No. 1
Biological Conservation 28 (1984) 73–87

Some Environmental Aspects of Proposed Hydro-Electric Schemes on the Zambezi River, Zimbabwe

R. F. Du Toit

c/o Department of Biological Sciences, University of Zimbabwe,
Box MP167, Mount Pleasant, Zimbabwe

ABSTRACT

Additional hydro-electric schemes on the Zambezi River, Zimbabwe, have been proposed to help meet that country's growing electricity demand. Preliminary environmental impact studies have shown that one of these schemes, at Mupata Gorge, poses a serious threat to the wilderness character and wildlife resources of the middle-Zambezi valley, while an alternative scheme, at Batoka Gorge, would entail much less environmental cost. Likely impacts of these schemes on mammals, birds, fish, terrestrial and aquatic vegetation, human health and other environmental aspects are discussed. It is recommended that further environmental research on Zambezi hydro-electric schemes be carried out on an international basis.

INTRODUCTION

Considerable attention has recently been given in Zimbabwe to the selection of a power development programme. Zimbabwe's annual electricity requirement during 1982 was about 8000 GWh, and over 30% of this was met from Zambian sources. The main options that are now available for meeting projected electricity demands are further hydro-electric development on the Zambezi River, thermal power stations located on Zimbabwe's extensive coalfields, and additional imports of electricity from neighbouring countries. The hydro-electric option has

Biol. Conserv. 0006-3207/84/$03·00

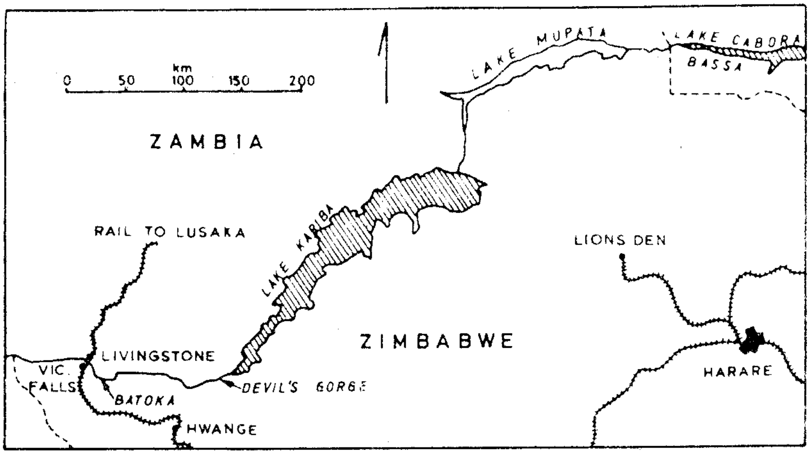

Fig. 1. Existing and proposed hydro-electric schemes on the middle-Zambezi River.

several large-scale components, chief among them being possible schemes at Batoka Gorge (1600 MW) and at Mupata Gorge (1200 MW) (Fig. 1). The latter scheme has aroused considerable concern among conservationists due to its threat to the wildlife of the middle-Zambezi Valley. In response to this concern, preliminary environmental impact assessments of both of these schemes were initiated by the Zimbabwean Government in 1981, and were undertaken by scientists from several Zimbabwean agencies, with some general guidance from the International Union for the Conservation of Nature and Natural Resources. For various reasons, the investigations were limited to the identification of likely impacts on Zimbabwean areas, according to current land-use patterns; impacts on Zambian areas, and downstream effects, were not assessed. The main conclusions of these brief studies are outlined in this paper.

THE PROPOSED SCHEMES

The Mupata scheme would flood a portion of the Zambezi Valley below Lake Kariba (Fig. 2). This valley is a down-faulted trough; its floor varies in altitude from about 350 m to 640 m, and the southern escarpment rises up to 1200 m above sea level. The Zambezi National Parks and Wildlife Area includes virtually all of the Zimbabwean section of the valley below

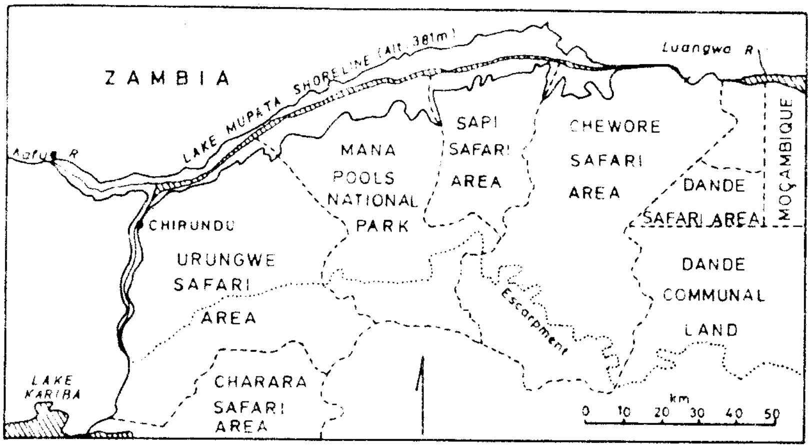

Fig. 2. The proposed Lake Mupata.

Kariba. Between Kariba Gorge and Mupata Gorge, the river is broad and flows between numerous sand-banks and islands; this is the last remaining 'sand-bank environment' of the middle-Zambezi (equivalent environments were inundated by lakes Kariba and Cabora Bassa). Extensive areas of alluvium (notably the Mana Pools area) lie along the river and have plant communities of high productivity and diversity, which sustain numerous large herbivores through the dry season.

The site proposed for Mupata Dam is about 30 km upstream of the Zimbabwe/Mocambique border. The wall (about 80 m high) would impound a reservoir with a surface area of 1230 km^2, flooding 200 km upstream to Kariba Gorge, with a maximum width of 14 km. About 46 % of the lake area would be in Zambia and about 54 % in Zimbabwe. The impounded volume would be $19{\cdot}8 \times 10^9$ m^3 at the normal retention level of 381 m above sea level. Inflow to the reservoir could be regulated by the Kariba scheme to keep the lake level as high as possible throughout the year, thus maintaining maximum potential for electricity generation.

The Batoka Gorge winds for about 100 km below the Victoria Falls (Fig. 3). Over this distance the surface of the basalt rock through which the narrow defile has been cut remains more or less horizontal (800 m above sea level), while the Zambezi drops approximately 260 m from its level at the base of the Falls (where the gorge is about 110 m deep). Most of the drop of the river is accounted for by a series of rapids. On the Zimbabwean side, a small section at the western end of the gorge is part of a National Park and the rest of the gorge is bordered by the Hwange

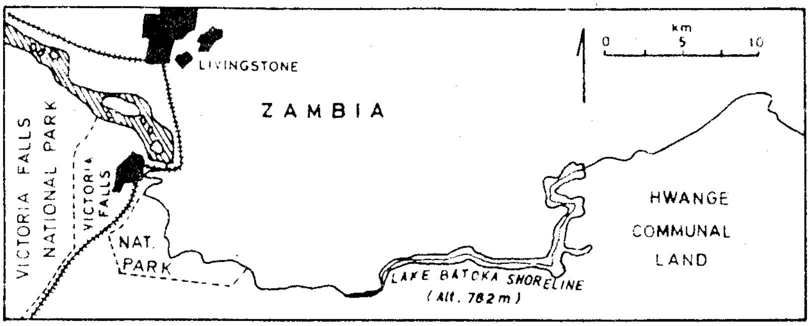

Fig. 3. The proposed Lake Batoka.

communal land, although no tribespeople live along the edge of the gorge due to the broken nature of the terrain here. Great seasonal variations in river flow, the rockiness of the gorge and the steepness of its sides are not conducive to the development of rich faunal or floral communities.

The wall in Batoka Gorge would be sited about 50 km downstream of the Victoria Falls, would be nearly 200 m high and would impound less than 2×10^9 m^3 of water. The lake, with a surface area of about 20 km^2, would be less than 1 km wide along most of its length and would flood back almost to the Victoria Falls with a normal retention level of 761 m above sea level. Since the Zambezi is not regulated by any scheme upstream of Batoka Gorge, inflow to the reservoir would be very variable and the scheme would be operated in a run-of-river mode, with its potential for electricity generation declining as the river flow decreased.

ENVIRONMENTAL ASPECTS OF THE MUPATA SCHEME

Impacts on mammals

The major objection that Zimbabwean conservationists have to the Mupata scheme is that it would flood the Mana Pools alluvial area, which is the foremost wildlife attraction in Zimbabwe, with a unique and aesthetic combination of wild animals, riparian woodlands and the Zambezi River.

Attwell (1970) and Jarman (1972) have described some of the ecological characteristics of this area. Extensive *Acacia albida* woodlands cover the younger alluvial deposits, while the slightly higher deposits (old islands or levees) support more diverse *Kigelia africana*/*Trichelia emetica*/*Lonchocarpus capassa* woodlands, and seasonally flooded channels are well grassed with perennial species such as *Vetiveria nigritana* and *Setaria sphacelata*. Plant productivity is greater and more prolonged, and shade and water are more abundantly available in the Zambezi alluvial system in the dry season, than on the rest of the valley floor and escarpment (Jarman, 1972). The main vegetation types in these latter areas are *Colophospermum mopane* woodlands, mixed-species layered dry forests ('jesse bush'), and various fairly open mixed-species deciduous woodlands.

As the productivity first of grasses and then of browse plants declines in the non-alluvial areas during the dry season (May-October), many grazing ungulates (such as zebra *Equus burchelli*, buffalo *Syncerus caffer*, and impala *Aepyceros melampus*) move down the catena towards the Zambezi River, followed by browsers (such as elephant *Loxodonta africana*, eland *Taurotragus oryx* and kudu *Tragelaphus strepsiceros*). Near the river, the *A. albida* trees are of particular significance as regards the provision of shade and browse since they have an anomalous foliage cycle, being leafless during the wet season and in leaf, with fruit, during the dry season. The production of pods by *A. albida* trees at Mana Pools is estimated to be over 1000 kg ha^{-1} $year^{-1}$, with September-October as the period of peak production (K. M. Dunham, pers. comm.). These pods, and the conspicuous new foliage of the *A. albida* trees, together with the leaves of evergreen trees such as *Trichelia emetica*, provide abundant food for browsing mammals, while the grazing species find perennial grasses growing at the height of the dry season in drainage channels between the blocks of riparian woodlands, and on islands in the Zambezi. As an indication of the mammal concentrations and of the resilience of the riparian habitats, densities of 32 elephant and 179 impala per square kilometre were recorded by Jarman (1972) in a riverside zone at Mana Pools in October 1965, and present dry-season mammal densities in this area are still of this order.

The importance of the riparian resources to large herbivores (discussed further by Jarman, 1972) is such that with the inundation of these resources the overall mammal carrying capacity of the valley would be reduced out of proportion to the total area lost. With present knowledge, confident estimates of population reductions cannot be made, but it is evident that the populations of species that depend heavily on the riparian resources throughout the year (such as the hippopotamus *Hippopotamus amphibius*, the waterbuck *Kobus ellipsiprymnus* and the bushbuck *Tragelaphus scriptus*) could well be halved with the creation of Lake Mupata. However, in the long term, the populations of some grazers might recover somewhat with the establishment of a shoreline grassland of *Panicum repens* (as happened at Lake Kariba).

The Mana Pools National Park and the contiguous safari areas together comprise a protected area of about 12800 km^2 within Zimbabwe, and an extensive area, with healthy animal populations, is also protected on the Zambian side of the Zambezi. There are few protected areas of over 10 000 km^2 in Africa, and species-area curves of large African mammals indicate that it is only in these reserves that the large mammal communities of the African savannas are likely to survive in the long term in something close to their pristine diversity (East, 1981). Hydro-electric development in the middle of this Zambezi wildlife refuge, with the inundation of the dry-season concentration zone, would thus be of considerable significance to big mammal conservation in Africa. The loss of wildlife and reduction in the wilderness character of the area would clearly diminish the tourism potential of the valley, which is equivalent to that of better-known sites such as the Kruger and Serengeti parks (Barkham, 1981).

Other impacts on existing biota

The diverse, extensive and near-natural riparian woodlands along the Zambezi (the finest example of this type of vegetation in Zimbabwe) contain at least four plant species that would be threatened with extinction within Zimbabwe if the area were to be flooded (T. Muller, pers. comm.). These plants are *Strophanthus courmontii*, *Cassine schlechterana*, *Ficus zambesiaca*, and *Cassipourea gassweileri*. *C. schlechterana* is a member of the family Celastraceae; some other members of this family have been shown to contain alkaloids with pharmacological properties. *S. courmontii* (Apocynaceae) also has a relative of importance to medicine, *S. kombe*, which grows in the Zambezi Valley and other parts of Zimbabwe, and is in demand for the treatment of cardiac ailments. Thus there may be valid considerations of genetic conservation relating to the flooding of this vegetation, particularly as the middle-Zambezi riparian woodlands are better conserved at present than are equivalent plant communities on the other major rivers in Africa (Barkham, 1981).

The sand and pebble banks of the Zambezi below Kariba are important bird habitats, and constitute a major proportion of this type of habitat in Zimbabwe; several species of river birds would be very adversely affected if these banks were submerged. The small Zimbabwean population of African skimmers *Rynchops flavirostris* would be much reduced with the loss of their major breeding area, as would the populations of red-winged pratincoles *Glareola pratincola* and white-collared pratincoles *Glareola nuchalis*. The riparian woodlands and wetlands that would be inundated are a refuge for various other birds that are rare elsewhere in Zimbabwe (e.g. Livingstone's flycatcher *Erythrocercus livingstonei*, the banded snake eagle *Circaetus cinerascens*, and the rufous-bellied heron *Ardeola rufiventris*). The creation of Lake Mupata would naturally benefit lacustrine species such as the fish eagle *Haliaeetus vocifer*, the reed cormorant *Phalocrocorax africanus*, and the darter *Anhinga melanogaster*; these birds are already abundant at Lake Kariba.

The effects of the Mupata scheme on invertebrates, amphibians and reptiles would be unlikely to warrant much concern in the long term.

Some predicted features of Lake Mupata

Lake Mupata would have a mean depth of only about 16 m. These shallow waters would be warm, and would be weakly stratified (the prevailing up-lake winds would promote mixing). Initially, the hypolimnetic waters would be anoxic, with considerable amounts of hydrogen sulphide generated from decomposing organic matter. However, with the relatively short replacement time of the reservoir (0·3 year) the quantity of this gas should diminish and the hypolimnion would retain some oxygen throughout the year. The mean ionic conductivity of the lake would be in the order of 95 μScm^{-1} once the waters attained chemical equilibrium (Magadza & Fair, 1981). This should encourage the growth of large phytoplankton and zooplankton populations, and aquatic macrophytes would also prosper.

The most important floating macrophyte would probably be the water hyacinth *Eichhornia crassipes*, since this plant became dominant on downstream Lake Cabora Bassa (Bond & Roberts, 1978), which has physico-chemical conditions more similar to those predicted for Lake Mupata than those of Lake Kariba, where *Salvinia molesta* is the dominant floating weed. *S. molesta*, *Pistia stratiotes*, *Azolla nilotica* and various other floating macrophytes would add diversity to the mats of *E. crassipes* on Lake Mupata. The actual extent, and period of development, of the weed mats is difficult to predict with current knowledge. The growth of *S. molesta* on Lake Kariba was eventually regulated by ecological factors including the declining nutrient status of the reservoir, wind and wave action, and, to a lesser extent, grazing by invertebrates such as the introduced grasshopper *Paulinia acuminata* (Marshall & Junor, 1981). The nutrient status of Lake Mupata would probably remain slightly higher than that of Lake Kariba due to the input of nutrients via the Kafue River, so the period over which extensive weed mats could develop might be longer. In the shallow waters, numerous protruding dead trees would tend to anchor the mats and thus prevent their dispersion by wind and waves. Chemical control of the weeds would be most unlikely to be economic. The most effective control strategy might be to drop the lake level at certain times to strand the mats, provided this was compatible with the operation of the power scheme (with the low wall, even a slight drop in the lake level would significantly decrease the potential for electricity generation).

If the lake level were to be kept fairly constant once the power scheme came into full operation, this would encourage the growth of submerged aquatic macrophytes in the littoral zone (e.g. *Ceratophyllum demersum*, *Lagarosiphon* spp., *Potamogeton* spp.). Stands of reeds and rushes (e.g. *Phragmites mauritianus*, *Typha latifolia*) can be expected on the lake margins in places where the wave action was not too strong, such as in shallow inlets. Although the aquatic macrophytes, both floating and rooted, would seriously hinder human activities such as navigation and fishing, and would greatly increase water loss through evapotranspiration, they would retain nutrients (released from the soil and organic matter of the flooded area) which would otherwise pass downstream via the turbines and floodgates. The macrophytes would provide shelter for small fish, a substrate for fish food organisms, a direct food source for herbivorous fish such as *Tilapia rendalli* (Marshall, 1982), and, when stranded, a mulch for shoreline vegetation on the sandy beaches.

Partial closure of the dam at the start of a rainy season would be desirable for fisheries development since the initial phase of filling would then coincide with the seasonal migration of cyprinids, characids and siluroids into shallow floodwaters for breeding. In the spreading waters of the new lake, the juveniles of these species would enjoy more freedom from predators and a greater availability of food than was possible in the river and would therefore survive in large numbers (Jackson & Rogers, 1976). Commercially important fish of the family Cichlidae (tilapias) should also become abundant. The sardine *Limnothrissa miodon* would be introduced via the Kariba turbines and its population would increase rapidly during the initial, nutrient-rich stage of the lake so that a pelagic fishery could soon be developed.

A conservative estimate for average sardine production from the proposed lake is given as 25 kg ha^{-1} $year^{-1}$ by Marshall (1982), on the basis of experience at Lake Kariba. Thus the total annual sardine catch might be over 3000 tonnes. An inshore fishery, with the use of gill nets to catch fish such as tilapias and distichodids, could benefit small-scale fishermen since they would require relatively little training or capital to become established. Marshall's conservative estimate for inshore fish production is 33 kg ha^{-1} $year^{-1}$, giving a potential catch of about 2000 tonnes per year (assuming that these inshore species would be limited to waters less than 15 m deep). Damage to the sardine nets due to snagging would be excessive if extensive bush-clearing was not carried out prior to impoundment. Bush-clearing would not be so essential for gill-netting operations and the best policy in inshore areas might be to clear lanes so that the nets could be set between belts of dead trees that were retained to provide a substrate for fish food organisms.

Socio-economic effects of the Mupata scheme in the Zimbabwean area of the Zambezi valley

During the construction phase of the scheme, and to a lesser extent thereafter, employment would be created for many tribespeople from the nearby Dande communal land; these people would also benefit from roads, health services and other facilities that would extend through their undeveloped area. The wall would be sited in the home area of the Va-Doma, a small group of hunter-gatherers, who could clearly have their lifestyle considerably altered due to this development. Several sites of historical and religious significance would be lost (sacred places featuring in the Mkorekore and Va-Mbara legends, and possibly one or two ruined Portuguese settlements on islands in the Zambezi).

The loss of modern man-made structures should be minimal, although alterations would have to be made to the Chirundu Bridge. It has been suggested that Lake Mupata could form part of a 'Zambezi waterway to the sea' for Zimbabwe (Mitchell, 1981); in addition to the new dam, a complex system of locks, dredged channels and ship-lifts would be required, with Mocambican participation, to make such a waterway possible.

Besides the loss of a major recreational amenity at Mana Pools (for which the formation of Lake Mupata, so similar in recreational attraction to Lake Kariba, would be little compensation), there would be adverse effects on big-game hunting, which is a valuable source of foreign currency in Zimbabwe. Hunting quotas would have to be reduced for some species as a result of declining game populations. The present designation of virtually all of the middle-Zambezi Valley as wildlife estate precludes any possible agricultural or mining activities, but the pattern of land-use may be reconsidered if Lake Mupata is created. Irrigation prospects would be poor (with the possible exception of paddy rice production near the lake) due to excessively sandy, sodic and/or shallow soils over most of the valley. Moist soils that were exposed when the lake level dropped could have some potential for crop production, depending on the period and extent of draw-down. The livestock carrying capacity of most of the valley would remain low, despite expected increases in rainfall in the vicinity of the new lake; however, the shoreline should provide good grazing for cattle, which could be utilized if tsetse flies (vectors of trypanosomiasis) were eradicated. Prospecting activity might be encouraged by the provision of better access routes but the mineral potential of the area is unlikely to allow much mining development, with or without the scheme, apart from some small-workings.

The major health problems that would be associated with the Mupata scheme would be malaria, schistosomiasis (bilharzia) and trypanosomiasis (sleeping sickness). Malaria, which would be due largely to *Plasmodium falciparum*, could be counteracted effectively through the use of prophylactic drugs and by spraying residual insecticides in dwellings, but schistosomiasis would be extremely difficult to control at populated localities along the shoreline. Sleeping sickness would be a threat sufficient to justify a costly spraying programme to eliminate tsetse flies from the valley. Various filarial diseases could also be expected.

ENVIRONMENTAL ASPECTS OF THE BATOKA SCHEME

Impacts on existing biota

The main vegetation types within Batoka Gorge are a belt of riparian trees (e.g. *Diospyros mespiliformis*, *Garcinia livingstonei*, *Ficus ingens*), growing amongst scree and on occasional sand deposits along the flood-line of the river, fairly open deciduous woodland dominated by

Colophospermum mopane on the gentler slopes, and dense mixed-species deciduous woodland (e.g. *Commiphora* spp., *Sterculia* spp.) on steeper scree slopes, between bare rock outcrops. The woody species that have been noted in these communities are common elsewhere along the river. The mammal and bird communities of the gorge are also rather limited in diversity and numbers. Extensive areas of scree slopes and rocky cliffs would be left around Lake Batoka for the mammals that frequent this type of habitat (e.g. klipspringers *Oreotragus oreotragus*, chacma baboons *Papio ursinus*, and vervet monkeys *Cercopithecus aethiops*). The rare Taita falcons *Falco fasciinucha* that nest in the gorge, along with black storks *Circonia nigra*, have breeding sites that are well above the prospective lake level. The creation of the lake should provide new feeding grounds to allow a greater diversity of bird species. Reptiles and amphibians would find more suitable habitats around the shores of Lake Batoka than those of the gorge at present (with its high annual floods and lack of reeds and rushes).

Some predicted features of Lake Batoka

A major feature of Lake Batoka would be the rapid throughflow of water; the mean replacement time has been estimated at fifteen days, and in peak-flow periods this could be as low as five days (Marshall, 1982). The water-body could only stratify when inflow was at its lowest (September to December) and should have relatively high oxygen levels in its bottom waters, despite a mean depth of over 50 m. The expected mean conductivity of the proposed reservoir is about $80\,\mu Scm^{-1}$. The development of plankton populations would be inhibited by the high flushing rate, except during the late dry season.

The growth of rooted aquatic macrophytes would be restricted by the lack of suitable substrate and by the likely seasonal fluctuations in water level. Floating macrophytes could cover much of the lake's surface, since the rapid throughflow of water would maintain adequate levels of nutrients for the development of mats of *Salvinia molesta*, as well as rafts of *Cyperus papyrus* and *Vossia cuspidata*. *Eichhornia crassipes* has not yet been recorded on the upper Zambezi, and it would not in any case be likely to be troublesome on Lake Batoka since the nutrient status would be too low for the hyacinth to prosper. Spraying of herbicides, in conjunction with the use of floating booms across narrow stretches of the gorge, might be a practical control strategy on such a small lake. With the steep sides, draw-down would probably not strand significant quantities of floating weeds. Mechanical harvesting of *Salvinia* would be facilitated by the depth of the water, the reduced wave action and the configuration of the lake, and might prove to be worthwhile, since such aquatic plants may be used to provide biogas and fertiliser (Anon., 1976).

Marshall (1982) has described the likely fish fauna of the proposed lake. Riverine species would dominate, including some fish with sporting or commercial value such as *Distichodus* spp., *Labeo* spp., *Heterobranchus longifilis* and *Hydrocynus vittatus*. The tilapias (Cichlidae) would be much less abundant, and, due to the shortage of plankton, the sardine *Limnothrissa miodon* would not prosper; however, the introduction of this sardine would be recommended since a small population would utilize the available plankton and thus retain nutrients and increase overall fish production (Marshall, 1982). The fisheries potential of Lake Batoka is difficult to estimate due to the lack of comparative data but the total annual yield would probably be under 100 tonnes. The most significant development could be that of a sport fishery, with both angling and spearfishing, and local tribespeople could extract valuable protein from the lake through gill-netting.

Socio-economic effects in the Batoka Gorge area

As with the Mupata scheme, the rather impoverished local population would benefit from employment opportunities and community services associated with the hydro-electric scheme. Since the proposed lake level is low in the gorge, it is not thought that any religious or historical sites would be lost, nor would any permanent structures be affected, and no agricultural or mineral resources would be flooded. The area around the gorge consists mainly of broken basalt terrain and extensive deposits of Kalahari sand, so the irrigation prospects of the proposed scheme are not promising. The scheme would flood out a scenic section of the river that is used by a few sportsmen for 'white-water rafting', but Lake Batoka would itself constitute a very attractive recreational amenity, and, being so close to the Victoria Falls, could generate considerable revenue through tourism.

Malaria and bilharzia would be inevitable health problems. Mats of floating weeds, and algae growing on rocks, would support schistosome-carrying snails. The inaccessible shoreline of Lake Batoka would ensure that contact between man and water was concentrated in certain localities, where chemical spraying to kill snails could be worthwhile. The environment of the gorge would seem to be ideal for the breeding of black flies (Simulidae), some species of which carry onchocerciasis (river blindness); fortunately, the vector species have not yet been found in Zimbabwe so this disease should not occur.

CONCLUSION

Lake Mupata, in flooding an extensive section of the middle Zambezi valley, would have very adverse impacts on wildlife resources of international significance, whereas Lake Batoka would flood only a small area (one-sixtieth that of Lake Mupata) which has few wildlife resources and negligible potential for economic activities other than electricity generation. Environmental diversity would be reduced by the Mupata scheme since the riverine/alluvial environment of the middle Zambezi would be replaced by a lake essentially similar to several other African impoundments; however, the Batoka scheme would enhance environmental diversity since only a relatively small portion of the basalt gorge environment would be flooded and the lake would have many unique characteristics. The significance of this, with current land-use patterns, pertains particularly to tourism, genetic conservation and scientific/educational values. Apart from the generation of electricity and the provision of employment, the main benefit of the Mupata scheme would lie in its fisheries potential, while that of the Batoka scheme would lie in its recreational attraction, which could complement the Victoria Falls.

Exploratory drilling has been carried out at the two dam sites, and largely on the basis of the geological information the Central African Power Corporation decided to continue investigations at Batoka Gorge with a view to commissioning that scheme before the Mupata scheme. This indicates the need for a final environmental impact statement on the Batoka scheme, to give advice on how adverse impacts could be minimized and beneficial impacts maximized, and for continuing background research in the area that would be affected by the Mupata scheme. Before a decision is made on the latter scheme, further information must be obtained on the socio-economic conditions on the populated Zambian side of the valley, and on the value of the Zambezi riparian area in terms of African ecosystem conservation and tourism.

Many of the major environmental impacts of a new hydro-electric scheme on the Zambezi would be directly related to those of other existing or proposed schemes on the river system. For instance, there is a problem of riverbank erosion downstream of Lake Kariba (Guy, 1981), which will be worsened when additional turbines are installed at Kariba, and which would be further aggravated if the Batoka scheme is built, due to changes in the river-flow regime. To ensure that the natural resources of the Zambezi system are not degraded unnecessarily, Zimbabwe, Zambia and Mocambique must plan further hydro-electric projects jointly, with early appraisal of the environmental implications of the various possible power development programmes, through holistic systems analysis, so that necessary remedial measures can be implemented effectively or undesirable schemes abandoned entirely.

ACKNOWLEDGEMENTS

Acknowledgements are due to the numerous scientists who participated in the environmental studies of the proposed schemes, and to the Department of Natural Resources, Zimbabwe, and the International Union for the Conservation of Nature and Natural Resources for supporting the research. Dr C. A. M. Attwell and Dr R. J. Phelps of the University of Zimbabwe, and Dr J. P. Barkham of the University of East Anglia, made constructive comments on the text.

REFERENCES

Anon. (1976). *Making aquatic weeds useful: some perspectives for developing countries*. Washington, National Academy of Sciences.

Attwell, R. I. G. (1970). Some effects of Lake Kariba on the ecology of a flood plain of the mid-Zambezi valley of Rhodesia. *Biol. Conserv.*, **2**, 189–96.

Barkham, J. P. (1981). *EIA Zambezi power projects*. Gland, Conservation for Development Centre, International Union for the Conservation of Nature and Natural Resources. (Duplicated report).

Bond, W. J. & Roberts, M. G. (1978). The colonization of Cabora Bassa, Mocambique, a new man-made lake, by floating aquatic macrophytes. *Hydrobiologia*, **60**, 243–59.

East, R. (1981). Species-area curves and populations of large mammals in African savanna reserves. *Biol. Conserv.*, **21**, 111–26.

Guy, P. R. (1981). River bank erosion in the mid-Zambezi Valley, downstream of Lake Kariba. *Biol. Conserv.*, **19**, 199–212.

Jackson, P. B. N. & Rogers, K. H. (1976). Cabora Bassa fish populations before and during the first filling phase. *Zool. Afr.*, **11**, 373–97.

Jarman, P. J. (1972). Seasonal distribution of large mammal populations in the unflooded middle Zambezi Valley. *J. appl. Ecol.*, **9**, 283–99.

Magadza, C. H. D. & Fair, P. (1981). *Some predictions on the limnology of the proposed Mupata Gorge and Batoka Gorge dams*. University of Zimbabwe, Division of Biological Sciences. (Duplicated report).

Marshall, B. E. (1982). *Fish production potential of the proposed Batoka and Mupata Gorge dams*. Lake Kariba Fisheries Research Institute. (Duplicated report).

Marshall, B. E. & Junor, F. J. R. (1981). The decline of *Salvinia molesta* on Lake Kariba. *Hydrobiologia*, **83**, 477–84.

Mitchell, R. L. (1981). The Zambezi River: can Zimbabwe have a port? *Zimbabwe Science News*, **15**, 123–6.