

# Lessons of the Volta—a New Man-made Lake in Tropical Africa

GEORGE W. LAWSON, Ph.D. (London)

*Professor of Botany and Chairman, Volta Basin Research Project, University of Ghana,  
P.O. Box 55, Legon, Ghana*

## ABSTRACT

Research has been proceeding on Ghana's Volta Lake since the dam was closed in 1964, and this has meant that a rather full picture has been obtained of the biological changes that occur when a great tropical river is transformed into a man-made lake. This has been achieved by regular sampling of phytoplankton, zooplankton, aufwuchs, bottom fauna, aquatic weeds, fish, and of the water itself for physical and chemical analyses. A striking feature of the changes that have been observed has been that the large amount of drowned woody vegetation has provided a considerable substratum for attached Algae, and has enabled burrowing insects such as the mayfly *Povilla*, which feed on these Algae, to increase greatly. This in turn has meant that insectivorous fishes have done unexpectedly well—especially in the upper reaches of the Lake. In the more southerly, deeper, clearer, and more stable waters, herbivorous fishes such as *Tilapia*, uncommon under riverine conditions, have now become dominant. These studies have shown the importance of starting observations—especially on the quantities of fish caught—early in lake development. They also provide an indication to future projects of what biological changes are likely to occur, and when, while emphasizing the need for full communication and cooperation between all research and other organizations investigating or using such lakes.

## INTRODUCTION

In these days of rapid economic development throughout tropical Africa, many hydroelectric schemes, often associated with subsidiary benefits such as irrigation, fisheries, and cheap water transport, are being put into operation or contemplated. It is important that experience gained from some of the earlier schemes be used to maximum advantage in the newer ones (*cf.* White, 1969). The purpose of this article is to point out some of the biological problems encountered during the creation of the Volta Lake, to explain how they have been dealt with there, and to draw any general conclusions from them that might have application in other tropical regions.

Though the Volta River was dammed at Akosombo (Figs. 1 & 2) as early as 1964, it has still to reach its

estimated full size of some 3,275 square miles (8,482 sq km), or over 3 per cent of Ghana's land surface. Relatively shallow, but of complex dendritic shape, it is expected to have an ultimate coastline totalling some 4,500 miles (7,242 km). Along most of its length the Volta Lake stretches through Guinea savanna, but some of the southern arms lie in forested areas (though of a relatively dry type). Much of the Volta basin lies in a rainfall region which has a single peak extending from about July to September, but as it takes a considerable period for the rain to gather into the streams and rivers that feed the Lake, the

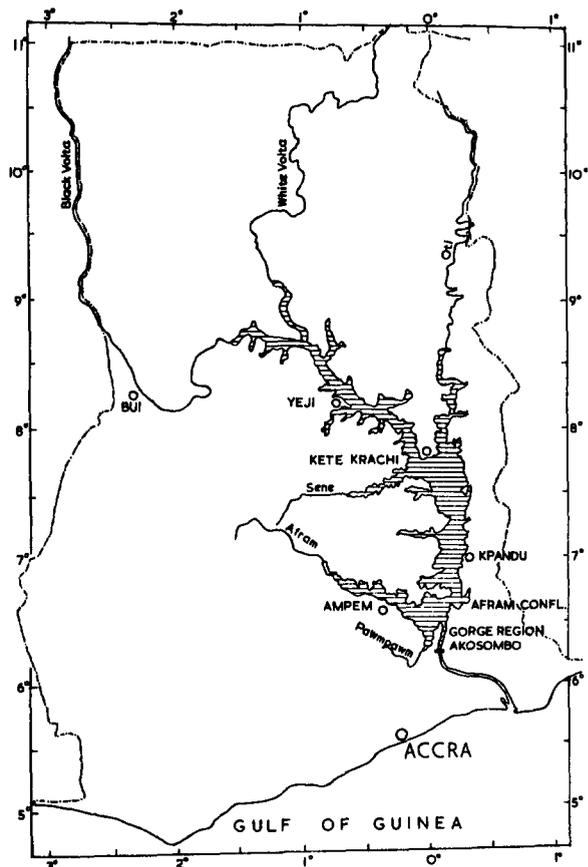


Fig. 1. Map of Ghana showing Volta Lake.

maximum height of water in the Lake occurs some time after the rainy season has ended.

In contrast to certain other African man-made lakes such as Kariba, there was little animal wildlife present in the flood area before the Volta Lake formed, and therefore no real attempt was made to save what there



Fig. 2. The Volta dam at Akosombo from the air.  
Photo: G. F. Richardson.

was. However, a large game reserve is planned to be situated adjacent to the central portion of the Lake on its western side.

Before the recent establishment of the United Nations Volta Lake Research Project, which has taken over the coordination of all research on the Volta Lake, most of the research into biological problems on the Lake had been carried out by the Volta Basin Research Project of the University of Ghana (Lawson, 1963). This research started with—and in some cases even before—the closure of the dam (S. Biswas, 1968). It represents, therefore, what can perhaps be regarded as the first fully-documented record of the process of biological change that takes place when a great African river is converted into a lake (Lawson *et al.*, in press). This process of 'lacustrination', as it may be called, has been followed by taking regular samples of water for analysis of the main constituents (S. Biswas, 1966), phytoplankton (S. Biswas, 1966a and in press), zooplankton, bottom fauna (Petr, in press), and fish, at frequent intervals throughout the length of the lake for a period of over five years. Observations have also been made on *aufwuchs* (*i.e.* all attached organisms [except macrophytes], including the various forms living free within the mat of sessile forms) (Lawson *et al.*, in press), on Bacteria (E. R. I. Biswas, 1968), and on the aquatic weeds (Lawson, 1967; Hall *et al.*, in press) and the invertebrates that infest them (Petr, 1968a). It is, of course, impossible in a short article to give an adequate summary of all the data that have been amassed, but an attempt will be made to point out some of the chief features of change that have emerged in the course of these investigations.

#### THE MAIN CHANGES OBSERVED

It has, first of all, been necessary to distinguish seasonal changes from long-term trends. For example, during the rainy season the large influx of water lowers the temperature and oxygen content, causes increased turbidity, and increases plant nutrients. The lake waters become brownish and come to contain a good deal of iron, while thermal and chemical stratification remain at a minimum (S. Biswas, 1969). When the floods end the water clears, the phytoplankton bloom, and stratification sets in to produce a slight but definite thermocline (*i.e.* a sharp drop in temperature with a small change in level) at a depth of about 20 metres. But superimposed upon these seasonal changes has been a long-term trend towards the gradual clarification of the surface waters—as measured in Hazen units and Secchi disk readings—as the lake stabilizes. As the water has cleared, micro-organisms have also decreased in numbers in the surface waters.

In the case of phytoplankton and zooplankton, the range of seasonal and local variation has been so great as to make it very difficult to distinguish long-term changes. As a general rule, blue-green algae (Cyanophyceae) have been commoner in the shallower parts of the Lake and diatoms (Bacillariophyceae) have been commoner in the deeper waters, but Cryptophyceae may occur sometimes in quantity under both types of condition. The zooplankton sampling has shown that though Copepoda, Cladocera, and Protozoa, are all present to varying degrees, the major constituent has nevertheless been the Rotifera.



Fig. 3. Vegetation flooded by rising water in savanna country near Kpandu. Photo: R. York.

The vegetation that has been partly or wholly submerged by the rising Lake (*cf.* Figs. 3, 4, & 5) has provided a greatly increased source of food for herbivorous fish. It is not, however, an entirely new source of food, as even before the lake was formed such fish invaded the flooded areas that were seasonally unin-



Fig. 4. Part of the Volta Lake near Ampem, showing former high forest which is now flooded. Photo: T. Petr.

(518 and 1,036 sq km) in extent, will mean that a continuing supply of terrestrial plant food will become available for the herbivorous fish with the habits described above.

There has fortunately been no sudden 'explosive' growth of water-weeds such as has occurred in certain other bodies of fresh water in Africa, and from this point of view the weed problem has not been serious. A good deal of weed is present, however, and in some parts it appears to be increasing. In the Afram arm of the Lake, a rather dense floating 'sudd' dominated by *Scirpus cubensis* (Fig. 5) covers large areas, and the large coarse grass *Vossia cuspidata* (Fig. 6) appears now to be extending rapidly along the margins of the



Fig. 5. 'Drowned' trees in the Afram arm of Volta Lake. The apparent islands are floating patches of vegetation—mostly *Scirpus cubensis* and *Ludwigia octovalvia*, with light-coloured *Pistia stratiotes* looking like shingle around the edges. Photo: J. Jenik.

dated, to feed and to spawn (Petr, 1968). The formation of the Lake merely meant that a great deal more food became available. About 60 per cent of the food intake of such fishes as *Tilapia zillii*, *Alestes macrolepidotus*, and *Synodontis* spp., has been found to consist of such plant material. When the lake has stabilized, there will be no new areas to be flooded after each rainy season, so that these extra sources of plant food will not be available. On the other hand, the normal rise and fall of water in the drawdown area, which is expected to be between 200 and 400 square miles



Fig. 6. Volta Lake near Yeji in central Ghana, showing flooded trees and a patch of the floating grass *Vossia cuspidata* which is now spreading rapidly along the margins of the Lake. Photo: R. York.

Lake from the north. Other prevalent aquatic angiospermous weeds are *Pistia stratiotes* (cf. Fig. 5) and *Ceratophyllum demersum*, both of which show a marked seasonal periodicity with a maximum between June and August. These weeds do not appear to be much eaten by fish, and in fact they have been found in the stomachs of only *Distichodus* spp. and *Alestes macrolepidotus*. The real ecological importance of aquatic weeds, as far as the Volta is concerned, is that they provide a substratum for many invertebrates which are important both as fish food and as vectors of human disease. Thus the presence of *Ceratophyllum*, which harbours the snail *Bulinus* (the vector of the parasite *Schistosoma*), increases the danger of bilharzia around the lake. But it may also be important in providing protected breeding grounds for fish. On the other hand, the possibility that increasing amounts of weed may protect breeding fish to such an extent that the end result may be vastly increased numbers of small and commercially useless fish, cannot be ruled out.

One of the most interesting conclusions that has come out of research on the Volta Lake is the importance of periphytic (*i.e.* attached underwater) Algae and the invertebrates that live on them—collectively known as *aufwuchs* (Lawson *et al.*, in press). The great number of flooded trees in the lake have provided an ideal substratum for periphyton in the epilimnion (*i.e.* surface layer rich in oxygen) both near the edges of the Lake and also farther offshore. Furthermore, these trees have provided a suitable substratum for burrowing organisms—especially nymphs of the mayfly *Povilla*. Coupled with the fact that the benthic population has often been limited by deoxygenation of the bottom waters, this has meant that *aufwuchs* production has been very much greater than that of the benthos.

The great production of periphytic Algae has influenced the trophic structure of the lake in two ways. The first is by providing an abundant source of food for such fish as *Tilapia galilaea*, which feed directly upon it. The second is that, by providing food for the spread of *Povilla*, it has given a big boost to the insectivorous fish that would otherwise be at a disadvantage during the conversion of a river into a lake. Such insectivorous genera as *Alestes* and *Eutropius* in fact now dominate the more northern parts of the Lake. However, in its more southern waters, which are clearer and more stable, being less directly influenced by the flood-waters, herbivorous fish such as species of *Tilapia*, uncommon under riverine conditions, have become the most important members of the fish population (Fig. 7). At the same time as these increases have taken place, some groups—especially mormyrids, which were formerly plentiful in the river

—have gradually decreased until they are now almost absent from commercial fish catches (Petr, 1968b).

Observations on southern parts of the Lake indicate that, in some places at least, though approximately the same numbers of fish are being caught as in the early years of the lake formation, they are often of smaller



Fig. 7. Drying (on palm leaves) salted Tilapia from the Pawmpawm arm of Volta Lake.

species. It is impossible to say with certainty, however, whether this indicates a falling off in productivity or merely that the fish are moving elsewhere. Other observations, it should be noted, such as the apparent increase in numbers and size of predatory fish such as *Lates niloticus*, seem to indicate rising productivity. Unfortunately, however, there are no really reliable figures that give an idea of the total fish productivity of the Lake and how it may be changing; but the Volta Lake Research Project is now actively working on this problem.

#### ENUMERATION OF 'LESSONS'

What are the lessons that can be drawn from all this work? In view of the number of hydroelectric schemes already mounted or planned, and of the rate of development in Africa and elsewhere, it is perhaps not too presumptuous at this stage to make tentative recommendations, from the experience of the Volta Lake, that might have application to other similar schemes. These may be stated briefly as follows:

1. Research on newly-forming man-made lakes is best carried out, at least initially, by Universities wherever possible. Governmental and international programmes are often cumbersome and require a long period of gestation before they get going. For example the UNDP programme on Ghana's Volta Lake commenced only in 1968—four years after the closure of the dam—despite the fact that negotiations had started several years earlier.

The great advantage as regards universities is that a supply of often enthusiastic personnel, scientific expertise, and something in the way of equipment, is immediately available and can be mobilized for work to begin at a very early stage. This work can be rapidly expanded by feeding in a relatively small amount of money earmarked for lake research.

2. All man-made lake projects in Africa are faced with the problem of what to do about the natural vegetation of the flood area that will become drowned when the water rises. In some cases, such as Kariba, extensive clearing was carried out before inundation; in others, such as Volta, little clearing was attempted (Figs. 4 & 5). On the face of it there appear to be good reasons for clearing. Absence of woody vegetation will mean that fishing nets do not get fouled and that lake transport is not interfered with. Trees tend to rot away above the water surface fairly quickly but, as experience elsewhere—Panama for example—has shown, the underwater stumps may remain for a great many years, constituting, because they are just submerged, an especial danger to boating. There is also the possibility that rotting underwater vegetation could mean mass mortality of fishes if the water were ever turned over and the heavily-reduced bottom water were brought to the surface. On the other hand, clearing of vegetation—especially by mechanical means as was done at Kariba—is a formidably expensive business. Clearing by burning is usually impracticable, as the area to be flooded often lies in savanna country where most of the trees only exist because they are sufficiently fire-resistant to withstand annual bush fires! Again, the ash from such burning, when dissolved in the flood-waters, would provide a rich plant culture-medium which might support not only the desirable phytoplankton but might, on the other hand, provide the right condition for a very undesirable 'explosive' growth of weeds (*cf.* White, 1969).

In the case of the Volta, only a limited amount of clearing was carried out round Akosombo and in the neighbourhood of some of the new resettlement towns, so as to provide stump-free fishing areas for the displaced populations. This clearing seems to have had one very undesirable and completely unforeseen result, namely, that bilharzia flourishes much more in the cleared areas than elsewhere. This appears to be due to the fact that aquatic weeds quickly establish themselves in the cleared areas, enabling a build-up of the bilharzia snail vector. There is, therefore, good reason to regard clearing as undesirable from the health point of view.

3. In a large dendritic-shaped lake such as the Volta (Fig. 1), the problem of assessing the amount of

fish caught is enormous. Apart from the main centres of fish distribution, there are numerous villages that have sprung up along the lake margin at any of which fish may be landed. Thus, although various estimates have been made, there are still no really reliable figures of what is being taken from the lake. The main reason for the lack of knowledge on this subject is simply that the man-power has not been available to collect data from all possible sites. In view of the obvious importance, however, of a reliable assessment of the catch, and of how it varies with time, it is suggested that for other similar schemes a big effort be made to ensure that a sufficient body of trained personnel is ready to go into operation and collect data on fish from landing sites, markets, road check-points, etc., as soon as the new lake begins to form.

An assessment of the total amount of fish that is being caught, and also of the standing crop of fish, can form the basis of a rational policy of exploitation. Otherwise there is the danger that a policy of merely getting fish without regard for the future might lead to a situation, not necessarily in which recovery was impossible, but in which there was serious socio-economic dislocation owing to too many people having got absorbed into a shrinking industry. In the case of the Volta, this could be serious, as there is now no alternative area of employment for professional fishermen in view of the effective destruction of the fishing grounds below the dam.

4. One fact that appears to be emerging from comparative studies of the Volta Lake and other African man-made lakes is that the patterns of biological changes that occur during lake formation tend to be very similar, so that what happens in one lake at a particular stage of its development is likely to happen in another lake in about the same period of time. For example, the water-bloom of blue-green algae that occurred shortly after the closure of the Volta dam was later repeated at Kainji at just about the same period of time after the closure of the dam there. Thus from a close study of one or more lakes it seems possible to make predictions about the future biology of new ones. For these reasons, close contacts should exist between the research personnel of the man-made lakes scattered throughout the continent.

5. Whilst everyone is well aware of the profound changes that take place *above* a dam, one thing that tends to be overlooked in the creation of man-made lakes is the effect on the river *below* the dam. In the case of the Volta, the riparian community in this lower part of the river was very much dependent upon the seasonal régime of water flow for its agricultural and fishing activities. The annual floods following the rainy season caused flooding over of the river banks

and filling of the many creeks that lie adjacent to the river. The combined irrigating and silting effect on the flooded land made it a specially favoured area for agriculture, and the creeks, fertilized each year by new water containing nutrients, were also highly prized for the fish they supported. A further feature of the economic life of the area was the clam industry in the river itself. The Clams (*Egeria radiata*) grew in quantities in the bottom of the river and were collected by women for sale.

The effect of building a dam above this area has been, first, that for a period of several years while the lake was filling up the flow of water below the dam was very much reduced. Thus there was no irrigation of the land which was formerly flooded each year after the rainy season, and no fertilizing of the creeks—some of which have begun to dry out. The decreased flow also meant increased salinity penetration up the river from the sea (Pople & Rogoyska, 1968). One interesting feature of this phase was the appearance in quantity of a water-weed, *Potamogeton octandrus*, hitherto unrecorded for Ghana (Hall & Pople, 1968). It increased at a phenomenal rate in the quiet, shallow waters of the sluggish undisturbed river below the dam.

The Lake will probably complete filling late this year (1969). When all the hydroelectric turbines are fully employed, the amount of water passing down the river as a steady flow throughout each year will be about the same amount as formerly passed seasonally after the rainy season. Thus the land near the river will not be flooded, and the creeks will continue to remain unfertilized by new water. The steady flow will also mean decreased salinity, as the sea water will be pushed out continually. As the Volta Clam grows well in freshwater conditions but requires periodic inundation of sea water to complete its sexual cycle, its reproduction has already been adversely affected.

In the early stages at least of the Volta dam project, it has been necessary for technical reasons to let out water from the dam by opening the sluice gates from time to time. This was done, for instance, on a large scale in September 1968, and one result was that the larvae of the fly *Simulium damnosum*, the carrier of the organism causing river blindness, which breed in abundance near Akosombo, were effectively swept away. Another result was that the *Potamogeton* 'meadows' were completely flushed out—showing that control of both *Simulium* and weeds below the dam is possible by regulating the water flow from the dam.

The capital city of Accra obtains a large portion of its water supply from Kpong, below the dam, and problems have arisen during periods when the sluice gates have been open because the manganese content

of the water may then rise above acceptable limits—due presumably to bottom deposits being stirred up.

6. From all that has been said above, it is clear that many biological features of man-made lakes are interrelated, and that action brought about by Man to influence or control one phenomenon may have far-reaching effects on other parts or aspects of the lake system. For this reason it must be emphasized that there should be maximum coordination between all the various bodies and agencies—such as medical and health services, fisheries, biological research, and engineering—that work on or have an interest in the lake. The Volta Lake Project has been fortunate in having a single authority responsible for everything connected with the Lake—the Volta River Authority—which has in its turn been wise enough to set up an efficient Coordinating Committee, comprised of all interested parties, to integrate all efforts concerned with research on the Lake. But even here there have been instances of lack of coordination and communication. For example, it was believed by some of the biological research workers that a mass mortality of fishes in one part of the lake was due to an oxygen deficiency there: it was only much later that they learnt that large quantities of DDT had been put in upstream by the health authorities!

These, then, are some of the lessons that can be learned from experience on the Volta Lake. No doubt there are many others; but if even a few can be passed on to other similar schemes it will help to make this article, and the extensive research programme which it attempts to summarize, worth while.

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#### Population Explosion of the Crown-of-thorns Starfish, *Acanthaster planci*

Since its effects are as far-reaching as 'the destruction of fisheries' and 'severe land erosion by storm waves' (R. H. Chesher in *Science*, Vol. 165, pp. 280-3, 1969), it is not surprising that the problem of the infestation of coral reefs by the coral-predating Crown-of-thorns Starfish (*Acanthaster planci* (L.)) is one of increasing concern in more and more parts of the Indo-Pacific region. Indeed, in an interview with *The New York Times*, Dr Chesher is quoted as saying 'If the Starfish population explosion continues unchecked, the result could be a disaster unparalleled in the history of mankind'. For among other effects 'will be the gradual disappearance of such [coral] islands . . . as livable places' (Smithsonian Institution Center for Short-lived Phenomena, *Card 687*, 21 July 1969).

Although a long-established species, *Acanthaster planci* did not attract particular attention until about 1960 when it appeared in abnormal numbers, apparently for the first time, in the region of Cairns in Queensland, Australia. In 1963 a research programme was established under the leadership of Mr R. Pearson, Fisheries Biologist of the Department of Harbours and Marine, and supervised by Dr R. Endean, Reader in Zoology in the University of Queensland.

In 1967, similar infestation was observed around the island of Guam in the western Pacific and a control programme was initiated under the direction of the University of Guam. In the summer of 1969 Dr R. H. Chesher headed an expedition from Guam which, with the help of transport from United States Navy and Coast Guard 'planes, studied the situation in a number of remote atolls in the western

Pacific; it comprised 'An International team of marine scientists . . . with hypodermics and diving gear to open a counterattack against a catastrophic invasion of coral-eating Starfish' (ibid.).

Meanwhile in the summers of 1968 and 1969 the Cambridge Red Sea Expedition studied *Acanthaster* in the region of Port Sudan, in addition to the investigation carried out some years previously by T. F. Goreau elsewhere in the Red Sea (Goreau in *Bull. Sea Fish. Res. Sta. Haifa*, Vol. 35, pp. 23-26, 1963).

Further infestations are now reported from the east coast of Malaya, from New Guinea, from the Fiji islands, and from Saipan and elsewhere in the western Pacific, while it is said that *Acanthaster planci* is also threatening coral reefs of the Seychelle Islands in the western Indian Ocean—vastly removed from the Pacific islands and the Great Barrier Reef off the east coast of Australia where its ravages are, perhaps, most serious of all.

The population explosion of *Acanthaster planci* is still not understood and the factors contributing to it may be numerous. Dr Endean (Report on Investigations made into Aspects of the Current *Acanthaster planci* (Crown of Thorns) Infestations. . . . Fisheries Branch, Queensland Department of Primary Industries, Brisbane, pp. 1-37, mimeographed, 1969) confirms the role of *Charonia tritonis* (Giant Triton) and *Cassia cornuta* (Giant Helmet), both large marine molluscs that are continually removed by shell collectors, as important predators of *Acanthaster planci*, suggesting that their encouragement (rather than chronic removal) might help to control the scourge. One of the greatest remaining worries is that the degradation is self-perpetuating in that the corals on which the Starfish feeds are probably among the most important predators of the larval stage of the Starfish itself.