 1992 and 1994. In 1999 most of the maize fields were inundated by early floods in February. Relief supplies of maize meal have become a regular feature and the Department of Agriculture encourages all farmers to grow some cassava to tide them over difficult periods. Since the 1970s rice has been introduced and is grown on an increasing scale, mostly as a cash crop. It faces serious competition from imported rice, which is generally preferred (Tembo 1994).

The current emphasis placed by the government on famine relief has created additional hardships to farmers, who now find they cannot sell their cash crops (reported in *The Post*, June 16, 1999). On the other hand, the agriculture minister, Mr Suresh Desai, complains that when there is a good crop farmers have got into the habit of selling their entire crop, confident they they will then qualify for relief handouts (*The Post*, June 21).

1.6.1 **Agricultural systems**

Trapnell and Clothier (1937) described the agricultural systems of the Kalahari Sands of western Zambia under three heads: Northern Kalahari System, Central Kalahari System and Southern Kalahari System. It is the Central system, essentially Kalabo and Mongu Districts, which is most relevant to this study.

The dominant Lozi occupy the central area of the Bulozi Plain and the banks of the Zambezi and some of its tributaries. Most of the smaller tribes are confined to specific geographic areas of floodplain. The Luyi, the dominant tribe before the Kololo invasion of the 1830s, and their associates developed a system of wetland cultivation to grow sorghum, the traditional cereal crop, and more recently maize. This system took advantage of the more fertile soils associated with the seepage zones. Rice has been introduced in recent decades. In the drier districts further south, bulrush millet and maize are grown as dryland crops on the slopes of large mounds partly constructed by termites on relict dunes (*lizulu*).

Around the beginning of the 20th century there was a migration of tribes from the northern Kalahari sands areas of Angola into Zambia, the Mbunda settling mostly on the Zambezi west bank. The Mbunda are primarily cultivators, with cassava and bulrush millet as their staples, and the tribe takes its name from the reddish-brown soils they prefer (Cheke Cultural Writers Association 1994). Since many of the Mbunda still have no cattle they rely mostly on cassava, a crop which is hoe cultivated and grown without manure.

1.6.2 **Cattle population**

The main change in the land use of the Bulozi Plain over the past 80 years has been the steady increase in cattle numbers. Even so, only a part of the plains are grazed and the bottleneck for further expansion is the lack of suitable upland forage to support the cattle during the flood period.

It is often necessary to move the cattle great distances to find suitable grazing. This creates problems because boys are now required to attend school and men are often unwilling to spend several months away from home.

During high floods villages on the Bulozi Plain move to the uplands, together with their cattle. The *Kuomboka* ceremony, when the Litunga moves from Lealui to his flood season court at Limulunga in a large barge, the *Nalikwanda*, is a popular ceremonial event. It usually occur in April, but in dry years Lealui remains accessible throughout the year, and the move is not necessary. Much of the best grazing land at the end of the dry season is not available because it is too far from the nearest water. An example of such an area is the Nyengo Plain in Kalabo District. One of the projects of the LDP was to promote the construction and maintenance of waterholes.

1.6.3 **Cattle and their diseases**

Prior to the Kololo invasion, the Lozi kept cattle but did not attach much value to them and made little use of them (Beerling 1991). Cattle raids were apparently a feature of the times, the northern tribes making raids on the Lozi, and the Lozi in turn raiding the Mashukulumbwe (Ila and Tonga of Southern Province) (Trapnell & Clothier 1937, Holmes 1993). It was the Makololo who introduced improved husbandry, which was continued after their defeat by the Lozis in 1864. They introduced castration to produce work oxen and improve the breeding. Special attention was given to the care of cows and heifers. The Kololo also taught the Lozi the value of cattle for draught power and for the purpose of trade. Payment of brideprices in cattle was another Kololo introduction.

The importance of cattle in the economy of the Province cannot be overstressed. From a figure of 70-72,000 in the early 1920s, following the loss of many cattle to disease, the numbers have increased steadily until the present population of over half a million head. This success is largely attributable to the provision of veterinary services by the Department of Veterinary and Tsetse Control Services (DVTCS).

As Beerling has pointed out, the growth of the cattle population has more or less kept pace with the human population. Since the demise of the traditional herds of Southern and Central provinces as a result of tickborne theileriosis, Western Province is now the main supplier of beef to the Copperbelt towns and Lusaka.

Being surrounded by tsetse-infested country the Bulozi Plain and associated wetlands of the Upper Zambezi are shielded from disease and escaped the rinderpest epizootic in the 1890s, which wiped out the herds of most other tribes of southern and eastern Africa. Yet disease outbreaks do occur, mostly brought in by the illegal movement of cattle.

Contagious Bovine Pleuropneumonia

The main disease threat to cattle, now as in the past, is contagious bovine pleuropneumonia (CBPP). This was introduced to Mossel Bay in South Africa in the 1850s, from where it spread northward. It was eradicated from South Africa, Botswana and Zimbabwe, but has persisted in Angola (Bbalo *et al*. 1998).

The first recorded outbreak of CBPP in Northern Rhodesia occurred in 1915, and was probably introduced in oxen brought from Angola to demarcate the British-Portuguese border. During the next few years a great number of cattle died; the precise number is not known because there are no reliable figures for the population before the outbreak (Beerling 1991). By the 1920s the numbers were reduced to 70-72,000 head. This initial outbreak was not brought under control until 1944. After the 1920s a cordon was maintained along the Angolan border to prevent infected animals coming into Zambia.

There was a second outbreak between 1970 and 1974, resulting from a combination of the dismantling of the cordon as a result of political pressure and an influx of Angolan refugees with their cattle (Bbalo *et al.* 1998). This outbreak was brought under control by mass vaccination, restoration and extension of the cordon, and a tightening of controls.

Sporadic cases of CBPP occurred along the Angolan border after 1974, but evidently did not cross the cordon. (Deaths of cattle are seldom diagnosed or reported.) The most recent CBPP outbreaks occurred in 1997. Herds along the Angolan border were affected, and from these the disease spread to a few villages on the east side of the cordon in Shangombo District. Control measures included the formation of disease risk zones around the outbreak areas, serological testing in high risk zones, vaccination followed by branding, and the slaughter of entire herds in which the disease was confirmed by post-mortem, with compensation paid to the owners.

Herds at risk were vaccinated in April-May 1997, and again in November-December. In the revaccination campaign 155,000 animals were treated, achieving an almost 100% cover. Slightly more than 1000 head were slaughtered (APH Bulletin, January 1998, Bbalo *et al.* 1998). Figures of the numbers slaughtered in the Caprivi and Botswana are far higher, more than 300,000 head in the case of Botswana.

Other Cattle Diseases

Cases of anthrax have also occurred over the past decade. When an animal dies it is eaten, even when anthrax is believed to be the cause of death, and meat in excess of domestic requirement is sold. There is a small though real risk of transmission to those handling the meat, but the demand for meat is so great that it is considered to be a risk worth taking. Other major cattle diseases are haemorrhagic septicaemia and liver fluke. The Province remains free of tick-borne Theileriosis which has ravaged the cattle herds of Southern and Central Provinces.

The middle section of the Upper Zambezi is free of tsetse and trypanosomiasis, which are restricted to the southern districts. A tsetse eradication programme was carried out in Senanga District, intended to attract settlement to reduce the population pressure on the floodplain. The farmers, however, were reluctant to move.

The SADC Livestock Sector has recently started to issue a monthly Animal Diseases Bulletin reporting cases of animal diseases in SADC countries. Several of the countries, including Zambia, do not have monitoring programmes for diseases and (with rare exceptions) data are generally not available.

1.6.4 **Cattle marketing**

The marketing of cattle is often problematic in that farmers frequently need cash at times when the demand fails to meet the supply. The large abattoir at Mongu came up for privatisation a few years ago. While it was run by the parastatal Cold Storage Board, it was grossly underutilised because traders from Lusaka and the Copperbelt offered better prices for animals which they transported live. The farmers, supported by donor funding, put in a bid for the abattoir but were unable to meet the maintenance costs. Kembe Estates entered into a partnership agreement with the farmers, and the manager tried to cut out the middlemen by buying directly from the farmers. But the power of the middlemen was underestimated, and Kembe Estates was forced out. Another Lusaka-based company, Zambeef, is now trying to come to an arrangement (A. de Kwaasteniet, pers. comm.).

A major constraint to the sale of cattle is the total ban on exporting live animals unless they are slaughtered within 24 hours of arrival at the destinations. Were this not the case commercial farmers along the line of rail would purchase animals for fattening in their feedlots, and thus could hold them until the beef market improves.

After the Tonga of Southern Province had lost most of their cattle to theileriosis, pressure was put on the Department of Agriculture to allow breeding stock to be purchased from Western Province. The Department would not yield. In April 1997 Contagious Bovine Pleuropneumonia (CBPP) was confirmed at Sinjembela on the Angolan border. As a result a complete ban was placed on the exportation of live animals. The current depressed state of the market, the result of a serious decline in the living standards of most Zambians following the implementation of structural adjustments in the national economy, has seriously affected the beef industry, and prices have remained static for the past decade. In retrospect a valuable opportunity to export breeding stock to help restore the Ila, Tonga and Lenje herds was lost. The risk at the time was minimal.

In the long run, if the Western Province cattle owners can avoid the disastrous losses suffered by other parts of the region, they are bound to benefit. The rangeland study of Jeanes and Baars (1991) estimates the carrying capacity of the Province at one million head of cattle, double the present number.

1.6.5 **Small livestock**

Small livestock include pigs, goats and sheep, as well as chickens, muscovy ducks, guineafowl and pigeons. Although they play an important role in the nutrition of rural families, they do not yet occur in sufficient numbers to have a serious impact on the vegetation.

1.6.6 **Crops**

Maize, sweet potatoes and (especially) cassava, are relatively recent introductions. The traditional cereals are sorghum, finger millet (*Eleusine corocana*) and bulrush millet (*Pennisetum glaucum*). New cultivars have replaced older ones.

Both the wetlands and drylands are cultivated. Village gardens with mixed cropping are to be found at the plain edge. Cash crops include maize, rice, sweet potatoes, cassava, sugarcane, mangos and cashew. The best time for planting wetland maize is July, after the recession of the flood. But after heavy rains the floods might not recede before September, and then the crops are likely to be drowned by rising flood water in February. In February 1999 virtually all the best maize was lost.

Early attempts to grow rice on the Bulozi Plain were frustrated by the unpredictable flooding. The Land and Water Management Project (LWMP) was started in January 1987 with the aim to improve water management (Anon. 1993). Although the project was not specifically focussed on rice, it was inevitable that a major concern of the project was to identify suitable habitats for rice. Dambos, especially the Lui, and pans, where seasonal flooding is relatively shallow, were identified as having more suitable habitat than the major floodplains.

The success of any crop on Kalahari sand is dependent on the presence of humus to hold the soluble nutrients. On the uplands the fertility of the soil lasts only as long as the humus, which, in cleared woodland is no more than two to three years. Traditionally farmers dung their village gardens by moving the kraals every few days until the whole field is dunged over a period of a year. Farmers also use chemical fertilizers, when they can get them. Since the ideal planting time for maize is in June and July (to be harvested before the start of the rains in November) and the national distribution of fertilizer is planned for planting in November, the Lozi farmers cannot find it when they need it. Since the removal of subsidies few farmers have been able to afford fertilizers, and food shortages have occurred, requiring the import of relief supplies.

The French Protestant missionary Francois Coillard, who establish one of the first Christian missions in the Province, is believed to have introduced the first plough to Zambia. Ploughing is used mostly for cash crops, especially rice and maize, while cassava and sweet potato fields are mostly prepared by hoe cultivation.

Cashew was introduced as a cash crop and for reafforestation in the early 1980s by a private company with funding from the Commonwealth Development Corporation. Yields on the commercial estate at Mongu and by the village outgrowers did not reach the levels obtained in the trials. Although the estate closed down and the CDC withdrew their support, the Cashew Company maintains its factory in Mongu, and is supplied by farmers, many of whom have increased their orchards. Mangos grow well along the seeps at the plain edge, and trucks returning to Lusaka during the season are laden with fruit.

1.6.7 **Genetic resources of crops**

Mention has been made earlier in this report of the response of farmers to the removal of subsidies and of famine relief. The effect of these actions on the genetic resources needs to be considered.

When hybrid maize seed and chemical fertilizers were available at subsidised prices, before the implementation of economic structural adjustments in the 1990s, there was a strong incentive for farmers to neglect their traditional varieties. Nevertheless most farmers did save seed and grew the traditional varieties for home consumption, and the hybrids cultivars for sale.

In 1992 the rains failed in January and February, the two critical months, and the maize crop failed over most of the country. 1994 saw another disastrous drought. During these and earlier droughts many farmers lost their traditional varieties, and then became dependent on hybrid seed. Hybrid maize is high yielding, but only with fertilization. When subsidies on fertilizers were removed, and the parastatal company which supplied them (NAMBoard) was privatised, farmers could no longer afford fertilizers, which were, in any case, frequently not available in remote areas.

The loss of traditional crop lines may have serious consequences for the farmers. As with much of modern technology, hybrid maize creates a dependency on supply. When the supply breaks down the farmers have nothing to fall back on. In the case of the farmers of Western Province, they have been forced to sell the cattle at unfavourable prices while flooding the national market.

1.7 VEGETATION AND PLANTS

One of the most striking aspects of the Bulozi Floodplain vegetation is the large number of species described by Linnaeus and other pioneers of plant taxonomy, indicating widespread distribution. These are tropical wetland plants, including many weeds, which have been dispersed either by water birds or by man together with his crops. Those weeds of known origin probably all come from the New World. Earlier introductions, mostly from the Middle or Far East, arrived before the first botanical collections and recordings were made, and thus their origins are obscure.

Arable weeds evolved in parallel with crops, and thus we can be sure that they originated where agriculture was first practised – in China, India, Mesopotamia, the Mediterranean area and the Americas. Australia, which had no cultivators before European settlement, has given us no edible vegetable crops and no arable weeds.

The Chairman of the Ndau Area Development Coordinating Committee, Mr Inambao Ilubala, reported that in recent years there has been a decline in *Trapa natans* (**njefu**), a rooted aquatic plant with floating leaves which grows in permanent water at the margins of the lagoons. The nuts of this plant, which mature in April, are one of the more important foods. The decline, according to Mr Ilubala, has been associated with the appearance of *Salvinia molesta* (Kariba weed or **mucimbami**). Previously Kariba weed occurred only at a few areas, e.g. at Lukona.

This replacement raises the suspicion of pollution favouring a weedy plant species at the expense of one which is less competitive in a nutrient-rich environment. The occurrence of kariba weed at Lukona, for example, may well be the consequence of building a secondary boarding school there, coupled with the fact that the Simunyange depression has no through-flow to flush out the accumulated nutrients.

1.7.1 **Endemic and near-endemic plant species**

The large component of pan-tropical plant species of the Barotseland wetland flora suggests that a process of replacement of the "original" flora has taken place. However, since wetland areas attract large numbers of migrating birds and mammals, it is reasonable to assume that the process of invasion is continuous.

It must be understood here that many of the specimens collected from the study area have not yet been identified, and recent revisions have revealed earlier misidentifications. It is likely therefore that more endemic species will be found when further taxonomic revision is carried out.

Genus *Emiliella* (Family Asteraceae): Torré erected the new genus *Emiliella* for the new species *E. drummondii*. Two varieties were described, both based on specimens collected by Drummond & Cookson on their expedition of November 1959 (var. *drummondii* Torre, Drummond & Cookson #6270; var. *moxicoensis* Torre, Drummond & Cookson #6488). The species occurs in the permanent wet seeps at the floodplain margins.

Gloriosa sessiliflora Nordal & Bingham (Colchicaceae): A new species of *Gloriosa* was discovered by Bingham and Luwiika (#10752) on a termite mound on the Bulozi Plain not far from Lealui in December 1995. The flowers are unique in the genus, being sessile (stalkless). The mound on which the plant was found is too small for human habitation or cultivation, although it is no doubt grazed regularly. When visited in February 1999, the base of the mound was flooded and most of the

Gloriosas were inundated. The plants were dying off at the time, which is normal for the genus, and the capsules were ripening.

During the field study in February 1999 substantial populations of the species were found on a high sand-bank of the Luanginga River northwest of Kalabo. This population was associated with riverine forest and most of the plants were growing under the trees, suggesting that the forest is an important habitat of the species.

Crinum sp. (Amaryllidaceae): Inger Nordal has recently informed the author that a *Crinum* species (family Amaryllidaceae), also collected by Bingham and Luwiika (#10703) in December 1995, is undescribed. This large herb has flowering stems about 60 cm high with umbels of large white flowers. It is fairly common and widespread both on the Bulozi Plain and on the floodplain of the Luanginga, occupying the higher levels.

Legumes: Leguminous plants (Family Fabaceae or Leguminosae) are next in importance to the grasses in grazing areas. The ability of the legumes to fix atmospheric nitrogen, making nitrogenous compounds available to other plants, gives them a special place in the ecology and economics of pastoral communities.

The Upper Zambezi wetlands are not especially rich in legumes, either in species or in biomass. Two reasons for this need to be considered, firstly the limitation imposed by the availability of nutrients, particularly phosphate, and secondly the likelihood of their elimination by grazing. The retention of nutrients, both soluble and in the form of fine particles subjected to leaching, is precarious in free-draining soils, and is highly dependent on the retention of a humus-rich surface layer. Nutrients which are leached from the upland soils eventually emerge in the seeps along the wetland margins. Yet the water in the channels of the Zambezi and its tributaries has virtually no nutrients (Huizing, pers.comm.). Evidently, all nutrients fed into the wetlands are taken up and utilised. Since large numbers of cattle are exported from the Province, and there is little indication of nutrient deficiency, the natural input from groundwater seeps appears to be sufficient to meet cattle requirements. These observations highlight the critical importance of the groundwater seeps, not only to the cattle, but to the entire biological system of the wetlands.

The second suggestion for the scarcity of legumes is that they have been eliminated by the cattle. In the absence of a monitoring programme this hypothesis is difficult to test. There is, however, circumstantial evidence. During the few days the consultant was at Ndau, a herd of 75 cattle spent a night at the school prior to being driven across the Bulozi Plain on the following day for sale in Mongu. Normally this occupation of the school premises is not allowed, but in this instance the community leaders tried to stop the movement across the plain because of the dangers to which the cattle would be exposed in view of the early flood.

In the late afternoon, before the animals arrived, a quick survey revealed a rich population of an annual herbaceous legume (*Crotalaria* sp., Bingham & Luwiika #11843) in the grassy clearing. By the following morning not one remained. The plants had produced no seed, and the entire crop was lost. This need happen only for a few seasons to eliminate the species from the area.

1.7.2 **Weeds**

A study of the wetland weeds of Western Province is yet to be undertaken. They are mostly indigenous grasses and sedges. Exotics include *Ageratum conyzoides* (Asteraceae) and *Datura* *stramonium* (Solanaceae), both annuals of New World origin. **Sitongwani** is the Lozi name for the Thorn Apple, *Datura stramonium*, elsewhere a common weed of cultivation. At Ndau it is regarded as an indicator of soil fertility. The genus is also North American.

Lantana camara is well established along the plain edge and on mounds on the Saana Terrace and elsewhere. It is frequently used as a hedge. Mango and guava invade the plain edges and swamp forests.

1.8 CONCLUSIONS

The major land use changes over the 20th century in the Upper Zambezi wetlands are listed below. Unfortunately, tangible evidence of the effect of these impacts on biodiversity is either not available or difficult to identify. For example, there appears to be only one airphoto survey covering the whole area, so historical comparison of airphotos is not possible.

1. The principal change has been the considerable increase in the population of cattle, now more than 500,000 head, especially since the introduction on effective veterinary services in the 1920s. While the traditional herds of Central and Southern Provinces of Zambia, and of the Caprivi and Botswana, have suffered catastrophic reduction through disease or disease control measures, the Western Province herd has lost relatively few animals. It is likely that the herbaceous legumes of both the wetlands and uplands have declined as a result of increased grazing pressure from cattle.

2. Although the human population of the province has increased more slowly than the national average, there has been an influx of people and local migration as a result of the civil wars in neighbouring Zimbabwe, Namibia and Angola, and from the illegal cross-border trade in diamonds and arms.

3. Much of the west bank is now depleted of wildlife, except in the National Parks. The Bulozi floodplain may have lost hippo, but there is no evidence that it supported significant populations of wildlife since it was first visited by European explorers in the last century.

4. The construction of canals to bypass the convoluted river channels for easier navigation. This is likely to have affected vegetation of the floodplains, and more especially of the riverbanks. Since the main flow of smaller rivers is now through the canals, flow in the river channels is sluggish and channels tend to be overgrown and choked with weedy vegetation.

5. The intensive cultivation of the most fertile of the wetland soils with maize, rice, etc., exacerbated by the burning of crop residues. Paddy rice was introduced as a cash crop in the 1970s. Cultivation of peaty soils is of particular concern, especially the destruction of peat in dry years by the burning of crop residues. However, such areas have been cultivated and grazed for so long that it is difficult to say what was there before.

6. Deforestation of the uplands resulting in changes in the hydrology on the floodplain below. Logging is still an important industry in the Province, with significant volumes of **mulombwa** or mukwa (*Pterocarpus angolensis*) and **muzauli** or rosewood (*Guibourtia coleosperma*) being exported to South Africa.

Another conclusion from this study is that the importance of fish in the diet of the the people of the province does not appear to have been given fair recognition. It seems likely that the availability of fish has to a large degree determined the well-being of the human population. This is especially true of the under five years of age group, which is the commonly used criterion of well-being of the community.

1.9. ACKNOWLEDGEMENTS

During the two weeks spent in the project area in February 1999, the consultant and his colleagues were greatly assisted by the staff of the IUCN Zambezi Basin Wetlands Project. We extend our thanks to Dora Ndhlovu Kamweneshe, Nyambe Nyambe, driver Eric Nawa and coxswain Masialeti. Gerry Hogg made himself and his Landrover available for our use. Accommodation during the February trip was generously provided by Francois Flanagan in Mongu, and by Ndau School. Mr Anderson Mazoka graciously provided space on a chartered flight when the Eastern Air flight from Mongu was overbooked. Shoprite and Freshmark assisted with the transport of equipment back to Lusaka.

Over the years that the consultant has visited Barotseland he has benefited from the knowledge of many people, or has been assisted in other ways. It would be impossible to name them all. Numerous informants gave valuable information on cultural practices, and on plants and their uses, while Ad Huizing provided information on the hydrology of the Kalahari sands. Officers in various government departments have provided useful information on numerous occasions.

RDP Livestock Services provided funds for several visits to the Province, as well as providing the use of offices and services. Many of the studies consulted were commissioned by RDP with funding from the Netherlands Government. Transport by 4x4 and by boat has been provided on various visits by the Livestock Development Project and IUCN.

Charles Peters, who accompanied the consultant during his visit to the Bulozi Plain in February, provided useful insights into prehistory and human ecology. Benny Luwiika assisted with the collection and drying of plant material.

1.10 REFERENCES

Anon. (1993). Land and Water Management Project Extension Proposal, Mongu, August 1993.

APH Bulletin (January 1998). Quarterly Bulletin of the Animal Production and Health Sub-programme of the Ministry of Agriculture, Food and Fisheries, Vol. 1, No. 2.

Bbalo, G., Flanagan, F.O., Mangani, P.M. & Muwowo, G.W. (1998). An outbreak of contagious bovine pleuropneumonia in Western Province, Zambia, and the measures used to control it. Proceedings of the ARC-Onderstepoort OIE International Congress, August 1998. Onderstepoort Veterinary Institute, South Africa.

Beaumont, A.N. (1982). Developing the crop potential of the Kafue Flats. In: Proceedings of the National Seminar on Environment and Change: the Consequences of Hydroelectric Power Development on the Utilization of the Kafue Flats, Lusaka, April 1978 (edited by G.W. Howard & G.J.Williams). Kafue Basin Research Committee, University of Zambia, Lusaka.

Beerling, M-L.E.J. (1991). The advantage of having cattle. Distribution of cattle and access to benefits in the Western Province of Zambia. Livestock Development Project, Dept. of Veterinary and Tsetse Control Services, Mongu.

Benson, C.W., Brooke, R.K., Dowsett, R.J. & Irwin, M.P.S. (1971). *The Birds of Zambia*. Collins, London.

Birmingham, D. (1983). Society and Economy before AD 1400. In: *History of Central Africa* (edited by D. Birmingham & P.M. Martin). Longmans.

Central Statistics Office (1995). Demographic Projections, 1990-2015. 1990 Census of Population, Housing and Agriculture. CSO, Lusaka.

Cheke Cultural Writers Association (1994). *The History and Cultural Life of the Mbunda Speaking Peoples*. Lusaka.

Clark, J.D. (1970). The Prehistory of Africa. London.

Cooke, H.J. (1976). The palaeogeography of the Middle Kalahari of northern Botswana and adjacent areas. In: *Proceedings of the Symposium on the Okavango Delta and its Future Utilisation*, August 1976, pp. 21-28. Botswana Society, Gaborone.

Ford, J. (1960). The influence of tsetse flies on the distribution of African cattle. Proceedings of the First Federal Science Congress, Salisbury, Southern Rhodesia, May 1960, pp. 357-365.

Fox, P.J. (1976). Preliminary observations on fish communities of the Okavango Delta. In: *Proceedings of the Symposium on the Okavango Delta and its Future Utilisation*, 30 August-2 September 1976, pp.125-130. Botswana Society, Gaborone.

Geological Survey Department (1981). Geological Map of Zambia, 1:1,000,000. Geological Survey, Lusaka.

Heemskerk, W. (1995). Vulnerability Assessment, Western Province. Farming Systems Research Team, Department of Agriculture, Mongu, Western Province.

Holmes, T. (1993). *Journey to Livingstone: Exploration of an imperial myth*. Canongate Press, Edinburgh.

Jeanes, K.W. & Baars, R.M.T. (1991). The Vegetation Ecology and Rangeland Resources, Western Province, Zambia. Volume 1: Main Report. RDP Livestock Services, Livestock Development Project, Dept. of Veterinary and Tsetse Control Services, Mongu.

Kamuhuza, A.K. & Mtongo, S.C. (1999). Report on the forest component for the systems assessment of the Ndau pilot area. IUCN Barotse Sub-project, Mongu.

McCarthy, T.S., Ellery, W.N. & Bloem, A. (1998). Some observations on the geomorphological impact of hippopotamus (*Hippopotamus amphibius* L.) in the Okavango Delta, Botswana. *African Journal of Ecology* **36**: 44-56.

McFarlane, M.J. (1995). Pans and dambos of Western Province, Zambia. A preliminary consideration of their geomorphology/hydrogeology. Unpublished report. Land and Water Management Project, Dept. of Agriculture, Mongu.

Money, N.J. (1972). An outline of the geology of Western Zambia. *Records of the Geological Survey* **12**: 103-123.

Peters, D.U. (1960). Land usage in Barotseland. Communications of the Rhodes-Livingstone Institute No. 191-60. Livingstone.

PHC Programme, Western Province (1994). Nutrition and food security in Western Province. Proceedings of a meeting, 30 May 1994, Mongu. Contributions from Ministry of Health, Department of Agriculture and Department of Veterinary Services.

SADC Livestock Sector. Monthly Animal Diseases Bulletin. Compiled by the Animal Health Surveillance & Development Unit, Directorate of Veterinary Services, Namibia.

Smithers, R.H.N. (1966). *The Mammals of Rhodesia, Zambia and Malawi*. Collins, London.

Tembo, G. (1994). Agricultural Marketing Survey. An analysis of the performance of agricultural marketing liberalisation in Western Province. Farming Systems Research Team, Department of Agriculture, Mongu.

Trapnell, C.G. & Clothier, J.N. (1937). The Soils, Vegetation and Traditional Agriculture of North-Western Rhodesia. Dept. of Agriculture. Reprinted in 1996 as "The Soils, Vegetation and Traditional Agriculture of Zambia. Vol. 1, Central and Western Zambia. (Ecological Survey 1932-1936)". Redcliffe Press, Bristol.

Verboom, W.C. & Brunt, M.A. (1970). An ecological survey of Western Province, Zambia, with special reference to the fodder resources. ODA Land Resources Study No.8. ODA, London.

Personal communication:

Nick Clinch (Executive Officer), Francois Flanagan and Hem Thakersi (RDP Livestock Services); Ad Huizing (Land & Water Management Project); Nyambe Nyambe (IUCN Mongu Office); Charles Peters (Anthropologist, University of Georgia, USA); Stephen Kalembwe Sakubilo (Ndau resident); M. Walusiku (Wildlife Warden, Western Province Command); Geoffrey Zyambo (former Director Department of National Parks & Wildlife Service).

Back to Contents

CHAPTER 1 : APPENDIX 1
NDAU SCHOOL PILOT AREA — A CASE STUDY

Mike Bingham

1. INTRODUCTION

IUCN-ROSA, under its Ecosystem Programme, is using the Ndau School area (see Figure 1.1) as a pilot area for community based natural resource monitoring. Therefore, it was specifically requested that a detailed assessment be made of both biodiversity and land use aspects. Also requested was a series of four transects along which plant cover and biodiversity could be assessed and monitored. These are described in Appendix 1.2.

Air photos of the area were obtained, but it appeared at the time that the only survey covering the Ndau area in the airphoto library of the Survey Department, Lusaka, was the 1:80,000 series from 1980. It was therefore not possible to do a comparative study as initially planned. However, subsequently other airphotos have been found to be available. The results of an analysis of these were too late to be incorporated into this report.

2. DESCRIPTION OF THE NDAU AREA

Ndau Primary School (15E25'S, 22E58'E) is situated on the west bank of the Bulozi Plain some 25 km south west of Mongu on the eastern edge of a low sand bar, the Kalamba Ridge, which is separated from the mainland of the west bank by a broad strip of grassland. This strip of grassland, the Simunyange Plain, may have been the floodplain of the Luanginga River before it broke through at Kalabo to form a new channel to the Zambezi. Alternatively, it has been suggested that the Kalamba Ridge is a sandbar thrown up by the Luanginga flowing down its east side (Charles Peters, pers. comm.).

The soil of the Kalamba Ridge is structureless white sand, and the vegetation consists of degraded Kalahari woodland with a patchy ground cover of a perennial grass (*Digitaria* sp.). The main difference from the uplands is the much shallower soil owing to the low relief of the ridge. Termite mounds and bush groups are absent, indicating a very low clay fraction extending down to the watertable. The absence of spiny shrubs in the woodland is an indication of soil of a low base status. Plants growing on such nutrient-poor soils are themselves poor in nutrients, and thus unpalatable to herbivores. Since they are unpalatable they do not need spines for protection. Cassava gardens have been cleared along the edge of the ridge, but appear to have been abandoned (Kamuhuza & Mtongo 1999).

The Simunyange Plain is a grassland with little relief, not fed by any rivers. There are gravel pits used during the construction of Lukona Secondary School. Some of the higher islands in the plain have village settlements.

The focus of the Ndau community is the primary school and rural health centre; the community is dispersed along the edge of the Kalamba Ridge and on islands of the Bulozi Plain. Ndau occupies a central position in Lumbo Ward, in the southwestern corner of Mongu District. The area selected for special attention in this study, the Ndau Pilot Area, is the southern half of the ward, but also includes the adjacent area of the Simunyange Plain, in Kalabo District.

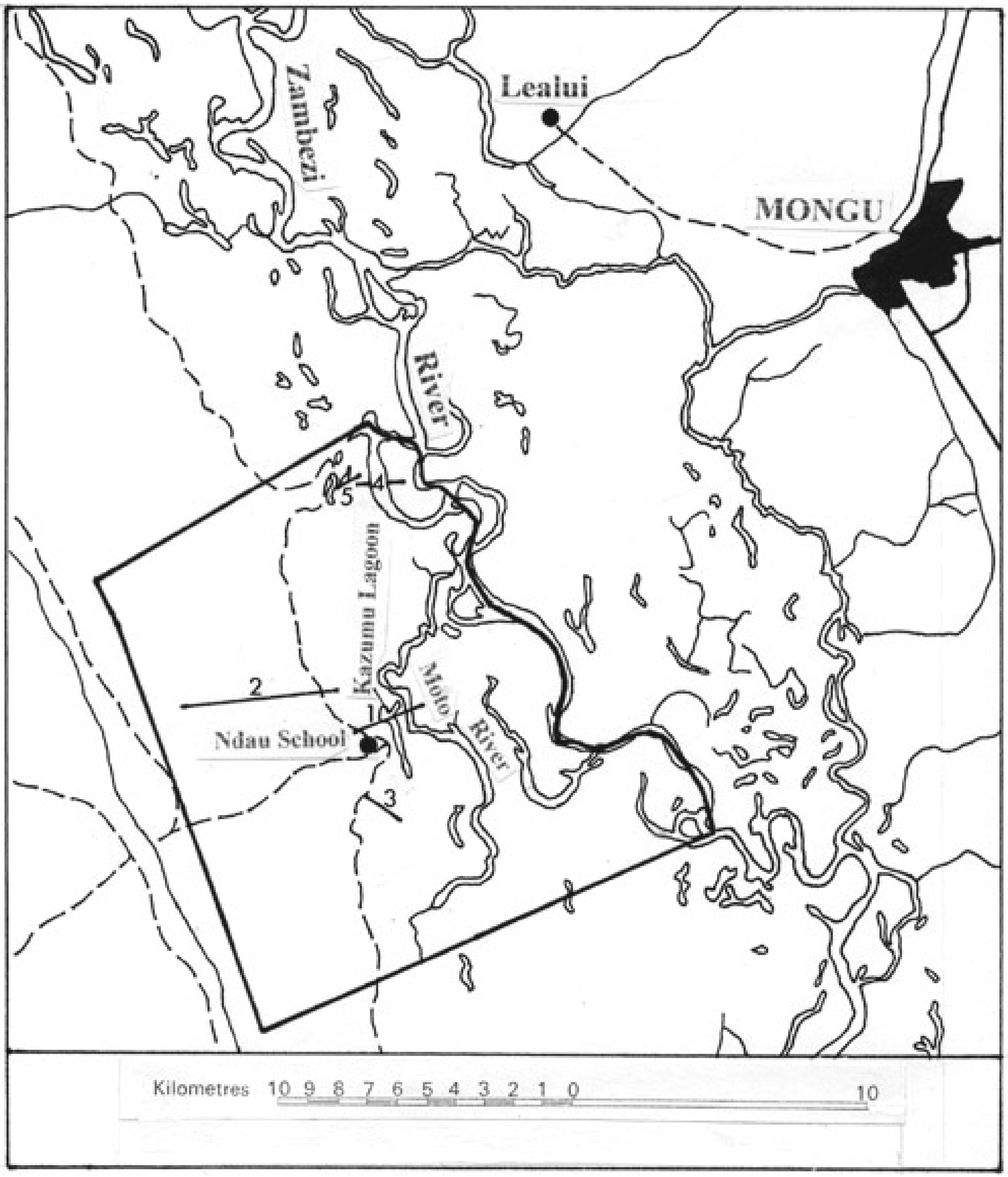
3. THE HISTORY OF NDAU VILLAGE

The Lozi (also referred to as the Lui or Luyi, or in the adjectival form, Luyana, the name by which they were known prior to the Kololo invasion of the 1830s) have been settled on the Bulozi Plain for many centuries with cattle. According to our source of information on Ndau, Mr Stephen Kalembwe Sakubilo, 60 years old and a life-long resident, the first Lozi kings used Ndau as their flood-season court, probably some time in the 15th century, and the village has been settled since that time.

4. LAND USE CHANGES EVIDENT AT NDAU

Life is dominated by the flooding regime of the Zambezi and its tributaries. The two main cash crops are maize and rice. Maize is grown on mounds or grown on elevated areas on the Bulozi Plain. The soils at Ndau

Figure 1.1 Ndau School area used as pilot area for IUCN community based natural resource monitoring.



village are particularly poor, lack springs and peat, and are used only for village gardens and small maize fields. Agricultural production at Ndau is unlikely to change much. The upland soils of the Kalamba Ridge are too poor even for cassava, and the wetland areas are at the mercy of the river. The Simunyange Plain was considered by the LWMP as a potential rice growing area, but found to be sub-optimal (Anon. 1993). The water levels in the plain were found to be purely rainfall dependant, and therefore unpredictable.

Cattle rearing constitutes the main farming activity of Ndau, as for most of the wetlands of the Upper Zambezi, and the life of the farming community revolves around the cattle and their needs. Although Ndau has not been affected by the recent outbreaks of contagious bovine pleuropneumonia, cattle purchased on the west bank for slaughter are driven across the plain, many passing through the village and putting the local animals at risk. All stock movement requires a permit issued by a livestock officer after inspection or inoculation.

Prospects for any breakthrough in agricultural technology to benefit the area seem remote. Yet the positive spirit of the community offers the prospect of improved natural resource management, which could lead to increased and sustainable production of the traditional resources – pasture, fish and forest products (including wetland plants for various uses). Given the poor prospects of increased crop production the community's major concerns lie with the conservation and management of the available resources. If the farmers appear to be conservative, and lacking in innovation, they are probably right in their judgement. The overall impression is that new technology and services have helped the community in some basic essentials, for example, English is widely spoken. But they have also contributed to the out-migration of young people.

Some of the Ndau community have started producing mukenge basketwork, a craft learnt from the Mbunda. This basketwork, which is dense and has a tightly woven texture, is made from the roots of a tree, *Combretum zeyheri* (**mukenge** in siLozi or **mujalu** in siMbunda), which is common in the Kalahari woodlands and is decorated with dyes made from local materials. In the space of the past decade mukenge crafts have become one of the most popular in the region.

5. HUMAN HEALTH AND DISEASE

In a recent survey conducted by the IUCN office in Mongu, improved health services were revealed to be of major concern (N. Nyambe, pers. comm.). The recent building of a Primary Heath Centre (PHC) manned by village health volunteers, has gone some way to improve the situation. The PHCs have replaced the clinics, which could never be funded sufficiently to perform satisfactorily. The new system uses PHCs together with Health Posts, manned by Prevalent Health Workers, these serving as first referral centres.

The domestic water supply is a source of chronic infection. Villages on the high banks have access to deep water resources, in deep wells or boreholes. At Ndau the watertable is close to the surface and during high floods the wells are submerged. The Department of Water Affairs has a programme of disinfecting the wells after floods, but erratic funding has prevented the Department from maintaining this programme.

A vulnerability assessment of the Province compiled by the Farming Systems Research Team (Heemskerk 1995) assessed each of the Districts by Wards. Lumbo Ward was classed as the least vulnerable out of four vulnerability classes. Like other wards of Mongu and Kalabo Districts, Lumbo benefits from the early *sitapa* maize harvest. Taking an average for the Province, malnutrition was found to peak in April, with those areas lacking suitable habitats for early maize most affected. This assessment was carried out over a two-year period under the National Nutrition Surveillance Programme. Such a short period can only give an approximate picture of the real situation, but it provides a baseline against which subsequent assessments can be compared.

What is disappointing about these assessments is that they have very little to say about the importance of fish in the diet. The communities of the floodplains not only have their sitapa gardens for growing early maize, they also have access to the best fishing grounds. There appears to be a serious lack of data on fish production and consumption at the village level, and it is likely that the low levels of malnutrition found in Mongu and Kalabo can be related to better access to fish there.

6. THE FISHING INDUSTRY

Itinerant fishermen setting up temporary camps are considered a threat to the fishing industry. Since they are not accepted or welcomed by the community they do not feel obliged to respect the bylaws regulating fishing practices. Unless the community takes a firm stand they could well lose control of their fishing resources to unscrupulous commercial operators.

7. EXPLOITATION OF THE FOREST RESOURCES

In 1948-1949 a commercial sawmill operated in the area, exploiting mostly **mukwa** (*Pterocarpus angolensis*). According to our informant, Mr Kalembwe, large specimens of **mwande** (*Afzelia quanzensis*) were eliminated by the high floods of the late 1950s and early 1960s, and these have not recovered. The **mukusi** (*Baikiaea plurijuga*) in the woodland are small and stunted, this species requiring deep soils for optimal growth. **Mungongo** (*Schinziophyton rautanenii*) is still abundant although it has been heavily exploited, all mature trees being coppiced. There are no trees left which are large enough for canoes. Mungongo is favoured since the wood is of low density. This tree thrives in the woodland, and there is good replacement. However, unless coppicing can be restricted there is little chance of canoe-sized boles being developed.

A very large canoe, currently in use, was made from one of the eucalypts planted in the village in the 1960s. Trapnell (1937) reports that gum trees are a feature of the Lozi villages, with *Eucalyptus rostrata* planted on the Plain, and *E. tereticornis*, *E. maculata* and other species planted elsewhere. These trees are generally not used, except by crows, but appear to serve as landmarks. At Ndau School trees which had died were simply left standing.

The Ndau School Conservation Club was formed in 1997. The club patron, Mr Crispen Libeka, a teacher at the school, showed us tree seedlings planted around the school grounds. They included mwande (*Afzelia quanzensis*) and muzauli (*Guibourtia coleosperma*) grown from seed, and mungongo (*Schinziophyton rautanenii*) transplanted from the nearby woodland, in addition to exotic flamboyants and jacarandas.

8. CONCLUSIONS

Lacking any special resources or strategic advantages, Ndau village has not seen any major land use change for the past 50 years. The most significant change in the Province is the increase in the number of cattle from about 70,000 in the early 1920s to the present population of over half a million. This success is largely attributable to the provision of veterinary services by the Department of Veterinary and Tsetse Control Services, which received strong support from the Netherlands Government during the 1980s and 1990s. No doubt there has been a significant increase in the Ndau cattle population during this period, and through the ownership of cattle, the farmers are relatively well off by national standards. The Kalamba ridge provides flood-season grazing.

Although there has been a decline in fish catches in recent decades, the reason for this is uncertain. Interventions, including the destruction of hippo, the construction of navigable canals or the use of illegal fishing methods, are considered. But the most likely cause of decline appears to be the series of low floods following poor rainy seasons.

Although the crop potential of Ndau is limited, the woodland of the Kalamba Ridge is an important source of timber and fuelwood. Exploitation and exceptional floods have depleted the number of trees large enough for the construction of dugout canoes or sawn planks. The local community is aware of the need for good management to restore the productivity of this valuable resource.

Back to Contents

CHAPTER 1 : APPENDIX 2
VEGETATION RECORDING IN THE NDAU SCHOOL AREA

Evaristo Chileshe

1. INTRODUCTION

The establishment of transects in the Ndau School area, and the recording of vegetation composition and structure along them, forms part of the Zambezi Basin Wetlands Biodiversity Project being implemented by the Biodiversity Foundation for Africa (BFA) and the Zambezi Society for IUCN ROSA. This vegetation monitoring is part of a longer-term IUCN study on community-based conservation monitoring and evaluation, for which the Ndau School area is a study site. It is proposed that the transects are revisited in future years to detect any change.

Effective resource management requires a knowledge of the relationship between present land productivity and its long-term potential, and data on vegetation composition and structure form an important part of this. Since vegetation integrates all environmental factors acting on a given site, knowledge on its type may be used to make inferences about the prevailing environmental patterns (Herlocker 1979).

Plants are also an important resource as they stabilize soil, provide forage for livestock and ungulates, and are also a source of fuelwood. The abundance and nutritive value of palatable grass species, for example, strongly influences animal performance. But for conservation purposes, grass species composition is usually of greater concern.

Vegetation is often impoverished by the impact of various land use activities. The process of change in these ecosystems usually leads to reduced productivity of desirable plants, and alterations in the biomass and diversity of life forms. Also, as indicated by Mentis (1984), conservation of genetic diversity can only be achieved by ensuring that no plant and animal species become extinct.

2. OBJECTIVES

There are two main objectives of the present study:

a) to provide an indication of past changes in species composition along the various environment gradients,
b) to provide baseline for subsequent monitoring of change.

3. METHODOLOGY

3.1 Approach

The method used in vegetation recording for the Ndau area follows Olang (undated) and Walker (1976). This method requires a subjective assessment where individual plant species are placed into one of the number of possible classes with respect to variables being estimated.

3.2 Location of transects

The initial choice for four vegetation recording transects in the Ndau School area, covering the main environmental gradients, was made by Bingham in an earlier report. For this he used airphotos, but did not visit the sites on the ground. To quote:

> "<u>Transect No.1</u> should run from near Ndau School (15E25.1'S, 22E58.1'E) to a conspicuous landmark on the east bank, e.g. a tower in Mongu. There are fallow cassava fields on the Kalamba Ridge which could be included. This transect will also take in the plain edge, the Kabumu (?Kabumi) Lagoon, and sections of plain on either side of the lagoon. It could be extended to the Moto Channel or beyond, even to the Zambezi, but in that case the more interesting sections should be selected to avoid long stretches of similarity.

Transect No.2 should run from a point within the Kalamba Protected Forest Area westward into the Simunyange Plain. It would make sense to extend it to the top of the sand scarp near Lukona School, but this is outside the pilot area. In fact it could be extended into the Lukona Local Forest. There are interesting differences between the two PFAs, although they are not wetland habitats.

Transect No.3 should run from a mound on a sand bar east of the lagoon where there is a thicket of *Acacia hebeclada*. Unfortunately a GPS reading was not obtained, but the IUCN coxswain could identify it. A line could be taken from this mound to another one which is inhabited and cultivated. Only good soils are to be found on the mounds.

Transect No.4 should originate from the bank of the Zambezi and run inland. It might be useful to make two transects, one from a sandbar (deposition phase) and the other from a high bank (erosion phase).

In July 1997 Liyo fishing camp (15E21.4'S, 23E05.8'E) was visited, situated on a lagoon with *Syzygium guineense* subsp. *barotsense*. This is on the same latitude as Kuta. Although the GPS reading puts it east of the Zambezi, it is possibly to the west and thus well within the pilot area. This patch of swamp forest could usefully be included in a transect.

Only Transect No.4 can be expected to show rapid changes, although not anthropogenic. The termite mounds are likely to be the most interesting from a biodiversity viewpoint."

Following this, the present consultant had discussions on the transect siting with the Ndau Area Development Committee Coordinating Chairman and the Patron for Ndau School Conservation Club. Owing to difficulties of access to some of the proposed transects through continued presence of floodwaters in August 1999, some modifications were made. For instance, Transect 3 was completely shifted and Transect 4 was cut into two, thus creating a total of five transects in the area. Locations are shown in the map in Appendix 12.1 (Figure 12.1).

The length of the transect lines varied from 0.7 to 5.4 km. The start and finish of each transect was noted with a GPS reading. The transect direction was noted using a compass.

3.3 **Recording of quadrats**

Quadrats were placed every 50 m along the fixed transect line in areas where changes are likely to occur, and at 100 m intervals in areas with less disturbance. In some cases quadrats were a larger distance apart where physical obstacles such as a river or water-filled depression were encountered. The quadrat dimension of 1 x 1 m was established using a peg which is placed in the middle of the quadrat for easy identification during the subsequent recording.

Plant species composition and relative cover-abundance (particularly for grasses) were subjectively recorded using an 8 point ranking scale with uneven class intervals (Walker 1976; Table 1). Additional recording was done noting plant species along the transect lines using step-point method at every 20 m interval.

To arrive at a rank value for an individual plant species, it was first asked if the value was more or less than half? If it was judged to be less, then the decision was made as to whether it was more or less than a quarter, and so on until all the individual plants were ranked and given appropriate percentage classes.

A subjective classification was also recorded, as follows:

Dominant (D): The main grass species present, with other species present only in small numbers.

Common (C): Frequently encountered at the quadrat as a mix with other grass species. However it remains one of the most frequently occurring species.

Present (P): Frequent at the site; encountered only once or a few times around the quadrat. This incorporates the category of rare (R).

Scattered (S): Not frequently encountered, but found around the area as scattered individuals.

Appendix 1.2 Table 1 Ranking scale used in vegetation recording.

Rank	Class interval (% cover)
0	0
1	1 - 10
2	11 - 25
3	26 - 50
4	51 - 75
5	76 - 90
6	91 - 99
7	100

4. DESCRIPTION OF TRANSECTS

4.1 Transect 1

Location
GPS readings: initial 710489 E / 8294230 N; close 711933 E / 829489 N.

This transect started from the base of the Kalamba forest near Ndau school (forest ridge), and ran eastwards through the sand plain to Kabumu lagoon across the Mota River. It included both sections of the Kabumu lagoon and Mota River, and ended a few metres after the river due to high levels of water at the time of recording. The transect was 2.3 km long with 20 quadrats. Quadrats 1 to 12 were set at 50 m intervals, whereas quadrats 13 to 20 were at intervals of 100 m or more.

Vegetation Units
Forest ridge: An area occupied by Kalahari woodland derived from the destruction of *Baikiaea* forest. This destruction was caused by prolonged shifting cultivation and repeated cutting of firewood. It is strongly degraded and the rate of regrowth of *Baphia massaiensis* is influenced by human activity. Dominant grass species were *Brachiaria nigropedata* followed by *Cynodon dactylon, Eragrostis pallens, Brachiaria dura, Aristida* spp. and *Hyparrhenia* spp., in order of abundance.

Plain depressions (wet area): The notable grass species in this unit were *Echinochloa pyramidalis, Orzya barthii and Leersia hexandra*.

Sand plain: This unit is between the depression and the Kabumu lagoon. The most productive and dominant grass is *Eragrostis pallens,* followed by *Brachiaria dura, Panicum coloratum, Cynodon dactylon* and *Eragrostis* spp., in that order. Other species could not be identified because they were too dry at the time of recording.

Lagoon edge: The grasses present were *Echinochloa pyramidalis* followed by *Leersia hexandra, Orzya barthii, Phragmites australis,* and the sedge *Cyperus papyrus*.

Plain between lagoon and Mota River: This unit had a diversity of grasses comprising highly productive species such as *Stipagrostis namaquensis* (butumo), followed by *Cynodon nlemfuensis* (sibuku), *Orzya barthii, Vetiveria nigritana* and *Phragmites australis* (in degraded form).

Vegetation Structure

The plain edge, depressions and the marshes within the plain contained the more productive and palatable grass species. These areas are also important grazing grounds for livestock.

The drier part of the plain along this transect supported poor grasses such as *Eragrostis pallens,* a productive climax grass but which is a very poor and coarse forage. However, this species has managed to provide protection to the soil against water and wind erosion. *Brachiaria dura* is seen as scattered individuals, and *Aristida* spp. are common.

4.2 **Transect 2**

Location

GPS reading: initial 709046 E / 8295345 N; close 704662 E /8295230 N.

This, the longest transect in the area, starts from Kabumu village by the plain and runs through the Kalamba forest about 400 m westwards onto the Simunyanga plain. It is about 5.4 km long with 50 quadrats. Quadrats 1 to 12 were at 50 m intervals and quadrats12 to 50 were set at 100 m intervals.

Vegetation Units

As described under Transect 1, the Kalamba ridge is highly degraded due to continuous exploitation for fuelwood and poles. Fire has also destroyed a large tract of forest, and together with prolonged cultivation of cassava and millet has resulted in the high levels of regeneration of *Baphia massaiensis*, *Bauhinia petersiana* (mupondopondo) and *Copaifera baumiana* (mukuwa). The middle of Kalamba forest has been much exploited for poles and timber. The vegetation shows tendencies towards *Burkea–Combretum–Erythrophleum–Guibourtia–Baikiaea* woodland. Even with the opening up of the forest, grass composition is still poor and sparsely distributed.

Forest edge: The grasses prevailing in this unit were dominated by *Cynodon dactylon*, followed by *Eragrostis pallens* and *Aristida* spp. More grass species should be seen in this unit during the wet season.

Kalamba forest: This area had an abundance of the grasses *Digitaria milanjiana, Andropogon chinensis*(?) and *Tristachya superba* in the middle of the forest, while *Panicum maximum, Eragrostis* spp., *Aristida* spp. and *Pogonorthria squarrosa* were found in scattered form in association with *Digitaria milanjiana*.

Simunyange plain: This unit had a variety of grass species with *Cynodon dactylon* abundant by the plain edge. The plain proper was very productive but with unpalatable *Eragrostis*, *Aristida meridionalis, Aristida* spp., *Tristachya* sp. and *Ctenium concinnum* (sickle grass). It is not normally utilized by livestock because of its unpalatable and coarse grass composition.

4.2 **Transect 3**

Location

GPS reading: initial 710342 E / 8291915 N; close 711120 E / 8290796 N.

The transect ran from Ngela village southwards towards the Mota River and cut across the plain, the Nalibalo depression and part of the mound. It covered part of the marsh and ended in the Nalibalo dambo. It had 21 quadrats and was 1.8 km in length. The distance of the transect does not tally with the number of quadrats because of physical barriers such as rivers or areas with water at the time of recording such that quadrats could not be established. Quadrats 1 to 12 were set at 50 m intervals, and quadrats12 to 21 at 100 m intervals or more.

Vegetation Units

The area was heavily degraded with a few stands of *Baphia massaiensis* and *Ricinodendron rautanenii* trees (mungongo). Grasses were either grazed or trampled since this is also a route for both humans and livestock. Traces of *Hyperthelia* and *Hyparrhenia* grass species towards the plain edge indicate that this unit once supported such species, which have now been grazed out and replaced by the abundant and aggressive *Eragrostis pallens*. More productive grass species were observed in depressions in the middle of the plain and the dambo.

Plain edge: Most of grasses in this unit were grazed out and trampled. *Eragrostis pallens* was still visible and abundant.

Depression (wetter part of plain): The bulky grasses here were dominated by *Echinochloa pyramidalis, Leersia hexandra, Acroceras macrum* (Nile grass), *Paspalum* sp., with *Cynodon dactylon* towards the drier part of the plain. The area is usually grazed from September to November.

Middle plain: This unit had a greater variety of grass species, and also *Sesbania sesban*. It was dominated by *Orzya barthii, Echinochloa pyramidalis, Cynodon nlemfuensis* (sibuku), *Panicum coloratum, Eragrostis tenuifolia, Vetiveria nigritana, Orzya barthii, Phragmites australis* and a number of sedges. It is an important grazing area during the last three months of the year.

Dambo: This dambo was dominated by *Orzya barthii, Leersia hexandra, Echinochloa pyramidalis* and *Cynodon nlemfuensis.*

4.4 **Transect 4**

Location

GPS recording: initial 711936 E / 8303897 N; close 710808 E / 8303212 N.

This transect started from Malakata village by the Zambezi in front of two mature *Faidherbia albida* trees and ran through the depression and highlands across the old Zambezi River. The transect was 1.6 km long and had 14 quadrats.

Vegetation Units

Grasses between the Zambezi proper and the old Zambezi are of poor quality and sparsely distributed. This is attributed to the deposition of sand from the main river. Most are not grazed by animals. However, the depressions and the river banks support palatable grasses and provide good grazing to the livestock, especially during the dry season.

Highland: Higher ground was dominated by *Orzya barthii, Cynodon nlemfuensis, Eragrostis* sp. and *Phragmites australis* (scattered and degraded in form).

Depression: This unit supported more productive and palatable grasses, and was dominated by *Echinochloa pyramidalis, Orzya barthii, Leersia hexandra* and *Cynodon nlemfuensis*.

Old Zambezi edge: Grasses in this unit were dominated by *Echinochloa pyramidalis, Leersia hexandra* and *Orzya barthii*, with *Phragmites australis* forming a thicket in the marsh a few metres away from the river bank.

4.5 **Transect 5**

Location

GPS reading: initial 710632 E / 8303712 N; close 710124 E / 8303471 N.

The transect started from the channel of the old Zambezi River (Kaoli) west of Liyembe village and covered part of the main plain. It is the shortest transect at 0.7 km long and with only 9 quadrats. The transect was supposed to reach Liyembe village in order to cover the larger part of the plain, as the plain is an important grazing area for livestock, but due to flooding at the time of marking it was not possible to continue. Quadrats 1 to 5 were at 50 m intervals, while quadrats 5 to 9 were at 100 m intervals.

Vegetation Units
This transect had productive and palatable grass species. The area is good for grazing, especially late in the dry season.

Zambezi bank: This unit is dominated by well-established *Echinochloa pyramidalis, Orzya barthii,* and *Acroceras macrum*, The grass *Vossia cuspidata* is likely to be present, but was difficult to identify in the absence of developed inflorescence.

Upper plain: The unit was dominated by *Cynodon nlemfuensis, Echinochloa pyramidalis* and *Orzya barthii*.

Depression: This unit supported many grass species and was dominated by *Cynodon nlemfuensis* (sibuku), *Orzya barthii, Stipagrostis namaquensis* (mutumo), *Echinochloa pyramidalis, Leersia hexandra* and *Vetiveria nigritana*.

5. ASSESSMENT OF DATA

5.1 Grass species composition

Vegetation units associated with the grassy plain had a similar grass species composition. The dry sand plain supports aggressive climax grass species such as *Eragrostis pallens, Cynodon dactylon, Brachiaria dura, Panicum coloratum, Aristida* spp., *Sporobolus pyramidalis*, *Setaria sphacelata* and other *Eragrostis* species. Dry depressions support more robust grasses such as *Stipagrostis namaquensis*, an important grass for thatching and fencing of houses in the Ndau area. *Phragmites australis* is also seen in sparse and usually degraded form. The plain wet depressions and river banks have similar hydrophyte grass or sedge species. The main ones are *Cynodon nlemfuensis, Echinochloa pyramidalis, Oryza barthii, Leersia hexandra, Phragmites australis* (forming dense thickets especially along the river banks), *Vetiveria nigritana, Acroceras macrum* and *Cyperus papyrus.* Scattered *Sesbania sesban* is not utilized by animals because of its rankness; by the time animals enter this unit the plant is already too dry to be utilized efficiently. This unit supports very palatable grass species and is very productive in terms of biomass.

The Kalamba forest on Kalahari sands shows a different grass species composition, including *Digitaria milanjiana, Eragrostis*, *Aristida*, *Pogonarthria squarrosa, Tristachya superba,* other *Tristachya* spp., *Andropogon chinensis* and *Panicum maximum* in old fields. The forest ridge has grasses such as *Brachiaria nigropedata, Cynodon dactylon, Eragrostis pallens, Brachiaria dura, Aristida* and *Hyparrhenia filipendula* (degraded form).

5.2 Utilization

The forest ridges (parts of Transects 1, 2 and 3) are generally over-utilized by animals, as shown by the depleted palatable grasses such as *Hyparrhenia* and *Brachiaria* and the invasion of more aggressive grasses such as *Eragrostis pallens, Cynodon dactylon* and *Aristida*. These units have further been made vulnerable by continuous cultivation of cassava and exploitation of fuelwood leading to encroachment of *Bauhinia* and *Baphia* shrubs. Changes in these units are likely to take place unless management interventions are made.

The drier part of the plain (Transects 1, 3 and 4) is not adequately utilized by livestock because most of the grasses are coarse and unpalatable. Human activities in this unit are also minimal. The high biomass production of *Eragrostis pallens* tend to keep the soil and the area intact.

The lower and river bank areas are the most vulnerable units in all the transects (except Transect 2). Many activities are taking place here. The recent droughts in the Ndau area have stimulated people to cultivate cassava along vulnerable units such as banks and depressions, a situation which was uncommon two years ago. The worst affected area is the Kabumu lagoon, which is now threatened with siltation. These areas are also potential grazing grounds for cattle. Most palatable grasses have been removed through clearing, which has also reduced the potential area for grazing. Inambao Ilubala (pers. comm.) observed that from 1990 to 1996, *Leersia hexandra* almost disappeared due to continuous burning, drought and overgrazing. This species, however, has reappeared since the reduction in burning and the good rains the area has received for the past two years.

The sedge *Cyperus papyrus* is heavily exploited by people, especially fishermen. It is in high demand as it is used for making mats and carriers for taking dry fish to market centres. This has an implication on birds and other animals that use these areas as breeding habitats. Inambao Ilubala (pers. comm.) indicated that for the past five years people have had no access to *Stipagrostis namaquensis* (butumo), an important grass in the area for making fences and thatching of houses. The species has been almost wiped out by fire. This year is the first time for five years that people are harvesting it. *Phragmites australis* is also depleted in the area, because people have been harvesting premature reeds. Degraded patches of this grass are seen in the area.

With this kind of disturbance these units are likely to change in species composition, distribution and productivity over time.

Wetter depressions seem to support stable grass associations such as *Cynodon nlemfuensis, Echinochloa pyramidalis, Orzya barthii* and *Leersia hexandra*, which form dense colonies. These areas tend to have natural barriers because they stay unutilized for a long time and are only grazed during the last three months of the year.

The Kalamba forest (Transect 2) is grazed during the rainy season from February to the time water level on the plain goes down. Palatable grass species are constantly grazed during this time. The opening up of the forest by fire, timber and fuelwood harvesting has not stimulated the diversity of grass species and distribution. Particularly noticeable is the encroachment of *Baphia massaiensis* and *Bauhinia* spp.

6. CONCLUSIONS AND RECOMMENDATIONS

a) Not all grass species could be identified or recorded at the time of transect marking as August is not a good month to find grasses with full and fresh flowers. Most grasses were dry making identification difficult. To record all grasses, especially the important ones, vegetation recording should be carried out between November and January just before the floods, which will also allow accessibility to the transects.

b) The length of the transects does not tally with the number of quadrats because of physical barriers, such as rivers or and wet depressions containing water at the time of marking. The actual transect distances were calculated and determined using a map.

c) Management interventions need to be put in place in order to reduce the over-exploitation of depressions and river banks, especially in the units where cassava is being grown.

d) Interventions will also be required on the utilization of papyrus and *Phragmites*.

e) Special management attention should be given to vulnerable vegetation units highlighted in this report.

7. ACKNOWLEDGEMENTS

Special thanks go to the Chairman of the Area Development Coordinating Committee (ADCC), Mr Inambao Ilubala, and the Patron for Ndau School Conservation Club for their assistance and guidance given to me during the transects marking. Without their presence, the work would have been difficult.

I wish to extend my sincere thanks to Mrs Dora Kamweneshe, IUCN Field Office Mongu and her staff for providing transport to and from Ndau and logistical support.

8. GRASS SPECIES LIST

Acroceras macrum *Stapf*
Andropogon chinensis *(Nees) Merr.*
Aristida meridionalis *(Stapf) Henr.*
Aristida spp.
Brachiaria dura *Stapf*
Brachiaria nigropedata *(Hiern) Stapf*
Ctenium concinnum *Nees*
Cynodon dactylon *(L.) Pers.*
Cynodon nlemfuensis *Vanderyst*
Digitaria milanjiana *(Rendle) Stapf*
Echinochloa pyramidalis *(Lam.) Hitchc.& Chase*
Eragrostis tenuifolia *(A.Rich.) Steud.*
Eragrostis pallens *Hack.*
Hyparrhenia filipendula *(Hochst.) Stapf*
Hyparrhenia spp.
Hyperthelia dissoluta *(Steud.) W.D.Clayton*
Leersia hexandra *Sw.*
Orzya barthii *A.Chev.*
Panicum coloratum *L.*
Panicum maximum *Jacq.*
Paspalum sp.
Phragmites australis *(Cav.) Steud.*
Pogonarthria squarrosa *(Roem.& Schult.) Pilg.*
Setaria sphacelata *(Schumach.) M.B.Moss*
Sporobolus pyramidalis *P.Beauv.*
Stipagrostis namaquensis *(Nees) De Winter*
Tristachya superba *(De Not.) Schweinf.& Aschers.*
Tristachya spp.
Vetiveria nigritana *(Benth) Stapf*
Vossia cuspidata *(Roxb.) Griff.*

9. REFERENCES

Herlocker, T.M. (1979). Vegetation of Southwestern Marsabit District. IPAL Technical Report No. D-1. Nairobi, Kenya.

Mentis, M.T. (1984). Monitoring in Southern African grasslands. South African National Scientific Programmes Report No. 91. Pretoria, South Africa.

Olang, O.M. (n.d.). Range monitoring methodologies. Kenya Rangeland Ecological Monitoring Unit. Nairobi, Kenya.

Walker, B.H. (1976). An approach to the monitoring of changes in the composition and utilization of woodland and savanna vegetation. Division of Biological Sciences, University of Rhodesia.

Back to Contents

CHAPTER 2
LAND COVER AND LAND USE CHANGE IN THE ZAMBEZI DELTA

Richard Beilfuss, Paul Dutton & Dorn Moore

2.1 INTRODUCTION

The Zambezi Delta is a wetland system of profound conservation and resource value. The delta is home to more than 350 000 rural villagers, who depend on the delta's rich natural resources for their livelihood. The delta is also the largest wetland system in the Zambezi catchment, and supports a great mosaic of wetland vegetation communities, including palm savanna, mangrove forests and papyrus swamps. Vast, seasonally flooded grasslands support diverse and abundant wildlife populations, including many waterbird species of international concern, and, until recently, legendary concentrations of buffalo, waterbuck and hippopotamus. The floodplain provides spawning grounds for riverine and anadromous fishes and critical dry-season grazing lands for domesticated livestock and wildlife. Extensive coastal mangroves and estuaries support a lucrative prawn fishery. Of particular importance is the 5 000 km^2 Marromeu Complex, located along the southern bank of the Lower Zambezi River in the delta, which includes the protected Marromeu Buffalo Reserve and three managed hunting units (Figure 2.1).

Throughout recorded history, the Zambezi Delta has undergone constant change in response to resource utilization pressures, climatic cycles, natural geomorphic processes, and especially the complex interactions between the indigenous delta population and successive traders and colonial inhabitants. During the past forty years, however, civil war, drought and the construction of large dams on the Zambezi River have resulted in unprecedented land use and land cover changes that threaten the ecological and social fabric of the delta.

The International Crane Foundation and Dutton Environmental Consultants were approached by the Biodiversity Foundation for Africa to assess the history of land use and land cover change in the Zambezi Delta, Mozambique, for the World Conservation Union (IUCN) Zambezi Basin Wetlands Conservation and Resource Utilisation Project. The terms of reference for this study are (a) to provide an historical account of land use and cover change in the Zambezi Delta, (b) to identify factors influencing land use and land cover change in the Zambezi Delta, (c) to discuss the implications of land use and ecological change in the Zambezi Delta on biodiversity and human welfare, and (d) to provide recommendations for the amelioration of negative land use and ecological changes in the Zambezi Delta.

We begin with a brief history of land use in the Zambezi Delta, followed by a comprehensive review of previous studies of land cover and land use change. These studies provide a basis for quantitative assessment of changes in the delta. Its present status and the patterns, causes and implications of land use and land cover change are then assessed using a combination of aerial photographs, satellite images, aerial surveys, field research, and interviews. The study provides recommendations for balancing the wise use of the natural resources of the delta with the conservation of its biological diversity.

2.2 METHODOLOGY

The study of land use/land cover change in the Zambezi Delta is an all-encompassing process, requiring an assessment not only of vegetation communities and human activity, but also of the many factors that influence land use/land cover changes, ranging from hydrology, geomorphology, soils and wildlife ecology to anthropology, agricultural economics, and political science. A complete treatment of this topic would therefore be voluminous and beyond the scope of this project. In the sections that follow, we aim to distill and synthesize key concepts from the wealth of published studies related to land use/land cover changes in the Zambezi system, and link them to our own observations and analysis of long-term change in the delta.

The brief history of land use in the Zambezi Delta is a literature review, drawn from a few selected publications, most notably the political anthropology studies of Isaacman (1972), Vail & White (1980), Newitt (1969), Negrão (1995) and Ishemo (1995), the water resources engineering studies of Bolton (1983), and the diagnostic overview of current socio-economic conditions in the delta by Schmidt (1997).

Previous land use and land cover studies is also a literature review, organized chronologically in sections that cover early accounts of the delta, historic land cover and land use mapping of the delta, Tinley's landscape framework for assessing the delta, environmental impact studies for Zambezi Basin development, and current land cover and land use practices in the delta. Sources include the journals and letters from the Livingstone expeditions, natural history surveys of the Lower Zambezi from the early 1900s, consultancy reports, published and unpublished project reports, academic treatises and various government documents.

Land cover change in the Zambezi Delta presents an analysis of the results of the present study. A combination of ground research, aerial transect surveys, interviews, archival photographs and Geographic Information Systems technology were used to assess changes in the land cover of the Zambezi Delta over the period 1960-1999. Maps include a 1960 land cover classification of the southern half of the Zambezi Delta (Figure 2.11) (see end of this review), a comparable 1999 land cover classification of the same area (Figure 2.12), and a series of insets highlighting examples of some of the land cover changes in detail (Figures 2.14-18). Key components of this analysis include:

1960 airphoto classification

A set of 1:49,350 scale aerial photographs dated 6 August 1960 were obtained from the Direcção Nacional de Geografia e Cadastro (DINEGECA). A total of 203 aerial photos cover the southern half of the Zambezi Delta. The airphotos were mosaiced into a single image using ERDAS OrthoBase software. The resulting mosaic was geo-referenced to 1960 topographic maps produced by DINEGECA. We classified the airphoto mosaic using supervised on-screen-digitizing techniques with ArcView GIS software, a process that enabled continuous scaling to identify features ranging from individual trees to broad land cover features. To aid in airphoto interpretation, we referred to the Block 10 map (scale 1: 100,000) of ecological regions in the southern half of the Zambezi Delta produced by Loxton-Hunting (1975) (Figure 2.5). The Loxton map was scanned and geo-referenced to the 1960 airphoto mosaic and used as a computer overlay for interpretation. The 15 land cover classification units for the 1960 basemap are compiled from Loxton-Hunting (1975), Tinley (1977) and Timberlake (pers. comm.) classifications, and personal observations.

1972 airphoto observation
A set of 1:50,000 scale aerial photographs dated 1 September 1972 were obtained from DINEGECA. A total of 194 aerial photos cover the southern half of the Zambezi Delta. We conducted a frame by frame comparison of each 1972 airphoto scene with each 1960 airphoto scene covering the same area. Changes in land cover during the period 1960-1972 were recorded. Difficult-to-identify features were assessed using stereo pairs of overlapping photographs.

1999 satellite image classification
A Landsat 7 ETM image dated 31 August 1999 was obtained from the USGS for classification purposes (Figure 2.13). A single image (path 166, row 73) covers the entire Zambezi Delta. The image was geo-referenced to the 1960 airphoto mosaic. We classified the southern half of the delta with supervised on-screen-digitizing using ArcView GIS software, a process that enables scaling down to level of individual pixels (30 x 30 m resolution). The image was classified using various false-colour combinations of the six visual ETM bands (blue, green, red and three infrared bands) for interpretation. The land cover classification units follow from those adopted for the 1960 airphoto classification. To aid in image interpretation, we conducted an unsupervised classification of the same image using 30 spectral ranges. Unique spectral signatures and patterns were recognized for mangrove forest (two types), saline mudflats, papyrus swamp, dense palm savanna, acacia woodland, secondary grassland, dry forest with pans, miombo woodland on alluvial fans, and coastal beach. The unsupervised classification image was used as a computer overlay with the false colour image, with both images used interchangeably during the classification process. We also used a 13 July 1996 Landsat TM image to aid in the classification of small areas where cloud cover obscured the classification of 1999 image (Figure 2.10). The 1996 image was geo-referenced to the 1999 Landsat ETM image and 1960 airphoto mosaic, and interpreted from a false-colour band combination.

1972 and 1986 image observation
To observe intermediate changes in land use/land cover in the delta over the period 1960-99, we obtained two additional satellite images. The earliest cloud-free Landsat MSS image available, dated 1 August 1972, was obtained from USGS (Figure 2.9). A Landsat TM image dated 15 May 1986 was also obtained from USGS. Both images were geo-referenced to the 1999 Landsat ETM image and 1960 airphoto mosaic. To assess the progression of geomorphological changes in the delta through time, we classified the Zambezi distributaries and coastal inlets on each image using the supervised classification seed tool in ERDAS software.

Photographic evidence
Archive photos taken during the 1970s were reprinted to provide a visual perspective on historical land use practices and land cover features in the delta. Photographs taken during aerial and ground surveys during the 1990s were reprinted to provide a visual representation of the land cover mapping units and illustrate areas of land cover change.

Ground truthing
Field research on land cover/land use change was conducted during the period 1995 to 1999. Eight aerial surveys were flown between 1995-1999 for the purpose of counting waterbirds and large mammals, and identifying landscape features and human activities. Each aerial survey covered the entire Marromeu Complex; some with a series of 4 km width transects running parallel to the coastline and others with a series of 5 km width transects on an east-west grid patterns. During 1998 and 1999, a continuous, timed record of land cover features and land use practices was recorded along each transect, with GPS points recorded for transect endpoints and important observations.

The transect lines were overlaid on the 1999 Landsat ETM satellite image, and survey observations were plotted along the transects and linked to observed features on the satellite image.

Field investigations of the land cover units were conducted during 1997-1999 in the following areas: (a) secondary grassland and palm savanna between Marromeu and Malingapans along the main Zambezi channel, (b) alluvial communities and *Acacia* savanna along the Marromeu-Chupanga road, (c) dry forest, wetland pans, miombo woodland/wet grassland on alluvial fans, and the floodplain ecotone of Coutadas 11 and 12, and (d) coastal mangrove, saline mudflats, dune grasslands and beach ridges along the coastline near Chinde. A boat survey along the Zambezi from Marromeu to Chinde was carried out in October 1998. Observations of coastal mangrove and mudflats, riverine vegetation, sandbars and land use practices were recorded. Time constraints prevented any systematic sample of representative areas of the different land use classes. Transect surveys across the delta are planned for the 2000 dry season.

Informal interviews
During the course of the project, we interviewed long-term residents of the Zambezi Delta about changes in land use practices and landscape features. Villagers were questioned in particular about the economic impacts of changes in their land use practices and about possible causal mechanisms for observed land use/land cover changes. Safari hunters were interviewed about the status of wildlife and carrying capacity of the delta grasslands. We also interviewed various consultants and government staff working in the delta to better understand ongoing project activities.

Factors influencing land use and land cover change in the Zambezi Delta presents a discussion of the land cover/land use changes observed with respect to water resources development projects, natural geomorphologic changes, drought cycles, economic development activities, civil war, decreases in wildlife populations, and increases in fire frequency and extent. These factors are assessed from field observations and literature review.

Implications of land cover and land use change in the Zambezi Delta is a discussion of the impact of long-term land use/land cover change on the biodiversity and human welfare of the delta.

Finally, **conclusions and recommendations** provides a summary of the key findings recommendations for the amelioration of negative land use and ecological changes in the delta.

2.3 BRIEF HISTORY OF LAND USE IN THE ZAMBEZI DELTA

Prior to the 12th century, the delta was sparsely populated and land use practices were limited to subsistence agriculture, hunting and fishing in the fertile floodplains of the Zambezi Delta. Between the 12th and 14th centuries, Swahili and Indian traders began exporting ivory and leopard skins from the delta, and greatly reduced the concentration of large herbivores, particularly elephant and hippo (Tinley 1977).

Portuguese settlers arrived in the delta in the 16th century to expropriate labour and land rights from the local communities. Although the annual Zambezi floodwaters were considered a major hindrance to slave movement (a distance of 300-400 km along the coast could take several months to traverse), slave trading flourished throughout the Zambezi Valley and had a profound effect on community life. At the peak of the slave trade in the 1820s, 12,000 to 15,000 slaves were exported annually from the basin through Quelimane (Isaacman 1972).

Under Portuguese rule, land tenure in the delta was organized around the *prazo* system beginning in the 16th and early 17th centuries. Prazos were parcels of land over which individual settlers were granted wide powers of jurisdiction on behalf of the colonial regime. Prazo Luabo, Prazo Melambe and Prazo Tembue covered the floodplains of the delta between the Cheringoma escarpment and Quelimane (Newitt 1969). As the prazos usurped powers from the indigenous chieftencies, successive renters of prazo lands controlled landholder rights, collected taxes and traded slaves. Agricultural productivity was low, but sesame, coconut, copra and groundnuts were traded for gold, ivory and cattle, and by the early 1800s the delta supported a very diverse and lucrative agricultural economy (Negrão 1995). Over time, the prazos exerted their independence from the Portuguese authorities and assumed characteristics more similar to the original African chieftaincies they had tried to supplant (Isaacman 1972). The 18th and 19th centuries marked a period of struggle between the rebellious prazos and the colonial government, with Portugal unable to control the prazos through either legislation or force. Eventually, however, the central government gained economic control of the prazo system through the development of port facilities and land concessions for plantation agriculture (Vail & White 1980).

Toward the end of the 19th century, the delta population reached 100,000 and the ivory trade began waning due to the near extirpation of hippo and elephant. The administration promoted large-scale cash crop production and the first commercial farm, the Mozambique Opium Cultivating and Trading Company at Mopeia, was established in 1870. The initial plantation labour force was forcibly recruited by the military because local landholders resisted collectivized labour (Negrão 1995). By 1890, control over the rural population was solidified through military posts, inequitable administrative regulations and excessive taxes. Smallholders were forced to allocate more household labor to large-scale sugar and copra production. The first sugar processing plant started production in Mopeia in 1893. In 1920, the Sena Sugar Estates were founded, and by 1930 the estates had acquired more than 100,000 ha of the most fertile agricultural lands of the Zambezi floodplain near Marromeu, Luabo and Mopeia (Negrão 1995). Cotton was introduced as a compulsory crop in 1926, and rice in 1941. At peak production, 346,000 ha of delta lands were in cultivation, with more than 293,000 ha (85%) of the total titled for commercial production of cash crops and livestock under Sena Sugar Estates, Madal Society and others. The allocation of land to commercial farms pushed small landowners to marginal lands and later reduced the size of lands available to them. Landholding size per family in the delta eventually decreased from 15 ha in the 1930s to less than one hectare during the 1970s (Negrão 1995). Tinley (1977) attributed this increasing land use pressure among rural villagers to the clearing of riverine and forest vegetation. Firewood demands for the sugar processing plants further contributed to local deforestation (Schmidt 1997).

During this period, land was also reserved for hunting concessions and wildlife protection. The Marromeu Buffalo Reserve was established as a protective sanctuary in the 1950s, after the Marromeu buffalo population had been devastated by large-scale systematic hunting for their meat and skins during and after World War II (Tinley 1994). The buffalo reserve includes about 160,000 ha of open floodplains and papyrus swamps west of the Micelo River.

Surrounding the Marromeu Reserve, hunting concessions (coutadas) were granted to individual operators over large areas. Coutadas 10, 11 and 14 cover 528,000 ha of land surrounding the reserve (Hatton & Munguambe 1997). The coutada operators strictly regulate and control land use rights on these lands, restricting local access not only to wildlife but also to fish and wood. Through this system, local landowners lost their rights to harvest most of the natural resources.

With the rise of the Sena Sugar Estates, the first large-scale infrastructure development occurred in the Zambezi Delta. After widespread flooding in 1926 caused damage to the sugar estates, protective dykes were constructed along the Zambezi River near the Marromeu plantations, and the dykes were set at the level of the 1926 flood (Bolton 1983). During the remaining century, this level was exceeded only in 1939, 1940, 1952, 1958 and 1978. In the 1930s, a railway line between Marromeu and Sena was constructed to link to the existing line between Beira and Sena (Bolton 1983). The railway (and parallel road system) was designed without proper hydrographic surveys and obstructed the passage of water into the upper distributaries of the delta between Chupanga and Marromeu (Tinley 1994). Drainage was further restricted by the construction of direct railway between Marromeu and Inhaminga during the 1970s. This combination of protective dykes and impeded drainage resulted in a dramatic reduction in the movement of floodwaters into the upper half of the southern Zambezi Delta.

In December 1958, Kariba Dam, the first major dam on the Zambezi River, began impounding water and further altered the natural flooding patterns of the delta. Kariba, which controls 50% of the Zambezi runoff, was operated to generate steady hydropower production by storing peak floods and releasing a constant outflow of water. During the 1960s and 1970s, the most important tributary of the Middle Zambezi, the Kafue River, was dammed at Kafue Gorge and Itezhi-Tezhi, further evening out the natural flow regime.

Control of the Zambezi River culminated with the construction of the Cabora Bassa Dam. With the closing of the dam in December 1974, the ancient flood cycles of the Zambezi River were harnessed and the hydrological connection between the river and the delta floodplains was severed (Beilfuss & Davies 1999). Inundation of the Zambezi Delta, when it occurs, is now dependent on local rainfall-runoff within the lower Zambezi Basin or erratically timed water releases to prevent overtopping of the dam.

The dam was constructed as part of a comprehensive plan for multi-purpose development of the Lower Zambezi system including the delta. The principle elements of the plan were (a) construction of Cabora Bassa Dam, and other mainstream dams, for hydropower generation, flood control and river navigation; (b) establishment of a navigable channel along the river for transshipment to a deepwater port; (c) establishment of large agricultural schemes in the tributary basins and main alluvial plain; and (d) development of mining and industrial projects (Hidrotecnica Portuguesa 1965). Bolton (1983) and Isaacman & Sneddon (in press) noted that a remarkable feature of the development planning for the Lower Zambezi was the almost total disregard for the indigenous population and their established patterns of land use. Even flood control – which promised some relief from the large floods that periodically devastated households and crops in the low lying areas of the delta – disrupted the land use practices adopted by local communities to harness the flood waters for economic gain (Chidiamassamba & Liesegang 1997).

After independence in 1975, land use practices changed dramatically in the delta. Most farmers, managers and technical personnel emigrated following Mozambique's independence, and the subsequent destruction of plantations, machinery and buildings, and loss of capital and investments, led to a sharp fall in production and the disintegration of the rural marketing infrastructure (Schmidt 1997). To rebuild the rural economy, the new Mozambican government formed agricultural cooperatives. Farms abandoned by Portuguese emigrants were taken over by the government and run as State farms, and villagers were coerced into collectivized labour (Negrão 1995). In March and April 1978, severe flooding of the Lower Zambezi and delta claimed 45 lives, caused more than US$ 62 million in damage, and necessitated relief operations costing about US$ 40 million. Nearly

75,000 people were displaced from the delta, and 18,000 ha of cropland were destroyed (Rendel Palmer & Tritton 1979). The central government used this as an opportunity to resettle displaced flood victims into agricultural collectives, and administered government assistance strictly through the State farms (Schmidt 1997).

The next decade was marked by brutal civil war in the region. There was a steep decline in agricultural activity throughout the delta as villagers concentrated around Marromeu and Chinde for safety. In parts of the upper delta nearly 100% of the population resettled, while those who remained suffered from the destruction of schools, clinics and businesses. Large areas of formerly cultivated fields were encroached by secondary grassland and thicket. While the civil war arrested land use development in the delta (less than 4.5% of Sofala Province was converted from natural vegetation to agriculture during the period 1972-1990), it had a devastating effect on wildlife (Schmidt 1997). In 1969, the Marromeu floodplains were maintained by a grazing regime of over 16,000 buffalo and some 5000 waterbuck, with small populations of 300 each of elephant and hippo (Tinley 1969). In the following years, the buffalo population ballooned to 45,000 and the waterbuck to nearly 50,000, during which time (1976 to 1983) a sustainable wildlife culling programme operated for meat, bone and skin products. A total of 30,000 animals were harvested over the eight-year period, but wildlife populations remained strong (Tello 1986). Then, over a period of only seven years – five at the end of the civil war and the first two years following the ceasefire in 1992 – the wildlife populations were decimated by illegal commercial meat hunting (Tinley 1994).

Although the effects of war on the people and wildlife of the delta will be felt for many years, life has gradually regained a sense of normality in the seven years since the 1992 peace accord. The three administrative districts (Marromeu, Chinde and Mopeia) that comprise the core of the Zambezi Delta cover an area of 1,789,000 ha and support about 350,000 people. The Chinde coast still has the highest population density in the region with 175,992 people, or 40 people/km^2. The inland areas have much lower populations but increasing densities, with 79,238 people or 13 people/km^2 at Marromeu and 86,234 people or 11 people/km^2 in Mopeia (Schmidt 1997).

Outside of the coutadas and protected areas, agriculture is the main land use in the Zambezi Delta. Maize, rice, sorghum, beans, cassava and millet are the most important crops. Near Marromeu, the total area under subsistence cultivation is about 21,717 ha, while the Sena Sugar Estates control 10,200 ha for sugar production (Schmidt 1997). The total cultivated area for subsistence agriculture at Mopeia is about 24,399 ha. At Chinde, Sena Sugar Estates controls 45,000 ha. Most of these holdings are fallow while the sugar plantations are rehabilitated. Madal Society controls an additional 17,000 ha near Chinde. The total cultivated area for subsistence agriculture is about 22,751 ha. Approximately half of the delta households grow short-duration crops, and 25-50% have fruit trees or coconut palms. Livestock numbers were drastically reduced during the war, but active programs to restock with goats and pigs are underway. Other forms of land use include hunting, fishing, gathering of plant foods, fuelwood collection and grass and wood harvest for construction. Unsustainable slash and burn agriculture practices near Marromeu, widespread until 1994, are reportedly decreasing in response to agricultural extension programmes (Schmidt 1997).

The sustainable utilization of wildlife resources in the southern half of the delta continues to be problematic. The Coutadas are now fully functional and have a steady flow of safari hunting clientele throughout the dry season. Aerial surveys in 1998 suggested that wildlife populations were recovering, with an estimated 7657 buffalo, 589 elephants and 506 waterbuck in the southern delta, and 189 buffalo and 378 waterbuck in the northern delta (DNFFB 1998). Repeat surveys in 1999, however, suggest much lower populations of these species. Changes in hydrology, climate, human settlement and fire patterns all complicate the recovery of wildlife.

2.4 PREVIOUS LAND USE AND LAND COVER STUDIES

2.4.1 **Early accounts of the Zambezi Delta**

The earliest written accounts of the people and landscapes of the Zambezi Delta date back to the Livingstone expeditions of 1858-1863, and are found in the travel diaries of Livingstone (Wallis 1956), Kirk (Foskett 1965), Stewart (Wallis 1952) and Thornton (Tabler 1963). Although the expedition provides detailed accounts of the natural history of the Lower Zambezi up to Cabora Bassa, most of the entries from the delta region concern changes in the geomorphology of the channels with respect to navigation. Describing the Mutu River, the northernmost distributary of the Zambezi draining to Quelimane, for example, Livingstone wrote:

> "The Mutu, at the point of departure, was only 10 or 12 yards broad, shallow, and filled with aquatic plants. Trees and reeds along the bank overhang it so much that, though we had brought canoes and a boat from Tete, we were unable to enter the Mutu with them, and left them at Mazaro. During most of the year, this part of the Mutu is dry, and we were even now obliged to carry all our luggage by land for about fifteen miles. As Kilimane [sic] is called, in all the Portuguese documents, the capital of the rivers of Senna, it seemed strange to me that the capital should be built at a point where there was no direct water conveyance to the magnificent river whose name it bore; and on inquiry I was informed that the whole of the Mutu was large in days of yore, and admitted of the free passage of great launches from Kilimane all the year round; but that now this part of the Mutu had been filled up."

Maugham (1910) provided the first detailed descriptions of the natural history, agriculture, flora, fauna and ethnography of the delta region. He noted plantations of over 150,000 coconut palms near Quelimane. Cultivated crops of millet and groundnut were also observed. *Borassus* palm savanna, along with the smaller palm *Phoenix reclinata,* occurred in immense numbers along the coastline and far into the interior. Maugham observed "vast expanses of Papyrus marsh south of Luabo, nine or ten feet high, and "stands of *Phragmites communis* surrounding nearly all the inland waters". He also mentioned "a species of *Stipa*, that covered hundreds of miles of country, that was much used for thatching".

Maugham maintained a running diary of land cover changes as he travelled north along the Zambezi River. He observed:

> "As one ascends the Chinde River....the banks are seen to be fringed by dense forests of mangroves, forming an impassable, almost impenetrable, screen or barrier which for many miles shuts out any glimpse of the grassy plains beyond. Near the main body of the Zambezi, the mangrove ceases; the river banks increase in height, and change from black, clinging viscous mud to a soil of a sandy, or more rarely clayey, nature. At the point where one turns into the Zambezi, here some 800 or 900 years wide, these banks, in the dry season, are fully 15 or 18 feet in height. Over the high banks, fringed with green reeds and high, snowy plumed spear-grass, clumps of trees now appear; several kinds of thinly-leaved acacias mingling with a curious pale green elm are most numerous, but away beyond, some-times singly and sometimes in groups of half a dozen or more, straight-trunked, clean-cut Hyphaene and Borassus palms tower 60 and 70 feet above the surrounding forest growths. Sandy islets

covered with grass and reeds are passed all day long, and floating islands of marshy greenery borne down on the current. Here and there on the banks above, the hive-shaped roofs of small native villages appear.

"The river, still 800 yards wide, is deeper at [Chupanga], there are no sand-banks visible. Continuing up the river, one is immediately struck by the increased luxuriance of the tropical vegetation. The high-river banks are covered with an exuberant growth of low bushes. Palms of various kinds become very numerous; immense baobabs, clumps of stiff euphorbias, and roves of feathery albizzias mingle with acacias of several kinds. Very few large trees appear, however, if we omit a species of camwood."

Maugham wrote that the forests of Chupanga were particularly rich in mammals and that hippos were numerous along the Zambezi, although the daily steamers had driven them into the more secretive marshes. Large numbers of sable antelope, eland, zebra and waterbuck were observed, and scavenging lions and Marrabou storks were particularly abundant. His observations included a large number of waterbirds throughout the delta floodplains, including large numbers of Grey Crowned Crane (*Balearica regulorum*), Saddlebilled Stork (*Ephipiorhynchus senegalensis)*, White Pelican *(Pelicanus onocrotalus*), flamingoes (*Phoenicopterus* sp.) and a variety of egrets, herons and shorebirds. Of the great herds of buffalo, Maugham wrote:

"Although nothing so numerous as he was before the great epidemic of rindepest, which swept through the country about the year 1896, [the Cape Buffalo] still exists to some extent on both banks of the Zambezi, where there is some indication of a tendency for their numbers to increase. In those portions of the country which have witnessed the rapid development of the sugar industry, buffalo are decreasing"

Later expeditions, such as MacDonald (1955), recount the benefits of the annual Zambezi floods for agricultural fertility:

"[The Zambezi] spreads itself in leisurely fashion across two miles of open valley where islets of tender green and long beds of rushes impede its flow. The banks are fertile – much more fertile than the eroded valley of much of the upper river. From Lupata to the extreme tip of the Delta the flagging current softly deposits some of the richest soils and humus it has forcibly torn from the denuded plains of Barotseland and the Sebungwe. The rest is carried out to sea"

and the great human costs of the exceptional Zambezi flooding events:

"The flooded Zambesi thunders down the gorges with ever increasing volume to overwhelm and inundate the plains below. Planters, farmers, and African villagers, two hundred miles farther downstream, view the weather portents with equal anxiety. A few more hours of rain and [the Shire] will race down its own wide valley sweeping all the crops before it into the great Zambezi, and down to the sea. The houses and property of the Zambezi River people, their crops – the sugar cane, coconuts, rice, bananas, and all the produce of the fertile soil – will be seized by the swirling waters and borne away."

2.4.2 **Previous land cover mapping**

The first attempt to map land cover in the Zambezi Delta was undertaken by Barbosa (1952) as part of a vegetation survey of Zambézia Province. The vegetation of the northern half of the delta was classified as hydrophilic grassland, with patches of morrumbala forest. Along the coastline, mangrove forests and salt flats were mapped at the outlet of the major delta tributaries. The later vegetation map of the Flora Zambesiaca area (Wild & Barbosa 1967) also covered the delta. Timberlake (1998) noted that the swamps of the Lower Shire Valley in Malawi were described as papyrus sudd (*Cyperus papyrus*, other *Cyperus* spp. and *Phragmites* reed beds), but only as "formations on alluvium" for the delta map. The delta map differentiated communities of coastal thicket (*Mimusops caffra*) and mangroves (*Rhizophora mucronata*). Extensive coconut groves near Quelimane were also mapped.

The first comprehensive studies of the Zambezi Delta were compiled under the auspices of the Zambezi Planning Authority (Gabinete do Plano de Zambèze, or GPZ), as part of plans to develop the Zambezi Basin in Mozambique for hydropower, agriculture and settlement. The Plano Geral de Fomento e Ocupação do Vale do Zambèze, produced by Hidrotecnica Portuguesa (1965), provided course basinwide maps (1:4 million) of topography, hydrology, geology, climate (rainfall, temperature, relative humidity, evapotranspiration), soils, vegetation, demography, ethnic groupings, agriculture and industry. The coastal mangroves were mapped from aerial surveys (Hidrotecnica Portuguesa 1961a). Floodplain vegetation of the delta, following from previous studies, was classified simply as formations on alluvium (Figure 2.2).

In 1973, A.O.C. Technical Services, in association with Hidrotecnica Portuguesa, Empresa Tecnica de Levantamentos Aereos and Loxton, Hunting and Associates, were contracted by the GPZ to survey the natural resources of the southern region of the Lower Zambezi Valley. The southern region was divided into three units, with two units (Blocks 10 and 11) covering the Zambezi Delta. Block 10 covered the region from the Zambezi River south to the Mungari River and from the Inhaminga-Inhamitanga-Chupanga road in the west to the Indian Ocean in the east, excluded the southeast corner of the delta from the Mungari River to the Cheringoma escarpment (Figure 2.3). Block 11 covered the entire northern half of the delta (Figure 2.4**)**. The consultants carried out detailed field investigations to describe and map the soils, ecological regions, physiographic regions, dryland arable production potential, pastoral potential, irrigation potential and surface water resources, groundwater development potential, and recommended land uses of the study area (Loxton-Hunting 1975).

Land cover mapping in the delta was organized in terms of landforms, soils and ecological regions. The most important physiographic feature is described as the extensive Quaternary Deltoid Plain. The level Deltoid Plain supports a very intricate network of distributary channels from the main Zambezi channel. The deltoid deposition of fine-textured materials has been superimposed on and cut into a system of beaches of fine sand. These relict beaches, more prominent near the existing coast, can be found up to 30 km from the present shoreline. Superimposed on the Deltoid Plain was a series of recent alluvial plains with a system of levees, channels, and pans. Most prominent of these recent alluvial plains is that of the Zambezi River itself, although the Salone, Cuncue and Pandu rivers also have extensive systems in their upper reaches near Marromeu. The sea was cutting back into the deltoid deposits near the coast, especially in the northern half of the Zambezi Delta. Tidal streams and mangrove communities occurred well inland of the coast. The tidal streams formed incised channels with no levee system.

Based on these landscape features, the deltoid plain was further subdivided into six physiographic units as characterized by soil moisture and inundation. These included: (1) seasonally flooded areas of strongly to moderately gleyed vertisols and some humic gleys, occupying the regionally depressed Quaternary Deltoid Plain and the backslopes of levees in the western zone; (2) tidally influenced areas occupied by mangrove swamps; (3) seasonally flooded areas of strongly gleyed soils with tidally influenced drainage lines; (4) elevated levee and watercourse areas, of recent alluvium with mainly sandy to medium textured alluvial soils, that are periodically flooded; (5) broad, relatively elevated floodplains and backslopes of levees, that are only periodically flooded; and (6) raised beaches in the deltoid plain.

Another important landform that strongly influences the land cover of the Zambezi Delta is the Inhaminga Plateau (also called the Cheringoma escarpment), a plain dipping coastwards from an elevation of 300 m above sea level at its highest point near Inhaminga to 15 m near Marromeu before it disappears under the Quaternary Deltoid Plain. There are prominent drainage lines running east and south from the Inhaminga Plateau to the Deltoid Plain that form alluvial fans as they drain rainfall-runoff to the western portions of the delta.

The vegetation cover of the delta region was mapped as "pedo-ecological units" based on a classification system developed by Loxton-Hunting (1975). The system involved visual assessment of vegetation characteristics, including species composition, canopy cover, height, density, basal cover and abundance. The resulting 1:100,000 land cover maps described seven pedo-ecological units for the Zambezi Delta, including *Communities on stratified alluvium* (mapping unit A); *Wooded grassland, grassland, and swamp grassland on the floodplain* (B); Hyphaene *and other species communities on moist sandy soils* (C); Acacia-Combretum imberbe-Spirostachys *communities on the low level terrace – high level terrace transition* (D); Acacia-Combretum *woodland and open woodland communities* (H); *Palm communities on seasonally wet floodplains* (X); and *Mangroves and associated communities* (Y). Each of these classes was further divided into subunits based on vegetation physiognomy, geomorphology, soils and microclimate. The community descriptions that follow are for the entire Zambezi Delta, with special emphasis on the southern half of the delta covered by Block 10 (Figure 2.3).

The Loxton-Hunting (1975) report remains the most comprehensive land cover mapping effort undertaken in the delta to date. The ecological descriptions for Block 10 and 11 are the oldest source of detailed land cover information available regarding historical species composition and edaphic conditions in the delta.

2.4.3 **Tinley's landscape framework**

One of the most important influences on the land use mapping efforts of Loxton, Hunting & Associates were the ecological studies of Ken Tinley. During the period 1968-1975, Tinley carried out extensive field research on the ecology and landforms of the region, from Gorongosa National Park across the rift valley and Cheringoma plateau to the Marromeu Buffalo Reserve and Zambezi Delta coast. Tinley framed the delta landscape in terms of ecological interdependence, a constantly changing 'kaleidoscope' of physical and biological components. He emphasized the soil moisture balance as the master controlling variable at the ecosystem level, with soil characteristics (such as nutrient status, pH, salinity and texture), flooding patterns and micro-relief determining individual species composition.

Because Tinley's research in the delta focused on the floodplain region near the Cheringoma escarpment, his geographic focus is complementary to the area to the east covered by the Loxton reports. In particular, Tinley emphasized the importance of the escarpment backslope drainage for the maintenance of southern delta floodplain (Figure 2.6). While the Zambezi seasonal floods were the major sediment and nutrient source replenishing the floodplain grasslands of the delta, the perennial streams that rise off the adjacent escarpment were considered crucial for the maintenance of the floodplain ecotone in the south.

Tinley identified four major landforms influencing land cover in the southern delta, including (a) alluvial fans from rivers draining the Cheringoma plateau; (b) delta floodplains of the Zambezi River, (c) estuary deltas of the Cheringoma river mouths, and (d) straight barrier beaches with recurved spits, dune ridges and small parabolic dunes. These landforms were broadly mapped and described in great detail by Tinley (1977, 1994). A brief description of each is provided below.

(a) **Alluvial fans** of perennial streams draining from the Cheringoma escarpment are interposed between Zambezi Delta deposits that extend along the coast to the Chiniziua River. The fans are covered in miombo thicket and forest, with waterlogged grasslands on the interdistributary slacks. Island thickets on termitaria dot the ends of the distributary fingers. The terminal drainage lines of the Cheringoma rivers either incised their courses as tortuous meandering streams that are tidal in their lowest reaches, or became aggraded with sand fill and alluvium that disrupted their link with the coastal estuaries.

(b) **Delta floodplains** occur at the leading edges of the alluvial fans, in a north-south meander drainage pattern following the Zambezi's old distributary courses. The delta alluvium was laid almost exclusively from the sequences of abandoned meander courses and their associated landforms of meander scrolls, cut-off meanders, interdistributary slacks and backswamp deposits. Along a few of these old distributaries, woody vegetation invaded into the grasslands along levees and meander scrolls. The major part of the area is a mosaic of freshwater and brackish marshes and grasslands, with papyrus swamps in the deeper abandoned courses. Medium height (50 cm) grasses occurred on dark hydromorphic clays, including *Setaria*, *Panicum*, *Echinochloa*, *Acroceras*, *Oryza*, *Ischaemum*, *Hemarthria altissima* and *Paspalum commersonii*. On saline clays, short grass (15-30 cm) areas are composed of *Sporobolus*, *Cynodon dactylon* and *Paspalum vaginatum*.

(c) **Estuary deltas** were formed by river and marine deposition processes, with the distributary mouths kept open by tidal scouring. On the inland margin of the mangroves are small to extensive areas of hypersaline bare mud flats. The largest such areas occur in the northern sector of the Zambezi Delta near Quelimane. These bare flats were formerly covered with mangrove until sediments trapped by mangrove roots accumulated above the high tide level and created hypersaline conditions too toxic for the mangroves to persist, as seen by dead and dying mangroves along the margins of the flats. As the bare flats become incised by springtide scour and localized rainfall runoff, the surface cuts are re-invaded by mangroves (typically pure stands of *Avicennia marina*). Mudflats located at point bar and inter-channel deposits are often colonized by dry land communities as they are leached of their excessive salt content. Except at the actual estuary mouths, where accretion is occurring, the whole Cheringoma coast is in a phase of erosion. Beach erosion by waves has already exhumed extensive areas of semi-consolidated mangrove and reedswamp muck soils. Extensive sections of dead and dying mangroves along the coastal front are exposed to direct wave action at high tide.

(d) **Straight barrier beaches** enclosing the estuary sediments are composed of parallel dune ridges and fronted by a wave-eroded shore, with small remnant sectors of hummock dunes formed by pioneer strand plants. The dune barrier is cut at intervals by tidal inlets linking the estuaries with the sea and which are constantly changing position. The peat and muds of these habitats and dead mangrove are exposed within the mid- to high-tide zone. Near the Nhandaze and Mungari distributary mouths are large areas of alternating dune and slack relief which occur in curved lines parallel to the coastline. The ridges are covered in dune thicket, with freshwater or brackish troughs in between. The younger dune ridges were initially colonized by strand plants and scrub, then gave way to dune thicket. The largest parallel dune area extends 5 km inland from the beach, but older isolated groups occur nearly 30 km inland from the delta coast. Saline grasslands or mangrove swamps separate the inland groups.

In addition to the interplay between physiography, geology, hydrology and soils, Tinley also emphasized the importance of disturbance in maintaining the land cover of the delta. Disturbance vectors in the delta range from the actions of animals to large-scale climate-driven events. In the delta floodplains, the actions of hill-building termites provide suitable sites for woody plant invasion above the level of seasonal flooding that maintained the intervening grasslands. The wallowing activities of hippo scoured and maintained open channels. On a landscape scale, the grazing machine of large herbivores exerted selective pressure on the delta grassland composition, while the mulch of grass flattened by large herds of buffalo and elephant enabled greater penetration of rain and resulted in better primary production of preferred food grasses. Dry season fires altered the physiognomy and boundaries of vegetation associations, contributing to the mosaic pattern of land cover. Meso-scale disturbance cycles, such as hurricanes, large floods or droughts, periodically superceded the local cycles of plant succession, suggesting that geomorphologically-induced substrate change, rather than zonation resulting from plant succession, was responsible for the dynamic equilibrium between plant cover and habitat change.

Tinley's thesis (1977) remains the seminal body of ecological research explaining the genesis and maintenance of the delta landscape. His period of research corresponded to the time when the effects of Kariba Dam were first observed on the delta and preparations were underway for the Cabora Bassa Dam.

2.4.4 **Environmental impact studies**

In 1973, an environmental team comprising aquatic scientists and ecologists was appointed by the colonial government of Mozambique to assess the environmental effects of Cabora Bassa Dam on the Lower Zambezi valley and related ecosystems. These studies were published in report form and in the scientific literature (e.g. Hall & Davies 1974; Davies, Hall & Jackson 1975; Davies 1975; Hall, Davies & Valente 1976; Hall, Valente & Davies 1977; Hall, Valente & Burholt 1977). The environmental team noted ecological changes already resulting from the construction of Kariba Dam, and predicted a number of changes in land cover and land utilization in the delta after construction of the Cabora Bassa. Tinley & Sousa Dias (1973) conducted wildlife reconnaissance of the Lower Zambezi Valley before the formation of Cabora Bassa.

From 1976-1981, the newly independent government of Mozambique conducted controlled wildlife culling operations in the Zambezi Delta. Tello & Dutton (1979) and Bindernagwel (1980) conducted aerial surveys and reported on the population and sustainable harvest of buffalo, elephant, waterbuck, sable, leopard, zebra, reedbuck, bushbuck, warthog, Lichtenstein's hartebeest and hippo on the Marromeu Complex. They also recorded ecological conditions in the delta, particularly after the widespread flooding of 1978/79.

In 1982, the government commissioned SWECO/SwedPower to conduct pre-investment studies for development of the North Bank hydropower station at Cabora Bassa (SWECO 1983). As part of the feasibility studies, they investigated the effects of Kariba and Cabora Bassa on the Lower Zambezi and the ecological and agricultural benefits of more natural flooding patterns.

SWECO mapped the land cover of the delta using a 17 August 1981 Landsat MSS satellite image. They conducted a supervised classification scheme to identify 32 unique spectral signatures, merged them into 15 land cover classes. The land classes included dry grassland, wet grassland, swamp, dense mangrove, wet mangrove, woodland, open shrubland, dry mudflats, wet mudflats, cultivated land, burnt land, bare soil, coastal beaches, shallow water and deep water. The map was intended to serve as a base map for future comparison to other Landsat images – detailed information was provided about the interpretation process and the spectral values for each signature used in the classification – but was mostly not used as the basis for their assessment of land cover and land utilization in the delta. Instead, SWECO generalized from the ecological regions used in the Loxton reports to assess the effects of flood regulation (Figure 2.7), with special attention to changes in agriculture, fisheries, game cropping practices and coastal mangrove utilization. Along the coast, however, SWECO mapped the distribution of mangroves in the delta based on the interpretation of the 1981 satellite image, pinpointing the location of strips of dead mangrove trees (Figure 2.8).

The SWECO studies provided the last comprehensive assessment of conditions in the Zambezi Delta before the heightened civil war precluded further research. Hydrological studies by Bolton (1983), Bernacsek & Lopez (1984), Sushka & Napica (1986) and Pinay (1988), however, continued to emphasize the impact of water resources engineering on the Zambezi River system. These reports paint a bleak picture of deteriorating conditions in the delta.

2.4.5 **Recent land cover and land use practices**

In October 1990, a survey team was hired by LOMACO to conduct an evaluation of the wildlife resources in the Marromeu Buffalo Reserve and surrounding coutadas following the cease-fire (Anderson *et al*. 1990). LOMACO owned the hunting concessions for the area and wanted recommendations for the resuming the sustainable harvest of wildlife from the delta. The team conducted fixed aerial survey transects across the southern delta floodplains to estimate the total wildlife populations in the region. They also recorded observations of land cover and land use patterns and the changes that had occurred over the civil war period. With the exception of a limited reconnaissance work by EMOFAUNA in 1989 (Chambal 1989), this was the first survey conducted over the delta since the game management surveys of 1977-1979 (Tello & Dutton 1979).

A number of ongoing studies are providing detailed accounts of changes in land cover and land use practices in the delta. Studies by Da Silva (1986), Gammelsrod (1992a, 1992b, 1996), Hoguane (1997) and colleagues are assessing the productivity of the delta shrimp industry, one of the most lucrative coastal-fishing industries in Africa.

In 1995, the Direcção Nacional de Florestas e Fauna Bravia (DNFFB) and the World Conservation Union (IUCN) launched a programme for the integrated management of the Gorongosa-Marromeu region. Two project goals relate to land use/land cover issues in the delta, conserving the biodiversity and natural resources of the Marromeu Buffalo Reserve and promoting the sustainable use of natural resources of Coutadas 10, 11, 12, and 14. Ecologists Tinley, Tello and Dutton were hired as consultants to provide a long-term perspective on changes in the region. The project includes socio-economic surveys and further wildlife reconnaissance surveys of the delta. A map shows the latest distribution of communities in the southern half of the delta, with a concentration of settlements along the main Zambezi channel, inland from Malingapans north to Marromeu, and west of Chupanga (Boyd & dos Santos 1997). Southward expansion of the Marromeu reserve to include the coastal mangroves, estuarine, dune and seashore areas is being promoted to protect key linkages across the landscape (Tinley 1994, Sousa 1997).

Most recently, the IUCN Zambezi Basin Wetlands Conservation and Sustainable Utilisation Project was initiated in 1996 to ensure the wise use of natural resources in the wetlands of the Zambezi Basin, including the Zambezi Delta. A series of IUCN reports describe current land use patterns in the Zambezi Delta (Schmidt 1997, DNFFB 1998, DNFFB 1999). As part of a pilot project for palm wine production, the DNFFB team carried out an inventory of two units totaling 33,600 ha of *Borassus aethiopum* palm and associated species (including *Hyphaene coriacea* and *Phoenix reclinata*) in a mosaic of grassland, savanna and old agricultural fields. DNFFB also surveyed 5500 ha of coastal mangrove communities, including Chinde, Pambane Island, Nyamatamanga Island, Nova Quelimane Island, a zone along Nhamacarre River, Marruma and Mucutchabondo Island, and Inhamissengo Island. The study identified the local uses for each of the nine species of mangrove and their regeneration potential.

Another of the Zambezi Basin Wetlands Project activities is to assess the importance of biodiversity from a conservation perspective. The Zambezi Society and the Biodiversity Foundation for Africa were contracted for this work, which includes producing a vegetation map of the Zambezi Delta. Vegetation mapping is based on the visual classification of a 1996 Landsat TM satellite image with local ground truthing. Four vegetation classes are recognized, including forest and woodland, savanna, grassland and swamp, and estuarine and coastal vegetation (J. Timberlake, pers. comm.). These are further described in Vol II, Chapter 1, Appendix 1.1 of the project report.

Finally, the Joint Venture IGNFI-CENACARTA produced a series of 1:250,000 land use/land cover maps for Zambezia and Sofala provinces, including the Zambezi Delta (shown in part in Figure 2.1). Floodplain grasslands are classified as natural grassland (controlled by edaphic conditions, with seasonal or permanent waterlogging) and anthropogenic grassland (created by forest clearing for grazing or agriculture). Natural grasslands that are inundated throughout the year are classified as "aquatic meadow", and high water table wetlands subject to seasonal flooding are classified as "meadow, liable to flood". Other mapping units include bare soils, mangrove, shrubland, medium thicket, tall thickets, bushland, wooded grassland, scrub wooded grassland, open woodland and woodland. Each mapping unit, with the exception of mangrove, is subdivided into natural and anthropogenic origin.

2.5 LAND COVER MAPPING AND CHANGE

2.5.1 **Land cover mapping**

Figures 2.11 and 2.12 show the land cover of the southern half of the Zambezi Delta in 1960 and 1999, respectively. Thirteen land cover classes were adopted for the purpose of ecological differentiation in the delta following the concept of "pedo-ecological units" used by Loxton-Hunting (1975) and Tinley (1977). Pedo-ecological units are broad natural units representing the interplay of climate, vegetation, physiography and soils. A single pedo-ecological unit may represent a range in vegetation type, density or physiognomy within an association. The physical and biological conditions that distinguish between two pedo-ecological units are rarely abrupt in space, but rather occur along a continuous gradient. Therefore, the boundaries between the land cover classes should not be viewed as fixed, nor should the composition of a particular land cover class be viewed as uniform. The 1960 airphoto mosaic and the 1999 satellite image (Figure 2.13) were used for mapping land cover. Community descriptions were compiled from J. Timberlake (pers. comm.), Tinley (1994), Loxton-Hunting (1975) and personal observations.

Dry *Milletia* forest with pans occurs on well-drained, sandy soils of the Cheringoma escarpment. The dense canopy includes *Millettia stuhlmanni* (Panga-panga) and *Pterocarpus angolensis*, with a well-developed deciduous substratum. Ovoid pans are spotted throughout the dry forest, possibly formed from eroded termitaria (Tinley 1977). Pans have distinct zonation pattern, with a ring of *Hyphaene* palms and mixed woodland at the periphery, surrounding a ring of short grasses and sedges on saturated soils, surrounding a centre areas of emergent and floating aquatic species, including *Typha latifolia, Nymphaea* spp. and *Cyperus papyrus*, in shallow standing water. The unit is clearly identified on airphotos and satellite imagery, with discrete boundaries.

Alluvial fans with miombo woodland and wet grassland slacks drain from the Cheringoma escarpment to the delta plain. The fans are covered in *Brachystegia* miombo thicket and forest, grading from dry *Millettia* forest on well-drained sandy soils higher on the escarpment. The interdistributary swales support wet grassland species on high water table sands, with a large number of termite mounds supporting wooded thickets. The unit is clearly identified on airphotos and satellite imagery, with boundary a gradation between wet slacks and open floodplain.

***Acacia-Borassus* woodland with mixed cultivation** occurs on the more elevated floodplain areas along the Zambezi River near the apex of the delta. Also occurs extensively across the floodplain north of the Zambezi. Primarily *Acacia* open woodland with varied associations of *Combretum imberbe* and other canopy species on slightly elevated ground and increasing composition of *Borassus* palm towards lower floodplain areas. It is extensively cultivated in parts. Dense woodland is clearly distinguished from open palm savanna on aerial photos, but medium density, transitional areas are difficult to distinguish. The unit is more difficult to distinguish on satellite imagery.

***Borassus* and *Hyphaene* palm savanna** associations are extensive in the southern half of the delta. *Borassus aethiopum* palm savanna, ranging from 5-25% canopy, occurs in the middle elevation floodplain areas between the *Acacia-Borassus* woodland and floodplain grasslands. It is often mixed with extensive cultivation, covering up to 40% of land area. The density of palms is highly variable, approximately 51 trees/ha near Marromeu, but ranging from 17-80 trees/ha (DNFFB 1998). *Hyphaene coriacea* palm savanna occurs on wet sands along the dry forest-floodplain ecotone and extends far into the floodplain grasslands on relatively wetter soils than *Borassus* savanna. Associations of *Borassus, Hyphaene* and *Phoenix reclinata* occur on the slightly drier levees of abandoned alluvial channels. The unit is clearly distinguished from open floodplain on airphotos, and is broadly distinguished from open floodplain on satellite imagery, but transition areas are difficult to define (probably related to percentage of canopy cover and soil moisture).

Floodplain grassland with papyrus swamp is a broad mosaic of grass and sedge associations ranging from bunch grasses on the seasonally flooded plains, through stoloniferous grasses in the near-perennially inundated depressions, to papyrus swamp, often bordered by *Phragmites* reed associations, in old anastomosing channels. Both inland freshwater grasslands and coastal saline grasslands are included. There is a large expanse of papyrus and reed swamp in the floodplain of the Cuacua distributary channel along the northern edge of the delta. Tinley (1994) identifies 22 grassland associations on hydromorphic soils of the southern delta, including *Echinochloa-Acrocera-Oryza* clays, *Bracharia* on duplex sands, and *Diheteropogon* on leached clays. Loxton-Hunting (1975) differentiate five associations to the east of the Mungari River. This unit includes less than 2% cover of woody species and grades into palm savanna at the upper margin. It is broadly distinguished from adjacent communities on airphotos and satellite imagery. Subunits of grassland associations are not readily distinguished from airphotos and are therefore lumped together, although flooded areas appear darker. Grassland appears as a mosaic of spectral data on satellite imagery, with clear signatures for papyrus swamps and general spectral differences between seasonal and permanent flooded areas.

Communities on ridge and swale terrain occur on raised dune ridges all along the coast and up to 15 km inland from the Indian Ocean. A broad mix of dune thicket, woodland, dry forest, and palm savanna associations on high ridges with medium saline grassland in the high water table swales. Ridges extensively planted with coconut, particularly north of the Zambezi. Swales are used for rice cultivation near Chinde, often with vegetables on the slopes between rice paddy and coconuts. It is clearly identified on airphotos and satellite imagery, with discrete boundaries.

Mangrove and associated communities occur all along the coastline on tidally influenced clay muds. The mangrove unit includes nine species of mangrove in typical zonation patterns with *Avicennia marina-Ceriops tagal, Rhizophora mucronata* and *Bruguiera gymnorrhiza*. The unit is heavily cultivated in areas, especially near Chinde. It also includes evergreen "inland mangrove" thicket of *Barringtonia racemosa* and associated species along tortuous meandering tidal channels that extend far into the saline grassland floodplain. Mangrove areas are clearly identified on airphotos and satellite imagery. The transition between coastal and inland mangrove associations is difficult to pinpoint on airphotos, and are therefore lumped together, but can be clearly differentiated on satellite imagery.

Saline mudflats and associated communities occur in association with coastal mangrove on hypersaline soils. They are sparsely vegetated with succulent and scrub species, and invaded at the fringe by mangrove thicket. The unit includes abandoned cultivation and clear-cut areas. The mapping units are small but clearly differentiated from mangrove on airphotos and satellite imagery.

Dune grassland and open beaches occur intermittently along the coast above the high water mark. They are carpeted by saline grasslands and shrubs on the crests of sand dunes. Foreshore dunes are covered by trailing pioneer species and annuals. The unit is clearly differentiated on airphotos and satellite imagery.

Communities on stratified alluvium with mixed cultivation occur as narrow bands along the natural levees of the Zambezi River, Salone depression and other prominent drainage channels, and in old abandoned channels. They include a mix of riverine thicket and *Acacia* woodland, often mixed with canopy of cultivated plants. Emergent marsh vegetation fringing the main river channel was not mapped separately. Alluvial formations are clearly differentiated on airphotos and satellite imagery, though they are difficult to distinguish from palm savanna on levee backslopes of small channels or from *Acacia-Borassus* woodland on upper floodplain reaches.

Secondary grassland derived from cultivation includes widespread areas near the Zambezi River that have been cleared for cultivation during the past century and have since reverted to grassland and thicket. They include tall *Hypparhenia* and *Setaria* grassland, occasionally with scattered *Borassus* palm savanna. They are mostly derived from *Acacia* woodland and *Borassus* palm savanna. In the 1999 land cover map, areas of abandoned sugar plantation are included. The unit is broadly distinguished from palm savanna and *Acacia-Borassus* woodland, although it is difficult to pinpoint transition zones.

Sugar plantations occur near Marromeu and Luabo, and are dissected by communities on stratified alluvium. They include widely scattered palm trees and cultivars, and are easily mapped from the 1960 airphotos by the distinctive irrigation grid pattern. This is mostly indiscernible on the 1999 satellite imagery.

Open water includes the Zambezi River and its distributary network, abandoned oxbow lakes and coastal inlets. It also includes shallow water lakes near the Cheringoma escarpment, although these are difficult to identify when densely covered with floating aquatic vegetation. Open water areas, particularly rivers and inlets, are easily distinguished on airphotos and satellite imagery. Vegetated sandbars and exposed sandbars are distinguished from open water areas in the main channel.

2.5.2 **Changes in land cover**

A comparison of the land cover maps and remote sensing imagery, in combination with repeat aerial surveys and field observations over the past thirty years, reveals several broad patterns of land cover change in the delta over the period 1960-1999. These include invasion of the open floodplain grasslands by palm savanna and *Acacia* thicket, displacement of flood-tolerant wetland species by dryland species and displacement of freshwater grasslands by saline grasslands, drying out of abandoned alluvial channels, loss of coastal and inland mangrove and associated evergreen thicket, geomorphological changes on the delta coast and inland sandbars and salinisation of wetland soils.

In the southern half of the delta, palm savanna is spreading into the upper margin of the open floodplain, decreasing the overall area of core floodplain contiguous with the Marromeu Buffalo Reserve. Extensive areas of young *Hyphaene* palms, up to 25% cover, were observed in several areas of the delta that were clearly open floodplain on the 1960 airphotos. The palms appear to be radiating into the open floodplain from the backslopes of elevated levees along abandoned distributary channels, where associations of palm and woodland thicket were present in 1960 (Figure 2.14). In the many floodplain areas where palm savanna occurred in 1960, the overall density of palms has increased, and young palms have colonized isolated patches of open floodplain (Figure 2.15). There has also been an increase in the extent and density of *Hyphaene* palms on moist sands at the base of the Cheringoma escarpment. In the southern coastal area, palm savanna has increased from less than 2% cover in isolated patches to more widespread areas of 5-10% cover (Figure 2.16). Some of these changes have been observed for over twenty-five years. Loxton-Hunting (1975) reported that *Hyphaene* was invading into *Setaria* and *Hyparrhenia* grassland units in the low-lying parts of the floodplain. Anderson *et al*. (1990) reported widespread encroachment of woody species into the floodplain during the period 1979-1990. Overall, it is difficult to quantify the change in palm density across the delta, because many areas have experienced an increase in the percentage of palm cover in addition to an invasion of previously unoccupied areas. Nonetheless, palm encroachment is clearly the single most important factor responsible for the reduction of open floodplain in the southern half of the delta.

North of the Zambezi, the most widespread land cover change is the invasion of *Acacia* woodland into the dry alluvial open floodplain. This process was first reported by Tinley (1975), who considered the invasion of clay-savanna tree species, including *Colophospermum mopane, Acacia borleae* and *Acacia polyacantha*, into the floodplain grasslands to be the most conspicuous widespread in-situ change in the delta landscape. Loxton-Hunting (1975) reported the encroachment of *A. polyacantha* into low-lying sites in the northeastern floodplain areas. Based on these observations, they predicted that woody vegetation would continue to encroach upon vast areas of floodplain grasslands from the upland margin, and this appears to be the case. A comparison of the Loxton-Hunting (1975) land cover maps and current satellite imagery reveals a dramatic restriction in the extent of open floodplain, which is now mainly restricted to the floodplain areas south of Luabo towards the coastline.

In the southern delta, *Borassus* palm savanna is also being invaded by *Acacia* woodland from the more elevated floodplains northwest of Marromeu. Areas of young deciduous trees were observed in mature *Borassus* canopy near the savanna-woodland ecotone, and areas reported by Loxton-Hunting (1975) as open *Borassus* savanna now contain dense woodland elements. Several open floodplain areas in *Acacia* woodland that were observed on the 1960 airphotos have also filled with woody species. Although not investigated during the present study, Loxton-Hunting (1975) also predicted that *A. polyacantha* open woodlands would develop into *Acacia-Spirostachys* thicket at the Cheringoma ecotone.

In the open floodplain grasslands of the delta, conditions appear noticeably drier during the dry season than during the period prior to 1979. Anderson *et al.* (1990) reported that there was a widespread reduction in flooded and open water areas between 1977 and 1990. These studies suggest the possible displacement of more flood-tolerant wetland species by more dryland species, and displacement of freshwater grasslands by more saline grasslands, as predicted by Tinley (1975, 1977) and Loxton-Hunting (1975). The degradation of the floodplain grasslands is of particular concern as it relates to the carrying capacity of the floodplain for large herbivores. Anderson *et al.* (1990) reported that the desiccation of the floodplain had accelerated the replacement of wetland vegetation by dryland vegetation, rendering the floodplains less favourable for the buffalo, waterbuck and reedbuck. Coutada operators in the delta now complain that the foraging quality of the delta grasses has decreased.

For the current study, we attempted to map certain grassland species, including the spike rush *Eleocharis angulata,* on satellite imagery using known GPS coordinates. However, the limited 30 x 30 m ground resolution of the images blurred the spectral signal for these and other species associations in the grassland mosaic. Extensive groundwork is therefore required to map the grassland species associations in the delta relative to edaphic conditions, although the extent of stoloniferous and bunch grasses may be differentiated by aerial survey. It should also be noted that comparison of changes in grassland composition relative to historical conditions is limited to the floodplain areas mapped by Loxton-Hunting (1975) east of the Mungari River.

Another land cover change in the floodplain grasslands is the drying out of abandoned alluvial channels. Most of the abandoned drainage lines in the delta are now invaded with grassland and floating aquatic species, and open water channels are rare. Anderson *et al*. (1990) also show a drainage line invaded by *Echinochloa crusgalli.* Invasive species such as *Eichhornia crassipes* (water hyacinth), *Salvinia molesta* (Kariba weed), *Pistia stratiotes* (Nile cabbage) and *Azolla filiculoides* (water fern) are now present on the delta waterways, but were not widely observed prior to 1979.

Towards the delta coastline, a number of land cover changes are also in evidence. Between 1972 and 1990, the total cover of mangrove was reduced by 4.9% in Zambézia Province and 2.4% in Sofala Province (Saket & Vasco Matusse 1994). Mangrove deforestation is highest near Chinde. Extensive areas of dead and dying mangrove are apparent all along the delta coastline, particularly near the Chinde, Catarina and Cuama distributary mouths. Mangrove clear-cut areas were also observed near the coast. The die-off of coastal mangrove has been reported since the early 1970s by Tinley (1975, 1977) and Loxton-Hunting (1975). Davies *et al*. (1975) reported an up to 400 m die-back along most of the coastal frontage. SWECO (1983) mapped areas exhibiting strips of dead mangrove on the delta coastline, and noted large areas of mangrove were cleared for agricultural lands, or degraded to shrub thicket after clear-cutting. DNFFB (1998) noted that the coastal mangrove has a high regeneration and propagation capacity.

At the inland margin, coastal mangrove associations have given way to associations of evergreen thicket, and these thickets in turn have given way to saline floodplain grasslands at the upper extent of tidal influence (Figure 2.16). The tortuous coastal inlet channels, draining from the Cheringoma escarpment to the west and papyrus waterways in the central Marromeu floodplains, have constricted in width and are colonized by grassland species. The continuous process of mangrove loss is further evidenced by the presence of saline mudflats in areas formerly covered by mangrove. Loxton-Hunting (1975) observed that drier mangrove phases were regressing to *Sporobolus* grasslands where local road works had blocked tidal drainage north of the Zambezi. Although small in overall extent, the loss of mangroves at the inland margin is occurring at all the major distributary channels along the delta coastline.

The delta coastline has also changed dramatically over the past forty years, particularly where the barrier beaches are actively cut by Zambezi distributary channels. Changes in the distribution of coastal mangrove associations, communities on saline mudflats, communities on ridge and swale terrain, and dune grassland and open beaches are evident related to these geomorphological disturbances (Figure 2.17). The coastal port of Chinde has been relocated twice after geomorphological changes at the Zambezi mouth destroyed the original settlements (White 1993). SWECO (1983) reported that coastal changes associated with sedimentation and erosion processes were frequent, such as mud islands colonized by mangrove and erosion scars along the coast and estuaries, but difficult to estimate. They noted that mangrove areas that had eroded away, and sediments that were stabilized and colonized by mangrove, could only have been detected if accurate maps were available before and after the changes occurred. Ongoing coastal erosion and mangrove recolonization are evident along the Zambezi mouth near Chinde, but have not been mapped.

Between 1960 and 1999, many of the sandbars on the Lower Zambezi have stabilized and are now permanently vegetated with riverine grassland and cultivated fields. In 1960, the Zambezi was characterized as a braided river of wide channels, with rapid shifting of bed materials and continuous shifting of the position of the river course. Sandbars were created at point bars on the convex side of river meanders, and meander scrolls were formed as the channel migrated laterally across the active floodplain. From the 1960s through the 1970s and 1980s, the Zambezi downcut a permanent channel in the floodplain alluvium (Figure 2.18). Several square kilometres of Inhangoma Island disappeared between 1960 and 1972 (SWECO 1983). Currently, most of the lower Zambezi River is a stable, braided meander chain of rivulets weaving between consolidated islands (Davies *et al*., in press). Exposed sandbars now occur in the tidal zone towards the coast.

Finally, although soil salinisation was not investigated during the current study, numerous previous studies have suggested that soil salinisation is occurring and affecting land cover in the delta. Tinley (1975) argued that substrates once highly productive throughout the year were now productive only during the rainy season, and that many soils had become alkaline or saline. He reported that during the initial filling of Cabora Bassa Reserve, saltwater intrusion occurred up to 70 km inland from the coast. Loxton-Hunting (1975) also claimed that soil salinisation was occurring in the upper reaches of the delta. SWECO (1983) observed, however, that no tangible evidence had yet been given for accelerated salinisation in the delta and it is uncertain if, or to what extent, the area covered with saline soils has increased. They noted that almost all of the vertisols in the delta are saline at a depth, and salinity in surface soils naturally increases with decreasing distance to the sea.

2.6 FACTORS INFLUENCING LAND USE AND LAND COVER CHANGE

2.6.1 **Water resources development projects**

Over the past half-century, water resources development projects have greatly altered the hydrology of the Zambezi Delta. Prior to the construction of Kariba Dam on the Middle Zambezi, peak floods inundated a mosaic of habitats in the 18,000 km^2 Zambezi Delta – flooding an area at times comparable in size to the Okavango Delta in Botswana (White 1993). Maximum flow in the Lower Zambezi occurred in March-April, several months after maximum precipitation in the Upper and Middle Zambezi. Low-lying floodplains were inundated with floodwaters for up to nine months of the year, and many areas were saturated throughout the dry season (SWECO 1983). With the closing of Kariba in 1959, approximately 54% of the total Zambezi runoff became regulated. The vast Lake Kariba reservoir now captures the transient minor flood (known locally as "gumbura") generated by local rainfall in the Middle Zambezi catchment, and effectively reduces and regularizes the major annual inundation ("murorwe") from the upper Zambezi catchment area (Davies 1986). These hydrological impacts were further exacerbated by the damming of the Kafue River, the most important Zambezi tributary below Kariba Dam. Nearly 90% of the total Zambezi catchment runoff is now controlled by Kariba and Itezhi-Tezhi Dams (RPT 1979, SWECO 1983).

Despite these changes in the Zambezi's hydrological regime, the sheer volume of floodwaters reaching the Lower Zambezi continued to seasonally inundate the floodplains of the delta until the construction of the massive Cabora Bassa dam in 1975. With the closing of Cabora Bassa, the last vestiges of the ancient floodcycles of the Zambezi River have been nearly eliminated. Only four significant tributaries enter the Zambezi below Cabora Bassa, and of those, only the Shire River is perennial. Flooding events in the Zambezi Delta, when they occur, are now dependent upon local rainfall within the Lower Zambezi sub-catchment, or unplanned (possibly catastrophic) water releases from Kariba Dam (RPT 1979). The timing, magnitude, duration and sediment deposition of these floods now differ greatly from natural flooding conditions (Suschka & Napika 1986, Beilfuss & Davies 1999). The last unobstructed major Zambezi flood occurred in 1958 (Tinley 1994).

These hydrological changes are further exacerbated by the construction of dykes along the lower Zambezi to protect the Sena Sugar plantations at Marromeu and Luabo. Dykes were set at the elevation of the 1926 flood peak and prevent floods of less than 12,000 m^3/sec from inundating the Marromeu floodplains (Bolton 1983). This level has been exceeded only in 1939, 1940, 1952, 1958 and 1978. Prior to that time, floods of 5,000 m^3/sec or more were sufficient to inundate the Marromeu Complex on an annual basis. Such flows lasted on average for 79 days (RPT 1979). The railway line constructed between Marromeu to Inhaminga and the road between Marromeu and Chupanga further impede drainage through several important distributor channels in the northwestern portion of the delta or Solane depression. The cumulative impact of these developments is a dramatic reduction in flooding and natural siltation on the south bank of the Zambezi during moderate flood years. The southern delta can now only be inundated by exceptional floods that recurve southwards downriver of Marromeu town to inundate the southern delta area (Tinley 1994). The western portion of the Marromeu Complex is now fed primarily by silt-free runoff from local rainfall on the Cheringoma Plateau. Beilfuss & Allan (1996) observed the Lower

Zambezi River more than 2 m below bankful discharge in the delta during the period when peak floods historically occurred.

Prior to the construction of Cabora Bassa Dam, a number of experts expressed concern about the detrimental impacts of water resources development on land cover and land use practices in the delta. These concerns were based on observed land cover changes that had resulted from changes in the flooding regime due to artificial levee construction near the Sena Sugar Estates and the operation of Kariba Dam. Loxton-Hunting (1975) argued that any further disturbance to the flood regime, whether by construction of dams, artificial levees, roads or natural blockage of drainage lines, would lead to rapid and undesirable changes in the delta. Tinley (1975) was also gravely concerned about the influence of hydrological changes on the ecology of the delta, stressing that the overwhelming factor determining the spatial distribution of forest, savanna and grasslands in the delta was the delicate soil moisture balance. Tinley was particularly concerned that with the construction of Cabora Bassa Dam, the southern delta alluvial grassland would become increasingly dependent on local runoff from the Cheringoma Plateau. He noted that the nutrient-deficient peaty blackwaters from the Cheringoma carry no silt, and therefore cannot substitute for the silt-laden Zambezi floodwaters. These concerns were fuelled when Cabora Bassa dam commenced filling in the fastest possible time and against the recommendations of the environmental impact assessment team for maintaining minimum flow releases (Davies 1998).

2.6.2 Natural geomorphological processes

The Zambezi Delta is a dynamic system, undergoing constant geomorphological change in response to the natural processes of erosion and sedimentation. Shifts in channel morphology near the coast have been described since the Livingstone expeditions of 1958-1863. Maugham (1910) commented:

> "A place which we call Chinde exists, it is true, but not the Chinde whose acquaintance I made fifteen years ago. That Chinde has long ago been born away in suspension in the eroding waters of the Zambezi, and now lies either at the bottom of the river, or has gone to strengthen the innumerable bars and sand-spits which constitute such a danger to vessels entering the tiny port. In a word, the Chinde of the [eighteen] nineties has been gradually washed away, and the present aspect and appearance of the townlet is as of one which the waters have suddenly invaded, engulfing one portion and still menacing the other.....since I have known the Chinde, a valuable strip of fully 200 years has completely disappeared from the existing river bank, the width of the stream at this point having proportionately increased."

Since the construction of Kariba and Cabora Bassa, the interpretation of geomorphological change along the delta coastline is confounded by alternative explanations for the phenomena observed. For example, Tinley (1994) observed that the delta coast and some 200 km on either side of it has been in a state of ongoing regression for about 35 years, with mangrove tree stumps and estuarine muds now exposed in the low tide surf zone of the open ocean. This time frame is coincident with that since the Kariba Dam was constructed. Reduced sediment load in the Zambezi River below Kariba, particularly the coarse sand fraction, therefore may be starving the unconsolidated coast of adequate sand supply, resulting in accelerating erosion and a receding shoreline (Tinley 1971, 1977). However, Tinley (1994) also notes that natural isostatic downwarping from the weight of the delta sediments and the slowly rising sea-level are also plausible explanations.

Taken over the 40 year period, the cumulative lack of annual sediment deposition in the delta estuaries caused by Kariba and Cabora Bassa would seem a reasonable explanation for the extensive tracks of dead mangrove observed at the mouths of the Zambezi during this study. However, mangrove die-off along the delta coast has been reported since the early 1970s, and the strips of dead mangrove were mapped by SWECO (1983) near the Rio Catarina. Attributing this die-off to Kariba Dam would suggest a large reduction in coastal sedimentation and a very rapid geomorphological response to the disequilibrium between coastal erosion and sedimentation. This is possible, but seems unlikely given that 50% of the Zambezi catchment occurs below Kariba Dam and the silt-hungry river was observed rapidly eroding its banks and bars along the Middle Zambezi to regain a quasi-equilibrium silt load (Begg 1973).

The dead mangrove communities observed at the Zambezi mouth may therefore be the result of natural geomorphological processes. In fact, studies are now underway to determine if a net loss of coastal mangroves is occurring at all, because mangroves are actively recolonizing the delta mouths as well (GEMA 1999). B. Chande (pers. comm.) reports that villagers living near the delta coastline do not think that there has been a net loss of mangroves, and recall that coastal mangrove die-off has occurred for many generations. However, sediment trapping by Cabora Bassa Dam that controls nearly 90% of the Zambezi catchment, is likely to have significant consequences for coastal morphology over time. As SWECO (1983) concluded:

> "It is impossible to state whether an equilibrium currently exists between the eroding and depositing forces or if, or when, this condition will occur. If protection of the mangrove is contemplated, one must obviously start by considering measures to decrease the direct impact of clear-felling practices. First of all, however, reliable quantitative and qualitative background data are needed on the physical parameters, such as sediment transport and accumulation in the delta region, current and coastal morphology, as well as on the biotic environment and its prerequisite for survival and development."

2 .6.3 **Drought cycles**

From 1980 through 1994, southern Africa experienced prolonged drought throughout the Zambezi Basin. At Songo, mean annual rainfall during the rainy season months of December-March decreased by 28%, from 771 mm/year during the period 1955-1973, to 566 mm during the period 1980-1994, or by more than 36% to 490 mm/year if the aberrant wet season of 1988 is excluded. Total rainfall in 1991 was the minimum on record (de Vries *et al*. 1997).

Because this period of drought coincides with the period since the last significant flood occurred in the Lower Zambezi (1978/79), it is difficult to discern whether land cover and land use changes attributed to the water resources development in the Lower Zambezi are actually due to the influence of large dams/dykes or to natural drought cycles. These changes include invasion of the open floodplain grasslands by palm savanna and *Acacia* thicket, displacement of flood-tolerant wetland species by more upland species and displacement of freshwater grasslands by more saline grasslands, drying out of abandoned alluvial channels and salinisation of wetland soils, as well as the loss of floodplain fisheries and the increased frequency and extent of fires.

One method to try to separate out the influence of drought and flooding cessation is to examine wetland pans in the dry *Millettia* forest that are not directly influenced by Zambezi flooding. Several pans were investigated in Coutada 11, and we observed young *Hyphaene* palms growing up to the edge of the shallow water zone, and dry forest species invading into the outer margin. Local landowners reported that the woodland thicket had encroached into the pans over the past 10-15 years, suggesting a direct response to drought conditions. The landowners also insisted, however, that the hydrological changes were due to Cabora Bassa Dam, claiming that the Zambezi in natural flood used to back up the headwater streams such as the Mungari into the Cheringoma escarpment and caused high water table conditions in the sandy substrate of the pans.

There are two additional arguments against the influence of drought as the major causal factor in the invasion of woody species into the delta. One is the observed encroachment of woody species into the delta floodplains in the 16 years following construction of Kariba Dam, a climatic period characterized by above-average rainfall. Loxton-Hunting (1975), for example, reported:

> "Widespread encroachment of *Acacia* spp. and *Hyphaene natalensis* into grasslands has already occurred in the drier floodplains, probably as a consequence of flood protection works along the Zambezi and reduced incidence of flooding due to Kariba."

The other argument is that climatic cycles are a regular feature of southern Africa, and there is no evidence of woody invasion during past drought periods.

Mukosa *et al*. (1995) classify the 80- year rainfall record for central Zambia into four periods: a dry sequence from 1907 to the mid-1920s; a normal sequence from the mid-1920s to 1947/48; a wet sequence from 1947/48 to 1979/80; and a dry sequence from 1980/81 to 1991/92 (and continuing to 1994/95). It is possible that woody species invaded the delta during the extended drought period of the 1910-1920s, and later died back during the nearly 60-year period of normal to above average rainfall. Accounts by local villagers, however, suggest that the floodplains were extensive open expanses for many previous generations. It is interesting to note that the end of the last dry period coincides with the construction of flood control dykes around the Sena Sugar Estates, suggesting the possibility that natural flooding in the southern delta has been reduced for nearly a century.

Overall, both drought and the reduced incidence of flooding due to dams and dykes are likely to have been responsible for land cover and land use changes in the delta, and their combined influence may have accelerated this process. Future studies during the current wet cycle should further enable ecologists to tease out the differing effects of these phenomena.

2.6.4 **Economic development**

The history of land use in the delta reflects a continuous pattern of change in response to the economic development of agriculture, fisheries, wildlife and natural resources. Of these, subsistence and commercial agricultural development have had the greatest effect on the natural land cover of the delta, particularly the quality of floodplain grasslands, palm savanna, and acacia woodland, as well as on coastal and inland mangrove and associated evergreen thicket.

As noted earlier, maize, millet and sorghum have displaced natural communities on stratified alluvium. Sorghum and millet are planted in drier, high-lying areas close to the river north of Marromeu. Slash and burn practices were common for clearing agricultural fields, removing forest cover and reducing soil fertility. Rice agriculture has had the biggest effect on land cover in the delta. It is cultivated in alternating row crops with coconut in the ridge and swale terrain of the coastal zone. The rate of land conversion to subsistence agricultural production in the delta was slowed by compulsory cash cropping in the early 1900s, by the State-run agricultural cooperative system after independence, and by the prolonged civil war (Negrão 1995). During the early 1980s, about 30,000 ha of floodplain near Quelimane was occupied by 200,000-300,000 small-scale rice farmers. The current population is considerably less, and many rice production areas have reverted to coastal thicket. Rice is also cultivated on coastal mudflats that have been cleared of mangrove forest (DNFFB 1998).

Commercial sugar plantations have also profoundly changed the delta landscape. Prior to the 1980s, 14,000 ha at Marromeu and 10,000 ha at Luabo were under sugar plantation, and there were plans to develop ultimately 54,000 ha on the south bank and 45,000 ha on the north bank (Turpie *et al*. 1998). These fertile floodplain areas reverted to thicket and savanna during the civil war period, but are now being actively restored and expanded.

Grazing potential in the delta region is high, particularly in the seasonally inundated floodplain grasslands and open *Acacia-Borassus* woodlands (Loxton-Hunting 1975). Prior to the 1980s, livestock grazing was widespread in the delta, but currently livestock are uncommon. Although livestock restocking programs are underway, grazing pressure will remain low for some time relative to historic conditions.

Prior to the 1980s, fishers concentrated in large numbers on the Zambezi floodplains, with seasonal fishing camps spread throughout the area between the main Zambezi channel and Mungari River distributary. Currently, subsistence fishing activity is restricted to the main channels. Most of the fishing camps are found in the coastal waters of Chinde District. This may represent a permanent economic transition because the youngest generation of fishers in the delta prefer the riverine fishery, and especially the more lucrative coastal fishery to the hazards of floodplain fishing (B. Chande, pers. comm.)

The economic exploitation of wildlife in the Zambezi Delta has been great throughout recorded history, particularly for commercial ivory and culling operations. The role of hunting in the subsistence economy has remained relatively small. Wildlife populations were most recently decimated during the civil war, and have not recovered. Limited safari hunting is now under the jurisdiction of the coutadas.

The impact of economic development on other natural resources in the Zambezi Delta has been substantial. Dry forest areas of *Millettia stuhlmanni* and *Pterocarpus angolensis* are harvested for construction materials and firewood. Commercial forestry practices in Sofala and Zambézia provinces that are removing large quantities of timber have been reported since the early 1970s (Loxton-Hunting 1975, Tinley 1977) and continues today outside of the immediate delta region (Hatton & Munguambe 1997). DNFFB (1998) determined that *Borassus* palms are heavily utilized in some floodplain areas. Fronds are used for roof coverings and sap is used to make traditional palm wine. Coastal mangroves are affected by selective-cutting and clear-cutting practices. The impact of selective felling is difficult to observe because only certain trees were removed from the canopy, but eight of the nine mangrove species are known to be harvested for construction poles and firewood (DNFFB 1998). SWECO (1983) reported that clear-cutting practices were widespread in the delta region, and the single-most important reason for the decrease in coastal mangrove. They observed large areas of mangrove that were transformed into cultivated land, or degraded to shrub thicket after clear-cutting for termite-resistant building materials. Coastal mangrove destruction has been particularly severe near Chinde (DNFFB 1998).

In summary, Loxton-Hunting (1975) observed:

> "The direct and indirect influence of human activities have had profound effects on the ecology of the area. Many of these effects are very recent whereas others are a consequence of centuries of human occupation. Clearance of vegetation for crop cultivation is the most prominent and direct influence of man on vegetation. Large areas of miombo woodlands and

mixed woodlands occur as mosaics of relict woodland, cultivated lands and various stages of secondary regrowth. Levee areas on floodplains have been extensively cultivated in the recent past but lands have been abandoned over large areas due to incompatibility of cultivation and cattle. The indigenous vegetation on the coastal dunes has been virtually eliminated by coconut plantations and small holder plots."

2.6.5 **Civil war**

The 17-year civil war in Mozambique greatly changed the face of the country. Hundreds of thousands of people were killed, especially in rural areas, and at least three million people were displaced from their homes (Nordstrom 1993). Many rural people migrated to cities, especially along the coast where the government retained control. The country went into severe economic depression (Kyle 1991). Agriculture was disrupted, so the country could not feed itself. By the late 1980s, Mozambique had one of the lowest per capita caloric intakes in the world (Sill 1992).

The civil war also had a profound effect on the land use and land cover in the Zambezi Delta. Some natural resources benefited from the hiatus of economic activity during the civil war, but others were decimated. Human populations in all the delta districts declined, and those villagers who remained aggregated around Chinde and Marromeu. Most agricultural fields were abandoned and reverted to secondary grassland, palm savanna and *Acacia* thicket, particularly in the Sena Sugar Estates after destruction of the sugar processing facilities. The deciduous woodland area towards the railway line was largely depopulated. Relative to the land use reports of Hidrotechnica Portuguesa (1965), Loxton-Hunting (1975), Tinley (1977) and SWECO (1983), it seems likely that the impact of human activity on the vegetation communities of the delta was recently at its lowest level in the past 40 years, and perhaps the past century. Wildlife populations, on the hand, were devastated by military hunting operations, with a 90-95% population reduction in buffalo, waterbuck, reedbuck, zebra and hippo between 1985 and 1992 (Anderson *et al*. 1990, Tinley 1994). Near 'safe zones' where people congregated during the war, there was intensive local pressure on natural resources and woodland thickets were cleared for firewood (Schmidt 1997). Livestock numbers were depleted, and still remain very low.

Mozambique has now enjoyed seven years of peaceful rebuilding since the 1992 cease-fire brought an end to the civil war. Some land use practices have returned to their pre-war levels, others are changing in response to new socio-economic opportunities (Turpie *et al*. 1998). Over time, the effects of the war on the people and land cover of the delta will diminish, but the delta will never be the same as it was.

2.6.6 **Decrease in wildlife populations**

The civil war, perhaps in conjunction with hydrological changes in the delta, had a devastating impact on wildlife populations and the delta was largely depauperate of large herbivores. The loss of wildlife has had mixed effects on land cover in the delta. The elimination of hippos has probably contributed to the drying out of abandoned alluvial channels and loss of open water areas. In the 1960s and 1970s, the wallowing activities of hippo were vital in maintaining open water conditions in the many small ponds and distributory channels of the delta (Tinley 1977). Their near-elimination from the delta has contributed to the loss of open water habitat and the succession of grassland in abandoned alluvial channels. These changes have been exacerbated by drier conditions across the delta.

The reduction in wildlife grazing pressure has also contributed to the increased extent of wildfires during the dry season. The intense grazing system of buffalo, waterbuck, zebra, sable antelope and other species that spread across the delta from the floodplain to the woodland ecotone in the 1960s and 1970s created a mosaic pattern of grazed and ungrazed grasses (Tinley 1977, Tello & Dutton 1978). This pattern created natural firebreaks to prevent or redirect the spread of wildfire. With the reduction in wildlife populations, vast expanses of ungrazed floodplain have created conditions of rank, highly combustible vegetation at the end of the dry season. Coupled with the general desiccation of the floodplain, wildfires now spread unchecked across extensive areas. The consequences of the increased frequency and extent of wildfires are discussed in the following section.

Wildlife populations now have unlimited access to the delta floodplain throughout the year because there are no large flooding events to drive them to the upland margin. The floodplain grasslands are now highly susceptible to overgrazing because they are no longer rested during the flood season each year. In this context, the decreased grazing pressure from reduced wildlife numbers has likely prevented further degradation of the floodplain grasslands.

As wildlife populations slowly recover in the delta, their impacts on the land cover will continuously evolve. Unless the hydrological conditions in the delta improve, careful management will be required to prevent the widespread degradation of the floodplain grasslands due to overgrazing.

2.6.7 **Increase in fire frequency and extent**

The influence of fire on the vegetation of the delta is profound and intimately connected with patterns of human activity. Traditionally, the alluvial grasslands were burned twice annually by hunters to attract game, in the normal dry season period and during dry spells in the mid summer rainy season. This produced a patchwork of grassland at different stages of growth attractive to the large wildlife population of the Marromeu Complex (Tinley 1977). Fire was a particularly important factor in maintaining the open physiognomy of woodland communities at the floodplain ecotone, including *Hyphaene* palm savanna and associated species on moist sandy soils and *Acacia-Borassus* woodland. Loxton-Hunting (1975) observed that late dry season fires, originating in wooded grasslands, swept into the open woodland and woodland communities, killing shrubs and small trees and sometimes canopy components. Riverine thickets and palm savanna were relatively resistant to burning. In the floodplain grassland, fires were hot and highly destructive to woody vegetation. Loxton-Hunting also observed that burning was common in *Vetiveria* and *Hyparrhenia* grassland on slightly elevated floodplain areas and helped remove invasive trees. Fire was considered unimportant in the wetter coastal grasslands and had little effect on grass competition.

As noted above, desiccation of the floodplain has now resulted in frequent, widespread fires across the delta. Nearly 95% of the delta burns during the dry season, and fires penetrate deep into the formerly inundated floodplains. Only the permanently flooded areas remain unburned. Extremely hot fires in the rank grasslands of the upper delta appear to be killing some patches of adult palms and *Acacia* spp., countering the invasion of woody species that has occurred with the drying of the floodplain. According to Bindernagel (1980), however, the increased frequency of burning is also contributing significantly to range deterioration and a reduction in carrying capacity. Programs are currently underway to better understand the reasons villagers set fires and reduce the overall impact of fire in the delta (B. Chande, pers. comm.).

2.7 IMPLICATIONS OF LAND COVER AND LAND USE CHANGE

2.7.1 **Biodiversity conservation**

Although the Lower Zambezi is young in geological terms and has relatively few endemics or species of restricted distribution (Timberlake 1998), the great value of the Zambezi Delta for biodiversity and wildlife conservation is in its complex mosaic of wetland habitats and in the high productivity of its floodplain grasslands.

From the outwash fans of miombo woodland and wet grasslands on the backslope of the Cheringoma escarpment, across the woodland, savanna, grasslands and papyrus swamps on floodplain alluvium, to the estuaries, mangroves and dunes of the coastline, the delta supports a wealth of wetland habitats. Within each broad habitat type, subtle differences in topography, soils and microclimate support a mosaic of vegetation associations of contrasting physiognomy. The juxtaposition of these varied habitats creates a great diversity of ecotones across the delta landscape, supporting the seasonal and annual biological needs of a wealth of species. Tinley (1977) noted that in other regions of Africa, such as in the Serengeti, vast migrations are required to cover a similar sequence of habitats. The delta also supports some of the highest quality mangrove forests on the East African coast.

The delta is also renowned for diverse and abundant wildlife populations supported by the high primary productivity of the floodplain grasslands. Some of the largest concentrations of buffalo and waterbuck in Africa grazed the flooded grasslands. Waterbirds, including many species of international concern, were widespread across the delta and large breeding colonies of pelicans, egrets, herons and storks remain. The biodiversity of invertebrates, amphibians, and reptiles is poorly understood, although inventories are recently underway (see various appendices in Volume II).

The preceding sections identified a remarkable number of land cover and land use changes that have occurred in the Zambezi Delta. The most obvious impact on the biodiversity of the delta during the past forty years was the decimation of nearly all of the large mammal populations of the Zambezi Delta. Zebra and hippo are on the brink of local extirpation, and other mammals have retreated from their normal habitats to avoid persecution. Large waterbird species were likely to have been heavily persecuted during this period also (Bento & Beilfuss 1999). However, changes in the mosaic of wetland habitats and the high productivity of floodplain grasslands pose the greatest threat to the delta's biodiversity in the long run.

Water resources development projects, natural geomorphological changes, drought cycles, economic development activities, decreased wildlife populations, and changes in fire frequency and extent have all contributed to shifts in the ecological communities of the delta. For example, the drying out of abandoned oxbow meanders and other alluvial features reduces the availability of contrasting habitats within the floodplains and savanna. With the drying out of the Cuacua distributary channel and subsequent invasion of reeds and papyrus, fish like *Alestes imberi* and *Labeo congoro* disappeared, the numbers of *Tilapia* and *Hydrocyon vittatus* decreased, and *Claria ngamensis* and *C. gariepinus* – species more tolerant of turbid and stagnant waters – become more common (SWECO 1983). Similarly, the invasion of palm savanna and *Acacia-Borassus* woodland into the open floodplain reduces the area of floodplain grassland associations. Water resources developments, drought cycles, economic development, and changes in burning patterns also threaten the productivity of the floodplain grasslands. The links between reduced flooding and grassland productivity include a reduction in stoloniferous grassland associations and increase in coastal saline grasslands.

The implications of these changes on mammalian biodiversity in the delta are described in several reports, including Loxton-Hunting (1975), Tinley (1977), Bindernagel (1980), Anderson *et al.* (1990), SWECO (1983) and Oglethorpe (1997). In general, the close juxtaposition of delta habitats with different soil moisture conditions allows ungulate species to meet their year-round life requirements through a rotational grazing pattern in response to natural flood cycles. When floods fail to appear, the system is disrupted. Grasslands are invaded by woody vegetation and thickets, and drought-resistant grassland species replace wetland species of higher nutrient content. The elimination of large floods facilitates year-round grazing on the open plains, and the stressed vegetation is further displaced by less palatable upland species. Buffalo are most susceptible to starvation and high mortality when their pastures dry out early in the dry season, especially when uncontrolled fires sweep across the delta. Hippo, the only truly aquatic mammal species in the delta, and waterbuck are also highly vulnerable to poor forage conditions in the wet floodplains. Elephant can turn to browse and the other major species obtain sufficient nutrition from remaining green zones of short grasses in water-edge zones (Tinley 1977).

The implications of land cover and land use changes on waterbird populations are not well known, but have been the subject of several recent reports by Beilfuss & Bento (1997) and Bento & Beilfuss (1999) for the delta specifically, and by Nilsson & Dynesius (1994) for the Zambezi Basin. Although we lack historical data on the abundance and distribution of most waterbirds in the delta, it is clear that widespread changes in the quantity and quality of many key waterbird habitats are occurring. These changes are especially significant for the many species that either depend on natural flooding cycles to meet their reproductive and feeding requirements (e.g. Wattled Cranes), depend on natural low flow periods in the Zambezi River for breeding (e.g. African Skimmer) or feeding (e.g. Openbilled Stork), or depend on the annual recruitment of fish prey in the delta floodplains (e.g. pelicans, many storks).

The Wattled Crane (*Bugeranus carunculatus*) is a Globally Endangered resident of sub-Saharan Africa. In undisturbed floodplain systems elsewhere in Africa, the breeding and feeding requirements of Wattled Cranes are intimately linked to the natural flood cycles of rivers. Wattled Crane pairs are "triggered" to nest as floodwaters begin receding after peak flooding. Nesting in deep, open water after the major flood peaks ensures that nests will be protected from predators and wildfires, but will not be drowned by further rising floodwaters. As floodwaters slowly recede, Wattled Cranes raise their single chick on the pulse of exposed plant and insect life (Konrad 1981). They feed preferentially on the underground rhizomes (tubers) of sedge species such as *Eleocharis spp*., the productivity of which depend on natural flood cycles (Beilfuss 2000). With the present erratic and mis-timed flooding of the Lower Zambezi system, Wattled Crane pairs may not be induced to initiate nesting. They may also lack wetland habitat with an adequate supply of tuber-producing sedges. Where nesting is attempted, unanticipated water level rises can drown nests and food sources. Rapid water level drawdown in the floodplains may expose nests to wildfires and predators and limit food availability. Observations from other disturbed systems support this explanation. On the Kafue Flats, Douthwaite (1974) observed that whereas 40% of Wattled Crane pairs attempt to breed in a year of normal flooding conditions, only 3% of all pairs breed in a year of negligible flooding conditions due to drought. When the hydrological regime of the Kafue Flats was altered by the Itezhi-Tezhi Dam, Konrad (1981) predicted a dramatic reduction in Wattled Crane nesting sites and feeding area. Dodman (1996) observed limited breeding activity on the Kafue Flats in 1992 (a drought year) and 1993 (normal precipitation year). In the Zambezi Delta, Wattled Crane pairs appear to be restricted to a narrow band of wetlands along the western margin of the delta where runoff from the Cheringoma Plateau inundates the floodplain during the rainy season and maintains high water table conditions throughout the dry season (Beilfuss 2000). Based on these and other observations, water resources developments in the Lower Zambezi system may be contributing to a significant decline in the Wattled Crane population of the Marromeu Complex.

The African Skimmer (*Rhynchops flavirostris*), now extinct in South Africa and restricted to a few river basins in southern Africa, occurs in small numbers in the Lower Zambezi. The survival of the African Skimmer depends in large part on the rise and fall of water levels in large rivers such as the Zambezi (Coppinger *et al.* 1988). In large, unregulated rivers, water levels rise many metres during floodstage, conveying heavy loads of suspended silt from upstream. As floodwaters recede, the silt is deposited and sandbars are formed. African Skimmers nest and roost on these exposed, open sandbars. At present the sediment load of the Zambezi is trapped by Kariba and Cabora Bassa dams, and floodwaters in the delta are primarily derived from the silt-free rainfall runoff from the Cheringoma Plateau (Davies 1986). The sandbars used as nest sites for Skimmers and other species are no longer deposited downstream. Over time, older sandbars may become vegetated and abandoned by nesting waterbirds (Dennis & Tarboton 1993). In the Middle Zambezi, this loss of sandbar habitat is exacerbated by unseasonable water releases from Lake Kariba. When water is released during the dry season, a metre-high wave surges downstream, sweeping away nests of any birds using the low islands (Coppinger *et al*. 1988). In the Lower Zambezi, erratic water releases from Cabora Bassa are probably affecting populations in the Marromeu Complex as well. There were no observations of Skimmer nesting activity during dry season surveys. The African Skimmer, with its strong dependence on the ebb and flow of the Zambezi and its sediments, is an excellent indicator for the myriad of species that depend on the natural hydrological fluctuations of the Zambezi. The Redwinged Pratincole, with similar habitat requirements, is probably also threatened by water resources development activity.

Openbilled Storks (*Anastomus lamelligerus*) concentrate in large numbers to feed on freshwater snails and mussels on the exposed sandbars of the Lower Zambezi during the dry season, and feed in shallow freshwater lakes in the coastal mangrove zone during the wet season (Beilfuss & Bento 1997). Regulation of the river has reduced flood peaks and increased dry season flows, resulting in fewer seasonally exposed sandbars and more permanently vegetated sandbar islands. At present, Openbilled Storks appear to be thriving in the Lower Zambezi system relative to other wetland areas in Africa (Dodman *et al.* 1998). However, further attempts to stabilize the Zambezi flow regime will greatly diminish the availability of sandbar habitats and threaten one of the largest populations of Openbilled Storks reported in Africa.

White Pelicans (*Pelecanus onocrotalus*) nest in large, conspicuous colonies in coastal mangroves and are very sensitive to disturbance (Dennis & Tarboton 1993). Changes in the extent of coastal mangrove over the past 40 years may increase the susceptibility of pelicans to disturbance and will eventually force abandonment of the nesting colonies. Large numbers of White and Pink-backed Pelicans fed in the Zambezi Delta floodplains during the 1960s and 1970s. In recent years, pelicans have abandoned the dry floodplains of the Zambezi Delta and now feed in Lake Urema of Gorongosa National Park. They continue to roost and breed in the coastal delta, but appear to be able to meet their feeding requirements there no longer.

The fates of other waterbird species in the Marromeu Complex are also linked to water resource developments in the Lower Zambezi. These impacts of these changes include the degradation of breeding habitats for some species and the impoverishment of feeding grounds for others. As with pelicans, Saddlebilled Storks (*Ephippiorhynchus senegalensis*), Goliath Herons (*Ardea goliath*) and many other piscivorus waterbird species depend on concentrations of laterally migrating fish that are trapped in shallow floodplain depressions as floodwaters recede. Saddlebilled Storks nest at the end of the wet season, and fledge their chicks during the dry season when food is concentrated and easy to obtain (Hancock *et al.* 1992). Goliath Herons feed on large fish in lake edges and shallow waterbodies of the floodplain (Hancock & Kushlan 1984). Such species are now unable to utilize the vast areas of the Marromeu Complex that no longer receive overbank flooding sufficient for fish to migrate to floodplain spawning grounds from the main channel.

Species requiring vast expanses of open floodplain, seasonally flooded marshland or brackish mangrove are also vulnerable to the further desiccation of the delta. At present, very few waterbird species occur in the northwestern portion of the south bank of the delta where the combined effects of dams and dykes are most marked. There are also very few in the drier north bank portion of the Zambezi Delta. The great majority of waterbirds are clumped in the southeast corner of the Delta where seasonal runoff from the Cheringoma escarpment still inundates the floodplains on an annual basis. There is very limited waterbird utilization of the active and abandoned agricultural and livestock grazing fields around Marromeu and Luabo villages, which may be due, in part, to local hunting pressures.

These changes to important waterbird habitats are exacerbated by other changes in the delta, particularly mangrove deforestation, the decrease in grazing and wallowing species (e.g. hippo), and the increased frequency of grassland fires. Mangrove and evergreen communities in the coastal zone support large breeding colonies of herons, egrets and storks (Beilfuss & Bento 1997). These breeding grounds are not only threatened by clear-cutting, but also by selective-cutting activities that occur during the breeding season. Many species of waterbirds feed preferentially in recently grazed floodplains, and are unable to utilize the rank grasslands of large portions of the delta that remain ungrazed during the dry season. Wattled Cranes, for example, are closely associated with areas grazed heavily by lechwe in the Kafue Flats and Bangweulu Basin in Zambia (Konrad 1981, Kamweneshe 1996). Similarly, several species of ducks feed on waste seed and rhizomes in heavily grazed areas. Channels that have been choked with floating and emergent vegetation no longer provide open water habitat for piscivorus birds. The traditional mosaic pattern of burned dry areas and unburned wet areas has given way to extensive fires across the grasslands that threaten grassland birds that nest in the standing vegetation (e.g. egrets, reed cormorants). The reduction in above-ground biomass resulting from widespread fires, however, may perhaps offset some of the waterbird habitat losses caused by low grazing pressure. There is no data available to quantify the impact of these changes on waterbird diversity and abundance in the Zambezi Delta.

2.7.2 **Human welfare**

Water resources development projects, drought cycles and civil war have also had a marked effect on human welfare in the Zambezi Delta. Land use changes affecting the local communities include loss of floodplain agriculture, reduced livestock grazing and carrying capacity, loss of floodplain fisheries, changes in natural resource utilization patterns and reduced wildlife hunting. Turpie *et al.* (1998) and Schmidt (1997) have assessed the economic value of some of these activities for the delta population.

The human impact of the potential loss of flood recession agriculture in the delta was first noted by Hidrotechnica Portuguesa (1961b):

"On the Inhangoma, the Zambezi floods ensure that the soils, which already are very rich in the principal nutrients have a water content which permits the cultivation cycle to continue year after year without large decreases of the yields. One must consider that, when the Zambezi once is regulated, the cultivation practices of this area must be much modified in order to avoid continuing reduction of the yields, which certainly would cause serious alimentary crises."

Data on the value of flood recession agriculture in the delta are very limited. SWECO (1983) provided a very rough estimate of the value of all subsistence agriculture practices at US$ 5-10 million per annum. Turpie *et al*. (1998) estimated the current value of subsistence agriculture at US$ 5.3 million per annum. The overall effect of a decrease in the area of flood recession cropping on human welfare is unknown, and salinisation may further reduce agricultural activity over time. SWECO (1983) noted cultivation is largely restricted to soils along the Zambezi River and the Catharina, Chinde and Micelo distributaries, and the main effect of reduced flooding may be that saline soils will occur progressively nearer the rivers such that only soils in the immediate vicinity of the rivers will remain productive. Chronic food insecurity is still high in the delta (Schmidt 1997).

Local livestock holdings, especially cattle and goats, were decimated during the civil war. Livestock restocking programs are currently underway in the delta, but most households own only chickens (Schmidt 1997). The economic value of the loss of livestock has not been calculated, but was likely to have been severe for many households, particularly during the civil war and regional drought when food security was low.

Fish are the most important source of protein for the delta population, especially during times of food shortage. Since 1979, the floodplain fishery in the delta has crashed, and been replaced by riverine and near-shore coastal fisheries. The change in volume and value of catches in unknown. SWECO (1983) estimated a total floodplain harvest of about 10,000 tons per annum under normal flooding conditions, and predicted the catch reduction under different water resource development scenarios. Recently, DNFFB (1998) and Turpie *et al*. (1998) estimated the total catch of registered fishing camps in Chinde at only 645 tons per annum. The current subsistence catch is unknown. DNFFB (1998) notes that fish are under-harvested in the delta.

The crash of the coastal prawn industry has important implications for the national economy. Hoguane (1997) estimated that the regulation of the Zambezi River is leading to a loss of US$ 10-30 million per annum. However, this loss of income has limited impact on the local subsistence economy.

There are very limited data on the human use of natural resources, but pressure on local resources increases during times of food shortage and crop failure. In general, there are few restrictions on local use of resources such as woodland, palm and mangrove, and assistance programs are exploring options for the sustainable use of these resources.

The net effect of the crash in the local wildlife population on human welfare is unknown. Prior to the civil war, the controlled culling of wildlife produced yielded about US$ 0.4 million per annum (SWECO 1983). In 1990, despite the low population numbers, the capital value of the standing crop of major herbivores species was still estimated at more than US$ 13 million, with a sustainable annual harvest of US$ 1 million per annum (Anderson *et al*. 1990). Today, low-level hunting activities continue in the surrounding coutadas. Local communities have very limited hunting rights, but receive meat from the safari operators.

2.8 CONCLUSIONS AND RECOMMENDATIONS

Over the past forty years, the Zambezi Delta has undergone substantial land cover and land use changes as a result of water resources development projects, natural geomorphological changes, drought cycles, economic development activities, civil war, decreased wildlife populations and changes in fire frequency and extent. Important land cover changes include the invasion of the open floodplain grasslands by palm savanna and *Acacia* thicket, displacement of flood-tolerant wetland species by dryland species and displacement of freshwater grasslands by saline grasslands, drying out of abandoned alluvial channels, loss of coastal and inland mangrove and associated evergreen thicket, geomorphological changes on the delta coast and inland sandbars, and salinisation of wetland soils. Significant land use changes include changes in subsistence and commercial agricultural practices, reduced livestock grazing and carrying capacity, loss of floodplain fisheries, changes in natural resource utilization patterns, and increased frequency and extent of fires. These changes threaten both biodiversity and human welfare in the delta.

The future of the Zambezi Delta depends on the amelioration of negative land use and land cover changes that have occurred, and the protection of the resources that remain. Recommended actions include prescribed flood releases from Cabora Bassa Dam, restoration of the Solane depression through improved water passage through existing dykes, protection of the Cheringoma escarpment, ratification of the Ramsar declaration and nomination of the Zambezi Delta as a wetland of international importance, and the sustainable use of natural resources, as well as further research.

2.8.1 **Prescribed flood releases**

The past forty years of water resource development on the Zambezi River has overwhelmed all other human impacts on the Zambezi Delta. Any efforts to rehabilitate these floodplain wetlands must therefore begin with improving the hydrological regime of the river basin (see Bayley 1991, Petts 1996, Stanford *et al.* 1996). The best available option for river basin managers is therefore to simulate historic hydrological conditions in the Lower Zambezi system through scheduled flood releases from upstream dams.

The use of prescribed flooding for the benefit of downstream communities and ecosystems has gained worldwide attention in recent years. In the western United States, artificial flood releases from large dams are being tested to meet instream flow requirements for riverine habitats, salmon fisheries and recreational demands (Stevens & Wegner 1995, Collier *et al.* 1996). In helping rebuild sandbars, beaches and backwater areas along the Colorado River, for example, controlled flooding from Glen Canyon Dam is demonstrating that prescribed floods can have beneficial effects and that dam management strategies can be developed to allow for such periodic events (Stevens 1997, Vaselaar 1997).

In Africa, the role of artificial flood releases below large dams is gaining acceptance as a strategy for integrated rural development (Acreman 1994). In the Komadugu-Yobe basin of Nigeria, there is unanimous consensus among policy-makers, scientists and river basin managers that artificial flooding should play a central role in the integrated development of the river basin. As a result, wet season floods were released from Tiga and Challawa Gorge Dams in 1994 (Polet & Thompson 1996). Controlled flood releases in the Phongolo River Basin in South Africa provide recession irrigation, grazing and water supply to downstream users. Flood release schedules are dictated by the community through Water Committees organized among fourteen wards that represent the views and needs of the 70,000 inhabitants of the Phongolo floodplain (Bruwer *et al.* 1997). Research downstream of Manantali Dam in the Senegal River Basin has demonstrated that controlled flood releases could be combined with existing demands for hydropower output to benefit more than 500,000 floodplain farmers (Horowitz 1994). In Cameroon, the Waza Logone flood restoration study is exploring the role of artificial floods in restoring the natural and socio-economic value of the Logone floodplain downstream of Maga Dam. Researchers are assessing the effects of various water management options on floodplain inundation for fisheries, agriculture, and grazing (Wesseling *et al.* 1996). In South Africa, an inexpensive, site-specific workshop technique has been developed to assess ecologically sensible flood flows and low flows for specific rivers and specific water-development projects. The technique, Instream Flow Requirements (IFR), uses experts in a simple iterative process known as the 'building block methodology' (King & Tharme 1994, Tharme 1996). A picture of the 'minimum flow' requirements is rapidly built for the river under consideration and the seasonal variability necessary to maintain basic ecological functioning of the system is then built into the operational rules for the relevant water development project.

Such artificial flooding regimes also offer enormous potential for the rehabilitation of floodplain ecosystems such as the Zambezi Delta. Re-establishing the physical and biological connections between the main channel, backwaters and floodplains is central to the rehabilitation of river systems (Gore & Shields 1995). Stanford *et al.* (1996) argue that the loss of biodiversity and habitat heterogeneity associated with dams can be ameliorated in part through restoring flood peaks and baseflows. Nutrient-rich flood pulses can stimulate primary productivity and enhance overall biological productivity across river-floodplain systems (Junk *et al.* 1989, Bayley 1995). The alternating wet and dry phases of natural flood cycles create and maintain the dynamic mosaic of channel and floodplain habitats that help support the diverse and productive flora and fauna of floodplains (Bayley 1991, Stanford *et al.* 1996). Re-establishing the hydrological connectivity between river and floodplain through flooding events is also integral to the diversity and resiliency of riverine fisheries (Welcomme 1995).

The observed benefits of the few flood pulses that have been released from Cabora Bassa Dam over the past 25 years further suggest that prescribed flood releases may be an important tool for the rehabilitation of the Zambezi Delta. After emergency flood releases from the dam in 1977-78, floodplain conditions improved dramatically for the local flora and fauna, and were maintained for nearly two years afterwards (P. Dutton, pers. obs.). Marked increases in buffalo and waterbuck were observed on the floodplain grasslands, and encroaching upland vegetation receded from the floodplain (Anderson *et al.* 1990, Chande & Dutton 1997). Because these releases were unplanned, however, they occurred as flash floods. The 1978 flood wave alone killed 45 people, displaced more than 200,000, and destroyed nearly 60,000 ha of crops (RPT 1979). Hydrological conditions in the delta also showed marked improvement when, after more than a decade of drought, emergency flood releases led to overbank flooding in 1997. Waterbird populations were more abundant and more widely dispersed (Beilfuss & Bento 1997). The flushing of stagnant waterways in the floodplain led to perhaps 10-20% reduction in cover by invasive floating aquatic plants such as *Azolla filiculoides* and *Eichhornia crassipes* (B. Davies, pers. comm.)

Rehabilitation efforts for the Zambezi Delta should thus aim to implement an artificial flooding regime that will re-establish, to the extent possible, historic hydrological conditions and variability in the Lower Zambezi system. Such variability should reflect annual fluctuations in climate and runoff in the Zambezi Basin. This model predicts that the full range of natural intra- and inter-annual variation of hydrological regimes is necessary to truly sustain the native biodiversity and evolutionary potential of floodplain ecosystems (Sparks 1992, Richter *et al.* 1996). Periodic larger floods, characteristic of the historic Zambezi system, may serve to reset parts of the floodplain by flushing accumulated organic matter and nutrients from peripheral swamps and dispersing seed propagules to the floodplain margin (for example, Bayley 1995, Bruwer *et al.* 1997). Ideally, a water management program for the Lower Zambezi system would consist of an integrated flood release strategy involving the coordinated management of both Kariba and Cabora Bassa Dams. Unfortunately, Kariba Dam was designed without any consideration for future water releases. Although Kariba's six sluice gates have a maximum discharge capacity of 9515 m^3/sec (roughly equivalent to the mean annual Zambezi flood peak prior to Kariba), the gates are installed near the crest of the dam and can only operate for emergency water releases when the reservoir is near capacity (Olivier 1977).

Prescribed flood releases from Cabora Bassa, however, are achievable. Cabora Bassa's eight sluice gates are located significantly lower on the dam wall (111 m below the crest) than at Kariba, and are below the average operating level of the reservoir. The discharge capacity of each of the eight sluice gates is approximately 1650 m^3/sec (Olivier 1977). When operated near maximum discharge capacity, the gates can create floods similar in magnitude to average pre-Kariba flooding events in the Lower Zambezi (Suschka & Napica 1986). It is thus physically possible to generate historic floods of varying magnitude and duration from Cabora Bassa Dam, depending on hydrological conditions in the reservoir and local runoff conditions in the lower Zambezi sub-basin. Floods must be generated as step-wise releases building to peak discharge, rather than high volume pulse releases which often function more as flushing flows and fail to mimic the historic hydrograph (for example, Scudder & Acreman 1996, Hollis 1996, Stevens 1997).

SWECO (1983) assessed the value of flood freshets for a variety of land cover and land use conditions in the delta. They predicted a number of likely and possible benefits of improved flooding conditions. In the floodplain grasslands, they predicted that prescribed flood releases would benefit the species composition of grass cover, reduce the extent of woody vegetation on grassland, increase the growth of aquatic vegetation on inundated plains, improve soil fertility by reduction in saline soils and deposition of silt, and reduce the growth of water weeds in channels. In the coastal mangroves, they predicted improved species composition and zonation, maintenance of the ecosystem by deposition of silt, and maintenance of shorelines by deposition of silt. They predicted an increased extent of flood recession cropping, and improved soil fertility related to reduction in the extent of saline soils. For floodplain fisheries, SWECO predicted improved fish feeding conditions on the inundated floodplains, more natural breeding behaviour of riverine fish, and improved survival of young fish on the floodplains and in the river. They noted that freshets may be of little vale for fish species which stay long on the plains after hatching. However, filling of floodplain pools and lakes will be largely achieved to the same extent as by normal floods, providing near-normal conditions for several species which are important in the Zambezi fisheries. SWECO also predicted that flood releases could improve the carrying capacity of floodplain grasslands by reducing grazing intensity, reducing the extent of saline soils, increasing the deposition of silt, improving the species composition of grass cover, altering the relative numbers of grazers and browsers, and reducing the extent of areas infested with tsetse fly. They noted, however, that it is doubtful that carrying capacity of grasslands would improved by the provision of short flood releases that would give only a brief resting period for the vegetation.

The extent to which these and other benefits of improved flood management can be achieved is unclear. The re-establishment of historic floodflows in the Lower Zambezi system does not necessarily result in the re-establishment of historic flooding conditions. The ecological integrity of river systems depends not only on the annual exchange of water with the floodplain, but also sediment, nutrients, organic and inorganic matter, and living organisms (Ward & Stanford 1995).

Kariba and Cabora Bassa reservoirs capture most of the sediment load of the Upper and Middle Zambezi systems, releasing clear, hypolimnetic waters downstream (Bolton 1983, Suschka & Napica 1986). Artificial flood releases from Cabora Bassa will probably increase sediment transport in the Lower Zambezi relative to current conditions. Flood discharges will result in considerable channel degradation and sandbank scouring in the unstable alluvial stretches of the river along the 590 km course to the coast (Suschka & Napica 1986). The magnitude and distribution of sediment transported to the delta under prescribed flooding conditions relative to historic flooding conditions, however, is unknown. Such processes are difficult to model, especially in combination with sediment inputs from Lower Zambezi tributaries, and must be evaluated primarily from empirical data following flood releases.

The re-establishment of historic floodflows in the Lower Zambezi system also does not imply that all of the ecological changes that have resulted from dam development can be reversed. Invasive surface-floating species are now established in the delta waterways, and global efforts to eradicate these problem weeds, which effect flow patterns and community structure of floodplain waterways, have had limited success (Mitchell 1985). Relatively large flooding events may be necessary to remove upland trees that set seed and established in the floodplain in the absence of the annual flood.

Finally, changes in land use and settlement patterns along the Lower Zambezi system may also constrain prescribed flood design. Although there is little settlement in the Marromeu Complex interior, widespread encroachment is occurring in historically flood-prone areas along the Lower Zambezi River. Most of the dwellings constructed, however, may be temporary structures erected for easier access to fishing areas (K. Wilson, pers comm). River terrace settlement was common and widespread along the Zambezi prior to basin development to take advantage of overbank flooding events (White 1993, Negrão 1995). Given the anticipated benefits of prescribed flooding for fisheries as well as flood recession agriculture, grazing and groundwater access, temporary movement away from flood-prone areas may be acceptable during peak flood releases with an appropriate education programme, flood warning system and community-based rural development programme in place. Further research and community-outreach will test these assumptions, but it is clear that the window of opportunity for implementing a prescribed flooding program will narrow with each passing year as villagers adjust their livelihoods in response to perceptions that the Zambezi River is permanently regulated.

2 .8.2 **Restoration of the Solane depression**

The southern half of the delta was historically inundated by distributary channels that branch off from the main Zambezi channel between the riverside villages of Chupanga and Marromeu. These floodways, including the Salone depression, are restricted by dykes constructed for the roadway and railway line along the Zambezi and the abandoned railroad levee between Marromeu and Inhamitanga. The impacts of these projects, described above, include the desiccation of the alluvial soils below the dykes and subsequent invasion of woody species and dry grassland species.

If the present route of the Inhamitanga-Marromeu railway line is of no further use, the levee should be breached by means of a bulldozer at sites identified from aerial survey and satellite imagery. If the railway line is to be rehabilitated, then a proper hydrographic survey should be conducted indicating where adequate elevation structures (not merely the occasional conduit pipe) should be provided in the levee to allow free access of floodwater to the delta. To facilitate this process, additional low-level colour photographs should be taken during the wet season to better indicate how the levee has drastically altered the flooding regime of the southern delta. Along the dyke between Marromeu and Chupanga, a proper hydrographic survey should also be conducted to improve free access of floodwater to the delta.

Before this process is undertaken, Tinley (1994) cautioned:

> "Because a delta's distributary channels are prone to shifting laterally as they become blocked off by their own sediments, enhancing or modifying their flow has to be done with care. For example, before any management action is taken to make wide gaps in the dikes where they cross the floodways, monitoring must first take place of how effectively the Marromeu half of the delta is inundated under present conditions by a planned drawdown release from Cabora Bassa in March (the original flood peak of the Zambezi). Otherwise, over-zealous deepening, as opposed to merely widening of floodways, especially near their offtake from the main Zambezi channel, could result in the catastrophic development of a major new river course through the middle of the Marromeu reserve."

2 .8.3 **Protection of the Cheringoma Escarpment**

The protection and management of the Cheringoma escarpment is fundamental to the conservation of wetlands of the southern half of the delta. The perennial streams draining the escarpment are vital in maintaining the delta wetlands, especially as Zambezi River flooding has been drastically reduced by Kariba and Cabora Bassa. Several species of waterbirds, including Wattled Cranes, breed exclusively below the alluvial fans of the Cheringoma streams. Tinley (1994) attributed the high number of vegetation communities and diversity of ecotones on the Cheringoma outwash plains to the large variation in their soils, salinity and microrelief brought about by the flux of river fan and littoral erosion and sedimentation processes.

Development activities must ensure that the perennial streams are not dammed or diverted. Any logging in the Cheringoma should be sustainable, cyclical harvesting that removes selected trees without eroding the backslope soils of the escarpment. Clear-cutting activity should be avoided, as it will alter the runoff dynamics and threaten the quality and quantity of runoff in the perennial streams.

2.8.4 **Ramsar status and wetland protection**

From among the many coastal wetlands of Mozambique, the Zambezi Delta is of the highest ecological and socio-economic value. The Inkomati, Limpopo, Sabie and Pungwe coastal floodplains are all vitally important for ducks and other waterbirds in Mozambique, but the size and diversity of the Zambezi Delta is unparalleled. It is an excellent example of the wetlands characteristic of the coastal zone of Mozambique, and it is part of a complex of high quality wetland habitats ranging from floodplain grasslands and papyrus swamps to mangrove estuaries. The Zambezi Delta has a substantial hydrological, biological and ecological role in the functioning of the Zambezi Basin and coastal system, and is a wetland of great socio-economic and cultural value. It is also part of the extensive Sofala Bank system, the most important prawn fishery in Mozambique. The fisheries sector contributes significantly to Mozambique's economy, accounting for 40% of GNP and US$ 55.4 million in revenue from the prawn fishery alone in 1996 (MICOA 1998).

The nomination and ratification of the Zambezi Delta as a Wetland of International Importance creates new opportunities for international awareness and ecotourism development, particularly in conjunction with ongoing efforts to link management and sustainable utilization of the Marromeu area with Gorongosa National Park to create an immense protected area system (DNFFB 1994). It offers to link the Marromeu Buffalo Reserve with the coastal mangrove, estuarine, dune and seashore areas between and including Baia Dumba to the main Micelo distributary mouth (Tinley 1994). It also creates a regional conservation network linking the Zambezi Delta with other major wetlands of the Middle and Upper Zambezi system, including the Okavango Delta and Kafue Flats, and enables Mozambican resource managers to gain better access to training in wetland management and monitoring and funding for research.

2.8.5 **Further research**

This study provides an overview of a variety of land cover and land use changes that either have occurred, or are likely to have occurred, over the past 40 years. Because of the vast size and inaccessibility of much of the delta, these land cover changes were assessed primarily from aerial surveys and remote sensing imagery. Field research is now needed to determine the degree to which many of these changes have occurred, and to establish baseline conditions for comparison to future changes in the delta. Some of the most critical needs include:

(a) Vegetation ecology research to determine the distribution of grass species and associations along soil moisture and salinity gradients in the delta floodplains, for comparison to the Loxton-Hunting descriptions and other sources. A new series of airphotos of the delta, mosaiced together, is urgently needed to assess changes in tree densities, grassland patterns and other land features that cannot be assessed from 30 m-resolution satellite imagery relative to the 1960 airphotos. The photomosaic will provide baseline data for assessing future changes that might result from improved flooding or other management practices.

(b) Hydrology research to determine changes in floodplain hydrology over the past 40 years in terms of the frequency, timing, duration and magnitude of floods in the delta. The impact of Cabora Bassa, the protective dykes at Marromeu and the road/railway dykes blocking upper delta waterways should be assessed separately. Research should model the potential for water releases of various magnitude, timing, and duration from Cabora Bassa Dam based on the water balance of the Cabora Bassa Reservoir. Research should also model the hydrological conditions resulting downstream for given prescribed flood releases.

(c) Geomorphology research to determine coastal sedimentation and erosion processes, and the link between geomorphological changes, mangrove loss and dam management practices.

(d) Wildlife biology research to determine the current carrying capacity of the floodplain grasslands, the factors affecting wildlife recovery in the delta, and the role of hippo in opening up delta waterways.

(e) Socio-economic research to quantify the long-term changes in flood recession agriculture, grazing, fisheries productivity, utilization of natural resources, and groundwater access. A socio-economic survey, involving participatory rural appraisal and oral histories, should be conducted in a selected sample of communities in the delta to estimate the economic and socio-cultural importance of flooding under historical and current conditions, particularly with reference to the construction of Cabora Bassa Dam. Research is needed to assess attitudes about the benefits and costs of flooding in different areas.

(f) Forestry research to determine the rate, extent and causes of mangrove deforestation along the coastline.

(g) Agricultural research to determine the degree of soil salinisation in the delta and its influence on agricultural (subsistence and commercial) practices.

2.9 ACKNOWLEDGMENTS

Funding for research in the Zambezi Delta was provided by the Disney Wildlife Conservation Fund, Florida USA; the Foundation for Wildlife Conservation Foundation for Wildlife Conservation, Wisconsin USA; and Dr Luc Hoffmann and the Mava Foundation in Geneva, Switzerland. Additional funding and logistical support was provided by the International Crane Foundation, Baraboo USA; Museu de Historia Natural, Maputo; IUCN, Beira; Durban Natural Science Museum, South Africa; The Zambezi Society, Harare, and Jeffrey Short, Chicago USA.

Thanks to Carlos Bento, Baldeau Chande, Roberto Zolho, Patrocinio da Silva, Jose Alves, Lindy Rodwell, Ken Wilson and Maria Doddema for logistical assistance related to fieldwork. We are also grateful to Howard Walker for generously donating his aircraft time and piloting skills for many of the surveys, and to Andre Pelser for piloting the most recent surveys. We thank ERDAS imagine software and ESRI for their generation contribution of software for the processing of GIS data. Finally, thanks to Jonathan Timberlake for reviewing a draft.

2.10 REFERENCES

Acreman, M. (1994). The role of artificial flooding in the integrated development of river basins in Africa. In: Integrated River Basin Development (edited by C. Kirby & W.R. White), pp. 35-44. John Wiley & Sons, Chichester.

Anderson, J., Dutton, P., Goodman, P. & Souto, B. (1990). Evaluation of the wildlife resource in the Marromeu complex with recommendations for its further use. LOMACO, Maputo.

Barbosa, L.A.G. (1952). Esboça da Vegetação da Zambézia. Documentário Moçambique No. 69. Junta de Exploração do Algodão, Maputo.

Bayley, P.B. (1991). The flood pulse advantage and the restoration of river-floodplain systems. *Regulated Rivers: Research and Management* **6**: 75-86.

Bayley, P.B. (1995). Understanding large river-floodplain ecosystems. *Bioscience* **45**: 153-158.

Begg, G.W. (1973). The biological consequences of discharge above and below Kariba Dam. In: Proceedings of the 11th Congres des Grands Barrages, pp. 421-430. Commission Internationale des Grands Barrages, Madrid.

Beilfuss, R.D. (2000). Piecing together the story of an African floodplain: water, wetlands and wattled cranes. *ICF Bugle* **26**: 1-2

Beilfuss, R.D. & Allan, D.G. (1996). Wattled Crane and wetland surveys in the great Zambezi Delta, Mozambique. In: Proceedings of the 1993 African Crane and Wetland Training Workshop (edited by R. Beilfuss, W. Tarboton & N. Gichuki), pp. 345-354. International Crane Foundation, Baraboo, Wisconsin.

Beilfuss, R. & Bento, C. (1997). Impacts of hydrological changes on the Marromeu Complex of the Zambezi Delta, with special attention to the avifauna. Paper presented at the Workshop on the Sustainable Use of Cahora Bassa Dam and the Zambezi Valley, 1997, Songo, Mozambique.

Beilfuss, R. & Davies, B.R. (1999). Prescribed flooding and wetland rehabilitation in the Zambezi Delta, Mozambique. In: *An International Perspective on Wetland Rehabilitation* (edited by W.J. Streever). Kluwer, Dordrecht.

Bento, C. & Beilfuss, R. (1999). The status of waterbirds in the Zambezi Delta, Mozambique. Unpublished consultancy report on feasibility study for water resources development on the lower Zambezi River. Joint Venture Consortium, Maputo.

Bernacsek, G.M. & Lopez, S. (1984). Investigations into the fisheries and limnology of Cahora Bassa Reservoir seven years after dam closure. FAO/GCP/MOZ006/SWE Field Document No.9. FAO, Rome.

Bindernagel, J.A. (1980). Multiple use of natural resource in the Marromeu Complex, Mozambique, with special reference to wildlife utilization. MOZ/76/007. FAO, Rome.

Bolton, P. (1983). The regulation of the Zambezi in Mozambique: a study of the origins and impact of the Cabora Bassa Project. PhD thesis. University of Edinburgh, Edinburgh.

Boyd, C. & dos Santos, S. (1997). Estudo socio-economico. In: Recursos Florestais e Faunisticos do Norte de Sofala. Volume 3: Informação de Base (Annex 8). DNFFB, Maputo.

Bruwer, C., Poultney, C. & Nyathi, Z. (1999). Community-based hydrological management of the Phongolo floodplain. In: *Water Management and Wetlands in sub-Saharan Africa* (edited by M. Acreman & G.E. Hollis), pp.199-212. IUCN, Gland.

Chambal, M.S. (1989). Preliminary survey of wildlife resources and management implications: a case study of Metachira, Gorongosa National Park and Marromeu Complex, Sofala Province. DNFFB, Maputo.

Chande, B. & Dutton, P. (1997). Impacts of hydrological changes on the Marromeu complex of the Zambezi Delta, with special attention to the mammal fauna. Paper presented at the Workshop on the Sustainable Use of Cahora Bassa Dam and the Zambezi Valley, 1997, Songo, Mozambique.

Chidiamassamba, C. & Liesegang, G. (1997). Alternativas e tecnicas adaptadas as cheias usadas pelas comunidades ao longo do Vale de Zambéze. Paper presented at the Workshop on the Sustainable Use of Cahora Bassa Dam and the Zambezi Valley, 1997, Songo, Mozambique.

Collier, M., Webb, R.H. & Schmidt, J.C. (1996). Dams and rivers: primer on the downstream effects of dams. U.S. Geological Survey Circular No. 116. USGS, Denver, Colorado.

Coppinger, M.P., Williams, G.D. & Maclean, G.L. (1988). Distribution and breeding biology of the African Skimmer on the upper and middle Zambezi river. *Ostrich* **59**: 85-96.

Da Silva, J. (1986). River runoff and shrimp abundance in a tropical coastal ecosystem - the example of the Sofala Bank (Central Mozambique). NATO ASI Series 67. Springer-Verlag, Berlin.

Davies, B.R. (1986). The Zambezi River system. In: *The Ecology of River Systems* (edited by B.R. Davies & K.F. Walker), pp. 225-267. Kluwer, Dordrecht.

Davies, B.R. [editor] (1997). Report on the Songo Workshop on the Sustainable Utilization of the Cahora Bassa Dam and the Valley of the Lower Zambezi. Arquivo do Patrimonio Cultural, Maputo.

Davies, B.R, Beilfuss, R.D. & Thoms, R.C. (In press). Cahora Bassa Retrospective, 1974-1997: effects of flow regulation on the Lower Zambezi River. *International Society of Theoretical and Applied Limnology.*

Davies, B.R., Hall, A. & Jackson, P.B.N. (1975). Some ecological effects of the Cabora Bassa Dam. *Biological Conservation* **8**: 189-201.

De Vries, K., de Conceição, L. & Buvane, A. (1997). Floods in the Zambezi River and extreme rainfall in the Tete-Songo area, 1996/1997. Report No. 17/97. DNA, Maputo.

Dennis, N. & Tarboton, W. (1993). *Waterbirds: Birds of Southern Africa's Wetlands*. Struik, Cape Town.

DNFFB (1994). Gorongosa-Marromeu: Management plan for integrated conservation and development 1995-1999. DNFFB, Ministry of Agriculture, Maputo.

DNFFB (1998). Avaliação preliminar dos recursos florestais, faunisticos e pesqueiros no delta do Zambéze. IUCN, Maputo.

DNFFB (1999). Inventario florestal no delta do Zambéze nos distritos de Marromeu e Chinde. IUCN, Maputo.

Dodman, T. (1996). Present status and distribution of cranes in the Kafue Flats, Zambia with reference to population estimates of the 1980s. In: Proceedings of the 1993 African Crane and Wetland Training Workshop (edited by R. Beilfuss, W. Tarboton & N. Gichuki), pp. 255-259. International Crane Foundation, Baraboo, Wisconsin.

Dodman, T., de Vaan, C., Hubert, E. & Nivet, C. (1998). African Waterfowl Census 1998. Wetlands International, Wageningen.

Douthwaite, R.J. (1974). An endangered population of Wattled Cranes. *Biological Conservation* **6**: 134-142.

Foskett, R. (1965). *The Zambezi journal and letters of Dr. John Kirk, 1858-63*. Oliver & Boyd, Edinburgh.

Gammelsrod, T. (1992a). Improving shrimp production by Zambezi River regulation. *Ambio* **21**: 145-147.

Gammelsrod, T. (1992b). Variation in shrimp abundance on the Sofala Bank, Mozambique, and it relation to the Zambezi Runoff. *Estuarine, Coastal & Shelf Science* **35**: 91-103.

Gammelsrod, T. (1996). Effect of Zambezi river management on the prawn fishery of the Sofala Bank. In: Water management and wetlands in sub-Saharan Africa (edited by M.C. Acreman & G.E. Hollis), pp. 119-124. IUCN, Gland.

GEMA (1999). Estrategias para a gestão comunitaria dos mangais no delta de Zambéze. Pesquisa competitiva sobre posse de terra. GEMA, IUCN, Maputo.

Gore, J.A. & Sheilds, F.D. jr. (1995). Can large rivers be restored? *Bioscience* **45**: 142-152.

Hall, A. & Davies, B.R. (1974). Cabora Bassa: apreciação global do seu impacto no Vale do Zambeze. *Rev. Mens. Econ. Moçamb., Lourenço Marques* **11**: 15-25.

Hall, A., Davies, B.R. & Valente, I. (1976). Cahora Bassa: some preliminary physico-chemical and zooplankton pre-impoundment survey results. *Hydrobiologia* **50**: 17-25.

Hall, A., Valente, I. & Davies, B.R. (1977). The Zambezi River in Moçambique: the physico-chemical status of the middle and lower Zambezi prior to the closure of the Cabora Bassa Dam. *Freshwater Biology* **7**: 187-206.

Hall, A., Valente, I.M.C.B. & Burholt, M.S. (1977). The Zambezi River in Mozambique: the suspended solids regime and composition of the middle and lower Zambezi prior to the closure of Cahora Bassa Dam. Unpublished report. Departmento da Quimica, Universidade Aveiro, Portugal.

Hancock, J. & Kushlan, J. (1984). *The Herons Handbook*. Croom Helm, Kent.

Hancock, J.A., Kushlan, J.A. & Kahl, M.P. (1992). *Storks, Ibises and Spoonbills of the World*. Academic Press, London.

Hatton, J. & Munguambe, F. [editors] (1997). First national report on the conservation of biological diversity in Mozambique. MICOA, Maputo.

Hidrotecnica Portuguesa (1961a). Bacia do Zambéze. Elementos agronomicos e silvicolas, Relatorio de agronomia – 1959 e 1960. Missão de Fomento e Povoamento do Zambéze.

Hidrotechnia Portuguesa (1961b). Missao de Fomento e Povoamento do Zambéze. Esquema geral. Aspectos pecuarios (1958-1960). Bacia do Zambéze: elementos economico-sociais. Ministerio do Ultramar, Maputo.

Hidrotecnica Portuguesa (1965). Plano geral de fomento e ocupacão do Vale do Zambéze. Missão de Fomento e Povoamento do Zambéze, Maputo.

Hoguane, A. (1997). Shrimp abundance and river runoff in Sofala Bank – the role of the Zambezi. Paper presented at the Workshop on the Sustainable Use of Cahora Bassa Dam and the Zambezi Valley, 1997, Songo, Mozambique.

Hollis, G.E. (1996). Hydrological inputs to management policy for the Senegal River and its floodplain. In: Water management and wetlands in sub-Saharan Africa (edited by M.C. Acreman & G.E. Hollis), pp. 155-184. IUCN, Gland.

Horowitz, M.M. (1994). The management of an African river basin: alternative scenarios for environmentally sustainable economic development and poverty alleviation. In: Proceedings of the International UNESCO symposium: Water resources planning in a changing world Koblenz (edited by C. Koblenz), pp. 73-82. International Hydrological Program of UNESCO/OHP National Committee of Germany, Karlsrue, Germany.

Isaacman, A.F. (1972). *Mozambique: the Africanization of a European Institution. The Zambezi Prazos 1750-1902*. University of Wisconsin Press, Madison.

Isaacman, A. & Sneddon, C. (in press). Toward a social and environmental history of the building of Cahora Bassa Dam. Paper presented at the Conference on African Environments: past and present. July 5-8, 1999. Oxford, UK.

Ishemo, S.L. (1995). *The Lower Zambezi Basin in Mozambique. A study in economy and society, 1850-1920*. Ashgate, Brookfield, Vermont.

Junk, W.J., Bayley, P.B. & Sparks, R., (1989). The flood pulse concept in river-floodplain systems. In: Proceedings of the International Large River Symposium (edited by D.P. Dodge), pp. 110-127. Canadian Special Publications in Aquatic Science **106**.

Kamweneshe, B.M. (1996). Status and ecology of Wattled Cranes in Bangweulu Basin, Zambia. In: Proceedings of the 1993 African Crane and Wetland Training Workshop (edited by R. Beilfuss, W. Tarboton & N. Gichuki), pp. 261-266. International Crane Foundation, Baraboo, Wisconsin, USA.

King, J.M. & R. Tharme (1994). Assessment of the instream flow incremental methodology and initial development of alternative instream flow methodologies for South Africa. Contract report 295/1/94 to the South African Water Research Commission, Pretoria.

Konrad, P.M. (1981). Status and ecology of Wattled Crane in Africa. In: Crane Research Around the World (edited by J.C. Lewis & H. Masatomi), pp. 220-237. International Crane Foundation, Baraboo, Wisconsin, USA.

Kyle, S. (1991). Economic reform and armed conflict in Mozambique. *World Development* **19**: 637-649.

Loxton, Hunting & Associates, A.O.C. Technical Services & Hidrotecnica Portuguesa (1975). Integrated Report on the Southern Region. Blocks 9, 10, 11. Volume I Report. Gabinete do Plano do Zambéze, Maputo.

MacDonald, J.F. (1955). *Zambesi*. St. Martins Press, New York.

Maugham, R.C.F. (1910). *Zambesia: a general description of the valley of the Zambezi River, from its delta to the River Aroangwa, with its history, agriculture, flora, fauna, and ethnography*. John Murray, London.

MICOA (1998.) Strategy and areas for action for the conservation of biological diversity in Mozambique. MICOA, Maputo.

Mitchell, D.S. (1985). Surface-floating aquatic macrophytes. In: *The Ecology and Management of African Wetland Vegetation* (edited by P. Denny), pp. 109-124. W. Junk, Dordrecht.

Mukosa, C., Pitchen, G. & Cadou, C. (1995). Recent hydrological trends in the Upper Zambezi and Kafue Basins. In: *Water Resource Use in the Zambezi Basin* (edited by T. Matiza, S. Crafter & P. Dale), pp. 85-98. IUCN, Gland.

Negrão, J. (1995). *One hundred years of Africa rural family ecology: the Zambezi Delta in restrospective analysis*. PhD dissertation. Dept. of Economic History, University of Lund, Norway.

Newitt, M.D.D. (1969). The Portuguese on the Zambezi: an historical interpretation of the prazo system. *J. Afr. Hist.* **10**: 67-85.

Nilsson, C. & Dynesius, M. (1994). Ecological effects of river regulation on mammals and birds: a review. *Regulated Rivers: Research & Management* **9**: 45-53.

Nordstrom, C (1993). Treating the wounds of war. *Cultural Survival Quarterly* **17**: 28-30.

Oglethorpe, J. (1997). Developments affecting the north of Sofala Integrated Management Area. In: Recursos Florestais e Faunisticos do Norte de Sofala. Volume 3, Annex 10. DNFFB, Maputo.

Olivier, H. (1977). *Great Dams of Southern Africa*. Purnell, Cape Town.

Petts, G.E. (1996). Water allocation to protect river ecosystems. *Regulated Rivers: Research & Management* **12**: 353-365.

Pinay, G. (1988). Hydrological assessment of the Zambezi River System: a review. Working Paper WP-88-089. International Insititute for Applied Systems Analysis, Laxenburg, Austria.

Polet, G. & Thompson, J.R. (1996). Maintaining the floods - hydrological and institutional aspects of managing the Komadugu-Yobe River basin and its floodplain wetlands. In: Water Management and Wetlands in sub-Saharan Africa (edited by M.C. Acreman & G.E. Hollis), pp.73-90. IUCN, Gland.

Rendel Palmer & Tritton (1979). Review of the hydrological network, and study of the design of a flood warning system for the Zambezi River. Consultancy report. RPT, London.

Saket, M. & Vasco Matusse, R. (1994). Study for the determination of the rate of deforestation of the mangrove vegetation in Mozambique. Forestry Department, DNFFB, Maputo.

Schmidt, I. (1997). The Zambezi Delta: diagnostic overview of its socio-economic characteristics. Research Consultancy Services/IUCN, Beira.

Scudder, T. & Acreman, M.C. (1996). Water management for the conservation of the Kafue wetlands, Zambia and the practicalities of artificial flood releases. In: Water Management and Wetlands in sub-Saharan Africa (edited by M.C. Acreman & G.E. Hollis), pp. 101-106. IUCN, Gland.

Sill, M. (1992). A geography of war. *Geographical Magazine*, November 1992: 45-50.

Sousa, M.I. (1997). Zona Costeira de Moçambique: Foz do Delta do Zambéze até a Beira. In: Recursos Florestais e Faunisticos do Norte de Sofala. Volume 3, Annex 7.DNFFB, Maputo, Mozambique.

Sparks, R.E. (1992). Risks of altering the hydrologic regime of large rivers. In: *Predicting Ecosystem Risk* (edited by J. Cairns jr., B.R. Niederlehner & D.R. Orvos), pp. 119-152. Advances in Modern Environmental Toxicology, Vol. 10. Princeton Scientific, Princeton, New Jersey.

Stanford, J.A., Ward, J.V., Liss, W.J., Frissell, C.A., Williams, R.N., Lichatowich, R.N.A. & Coutant, C.C. (1996). A general protocol for restoration of regulated rivers. *Regulated Rivers* **12**: 391-413.

Stevens, L.E. & Wegner, D.L. (1995). Changes on the Colorado River: operating Glen Canyon Dam for environmental criteria. In: Proceedings of a national symposium on using ecological restoration to meet Clean Water Act goals, edited by J.C.Traub, pp. 65-74. US Environmental Protection Agency, Chicago, Illinois.

Stevens, W.K. (1997). A dam open: Grand Canyon roars again. New York Times, February 25, pp. B7, B12.

Suschka, J. & Napica, P. (1986). Ten years after completion of Cahora Bassa Dam. In: The impact of large water project on the environment: proceedings of an international symposium, October 1986, pp. 171-203. UNEP/Unesco, Paris.

SWECO/SwedPower(1983). Cahora Bassa hydroelectric power scheme – Stage II. Pre-investment report, Part 5 – Ecology. Stockholm, Sweden.

Tabler, E.C. [editor] (1963). *The Zambezi Papers of Richard Thornton*, Vol. 1 (1858-1860) and Vol. 2 (1860-1863). Chatto & Windus, London.

Tello, L.P. (1986). Wildlife cropping in the Zambezi Delta, Mozambique. In: Proceedings of Working Party on Wildlife Management and National Parks of the African Forestry Commission, pp. 323-385. African Forestry Commission, Nairobi.

Tello, L.P. & Dutton, P. (1979). Programa de Operação Bufalo. Unpublished report, Direcção de Fauna Bravia, Maputo.

Tharme, R. (1996). Review of international methodologies for the quantification of the instream flow requirements of rivers. Report to the South African Department of Water Affairs & Forestry, Pretoria.

Timberlake, J. (1998). Biodiversity of Zambezi Basin Wetlands: review and preliminary assessment of available information. Phase 1. Final report. Consultancy report by BFA/Zambezi Society for IUCN-ROSA, Harare.

Tinley, K.L. (1969). First air count of the buffalo at Marromeu. *Veterinaria Moçambicana* **1**: 155-170.

Tinley, K.L. (1971). Determinants of coastal conservation: diversity and dynamics of the environment as exemplified by the Mozambique coast. In: Nature Conservation as a Form of Land Use: Proceedings of a SARCUSS symposium, pp. 124-153. SARCUSS, Pretoria.

Tinley, K.L. (1975). Marromeu wrecked by the big dam. *African Wildlife* **29**: 22-25.

Tinley, K.L. (1977). *Framework of the Gorongosa Ecosystem*. DPhil thesis. University of Pretoria, South Africa.

Tinley, K.L. (1994). Description of Gorongosa-Marromeu Natural Resource Management Area. Section 2: ecological profile of the region (form, content, process). IUCN ROSA, Harare.

Tinley, K.L. & Sousa Dias, A. (1973). Wildlife reconnaissance of the lower mid-Zambezi Valley, before the formation of the Cabora Bassa Dam, Mozambique. *Veterinaria Mocambiçana* **6**: 103-131.

Turpie, J., Smith, B., Emerton, L. & Barnes, J. (1998). Economic value of the Zambezi Basin Wetlands. Phase I Report. IUCN ROSA, Harare.

Vail, L. & White, L. (1980). *Capitalism and Colonialism in Mozambique*. University of Minnesota Press, Minneapolis.

Vaselaar, R.T. (1997). Opening the flood gates: the 1996 Glen Canyon Dam experiment. *Restoration & Management Notes* **15**: 119-125.

Wallis, J.P.R. (1952). *The Zambesi journal of James Stewart, 1862-63*. Chatto & Windus, London.

Wallis, J.P.R. [editor] (1956). *The Zambesi Expedition of David Livingstone, 1858-1863*. Vols. 1 and 2. Chatto & Windus, London.

Ward, J.V. & Stanford, J.A. (1995). Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. *Regulated Rivers* **11**: 105-120.

Welcomme, R.L. (1995). Relationships between fisheries and the integrity of river systems. *Regulated Rivers* **11**: 121-136.

Wesseling, J.W., Naah, E., Drijver, C.A. & Ngantou, D. (1996). Rehabilitation of Logone floodplain, Cameroon, through hydrological management. In: Water Management and Wetlands in sub-Saharan Africa (edited by M.C. Acreman & G.E. Hollis), pp. 185-198 IUCN, Gland.

White, L. (1993). *Bridging the Zambezi: a colonial folly*. MacMillan Press, Hampshire, UK.

Wild, H. & Barbosa, L.A.G. (1967). Vegetation map of the Flora Zambesiaca area. M.O. Collins, Harare.

Back to Contents

Figure 2.1 Map of the Zambezi Delta showing Marromeu Buffalo Reserve and surrounding coutadas.

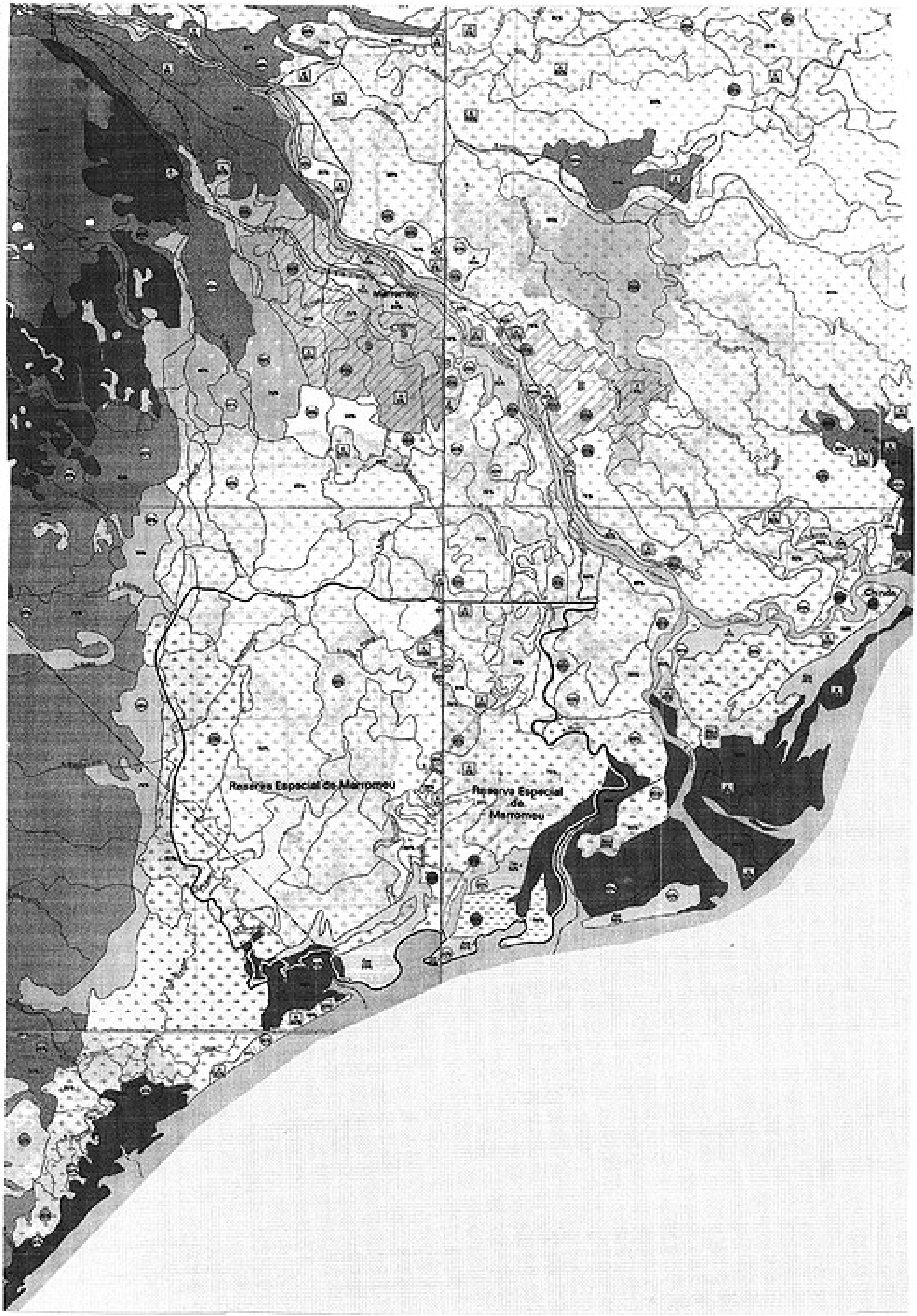


Figure 2.2 General vegetation map of the Lower Zambezi system from Plano Geral de Fomento e Ocupacao do Vale do Zambeze (from Hidrotecnica Portuguesa 1965).

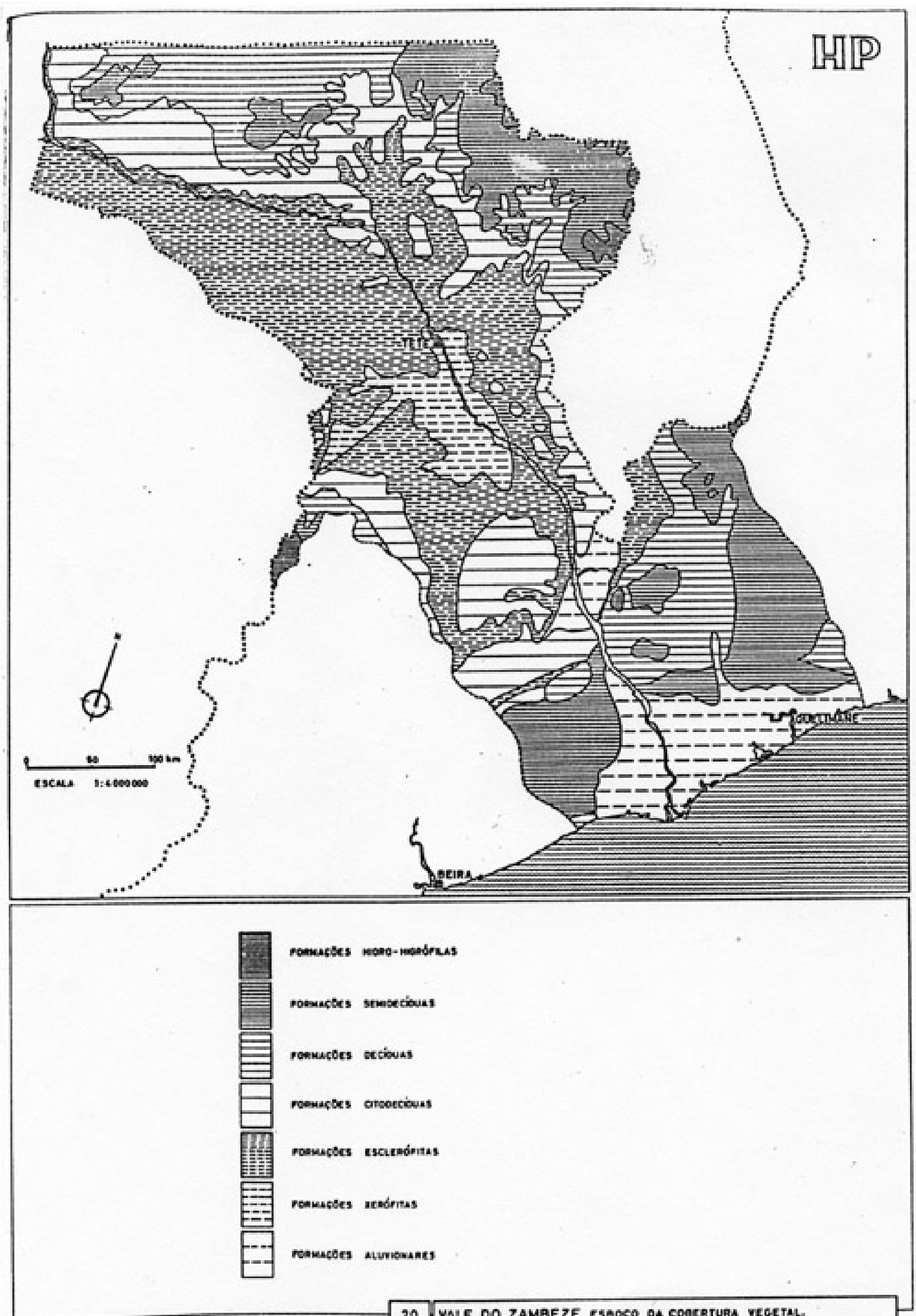


Figure 2.3 Land cover map of the ecological subregions in Block 10 (from Loxton Hunting & Associates 1975).

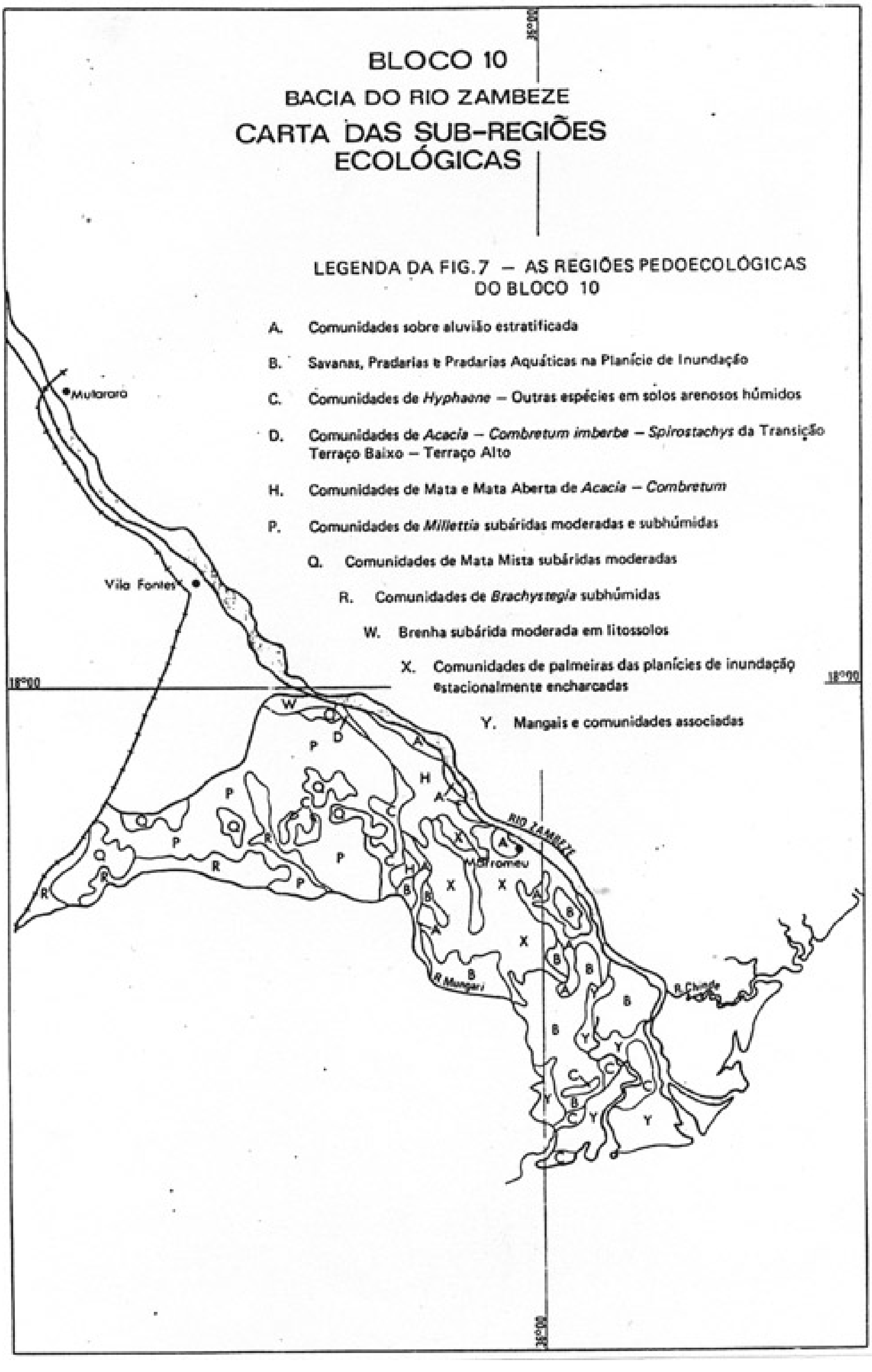


Figure 2.4 Land cover map of the ecological subregions in Block 11 (from Loxton Hunting & Associates 1975)

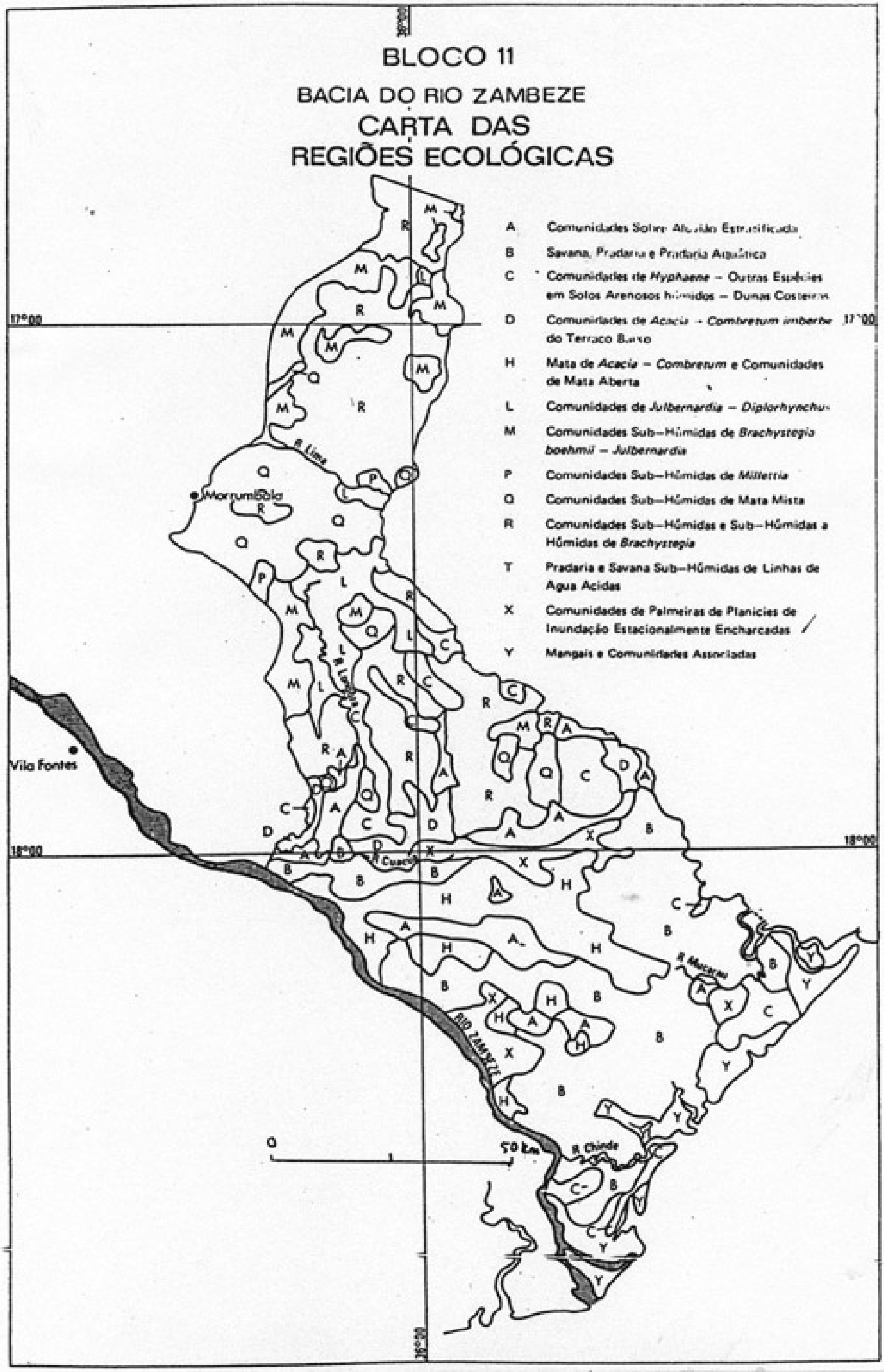


Figure 2.5 Ecological regions of Block 10, southern sector of the Zambezi Delta, as mapped by Loxton, Hunting & Associates 1975. (For legend, see over)

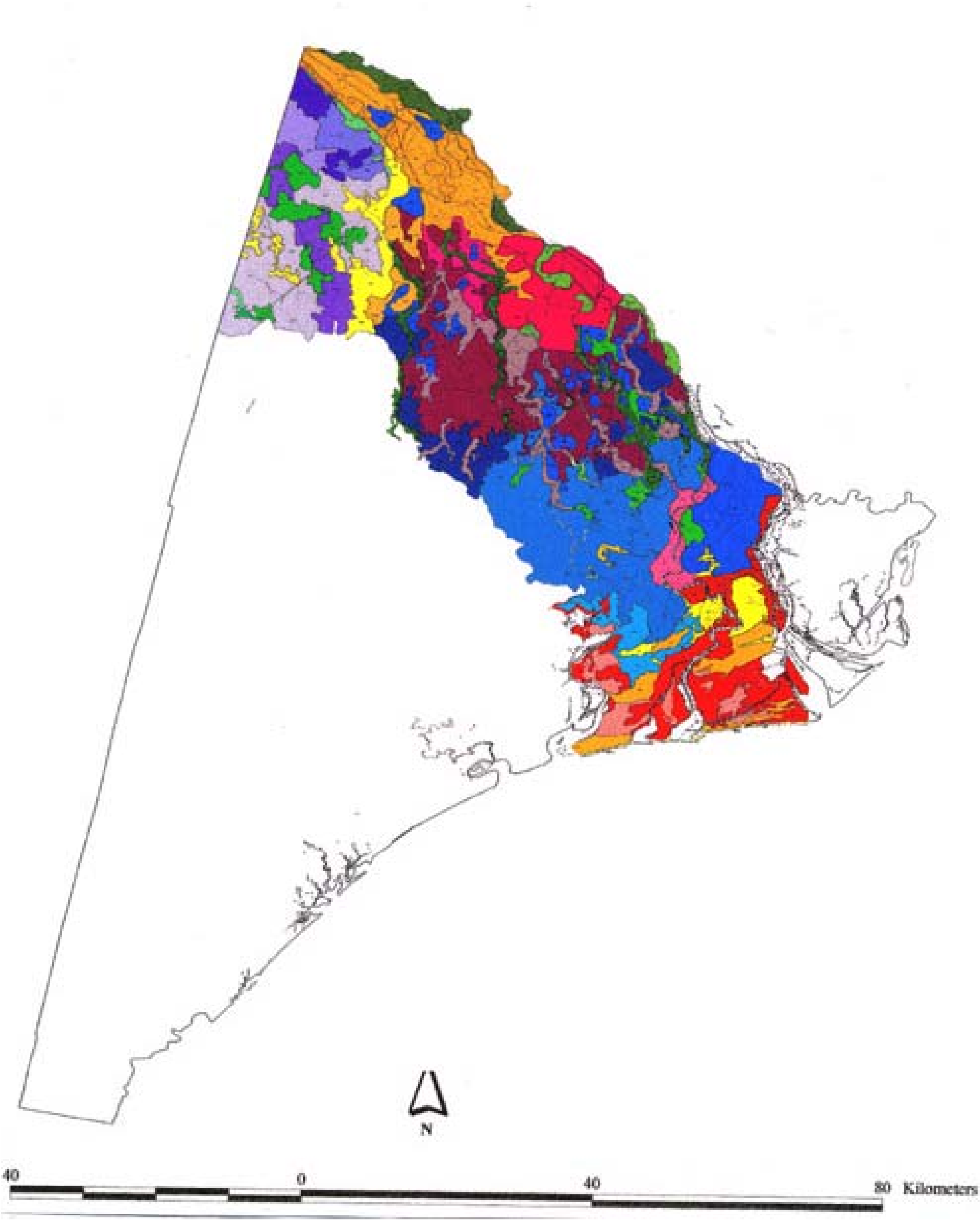


Figure 2.5 Legend

LEGEND

Communities on stratified alluvium

- A9 Acacia polyacantha savanna
- A20 Acacia-Phoenix-palm savanna complex
- A21 Acacia-Phoenix complex with Cyperus grassland--on old termitaria
- A22 Borassus-Phoenix palm savanna with cultivars

Wooded grassland, grassland, and swamp grassland on the floodplain

- B13 "Tapia"-Echinochloa swamp grassland mosaic
- B14 "Chimanganyati" swamp grassland
- B15 Setaria-Vetiveria-Hyparrhenia wet grassland mosaic
- B16 Phragmites grassland on acid saline soils
- B17 Erichloa-Hemarthria grassland mosaic

Hyphaene – other species communities on moist sandy soils

- C4 Parinari-Hyphaene open woodland--Ischaemum grassland-cultivars on coastal dune ridges
- C5 Borassus-Acacia open woodland-Hyphaene-grassland-mangrove complex on coastal dune ridges
- C6 Hyphaene-Annona-Parinari open woodland on wet pale sands

Acacia-Combretum imberbe-Spirostachys communities on the low level terrace--high level terrace transition

- D27 Acacia-Combretum imberbe-Spirostachys communities

Acacia-Combretum woodland and open woodland communities

- H9 Acacia polyacantha woodland with cultivated understory
- H10 Acacia polyacantha woodland
- H11 Mosaic of Borassus open woodland-Acacia woodland-Acacia clump thicket

Mild subarid and subhumid Millettia communities

- P3 Millettia-other species tall semi-deciduous thicket
- P14 Tall to high Millettia semi-deciduous thicket
- P15 Tall to high Millettia-other species deciduous thicket
- P16 High mixed evergreen-deciduous Celtis-Xylia forest thicket
- P17 Complex of high mixed evergreen-Millettia deciduous thicket-Brachystegia thicket-grassland

Mild subarid mixed woodland communities

- Q13 Xeroderris-Markhamia semi-deciduous woodland

Palm communities on seasonal floodplain wetlands

- X1 Hyphaene savanna--Seteria grassland complex
- X2 Medium Hyphaene-Borassus woodland and open woodland
- X3 Borassus palm savanna
- X4 Sugar cane plantation with Borassus palm

Mangroves and associated communities

- Y1 Barringtonia thicket-Echinochloa swamp grassland-with cultivated areas
- Y2 Avicenia-Rhizophora-Bruguiera mangrove complex
- Y3 Avicennia mangrove-hypersaline estuarine mudflat complex
- Y4 Avicennia mangrove-wet grassland complex with cultivated areas

Figure 2.6 Map of the regional landscape showing perennial streams of the Cheringoma plateau and southern half of Zambezi Delta (from Tinley 1994)

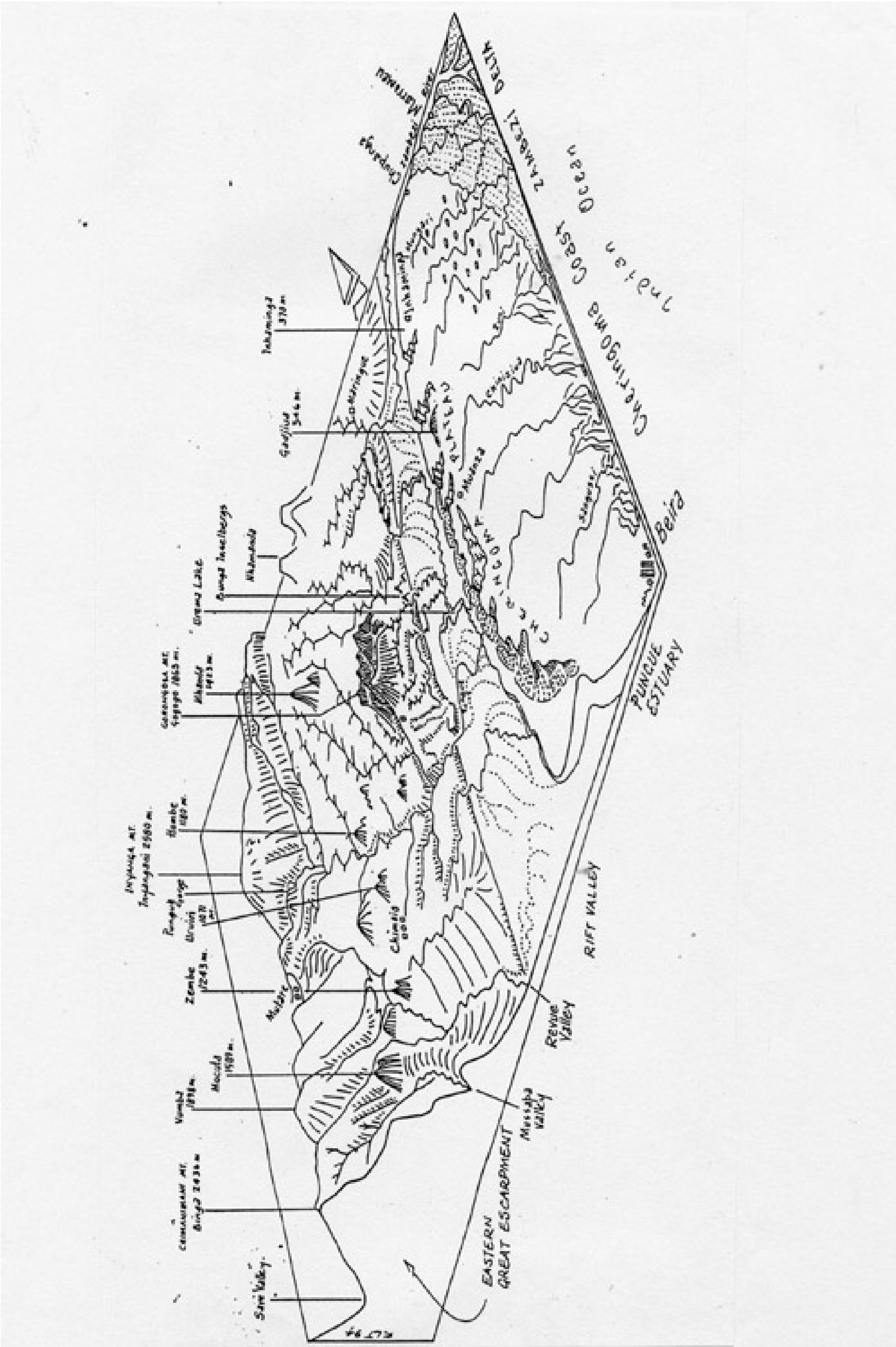


Figure 2.7 Land cover map of the Zambezi Delta (from SWECO 1983)

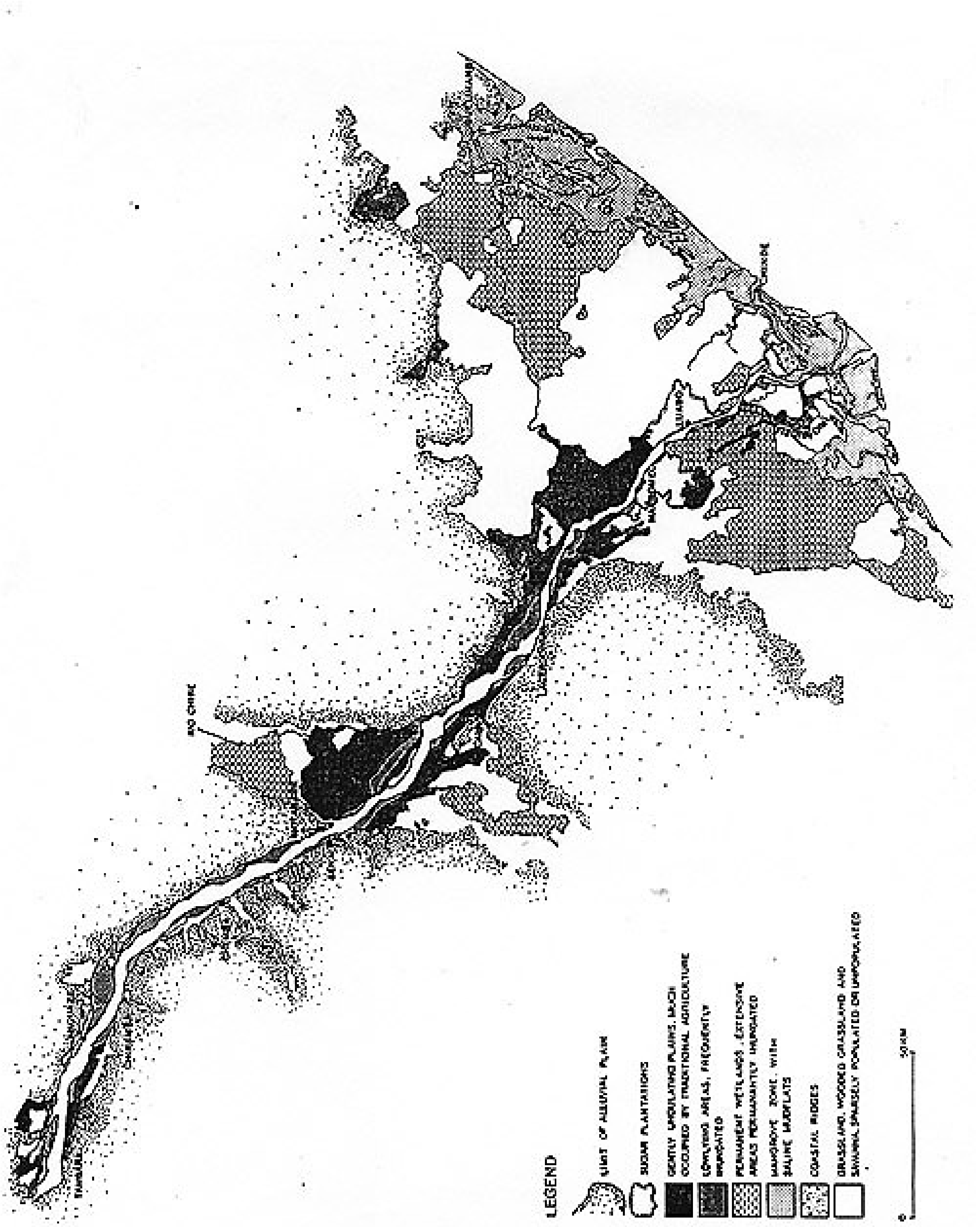


Figure 2.8 Land cover map showing coastal mangroves of the Zambezi Delta (from SWECO 1983).

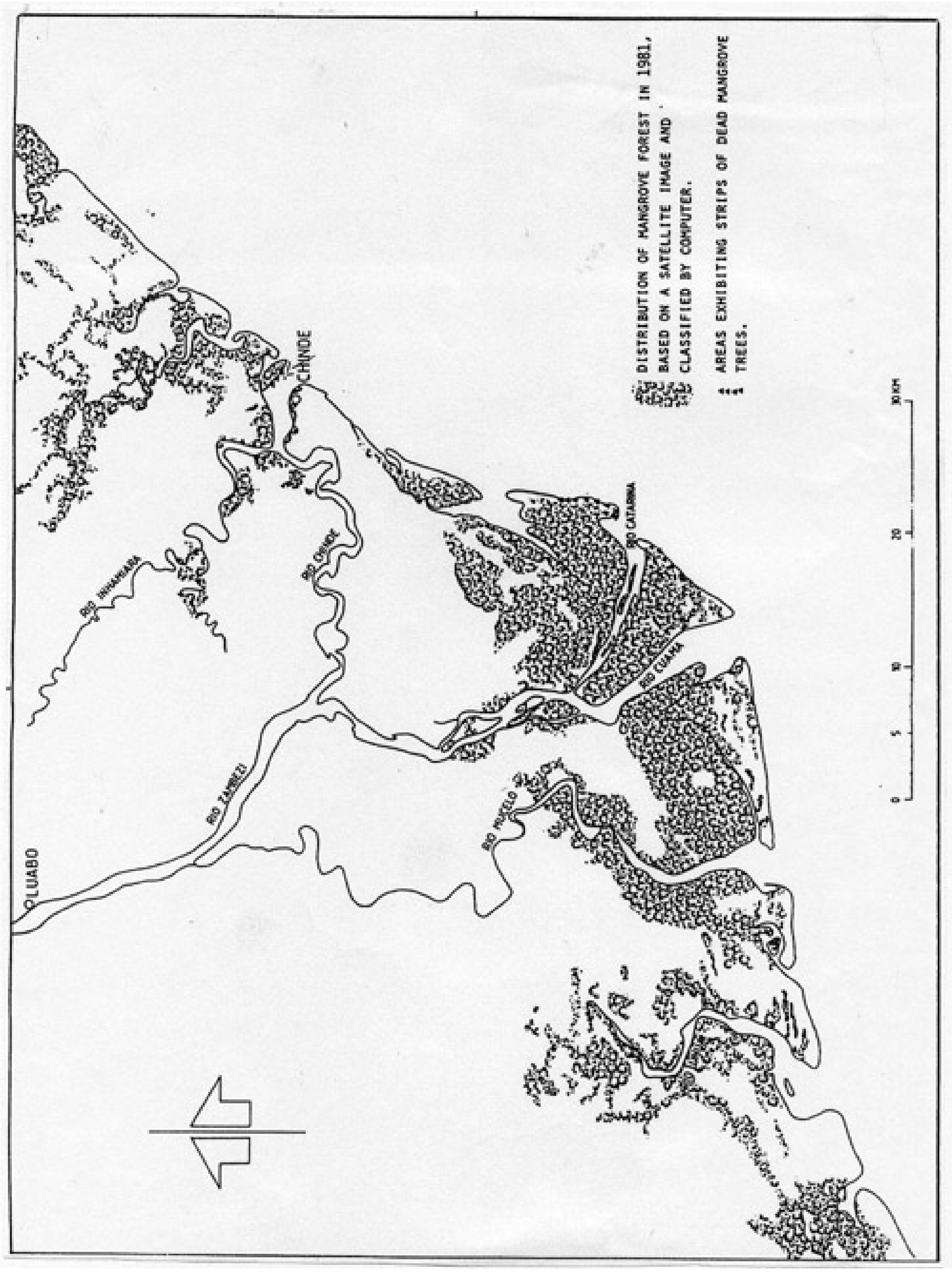


Figure 2.9 Landsat MSS satellite image of the Zambezi Delta, 1 August 1972.

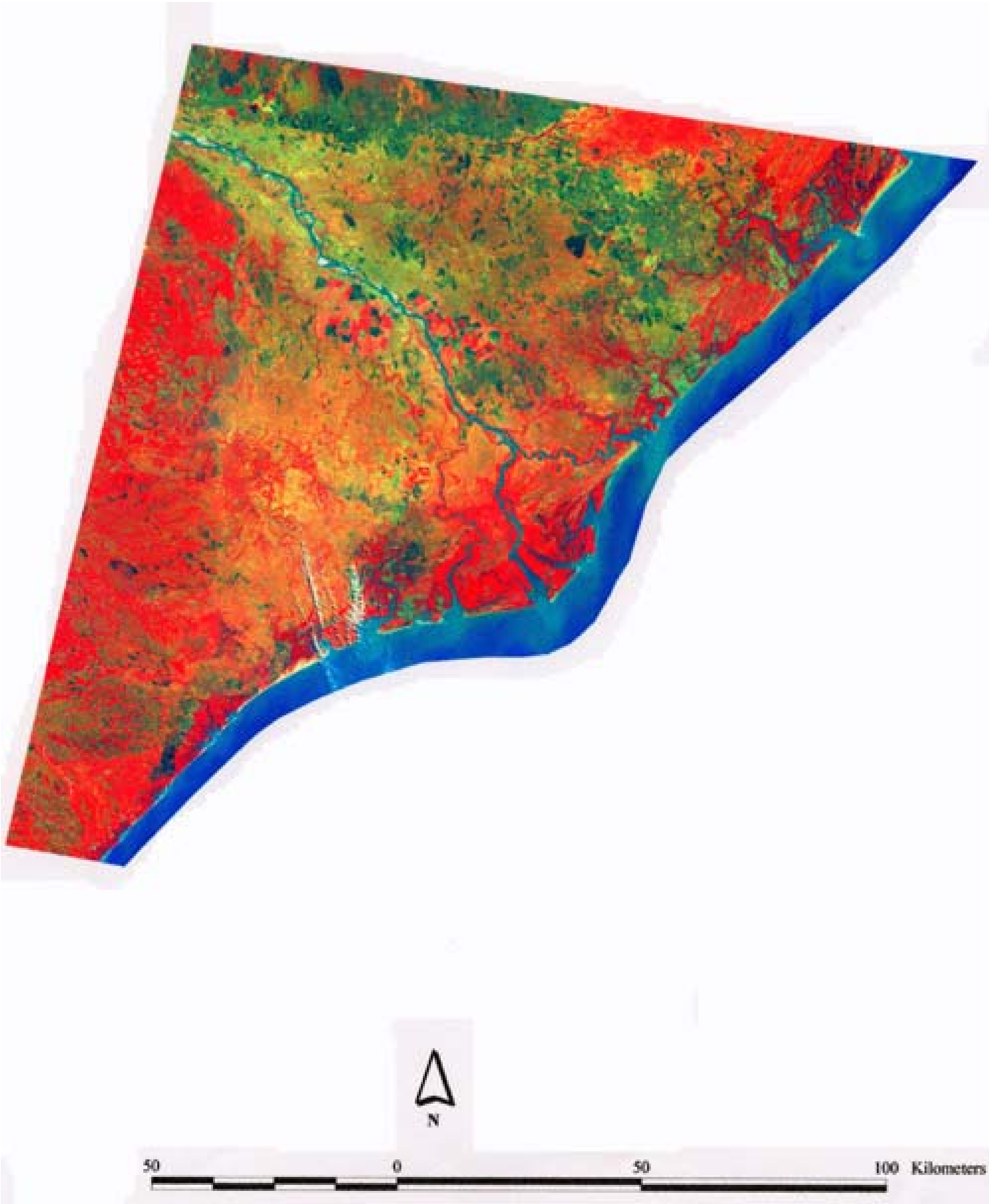


Figure 2.10 Landsat 5 TM satellite image of the Zambezi Delta, 13 July 1996.

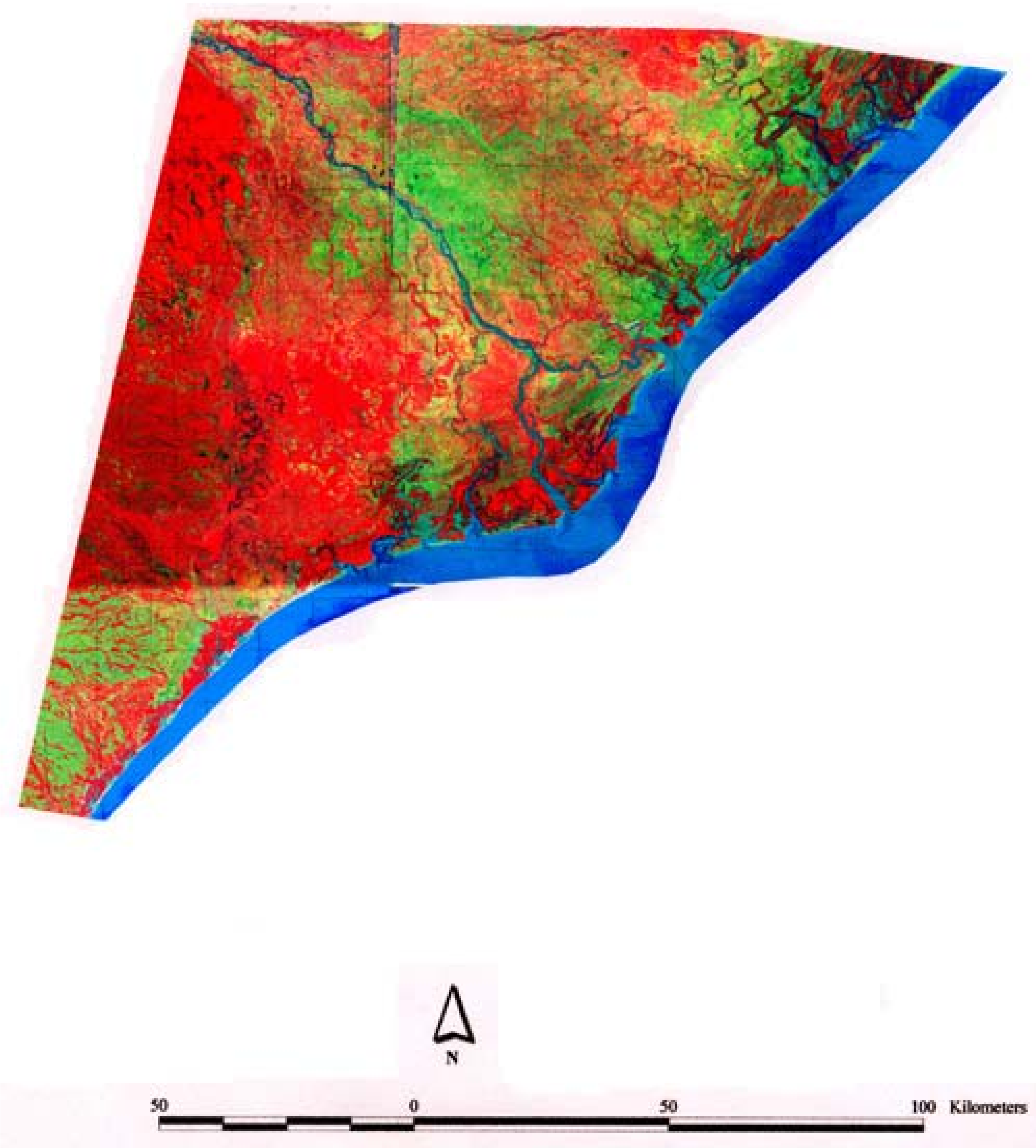


Figure 2.11 1960 land cover map of the southern half of the Zambezi Delta. Based on classification of 6 August 1960 aerial photography mosaic.

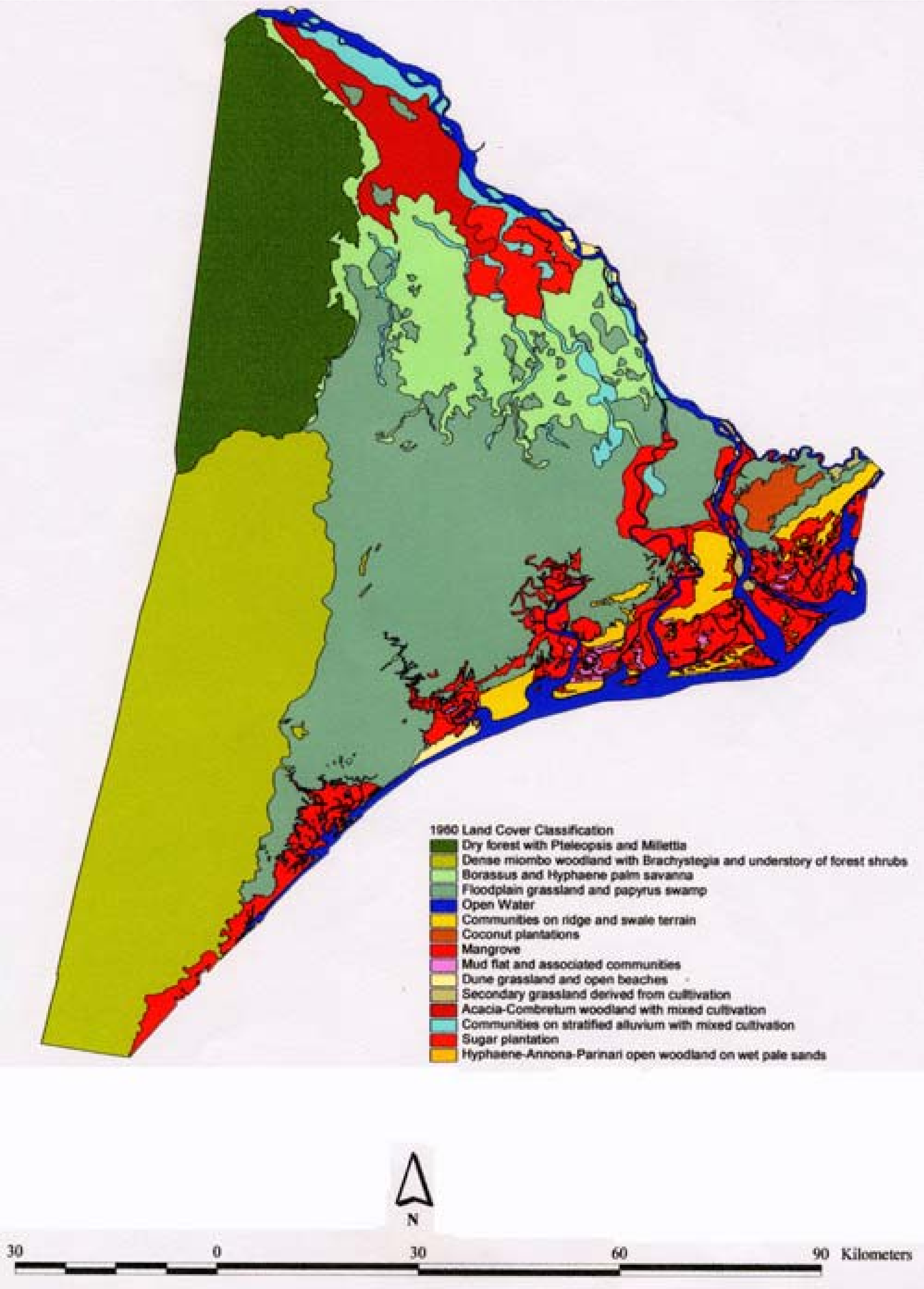


Figure 2.12 1999 land cover map of the southern half of the Zambezi Delta. Based on classification of 31 August 1999 Landsat 7 ETM image.

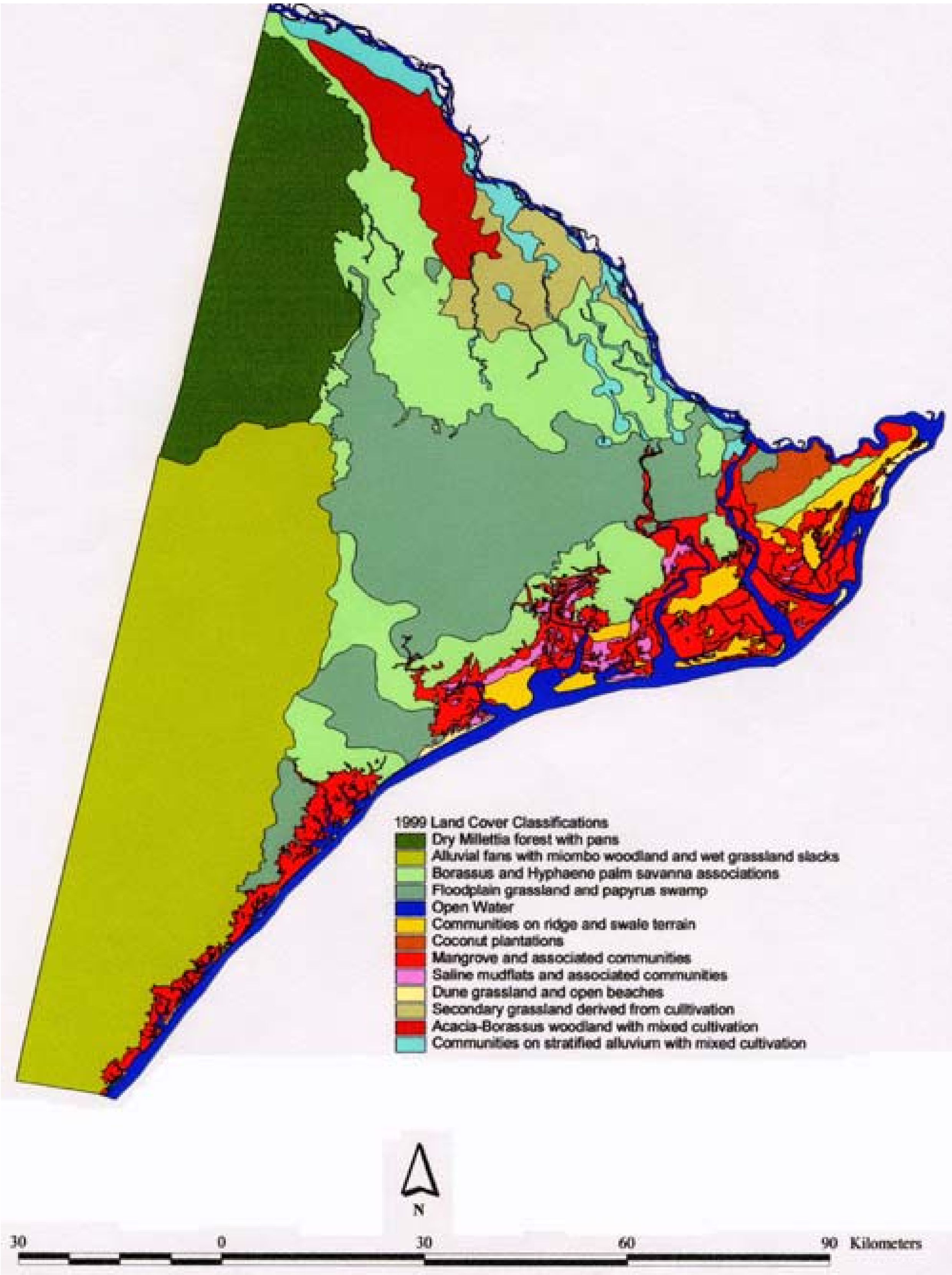
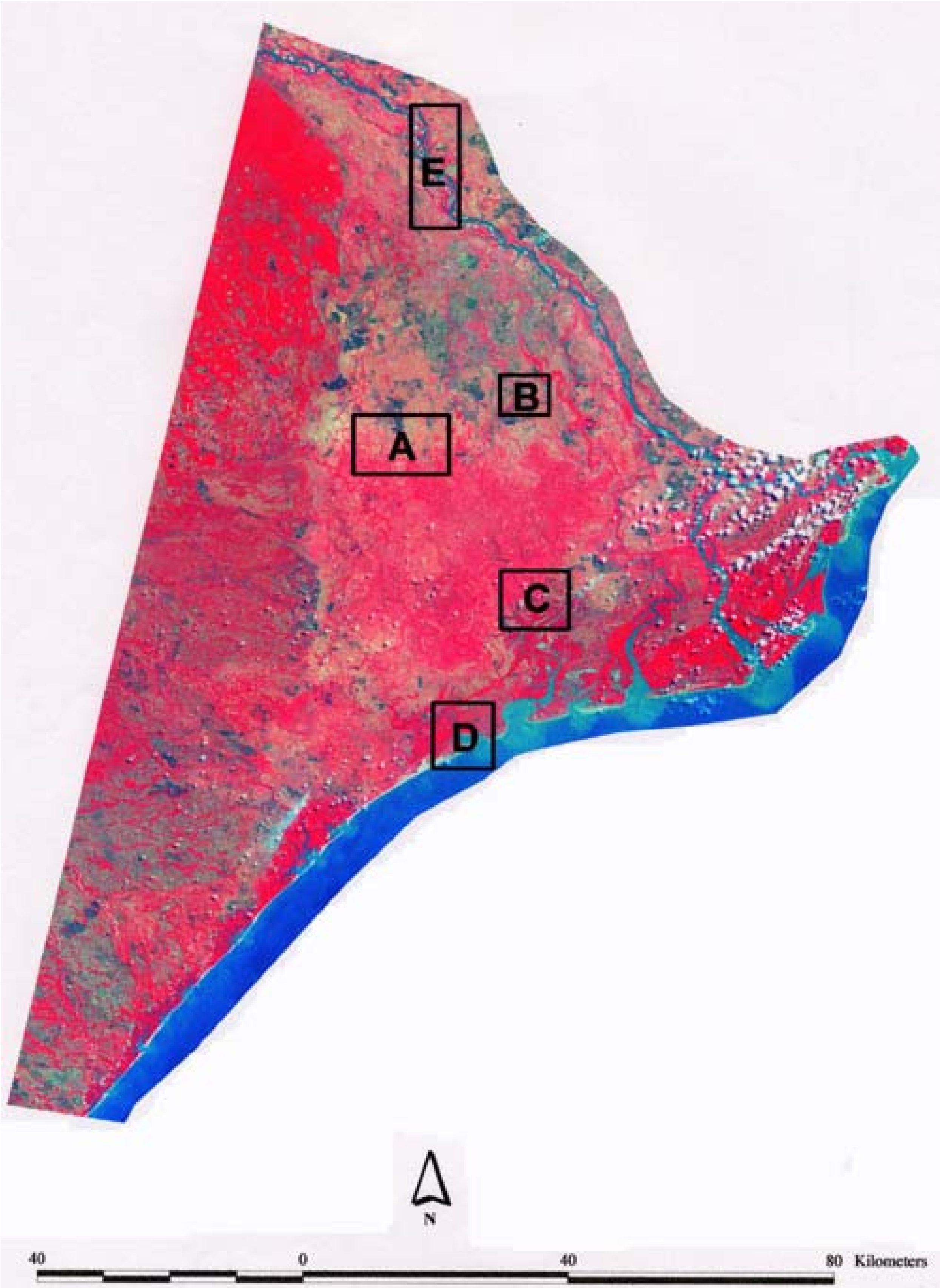
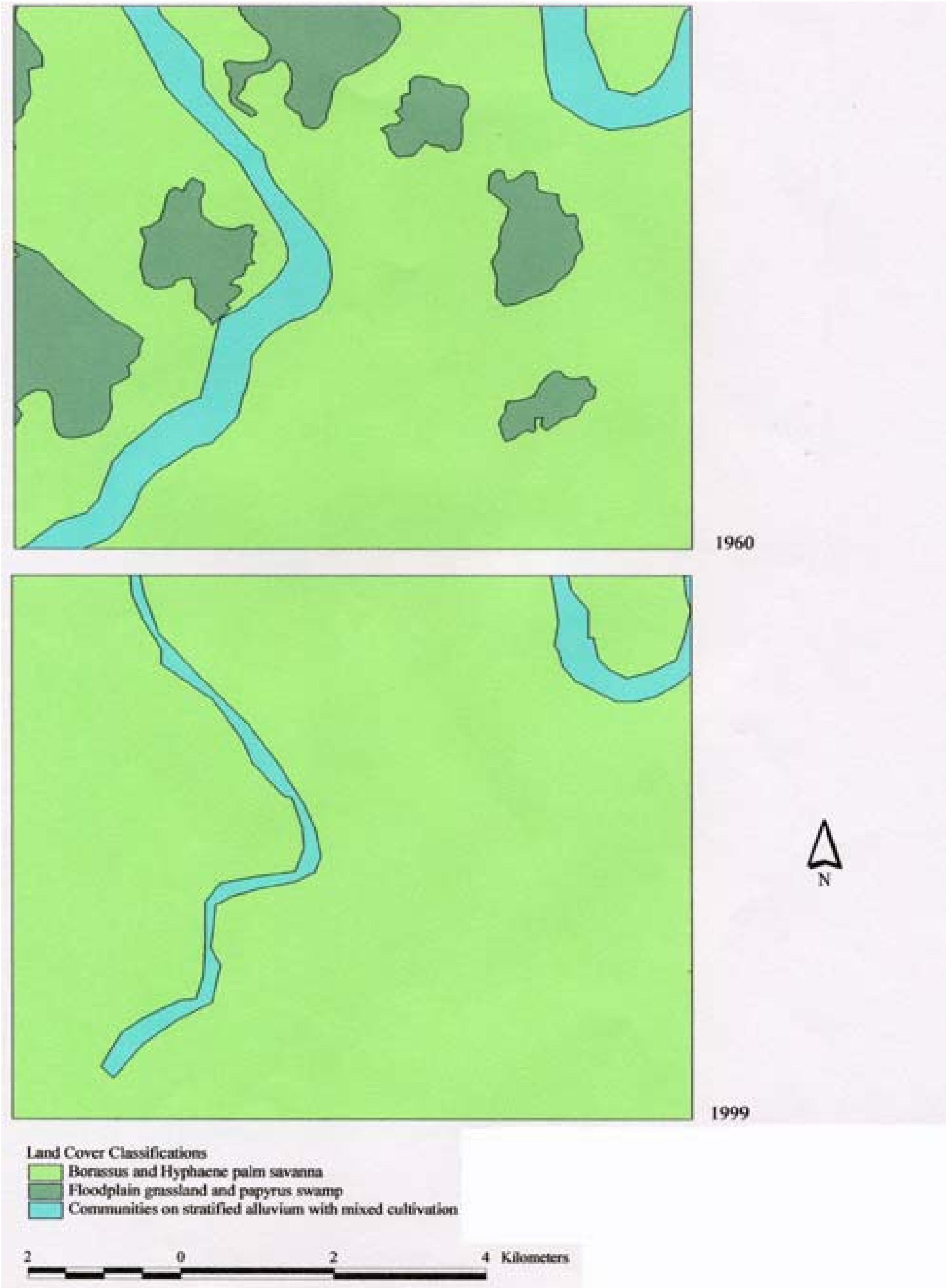


Figure 2.13 Locations of inset boxes for showing change detail.



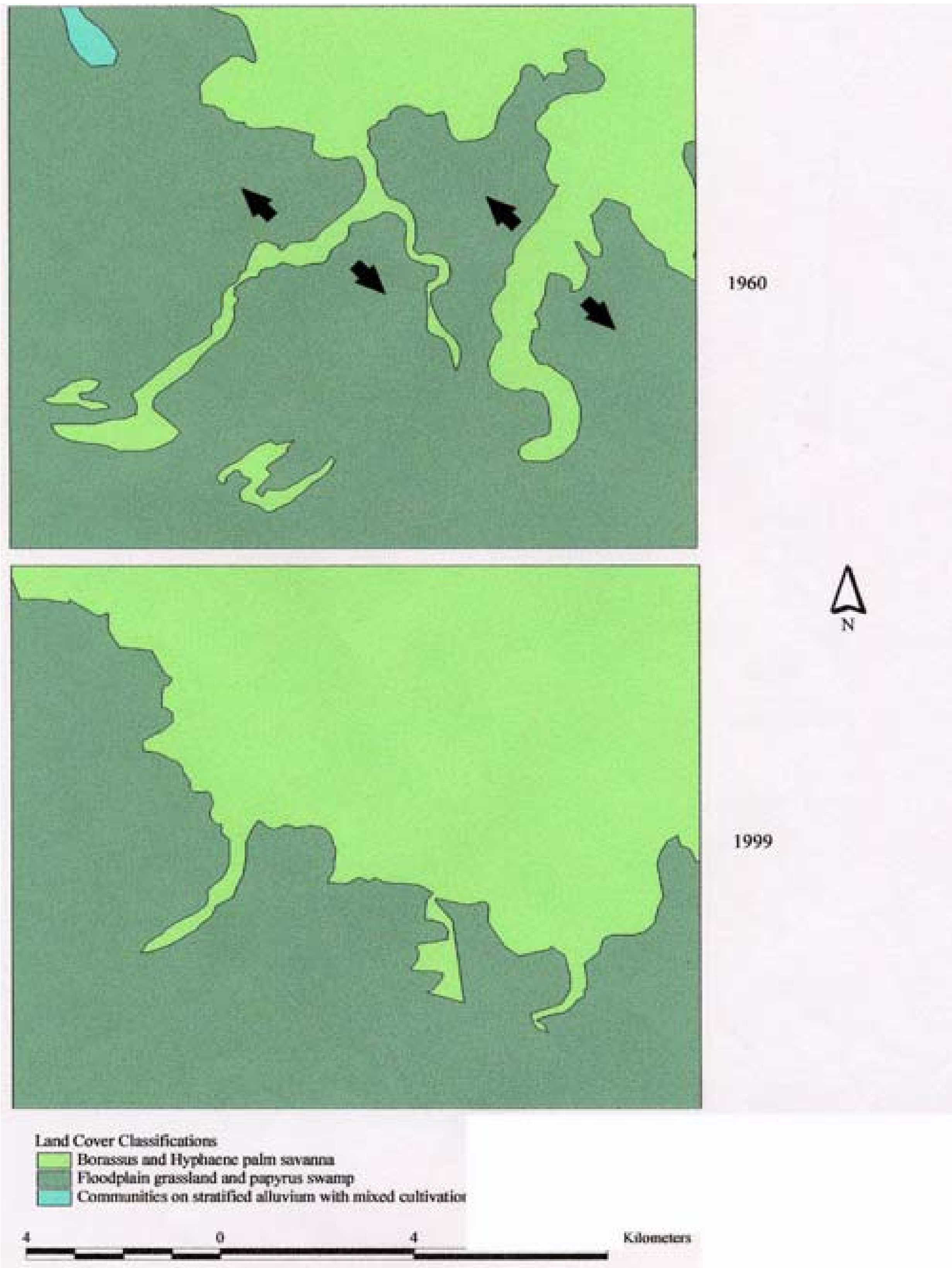
A

Figure 2.14 Inset Box A showing change in land cover between 1960 and 1999. Note encroachment of palm savanna into open floodplain grasslands.



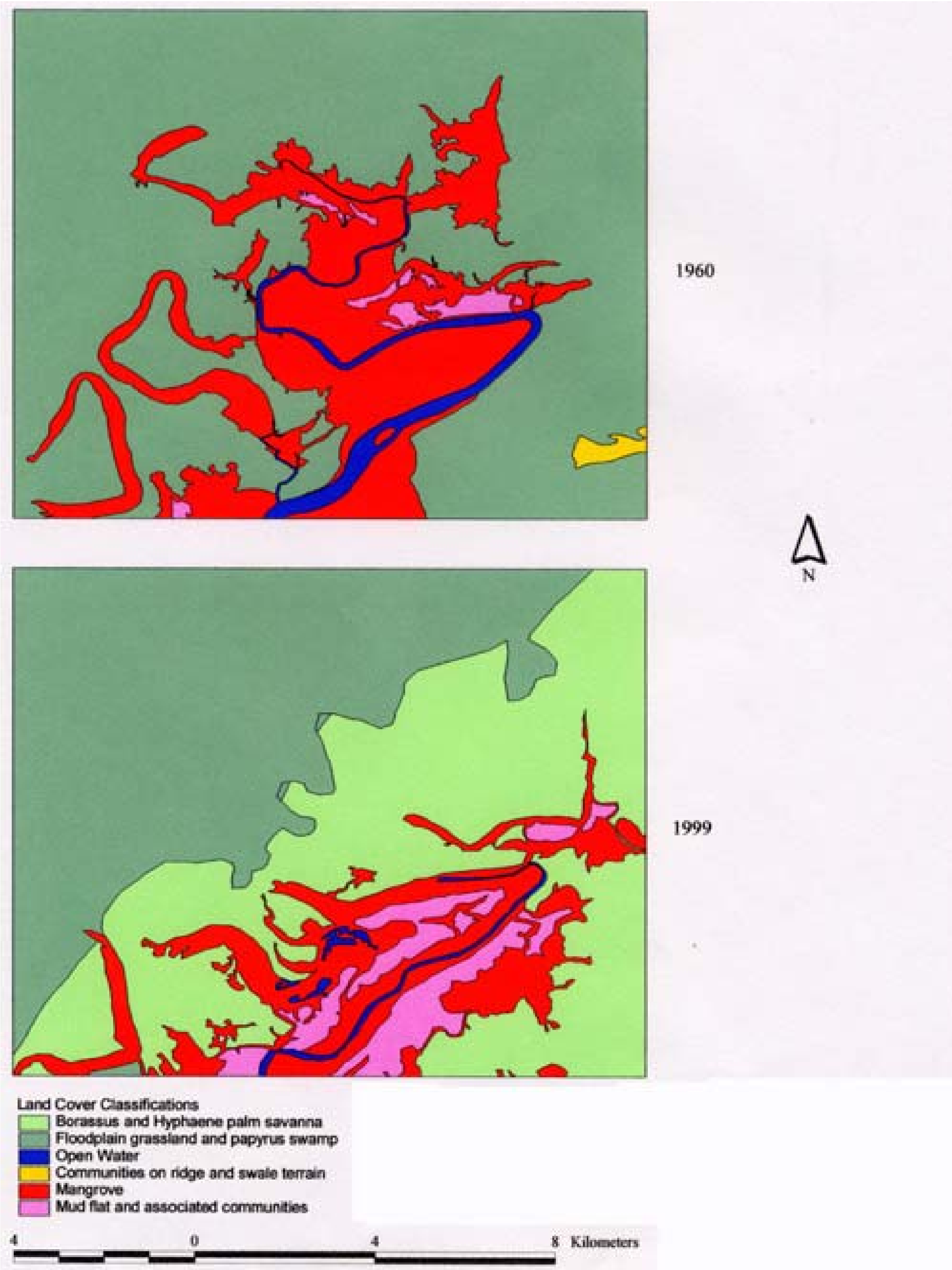
B

Figure 2.15 Inset Box B showing change in land cover between 1960 and 1999. Note radiation of palm savanna into open floodplain from levee backslopes.



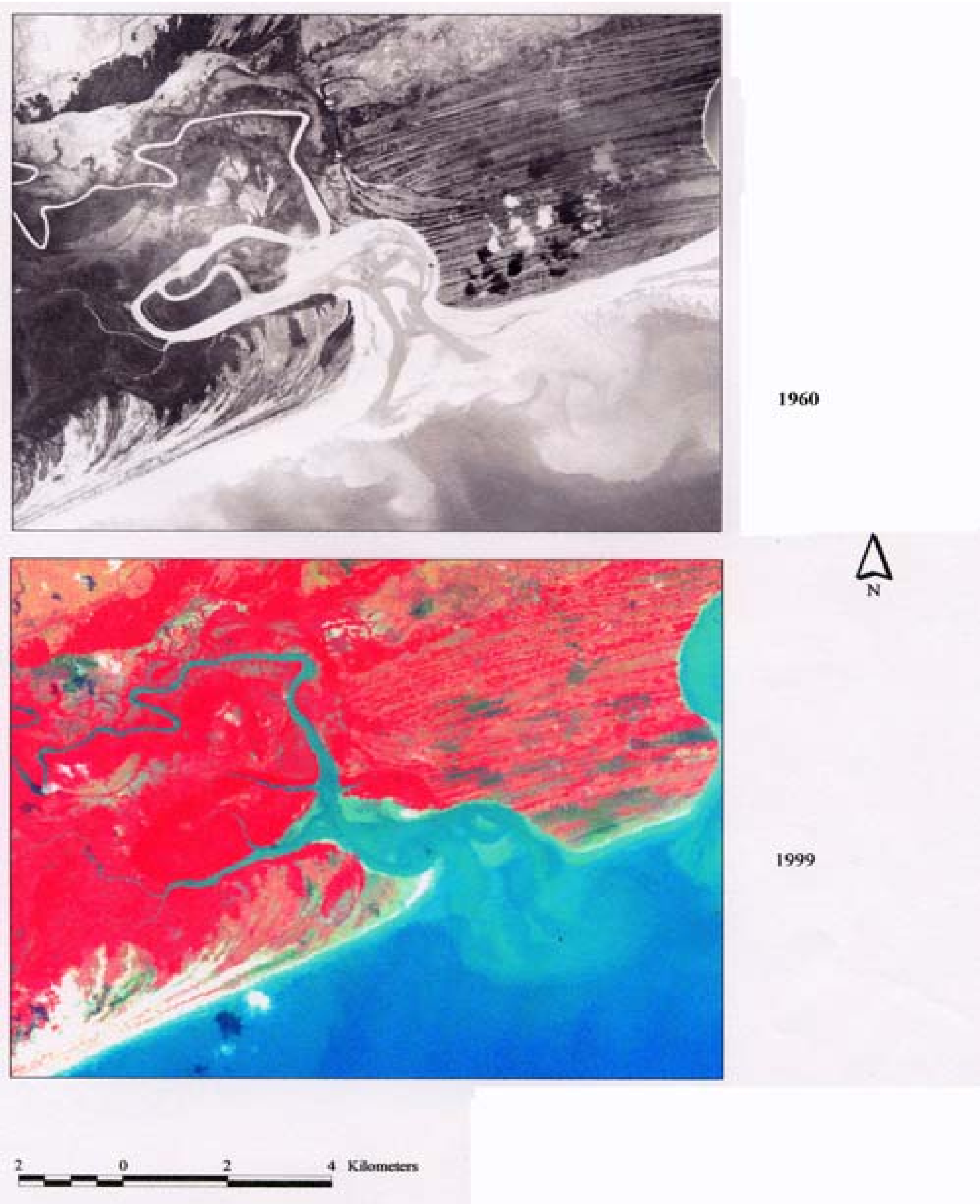
C

Figure 2.16 Inset Box C showing change in land cover between 1960 and 1999. Note loss of inland mangrove and constriction of coastal inlet channel. Palm savanna has also invaded into the open floodplain.



D

Figure 2.17 Inset Box D showing change in coastal geo-morphology between 1960 (airphoto) and 1999 (false colour IR composite). Note erosion of coastal dune ridges and abandoned meander bend (now vegetated by mangrove thicket).



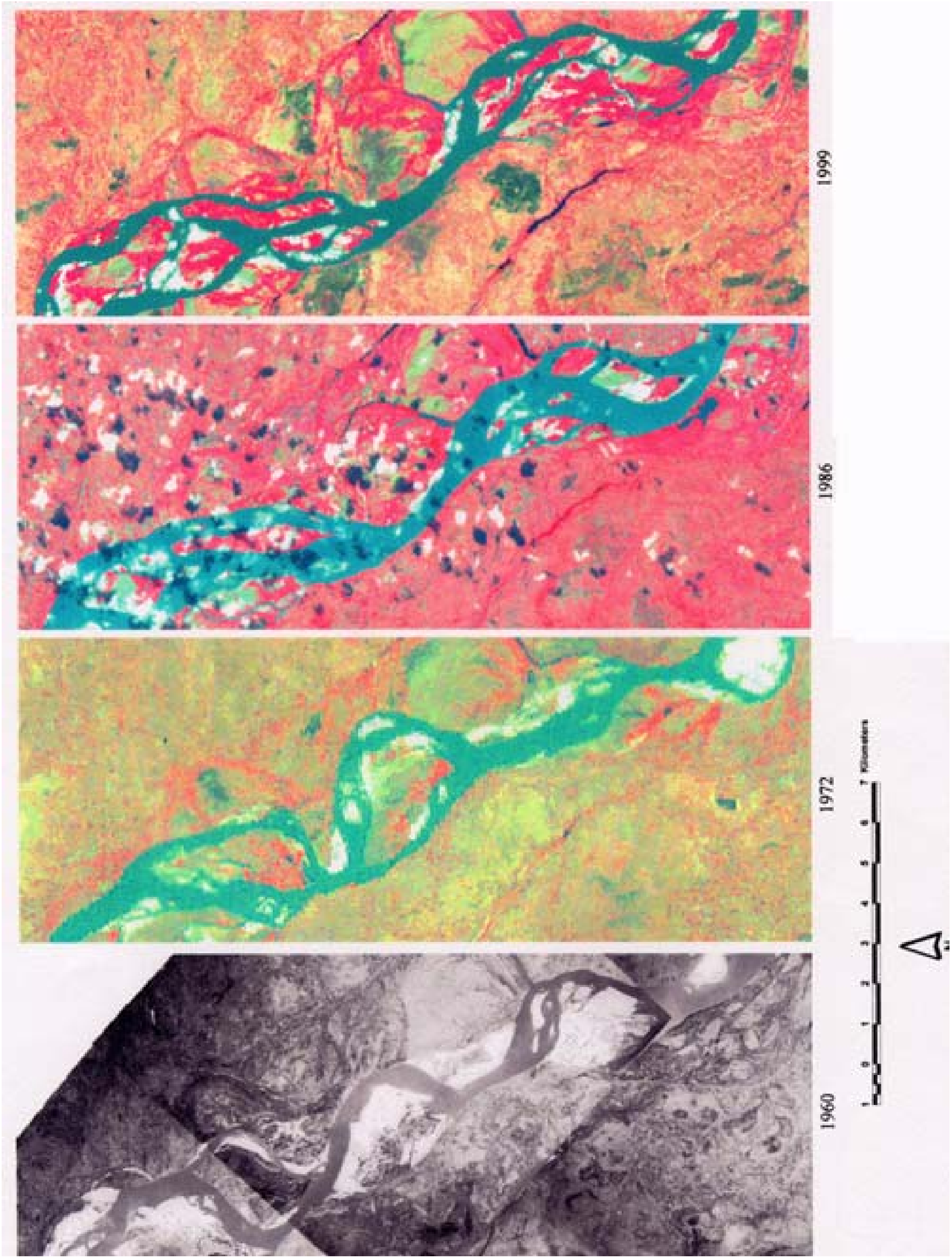


Figure 2.18 Inset Box E showing changes in Zambezi River morphology between 1960 and 1999. Note the reduction from several active channels to one dominant, downgrading channel.

E

Back to Contents

CHAPTER 3
HUMAN IMPACTS ON WETLAND BIODIVERSITY IN THE ZAMBEZI BASIN

Chris Magadza

3.1 INTRODUCTION

An evaluation of human impacts on the biodiversity of the Zambezi Basin wetlands has a number of limitations. Firstly, there is a scarcity of historical data on which an evaluation of changes in biodiversity can be based. Also, where such studies have been made they have been influenced by the investigators' special interests, such as a bias on large mammals or woody angiosperms. Perhaps due to limited taxonomic capability for smaller organisms such as invertebrates and non-flowering plants, this component of wetland biodiversity, which often shows the most sensitivity to environmental perturbation, has not contributed much to our knowledge.

Secondly, unlike in temperate regions, which have many well-dated sites to reconstruct a regional scenario of biodiversity change, the savanna belt has limited data that can provide a broad spectrum of regional biodiversity change, though recent work in East Africa promises valuable insights into historical and palaeontological changes in African wetlands.

Thirdly, most large water resources management projects have been implemented without any preliminary environmental impact assessment, or when such preliminary studies were undertaken no provision for a post-project assessment was made. This is conspicuously so for Lake Kariba, Cabora Bassa, Itezhi Tezhi and current work on the Zambezi below Cabora Bassa. Even more conspicuous is the Zimbabwe programme of water resources development where large dams, such as Mazvikadei and Osborne, are constructed without impact assessments being carried out, partly because the economic services expected from them override any environmental issues and partly because water resources development in Zimbabwe is separate from environmental management.

However, it is becoming increasingly apparent that we cannot divorce economic growth from environmental stewardship. Water and the various ecological environments it supports and depends on for its qualities, is an integral part of human development. Although several engineering processes for wastewater management are available it is now becoming more evident that natural processes of wetlands are as efficient as the most sophisticated engineering processes. Even though it has been argued that headwater wetlands, termed vleis or dambos, are not significant water reservoirs, their role on regulating stream flow is recognized.

From a hydrological point of view, wetlands may be impacted on in the long term by climate variation and climate change. While studies on Lake Chad in Tchad and Lake Chilwa in S Malawi show that these water bodies can display high variation in their hydrological status due to climate variation, there are now sufficient climate modelling results to begin to speculate on the future of wetlands in the Zambezi Basin and the implication of any climate-related changes to biodiversity. Thus the need to conserve wetlands of all sizes goes beyond what might appear to be the esoteric needs of conservationists to being the basis for sustainable development. In this discussion I will examine the various human impacts on wetlands from a water resources development viewpoint as well as from the point of view of human settlement. Finally, I will attempt to place the current status of Zambezi Basin wetlands in the context of climate change.

3.2 IMPACTS OF WATER RESOURCES DEVELOPMENT

In discussing the ecological impacts of water resources development in the Zambezi Basin it may be instructive to distinguish between the large hydroelectric projects on the Zambezi River and its main tributaries (Kafue and Shire) and upland water resources development projects for water supply and irrigation.

The Zambezi Basin developments that have been discussed most are the Lake Kariba, Lake Kafue and Cabora Bassa projects, and to a lesser extent, Itezhi Tezhi and the Liwonde Barrage on the Shire. With the exception of the Kafue project, which took into account the ecological and socio-economic role of the Kafue Flats, no meaningful pre-impoundment studies to document the biodiversity status of areas and wetlands likely to be impacted by the development were undertaken. On Lake Kariba, only a pre-impoundment fish species was made (Jackson 1959), thus details on the impacts of human intervention with respect to hydropower development are circumstantial. For example, though it is widely believed that the Mana Pools wetlands were an edaphic floodplain ecosystem dependant on flooding of the Zambezi, Du Toit (1982) contends that prior to the impoundment of Lake Kariba the Zambezi would have flooded the Mana Pools floodplain not more than three times from the beginning of the 20th century. For this reason I have argued elsewhere (Magadza in Timberlake 1998) that the Middle Zambezi floodplain (e.g. Mana Pools, Chewore 'amphitheatre') is a result of local flooding by rivers such as the Rukomeche off the Zimbabwe escarpment.

3.2.1 **The proposed Batoka Gorge Dam**

The plans for the Batoka Gorge hydroelectric reservoir upstream of Lake Kariba are now advanced. This facility is designed as "run-of-river" type, i.e. it will come on-stream when there is sufficient flow to operate the turbines. With a crest height of 180 m the dam is designed to produce 1600 MW from two 800 MW stations on either bank. All the hydrological and impact modelling assumes the installation of two generating plants, a questionable condition considering the differing priorities attached to the project by the two partner governments, Zimbabwe and Zambia.

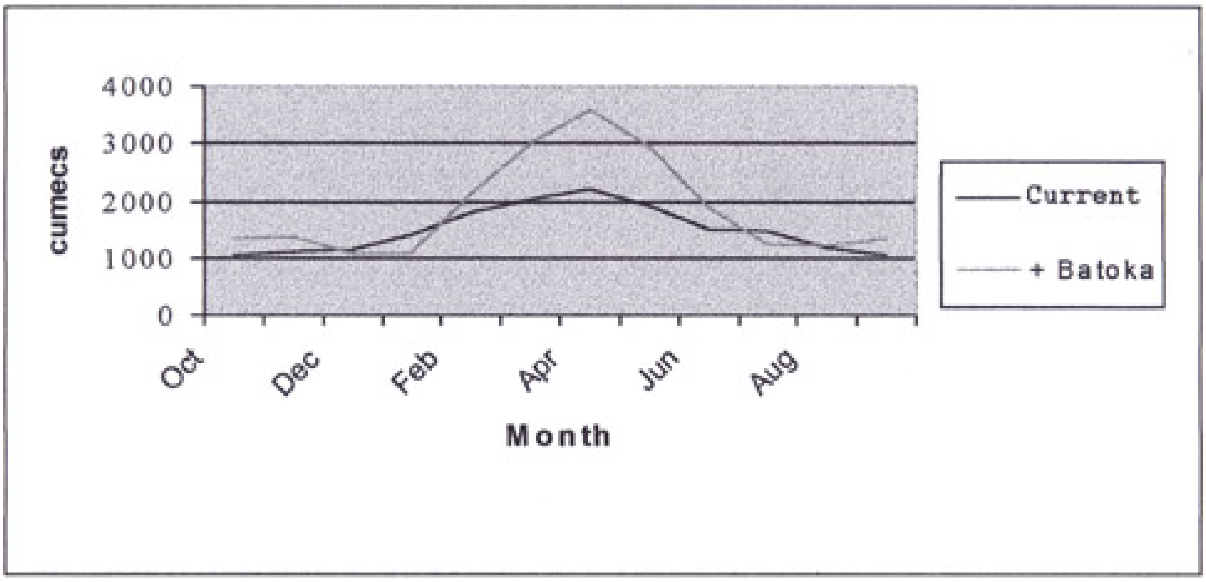
On-site impacts of the proposed dam have highlighted the fate of birds of prey (particularly Taita Falcon) in the gorge area. The environmental impact study (Conybeare 1998) argues that none of the nests will be drowned, but fails to take cognisance of the fact that the nest height above water will be reduced from a mean of more than 130 m to about 40 m. Furthermore, most of the nests are located near the top of the cliffs, areas which are likely to be developed for tourism.

Downstream of Lake Batoka the areas most likely to be impacted are Lake Kariba and the Middle Zambezi between Kariba and Cabora Bassa. Results from modelling done during the feasibility study (Zambezi River Authority 1998) indicate a considerable dampening of the lake level fluctuations on Lake Kariba. A simulation of the period 1980-1991 shows that had Batoka then been on-stream the Kariba lake level would not have dropped below 487 m, whereas it actually dropped to 475 m.

The implication of these results is on the type of shoreline ecosystem that will develop on Lake Kariba. When reservoir shorelines fluctuate widely, nutrients tend to be leached out, and often a barren shoreline develops. However, if the lake levels stabilize then the opportunity of edaphic community development is promoted. In the mid-1980s the lake level had stabilised near the 477 m level and extensive *Typha-Phragmites* wetlands with an aquatic fauna had developed. These disappeared abruptly when the lake level dropped rapidly.

Below Lake Kariba the likely impact of the Batoka Gorge dam will be an alteration of the flow regime as shown on the simulated flow at Mana Pools in Figure 3.1. From this it will be seen that peak autumn discharge will increase by just over 30%. The biological consequences are not easy to predict except that more riverbank wetlands may be flooded. If the Zambezi remains relatively devoid of silt it may also mean an increased mobility of stream channel islands.

Figure 3.1: Simulated flow at Mana Pools as a result of the impact of Batoka Gorge dam.

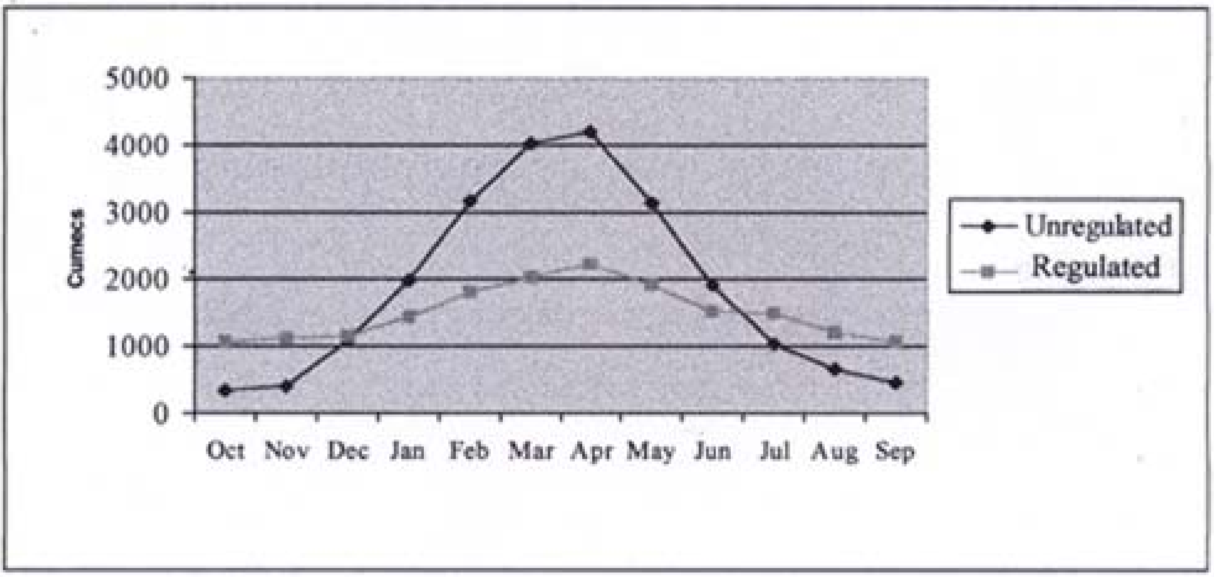


3.2.2 **The Middle Zambezi**

The best-known wetland in the Middle Zambezi is Mana Pools. In spite of this, the impacts of hydropower development are relatively little known, although an initial provocative paper by Attwell (1970) predicted significant changes in vegetation composition of the floodplain subsequent to damming of Lake Kariba. Figure 3.2 shows the change in river flow pattern at Mana Pools following the establishment of the Lake Kariba and the Kafue River dams. There is a 50% reduction in flood volume in the regulated phase of the Zambezi flow, a change that would affect many wetlands along the river in the long term.

Though it was anticipated that construction of large impoundments on the Zambezi would have lasting impacts (Davies 1986), there has not been an explicit research effort to monitor and evaluate these impacts. There have, however, been various short-term surveys conducted at irregular intervals as opportunities arose. This is an area where the research capacity of the Department of National Parks and Wildlife Management in Zimbabwe could have contributed significantly to our understanding of pre- and post-impoundment impacts of Kariba dam. In the Zimbabwe country report to the Conference of Parties on Biodiversity, for example, it is stated that the main biodiversity concern of the Department of National Parks was the monitoring of population of animals of tourist importance – the so-called big five.

Figure 3.2: Change in river flow pattern at Mana Pools following the establishment of the Lake Kariba and the Kafue River dams



However, there has been considerable progress in understanding the impact of reduced sediment load and altered flow regime, on stream bed dynamics (Nugent 1990). Below Lake Kariba, the Zambezi is a regulated eroding river, now causing constant shifts in streambed morphology, and it has been suggested that this has affected crocodile habitat. The asynchronous discharge from Lake Kariba for lake-level (not flood) control is disynchronous with the normal fish breeding migration schedules in the Mana Pools area (Kenmuir 1976). It has also been observed that on the Zambezi below the dam potamodromous fishes are attracted to the dam wall area during increased discharge. On Lake Chivero during spilling many *Labeo* and *Clarias* fish can be observed attempting to scale the dam wall. The degree of spawning failure caused by insurmountable dam wall barriers has not been assessed, but unpublished data by Anne Peebles (pers. comm.) showed missing age groups in Lake Chivero *Labeo* populations corresponding to years of low river flow when the migrating fishes could not surmount weir barriers on the river. *Labeo altivelis* and *Hydrocynus vittatus* are now virtually extinct in Lake Chivero (Brian Marshall, pers comm.). On the other hand, during a survey of fish species at Batoka Gorge, Moyo (1998) caught a seven-year-old eel. There has been speculation on how elvers of *Anguila mossambica* surmount such a formidable barrier as the Kariba dam wall. I have seen elvers scale similar barriers on the Waikato River lakes in New Zealand as long as there is film of water on the dam wall to avoid desiccation. It is possible that elvers can do the same on a wet Kariba dam wall.

The most significant impact of the impoundment of Lake Kariba on the biodiversity of the Zambezi Valley was the obliteration of the Gwembe Valley. No one will ever know what biodiversity loss this meant, though Jarman (1972) seems to indicate that, by comparison with the present woodland mammalian species, that the loss was not significant. However, from an ornithological perspective it can be concluded that a number of special habitats for wetland and riverine forest birds would have been lost. Similar conclusions can be made for a number of bat species as well as rodents. Whether there were endemic species to that part of the Middle Zambezi will never be known.

On the other hand, Bowmaker, Jackson & Jubb (1978) argued that the loss to the terrestrial system was replaced by an aquatic system of greater biodiversity than the original riverine ecosystem, at least as judged by the fish biodiversity and biomass. Of the 62 species they recorded from the

Middle Zambezi, 47 occurred in Lake Kariba, in comparison to a much lower number recorded by Jackson (1959) prior to the impoundment. Magadza (1995) also noted that the biodiversity of Lake Kariba has been significantly enhanced by biomanipulation, in which studied introduction of species to improve ecosystem performance as well as to control invasive weeds has increased biodiversity in the lake. The introduction of *Limnothrissa miodon* and subsequent development of planktonic communities in Lake Kariba introduced a truly lentic ecosystem – a feature that was not present in the Zambezi River.

Dunham (1990) surveyed the vegetation of the Middle Zambezi and showed the relationship of environmental factors (such as soil moisture) to the distribution of floodplain vegetation. Given Dunham's results it can be inferred that some change in the structure of floodplain vegetation would have taken place as a result of cessation of flooding on higher ground. In a later study (Dunham 1994) described a decline in grazers in the floodplain areas of Mana Pools which was attributable to seasonal drought as well as to a lack of flooding of the alluvial plains.

Taylor (1985), working on the gentle sloping shoreline near Fothergill Island, contended that in some way the shoreline of Lake Kariba had substituted the drowned Gwembe Valley wetlands in that it provided equivalent dry season services the valley would have provided. However, it appears that this condition is a function of dam operation rules as well as ambient climatic conditions. Following the installation of the north bank power station the annual spills that gave rise to the exposed shoreline that Taylor worked on were no longer necessary, except as a flood control measure. For example, where the shoreline has been exposed for several years due to low lake levels, it has reverted in places to dry *Acacia* woodland. Thus from a biodiversity standpoint the shoreline of Lake Kariba, like shorelines of other reservoirs, offers an unstable environment which can be exploited by opportunistic species which can exploit temporary wetlands.

3.2.3 **The Kafue Flats**

The Kafue dam was designed with conservation of the ecosystems of the Kafue Flats as well their cultural and pastoral importance in mind (Chapman *et al*. 1971). Thus the dam would inundate a maximum of 800 km^2. Furthermore, the biological importance of the flood was recognized as critical to the breeding behaviour of the floodplain fishes. The Kafue is one of the major fisheries in Zambia. As early as the 1960s it was recognized that in addition to the flow required to run the power station, an "environmental flow" was required. For this reason the Kafue dam is supposed to be operated in tandem with Itezhi-Tezhi dam, with the latter providing the "live" storage required to run the power plant while also storing sufficient environmental water to pulse the floodplain at the appropriate time to induce the fish spawning run. However, what the designers did not anticipate were:

(a) the operational significance of a marked cyclicity in the Kafue River flow of approximately six to seven years; and
(b) the attitude of the plant operators to the environmental issues inherent in the design of the system. Soon after the commissioning Kafue power station, and before the completion of the Itezhi-Tezhi Dam, the Kafue River registered one of its low flow periods in the 1972/73 season. Consequently, to ensure adequate storage for the next hydrological season the Kafue dam storage level was raised by about 1.14 metres.

Magadza (1992) noted that the inundated area at peak of storage was more than 2000 km^2. The rapid flooding of the flats with a considerable amount of dead organic matter resulted in anoxia, causing considerable fish deaths for several weeks. Dudley & Scully (1980), in a survey of fish catches on the Kafue Flats, noted the apparent dominance of one species, in comparison to six species that were frequent in pre-impoundment catches. They also noted a decline in predator species.

Within the Kafue Flats there are two national parks, Blue Lagoon on the north bank and the Lochinvar on the south. These sanctuaries are the main refugia of the Kafue lechwe, *Kobus leche kafuensis*, and many species of waterfowl and other antelopes. The expanding waterfront forced these animals onto a narrow belt between the dry land and the flooded lake, exposing them to massive poaching. Outside the sanctuaries, especially in the upper reaches of the flats, wildlife is outcompeted by domestic stock and cropping.

Because of the nutrient-rich nature of the flats, the lentic conditions favoured the proliferation of floating vegetation comprising *Vossia cuspidata, Aeschynomene* and *Ipomoea* species (Magadza 1992). These floating mats occupied most of the surface of the lake, making it unsuitable for diving birds such as cormorants. Thus while prior to the damming of the Kafue River cormorants were observed in huge flocks along the river channels, in the post-impoundment period small flocks of cormorants were evident only in open lagoons, particularly by the Blue Lagoon causeway (pers. obs.). However, recent counts of various wetland bird species (Dodman *et al*. 1997) indicate healthy populations of several species in the two national parks as well as on the Bangweulu swamps.

Downstream of the Kafue Dam there is a river stretch of some 20 km before the tail race exhaust from the power plant joins the main river. The author has observed periods (dry season 1974) when there was no stream flow in that river stretch as all the flow was diverted to the power house through the tunnel bypass. This is a phenomenon that will be repeated each time there is water supply stress in the system. Its impact on biodiversity is unknown.

3.2.4 **The Shire River**

The most extensive wetland system in the Zambezi in Malawi are the wetlands in the Lower Shire River, namely the Elephant and Ndinde marshes. Historical records indicate wide variations in the condition of these wetlands due to natural climatic variation (Bartlett *et al*. 1996). The impact of hydroelectric developments on these wetlands as such appears to be minimal in comparison to other human influences discussed below (Dudley, Manning & McCormick 1991).

3.2.5 **The Lower Zambezi**

Perhaps the most noticeable impact on biodiversity of water source development in the Zambezi Basin is on the Lower Zambezi. These impacts have been discussed by various authors (Anderson *et al*. 1990, Beilfuss & Allan 1996, Davies 1975, Davies *et al*. 1975, Singini 1996, Tinley 1975, and are summarized in Chapter 13). They include a drastic decline in the large mammal populations, particularly buffalo, in Marromeu on the south side of the Zambezi Delta, a decline in shrimp production offshore (Da Silva 1986, Gammelsrod 1992), salt intrusion into the coastal wetlands due to cessation of flooding, and human encroachment onto the riparian strip due to cessation of river bank flooding. The decline in shrimp production would indicate significant changes in ecosystem energy flows in the delta area. Marromeu is considered Mozambique's major wetland and is an important contributor to wetland biodiversity in southern Africa.

3.3 IMPACTS DUE TO HUMAN SETTLEMENT

3.3.1 The Upper Zambezi

Table 3.1 shows the distribution of fish biodiversity in the Zambezi Basin, and it can be seen that the Upper Zambezi sub-basin is the richest. This fish diversity is floodplain-based, largely on the Zambezi floodplain in Western Zambia and in the Chobe swamp area. Magadza (1995) has indicated that as the Chobe swamps became drier there was a noticeable decline in wetland biodiversity in terms of population numbers. The Barotse floodplain is also coming increasingly under settlement pressure.

Table 3.1. Fish biodiversity in the Zambezi sub-basins (data from FAO/ALCOM 1999).

sub-basin	No. fish species
Upper Zambezi	87
Middle Zambezi	52
Lower Zambezi	81
Shire	35
Kafue	54
Luangwa	21

The standard tool for rural settlement expansion is fire. Satellite images from the NOAA (1992) fire monitoring library show the intensity of dry season fires in southern Africa. In western and northwestern Zambia fire distribution corresponds to the floodplains and wetland headwaters. Such fire patterns also largely reflect settlement intensity as village density in the floodplain is distinctly higher than that on the surrounding high ground. Floodplains and adjacent wetlands are areas of intensifying agricultural activity and population growth.

Although the Upper Zambezi is served by three moderate-sized national parks (Cameia in Angola, Liuwa Plains and West Luanga in northern Zambia, and Siomangweze in southwestern Zambia), there has been very little study done on the biodiversity of this region. This is partly due to its remoteness from any research facility but also due to the Angolan war. Biodiversity studies in this sector of the Zambezi have largely consisted of limited surveys to produce checklists of various groups of plants and animals, mostly angiosperms and vertebrates. However, these surveys are so infrequent and limited in scope that they are unable to inform on any impacts human settlements may have had on the wetland biodiversity. As early as 1975, Clarke (1975) noted the poor conservation status of the Zambezi floodplain due to human cultivation and cattle grazing. Hatton & Guerra-Marques (1992) give a status report on the biodiversity of Cameia National Park wetlands and note the human pressure there.

The biodiversity of the Chobe-Linyanti wetlands is better known largely due to a concerted effort by the Government of Namibia to document the biodiversity of its wetlands. A status report was published as special edition of Madoqua (Volume 17) in 1991. One of the impacts cited in the report (Williams 1991) is habitat degradation due to human settlement, particularly in the Kavango riverine wetlands and Caprivi Strip. Other identified threats to biodiversity were alien species, toxic substances and poaching. Williams points out that the riparian wetlands of the Kavango support about 50 bird species which are not found elsewhere in Namibia. Further degradation of these riparian forests has resulted in the virtual extinction of a number of bird species which were restricted to that habitat. In the West Caprivi area, 54% of the riparian birds have been recommended for inclusion in the Red Data Book.

3.3.2 **Malawi**

Elephant Marsh was the first National Park to be gazetted in Malawi in 1897, but just under one hundred years later it was deproclaimed in 1992 (Hayes 1978). Population growth under traditional tenurial system, which places no clear responsibility on the land user for biodiversity conservation, is the major driving force in the status of wetland biodiversity in Malawi, and indeed in other comparable parts of Africa. In 1859 there were several species of large mammals present in the Elephant Marsh, namely elephant, buffalo and various antelope. Now researchers report ongoing conflict between humans and hippopotamus and crocodiles. Mkanda (1994) reported a 72% decline of hippopotamus (from 1620 to 448) in the Elephant Marsh in less than eight months. This was attributed to drought, conflict with farmers and uncontrolled commercial shooting.

Historically, the Elephant and Ndinde marshes have expanded and contracted in response to flow regimes and extent of flooding. During the wetter periods people retreat to higher ground, allowing an increase in wetland biodiversity. During drier years the floodplain is recolonized and larger vertebrates are threatened. Though this dynamism appears to have been sustained over the last century with respect to birds, it has led to the complete extinction of certain mammal species. The future of aquatic vertebrates, such as hippos and crocodiles, may be precarious as human pressure increases in the drier years.

Both the Elephant and Ndinde marshes are under threat from exotic plants such as *Eichhornia crassipes* and *Salvinia molesta*. This is a result of poor waste management in the metropolitan area of Blantyre and from the SUCOMA sugar estate. Though SUCOMA cane fields appear to have created additional habitat for some bird species, Hanmer (1977) evaluates the impact of human activity in the Lower Shire as negative.

On a broader scale, Malawi's wetlands are impacted by human settlements as such settlements affect the lake levels in Lake Malawi, and consequently coastal and downstream flooding, largely through hillside deforestation (Calder *et al.* 1995) and clearing of lakeshore wetlands, such as the

A modelling study was done to investigate the effects of land use change from natural forest to agricultural land on large-scale catchment runoff in southern Africa is described. Estimates of average monthly potential evaporation, together with measurements of monthly rainfall, were used in the model to predict the monthly levels of Lake Malawi. These were compared with observed levels. From 1896 to 1967 the major fluctuations in lake level, both seasonally and annually, are described. The overall agreement between prediction and observation indicates that variations in rainfall alone, without changes in either evaporative demand or in the hydraulic regime of the lake, are sufficient to explain lake level changes. For the more recent period (1954-1994), model predictions of lake level which take into account a decrease in forest cover of 13% over the period 1967-1990 agree well with observations both annually and seasonally. Without this decrease in forest cover, the model predicted that the lake level would have been about 1 m lower than that observed during the southern African drought of 1992. The model can be used for real-time water resource management applications such as the operation of barrages regulating the flow from Lake Malawi or for the issuing of flood or drought warnings.

From: Calder, I.R. *et al*. (1995). The impact of land use change on water resources in sub-Saharan Africa: a modelling study of Lake Malawi. *J. Hydrol.* **170**: 123-135.

3.3.3 **Urban impacts**

In a study of inshore waters of Lake Kariba in the Kariba Town municipality, Magadza and Dhlomo (1996) found high incidence of coliform bacteria in the inshore waters during the wet season. These data have been confirmed for the dry season of 1998, where specific *E. coli* bacteria were assayed (van Bochove & van der Doe 1998), and show the inadequacy of waste management in the lakeside urban environment. Other similar urban areas are emerging on the Lake Kariba shoreline, with even less-developed infrastructure for wastewater management.

Beyond the shorelines of Lake Kariba, the riverside settlements of Victoria Falls and Livingstone have now emerged as important sources of pollution to the river and ultimately the lake. Feresu and Van Sickle (1990) followed a plume of faecal coliform bacteria emanating from these two urban centres for over 20 km of river reach where the bacterial counts were well above WHO recommendations. These observations show a multiplicity of nutrient sources into Lake Kariba from the hinterland as well as from the lake shores.

In a study of waste disposal in Livingstone and Victoria Falls, Masundire (1998) established that only 1% of the Livingstone sewage ever gets to the treatment ponds, while Victoria Falls suffers frequent pump breakdowns and discharges directly into the Zambezi. Microbial results show the presence of human coliform in the entire river stretch from Kazungula to Batoka Gorge. These data indicate inflow of considerable amounts of wastewater into the Zambezi. The discharge of untreated or poorly treated wastewater predisposes the river and wetlands to eutrophic conditions with a high-risk invasion by alien plants, such as occurred in Lake Liambezi in the late-1970s (Schlettwein & Bethune 1992).

Figure 3.3 Levels of lead along the Zambezi River between Kazungula and Batoka Gorge.

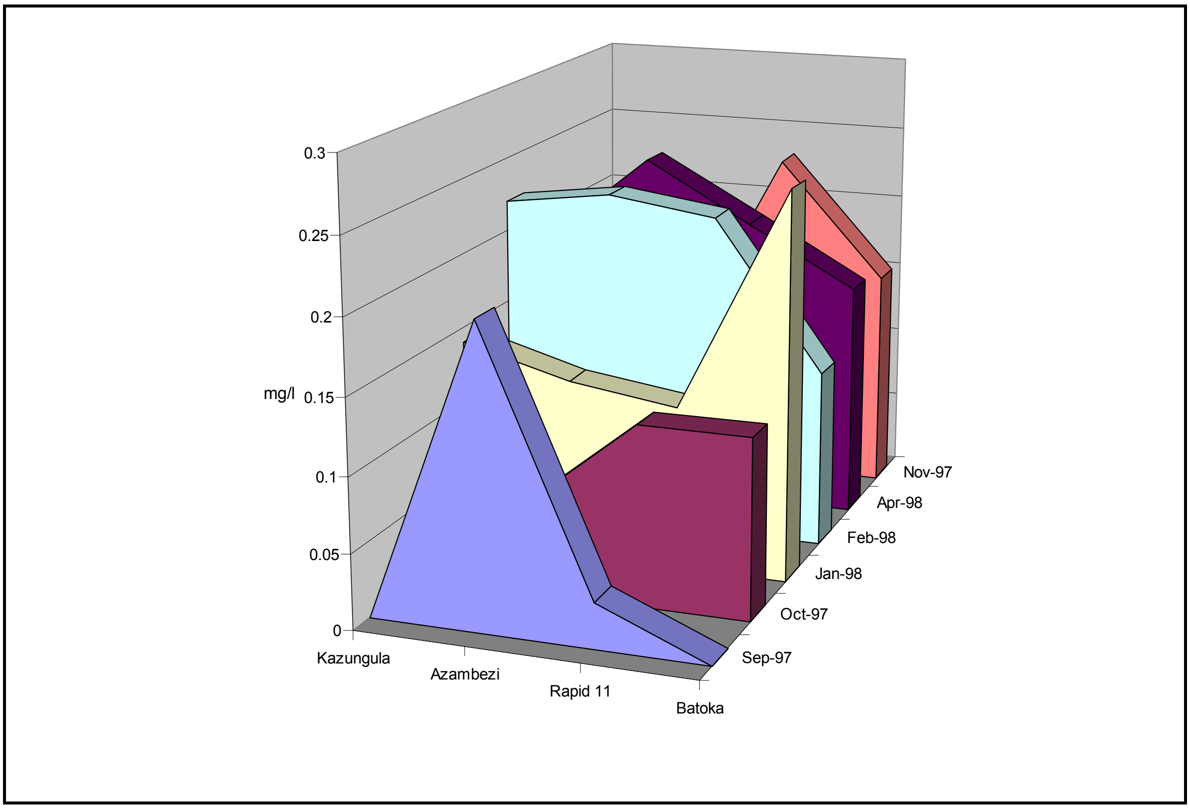


Figure3.3 shows the levels of lead along the Zambezi River between Kazungula and Batoka Gorge. Though the pattern is variable, the data clearly show sources of lead in the area between and above the falls. The source of this heavy metal is said to be the many boats that service the tourism industry on the river. Copper concentrations were uniform over the entire river reach (c. 0.8 mg/l), suggesting an upstream source, while cadmium levels ranged between 0.02 and 0.05 mg/l.

The concentration of trace metals, especially that of lead and cadmium, are an order of magnitude higher than those found in other African inland waters (Calamari & Naeve 1994). In a study of metal-metal interaction in the toxicity of trace metals on *Bulinus globosus* in Lake Kariba, Tomasik *et al.* (1995) found high synergy effects of lead at 0.1 mg/l in the presence of copper at 0.012 mg/l. Similar synergism was found for zinc at 0.1 mg/l. The concentrations of lead and copper reported by Masundire (1998) fall within these conditions. Thus while there is no field data to indicate toxicity effects on wetland organisms, experimental data indicates the possibility of toxicity.

3.4 CLIMATE CHANGE

Magadza (1996) examined the abundance of wetland species in the Chobe swamps. The data indicated a severe reduction in abundance of vertebrate species with increased drying of the swamps, such as occurred with the dying out of hippopotamus and crocodiles in Lake Liambezi. Ellenbroek (1987) noted that the vegetation of the Kafue Flats was dominated by C_3 grassland. A combination of increased temperature and carbon dioxide fertilization could result in a change in species composition towards dominance by C_4 plants, many of which might be woody species (Ohsawa *et al*. 1998). Experimental carbon-enrichment also suggests that the fodder quality would be reduced (Ohsawa *et al*. 1998). The impacts of such changes on the species composition of tropical wetlands and their carrying capacity may still be a matter of conjecture, but Hulme (1995), in a study on climate change impacts in the SADC region, suggested biome shifts due to climate change. Although wetlands were not specifically considered, the general suggestion was that climate change will result in significant ecological shifts. Of particular interest for wetland conservation is their hydrological study, which indicated a reduction in runoff in the major catchments. This finding stresses the need for careful planning with respect to management of wetlands in water allocation to meet what may be increasingly competing demands between human and environmental requirements.

Reibsame (1989) has shown that there is a decrease in run-off for a 10% decrease in precipitation at different temperatures. An extrapolation of his data to take into account the high summer temperatures of mid-continental Southern Africa would lead to an estimated decrease in run-off in excess of 50%. These results indicate the effect of increased evaporation at elevated temperatures.

Noting these model results, and observing that in swamps like Lake Bangweulu and the Okavango Delta only about 10% of total precipitation registers as run-off, Magadza (1996) has warned that, even without significant reduction in precipitation, the projected temperatures for the period 2030 and beyond will cause many of the large wetlands to shrink significantly or disappear altogether due to elevated evapotranspiration.

3.5 UPLAND WETLANDS OR DAMBOS

An important aspect of biodiversity that has received little attention is that of the upland vleis or dambos.

Lawton (1963) studied the palaeoecology of dambos in the northern province of Zambia, just outside the present-day Zambezi Basin, and found that during the climatically wetter periods the dambos of that region were associated with rainforest. The forest component of this ecosystem included species of *Ouratea* and *Cynometra* (probably *C. alexandri*), both components of the tropical rainforest flora presently found in the Congo. A specimen of *Ouratea* wood was carbon-dated to about 57,000 years before present. In later stratigraphies species such as *Colophospermum mopane*, *Burkea, Pericopsis, Dalbergia* and *Swartzia* were identified. These findings indicate alternations between wet and dry periods in which the wet periods were characterised by forest consisting of tropical rainforest species.

These palaeontological data also suggest that human occupation of these wetlands dates back more than 50,000 years. In the Lake Bangweulu sediments black ooze, commonly called peat, is in fact fine-grained carbon particles, a product of bush fires. It can therefore be concluded that humans have impacted on wetland dambos through fire and cultivation for over 50 millennia.

Lawton also noted that the forest was responsible for the maintenance of stream flow throughout the year, and that where the *mushitu* had been degraded the streams stopped flowing in the dry season and the wetland dried out.

Although other countries within the Zambezi Basin have acceded to the RAMSAR Convention on wetlands, Zimbabwe has not, on the basis that the country does not have vast wetlands such as the Everglades or the Lake Victoria papyrus swamps. This position, of course, discounts dambos as insignificant wetlands. Hopefully, this discussion on RAMSAR, though based on limited information precisely because of the scientific neglect dambos have received, has indicated their significant role and may stimulate discussion on them beyond their potential for agriculture. One of the questions that arises from the foregoing discussion is whether dambo habitats, once destroyed, can recover through normal successional processes. Experience in Zimbabwe suggests that the degradation cycle can be arrested if the fundamental elements of the dambo are still present. This is the case with the Senkwe vlei in Matabeleland North and the Dikani vlei in Lower Gweru, Zimbabwe.

3.6 THE ROLE OF WETLANDS IN BIODIVERSITY CONSERVATION

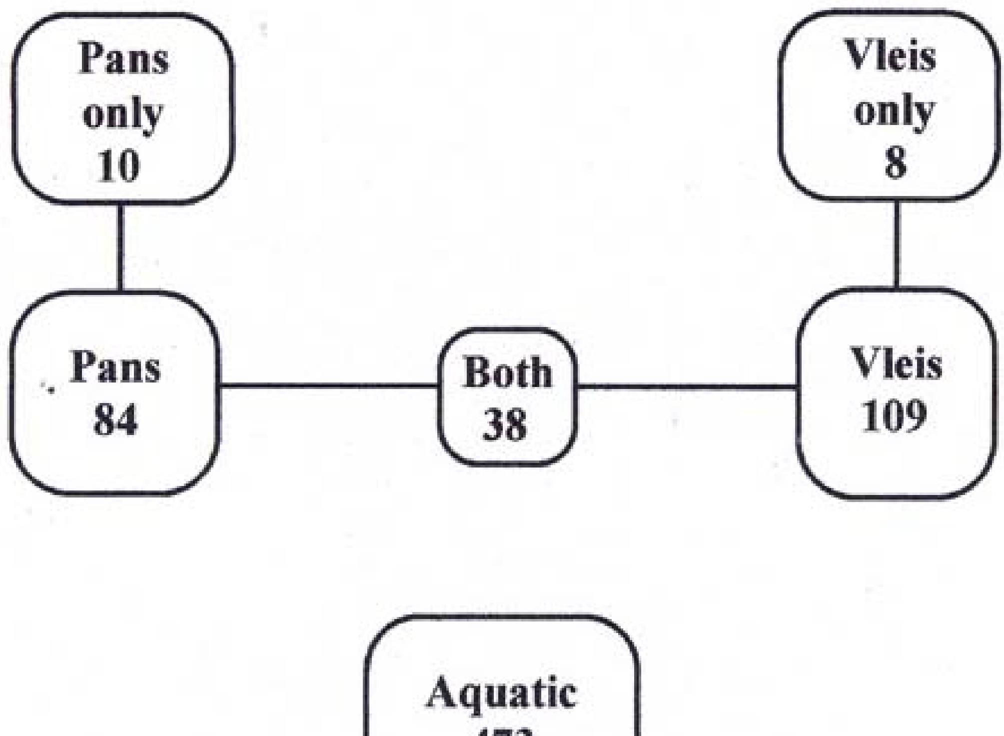
Gibbs Russell (1975, 1977) has produced a comprehensive list of aquatic vascular plants of Zimbabwe. Figure 3.4 is a summary of the habitat distribution of the 473 species which she found and shows the number of species occurring in natural wetlands (pans and dambos), together with occupance in all aquatic habitats combined. Of the 117 species found in pans or dambos, only 38 are found in both habitats, indicating the distinctiveness of the two. Relatively few species were found on dams. Pans are typically ephemeral while dambos are perennially waterlogged, therefore dambo vegetation may represent a group of species that are associated with permanently wet areas. Of the 109 dambo species, eight are found exclusively in this habitat, while 101 were also found in other aquatic habitats with permanent water, such as streams and rivers. Thus among the vascular plants, dambos can be shown to provide a distinctive ecological habitat. Since streams depend on dambos for their dry season flow, the destruction of the dambo habitat also has downstream impacts. Thus the destruction of dambos could cause the extinction of at least 109 wetland vascular plant species from Zimbabwe's highveld flora.

Similar considerations apply perhaps to a greater degree on non-vascular plants as well as many animal species. For example, the seep at the headwaters of Nyatsime stream in Chihota, northern Zimbabwe, has a resident population of Marsh Owls whose numbers have steadily decreased over the last ten years due to grazing pressure. Table 3.2 shows the difference in species richness between two streams in the Lake Kariba area. At the time of sampling, the Nyaodza stream was a perennial stream while Charara was highly seasonal. These streams differ both in richness of species and in their abundance.

Table 3.2. Comparison of species diversity in two streams near Lake Kariba.

	Nyaodza	Charara
Number of organisms collected over sampling period	2924	131
Index of biodiversity	5.88	1.8

Figure 3.4: Habitat distribution of wetland plant species and the number of species occurring in natural wetlands (pans and dambos). From Gibbs Russell (1975).



3.7 SUMMARY AND CONCLUSIONS

The discussion on human impact on biodiversity of wetlands is limited by the fact that although there are considerable data in surveys of flora and fauna in the Zambezi Basin, few of them were conducted to track changes in biodiversity. Furthermore, more frequently than not, projects on water resources development are implemented without an Environmental Impact Assessment that clearly captures the biodiversity before and after the event. Secondly, many of the important wetlands, such as the Upper Zambezi floodplains, are remote from research centres. Consequently not much is known about them unless they happen to be associated with an easily accessible fishery industry.

However, this discussion has attempted to gather what information there is on human impacts on biodiversity. It identifies three types of human-mediated impacts: (a) those arising directly from the effects of water resources development (such as hydro dams), (b) those evolving through human settlements and their associated land use, and (c) those likely to arise from global warming.

It is clear that hydropower generation has had fundamental impacts on the Lower Zambezi, and probably also on the Middle Zambezi. Had the issue of these impacts been taken on board as part of the development and post-project management of these facilities, perhaps a great deal more than we know now would have emerged.

Humans have been associated with wetlands for time immemorial. However, there are two processes that have altered the equilibrium between human use and ecosystem resilience. One is the high population growth and intensity of rural land use, coupled with deteriorating soil fertility. This process creates pressure in particular on ecosystems that appear to be more productive, e.g. wetlands. Hence in areas where no significant development has occurred, human presence alone is now the major threat to wetland biodiversity. The second process is coupled to water resources development, where new opportunities arise resulting in rapid growth of human settlement. On the other hand the withholding of protective floods to wetlands has facilitated their occupation by humans in areas adjacent to river banks, resulting in the degradation of riparian habitats.

Global warming and its projected hydrological effects is likely to have significant impacts on wetlands. The hydrological impacts are likely to be amplified by desperate peasant farmers seeking better crop production and grazing in wetland areas.

Many documents advise the taking on board of traditional wisdom in biodiversity management and conservation. However, such traditional conservation cultures operated under totally different scales of economy and population pressure. Most traditional wise men will reminisce on how their forefathers managed the natural resources, but will be devoid of strategies to deal with current problems at a traditional level.

The underlying issue in wetland biodiversity conservation is the land tenure system, and this has remained unaddressed throughout the whole of Africa with the political leadership still working on assumptions that pertained more than half a century ago. Although in Zimbabwe the issue has been politicised for short-term political fix, the problems of natural resources management under usufruct tenurial systems throughout the Zambezi Basin now needs urgent review.

3.8 REFERENCES

Anderson, J., Dutton, P., Goodman, P. & Souto, B. (1990). Evaluation of the wildlife resource in the Marromeu complex with recommendations for its future use. LOMACO, Maputo.

Attwell, R.I.G. (1970). Some effects of Lake Kariba on the ecology of a floodplain of the mid-Zambezi Valley of Rhodesia. *Biol. Cons.* **2**(3): 189-196.

Bartlett, M.-A., Hickley, M., Lennard, D., Bartlett, R., Pasteur, A., Chiwona, E., Munthaloi, H., Chikuni, A., Salubeni, A. & Ngonda, J. (1996). The ecology and human geography of the Elephant Marsh-Lower Shire valley, Malawi. Report of the Cambridge Expedition to Malawi, July-August 1991. Pembroke College, Cambridge University.

Beilfuss, R.D. & Allan, D.G. (1996). Wattled crane and wetland surveys in the Great Zambezi Delta, Mozambique. In: Proceedings of 1993 African Crane and Wetland Training Workshop (edited by R.D. Beilfuss, W.R. Tarboton & N.N. Gichuki), pp. 345-353. International Crane Foundation, Baraboo, USA.

Bowmaker, A.P., Jackson, P.B.N. & Jubb, R.A. (1978). Freshwater fishes. In: *Biogeography and Ecology of Southern Africa* (edited by M.J.A. Werger), pp. 1181-1230. W. Junk, The Hague.

Calamari, D. & Naeve, H. (1994). Review of pollution in African aquatic environments. CIFA Technical Paper No. 25. FAO, Rome.

Calder, I.R., Hall R.L., Basatabel, H G., Gunston, H.M., Shela, O., Chirwa, A. & Kafundu, R. (1995). The impact of land use change on water resources in sub-Saharan Africa: a modelling study of Lake Malawi. *J. Hydrology* **170**(1-4): 123-135.

Chapman, D.W., Miller, W.H., Dudley, R.G. & Scully, R.J. (1971). Ecology of fishes in the Kafue River. FAO FI:SF/ZAM 11: Technical Report 2. FAO, Rome.

Clarke, J.E. (1975). Zambia's wetlands. *Black Lechwe* **12**(1): 14-17.

Conybeare, A. (1998). Wildlife studies. In: Batoka Gorge hydroelectric scheme feasibility report, Vol 4. CivilConsult/Soils Incorporated, pp. 35- 88. Zambezi River Authority, Lusaka.

Da Silva, J.A. (1986). River runoff and shrimp abundance in a tropical coastal ecosystem - the example of the Sofala Bank (Central Mozambique), pp. 329-344. NATO ASI Series 67. Springer-Verlag, Berlin.

Davies, B.R. (1975). Cahora Bassa hazards. *Nature* **254**: 447-448.

Davies, B.R. (1986). The Zambezi River system. In: *The Ecology of River Systems* (editors B.R. Davies & K.F. Walker), pp. 225-267. Kluwer, Dordrecht.

Davies, B.R., Hall, A. & Jackson, P.B.N. (1975). Some ecological aspects of the Cabora Bassa dam. *Biol. Cons.* **8**: 189-201.

Dodman, T., de Vaan, C., Hubert, E. & Nivet, C. (1997). African Waterfowl Census, 1997. Wetlands International, Wageningen.

Du Toit, R.F. [compiler] (1982). A preliminary assessment of the environmental implications of the proposed Mupata and Batoka hydroelectric schemes (Zambezi river, Zimbabwe). Natural Resources Board, Harare.

Dudley, R.G., Manning, I. & McCormick, S. (1991). Kapichira environmental assessment: Malawi Power V Project. Consultancy report for Associates in Rural Development, Burlington, USA.

Dudley, R.G. & Scully, R.J. (1980). Changes in experimental gillnet catches from the Kafue floodplain, Zambia, since construction of the Kafue Gorge dam. *J. Fish Biol.* **16**: 521-537.

Dunham, K.M. (1990). Vegetation-environment relations of a middle Zambezi floodplain. *Vegetatio* **82**: 13-24.

Dunham, K.M. (1994). The effect of drought on the large mammal populations of Zambezi riverine woodlands. *J. Zool., London* **234**: 489-526.

Ellenbroek, G.A. (1987). *Ecology and Productivity of an African Wetland System: the Kafue Flats, Zambia*. W.Junk, Dordrecht.

FAO/ALCOM (1999). ALCOM SADC water resources database, version 9902. CD-ROM. FAO, Harare.

Feresu, S.B. & Van Sickle, J. (1990). Coliforms as a measure of sewage contamination of the River Zambezi. *J. Appl. Bacteriology* **68**: 397-403.

Gammelsrod, T. (1992). Variation in shrimp abundance on the Sofala bank, Mozambique, and its relation to the Zambezi runoff. *Estuarine, Coastal & Shelf Science* **35**: 91-103.

Gibbs-Russell, G.E. (1975). Distribution of vascular aquatic plants in Rhodesia. *S. Afr. J. Sci.* **71**: 270-272.

Gibbs-Russell, G.E. (1977). Keys to vascular aquatic plants in Rhodesia. *Kirkia* **10**: 411-502.

Hanmer, D.B. (1977). Man-induced changes in the Lower Shire valley with special reference to the avifauna. *Nyala* **3**: 33-37.

Hatton, J. & Guerra-Marques, L. (1992). Wetlands, coastal zone systems and marine fisheries. In: *Angolan Environmental Status Quo Assessment*. IUCN ROSA, Harare.

Hayes, G.D. (1978). *A Guide to Malawi's National Parks and Game Reserves*. Montfort Press Limbe, Malawi.

Hulme, M. [editor] (1995). *Climate change and Southern Africa: an exploration of some potential impacts and implications in the SADC region*. Climate Research Unit, University of East Anglia, Norwich/WWF International, Gland.

Jackson, P.B.N. (1959). *Summary of the Zambezi valley surveys.* Joint Fisheries Research Organisation Annual Report No. 8 (1958). Government Printer, Lusaka.

Jarman, P.J. (1972). Seasonal distribution of large mammal populations in the unflooded Middle Zambezi Valley. *J. Appl. Ecol.* **9**: 283-299.

Kenmuir, D.H.S. (1976). Fish spawning under artificial flood conditions on the Mana flood-plain, Zambezi river. *Kariba Studies* **5**: 86-97.

Lawton, R.M. (1963). Paleoecological and ecological studies in the Northern Province of Northern Rhodesia. *Kirkia* **3**: 46-76.

Magadza, C.H.D. (1992). Limnology of the Kafue Gorge dam. In: *Lake Conservation and Management: Proceedings of the 4th International Conference on the Conservation and Management of Lakes* (edited by L. Hongliang, Z. Yutian & L. Haisheng), pp. 220-253. CRAES/UNEP/ILEC, Beijing, China.

Magadza, C.H.D. (1995). Reservoir management using food chain manipulation. In: *Guidelines of Lake Management.* Vol. 7, Biomanipulation in lakes and reservoirs management (edited by R. De Bernardi & G. Giussani), pp.197-205 . ILEC/UNEP, Kosatsu, Japan.

Magadza, C.H.D. (1996). Climate change: some likely multiple impacts in southern Africa. In: *Climate Change and World Food* (edited by T.E. Downing), pp. 449-483. NATO ASI Series 1, Vol. 37. Springer, Berlin.

Magadza, C.H.D. & Dhlomo, E.J. (1996). Wet season incidence of coliform bacteria in Lake Kariba inshore waters of Kariba Town area. *Lakes & Rivers: Res. & Managm.* **2**: 89-96.

Masundire, H. (1998). Limnology and water quality. In: Batoka Gorge hydroelectric scheme feasibility report, Vol 4. CivilConsult/Soils Incorporated, pp. 89-119. Zambezi River Authority, Lusaka.

Mkanda, F.X. (1994). An assessment of hippopotamus (*Hippopotamus amphibius* L.) and human needs and attitudes in the lower Shire valley, Malawi. Biodiversity Support Programme Final Report. Dept. National Parks & Wildlife, Lilongwe, Malawi.

Moyo, N. (1998). Fish and fisheries. In: Batoka Gorge hydroelectric scheme feasibility report, Vol 4. CivilConsult/Soils Incorporated, pp. 117-138. Zambezi River Authority, Lusaka.

NOAA (1992). Fire monitoring by AVHRR; African Fires, September 1992. File <af_9209.gif>.

Nugent, C. (1990). The Zambezi River: tectonism, climatic change and drainage evolution. *Palaeogeography, Palaeoclimatology, Palaeoecology* **78**: 55-69.

Ohsawa, M., Egichi, T., Takana, N., Ikeda, H., Nemoto, M. & Hada, Y. (1998). Impacts on Natural Ecosystems. In: *Global warming: the potential impacts on Japan* (edited by S. Nishioka & H. Harasawa), pp. 35-99. Springer, Berlin.

Reibsame, E.R. (1989). Assessing the implications of climate fluctuations: a guide to climate impact studies. UNEP, Nairobi.

Schlettwein, C.H.G. & Bethune, S. (1991). Aquatic weeds and their management in southern Africa: biological control of *Salvinia molesta* in the Eastern Caprivi. In: *Wetlands Conservation Conference for Southern Africa* (edited by T. Matiza & H.N. Chabwela), pp. 173-187. IUCN, Gland.

Singini, P.J.T. (1996). The Marromeu complex of the Zambezi Delta: Mozambique's unique wetland. In: Proceedings of 1993 African Crane and Wetland Training Workshop (edited by R.D. Beilfuss, W.R. Tarboton & N.N. Gichuki), pp. 341-343. International Crane Foundation, Baraboo, USA.

Taylor, R.D. (1985). *The response of buffalo,* Syncerus caffer*, to the Kariba lakeshore grassland (*Panicum repens *L.) in Matusadona National Park*. PhD thesis, University of Zimbabwe, Harare.

Timberlake, J.R. (1998). Biodiversity of the Zambezi Basin wetlands. Consultancy report for IUCN-ROSA. BFA/Zambezi Society, Harare.

Tinley, K.L. (1975). Marromeu: wrecked by the big dams. *African Wildlife* **29**(2): 22-25.

Tomasik, P., Magadza, C.H.D., Mhizha, S., Chirume, A., Zaranyika, M. & Muchiriri, S. (1995). Metal-metal interactions in biological systems. *Water, Air & Soil Pollution* **1995**: 124-145.

Van Bochove, J. & Van Doe, J.C. (1998). *Sewage pollution in Lake Kariba.* Unpublished project report. University of Zimbabwe/Hoegeschool Zeeland Aquatic Ecotechnology, Netherlands.

Williams, A.J. (1991). Wetland birds and conservation in Namibia: an overview. *Madoqua* **17** (2): 245-248.