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ECOLOGY AND DEVELOPMENT: THE KARIBA LAKE BASIN[1]

[1]This paper is based on information gathered by my colleague, Dr. Elizabeth Colson, and myself in 1956-57; 1962-63; 1965 and 1967 as part of our long-term study of those Gwembe Tonga who were re- located in connection with the Kariba Dam scheme. The first two studies were sponsored by the Rhodes-Livingstone Institute, now the Institute for Social Research of the University of Zambia.

Though the Institute also provided assistance and hospitality during our more recent restudies, Dr. Colson's six-week visit in 1965 was financed with a grant from the Social Science Research Council, while my four-month visit in 1967 was financed partially by the Food and Agriculture Organization of the United Nations, with the rest of my support being provided by the California Institute of Technology. From the very beginning, most of our research has been carried out within Gwembe District on the north bank of the Zambezi, although we also visited the Southern Rhodesian portions of the Middle Zambezi Valley in 1957 and 1963. Except where otherwise mentioned, however, the analysis in this paper relates to that portion of the Kariba Lake Basin and hinterland which lies in what was formerly Northern Rhodesia and is now the Republic of Zambia. The author takes sole responsibility for all views expressed.

INTRODUCTION

The formation of Lake Kariba in Central Africa began on December 2, 1958, when the sluice gates of the first dam across the Zambezi were closed. During the next few weeks the water rose rapidly, with deserted villages 100 feet above the normal river level inundated within two months. The subsequent rise was more gradual with the encroaching water not reaching the proposed shore line until the middle of 1963. With a storage capacity of approximately 130 million acre feet and a surface area of over 1700 square miles, the new reservoir was by far the largest manmade lake in the world. The first of the major African impoundments, its creation also initiated a trend which can be expected to play a major role in altering portions of the African landscape as well as the lives of millions of people.

Since the completion of the Kariba Dam, approximately 75,000 people, or one per cent of the population of Ghana, have been relocated in connection with the Volta Dam at Akosombo. In Egypt and the Sudan, over 100,000 people have been shifted as a result of the Aswan High Dam. When filled, the lakes backed up behind these dams will each have a surface area half again as large as that of Lake Kariba, although their storage capacity will be slightly less. Looking to the future, we can expect all of the major African rivers, as well as many of the lesser ones, to be dammed within the next generation. At Kainji in Northern Nigeria, the first dam on the Niger was sealed this year. Some 500 square miles in surface area, the new lake will probably fill within a single year, flooding an area which formerly contained the residences of approximately 50,000 people. In the Ivory Coast, construction on the Bandama Dam will begin early in 1969. Elsewhere, surveys currently being undertaken on other river systems, including the Senegal, Mono (Dahomey-Togo), Congo, Tana (Kenya), Kafue (Zambia), and Orange (Southern Africa), can be expected to lay the basis for new dams. With only a few exceptions, new construction can be expected to lead to the inundation of large areas and the relocation of thousands of people.

The creation of major manmade lakes in Africa presents the scientist with an exceptional research opportunity. Provided appropriate studies are made before, during and after inundation, the impact of flooding on the physical and biotic environment, as well as on the lifeways of the associated human populations, can be monitored. Dam construction and population relocation, for example, accelerate change in certain areas of human behavior. During the months preceding and following resettlement, relocation also increases physiological, psychological, social and ideological stress among the populations involved.[1] The behavioral scientist who wishes to study this change, and to learn how the population attempts to manage the accompanying stress in adjusting to a new

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[1] See Scudder, 1968.

habitat, is presented with what amounts to a quasi-laboratory situation. While obviously it is not possible to repeat the process of lake formation and relocation in the same area, it is possible to choose another river basin where approximately the same sequence of events is about to occur and to observe the processes of change there. Provided the studies involved are properly designed, executed and analyzed, it is my belief that they can make a major contribution to our understanding of human behavior.

While manmade lakes research in a wide range of disciplines, including meteorology, geophysics, hydrology, limnology and the biological and social sciences can make major contributions to our understanding of what occurs when extensive areas are inundated, they also have important implications for regional development which could raise the living standards of millions of Africans. While the primary purpose of African dam projects is usually the provision of hydroelectric power, they also provide an opportunity to improve flood control and transportation, and to develop river and lake basins by realizing a program which could include, for example, agriculture and fisheries, conservation areas and national parks, tourist and recreational facilities, and residential and industrial townships. To date, this opportunity has only been partially realized. Though the reasons involved are many and lie beyond the scope of this paper,[1] it is obvious that one basic problem concerns

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[1] See Scudder, 1966a.

our lack of knowledge of the ecological implications of large-scale manmade lakes as they relate to the development of the lake basin and its hinterland. In this paper I should like to review some of the events that accompanied the filling of Lake Kariba and comment on their implications for the lives of the residents of the area.

There is also another type of problem which I wish to stress, which relates to our inability to relate current ecological knowledge to human populations, in this case the 50,000 people relocated in connection with the Kariba scheme. While it is true that no ecological surveys of the lake basin or the relocation areas were initiated, let alone completed, prior to the decision to proceed with the construction of the dam in 1955, it was known that there was insufficient land, under the present system of agriculture, for the approximately 29,000 Tonga-speakers who required relocation on the north bank of the Zambezi. It was also known that their present agricultural practices would lead to serious erosion along the tributary systems and inland degradation unless certain changes were made. While those changes suggested by government personnel made sense ecologically, they were unacceptable to the Tonga, so that today the type of erosion and degradation that was predicted is occurring in a number of areas. The problem arises from the fact that the land management system proposed by the agriculturalists was incompatible with the farming system and current values of the Tonga. For this reason the current predicament was quite predictable. What was needed from the beginning, and is still needed, was a compromise system which would not only be acceptable to the Tonga, but also would make sense ecologically.

ECOLOGICAL ASPECTS OF THE LAKE KARIBA FISHERIES

Since this topic has already been well documented in the literature, my intention in this section is to briefly summarize the situation, while referring the interested reader to more detailed sources.[1] On the north bank the first Tonga began to fish the lake with gill nets as soon as impoundment began. Within a year a government survey reported 407 fishermen with this number increasing to over 2000 in 1962. Using over 4000 gill nets, they caught an estimated 3000 short tons of fish during the year, with the 1963 estimated yield being nearly 4000 short tons. Throughout this rapid buildup, the Provincial Administration and the Departments of Fisheries, Forestry and Community Development played an important role.[2] In 1964, however, annual production dropped sharply (to 2100 short tons), and since then production has continued to drop, with the lake supporting under 500 fishermen during 1967. The reasons behind this decline are not connected with the fishing industry as such. Rather they are of a primarily ecological nature.

Fish populations: distribution and density

Before Kariba, the free-flowing Middle Zambezi was poor in fish species, Jackson (1961) listing 28 as opposed to over 100 observed

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[1] For a recent, though brief, review on which I have drawn heavily in parts of this section, see Coulter, 1967.

[2] This is described in Scudder, 1965, which deals with the development of the Kariba Lake fisheries through 1963.

on the Middle Niger within the area to be flooded by the Kainji Dam. Furthermore, owing to a difficult environment with a short breeding season and predation by the Tiger fish (Hydrocynus vittatus), especially during the period that the Zambezi was restricted to its primary channel, the density of most species was low.

During the years immediately after impoundment, a much more favorable environment prevailed. Not only were predators dispersed, but herbivores profited from a greatly increased food supply including flooded vegetation in the shallower waters and a bloom of phytoplankton. According to Coulter, not only were the 1958-59 and 1959-60 breeding seasons apparently longer, but survival rates among fry were "very high." As they matured, it was these that formed the basis for the new fisheries rather than succeeding generations in which recruitment was lower. Aside from the chemical and biological stabilization of the lake, which could have led to a reduced biomass after the termination of bloom conditions, the reasons behind this drop in productivity are not clear. There are a number of possibilities of which several are probably significant. One is a buildup in the numbers of Tiger Fish so that today, as predators, they may play the same role as they did in the undammed river. Another is that commercial species may have moved to a greater extent into shallow uncleared areas (see below) or into deeper uncleared waters which formerly were deoxygenated to a greater extent.[1] Yet another reason concerns the ecology of the most desirable species in the lake fisheries. This is a riverine ciclid, Tilapia mortimeri (formerly T. mossambica), which may be unable to adjust to lacustrine conditions. Regardless of the reasons, however, production has dropped. As for Tilapia catches, they "have consisted mostly of larger fishes each year, with relatively very little recruitment of smaller sizes, and the fishery apparently depends upon the successful generations spawned between 1958 and 1960." (Coulter, 1967)

Fish Populations: Stocking

In hopes of building up a lacustrine population of Tilapia, 28 tons of T. macroshir were stocked between 1959 and 1962. To date there is little evidence of success with only the occasional macroshir being caught either by fishermen or Department of Fisheries personnel. More recently, the UNDP-FAO-Zambian Central Fisheries Research Institute has initiated a program to stock the lake with the Lake Tanganyika sardine (Limnothrissa miodon), along with other species, such as a fresh-water shrimp and a Nile perch (Lates sp), necessary for the creation of an open-water

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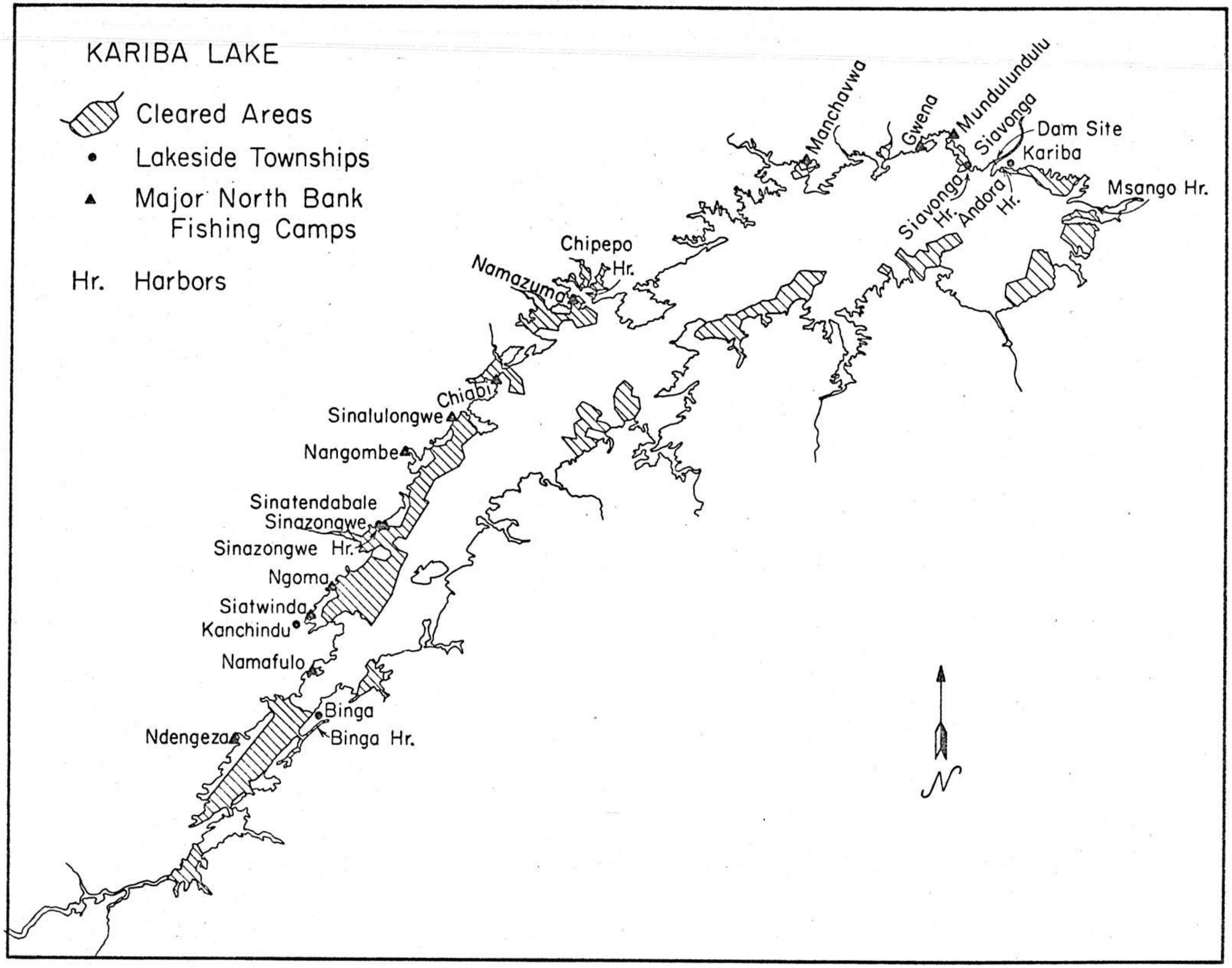
[1] In 1960 a thermal discontinuity formed at about 30 meters depth, below which deoxygenation occurred as the result of the decomposition of vegetation on the lake bottom, oxygen being replaced by high concentrations of hydrogen sulphide. In recent years, the degree of deoxygenation has grown less while concentrations of hydrogen sulphide are "now found only in the deeper, bottom valleys towards the end of the annual stratification period" (Coulter, 1967). For more detailed information on the hydrology of Lake Kariba, see Harding, 1966.

community. Needless to say, this is a long-term and hazardous enterprise which may or may not have a profound effect on the future fisheries.

Bush Clearing

In large-scale manmade lakes extensive bush clearing, though expensive, is desirable for a number of reasons relating, for example, to fisheries, the formation of aquatic weed mats, health and aesthetic considerations. At Kariba nearly one-quarter of a million acres were cleared at a cost of approximately £10 per acre. Of these, 126,000 acres were cleared along the north bank, with the main pitches concentrated on either side of Sinazongwe harbor. As figure 1 shows, most of the lake basin was uncleared. Furthermore, within fishing pitches clearing extended from approximately the 1590 contour (close to the upper margin of the drawdown area) to 1530 feet, so that the deeper areas remained uncleared. As far as the fishermen are concerned, these uncleared areas are very difficult to fish, especially when the crowns of the trees project beyond the surface and hence form anchors for mats of Salvinia auriculata and other sudd components. While it is to be hoped that the Central Fisheries Research Institute will be able to develop better techniques for use in these areas, underwater snags will continue to shred nets which the fishermen of today cannot



After a 1962 Map Drawn by the Irrigation Division of the Government of Southern Rhodesia afford to lose. On the other hand, many fishermen cannot afford not to fish the uncleared areas simply because the principal fish populations are now congregated there, in part no doubt because of a better food supply and a greater degree of protection.

The Invasion of Aquatic Plants

The rapid buildup of the aquatic fern, Salvinia auriculata, on Lake Kariba and its role in facilitating the colonization of other plants, thus creating a "sudd" community is well documented.[1] The "weed" was first observed on the lake in 1959. By 1962 it covered more than 1/10th of Kariba's surface area, although thereafter the extent declined significantly.[2] Nevertheless, the weed continues to present a formidable problem to the fishermen. Except in sheltered areas which were never cleared, the problem is least severe at the lower end of Kariba, in part because the prevailing wind blows up the lake throughout most of the year. It is most severe in Mwemba, which is particularly unfortunate since there is insufficient land in that chieftaincy to support its agricultural population. Periodically, certain fishing camps are literally closed by floating mats of Salvinia, which make the movement of boats extremely difficult, if not impossible. In other, more fortunate

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[1] See especially Boughey, 1963.

[2] Quoting Mitchell, who made periodic surveys of the degree of weed infestation, Little (1965) mentions 400 square miles as the extent of greatest coverage. Coulter (1967), on the other hand, mentions 250 square miles.

camps, fishermen venturing out to check their gear may find that floating mats have either covered or swept away their nets during the night.

In conclusion, it is obvious that all of the factors briefly summarized have contributed to the present depressed nature of the Kariba Lake fisheries. During the heady months of 1962 and 1963, when production continued to spiral and the numbers of fishermen to increase, it appeared that the earlier estimates of Kariba productivity (which extended to 20,000 tons per annum) might well be realized. In that event fishing would certainly play a critically important role in the development of Gwembe District through the provision of a reliable cash income and a substantial number of jobs, the latter being particularly important because of the scarcity of cultivable land in the relocation areas. Unfortunately, events have turned out otherwise, although it appears unlikely that productivity will drop much lower.

LAKE FORMATION, THE DISTRIBUTION OF TSETSE FLIES, AND ANIMAL TRYPANOSOMIASIS

There are two species of tsetse, Glossina morsitans and Glossina pallidipes, resident in the Middle Zambezi Valley. Of these, the second is not common, having first been identified in 1942 in the Southern Rhodesian portion of the Valley, while north of the Zambezi its presence was apparently not documented until about 1964. In the opinion of some, only G. pallidipes is a carrier of human sleeping sickness in this area. Regardless of the true position, however, sleeping sickness is rare in what is now the Zambian portion of the Valley, with only the odd case occasionally diagnosed, and even then the victim may have contracted the disease elsewhere.[1] For this reason, my intention in this section is to deal only with animal trypanosomiasis, and especially with bovine trypanosomiasis, which poses a constant threat to Tonga livestock near the fluctuating

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[1] The position in regard to human sleeping sickness in the Rhodesian portion of the Valley is quite different. As a result of an outbreak of the disease in 1912 in the Lubu Valley of Sebungwe District, an unknown number of Tonga were resettled in 1913. Thereafter the threat of renewed outbreaks remained a problem. This was especially the case at the time of Kariba resettlement when some Tonga wished to move back to areas of former infection. After the lake began to form, an outbreak of the disease did occur in Sinakatenge and adjacent resettlement areas, which apparently assumed serious proportions. Though I do not know whether or not the distribution of the fly involved had been influenced by the rise in lake level, the situation definitely deserves careful analysis in connection with the subject material dealt with in this paper.

margins of the fly areas.[1] Though there have never been over 30,000 cattle in the Valley at any time during the present century, Gwembe District does contain some of the best ranching country in Central Africa. Furthermore, in spite of the fact that its rural population control over 1-1/4 million head, Zambia is still dependent on cattle imports in large part because of the poor condition of local stock and the unwillingness of their owners to market them. Under these circumstances, the development potential of a cattle industry in the Valley is considerable, provided, of course, the tsetse fly can be brought under control.

The distribution of G. morsitans in the Northern Rhodesian portion of the Middle Zambezi Valley was mapped between 1949 and 1955 as part of a territory-wide survey of Glossina species. Two main concentrations, along with two smaller foci, were found, which are shown in figure 2, upon which the future lake shore margin has been superimposed. Within these pockets the distribution of the fly often formed a dentritic pattern, the preferred fly habitat being associated with changes (ecotones) between vegetation zones, especially in river and stream valleys, but also in connection with thickets and dambo (hardpan) margins, and the foot of the escarpment

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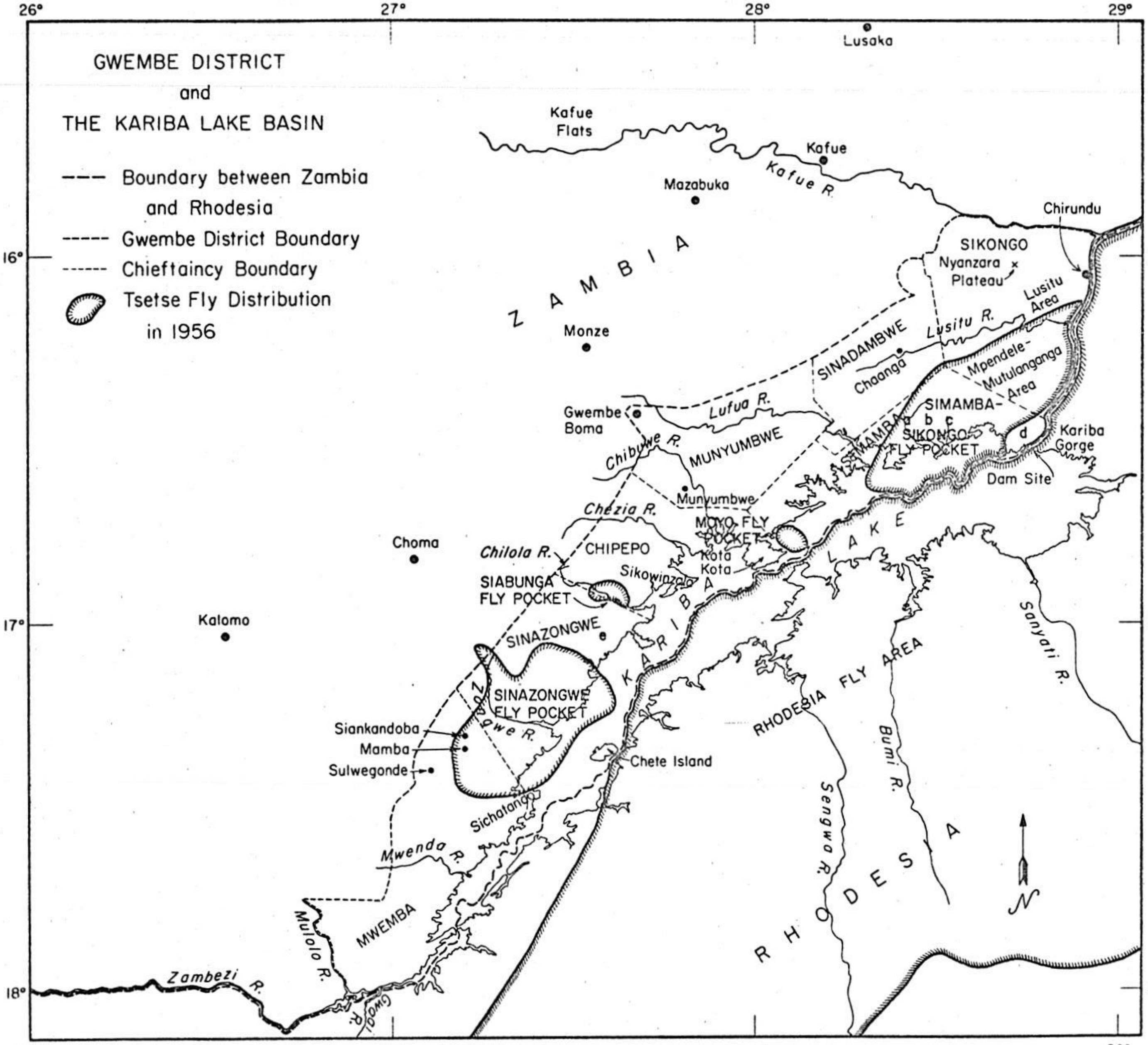
[1] See Scudder, 1962: 164-173, for background information on animal trypanosomiasis in the Gwembe Valley.



a = Nahunwe R.
b = Bunga Hill
c = Loteri R.
d = Kariba Hills
e = Buleya - Malima

and the base of Karroo and granitic formations throughout the Valley.[1]

Prior to the decision to proceed with Kariba, no tsetse or veterinary personnel were stationed in the Valley. While this situation was obviously hard on those residents who tried to build up herds of cattle and small stock, it was realistic in terms of relative priorities elsewhere in Northern Rhodesia, available funds and personnel. Not only was the Valley a net importer of cattle at the time, but for a number of reasons[2] it was also a much more difficult area within which to carry out control operations. On the other hand, its fluctuating tsetse population posed a constant threat to African and European herds on the Plateau unless it was effectively contained. Containment in 1955 was relatively easy and was achieved by stationing a number of pickets in the escarpment area in such a way as to

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[1] According to Steel and Gledhill (on whose undated manuscript I have drawn heavily in the paragraphs that immediately follow), "none of the main vegetation types to be found in the Valley itself comprises a complete fly habitat." On the other hand, this does not appear to be the case in the Southern Rhodesian portion of the Middle Zambezi Valley where Pilson (oral communication, 1963) was impressed by the number of G. morsitans in Brachiastygia savannah woodland near the Lusulu research station. Whether or not mopane and other vegetation zones alone the Kariba lake shore margin form a complete fly habitat today remains to be substantiated.

[2] The following are listed by Steel and Gledhill: isolation, difficulty of communications during at least half of each year, the large proportion of areas unsuitable for human settlement, inclement climate, famine conditions (with those seeking food elsewhere carrying fly with them), larger game populations, and the large proportion of virtually useless agricultural land, which is either uninhabited or only sparsely inhabited.

cover the main exits from the Valley. Here hitchhiking flies were dealt with by spraying travelers, while cattle themselves were excluded from the Plateau unless previously inoculated, in order to reduce the danger of mechanical transmission of the disease. As for Plateau cattle close to the escarpment which were infected, they could be treated by locally stationed veterinary assistants. "Thus the position was being held satisfactorily by merely palliative measures and no direct anti-tsetse measures were called for" (Steel and Gledhill, 304).

The situation changed drastically, however, once the 1955 decision to proceed with Kariba was made. Because there was insufficient land within the Valley available for the resettlement of 29,000 north bank Tonga, it was essential that the more desirable areas be opened up for occupation. Since a number of these were tsetse-infected, extensive eradication and control measures were now necessary for the first time in the Valley's history. Furthermore, as cattle were moved from fly-free areas into relocation areas recently cleared of tsetse, they would have to be placed on a fixed regime of prophylactic drugs in order to protect their health.[1]

[1] In 1962, drug instructions from the Livestock Officer to his Veterinary Assistants in the Valley were as follows: where heavy fly, poor communications and few cattle -- use prothidium three times yearly; where heavy fly and many cattle -- use anthrycide every two months; where no fly but diseased cattle as shown by blood smear tests -- use novidium selectively; and where cattle to be exported to the Plateau -- use dimidium bromide. (In all cases berenil to be held in reserve as a precaution against drug resistance in certain strains.)

To expedite inoculation, crushes (kraals) were constructed where necessary and the Tonga were instructed when and where to group their cattle for treatment. Needless to say, these intensive measures were expensive and required the use of scarce personnel and capital, which may well have been better used elsewhere. Since it was not feasible to relocate the people outside the Valley, however, the Northern Rhodesian government had little choice, granted the unstated but implicit resettlement philosophy that the people should certainly be no worse off following relocation than before. The resulting costs to both the government and the Tonga must, of course, be assessed in any future analysis of the benefits and costs accruing from the Kariba Dam project.

By the end of 1956, three Tsetse Control Supervisors had been assigned to the Valley, along with supporting staff. Three Veterinary Assistants were also stationed locally, although a full time livestock officer was not appointed until 1960. The first pickets were established and discriminative clearing and the use of insecticides applied from the ground[1] were initiated after further surveys

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[1]To the best of my knowledge, the only aerial spraying used in the Valley in connection with resettlement occurred on the Southern Rhodesian side. This was in the Lubu area, which had been evacuated in 1913 as a result of human sleeping sickness. Following aerial spraying around 1957, there was a radical drop in fly numbers, after which the evacuees arrived and began to clear new gardens. Though a gradual increase in fly was noticed at first, as the garden area became more extensive, the fly population began to drop. By the end of 1962, the number of cattle had increased from 300 to over 1000, although they remained dependent on anthracide injections every two months (oral communication from J. Ford, sometime director of Southern Rhodesia's Tsetse and Trypanosomiasis Control and Reclamation Department; 1963). The cost of this operation was high and involved £ 42,000 and the loss of one aircraft with its pilot.

to pinpoint the main fly concentrations. During 1957, a fourth supervisor was appointed and eradication efforts continued on a large scale, with special stress placed on the Sinazongwe area. By the end of 1958, when the dam wall was sealed and the lake began to form, the situation in the various resettlement areas being prepared for cattle appeared satisfactory. It improved during the next year as tsetse operations continued and as the evacuees began to open up new gardens, hence consolidating the gains made by reducing the extent of regeneration and clearing further areas.[1] Because of its isolation and light density of fly, the Siabunga Pocket was easily eliminated. In the Sinazongwe Pocket, the situation was quite different, the concentration of fly being heavy in certain areas. These required a major effort which continued through 1961, when the last major concentration was brought under control. Indeed, by 1963 the Tsetse Control Supervisor stationed at Sinazongwe was of the opinion[2] that the tsetse problem was largely over in the southern portion of the Gwembe District (from the Chibuwe to the Mulolo), provided surveys and pickets continued so that a new buildup in any area could be spotted and treated before the fly had time to spread outward.

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[1] Wherever possible, tsetse control operations were closely correlated with human settlement. Otherwise, as in the Mpendele-Mutulanganga area below the dam, costly clearing and spraying operations had to be repeated as the fly moved back into former habitats.

[2] Oral communication; 1963.

More difficult to handle was the Simamba-Sikongo Pocket. Not only was this larger in size, but it also contained a number of relatively waterless and unpopulated areas (in particular, Bunga Hill, the Kariba Hills, and the Nyanzara Plateau). These areas were not only hard to get at, but were also areas in which temporary eradication could not be followed up by human settlement. Furthermore, the danger of reinfestation from Southern Rhodesia below the exit of Kariba Gorge was an unmanageable problem under present conditions. As for the small Moyo Pocket in the southwestern corner of Simamba, this was ignored. No doubt a number of reasons were responsible for the lack of attention paid to this concentration, including isolation and the fact that the entire pocket not only lay outside of the areas set aside for relocation, but also would eventually be inundated by the rising lake.

During 1960 and 1961, reports dealing with the tsetse situation tended to be rather optimistic. Throughout the Kariba Lake Basin it was assumed to be only a factor of time before the fly was eliminated entirely (or at least contained in small pockets remote from human habitation), whereas down-river from Kariba Gorge the assumption was that a combination of clearing, spraying, human settlement and selective game elimination would control the threat of serious encroachment from across the Zambezi. In the meantime, the number of cattle in Gwembe District continued to increase (see Table I). This was an altogether desirable situation. Not only were the cattle seen by the government as an integrated part of agricultural development leading to better husbandry and to cash cropping, but also a cattle industry in certain parts of the Valley seemed a distinct possibility. This was especially the case in the southern half of Mwemba chieftaincy and in the Mpendele-Mutulanganga area, which lay between the Kariba Hills, the southeast corner of the lake, and the Lusitu.

In comparison to the neighboring plateau, the Valley, except for tsetse, provided a much better habitat for cattle. The reasons for this were simple: better water and better feed, the latter including both grazing and broozing. Though a definite stress period often came toward the end of the dry season, the potential pastures were there, provided early burning by the Tonga could be controlled and provided the herders could be persuaded to move their stock back into the escarpment country or down toward the lake (in Mwemba) or to specially selected grazing areas (Mpendele-Mutulanganga) during the drier months. While such problems would not be easily overcome, they appeared no less manageable than in other livestock areas. Certainly the Tonga wished to build up their herds, had shown a desire in Munyumbwe and Sinadambwe to sell cattle to traders as early as 1951 if not before, and to date had cooperated closely with the local veterinary assistants in connection with prophylactic and curative inoculations. Against this background, most tsetse and livestock officers who

TABLE I. Gwembe District Cattle Figures[1]

	1951	1956	1959	1962	1964	1966
Mwemba	3061	5766	5355	6586	7410	n/d
Sinazongwe	407	351	935	2403	3840	n/d
Chipepo	338	1167	1199	1862	2166	2630
Munyumbwe	5420	8356	7484	8139	4399[2]	3977[3]
Sinadambwe	6141	4264	1881	2867	2145	2061
Simamba[4]	156	n/d	79	169	19	41
Chipepo (Lusitu)	-	-	562	1562	2177	2524
Sigongo	1383	602	435	629	353	560[5]
	16,906	20,506	17,930	24,217	22,509	n/d

1 Information provided by the District Commissioner, Gwembe (1951-1956) and the Livestock Officers, Gwembe (1962) and Mazabuka (1964-1966).

2 Not including 10 Chambwe villages which are included in Sinadambwe total.

3 Not including 10 Chambwe villages which are included in Sinadambwe total (Chambwe total was 472).

4 Simamba figures questionable throughout (some stock may be included within Sinadambwe totals).

5 Two sets of figures available; other is 908.

were familiar with the Valley saw no reason why a profitable cattle industry could not be developed. This would be especially appropriate for south Mwemba, where a human population of over 5000 in 1963 did not have sufficient land for cultivation. In the Mpendele-Mutulanganga area, which had some of the best cattle country in the Valley, and which was currently unpopulated, some people even discussed the possibility of fenced grazing schemes which would support, under proper management, roughly one cow for every ten acres.

The first sign that all might not be well was contained in the 1960 Annual Report of the Department of Veterinary and Tsetse Control Services. Here it was noted that fly had spread to previously fly-free Kota Kota Hill in the mid-lake area. Though the source of the spread was not noted, presumably this was the Moyo pocket which was now largely, if not totally, under water, the fly being forced to move from a favored habitat into a less favored one as a result of flooding. No doubt, whatever spread occurred was facilitated by two other types of movement: one of game, which also had to seek new habitats as the water rose, and the other of fishermen, who moved to and fro throughout the area.

During 1961 and 1962, none of the reports that I have read refer again to the Kota Kota situation. By 1963, however, the situation had really deteriorated, with fly now present in an area extending from the Nahunwe (east of the Lufua) to the Chibuwe River west of Kota Kota. Apparently expanding outward from Kota Kota Hill and perhaps also Bunga Hill, tsetse encroachment was now a definite threat to the sizable cattle populations along the Chaanga-Munyumbwe road and in Chipepo. By this time the lake had reached its highest level and the lake shore margin was beginning to stabilize. Formerly an incomplete tsetse habitat because of extremely high temperatures during the dry season, much of the vegetation along the lake's edge was now retaining its leaves for a longer period of time. This was especially the case with mopane (Colophospermum mopane), which might retain a partial leaf cover throughout the dry season, hence creating a lakeside tsetse refuge where none existed before. Another serious factor was a continuing buildup of the new lake fisheries, which reached its peak on the north bank during 1963. In seeking out new fishing grounds along the lake shore margin and on islands, fishermen doubtless facilitated the spread of fly. Perhaps even more important in this regard were the movements to and from outlying camps of fish traders. This would be especially true of those who hawked fish both fresh and dry to the nearest villages, moving through the intervening bush either on foot or on bicycles. According to Steel and Gledhill, "in ... Northern Rhodesia, it may be stated that somewhere in the region of 90% of the cases of Bovine Trypanosomiasis recorded in a year are initially the direct outcome of carried Tsetse Fly." As far as carriers were concerned, they suggested that the fish trade was of particular importance, with dried fish perhaps even luring the fly from its resting places. As an example from the Plateau, they noted bicycle traders in connection with the Kafue Fisheries in parts of Namwala District who traveled to and from between fly and fly-free areas, hence seriously threatening the substantial herds of Ila cattle. Suggesting that possibly a fishing and a cattle industry were incompatible under such conditions, they went on to say that, "It is no exaggeration to say that with uncontrolled traffic, the marginal fly area has now been increased to perhaps thirty to forty miles outside the true fly habitat."

Though the rapid buildup in lakeshore fly between the Nahunwe and the Chibuwe is tied up with the formation and recent stabilization of Lake Kariba, its rapid encroachment inland, as in the Kafue case, was no doubt facilitated by the movement of fish traders. While pickets established along the roads leading from the major fish camps and markets were able to inspect and spray travelers, including motorized fish traders, those traveling on small trails would not be intercepted. And between the Chibuwe and Manchavwa camp (just east of the Lufua), this and water travel were the main means of transport, there being no roads serving this extensive area at the time.

Table I suggests the impact of fly encroachment during 1963 and 1964 on cattle in Munyumbwe's Chieftaincy, which before Kariba was the only chieftaincy in the District thought to be fly-free.

In 1962, 8,139 cattle (slightly over one per capita) were recorded there, while the District Livestock Officer in his annual report stated that the health of Valley cattle in general was excellent. Furthermore, the export of cattle from the Valley seemed to be picking up, with 249 of the 283 sales recorded taking place in Munyumbwe. The next two years, however, were catastrophic for the Munyumbwe cattle industry, with the number of cattle dropping to less than 5000 by the end of 1964. By the end of 1966, cattle were still dying, although the rate of decrease had fallen off, with the total cattle reported from Munyumbwe being 4449 at the end of the year.[1] While the pastures of this chieftaincy had been over-grazed at the time of the sudden decline and cattle were suffering from poverty, especially toward the end of the dry season, none-theless there can be little doubt that the primary cause of death was bovine trypanosomiasis carried by flies moving inland from the Kota Kota and the Lufua-Nahunwe areas. Having crossed the Munyumbwe-Chaanga road from the south, fly had established

[1] The first government-sponsored sale in the Valley occurred in 1951 in the Lukonde area of Munyumbwe's chieftaincy. In 1964, the Cold Storage Board organized its first sales in Gwembe District. Between October 1963 and September 1964, 408 Valley cattle were sold to all buyers, of which 236 were from Munyumbwe (1963-64 Annual Report of the Chief Agricultural Supervisor, Gwembe). According to the Technical Assistant-in-Charge, Gwembe Boma, in 1966 and 1967 Cold Storage Board buyers were no longer making Munyumbwe purchases during their occasional trips there, primarily because of deaths from bovine trypanosomiasis. Farmers who lost oxen were particularly hard hit, with some using cows for traction for the first time.

themselves in the Munyumbwe neighborhoods of Lumbo, Bondo and Lukonde apparently for the first time in the District's history. Moving up the escarpment, they even threatened cattle in Chona's Plateau chieftaincy until extensive spraying was carried out in 1966 and 1967.

In Sinadambwe, the picture is not so clear, since a significant decline began there prior to the formation of Kariba Lake. In my 1962 volume on the Gwembe Tonga, I have suggested that bovine trypanosomiasis was the most likely cause of this decline owing to both mechanical transmission of the disease from infected cattle outside of the Simamba-Sikongo pocket and to fly encroachment from within this pocket. I see no reason for changing this view, believing that the even more significant decline between 1956 and 1959 represented a continuation of the same process. While it is true that control operations were initiated during 1957 in the Simamba portion of the pocket, it was not until late in 1958 that a concentrated attack was begun on the major fly concentrations. This is probably of significance in regard to the reversal of the decline in the number of Sinadambwe cattle during the early 1960's, with 2371 reported in 1960, 2742 in 1961, and 2867 in 1962. Unfortunately, by 1964 numbers were once again dropping, the totals being even less than those entered in Table I, since the 1964 and 1966 Sinadambwe figures include several hundred cattle from the ten Chambwe villages inside the eastern boundary of Munyumbwe and perhaps a few

Simamba beasts. Indeed, by the end of 1966 the total had fallen below the 1959 low point. This reversal presumably is also tied up with the buildup in fly along the lake shore margin, which we have already discussed in connection with the Munyumbwe livestock industry -- Sinadambwe being at the eastern end of the new lake shore fly zone extending from the Nahunwe to the Chibuwe.

By the end of 1963 then, the unexpected relationship between the now stabilized lake shore margin and the buildup and spread of fly in Simamba was quite evident. It was also clear that this development greatly increased the area requiring tsetse control operations. On the other hand, the belief continued to exist that it was "still practicable to aim at tsetse eradication in the Gwembe Valley as a short-term policy."[1]

In the Simamba area the strategy had been to move gradually west or up the lake from the Simamba-Chaanga road, along which small concentrations of fly were virtually eliminated by clearing in 1957. During 1958 and 1959, effort was concentrated on the Loteri system and Bunga Hill with good results. Between 1960 and 1963, residual insecticides were applied throughout the area between Bunga Hill and the Lufua estuary, with nearly 1000 lineal miles of habitat sprayed during the latter year. At that time some areas had to be re-sprayed (especially south of Bunga Hill) because of the

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[1] 1963 Annual Report of the Department of Veterinary and Tsetse Control Services -- section 60.

buildup of fly along the lake shore.[1] During 1964 the entire area sprayed the previous year had to be resprayed. Though it was clear of fly immediately after the 1963 treatment, subsequently massive encroachment from the still untreated lake shore areas west of the Lufua occurred. Reinfestation from this area also threatened the peninsulas jutting out into the lake immediately east of the Lufua and the Nahunwe rivers, fishermen en route to Gwena camp being potential carriers.

As a result of the danger of reinfestation from west of the Lufua, the first access roads were cut on the west bank during 1964, with both sides of the Lufua sprayed from the lake upstream to the Lufua-Lusengazi confluence. By the year end, the fly position east of the Lufua was satisfactory, although the costs of 1964 control operations were heavy, the major item (£28,696) being spraying.[2] The year was also hard on staff, with supervisory personnel in North Gwembe cut back from three to one. Furthermore, though vehicular spraying remained the main means of attack, the proportion of knapsack spraying rose because of the roughness of the terrain. In 1965, a pontoon was established on the Lufua and further access roads on the west bank were opened up. Heavy fly

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[1] The insecticide most commonly used was a 3% Dieldrin emulsion, which must be applied to 1-1/2 to 2 lineal miles per square mile of tsetse infestation for effective control in Gwembe District (J. D. Gledhill, Assistant Director for Tsetse Control Operations, oral communication: 1967).

[2] While these costs refer to Gwembe District as a whole, most of the spraying during the year occurred in the Simamba area.

concentrations were found and sprayed. Again District costs were high, with the cost of spraying, most of which was again in the Simamba area, coming to £43,552. A record 1338.1 lineal miles were treated with 100,265 gallons of Dieldrax 15Y 3% emulsion and 13,454 gallons of DDT 75% W.P. at 5% strength.

During 1966, no major spraying of a new area was undertaken, the services of the Insecticide Unit being required outside the Valley. Rather from the new holding line on the Nangandwe River (nearly half-way between Kota Kota Hill and the Lufua), a major effort was made to extend the road system into the area linking the Nangandwe system with the Chibuwe system to the west. The strategy here was to first contain Kota Kota Hill (hence protecting the cattle in Munyumbwe and Chipepo), and then to eradicate the fly on Kota Kota itself. Containment was programmed for 1967, hence setting the stage for the first spraying of Kota Kota Hill during the current year. If successful, fly would be eliminated for the first time in recent history from the Simamba area, although, as we shall see, the danger of reinfestation from without remains a serious danger.

Simamba was not the only area which provided a new habitat for tsetse fly as a result of the stabilization of Lake Kariba. In Chipepo, fly was found to have reestablished itself in the isolated Sikowinzala area during 1967. Encroachment from here would pose a very serious threat to the substantial herds in the Tonga neighborhoods of Chezia and Chilola. Eradication would require surveys and the opening up of new spray lanes and tracks, and then the application of residual insecticides. Further up the lake, occasional fly were found in otherwise fly-free Sinazongwe, presumably having been brought in by boat from Chete or other islands close to the heavily infested Rhodesian side of the lake. In Mwemba, the rapid buildup of lake shore fly in the Sichitando peninsular area in 1963 required extensive spraying late that year. Inland, a number of cattle died of bovine trypanosomiasis in the upper Mweenda area at the base of the Plateau. Kraaled within a fly-free area, these cattle perhaps were victimized by traveling fly or perhaps they sickened as a result of mechanical transmission from an infected beast imported from a fly area. One possibility here was the Sichitando area; another was the Sinankumbe-Sulwegonde area to the east. Here fly appeared in 1967 and required the application of insecticides in an area which apparently had been fly-free in the past, although it lay only a short distance southwest of the outer margin of the former Sinazongwe pocket. Hence the 1967 presence of fly probably represented a previously unknown extension of that pocket rather than a new establishment of fly from a lake side population.

Though the Sikongo portion of the Simamba-Sikongo Pocket falls largely outside of the Kariba Basin, it nonetheless warrants some attention. For our purposes this portion can be divided into three sections, including the Kariba Hills to the south, the Mpendele-Mutulanganga area in the middle, and the Lusitu area to the north. Just inland from the damsite, the Kariba Hills contained a fly population which in 1963 encroached on the lake shore at Mundulundulu fish camp, hence creating a possible means whereby the lake shore margin of the Simamba portion could be reinfested. Fortunately, at the time, the danger was identified and the threat temporarily removed through control operations. These were continuing during 1967 through discriminative clearing in the tributary valleys of the Kariba Hills.

As for the northernmost area of the Sikongo portion, this extended into the Lusitu area, which had been chosen for the relocation of some 6000 Tonga who could not be resettled within the actual lake basin because of land scarcity. Fly eradication here had high priority in 1957 and was successful to the extent that 243 of the immigrants' cattle were able to join them within a month of their relocation in 1958. During the next year a major effort was continued to completely eradicate the fly between the Lusitu River and the Chirundu-Lusaka road. By 1967 this aim had yet to be achieved. Standing in the way were at least three problems. One was the persistence of a small number of fly in the remote, rugged and unpopulated Nyanzara Plateau in the northeast corner of the area. Another was the movement of fly from Rhodesia directly across the Zambezi into the resettlement areas. Though this movement is hard to document, its significance was brought home to me in 1962 when Tonga told me of a herd of elephant that had crossed the Zambezi to feed in the Lusitu delta area. While there they mixed with some cattle, one of which was trampled to death. When subsequently found by Tonga herders, its mutilated body was the focal point of a small number of tsetse. As for the third problem, this relates to the fly still present in the Mpendele-Mutulanganga system. In spite of two pickets along the tracks exiting from this area, infection is still spread across the Lusitu. In some cases cattle owners are themselves directly to blame, as when one villager took two oxen into the Mutulanganga area during 1966 to bring back poles for building purposes. Subsequently both sickened and died. In other cases hitchhiking flies are probable responsible for infection, coming in on game, hunters and fish traders.

In spite of the use of both prophylactic and curative drugs in the Lusitu, during March 1967 a serious outbreak of bovine trypanosomiasis occurred. When it had run its course by August, at least 454 cattle had died out of a total population of less than 3500. This was a terrible loss for a society which is becoming increasingly dependent on oxen for plowing. Prior to the epidemic, some cattle owners had begun to sell stock to traders. Now the emphasis would be placed on rebuilding one's herds. External sales, as in the Munyumbwe and Sinadambwe areas in recent years, would probably become almost insignificant.

Looking to the future, there is little room for miscalculation. The original strategy of the Department of Tsetse Control within the Kariba lake basin was to eliminate the fly in areas of human settlement, with the Tonga themselves consolidating departmental gains through the practice of their extensive system of agriculture. Elsewhere in the Valley, eradication was also to be attempted, although in some of the remoter areas a policy of containment, based on periodic checks, spraying and discriminative clearing, would be the best that could be achieved.

Though initially this policy did not take into consideration the possible relationship of the stabilized lake shore margin to tsetse ecology, it has been remarkably successful in achieving its aims, with over 3500 square miles cleared of fly within Gwembe District by the end of 1966.[1] Continued vigilance, however, is absolutely necessary if current gains are to be maintained. There are at least four reasons for this. First, low density and isolated pockets of fly still exist in some of the more rugged portions of the Valley, and it is probably impossible to completely eliminate these. Rather, periodic checks and surveys are necessary so that any buildup in fly can be dealt with before they present a serious threat to Valley cattle. Here it must be borne in mind that the 1967 epidemic in the Lusitu, which took the lives of nearly 500 cattle, probably was derived, at least in part, from the isolated fly

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[1] J. D. Gledhill, oral communication, 1967.

population of the Nyanzara Plateau. Second, the risk of fly crossing the Zambezi from Rhodesia in the area between the end of Kariba gorge and the Zambezi-Kafue confluence is ever-present. While the present pioneer settlement in the Mpendele and Mutulanganga areas, along with the extensive spraying and clearing operations of the Department of Tsetse Control,have probably nearly eliminated resident fly from the lower portion of the drainage systems of these two rivers, wind-blown and/or game-carried movement across the Zambezi will, of course, continue to pose a threat to cattle in those areas and in the Lusitu. Where human settlement does not exist, discriminative clearing will continue to be necessary as regeneration occurs, and potential fly habitats will have to be periodically sprayed.[1] Third, the danger of fly movement across the lake from Rhodesia or from islands near the Rhodesian shoreline can be expected to continue indefinitely. Here the unintentional carriers will be fishermen and other boat users. Again, the only recourse is periodic surveys backed up by the potential to eliminate re-infestation by whatever means are necessary. Fourth, the danger of encroachment from Rhodesia upriver from the far end of Kariba may present as serious a threat as spread of tsetse across the Zambezi below the dam. Although there was no south bank fly in

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[1] In the opinion of the Assistant Director for Tsetse Control Operations, spraying along the uncleared riverine ecotone will be necessary four times a year, in connection with other methods, such as game elimination and control of human movements (oral communication). It is unfortunate for control operations that the pioneer settlers took their cattle with them.

this area before lake formation, recent information suggests that fly is spreading up the lake on the Rhodesian side for the same reasons that tsetse in Simamba spread up the lake to Kota Kota Hill. Although no fly apparently have yet been found in Zambia at the junction of the lake with the inflowing Zambezi, it would appear to be only a matter of time before fly begin to cross the river. Here again, periodic surveys backed up by an ability to control invasion are necessary.

Current tsetse control operations in the Middle Zambezi Valley are expensive in terms of capital, personnel and equipment. On the other hand, a serious cut in any one of these factors could lead to a very rapid deterioration of the situation and the eventual elimination of cattle from all, if not most, of the Valley. At the same time, containment methods would be once again necessary, although on a larger scale than before, to protect cattle on the adjacent plateau. So long as the Valley is relatively fly-free, these methods are unnecessary.

From the point of view of the Gwembe Tonga themselves, the eradication of fly is of immense importance. With the beginning of the cash cropping of cotton and sorghum in the past few years, cattle are playing an increasingly important role in agricultural development, which would be set back if ox-traction was restricted by fly encroachment. At the same time, the Gwembe Tonga from Mwemba to the Lusitu have shown a willingness to sell cattle for export, provided their herds are sufficiently large to meet their immediate agricultural needs. With the major exception of Munyumbwe prior to the recent epidemic, most of the Valley has always been understocked with cattle. Aside from the south Mwemba and Mpendele-Mutulanganga areas already mentioned, the entire lake shore margin would appear to have a considerable potential for a developing cattle industry, a potential which is denied to agriculture because of the extreme irregularity in lake drawdown. Between 1962 and 1967, the number of cattle in Chiabi has increased from 260 to 498. With a higher per capita average (slightly over one) than the rest of Chipepo, presumably the villagers here have profited directly from easy access to an extensive lake shore margin -- especially during the dry season -- when before -- Kariba grazing was particularly short. Because of their relative remoteness from the main road system, farmers in this area are still looking for a profitable cash crop which could well be cattle, unless, of course, tsetse encroachment from Sikowinzala or elsewhere was allowed to occur.

As an employer of labor on both a full-time and seasonal basis, the Department of Tsetse Control has made a different kind of positive contribution to the economy of Gwembe District. According to the Chief Tsetse Control Supervisor (oral communication), and my own rough calculations, at least 87 full-time staff were employed in the Valley during 1967, while the number of casual laborers employed during the dry season fluctuated between 200 and 300, making the Department one of the major employers of Valley labor. Not only are those seasonally employed working during the non-agricultural season, but some at least are putting their earnings into the purchase of cattle. Finally, the development of a mining township in the Sinankandobo-Maamba area of Mwemba, of a pilot project in village regrouping in the Kanchindu area, and of other residential townships along the lake shore margin at Sinazongwe and Siavonga make it desirable to keep the fly situation under control, since the danger of human sleeping sickness in the Middle Zambezi Valley continues to be a serious one on the Rhodesian side, and hence presumably is a possibility on the North Bank.[1]

In the future, it is also possible that current research will provide results which will reduce the costs of control operations. According to the Assistant Director for Tsetse Control Operations (1966 Annual Report), "under the hot dry conditions in the Zambezi Valley the effective persistence on tree boles of a deposit from a 5% D.D.T. wettable powder formulation is at least as good as that obtained using a 3% dieldrin emulsion formulation." If so, the use of DDT will reduce the costs of insecticides, although in the cases of all such chemicals not enough is yet known about the long-term

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[1] According to J. Ford, some eight cases of sleeping sickness were diagnosed near Kariba Township between December 1961 and April 1962 (oral communication).

ecological effects of extensive use. In this regard, biological control through the release of sterile males is particularly promising, especially in isolated pockets with a low tsetse population. Located in rough terrain, these are particularly difficult and costly to treat effectively with insecticides, yet such conditions are quite typical of Gwembe District. Yet another promising technique for reducing costs, though one which is hardly appealing to ecologists, is the application of arboricides such as 245T, which have already been used in Zambia in combination with late burning with good results.

AGRICULTURE, THE LAKE SHORE MARGIN AND RIVER FLOW BELOW THE DAM

Before Kariba, most Tonga lived within a mile of the Zambezi and the lower reaches of its major tributaries. The people were farmers, producing two crops during the agricultural season. These were grown primarily for local consumption, the Valley having been a serious famine area throughout its recorded history.[1] Indeed, no farmers grew cash crops in lieu of food crops, although a few of the more enterprising intentionally grew some cereals for sale, while a much larger number tried to sell the unexpected surpluses that occasionally occurred.

The Zambezi system played a major role in the agricultural economy. With the advent of the rains, tributary deltas and the more fertile alluvia immediately inland from the primary channel of the Zambezi were planted, with crops of cereals, legumes and cucurbits harvested prior to the river's expected annual flood in April (see figure 3). The second alluvial crop was planted after the flood waters began to recede, with seed sown just behind the retreating water line from late April until September, and harvested

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[1] See Scudder, 1962, for a detailed description of the Tonga agricultural system and the history and causes of famine in the Middle Zambezi Valley.

prior to the initial rise of the Zambezi in December. Only alluvia were planted during the dry season, although they were supplemented during the rains (usually November-March) by the cultivation of colluvial soils and Karroo sediments. While these latter soils were of major importance to a majority of farmers just prior to Kariba relocation, in large part this was because of recent population increase and the degradation of those alluvia which were not annually inundated. Karroo soils were definitely of secondary importance before 1950.

After Kariba: The Lake Shore Margin

The position changed drastically in the Kariba Lake basin after the lake was formed, simply because the alluvial soils were completely inundated except along the middle and upper reaches of the tributary system, where the extent of alluvial deposits has always been limited. As a result, the agricultural system of most evacuees was now primarily dependent on the less fertile and more easily erodable Karroo sediments. An unknown factor was the agricultural potential of these soils within the drawdown area of the lake. While the situation was such that one could not expect the lake to gradually build up an extensive layer of silt along its margin to increase soil fertility, the action of water on the soils and the presence of a high water table might well allow a continuation of the Tonga practice of growing two crops per year -- provided, of course, fluctuations in lake level were consonant with agricultural demands.

In large-scale manmade lakes in the tropics, whose shorelines measure in hundreds if not thousands of miles, the potential of the drawdown area and the inner lake shore margin could be considerable. In terms of agriculture, both dry and wet crops (rice in particular) might be grown with or without irrigation, depending on the circumstances. Areas not used for crop agriculture could be grazed under varying degrees of management. At one end of a range of possibilities would be uncontrolled grazing on whatever vegetation appears -- as occurs at present at Kariba. At the other end would be aerial or ground sowing of ecologically selected perennial grasses and their utilization as part of a grazing scheme. Fish ponding, preferably on a peasant basis, might also be developed, while certain unutilized areas could be incorporated within conservation zones and national parks. Unfortunately, to date very little research has been carried out in regard to the soil and vegetation characteristics of the lake shore margin in connection with any of the major African reservoirs, although P. M. Ahm of the University of Ghana has initiated a much-needed project to survey the agricultural potential of the drawdown area of Lake Volta, the intention being to provide information for the intelligent utilization of the most promising locations.

At Kariba, study of lake vegetation was restricted to the Southern Rhodesian side, where Boughey and Mitchell concentrated on the sudd aspects and ecology of *Salvinia auriculata*, and at least one university researcher dealt with phytoplankton. To the best of my knowledge, however, no one has documented through time the development and composition of fixed vegetation within the drawdown area or along the margin of the high water level, let alone related this to the possibility of a cattle industry using the lakeside area during the dry season. While certain grasses with a high nutrient value have been observed at Kariba (for example, Vossia sp. and Echinochloa sp.), the relative proportions of these through time (and especially since lake stabilization) are unknown.

As for the agricultural potential of the drawdown soils, it took experimentation by the Tonga to provide a partial answer. While the lake was gradually filling between the end of 1958 and the 1963 dry season, no drawdown cultivation was possible, with all lake basin Tonga dependent on a single rains crop for the first time in their lives. In October 1963, the high point to date was reached, with the water level dropping thereafter over twenty feet before it began to rise again in March 1964. During this time period, up to two miles of shoreline were exposed in certain areas because of the gentle gradient. Though without prior experience, some lake-shore Tonga responded to this situation by planting 90-day maize in the drawdown area in November. The results were excellent, with "some of the best maize ever reaped in the Valley" harvested in February and March.[1]

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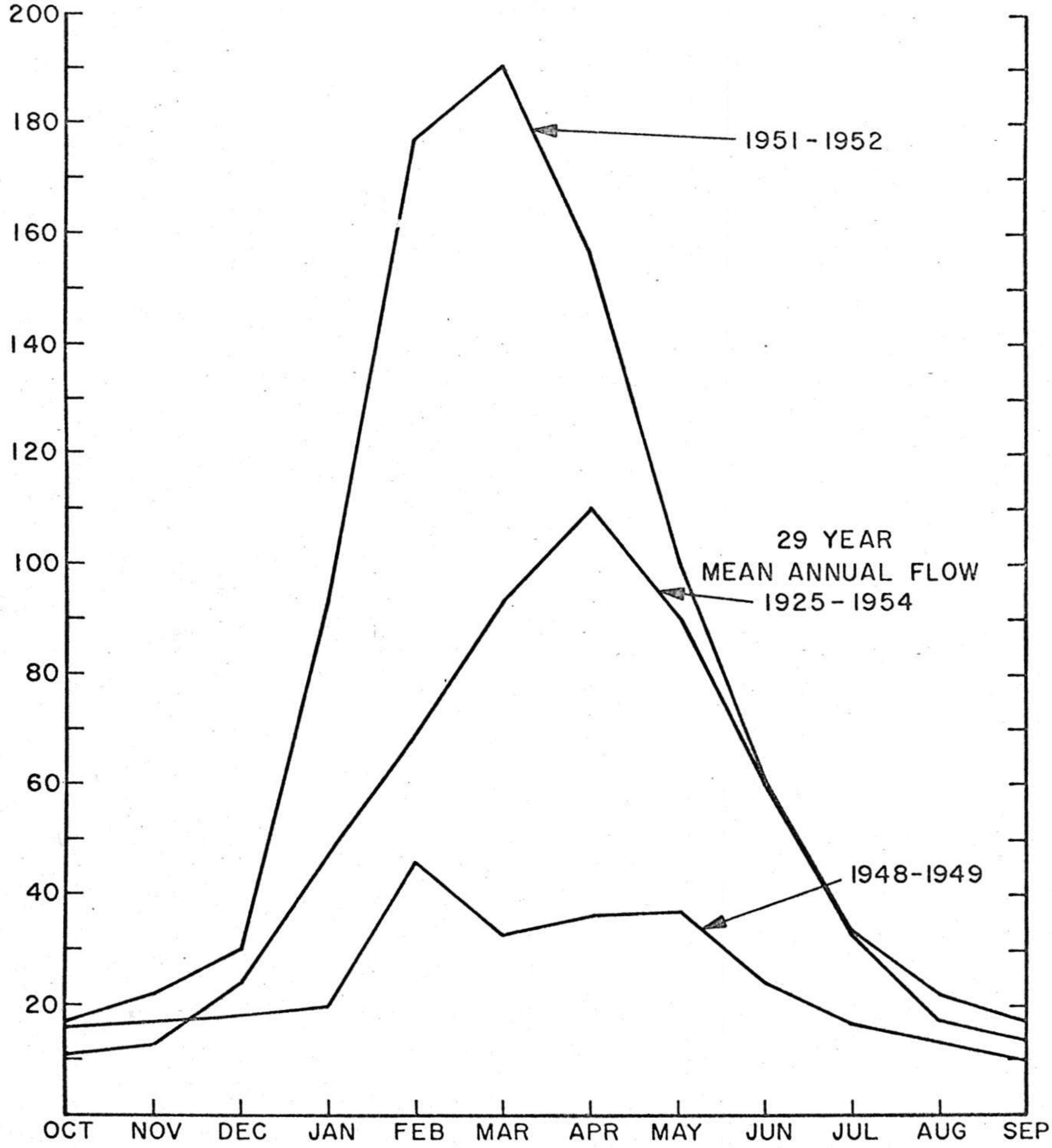
[1] March 1964 monthly report of the Chief Agricultural Supervisor.

While this result was most encouraging, the major problem was to regularize it on an annual basis. The problem was entirely manmade, and derives from the fact that the annual regime of Lake Kariba since 1963 is more irregular than that of the Zambezi before damming (see figures 3 and 4). For drawdown agriculture in the Middle Zambezi Valley, it is desirable to have a four-month growing season for most crops. It is also desirable that this season occur at roughly the same time each year and at a time when the population is not involved in other labor-intensive tasks. Unfortunately, these conditions are less satisfactory today than before Kariba. Prior to relocation, the dry season cultivation of the riverine drawdown fell within the period April-November, although a small proportion of the crop might be harvested as late as December. Aside from the harvest of giant sorghum in April-May and the preparation of garden land for planting in October-November, the agricultural activities involved did not overlap with those practiced during the rains. Today this is not the case, since the most reliable drawdown season extends from August-December, and hence overlaps with the rainy season plowing, sowing and first weeding of inland gardens. But even more serious than this is the annual variation in the lake drawdown with the resultant uncertainty of the farmer as to when to plant.

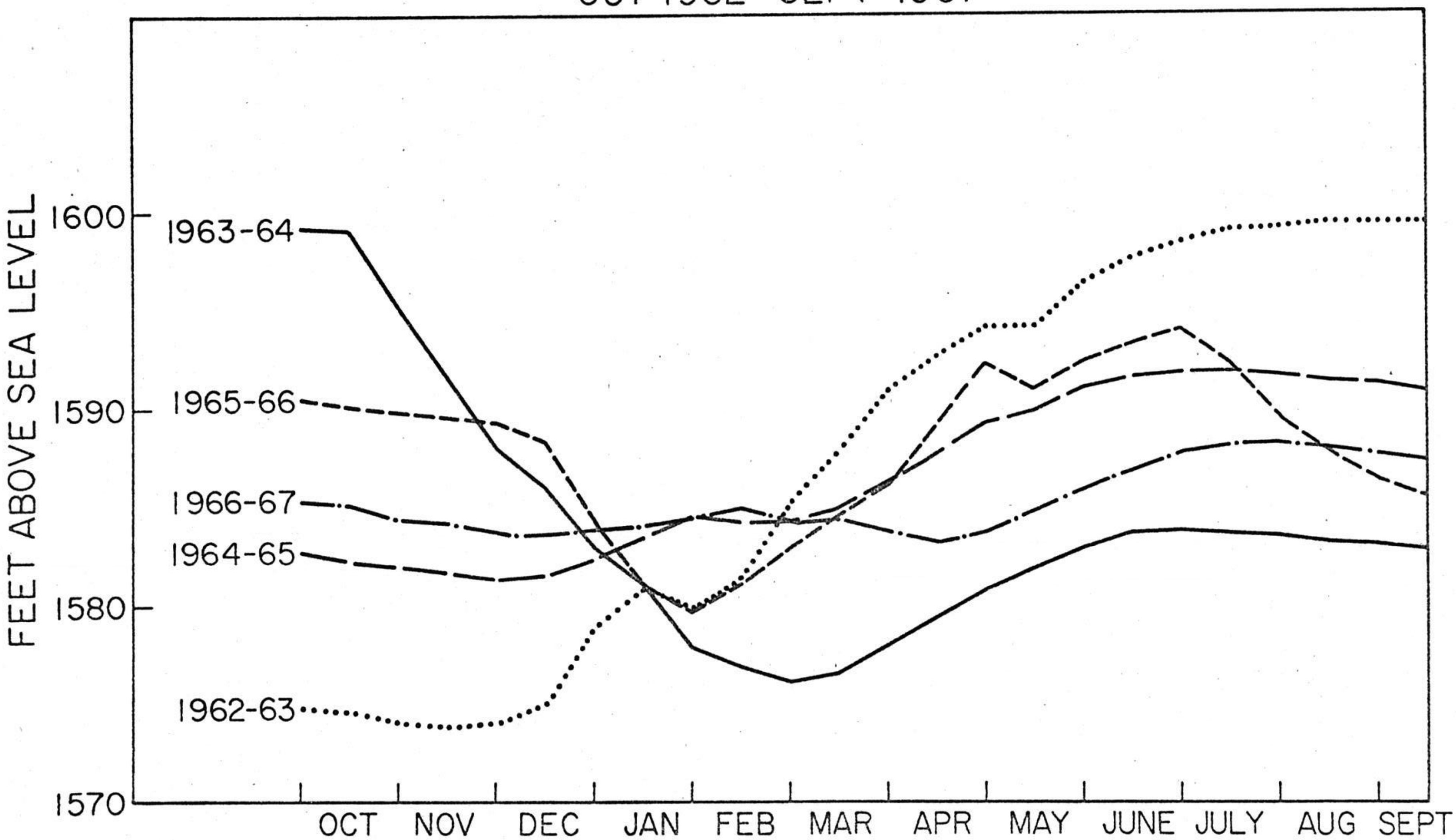
ANNUAL PRE-LAKE FLOW REGIME OF THE ZAMBEZI RIVER IN COMPARISON WITH SELECTED WET AND DRY YEARS

IN THOUSANDS OF CUBIC FEET PER SECOND



CALCULATED FOR KARIBA BY THE HYDROLOGICAL BRANCH, DIVISION OF IRRIGATION, FORMER CENTRAL AFRICAN FEDERATION

LAKE KARIBA WATER LEVELS:
ON THE 1st AND 15th DAY OF EACH MONTH
OCT 1962 - SEPT 1967



The extent of this uncertainty can be seen by briefly reviewing the drawdown situation since the record February-March 1964 harvest. During the latter month, the lake level began to rise again, reaching its 1964 peak in June-July. Thereafter, a gradual drop of only slightly over two feet (as opposed to 20 the year before) occurred, with the low point of the 1964-65 season reached in December, as opposed to March in 1963-64. Furthermore, by the middle of January, the rising lake had already passed its 1964 peak. In other words, any Tonga who had tried to repeat the successful 1963-64 experiment by again planting maize in November, would have had their entire crop flooded out prior to its harvest. Unfortunately, I have no information on how many farmers found themselves in this predicament. Certainly some had planted earlier, no doubt in part because of advice given by the agricultural department in September, and they would have been able to reap their crop before the next rise. This rise peaked in July 1965, with the water level then dropping about three feet during the next four months. Starting in December, however, the level dropped nearly ten feet in two months. Those who planted early in December, as well as those who sowed a crop during the preceding four months of gradual drop, were able to harvest their crops. But those who planted the much more extensive area that emerged during the latter part of December and January, would have lost out, since the lake level began to rise quite rapidly during February and

March. The agricultural season in question (1965-66) was a bad one at the southern end of the Valley because of inadequate rainfall in December. Because of reports of possible famine in Mwemba, an Agricultural Officer and a Livestock Officer with previous experience in the Valley were asked to carry out a reconnaissance in January and February. During the first month they reported that the only good stands of cereals observed were "odd spots" along the lake shore. The next month, the Livestock Officer noted that the January rise had flooded out drawdown crops planted in both Chipepo and Sinazongwe.[1] Because of the drought it is likely that areas planted had been quite extensive, with concerned farmers sowing the drawdown after the failure of the rains in December-January. Their subsequent total loss of this drawdown planting must have been most discouraging.

The 1966 rise continued until about the first of May, after which the water level fell approximately a foot. Because of the poor rains harvest, some Tonga may have been tempted to plant at this time, especially since it coincided with the dry season planting date that the people followed before Kariba. This would have been a mistake, however, since the 1966 rise continued during the second half of May, with the 1966 highpoint reached on approximately the first of July. During the next three months, the water

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[1] He was not able to observe what had happened in Mwemba, because by then the rains had finally set in, with the result that the Mwemba river crossings were impassable.

level dropped nearly ten feet, and then continued to drop very gradually until the middle of December, when an equally gradual rise began. During this drop, conditions for drawdown planting were good, and at least some farmers in Chipepo took advantage of them in August, presumably with satisfactory results. A year later at the same time, however, I observed no planting along the lake shore margin. Moreover, by October still no planting had taken place along the land-starved southern end of the lake. Although the water level had in fact begun to drop in August, the drawdown was very gradual, being only about two feet by the first of November.

It is too early to know how the Tonga will respond to a continuation of this type of uncertainty. One possibility is that they will consider the risks too great, so that in the future virtually no crops will be grown in the extensive drawdown even during years when a large harvest might be possible. This is what occurred along the Nile after the second heightening of the Aswan Dam in 1933. There, after a number of disappointing seasons when crops were prematurely flooded out, the Nubian population ceased cultivating cereal crops almost entirely within the drawdown area.[1]

A second possibility, perhaps more likely, is that some Tonga, for a wide variety of reasons which need not concern us here, will be willing to put up with the uncertainties involved. For these, early planting (July-August) would appear to be the wisest,

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[1] See Scudder, 1967.

although should the lake level drop sharply thereafter, there is the danger that crops will find themselves above the water table during the hottest portion of the year. On the other hand, late planting on recently exposed soils either just before or just after the advent of the rains, may be flooded out by a rise in lake level which in some years may begin as early as December and in others be delayed until February or March.

Regardless of the alternative chosen by the Tonga, the potential of the lake shore margin will be underutilized in terms of both productivity and the provision of jobs.[1] This situation was unplanned, since no one in a position of responsibility considered the relative merits of the drawdown area as a resource for development. Looking to the future, planners should think more in terms of creating more productive ecosystems rather than simply in terms of kilowatt hours and other statistical indices. More specifically, they should pay more attention to the food-producing potential of the lake shore margin as opposed to the river system below the dam site. In some cases it may well be that this is sufficiently great to warrant establishing a fixed drawdown regime such as

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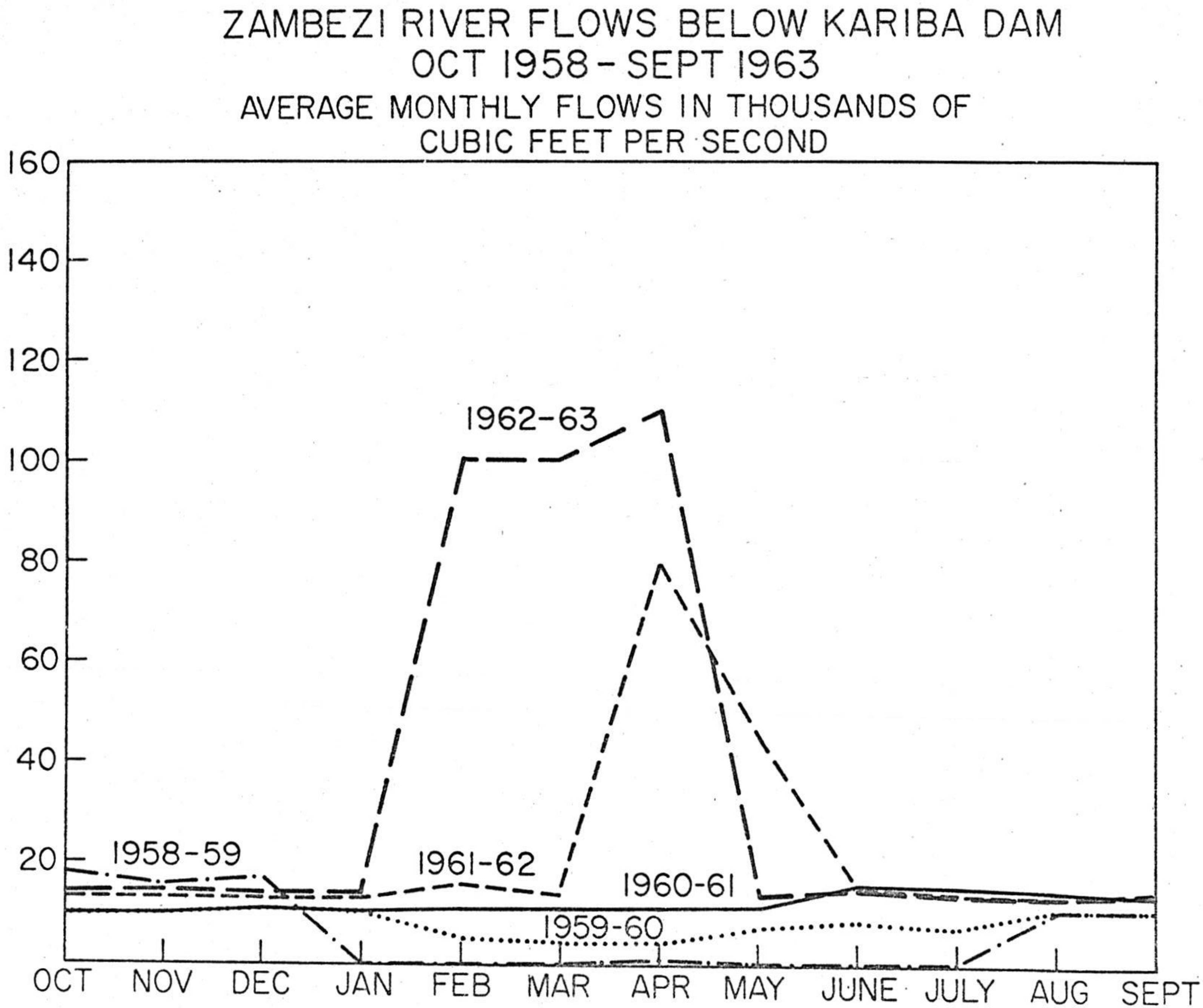
[1] In terms of population projections, far too little attention has been placed on increasing job opportunities throughout the Third World. Systems of lake shore agriculture which will provide a means of livelihood for thousands of rural residents should definitely be built into future benefit-cost analyses.

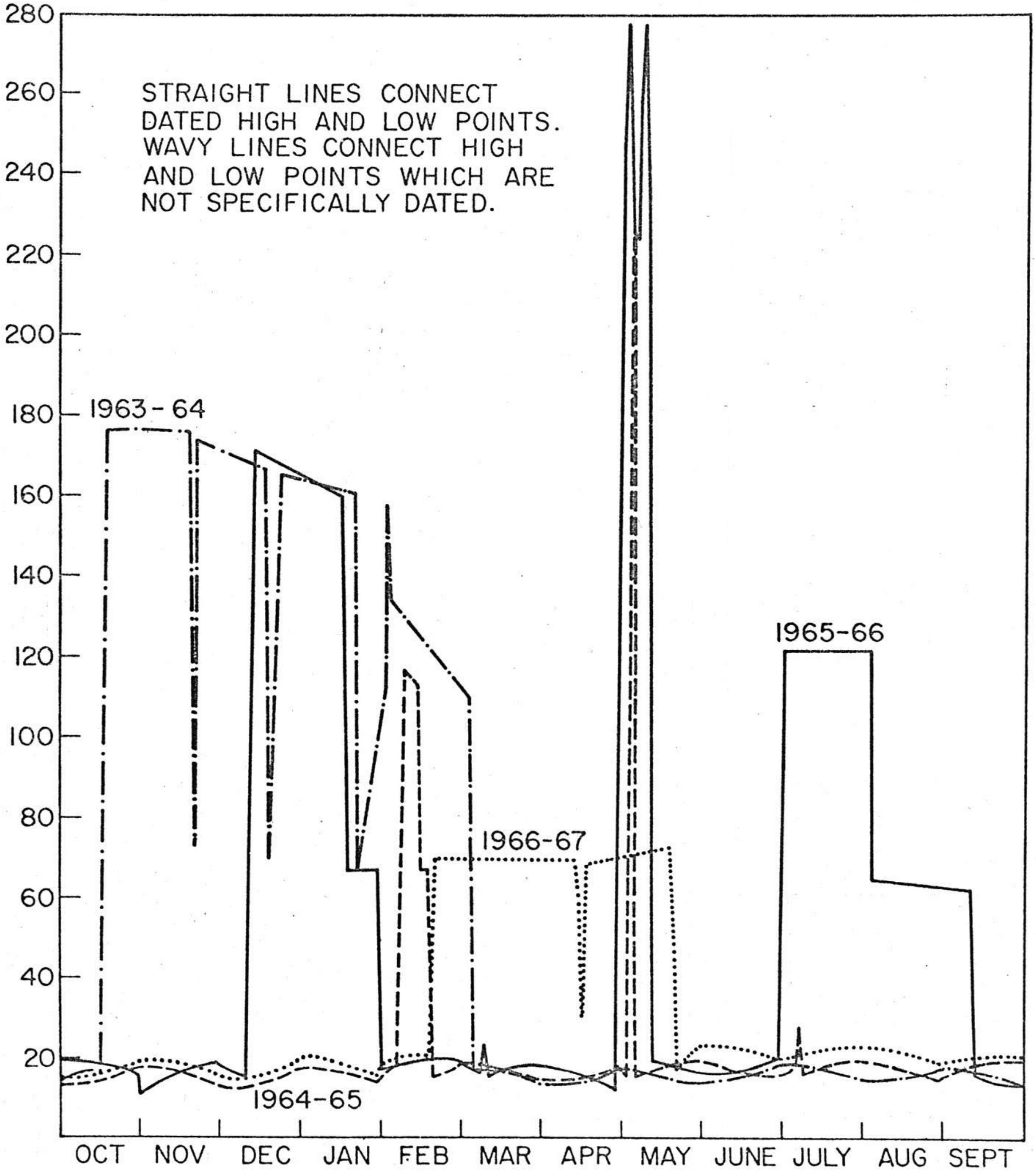
does not exist for any of the major African projects now in operation or under construction. Under these circumstances, the power producing potential of the dam generators would have to be integrated with other power producing facilities, such as thermal stations, so that conflicts between power and agricultural uses of water would not always be at the sacrifice of the latter. In other words, if power needs could not be met by the dam without seriously altering a fixed drawdown regime, they could be met by increasing output from another installation built into a nationally or regionally organized system.

After Kariba: River Flow Below the Dam

The impact of the Kariba dam on agriculture below the dam site is an excellent example of how man's engineering capacities can drastically reduce the productivity of an existing ecosystem. Figure 5 shows river flows from October 1958 through September 1963, while figure 6 deals with the period October 1963 through September 1967. A glance at these is sufficient to show the extreme irregularity that has been introduced into the annual regime of the Zambezi between Kariba gorge and the Kafue River as a result of the dam. Though fortunately commercial agriculture is of virtually no importance at present in the stretch of river involved, this is of little comfort to those thousands of Africans who desire to cultivate the fertile alluvia on a twice annual basis. Once again, we have


ZAMBEZI RIVER FLOWS BELOW KARIBA DAM
OCT 1958 - SEPT 1963
AVERAGE MONTHLY FLOWS IN THOUSANDS OF
CUBIC FEET PER SECOND
160
140
120
100
80
60
40
20
1962-63
1958-59
1961-62
1960-61
1959-60
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT

ZAMBEZI RIVER FLOWS BELOW KARIBA DAM
OCT 1963 - SEPT 1967
IN THOUSANDS OF CUBIC FEET PER SECOND



the same pattern of increased risks for the farmer in an already high-risk environment. Once again, it is too early to predict how the farmer will respond, although it is already obvious that he has suffered far more loss from man's manipulation of the Zambezi than he ever did during any equivalent time period in the past.

During the first three years (October 1958-September 1961), there was no Zambezi flood at all between the dam and the Kafue; indeed, no water was released during the first seven months that the dam was sealed except for a small trickle in March-April 1959. During the rainy season, the agricultural implications of having the Zambezi restricted to its primary channel throughout this period were inconsequential for alluvium previously cultivated. On the other hand, the area that could be cultivated during the dry season was greatly reduced because of the absence of annual flooding. During the 1961-62 season, the dam-controlled regime approximated the original flow pattern for the first time since impoundment began. While this must have been a relief to those farmers who had suffered during the previous three dry seasons, it proved disastrous for those who had begun to cultivate rainy season gardens on the lower level alluvia. This land had never been cultivated during the rains in the past because of flooding during the annual rise of the Zambezi. When this pattern was approximated in April 1962 through nearly a six-fold increase in river flow over the previous month, these new gardens were inundated by over ten feet of water within a single day.[1] The next year the manmade flood of the Zambezi came in February, again destroying crops within these lower terrace alluvial gardens, but fortunately not rising sufficiently high so as to destroy the extensive maize gardens planted in the Lusitu delta.

The case was altogether different, however, during 1963-64. Then three sluice gates were alternately opened and shut throughout most of the rains, so that virtually none of the Zambezi and tributary delta alluvia could even be planted during the most important agricultural season. Furthermore, since the river dropped rapidly in March, and no rain fell during April, "dry season" crops planted at that time on the higher alluvia would have been subsequently heat struck. The next three years continued a similar pattern of extreme irregularity, with 1965-66 being a particularly disastrous year for the alluvial cultivator. Then early-planted rainy season crops would have been flooded out by the December rise, whereas most late-planted crops would have been destroyed by the April peak.[2] As if this were not enough, those crops planted during the

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[1] The loss of crops at that time subsequently led to a food shortage in the Lusitu village of Kadabuka, which was most dependent on the gardens concerned (The District Assistant, Lusitu, oral communication, 1963).

[2] Planting during the middle of the season, of course, would have been impossible, because the water level remained up during most of December and January.

the first part of the dry season would have also been flooded out, this time by the opening of two sluice gates in June. Under the circumstances, it is hard to imagine how those regulating the flow of water through the dam could have acted in a way more detrimental to downriver agriculture.

At this point it is important to repeat, in all fairness, that agriculture in this downriver area today is quite unimportant at the national level. On the other hand, I am not aware that those planning for Kariba even considered the implications of alternate outflows for the future development of the downriver area. I am not so much protesting against what happened as against the narrow viewpoint of those responsible for planning installations like Kariba. This project was essentially a uni-purpose scheme. The population to be relocated were seen not as a resource but as an expensive nuisance, whose very existence was unfortunate. As for the future lake, it was strictly a dam by-product, whereas the needs of downriver inhabitants were considered only where backed up by political power, and then were seen as constraints by those who viewed the Kariba Project almost entirely as a means for generating power.

POPULATION RELOCATION, AGRICULTURE AND LAND DEGRADATION

My own study of a single Tonga village in 1956-57 showed that the large majority of farming households cultivated approximately one acre per capita, the expected harvest from this acreage being sufficient to support the population during most years.[1] Unfortunately, just prior to relocation, there was insufficient land in much of the valley to provide this minimum, in large part because of population increase and land degradation.[2] Though the annually inundated alluvial soils could support permanent cultivation for an indefinite period, over 20% of the farmers in our five river villages did not have any access to such lands. Furthermore, of those who did, only a small proportion controlled large enough acreages to meet their consumption needs. In other words, most of the population also relied on the cultivation of less fertile upper-level alluvia and on colluvial and Karroo soils which had to be periodically fallowed. Though the Tonga were quite familiar with the amount of fallowing that their various garden types required to

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[1] See Scudder, 1962, 218-219, and Appendix B. Information collected by the Department of Agriculture ranged, on the average, from one acre to one and one-half acres per capita.

[2] As used in this paper, land degradation includes both sheet and gully erosion and reduced fertility arising from overcultivation and overgrazing with or without accompanying erosion.

restore fertility, lack of additional land was responsible for the overcultivation and hence exhaustion of certain alluvial gardens by the 1930's. This process continued during the 1940's, at which time certain farmers began to pioneer less fertile Karroo soils well back in the bush. By 1957, most of the better Karroo soils within walking distance were under cultivation, while extensive areas of upper terrace alluvium were so degraded as to be under indefinite fallow. While the situation would have continued to deteriorate, since the exhaustion of the Karroo soils was only a matter of years away, relocation intervened. The overtaxed lands were flooded and the people were moved back toward the outer margin of the Valley or into the Lusitu area below the dam site.

Resettlement, however, did not solve the land problem. In fact, for many villages in the southern portion of the Valley, it only made it worse, since those soils least susceptible to degradation through cultivation had been permanently flooded along the banks of the Zambezi and the lower reaches of the major tributaries. Table II shows the amount of land available for relocation within the Valley. Under the local system of agriculture, less than 40% of this land could support semi-permanent cultivation (category 1), [1]

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[1] This land consists mainly of deep woodland soils which had been only partially cultivated prior to relocation. Though their origin is still in doubt apparently, Bainbridge and Edwards (1963) believe that they were derived from non-Karroo parent material, being transported into the Valley from the adjacent escarpment and plateau. Mostly sandy clays, they are quite susceptible to erosion.

TABLE II. Cultivable Land and Population in Gwembe District Relocation Areas (1958).

Chieftaincy	Population to be relocated	Land Available for Relocation	Type [1]
Mwemba	9,000	20,000	Mostly category 2
Sinazongwe	9,000	30,000	At least 14,000 acres, category 1
Chipepo	9,300	8,000 (8,281)	Mostly category 2
Sinadambwe	none	4,550	Mostly category 2
Simamba	2,200	7,800	Mostly category 2
Lusitu	none	25,000	Mostly category 1
Mpendele-Mutulanganga	none	7,500	Categories 1 and 2
	29,500	102,850	Approx. 40,000 acres Category 1

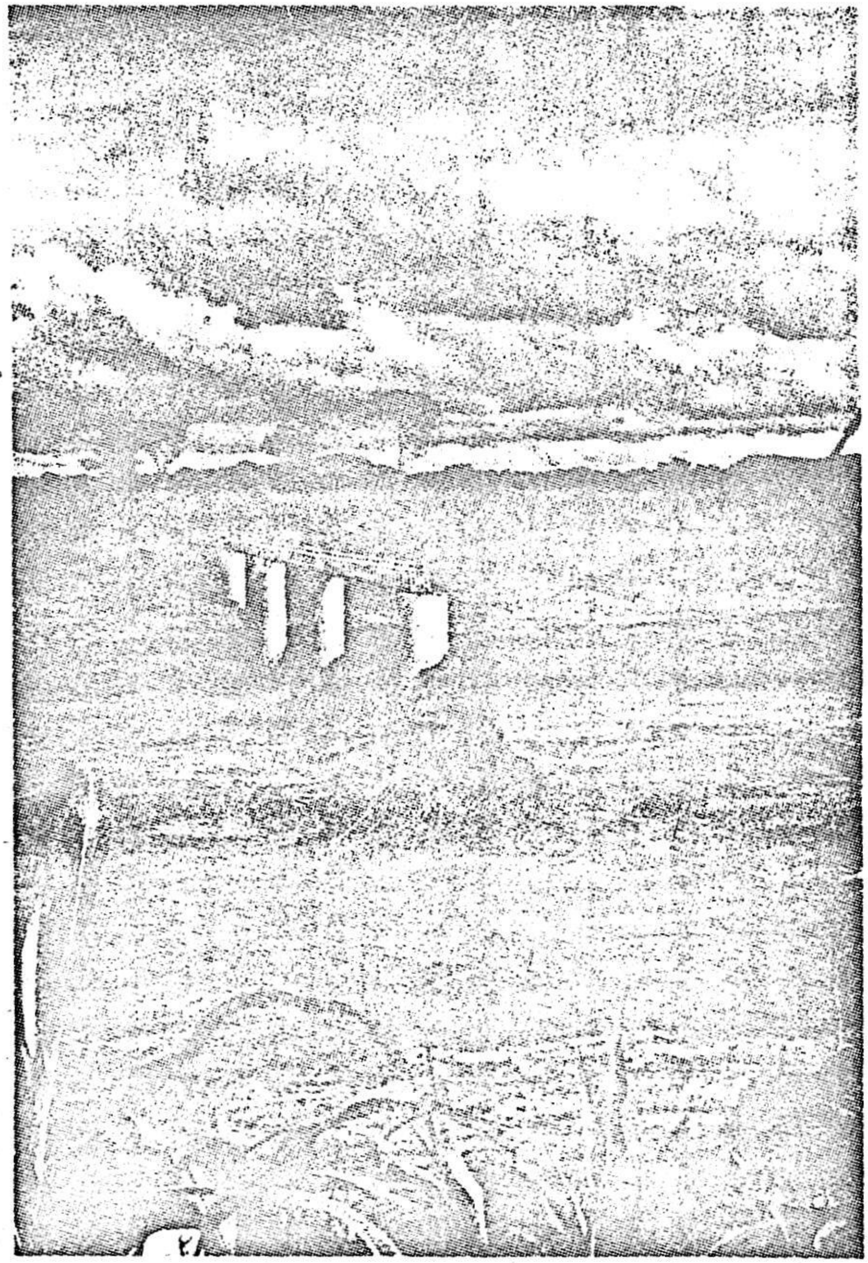
[1] Category 1: Supports "semi-permanent agriculture" (5-10 years cultivation followed by 5-10 years fallowing).
Category 2: Supports "bush-fallow agriculture" (2-10 years cultivation followed by 20 years fallowing).

which involves 5-10 years of continuous cropping, followed by a fallow period of approximately equal length. The rest (category 2), ranging in quality from fair to poor, could support at best cultivation for about six years, followed by a 20-year fallow. With almost all of the arable land in the Valley surveyed, this meant that semi-permanent cultivators needed an absolute minimum of two acres per capita, whereas bush fallow cultivators needed five or more. The situation was by far the worst in Mwemba, where 9000 people had access to approximately 20,000 acres of category 2 soil, much of which fell in the less fertile and more easily erodable grades. To meet their needs, at least 40,000 more acres were needed. In Sinazongwe, the 4000 people who moved into the Buleya-Malima area were in a much better position, since they had access to perhaps 14,000 acres which could be cultivated semi-permanently. The 6000 people relocated in the Lusitu were in an equally favored position, with access to at least 20,000 acres of category 1 land. As for the remaining 10,500 people, they fell between the Mwemba and Lusitu-Buleya-Malima extremes. Worse off were the 3300 relocated within Chipepo, since they had access to only 8281 acres of fair to poor quality (category 2).

The problem of land shortage presented by relocation was obvious from the start to all government officials concerned. After resettlement had been completed, it was known that approximately one-third of the population would find themselves in serious straits within ten years. The rest were more fortunate, although there was little room for population increase in some areas and all areas could easily become degraded in the years ahead through erosion, overcultivation, and overgrazing.

The response of the Department of Agriculture to this situation was to push erosion control and intensification, although there was general agreement that the situation in the southern portion of Mwemba was hopeless unless further relocation occurred. Two types of erosion control were stressed. The first would involve a prohibition of cultivation within 25 yards of the banks of major tributaries. The need for such an ordinance was obvious to all ecologically-oriented personnel who were familiar with the tributary system on the Plateau, in the escarpment and in the Valley. Referring to Mazabuka District on the Plateau, Bainbridge and Edwards reported that "The amount of run-off, coupled with sheet and gully erosion that takes place during the heavy rains is quite frightening." With much of their grass cropped right down to the roots, dambos along the upper reaches of rivers like the Lusitu are increasingly subject to abnormal flash floods. In the escarpment country leading down into the Valley, the same authors refer to air photographs which "show clearly the denudation of the protective strips of woodland along the stream banks and the spreading of the cultivation away from the streams up the steep slopes." Without a protective cover, flash floods each year remove more of the soil, with the authors estimating that within 10 to 15 years "there will no longer be sufficient soil left in the escarpment to carry the present population." In the Valley, flash floods periodically sweep the now unprotected banks of the major tributaries. When the Lusitu rose to record heights in a matter of hours in March 1963 (figures 7 and 8), the extensive river bank areas under cultivation since relocation were severely eroded (figure 9). Clearly this would not have occurred if the riverine fringe vegetation had not been systematically removed through the upper, lower, and perhaps middle reaches of the Lusitu. As for the second type of erosion control, here the stress was on the construction of contour ridges to keep in situ relocation area soils. Initially, £25,000 were allocated for this task, the hope being that eventually the Native Authority (now the Gwembe Rural Council) would take over responsibility for the financing, construction and maintenance of ridges, with the Department of Agriculture's responsibility being restricted to locating and pegging them.

Turning to intensification, in relationship to the control of land degradation, the core of the program was a two- or four-crop rotation supplemented by the use of cattle manure. This system was carefully worked out by a first-rate research man with long Valley experience on experimental plots cleared from the different Valley soils. It was then applied on departmental demonstration gardens and on the holdings of Peasant Farmers and Native Authority



Improved Farmers. The first ten Peasant Farmers were selected by the District Commissioner in 1959. After receiving credit from a revolving fund under the DC's jurisdiction for their equipment and cattle needs, they became the responsibility of the Department of Agriculture. At first, each Peasant Farmer was restricted to a 20-acre holding. While building this up, he was supposed to follow a four-crop rotation involving equal acreages of maize, sorghum, cotton, and a green manure crop. Supplemental manure (at 3 tons per acre) was to be applied annually to half the acreage planted in grain, with each farmer told to build up a herd of 20 cattle to meet his ox traction and manure needs. As for the NA Improved Farmers, they had much smaller holdings on which they could receive a one pound sterling bonus per acre, provided they followed a simple grain-legume rotation and manured half the grain plot each year.

If actually practiced, the recommended measures most likely would have been effective in maintaining soil fertility and preventing erosion. The degree of acceptance, however, by the farmer has been minimal. No ordinance prohibiting cultivation within 25 yards of tributary beds was enacted. Even if it had been, it is unlikely that enforcement would have been possible. Throughout their known history, the Tonga have always cleared tributary banks, except for occasional shade and fruit trees, in order to cultivate the fertile alluvial soils. After relocation and the loss of Zambezi and delta alluvia, these soils became even more desirable, with tributary bank clearing extended throughout much of the Valley. This was especially the case in Mwemba, where other soils were not only extremely limited, but also of generally poor quality. While those Tonga involved were well aware of the resulting dangers of erosion, they saw no option but to continue as in the past. As for the alternative suggested by the Department of Agriculture, this was seen as no alternative at all, since no acceptable substitute for river bank cultivation was presented to them. While contour ridging was not actively opposed, the Native Authority was unwilling to publicly back it through its own regulations and sponsorship. Well aware that the Valley residents did not really understand the basis for contouring, the Native Authority did not wish to associate itself with a potentially unpopular measure. After all, their support had always been low and this was especially so after relocation, which the NA councillors and chiefs had been pressured into supporting by the Central Government. Though some 1230 miles of ridges (protecting 14,247 acres) were dug under the jurisdiction of agricultural staff by October 1964, they never received popular understanding, let alone sufficient support to provide for their maintenance. A year later, construction apparently stopped in the Lusitu, and thereafter I recall seeing only occasional references to them in Agricultural Reports. Though I do not know how these ridges are faring today, some Lusitu farmers have broken them down in connection with the cultivation and extension of their own gardens.

Intensification in the Valley has fared no better as a degradation control device. Out of a total District farming population of well over 10,000 males, to the best of my knowledge there have never been over 25 Peasant Farmers and 75 Improved Farmers. Moreover, the degree of intensification among these has decreased, if anything, through the years. According to the Agricultural Assistant, Lusitu, in 1965, those wishing to become Rural Council Improved Farmers wanted to grow unrotated cotton. In 1967, most Peasant Farmers had sown cotton or maize in plots that they were supposed to plant in green manure crops. In the Kayuni Block of the Lusitu, the most enterprising of the five Peasant Farmers there was mono-cropping cotton during a four-year period, after which he planned to carry on a cotton/maize rotation.[1] He had also stopped applying manure, although here the reason, as with other progressive farmers, was the breakdown of his scotchcart, for which it was literally impossible to get parts owing to the Rhodesian crisis. Moreover, he had substantially increased his acreage with 20 acres now planted in cotton and 9 in maize, versus only 3 in sun hemp and one in groundnuts during the 1966-67 season. As for the application of manure at the village level, no one in the village that I have been following over the past ten years had applied it during the previous season, or any other season for that matter. The same

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[1] This warrants testing under Valley conditions as a possible basis for a compromise rotation.

applied to any form of rotation. Indeed, I doubt that it is an exaggeration to state that no more than 1% of the Valley farmers have ever practiced either animal manuring or crop rotation on a regular basis.

The present relocation areas just cannot support the existing population under these agricultural practices. In South Mwemba, the population has exceeded the carrying capacity of the land and is once again subjected to periodic food shortages which are bound to get worse with time. To prevent this, the government has decided to re-relocate at least 6000 people, and it is only a matter of time before this resettlement occurs. Elsewhere, the situation is still within the control of the local population, since exhausted fields can still be replaced by uncultivated land around the margins of the relocation areas or in the few areas which have yet to be settled. On the other hand, I expect all available land to be utilized within the next ten years unless there is a major reduction of population or change in agricultural techniques. In the highly favored Lusitu area, the surplus population is already crossing into the previously unsettled Mpendele-Mutulanganga area. Though no one in my own Lusitu study village had joined this movement by 1967, some of the men had begun to clear distant gardens on the far side of the Lusitu. In all cases, no intensification was occurring; rather pioneer farmers were simply reestablishing the same extensive system of bush fallow cultivation.

Though the problem outlined in the last few paragraphs is a severe one, it is not my purpose in this paper to propose possible solutions. Rather I wish to emphasize in closing that what we are dealing with here are two incompatible systems of agriculture. One, proposed by the Department of Agriculture, is satisfactory from an ecological point of view, but is not acceptable to the farming population. The other, while satisfying to the farmer, has serious, indeed catastrophic, ecological implications under the present population conditions. The problem is to design a compromise system which is acceptable to all involved. Throughout Africa, research stations have tended to develop new techniques without taking into consideration the total context within which the farmer, for whom these techniques are designed, lives. Ecologists, I think, tend to make a similar mistake when they propose alternative land-use systems without asking the questions, "Can these support the existing human population which, after all, is the ecological dominant in the area?" Or, "If not, is there an alternative way of life available for the people which there is a reasonable likelihood they will accept?" If, for example, cattle pastoralists are to be driven out of an area to be used for game cropping or conservation purposes, the same concern must go into planning an acceptable future for them as relates to other communities within the habitat concerned. Failure to do this is not only morally indefensible, but is also apt to be politically unacceptable. In other words, a technical or ecological solution to problems of environmental degradation is not of much use unless it is understood and implemented by the relevant people at the local and national levels.

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