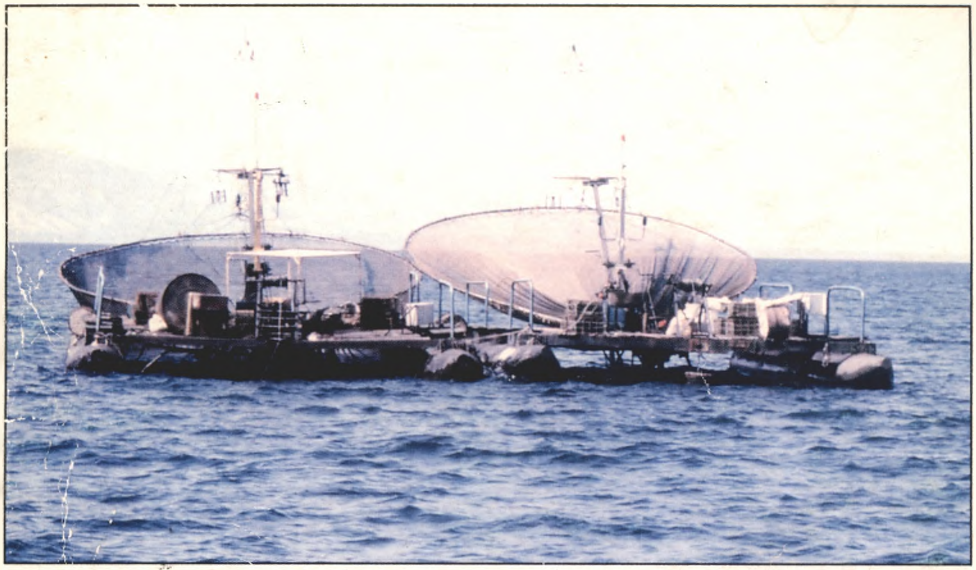

ADVANCES IN THE ECOLOGY OF LAKE KARIBA

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Cover Top: Typical ringnets as utilized in Kapenta fisheries on Lake Kariba
Bottom: Lake Kariba: The littoral area and draw-down zone
Back cover: Lake Kariba: The ecology of the littoral area is strongly influenced by wildlife.

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CONCLUSION

Jacques Moreau and Nils Kautsky

As quoted in the introduction, the SAREC/UZ Research Project on Ecology of Lake Kariba aimed to contribute to the development effort of this region by providing essential data relevant to the management of natural resources of Lake Kariba. In this respect, this conclusion attempts to raise some points which appeared to be of particular importance during the core activity of the project.

THE EVOLUTION IN TIME AND STABILITY OF THE LAKE

Basically, the SAREC/UZ Project took place between 1983 and 1990, i.e. mainly within a period of severe drought. As a consequence, the data collected by the project represented a particular window in time of the general evolution of the lake. This is of primary interest as these data deal with a critical situation in the lake history (the drought) whereas former investigations took place in a period of more "normal", but still changing, hydrological pattern (see contributions issued before 1985 and reported in the reference list).

The general evolution of the lake can be summarized as follows (Figures 11.1 and 11.2):

- 1958–1963: Phase of rapid filling and eutrophication, massive *Salvinia* growth
- 1964: Rapid drop in lake level and simultaneous massive kills of *Salvinia* by stranding
- 1965–68: The water level is relatively stable; the *Salvinia* mats develop again extensively and the water body tends to be mesotrophic. The *Salvinia* eating grasshopper *Paulinia acuminata* is introduced.
- 1968–1974: *Limnothrissa miodon* is introduced; the water level rises and stabilises and *Salvinia* starts to decline which leads to an important release of nutrients. These nutrients are locked in macrophyte and mussel biomass which are rapidly establishing. The abundance of several "lacustrine" fish species increases.
- 1974–1981: The *Limnothrissa* fishery is developing whereas other fish species tend to decrease. *Salvinia* has more or less disappeared and the lake level is still very high. The river flows are about 50 km^3 yr^{-1}. Mussels and aquatic vegetation are well established.
- 1982–1994: This is the time of severe drought; the lake level falls by 7–12 metres; the river flows are only 20 km^3 yr^{-1} (i.e. 40% of normal) and the lake might be mesotrophic or even oligotrophic.

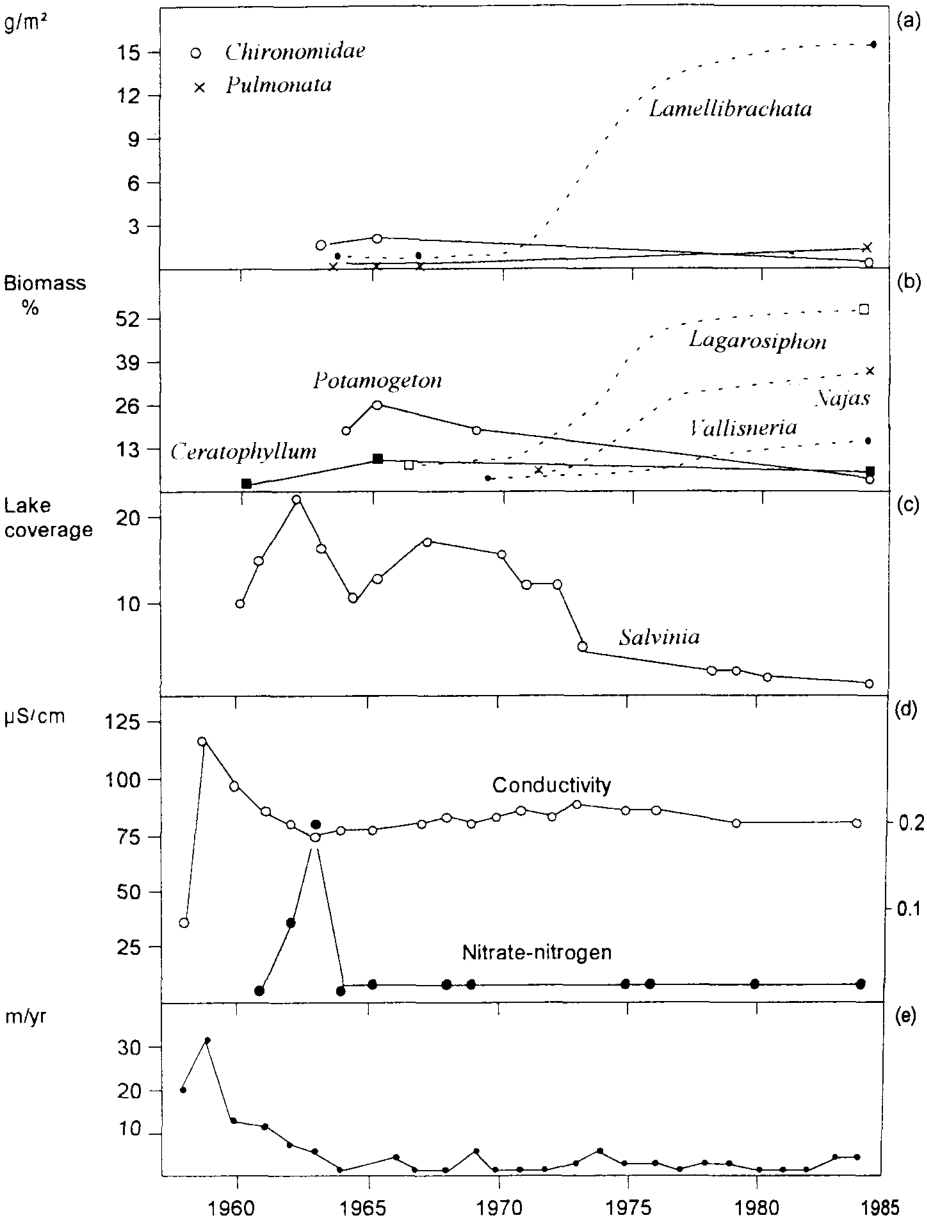

Figure 11.1 Changes in the development of (a) benthic fauna, (b) submerged macrophytes, and (c) *Salvinia molesta* in Lake Kariba in relation to changing water chemistry (d) and lake level fluctuations (e) (from Machena 1989)

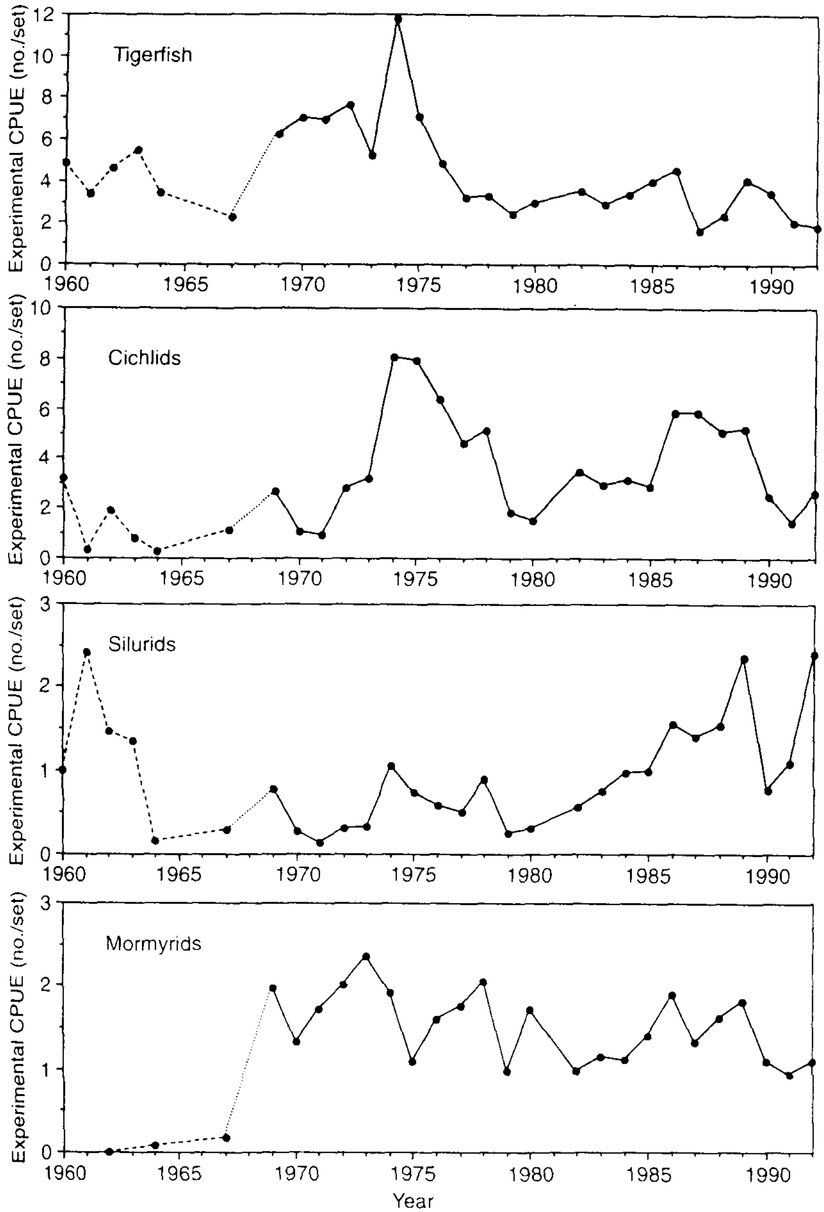

Figure 11.2 Trends in experimental catch per unit effort at lakeside (between 1960 and 1992) for the most important fish species or families. Data for the period 1960–1967 calculated from Kenmuir (1984), dotted line between 1967 and 1969 interpolated. Redrawn from Karenge and Kolding (1995)

Changes are still taking place in the littoral fish community with the development of an important population of Mochokid fishes (Karenge and Kolding 1995, R. Sanyanga, pers.comm.).

In summary, the major developmental changes in the initial phase were due to variations in nutrients, water levels, and the introduction/immigration of new species.

This short review clearly shows that even 40 years after its creation, Lake Kariba is still unstable as far as large-scale trends are considered. The consequences of these changes are, indirectly, delt with in various contributions (see for instance Lindmark, Marshall, Machena, Kautsky and Kiibus this volume) whereas in some particular aspect a relative stability can be observed i.e.

- The diversity and seasonal pattern of phytoplankton (Cronberg)
- The structure and organization of the vegetation of the draw-down zone (Skarpe)
- The depth distribution of macrophytes (Machena) and benthic invertebrates (Kautsky and Kiibus)
- The ecology of birds (Hustler) and crocodiles (Games and Moreau)

All over the book, it appears that the main reason for changes of abundance and production within the various communities are the large changes of the water level and simultaneous variations in the annual nutrient inflows.

For instance, it appears that the reduced amplitude in water level fluctuations might have contributed to the reduction of *Salvinia* growth in the seventies (Marshall and Junor 1981).

The extent of the floods determines the quantity of nutrients released. Thus, poor rainy seasons have been likely to cause a decrease in productivity and the biomass of various pelagic communities; it seems that the recent decrease of primary production is related to the decrease of nutrient inflow (Lindmark, Cronberg, this volume) and the influence of river flow was demonstrated by Marshall (1982 and 1988a) who investigated the relationships between phytoplankton, zooplankton and sardines (see Marshall this volume).

Another reason for the observed decrease in the pelagic productivity appeared to be the development of the littoral plant and mussel communities which contributed to substantially lower drainage of nutrients and also their availability for the pelagic producers (Kiibus and Kautsky 1996). The mussels were also shown to be able to remineralize large amounts of nutrients which would otherwise sediment out of the trophogenic zone (Kautsky and Kiibus this volume).

- It is difficult to predict what will be the future of the evolution of Lake Kariba as it will be strongly under the influence of the rainfall pattern; however, some human related factors will have an increasing impact:
- Small-scale pond farming and experimental cage culture of *Tilapia* have been running for recent years and there are now plans for large-scale aquaculture the impact of which on the general ecology and functioning of the whole ecosystem will be far from negligible (Berg *et al.* 1996, Troell and Berg in press)
- The general development of industries and agriculture in the drainage basin of the lake: Mining is already carried out and induces increasing pollution by heavy metals; it is needed to investigate the ecological and toxicological effects these pollutants may have on the aquatic flora and

fauna in the future (Berg *et al.* 1995). Simultaneously, pesticides are extensively used for the control of tsetse flies, mosquitoes and agricultural purposes and may have acute toxic effects on vulnerable populations (Berg *et al.* 1992, Berg 1995).

- The fishing effort is likely to increase on the littoral zone on both the Zimbabwean and Zambian sides of the lake as a result of the increasing demand of fish as food for human riparian populations

NATURAL RESOURCES AND MANAGEMENT ISSUES

A proper management of the pelagic ecosystem (with focus on *Limnothrissa miodon* fisheries) will be difficult to implement as it is clear that the fluctuations in the sardine biomass and production will follow the carrying capacity of the zooplankton which again is a function of the nutrient inflows to the lake.

However, there are a few ways in which nutrients in the lake could be fairly easily managed and channelled into fish production.

- In Lake Kariba, and other dammed lakes where the turbine intakes are situated below the thermocline, much of the nutrients mineralized in deep water never return to the surface layers but are drained through the outflows. In order to decrease this phenomenon of first importance for the whole Lake Kariba ecology, the design of the turbine intake could be modified in order to collect water from the eplilimnion instead. A proper water regulation should be designed in order to protect the littoral communities which have been shown to be severely affected by unexpected and important water level fluctuations, whereas limited water level fluctuations can be beneficial (Karenge and Kolding 1995). The littoral community is important as its development contributes to significantly reduce the drainage of nutrients out of the lake. However, the energy production from the dam is the highest priority which is acceptable as Zimbabwe experienced severe shortages of electric power during the last ten years.
- In order to protect water quality and sustainability of both pelagic and littoral fisheries, the aquaculture development has to remain within the carrying capacity of the lake. However, a moderate increase in eutrophication of the lake, due to aquaculture may be beneficial as it might shift the lake productivity back to levels experienced during earlier stages in its development.
- The mussel resource contains 50 times more protein than the stock of *Limnothrissa*; however, this resource is clearly under-utilized. On the other hand, it is well known that mussels can play an important role in the nutrient dynamics of the lake, speeding up remineralization and regenerating nutrients in the photic zone, making them available for enhancing the primary production (see Kautsky and Kiibus this volume). From this point of view at least, the cost-benefit impact of the introduction of squeaker in order to exploit, and simultaneously reduce, the mussel population has to be carefully investigated.

- Similarly, the direct utilisation of the littoral primary production as food by a mainly riverine fish fauna is very limited whereas it is used, most likely, as detritus. In such a case, the need of introducing further species from other African lakes has to be assessed in more detail by using a code of practise or other relevant protocole (see, for instance, ICES 1988).

The competition between fishermen, fish-eating birds and crocodiles is very limited; mainly because the target prey are not really the same, due to their difference of sizes. Moreover, as in several other situations (see Christensen and Pauly 1993 for review), the predation inside the aquatic environment has the major impact on the demographical structure of fish populations.

RESEARCH PRIORITIES

The fish production of the pelagic zone is directly controled by the abundance of zooplankton and phytoplankton. In addition, the seasonal cycle of abundance of phytoplankton (Cronberg this volume) and zooplankton (Marshall this volume) is well known. However, further investigations are needed in order to quantitatively assess the "bottle-neck effect" of the seasonal shortage of plankton on the whole sardine annual production. This problem could be properly approached with monthly monitoring of the plankton production and simultaneous demographical analysis of the clupeids.

In addition, it would be very useful to find ways to predict possible production and catch of sardines during next fishing season based on previous years rainfall.

The composition of vegetation communities in the draw-down zone at the end of the 1980's, has been estimated as well as the amount of above-ground phytomass production. The interactions between the geolittoral zone and the lake is hypothesized to consist primarily of nutrients and energy transfers, directly through the lake inundations and indirectly through animal activities. It is now needed to quantify the internal cycling of nutrients as well as the flow between land and water and the relative importance of the different processes, including the activities of hippopotamus and other large herbivores.

Similarly, the SAREC/UZ Project has helped to reveal the organization of macrophyte communities in Lake Kariba. As many animals (secondary producers) are in various ways dependent on the vegetation, their abundance and distribution would be dependent on the organization of the vegetation and ultimately on the operative physical factors. Therefore, in order to increase our understanding of the ecology of the littoral communities, further studies could be carried out:

- to elucidate the nature of interactions between snails and the particular plant species with which they are associated; this could also be important for the mapping of bilharzia around the lake;
- to study the light responses of each macrophyte species and competiton between species, to determine if this is an important factor of the zonation;
- to correlate the biomass and species distribution of inshore fish with the vegetation, to determine the extent to which fish populations are regulated by the organization of the vegetation, and to what extent littoral prouction is used as fish food.
- to investigate the carrying capacity of sustainable fish ponds and cage farming.

Finally, before advocating or supporting the introduction of *Synodontis multipunctatus* from Lake Tanganyika, its biology has to be investigated in detail. It must be known if it can, for example, eat large mussels like *Aspatharia* spp. or *Mutela* sp. In addition, the possible impact of this introduction on the whole littoral fish community (including already existing native squeakers) has to be assessed as much as possible (ICES 1988).

ADVANCES IN THE ECOLOGY OF LAKE KARIBA

This book assembles contributions of several authors engaged in the SAREC/UZ Project on the Ecology of Lake Kariba. Various problems, regarded as particularly important, are dealt with, for instance:

- The evolution of the lake in time;
- The function of the pelagic ecosystem with focus on *Limnothrissa miodon* and the reason of variations of yields;
- The relations between the primary production and the fish production in the littoral area;
- The possible impact the large water level fluctuations on the nutrient flow and production on the grass land and in the littoral region;
- The utilisation of the mussel resource;
- The competition between fishermen, fish-eating birds and crocodiles.

This is an essential reading for students, academics and environment managers interested in tropical aquatic ecology in Zimbabwe and in the rest of the world.

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